MaPhy Faculty Handbook

Handbook of the Faculty of Mathematics and Physics

Leibniz
Universität
Hannover

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Greeting of the President

The Faculty of Mathematics and Physics is one of nine faculties at Leibniz University Hannover. It is well-positioned in national and international competition and has un-dergone a profound process of transformation in promising areas over the past five years. The great number of research initiatives, research centres, research buildings, coordinated programmes and Clusters of Excellence documented in this handbook is unique in Lower Saxony and far beyond.

The faculty draws its strength from the positive interaction between fundamental knowledge and practical application, between pure and applied mathematics, as well as between theoretical and applied physics. The firm roots in basic research, com-bined with the development of strong research foci, result in the aforementioned re-search successes. Mathematics and physics as important areas of our society are indispensable for the future-oriented profile of Leibniz University Hannover.

Furthermore, the faculty is aware of its great responsibility with regard to educating future teachers in the subjects of mathematics and physics. Only good teaching staff in these core subjects will spark the interest of pupils and encourage them to pursue studies in mathematics and physics, therefore providing an incentive for the neces-sary next generation of scientists.

This faculty handbook documents the development of the faculty over the past five years and its current focus, degree programmes, and research areas. It demonstrates how different disciplines and subject cultures have challenged and complemented each other and grown together constructively. In this way, the handbook provides in-sights into the great diversity of the faculty while exploring future development oppor-tunities.

I cordially invite you to form your own impression and hope you enjoy reading it.

Prof. Dr. Volker Epping
President of the Gottfried Wilhelm
Leibniz University Hannover

Photo credit: Leibniz University Hannover, Department of Communication and Marketing, photographer Christian Bierwagen

Greeting of the Dean

To mark the tenth anniversary of the founding of the Faculty of Mathematics and Physics, the first edition of this Faculty Handbook was produced in 2015. Since then, a lot has happened: Many excellent new appointments of professors and the success of the Clusters of Excellence PhoenixD and QuantumFrontiers may be mentioned here as examples.

The second edition of this handbook also aims to provide orientation in this rapidly evolving diversity by presenting scientists, research fields, collaborations and teaching activities.

The popularity of our study programs is certainly still related both to the fascination that mathematics and physics possess for many, and to the excellent career prospects of our graduates - in business and public service, in schools and academia. Thanks in part to the particularly dedicated student body (Fachschaft), our faculty offers its students a home on the not always easy path to a successful graduation.

Even though the state of research has advanced significantly in recent years - not least thanks to the contributions of our faculty's scientists - many fundamental questions in mathematics and physics remain challenges for the future.

C. Wyrwa

Prof. Dr. Ulrich Derenthal
Dean

History of the Faculty of Mathematics and Physics

View of the marketplace from the west, Bornemannsches Haus in the background, c. 1835.

The Polytechnic (after 1860)

The history of Leibniz University begins in 1831 with the foundation of the Higher Vocational School with the director Karl Karmarsch. He considered mathematics as a teaching subject extremely important for Technical Studies and appointed the holder of the mathematics teaching position as deputy director. Between 1856 and 1858, two additional teaching positions were created for „Lower" and „Higher Mathematics". With the transformation of the Polytechnic into an Institute of Technology between 1876 and 1880, mathematics, which had previously only been a field of teaching, became a field of research.

Physical research in Hannover began in 1853 under Gustav von Quintus Icilius, who had received his doctorate from Gauß in Göttingen. After the First World War, the Institute of Technology was granted the right to train secondary teachers in the subjects of mathematics, physics and chemistry. Moreover, the diploma degree was created in mathematics and physics. The Institute of Meteorology was founded outside the university in Sarstedt at the College of Horticulture and Land Culture in 1949, moved to Herrenhausen in 1950, and was part of the Biology Department in the 1970s.

In 1981, the university was reorganized into 17 departments and three faculties; one of these faculties was the Faculty of Mathematics and Natural Sciences, which, however, was already dissolved in 1982. From then on there was the Department of Physics and the Department of Mathematics, and from 1997 the Department of Mathematics and Computer Science. Since 2005, the university has been divided into nine faculties. The Departments of Mathematics and Physics were merged. At about the same time, the Institute of Mathematics and Physics Education was founded. Today the faculty consists of six mathematical institutes, seven physics and meteorology institutes and the joint institute of didactics. With the reorganization into a faculty, the bachelor's and master's degree programs were introduced in 2005. The diploma programs as well as the teaching programs with state examinations were phased out.

Two Nobel Prize winners in physics have conducted research in Hannover: Johannes N. Stark received the Nobel Prize in Physics in 1919 for the discovery of the optical Doppler effect. Hans Daniel Jensen received one half of the Nobel Prize in Physics in 1963, together with Maria Goeppert-Mayer, for detailing the understanding of atomic nuclei.

The Institute of Technology in the Welfenschloss on a postcard from 1880

Leibniz Universität Hannover

Institutions MaPhy

Handbook of the Faculty of Mathematics and Physics

Institute of Algebra, Number Theory and Discrete Mathematics

private

Prof. Dr. Christine Bessenrodt
(† January 24, 2022)
Executive Director

S. Gerhard

Hiltrud Trottenberg
Office

As described by its name, the Institute for Algebra, Number Theory and Discrete Mathematics covers several related areas of mathematics that are connected by fruitful interactions and that also have connections to other Institutes in our Faculty. There are also interdisciplinary connections to physics; the Institute thus also participates in the Riemann Center.

Focus areas of the research in algebra are the representation theory of finite groups and (mostly finite-dimensional) algebras; the topics often have relations to algebraic combinatorics and also to number theory, as their methods are useful in particular in studying arithmetical questions on dimensions. In connection with the representation theory of the symmetric groups and related algebraic structures also symmetric and quasisymmetric functions and the associated Hopf algebras are studied. In the study of representations of algebras central topics are cluster algebras, cluster categories and homological algebra; combinatorial aspects are also crucial in the investigations of cluster theory.

Focus topics in the research in discrete mathematics are reflection groups and arrangements of hyperplanes. Reflection groups and related structures also play an important role in algebraic studies as invariants of certain Hopf algebras. These Hopf algebras have recently been of increased interest also in mathematical physics. In the context of arrangements of hyperplanes, in particular structures from algebraic and discrete geometry are investigated. Among these are (oriented) matroids, certain modules of derivations, but also some invariants arising in topology. Another connection to topology is provided via the ideal theory of ordered sets and lattice theoretic generalizations of topologies. Also in this area combinatorial enumerations are of great interest.

The research in number theory has strong relations to arithmetic geometry and thus builds a bridge to algebraic geometry. A focus topic is the existence and distribution of rational points on algebraic varieties. These problems are investigated both with methods coming from algebraic and analytic number theory as well as with geometric methods. A central role is played by torsors and Cox rings.

With the hiring of Ziyang Gao on the professorship for Arithmetic and Geometry in October 2021, the research at LUH in Diophantine Geometry is further strengthened; this establishes a strong focus in the area of arithmetic and algebraic geometry with several working groups.

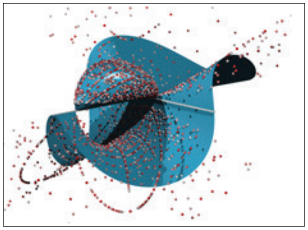
The research groups of the institute have participated in the DFG Priority Programmes 1388 »Representation Theory« and 1489 »Algorithmic and Experimental Methods in Algebra, Geometry and Number Theory«; via many activities we have strong national and international contacts and connections in the mathematical community.

With the hirings in Discrete Mathematics and Number Theory in 2013/14, collaborations within the institute, with other institutes of our Faculty and with partners at neighbouring universities have been intensified. Beyond these, we had and have many cooperation partners all over the world, notably in Austria, Canada, China, Denmark, France, Ireland, Japan, United Kingdom, and the USA. Our collaborators enrich the scientific life at Leibniz University when they visit us for longer research stays or report on their work in our institute. Also among the members of our institutes several nationalities are represented.

Our research projects and our collaborations have been supported in particular by institutions such as the DFG, DAAD, Alexander von Humboldt Foundation, and research organisations of the countries of our partners. Research visits and the participation in focus programmes of renowned research centres (such as the Mathematisches Forschungsinstitut Oberwolfach, MSRI in Berkeley, Isaac Newton Institute in Cambridge, Mittag-Leffler-Institute near Stockholm, Beijing International Center for Mathematical Research, American Institute of Mathematics) as well as the presentation of our research at international meetings are important aspects in making our research internationally visible. We are also active in the organisation of national and international meetings and as members of Scientific Committees and Program Committees of international conferences.

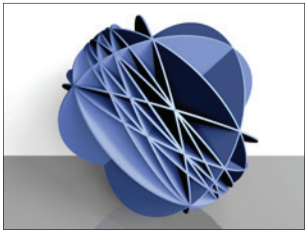
Members of the Institute of Algebra, Number Theory and Discrete Mathematics

Our activities in teaching courses at our Faculty include basic as well as advanced courses and seminars, with topics representing the wide scope of our institute; we provide mathematical instruction for Bachelor students in mathematics, physics, meteorology and computer science as well as for those who plan to become teachers. For Master students we regularly offer specialized courses close to our research areas and related topics (e.g., coding theory and cryptography). We are very active also in supervising theses on all levels, from Bachelor and Master theses (both for students of mathematics as well as for prospective teachers of mathematics) to PhD projects in mathematics; topics for such theses are offered across all areas represented by our institute.



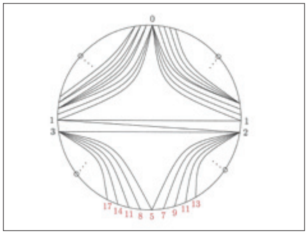
Ulrich Derenthal

Rational points of bounded height on a singular cubic surface



Michael Cuntz

A simplicial arrangement of hyperplanes



C. Bessenrodt und T. Holm

Geometric model of an SL_2 tiling

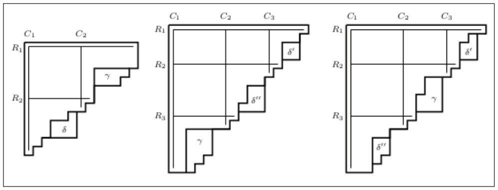
Prof. Dr. Christine Bessenrodt

private

Prof. Dr. Christine Bessenrodt
(† January 24, 2022)

Algebra and Number Theory
Welfengarten 1, 30167 Hannover

The research topics of the algebra group center on the representation theory of groups and algebras and related topics in algebraic combinatorics; there is often a close relation to number theory. A particular focus is on symmetric groups and related groups; the alternating groups and their covering groups play a special role as important building blocks in the theory of finite groups. Representations of finite groups are investigated over the complex numbers as well as in positive characteristic; some of the classical problems that we study are the relations between the structure of a group and that of its group algebra, the dimensions of representations, and the structure of tensor products. For obtaining answers to the representation theoretical questions for the families of groups mentioned above, partitions, tableaux and related combinatorial objects are of central importance; the weighted enumeration of such objects also leads to the theory of symmetric and quasisymmetric functions, with connections e.g. to invariant theory, Lie theory and physics. It is an essential goal in the area to determine properties of representations in an efficient way from the parameterising objects; besides combinatorics, often number theoretic considerations play an important role. On the other hand, by introducing algebraic structures into the combinatorial settings, the analysis of combinatorial objects can be generalised and refined. These algebraic topics (and related ones) are in fruitful interaction with Algebraic Combinatorics and Additive Number Theory, which are both internationally highly active areas.



Christine Bessenrodt

Tensor products: reductions on Young tableaux

Important research projects

- Representations of symmetric groups and their double covers (cooperation with C. Bowman/UK, E. Giannelli/Italy, A. Kleshchev/USA, J. Olsson/Denmark, R. Stanley/USA, et al.)
- Representation theory of finite groups (cooperation with J. Zhang/China, et al., support by the SGRC and BICMR, et al.)
- Symmetric and quasisymmetric functions (cooperation with Humboldt Fellow S. van Willigenburg/Canada et al., support by the Alexander von Humboldt Foundation, et al.)
- Kronecker coefficients and plethysms (cooperation with Humboldt Fellow C. Bowman/UK et al., support by the Alexander von Humboldt Foundation, et al.)

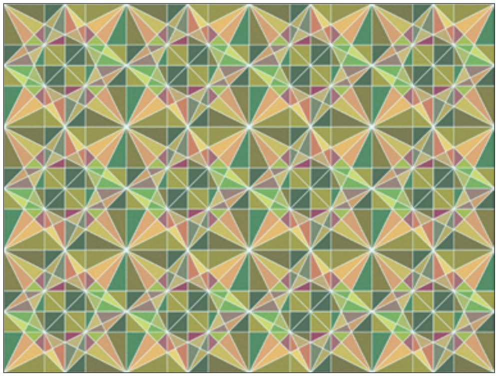
Important professional positions

2002 to 2022	Professor, Leibniz University Hannover
1993 to 2002	Professor, Universität Magdeburg
1990 to 1993	Heisenberg Fellow (DFG)
1990	(summer term) Substitute Professor, Universität Duisburg
1984 to 1990	Scientific Assistant, Universität Duisburg
1982 to 1983	DFG-Postdoc, University of Illinois in Urbana
1975 to 1988	Universities of Düsseldorf, Essen, Duisburg: study of mathematics and physics, doctorate (Award for Dissertation 1980/81), habilitation

Important publications

- Stable rationality of certain PGL_n quotients (mit L. Le Bruyn), Invent. math. 104 (1991), 179-199.
- On Kronecker products of complex representations of the symmetric and alternating groups (mit A. Kleshchev), Pacific J. Math. 190 (1999) 201-223.
- Skew quasisymmetric Schur functions and noncommutative Schur functions (mit K. Luoto, S. van Willigenburg), Advances Math. 226 (2011), 4492-4532.
- Complex group algebras of the double covers of the symmetric and alternating groups (mit H. Nguyen, J. Olsson, H. Tong-Viet), Algebra Number Theory 9 (2015), 601-628.
- Multiplicity-free Kronecker products of characters of the symmetric groups (mit C. Bowman), Advances Math. 322 (2017), 473-529.

The topics covered by my working group belong to one or more of the areas algebra, combinatorics, or geometry. The focus is on structures involving reflections as for example arrangements of hyperplanes. We often use methods from computational algebra because experiments are essential to find conjectures or proofs.



Michael Cuntz

An affine crystallographic arrangement

In the theory of quantum groups, many algebras like for example Nichols algebras are investigated via invariants generated by reflections. Sometimes these invariants are Weyl groups, sometimes they have less symmetries. Apart from being valuable tools for classifications, these discrete invariants can also lead to predictions and insights on the algebraic side. In the special case of dimension two, these invariants are so-called frieze patterns. These frieze patterns appear in many other areas of mathematics, they may for instance be interpreted as smooth compact toric varieties but they also correspond to cluster algebras of Dynkin type A. There are many intriguing variants and generalizations of these patterns. Simplicial arrangements are sets of hyperplanes decomposing the space into simplicial cones. In dimension three for example, they may be viewed as sets of lines producing triangles as regions. Simpliciality is a combinatorial property of the corresponding matroid. Terao's conjecture is about a module of derivations and whether its properties are of combinatorial nature.

C. Wyrwa

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Important professional positions

2013 to today	Professor, Leibniz University Hannover
2002 to 2013	PhD and Habilitation in Kassel and Kaiserslautern
1996 to 2002	Study of Mathematics in Heidelberg and Paris

Important research projects

» Subproject of the SPP 1388 Darstellungstheorie: Affine Nichols algebras of diagonal type and modular tensor categories
» Subproject of the SPP 1489 Computeralgebra (with G. Röhrle): Arrangements of complex reflection groups: Geometry and combinatorics
» Subproject of the SPP 1489 Computeralgebra (with C. Stump): Combinatorial and geometric structures for reflection groups and groupoids
» DFG-project: Arrangements with Symmetries

Important publications

» M. Cuntz, S. Lentner, A simplicial complex of Nichols algebras. Math. Z. 285, no. 3-4 (2017), 647-683.
» T. Abe, M. Barakat, M. Cuntz, T. Hoge, H. Terao: The freeness of ideal subarrangements of Weyl arrangements. J. Eur. Math. Soc. 18,6 (2016), 1339–1348.
» M. Cuntz, I. Heckenberger, Finite Weyl groupoids. J. Reine Angew. Math. 702 (2015), 77–108.
» M. Barakat, M. Cuntz: Coxeter and crystallographic arrangements are inductively free. Adv. Math. 229,1 (2012), 691-709.
» M. Cuntz: Crystallographic arrangements: Weyl groupoids and simplicial arrangements. Bull. London Math. Soc. 43,4 (2011), 734–744.

Prof. Dr. Ulrich Derenthal

Prof. Dr. Ulrich Derenthal

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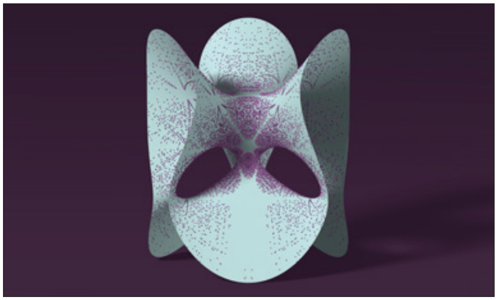
One of the oldest questions in number theory is the question of rational solutions to Diophantine equations. In terms of arithmetic geometry, this can be formulated as the question of rational points on the algebraic varieties defined by the Diophantine equations.

The Number Theory Group is concerned with fundamental questions regarding the existence and distribution of rational points on algebraic varieties: When do rational points exist (Hasse principle)? How are they distributed locally (weak and strong approximation)? How are they distributed globally (Manin's conjecture)?

We study these questions using a combination of algebraic, geometric, and analytic methods. A central geometric tool are universal torsors over the underlying varieties. Universal torsors can be described explicitly using Cox rings. Quantitative statements about rational points are usually obtained by analytical methods. If the Hasse principle or strong or weak approximation fails for a variety, this can often be explained algebraically by Brauer-Manin obstructions.

These questions are of particular interest for cubic surfaces, for example. While the geometry of smooth cubic surfaces is well understood, the above questions regarding their arithmetic are open. For some singular cubic surfaces, we could prove Manin's conjecture.



Oliver Labs, Ulrich Derenthal

Rational points of bounded height outside the 27 lines on Clebsch's cubic surface. Manin's conjecture predicts their number.

Important professional positions

2021 to today	Dean of the Faculty of Mathematics and Physics
2019 to 2021	Vice dean of the Faculty of Mathematics and Physics
2014 to today	Professor, Ludwig-Maximilians-Universität München
2010 to 2014	Professor, Ludwig-Maximilians-Universität München
2009 to 2010	Juniorprofessor, Albert-Ludwigs-Universität Freiburg
2006 to 2009	Postdoc and Lecturer, Universität Zürich; Research Fellow, Princeton University
1999 to 2006	Studies and doctorate in mathematics, Georg-August-Universität Göttingen

Important research projects

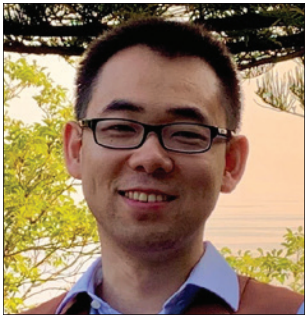
» Geometric and Analytic Number Theory (with V. Blomer, J. Brüdern, E. Kowalski, P. Michel, SNF-DFG Project)
» Degeneration of Torsors (with N. Hoffmann, Limerick)
» Rational points and Brauer-Manin obstruction: adelic topology, weak and strong approximation (host of Humboldt Fellow Y. Cao)

Important publications

» R. de la Bretèche, T. D. Browning and U. Derenthal, On Manin's conjecture for a certain singular cubic surface, Annales Scientifiques de l'École Normale Supérieure 40, no. 1, 1-50 (2007)
» U. Derenthal and C. Frei, Counting imaginary quadratic points via universal torsors, Compositio Mathematica 150, no. 10, 1631-1678 (2014)
» I. Arzhantsev, U. Derenthal, J. Hausen and A. Laface, Cox Rings, Cambridge Studies in Advanced Mathematics 144, Cambridge University Press, Cambridge (2015), 530 pages
» U. Derenthal and D. Wei, Strong approximation and descent, Journal für die reine und angewandte Mathematik, 731, 235-258 (2017)
» U. Derenthal and M. Pieropan, The split torsor method for Manin's conjecture, Transactions of the American Mathematical Society, 373, no. 12, 8485-8524 (2020)

Arithmetic geometry concerns the study of integer and rational solutions to Diophantine equations. This topic originated at least from ancient Greek time and it is still a central branch of mathematics. Moreover, it is often the case that easy-to-state problems in number theory turn out to be extremely difficult (e.g. Fermat's Last Theorem), and their study leads to groundbreaking discoveries in other fields of mathematics.

While the study of these questions initiated thousands of years ago, in recent years there has been dramatic improvement for our knowledge on this subject. There are deep and fruitful interactions with other fields such as algebraic geometry, topology, complex analysis, mathematical logic, and representation theory. And different aspects have been developed, for example height formulas and height bounds for algebraic points, unlikely intersection problems, automorphic methods, and p-adic approaches.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Prof. Dr. Ziyang Gao

Mathematics (Arithmetic Geometry)
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Important professional positions

01.10.2021	Professor (W3), LUH.
2015 to 2021	Chargé de recherche, CNRS Paris, France.
2016 to 2018	Instructor, Princeton University.
2015 to 2016	Member, IAS.

Important research projects

» ERC-Starting Grant: Unlikely Intersections and Uniform Bounds for Points.
» ANR-T-ERC(7): Uniform bound on rational and algebraic points.

Important publications

» V. Dimitrov, Z. Gao, P. Habegger; Uniformity in Mordell–Lang for curves, Annals of Mathematics, vol. 194, p. 237–298, 2021.
» Z. Gao; Generic rank of Betti map and unlikely intersections, Compositio Mathematica, vol. 156 (12), p. 2469-2509, 2020.
» Z. Gao; Mixed Ax–Schanuel for the universal abelian varieties and some applications, Compositio Mathematica, vol. 156 (11), p. 2263-2297, 2020.
» Z. Gao, P. Habegger; Heights in families of abelian varieties and the Geometric Bogomolov Conjec- ture (with P. Habegger), Annals of Mathematics, vol. 189, p. 527-604, 2019.
» Z. Gao; Towards the André–Oort conjecture for mixed Shimura varieties: the Ax– Lindemann theorem and lower bounds for Galois orbits of special points, Journal für die reine und angewandte Mathematik (Crelle), vol. 732, p. 35-146, 2017.

apl. Prof. Dr. Thorsten Holm

S. Gerhard

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Algebra and Algebraic Combinatorics
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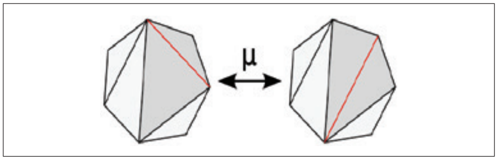
My research area is the representation theory of finite-dimensional algebras and related algebraic structures, e.g. stable and derived categories. In recent areas my work also has strong links to algebraic combinatorics.

In particular, I'm interested in cluster algebras and various topics related to them. Cluster algebras have been introduced by Fomin and Zelevinsky around 20 years ago and since then have undergone a very rapid development, with numerous applications in various areas of mathematics and theoretical physics.

A particularly successful approach is categorification, that is, cluster algebras are modelled by certain triangulated categories, the socalled cluster categories. This allows to apply deep methods from representation theory and homological algebra for proving results about cluster algebras.

Many cluster categories have a rich combinatorial structure usually coming from triangulations of certain geometric objects and their mutations. In several articles we could completely describe the algebraic structure of cluster categories by new geometric-combinatorial objects. This fruitful interplay between algebra and combinatorics also becomes apparent in the theory of frieze patterns and SL2-tilings, topics which I'm currently working on. These frieze patterns (over natural numbers) have been introduced by Conway and Coxeter already in the 1970's but now enjoy revived interest because of their close connections to cluster algebras. In cooperation with P. Jørgensen (Aarhus) and with M. Cuntz (Hannover) we could recently generalize considerably some of the classic results of Conway and Coxeter.



Mutation of two triangulations of the heptagon

Important research projects

- » 2012-2015: Principal investigator in a subproject of the DFG priority program SPP 1388 Representation Theory; Project: Cluster categories and torsion theory
- » 2009-2012: Principal investigator in a subproject of the DFG priority program SPP 1388 Representation Theory; Project: Cluster categories, cluster-tilted algebras and derived equivalences
- » 1996-1997: DFG research grant (PostDoc at the University of Oxford)

Important professional positions

2007 to today	Professor, Leibniz University Hannover, Institute of Algebra, Number Theory and Discrete Mathematics
2004 to 2007	Lecturer (with tenure), University of Leeds
1994 to 2007	Assistant position, Otto-von-Guericke-Universität Magdeburg
1996 to 1997	PostDoc, University of Oxford
1992 to 1994	PhD student, Universität Essen (Graduiertenkolleg »Theoretical and Experimental Methods of Pure Mathematics«)

Important publications

- » M. Cuntz, T. Holm, P. Jorgensen: Frieze patterns with coefficients. Forum Math. Sigma 8 (2020), e17
- » T. Holm, P. Jorgensen: A p-angulated generalisation of Conway and Coxeter's theorem on frieze patterns. Int. Math. Res. Not., Vol. 2020, No.1, 71-90
- » T. Holm, P. Jorgensen: On a cluster category of infinite Dynkin type, and the relation to triangulations of the infinity-gon. Math. Z. 270 (2012), 277-295
- » K. Erdmann, T. Holm, O. Iyama, J. Schröer: Radical embeddings and representation dimension. Adv. Math. 185 (2004), no. 1, 159–177
- » T. Holm: Derived equivalence classification of algebras of dihedral, semidihedral, and quaternion type. J. Algebra 211 (1999), 159–205

Institute of Algebraic Geometry

Leona Ohsieck (www.leona-ohsiek.de)

Prof. Dr. Stefan Schreieder
Executive Director

Natascha Krienen
Office

Ute Szameitat
Office

The most elementary systems of equations in mathematics are the linear ones. They always admit an algorithmic solution. The first non-linear objects in geometry are conics which generally lead to quadratic equations and again lend themselves to an elementary treatment. In comparison, a foundational result from algebra states that univariate equations of higher degree soon cede to be solvable.

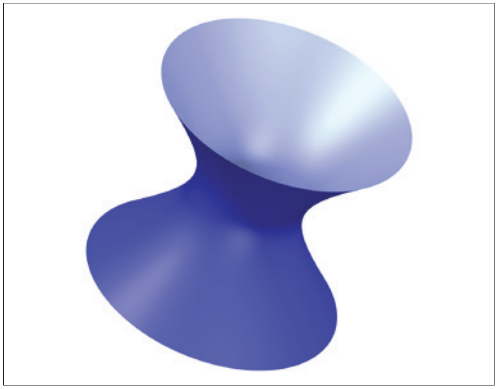
Algebraic geometry combines both these points of view by investigating solution sets for systems of polynomial equations in several variables in full generality. These solution sets are called algebraic varieties; they form the fundamental objects of algebraic geometry.

There are many interesting questions arising such as:

- Is it possible to describe the solutions of a given system of equations by explicit formulas?
- Given an algebraic variety, what subvarieties does it possess?
- Which topological shapes can be realized as algebraic varieties?
- What is the connection between arithmetic and geometric properties of the equations?
- How do algebraic varieties relate to their algebraic invariants (cohomology, Hodge structures, Chow groups, derived categories)?
- Is it possible to classify algebraic varieties of given type?

The institute hosts research on all these questions. A special focus lies on the following topics: rationality questions, algebraic cycles and Chow groups, topology of algebraic varieties, algebraic surfaces and their arithmetic, Calabi-Yau varieties, irreducible holomorphic symplectic manifolds and their moduli spaces, modular forms, derived categories, Hodge theory, singularities.

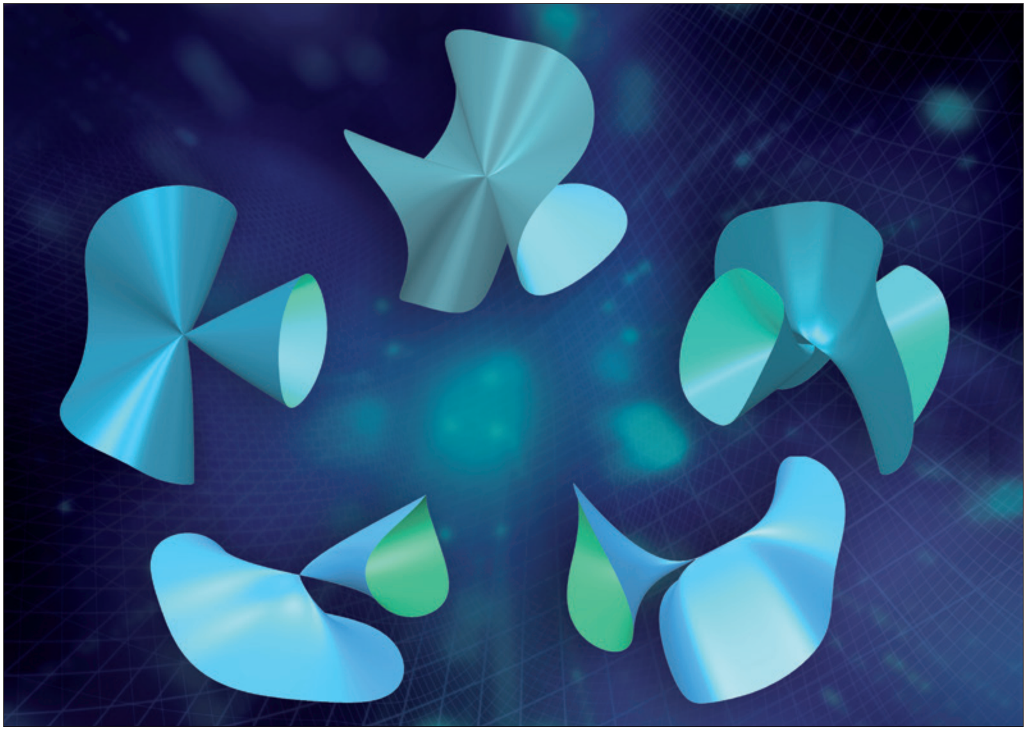
Algebraic geometry is closely connected to several other areas of mathematics, in particular to number theory, differential geometry and algebraic topology, but there are also applications to other areas. Recent results have unveiled interesting relations with some areas of physics, especially string theory. Meanwhile the study of algebraic curves over finite fields led to the discovery of novel codes which proved instrumental in information transfer and cryptography.



W. Ebeling

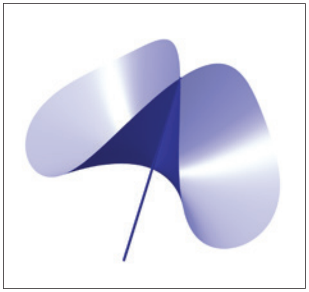
Hyperboloid - Zero set of a quadratic equation

A. Frühbis-Krüger und K. Frey



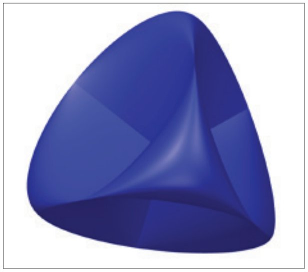
Mirror symmetry of isolated singularities of algebraic varieties

W. Ebeling



Whitney unbrella - algebraic varie
with non-isolated singularities

W. Ebeling



Steiner's Roman surface - an algebraic
variety with non- isolated singularities

Prof. Dr. Wolfgang Ebeling

S. Gerhard

Prof. Dr. Wolfgang Ebeling

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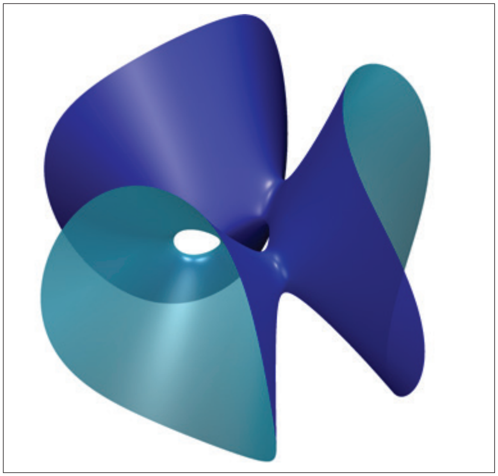
Singularities are special points of algebraic varieties where information on the geometric structure of a neighborhood of the point is condensed. A method to investigate such points consists in considering an unfolding or a deformation of the singularity. From such an unfolding, one can read off certain invariants which characterize the topology of the singularity.

One can divide singularities into classes according to their type. Such a classification was started by the Russian mathematician V. I. Arnold in the seventies of the last century. He also discovered a strange duality between the individual classes which is not correctly understood up to now. It has turned out that there are connections with modern mathematical physics, in particular with string theory. There is a relation between the strange duality and the mirror symmetry discovered by physicists. These connections are more closely explored in the working group. Recently, this comprises the study of singularities with group actions.



A. Frühbis-Krüger

Unfolding of a singularity of type D4

Important research projects

» Homological mirror symmetry for singularities (DFG SPP1388)
» Orbifold concepts in equivariant singularity theory (DFG normal procedure)

Important professional positions

retired since 2020

1990 to today	Professor for Mathematics, Leibniz University Hannover
1988 to 1990	UHD (Associate Professor), TU Eindhoven
1987 to 1988	Systems Analyst, Ford Motor Company, Cologne
1985 to 1987	Research grant of the DFG
1983 to 1985	Scientific Assistant, University of Bonn

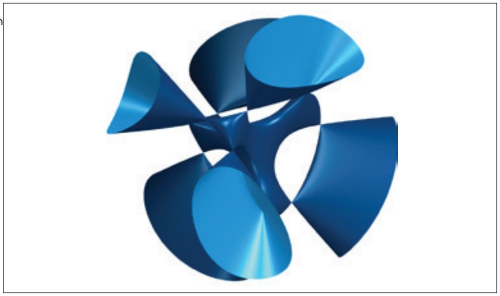
Important publications

» W. Ebeling: An arithmetic characterisation of the symmetric monodromy groups of singularities. Invent. Math. 77 (1984), 85-99
» W. Ebeling: The monodromy groups of isolated singularities of complete intersections. Springer Lecture Notes in Math. Vol. 1293, Springer-Verlag, Berlin etc., 1987
» W. Ebeling, J. H. M. Steenbrink: Spectral pairs for isolated complete intersection singularities. J. Algebraic Geometry 7 (1998), 55-76
» W. Ebeling, A. Takahashi: Strange duality between weighted homogeneous polynomials. Compositio Math. 147 (2011), no.5, 1413-1433
» W. Ebeling, S. M. Gusein-Zade: A version of the Berglund-Hübsch-Henningson duality with non-abelian groups. Int. Math. Res. Not. 2021 (2021), no.16, 12305-12329

Prof. Dr. Klaus Hulek

My field of research is algebraic geometry. The central objects which one studies in algebraic geometry are varieties: these are sets of solutions of polynomial equations. Algebraic varieties play a fundamental role, not only in many areas of mathematics, but also in theoretical physics, notably in string theory.

The aim of algebraic geometry is to understand the structure of varieties and to classify them. Understanding the structure of algebraic varieties means that one wants to determine fundamental algebro-geometric properties such as the Kodaira dimension. At the same time one wants to understand the underlying topological structure and basic topological invariants of varieties as well as their differential-geometric properties such as their curvature. A crucial role is also played by the arithmetic of algebraic varieties. An example is the existence and distribution of rational points on an algebraic variety. In this way algebro-geometric, topological, differential and arithmetic structures are interlinked in manifold ways.



A. Frühbis-Krüger

Kummer surface

My special interest lies in the classification problem. Typically, solving a classification problem in algebraic geometry cannot be achieved by providing a finite list of the objects to be classified. Instead, these varieties often depend on continuous parameters and the solution of a classification problem consists in constructing a classifying space – a moduli space. The points of this moduli space then parametrise the objects to be classified. Moduli spaces are themselves algebraic varieties and the structure of these spaces often also provides a deep insight into the structure of the original objects themselves. My main interest lies in studying moduli spaces of abelian varieties, K3 surfaces, irreducible holomorphic symplectic manifolds and cubic hypersurfaces.

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Important professional positions

1990 to today	Professor, Leibniz University Hannover
2015	Member, Institute for Advanced Study Princeton
2005 to 2014	Vice President for Research, Leibniz University Hannover
1985 to 1990	Professor, University of Bayreuth
1982 to 1983	Research Associate, Brown University, Providence, USA

Important research projects

» Geometry and topology of moduli spaces
» Degenerations of varieties with trivial canonical bundle
» Modular compactifications

Important publications

» S. Grushevsky, K. Hulek, The class of the locus of intermediate Jacobians of cubic threefolds. Inv. Math. 190 (2012), 119-168
» V. Gritsenko, K. Hulek, G.K. Sankaran, The Kodaira dimension of the moduli of K3 surfaces. Inv. Math. 169 (2007), 519-567
» D. Eisenbud, M. Green, K. Hulek, S. Popescu, Restricting Linear Syzygies: Algebra and Geometry. Comp. Math. 141 (2005), 1460-1478
» W. Barth, K. Hulek, C. Peters, A. Van de Ven, Compact Complex Surfaces (Second enlarged edition). Springer Verlag, Berlin 2004
» K. Hulek, Stable Rank-2 Vector Bundles on P2 with c1 odd. Math. Ann. 242 (1979), 241-266

Prof. Dr. Stefan Schreieder

Leona Ohsieck (www.leona-ohsiek.de)

Prof. Dr. Stefan Schreieder

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I am working in the field of algebraic geometry, with connections to differential geometry, topology and number theory. The main goal of algebraic geometry is to study the solutions of algebraic equations and the resulting geometric shapes. The methods come from several areas of mathematics and are sometimes also inspired by physics. Conversely, algebraic geometry has applications to several branches of mathematics, as well as to theoretical physics, especially string theory.

Algebraic equations are equations that are given by polynomials in several unknowns. A classical example is given by the circle equation, which is an equation of degree two in two variables whose solutions prescribe exactly the points on the unit circle.

One part of my research concerns rationality problems, that is, the question which equations admit a one-to-one parametrization of (almost all of) their solutions by an algebraic formula. For example, already the ancient Greeks were aware that such a formula exists for the circle equation. On the other hand, for equations of large degree (compared to the number of unknowns), it has been known for more than a century that such a parametrization is not always possible. For many important equations of low degree, it is however still open whether or not such a parametrization of their solutions exists. This includes for example the famous example of cubic equations in at least five variables, which is an open problem up to date. In the past I made significant progress in this area, concerning in particular equations whose degree depend logarithmically on the number of unknowns.

Another branch of my research concerns the question which topological shapes may be constructed as solution sets of algebraic equations over the complex numbers. For instance, in complex dimension one, it is well known that this holds true for the 2-sphere, the surface of a donut, or a surface of higher genus, having at least two ‚holes'. Even though it is known since the early last century that not every topological shape can be realized as the zero set of algebraic equations, the class of all shapes that have this property is still poorly understood. In my own research I am using modern methods from birational geometry, and, in particular, from the so called minimal model program, to study this sort of questions with the aim of shedding some light on the class of topological shapes that may be described by polynomial equations.

Important professional positions

Since 2020	Professor (W3), Leibniz University Hannover
2017 to 2020	Professor (W2), Ludwig-Maximilians-University Munich
2015 to 2017	Assistant, University of Bonn
2012 to 2015	PhD student at Max-Planck-Institut for Mathematics in Bonn

Important research projects

» ERC-Starting Grant RationAlgic (Grant No 948066, 2021-2026)
» Topological Properties of Algebraic Varieties (DFG Grant, 2019-2022)

Important publications

» S. Schreieder, Stably irrational hypersurfaces of small slopes, Journal of the AMS 32 (2019), 1171—1199.
» S. Schreieder, On the rationality problem for quadric bundles, Duke Math. Journal 168 (2019), 187–223.
» D. Martinelli, L. Tasin and S. Schreieder, On the number and boundedness of log minimal models of general type, Annales scientifiques de l'ÉNS 53 (2020), 1183–1210.
» S. Schreieder, On the construction problem for Hodge numbers, Geometry & Topology 19 (2015), 295--342.
» D. Kotschick and S. Schreieder, The Hodge ring of Kähler manifolds, Compositio Math. 149 (2013), 637--657.

Prof. Dr. Matthias Schütt

My research centers around the interplay of algebraic and arithmetic geometry. The overall philosophy that arithmetic and geometric properties govern each other manifests itself beautifully in the one-dimensional setting. Highlights are Faltings' finiteness results for curves of genus at least 2 (and for abelian varieties) as well as Wiles' and Taylor's proof of Fermat's Last Theorem.

Renate Vistorin

K3 Surface with many symmetries

Already starting from dimension two, the underlying concepts of rational points and modularity are much harder to grasp. My endeavours often investigate K3 surfaces; as two-dimensional Calabi-Yau varieties, they have great relevance not only in algebraic and arithmetic geometry, but also for neighbouring areas such as differential geometry, string theory and dynamics. My main results concern K3 surfaces with large Picard number or special structures. For instance, I proved in joint work with Noam Elkies that, just like elliptic curves, the so-called singular K3 surfaces admit a correspondence with certain modular forms.

A key feature of my research is the study of elliptic fibrations. Not only do they allow for essential insights into the structure of algebraic surfaces, but they also pave the way towards novels results in dynamics. Further projects deal with classical and fundamental topics such as rational curves and Picard numbers of algebraic surfaces, but also with varieties of higher dimension such as Calabi-Yau varieties and Hyperkähler manifolds.

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Important professional positions

2013 to today	Professor for Algebraic Geometry, Leibniz University Hannover
2009 to 2013	Juniorprofessor, Leibniz University Hannover
2008 to 2009	Postdoc, Københavns Universitet
2006 to 2008	Postdoc, Harvard University
2006 to 2006	Predoc, Università di Milano

Important research projects

» Arithmetic of algebraic surfaces (ERC Starting Grant 279723)
» Lines on surfaces in IP^3
» Maximal root types on Enriques surfaces
» Finite symplectic automorphism groups of supersingular K3 surfaces
» Real multiplication on K3 surfaces

Important publications

» Mordell-Weil lattices (mit T. Shioda) Ergebnisse der Mathematik und ihrer Grenzgebiete. 3. Folge, Vol. 70, Springer (2019)
» Dynamics on supersingular K3 surfaces, Comment. Math. Helv. 91 (2016), 705-719.
» 64 lines on smooth quartic surfaces (mit S. Rams), Math. Ann. 362 (2015), 679-698.
» Picard numbers of quintic surfaces, Proc. LMS 110 (2015), 428-476.
» Modular forms and K3 surfaces (mit Noam D. Elkies), Advances in Mathematics 240 (2013), 106-131

Institute of Analysis

private

Prof. Dr. Elmar Schrohe
Executive Director

private

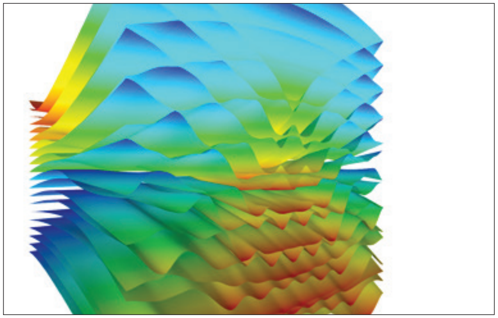
Susanne Rudolph
Office

Analysis has its origin in the invention of differential and integral calculus by Gottfried Wilhelm Leibniz and Isaac Newton.

Research at the institute focuses on the interplay between analysis and geometry. We consider operators and equations that often originate in physics or applied sciences.
We study partial differential equations on manifolds with geometric singularities, such as conical points or edges, investigating to what extent the geometry of the base space is reflected in the solutions of the equations. Do they have other properties than the solutions of the corresponding equations in the smooth case? How do the solutions behave near the singularities?

The question as to what extent the spectrum of an operator contains geometric information is of a similar nature. This plays a special role in the investigation of quantum mechanical systems where the spectrum represents the relevant energy levels. One focus is on the analysis of Schrödinger operators in a magnetic field, whose model properties (periodic, almost periodic, random) have their origin in solid-state physics. Here, operators on singular spaces (quantum graphs) are important as well.

Spaces with special geometry, such as Heisenberg or more generally Subriemannian manifolds, are of particular interest. In addition to the usual Riemannian metric, they are equipped with another one, namely the Carnot-Carathéodory metric, with respect to which their dimension seems to increase. The



Gruber

Mathematical physics/spectral theory:
Spectrum of a Schrödinger operator with magnetic field varying as a function of perturbations.

hidden additional dimension can be seen, for example, in the analysis of the heat equation for the associated geometric operators or the investigation of their spectral zeta function. Conversely, one can try to assign such a geometry to a given operator in order to draw conclusions about its analytical behavior.
Subriemannian manifolds play a role in the modeling of motions subject to constraints that depend on position and velocity. One encounters such problems in everyday life when trying to park a car in confined space. The concept of geometry under constraints has one of its origins in questions of thermodynamics and has recently also found applications in control theory or robotics.

Algebras generated by these operators have a rich structure. Methods of non-commutative geometry allow to draw conclusions about the nature of the base space from their algebraic and analytic properties. For this purpose, we compute the K-theory and cyclic homology of associated algebras of pseudodifferential operators and boundary value problems or construct so-called ‚spectral triples'.

We also consider algebras of Toeplitz operators on Bergman and Hardy spaces consisting of holomorphic functions over symmetric domains. There are natural links to complex analysis and Lie theory.

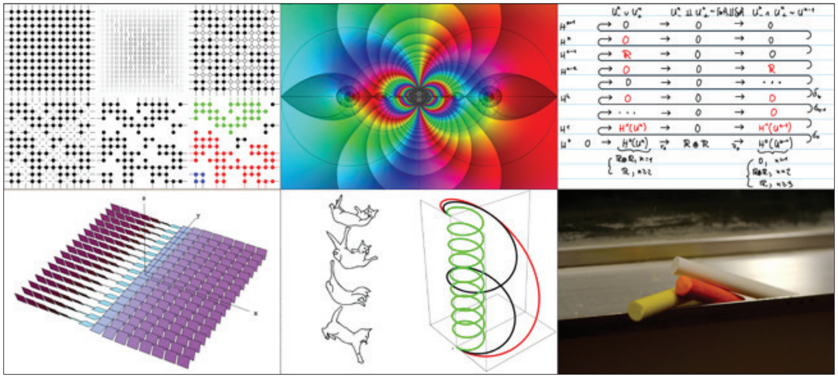
Non-commutative geometry also allows a formulation of the standard model of particle physics coupled to gravity. Compared to conventional versions, this offers a more convincing derivation, but does not provide a solution to the quantization problem. We are therefore participating in the exciting search for a model in non-commutative geometry that has the standard model coupled to gravity as a semiclassical limit. In particular, such a model would include a quantization of gravity.

There are a number of international research collaborations with working groups on the topics described above, e.g. in Copenhagen, Mexico City, Tokyo and Turin.

In the field of teaching, the Institute of Analysis offers a wide range of basic lectures for students of mathematics, physics and other subjects. Our focus is on the analysis cycle, complex analysis, functional analysis and partial differential equations but we also offer courses in stochastics. Special lectures and research seminars then open up opportunities for bachelor, master and doctoral theses.

S. Gerhard

Prof. Dr. Wolfram Bauer



Bauer/Gruber

Graph theory: modeling percolation by random graphs, Function theory: isolated singularities and cluster point, Differential topology: diagram hunting with the Mayer-Vietoris sequence, The Heisenberg group as a Subriemannian manifold: visualization of a distribution, Subriemannian geometry: the falling cat as a „connectivity problem" on a Subriemannian manifold and geodesics of the Heisenberg group, Media: (also) Cretaceous time.

Prof. Dr. Wolfram Bauer

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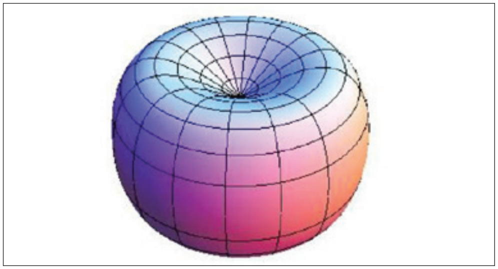
The evolution of an n-particle system under non-holonomic constraints can often be formulated as a „connectivity problem" in Subriemannian geometry. Can any initial configuration of the system be connected to any final configuration, and how is this done with the least energy? Such questions also play a role in other fields. Applications arise, for example, in control theory or robotics.

In generalization of the Laplace-Beltrami operator, Subriemannian structures often induce geometric differential operators. We study connections between analysis and geometry. Heat kernels and spectral zeta functions as well as a description of the Subriemannian geodesics are important objects in the analysis. Currently, we consider compact nilmanifolds over two-step nilpotent Lie groups of (pseudo) Heisenberg type.

Within this example class, non-homeomorphic isospectral families can be classified. The case of higher-step groups forms a challenge for our future research.

Another focus of research is on operator theory over Bergman and Hardy spaces of holomorphic functions. Applications arise in the area of deformation quantization as well as operator ideals, spectral theory, and index formulas. Located at the border of different mathematical fields, the work is based on methods of functional analysis, complex analysis and Lie theory. In particular, commutative Toeplitz algebras will be classified and their Gelfand theory will be described.



I. Markina

Unit sphere of the Heisenberg group with respect to a Subriemannian metric (Carnot-Carathéodory metric)

Important research projects

- Host within the Georg Forster Research Fellowship Program of the Alexander von Humboldt Foundation. Project: function and operator theory in spaces of holomorphic functions; awardee: Dr. Edgar L. Tchoundja (starting May 2021)
- Spectral analysis of Sub-Riemannian structures, research project within the DFG priority program SPP 2026 „Geometry at Infinity" (2017-2020)
- Aspects of heat flow on special manifolds and applications in operator theory. funded by the Emmy Noether Program of the DFG (2008-2014)

Important professional positions

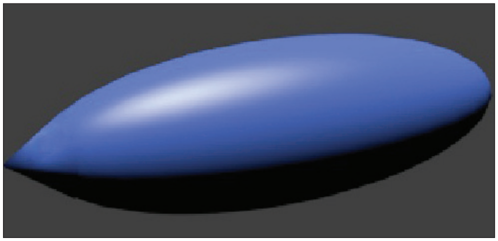
2014 to today	professor at Leibniz University Hannover
2010 to 2014	Junior Research Group Leader within the Emmy Noether Program of the DFG at the Georg-August Universität Göttingen
2008 to 2010	Junior professor at Ernst Moritz Arndt Universität Greifswald
2006 to 2008	postdoc, Tokyo University of Science
1995 to 2005	Study at the Johannes Gutenberg-Universität Mainz; visiting researcher, SUNY at Buffalo

Important publications

- W. Bauer, A. Froehly, I. Markina. Fundamental solutions of a class of ultra-hyperbolic operators on pseudo H-type groups. Adv. Math. 369, 1-46 (2020)
- W. Bauer, N. Vasilevski. On the structure of commutative Banach algebras generated by Toeplitz operators on the unit ball. Quasi-elliptic case I: Generating subalgebras. J. Funct. Anal. 265, no. 11, 2956-2990 (2013)
- W. Bauer, K. Furutani, C. Iwasaki. Spectral zeta function of the sub-Laplacian on two-step nilmanifolds. J. Math. Pures Appl. (9) 97, no. 3, 242-261 (2012)
- W. Bauer, L.A. Coburn, J. Isralowitz. Heat flow, BMO, and the compactness of Toeplitz operators. J. Funct. Anal. 259, no. 1, 57-78 (2010)

The interaction of analysis and geometry is a central topic of the research group. One example are nonlinear parabolic evolution equations on manifolds with singularities, such as conical points or edges. What can be said about regularity and asymptotics of the solutions near the singularities? To answer such questions, we develop adapted pseudodifferential calculi and analyze the properties of the associated operators. The technology obtained can also be used to study the solvability of boundary value problems with non-elliptic boundary conditions.

E. Schrohe



Manifold with conical singularity

Another example is the analysis of the structure of algebras of pseudo-differential operators, Fourier integral operators, and boundary value problems. Can we - in the spirit of Alain Connes' noncommutative geometry - extract information about the underlying space from the K-theory and cyclic homology of such algebras? What are the structure-preserving isomorphisms? What about the index theory of the associated operators? Pseudodifferential operators and Fourier integral operators can also be used to construct special states on globally hyperbolic spacetimes. Here we are particularly interested in the case where the underlying Lorentz metric has low differentiability properties.

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Important professional positions

2003 to today	Professor of Analysis, Leibniz University Hannover, Germany
1997 to 2003	Professor of Analysis, Potsdam University
1992 to 1996	Postdoctoral Researcher and Deputy Head (C3) of the Max Planck Research Group 'Partial Differential Equations and Complex Analysis' at Potsdam University
1984 to 1985	Visiting Scholar, University of California, Berkeley

Important research projects

» Analysis on singular manifolds: Nonlinear evolution equations on manifolds with singularities
» Operator algebras: K-theory and index theory, in particular for Fourier integral operators. Structure of algebras of pseudodifferential operators and boundary value problems.
» Boundary value problems with singular boundary conditions.
» Microlocal analysis on globally hyperbolic spacetime manifolds.

Important publications

» A. Savin, E. Schrohe. Analytic and algebraic indices of elliptic operators associated with discrete groups of quantized canonical transformations. J. Funct. Anal. 278:108400 (2020)
» N. Roidos, E. Schrohe. Smoothness and long time existence for solutions of the porous medium equation on manifolds with conical singularities. Comm. Partial Differential Equations 43(10):1456–1484 (2018).
» K. Bohlen, E. Schrohe. Getzler rescaling via adiabatic deformation and a renormalized index formula. J. Math. Pures Appl. 120:220-252 (2018).
» S. Melo, T. Schick, E. Schrohe. A K-theoretic proof of Boutet de Monvel's index theorem. J. Reine Angew. Math. 599, 217-233 (2006)
» G. Grubb, E. Schrohe. Trace expansions and the noncommutative residue for manifolds with boundary, J. Reine Angew. Math. 536, 167 - 207 (2001).

Institute of Applied Mathematics

private

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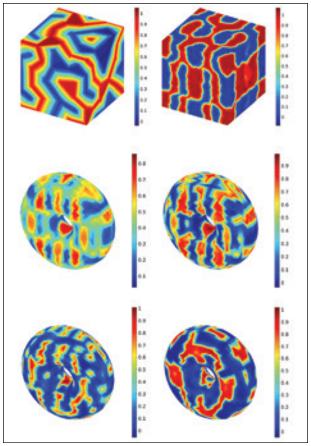


The research at the Institute of Applied Mathematics (IfAM) is motivated by practical questions from natural sciences, engineering and economics. Therein, mathematical modelling, theory and numerical methods are addressed. At IfAM the following research groups are located: Applied Analysis (Prof. Escher), Mathematical Modelling and Nonlinear Differential Equations (Prof. Walker), Mathematical Modelling with Focus on Life Sciences (Prof. Lankeit), Algorithmic Optimization (Prof. Steinbach), Numerical Analysis (Prof. Beuchler), and Scientific Computing (Prof. Wick)

Mathematics has an increasing importance in natural sciences and engineering, as well as in medicine, economics and social sciences. These fields yield complex questions and models, which must be treated by state-of-the-art mathematical methods. Reliable models for complicated situations are based on natural scientific laws, which can often be described with the help of nonlinear partial differential equations and evolution equations. On the one hand, Applied Analysis and Mathematical Modelling derive models for natural sciences and engineering and, on the other hand, address validation and mathematical analysis of existing models. Such validations include fundamental existence and uniqueness results and investigation of qualitative properties of solutions. The research group Mathematical Modelling with Focus Life Sciences specifically focuses on similar questions on problems in biology. Here, a focus is on parabolic differential equations, chemotaxis, which describes partially directed movements of cells in reaction to chemical signals.

Algorithmic Optimization addresses problems of optimal design and optimal control, for instance profit maximization or minimization of resources under given constraints. Often, parts of the constraints describe technical or commercial processes, for instance using differential equations. The main input data (future prizing, needs, and so forth) are often based on statistical predictions. These result into fields such as nonlinear optimization and control of stochastic optimization with an emphasis on the design of efficient algorithms for the numerical solution of complex applications.

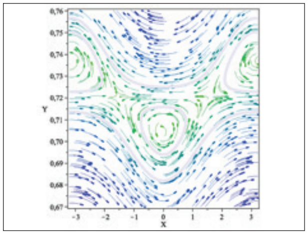
The research group Numerical Analysis investigates reliability and efficiency of methods, which are required to solve mathematical problems with the help of computers. Specifically, approximations for partial differential equations and effective iterative solution methods of the resulting discretizations are of interest.

The previously derived models and methods are applied to engineering problems, which include their algorithmic realization, research software development, and with feedback to mathematical and numerical analyses. These last tasks are in the focus of the research group Scientific Computing.

Relating analytical and numerical methods to applications is of outmost importance at IfAM. Evidence is given by several collaborations with engineering institutes as well as partners from industry and economics. State-of-the-art analytical methods and numerical algorithms are designed and the latter are implemented on clusters allowing for parallel high-performance computing. Such efforts allow for the efficient numerical simulations and optimization. A specific pleasure is the similarity of various mathematical models, but motivated from distinct applications, which shows the power of mathematics to identify certain structures and similar principles.

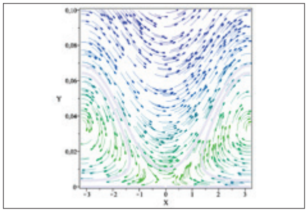
At IfAM, some topics are funded by third-party projects from the German Research Foundation (DFG) and the Bundesministerium für Bildung und Forschung (BMBF). Furthermore, IfAM is part of interdisciplinary cooperations, such as the International Research Training Group IRTG 2657 „Computational Mechanics Techniques in High Dimensions (CoMeTeNd)", the excellence cluster PhoenixD, and the Leibniz Research School „QUEST". The latter allows for interdisciplinary dissertation projects. Moreover, IfAM has projects within the Sonderforschungsbereich (SFB) „Offshore-Megastrukturen" and the DFG priority program SPP 1962 „Optimization of fracture propagation with a phase-field methods".

Lectures and courses at IfAM aim for unity of research and teaching. Application-oriented classes include for instance »Numerische Mathematik«, »Gewöhnliche Differentialgleichungen«, »Partielle Differentialgleichungen«, »Numerik partieller Differentialgleichungen«, »Nichtlineare Optimierung«, »Halbgruppen & Evolutionsgleichungen and »Nichtlineare Funktionalanalysis«, offered on a regular basis. Besides basic lectures, numerous special classes and seminars build the basis for Bachelor and Master theses. In addition, several service courses are offered for engineering and economics faculties and teaching education.



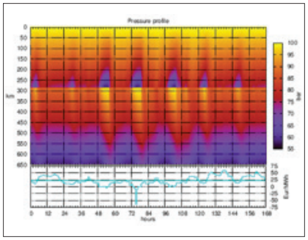
Escher

Streamlines of two-dimensional flow with general vortex distribution.



Escher

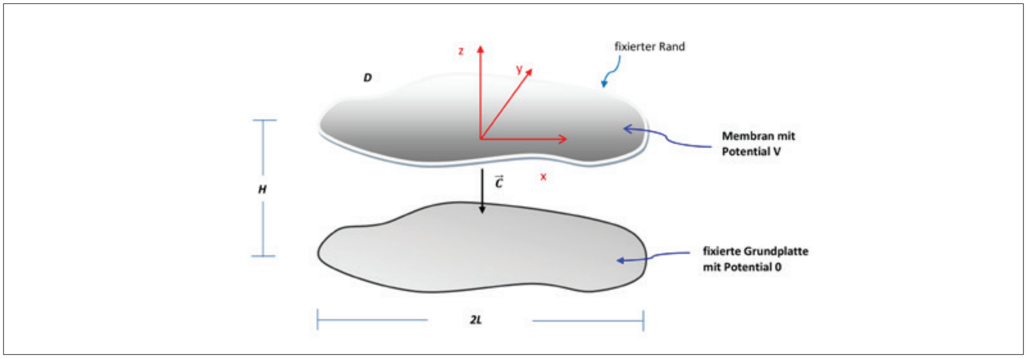
Streamlines of two-dimensional flow with general vortex distribution.



Steinbach

Optimal pressure evolution of a gas pipeline over one week for the compensation of oscillations of regenerative produced electric energy via pressure reserve (<<line pack>>).

Walker



Microelectromechanical systems (MEMS) are key components in electronics nowadays. Idealized MEMS devices consist of a fixed ground plate and a membrane which is actuated by a voltage difference. A contact of the two components leads to instabilities or singularities.

Prof. Dr. Sven Beuchler

C. Wyrwa

Prof. Dr. Sven Beuchler

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The group Numerical Analysis researches on the area of numerical methods for partial differential equations. These equations are the result of the mathematical modelling of complex processes in physics or engineneering. The solution of the partial differentail equations is replaced by the solution of an alternative problem which has the form of a linear or nonlinear system of algebraic equations. The more exact the numerical computed solution approximates the exact one, the larger becomes the size of the system. Therefore, one wants to obtain a sufficient accurate solution with as less as possible unknowns.

The main focus is the development, theoretical investigation und implementation of suitable and fast approximation algorithms for the solution of these partial differential equations. Besides the classical methods from numerical analysis this requires also techniques from other areas of mathematics. This includes besides programming, Linear Algebra, symbolic mathematics, mathematical programming also techniques in functional analysis.

Practical applications include for instance the numerical simulation in thermodynamics, electrodynamics and continuum mechanics. In a recent research project, an optical device (beam propagator) has to be simulated and optimized. Besides deep knowledge in mathematics this requires also the basic understanding of fundamental equations in physics as the system of Maxwells equations.

Important research projects

» Finite Elements of high order: solvers, basis functions and mesh refinement
» Simulations in electro dynamics
» Optimization with partial differential equations

Important professional positions

2017 – today	Professor, Leibniz University Hannover
2010 – 2017	Professor, Universitaet Bonn
2003 – 2010	Postdoktorand, Johannes-Kepler Universi taet Linz und Johann Radon Institute for Computational and Applied Mathematics Linz
2000 to 2003	Assistent, Technische Universität Chemnitz

Important publications

» Beuchler, S.; Schöberl, J. New shape functions for triangular p-FEM using integrated Jacobi polynomials. Numer. Math. 103 (2006), no. 3, 339–366.
» Beuchler, Sven Multigrid solver for the inner problem in domain decomposition methods for P-FEM. SIAM J. Numer. Anal. 40 (2002), no. 3, 928–944.
» Beuchler, S.; Schneider, R.; Schwab, C. Multiresolution weighted norm equivalences and applications. Numer. Math. 98 (2004), no. 1, 67–97.
» Beuchler, Sven; Pillwein, Veronika; Zaglmayr, Sabine Sparsity optimized high order finite element functions for H(div) on simplices. Numer. Math. 122 (2012), no. 2, 197–225.
» Beuchler, Sven; Pechstein, Clemens; Wachsmuth, Daniel Boundary concentrated finite elements for optimal boundary control problems of elliptic PDEs. Comput. Optim. Appl. 51 (2012), no. 2, 883-908.

In the Applied Analysis group, mainly nonlinear evolution equations are studied. Evolution equations represent the mathematical framework in which - mostly nonlinear - partial differential equations are studied, which describe the temporal evolution of certain quantities, such as the propagation of waves, the diffusion of substances, the melting of ice or the growth of tumors.

Besides the well-posedness of such systems, qualitative statements about the corresponding solutions are of central importance. One often observes the coexistence of temporally global solutions and those that form singularities in finite time. If the latter occurs, one is particularly interested in the nature of the singularities that occur. For example, in models describing water waves, one speaks of wave breaking when the amplitude of the wave itself remains bounded but its slope becomes infinite.

Another research project deals with regularity properties of streamlines of periodic waves. Under certain assumptions, the classical equations of hydrodynamics reduce to a free boundary value problem for the stream function and the wave profile.

In addition to free boundary value problems in fluid mechanics, other nonlinear evolution equations from natural science applications are studied analytically, such as microelectromechanical systems, tumor growth models, and phase transition models.

private

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Important professional positions

2014 - today	Vice President for Appointments, Staff Development and Continuing Academic Education
2011 - 2015	Member of the University Council
2011 - 2015	Member of the Senate
2000 - today	Professor at IfAM, Leibniz University Hannover
1998 to 2000	Professor at the Department of Mathematics

Important research projects

» Graduiertenkolleg GRK 1463 »Analysis, Geometry and String Theory«
» International Research and Training Group IRTG 1627 »ViVaCE Virtual Materials and their Validation: German-French School of Computational Engineering«
» DFG-Projekt »Strömungsprozesse im Flüssigschlick: Mathematische Modellierung und numerische
» Simulation«

Important publications

» (with A. Constantin): Analyticity of Periodic Traveling Free Surface Water Waves with Vorticity, Annals of Mathematics, 173 (2011), 559-568
» (with A. Constantin): Wave breaking for nonlinear nonlocal shallowwater equations, Acta Mathematica, 181 (1998), 229-243
» (with B. Kolev): Geodesic completeness for Sobolev Hs-metrics on the diffomorphism group of the circle, Journal of Evolution Equations 14 (2014), 949-968
» (with Ph. Laurençot and Ch. Walker): A parabolic free boundary problem modeling electrostatic MEMS, Archive of Rational Mechanics and Analysis 211 (2014), 389-417
» (with B. Matioc): On the analyticity of periodic gravity water waves with integrable vorticity function, Differential and Integral Equations, 27 (2014), 217-232

Prof. Dr. Johannes Lankeit

C. Wyrwa

Prof. Dr. Johannes Lankeit

Mathematical Modelling especially in Biosciences
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Especially in the biological sciences there are phenomena which are difficult to assess experimentally and where mathematical description and investigation offers itself as expedient approach to gaining knowledge.

Mathematical modelling, in my opinion, in particular involves understanding the models and their components with regard to their mathematical properties. Not least because of this, a focal point of my research is the analysis of parabolic differential equations.

Spontaneous emergence of structures in biological systems exemplarily occurs in the context of chemotaxis models. The PDE systems describing chemotaxis (partially directed movement of cells in response to concentrations of chemical signal substances) are related to reaction-diffusion systems, but contain an additional, "cross-diffusive" term complicating their analysis. They and related models appear not only during investigation of chemotactic aggregation (in the classical "Keller-Segel system"), but also as part of more complex descriptions, e.g. concerning the spread of tumours, or in ecology.

The interaction of chemotaxis effects with fluids (as represented by the Navier-Stokes equations) is interesting both in its result (appearance of (convection) patterns) and on a theoretical level (effect on existence and regularity of solutions).

More generally, I am also interested in the emergence of structure and singularities in evolution equations or systems of partial differential equations: How can simple mechanisms cause complicated phenomena? In particular, I study blow-up in parabolic equations. Where, when and how can such explosions occur, how can they be excluded?

Important professional positions

2020 - today	Professor at IfAM, Leibniz University Hannover
2019 - 2020	Scientific employee, Universität Paderborn
2018 - 2019	Postdoc, Comenius University, Bratislava
2013 - 2018	Scientific employee, Universität Paderborn
2012 - 2013	Scientific employee, Universität Duisburg-Essen

Important research projects

Important publications

» Marek Fila and Johannes Lankeit. Continuation beyond interior gradient blow-up in a semilinear parabolic equation. Math. Ann., 377(1-2):317–333, 2020.
» Marcel Braukhoff and Johannes Lankeit. Stationary solutions to a chemotaxis-consumption model with realistic boundary conditions for the oxygen. Math. Models Methods Appl. Sci., 29(11):2033–2062, 2019.
» Nikos I. Kavallaris, Johannes Lankeit, and Michael Winkler. On a Degenerate Nonlocal Parabolic Problem Describing Infinite Dimensional Replicator Dynamics. SIAM J. Math. Anal., 49(2):954–983, 2017.
» Xinru Cao and Johannes Lankeit. Global classical small-data solutions for a three dimensional chemotaxis Navier-Stokes system involving matrix-valued sensitivities. Calc. Var. Partial Differential Equations, 55(4): 107, 2016
» Johannes Lankeit. Eventual smoothness and asymptotics in a three-dimensional chemotaxis system with logistic source. J. Differential Equations, 258(4):1158–1191, 2015.

The group Algorithmic Optimization works primarily in the areas of Nonlinear Optimization and Multi-Stage Stochastic Optimization, especially in connection with Differential-Algebraic Equations or Partial Differential Equations for modeling complex physical, technical or economic processes.

These classes of optimization models arise in various problem areas in industry and business, especially planning and control. Typically the models involve discrete decisions or additional mathematical difficulties due to application-specific peculiarities. Currently we focus on applications in the area of hybrid mecanical multibody systems.

Our research aims at developing robust and efficient numerical algorithms for challenging practical problem classes, with an emphasis on exploiting specific structural properties on various mathematical levels. We implement the algorithms as software packages and libraries and specialize them for individual applications if appropriate.

S. Gerhard

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Important professional positions

2006 - today	Professor, Leibniz University Hannover
2006 - 2006	Visiting Research Professor, Univ. of Applied Sciences Vorarlberg, Austria
1997 - 2006	Postdoctoral researcher, Zuse Institute Berlin
1989 - 1996	Researcher, Univ. Augsburg and Heidelberg

Important research projects

- » Model Order Reduction and Efficient Simulation for Offshore Wind Energy Plants
- » Optimal Planning in Gas Networks
- » Minimum Cost Operative Planning in the Drinking Water Network of Berlin
- » Dynamic Portfolio Optimization

Important publications

- » L.C. Hegerhorst-Schultchen, C. Kirches, M.C. Steinbach: Relations between Abs-Normal NLPs and MPCCs. Part 1: Strong Constraint Qualifications. J. Nonsmooth Anal. Optim. 2, 6672, 2021.
- » C.G. Gebhardt, D. Schillinger, M.C. Steinbach, R. Rolfes: A Framework for Data-Driven Structural Analysis in General Elasticity Based on Nonlinear Optimization: The Static Case. Comput. Methods Appl. Mech. Eng., 365, 2020.
- » J. Hübner, M. Schmidt, M.C. Steinbach: A Distributed Interior-Point KKT Solver for Multistage Stochastic Optimization. INFORMS J. Comput. 29(4), 612-630, 2017.
- » J. Burgschweiger, B. Gnädig, M.C. Steinbach: Optimization Models for Operative Planning in Drinking Water Networks. Optim. Eng., 10(1), 43-73, 2009.
- » M.C. Steinbach: Markowitz Revisited: Mean-Variance Models in Financial Portfolio Analysis. SIAM Rev. 43(1), 31-85, 2001.

Prof. Dr. Christoph Walker

S. Gerhard

Prof. Dr. Christoph Walker

Mathematical Modelling, especially nonlinear differential equations

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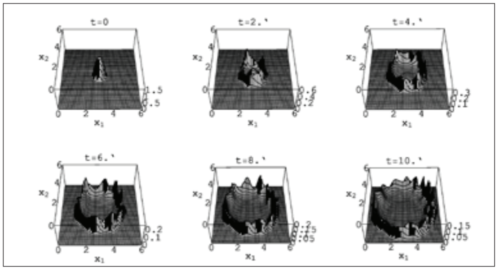
Many processes in natural sciences and engineering can be described by nonlinear partial differential equations. Mathematical Modelling is a way to examine to what extent such equations can reflect the really observed phenomena. Well-posedness (existence and uniqueness) and the qualitative behaviour of solutions are important subjects. For the examination, tools from various fields of applied analysis are used, such as operator semigroups, maximal regularity, dynamical systems, bifurcation theory and variation methods.

Microelectromechanical systems (MEMS) are subjects of current research. The modelling of a membrane which is suspended over a baseplate and deforms due to voltage differences leads to a free boundary problem for the electrostatic potential coupled to a singular evolution equation for the membrane. Research includes, among other things, the voltage-dependent number of equilibria and the long-term behaviour of solutions especially in the unstable regime when membrane and baseplate make contact.

Another research project deals with equations for the temporal change of age-structured populations that propagate in space (e.g. tumour cells or bacteria). Such equations cannot be assigned to any basic type of partial differential equations (hyperbolic or parabolic). Besides this, research involves also coagulation-fragmentation processes from the field of chemistry (polymerisations, liquid-liquid dispersions) or biology (prion proliferation) which are modelled by infinite systems of coupled, nonlinear-integral differential equations and describe the accumulation or disintegration of certain „particles".



Walker/Webb

Simulation of tumor invasion into tissue

Important research projects

- » Nonlinear evolution equations and operator semigroups
- » Free boundary value problems
- » Applications of Nonlinear Differential Equations in natural sciences (i.e. MEMS, structured population models, coagulation fragmentation processes)

Important professional positions

2007 - today	Professor, Leibniz University of Hannover
2004 - 2007	Assistant Professor, Vanderbilt University, Nashville TN (USA)
2003 - 2004	Postdoc, University of Zurich (Switzerland)
1999 - 2003	Assistant, University of Zurich (Switzerland)

Important publications

- » Ph. Laurençot, Ch. Walker. *Shape Derivative of the Dirichlet Energy for a Transmission Problem.* Arch. Ration. Mech. Anal. 237 (2020), 447-496.
- » Ph. Laurençot, Ch. Walker. *Some Singular Equations Modeling MEMS.* Bull. Amer. Math. Soc. 54 (2017), 437-479.
- » J. Escher, Ph. Laurençot, Ch. Walker. *A Parabolic Free Boundary Problem Modeling Electrostatic MEMS.* Arch. Ration. Mech. Anal. 211 (2014), 389-417
- » Ch. Walker. *On Positive Solutions of Some System of Reaction-Diffusion Equations with Nonlocal Initial Conditions.* J. Reine Angew. Math. 660 (2011), 149-179
- » Ch. Walker, G.F. Webb. *Global Existence of Classical Solutions for a Haptotaxis Model.* SIAM J. Math. Anal. 38 (2007), 1694-1713

Prof. Dr. Thomas Wick

In the Scientific Computing research group, we design, implement and analyze numerical methods for nonstationary, nonlinear, coupled partial differential equations and variational inequalities. Applications include problems from fluid dynamics, elasticity, fluid-structure interaction, thermoporoelasticity and fracture propagation in elasticity and porous media. A main emphasis is on nonlinear solvers, adjoint-based goal-oriented a posteriori error estimation, adaptive methods and parallel high performance computing. These concepts serve also as inner solvers in numerical optimization such as optimal control, optimal design and parameter estimation.

Our mathematical and numerical modeling specifically include interdisciplinary cooperations with engineering as well as medical-economy-mathematical work. The latter employs mathematical structures in form of ordinary differential equations for modeling intervention and resilience in medical applications.

The Scientific Computing group has a strong international emphasis with projects in south America (Peru, DAAD), Asia (IIT Indore, DAAD) and France within the international research training group IRTG 2657 with the Ecole Normale Superieur Université Paris-Saclay (France). These projects include research, teaching and both simultaneously. Moreover, the group maintains research collaborations with Linz (Austria) and UT Austin (USA), and hosted long-term visiting PhD students from China (Meng Fan) and the Charles University in Prague (Shahin Heydari) as well as two cotutelle theses associated to the IRTG 2657.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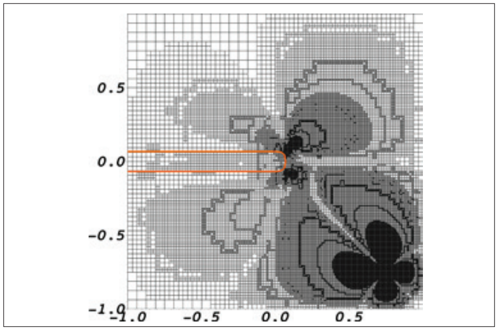
T. Wick


Adaptively refined mesh

Important professional positions

2017 - today	Professor, Leibniz University Hannover
2016 - 2017	Maitre de conferences, Ecole Polytechnique
2015 - 2015	Substitute professor, TU Munich
2014 - 2016	Research Scientist, RICAM Linz
2012 - 2014	Postdoc (partially Feodor Lynen fellow), ICES, UT Austin
2008 bis 2011	Doctoral researcher, Heidelberg University

Important research projects

» Computational Mechanics Techniques in High Dimensions (CoMeTeNd) in collaboration with ENS Paris-Saclay
» DFG-SPP 1962 Optimizing Fracture Propagation Using a Phase-Field Approach
» Indo-German Higher Education Partnership 2019 - 2023, DAAD (German Academic Exchange Service) Leibniz University Hannover - IIT Indore / Germany – India
» Member of PeCCC (Peruvian Competence Center of Scientific Computing), Stärkung des Wissenschaftlichen Rechnens in der Lehre in Peru
» Member of the cluster of excellence PhoenixD

Important publications

» T. Wick; Multiphysics Phase-Field Fracture: Modeling, Adaptive Discretizations, and Solvers, Radon Series on Computational and Applied Mathematics, Band 28, de Gruyter, Oktober 2020
» B. Endtmayer, U. Langer, T. Wick; Multigoal-Oriented Error Estimates for Non-linear Problems, Journal of Numerical Mathematics (JNUM), Vol. 27(4), 2019, pp. 215-236
» T. Wick; An error-oriented Newton/inexact augmented Lagrangian approach for fully monolithic phase-field fracture propagation, SIAM J. Sci. Comput., Vol. 39(4), 2017, pp. B589-B617
» T. Richter, T. Wick; Variational Localizations of the Dual-Weighted Residual Estimator, Journal of Computational and Applied Mathematics, Vol. 279 (2015), pp. 192-208

Institute of Differential Geometry

Prof. Dr. Knut Smoczyk
Executive Director

Melanie Eggert
Office

Differential geometry can be divided into classic and modern sub-areas. Surfaces and bodies in euclidean space as well as their geometric properties are the subject of the classical theory. These objects include, for example, minimal surfaces that appear in nature in the form of soap films. In contrast to this, modern differential geometry is founded on a theory that results from an intrinsic description of geometric objects, i.e. from a description without referring to an ambient space. Central sub-areas in this context include: Riemann geometry, Kähler geometry, symplectic geometry, Lorentz and sub-Riemannian geometry.

Differential geometry is closely linked with other mathematical disciplines such as analysis, topology, algebraic geometry and representation theory. Differential geometry is also essential for areas of application within theoretical physics - its influences range from mechanics to special and general relativity, string theory and cosmology.

Teaching
Teaching in differential geometry forms a core component within pure mathematics and the institute regularly offers the following courses for students in the bachelor's and master's degree programs: Classical Differential Geometry, Manifolds, Riemannian Geometry and Complex Differential Geometry.

In addition to these basic lectures on differential geometry, numerous special lectures and other courses are offered, which prepare students in particular for their upcoming final theses. In addition, topics from classical differential geometry and Euclidean geometry are ideal for final theses in degree courses for teachers.

Research
At the Institute of Differential Geometry, the individual branches of research are represented in several research groups.

Geometric evolution equations, geometric partial differential equations and geometric analysis form a central area of research at the institute. Geometric evolution equations are among the most exciting tools in modern differential geometry and have therefore been used successfully in many areas, such as in the proofs of the Poincaré conjecture, Thurston's geometrization conjecture or the differentiable sphere theorem. The most important geometric evolution equations are: Ricci, Sasaki-Ricci and Kähler-Ricci flow, mean curvature flow, Yamabe flow, harmonic map heat flow, Willmore flow, Yang-Mills and spinor flow.

The Lagrangian mean curvature flow is of great importance both in the context of the Strominger-Yau-Zaslow and Thomas-Yau conjectures and in the mirror symmetry of Calabi-Yau manifolds and the theory of special Lagrangian submanifolds. In addition to the evolution equations already listed, the institute deals with projects in the field of Kähler geometry and contact geometry, e.g. with Yamabe problems on the space of adapted contact metrics on a contact manifold. These questions can also be investigated very well using geometric evolution equations. Since singularities usually occur under mild initial conditions, the study of the limiting cases that can be observed is relevant.

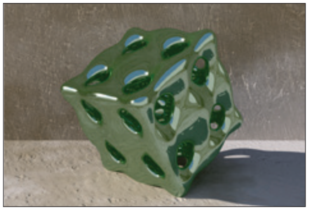
Gauge theory is one of the other research fields at the institute. Examples of gauge theories are electromagnetism, the Yang-Mills theory, and the Yang-Mills-Higgs theory. Mathematically, gauge theories are formulated on principle fiber bundles or vector bundles. The solutions are connections that satisfy certain partial differential equations. The modular spaces of the solutions often have a very interesting geometry. In the Yang-Mills theory this is the moduli space of instantons, in Yang-Mills-Higgs theory it is the moduli space of magnetic monopoles. Conversely, understanding the moduli spaces provides new information about the dynamics in the relevant physical theory.

Several important geometric structures can be constructed and examined via their twistor space, i.e. as a parameter space of (real) rational curves in a complex manifold. Naturally occurring examples of these geometries, which contain hyperkähler metrics, are of great importance in several branches of mathematics and mathematical physics: e.g. quiver varieties in representation theory, Hitchin's moduli spaces in algebraic geometry and the theory of integrable systems, gauge theoretical moduli spaces of monopoles and instantons in mathematical physics.

Global surface theory forms a third research area. This theory examines the optimal realization of surfaces in (three-dimensional) space forms under certain obstructions. The institute is particularly interested in minimal and CMC surfaces as well as in Willmore surfaces and harmonic maps into symmetric spaces. Techniques from geometric analysis, the theory of integrable systems, gauge field theory and algebraic geometry are required and used. Applications can be found, for example, in theoretical physics, for example in string theory and the AdS / CFT correspondence.

The behavior of surfaces depends fundamentally on the curvature of the ambient space. Proving the existence of special surfaces in positively curved spaces is particularly challenging. In this context, the Kusner conjecture should be mentioned, which is a direct generalization of the Willmore conjecture, which was only proven in 2012.

In the case of a negative curvature of the ambient space, minimal surfaces or harmonic maps are usually unique in their homotopy class. This puts the maps in a direct relation with representations of the fundamental group of the surface, which has been intensively investigated in numerous important works in recent years (in a wide variety of areas such as number theory, geometric group theory, string theory, as well as algebraic and differential geometry). In our research, complex curves in the moduli space of flat connections and the associated relation to monodromy problems of differential equations, which in turn play a central role in many areas of mathematics, play a special role in our research. As a result, the techniques we have developed are also used outside the global surface theory.



Prof. Dr. Roger Bielawski

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Prof. Dr. Roger Bielawski

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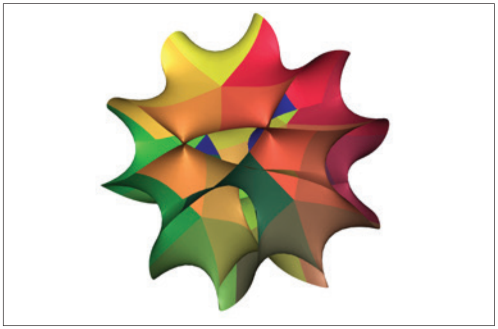
The focus of my research is differential geometry - a central area of pure mathematics, with strong connections to other mathematical fields such as analysis, topology, algebraic geometry, and representation theory.

Furthermore, differential geometry is also essential for many applications, in particular in physics - from mechanics to string theory and cosmology.

The main topics of my mathematical research are Riemannian and symplectic manifolds and their relations to mathematical physics. I use a variety of methods, from calculus to algebraic geometry and the theory of integrable systems. In particular, I work in the following broad areas:

- Construction and classification of Riemannian manifolds with special holonomy, in particular Ricci-flat Kähler and hyper-Kähler manifolds.
- Moduli spaces in gauge theory, in particular natural geometric structures on the moduli spaces of instantons and monopoles.
- Twistor theory: Methods of algebraic geometry in differential geometry and in integrable systems.
- Noncommutative symplectic geometry, in particular deformation quantization of instanton moduli spaces and their applications to integrable systems.



Andrew J. Hanson

A section through a quintic Calabi-Yau manifold

Important research projects

» Construction, classification and properties of Ricci-flat Kähler and hyper-Kähler manifolds.
» Asymptotics of monopole metrics; the Sen conjecture.
» Deformation quantization of the instanton moduli spaces

Important professional positions

2012 - today	Professor, Leibniz University Hannover
2006 - 2012	Professor, University of Leeds
1998 - 2006	LLecturer and Reader: University of Edinburgh and University of Glasgow
1994 - 1998	Postdoc: McMaster University and MPIM Bonn
1988 - 1993	Doctoral studies, McGill University

Important publications

» (with L. Schwachhöfer) Pluricomplex geometry and hyperbolic monopoles, Commun. Math. Phys. 323 (2013), 1-34
» Monopoles and clusters, Commun. Math. Phys. 284 (2008), 675-712
» Prescribing Ricci curvature on complexified symmetric spaces, Math. Res. Lett. 11 (2004), 435-441
» (with A. Dancer) The geometry and topology of toric hyperkaehler manifolds, Comm. Anal. Geom. 8 (2000), 727-759
» Complete hyperkaehler manifolds with a local tri-Hamiltonian Rn-action, Math. Ann. 314 (1999), 505-528

My research lies in the area of differential geometry and geometric analysis with interconnections to algebraic and symplectic geometry. It mainly concerns with optimal realizations of (Riemannian) surfaces of a given topological type in space.

Optimal here means that the surfaces minimize the area or the Willmore functional under certain geometric constraints. The topological constraint in particular requires a variety of techniques from different branches of mathematics, some of which are still to be developed. Remarkably, it is currently not possible to compute geometric quantities such as the area of a minimal surface once the topology of the surface is more involved. In my investigations, the moduli space of flat connections over Riemann surfaces naturally appears. Solving monodromy problems is therefore of central importance, and also provides a link to numerous other problems in mathematical physics such as mirror symmetry and the AdS/CFT correspondence.


Nicholas Schmitt


Nicholas Schmitt


C. Wyrwa

Prof. Dr. Lynn Heller

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Important professional positions

2017 - today	Junior Professor for Differential Geometry, Leibniz University Hannover
2009 - 2017	Research Associate, Tübingen

Important research projects

» DFG HE 7914/2-1, Grenzwerte energieminimierender Minimalflächen in der 3-Sphäre

Important publications

» (with Indranil Biswas, Sorin Dumitrescu, Sebastian Heller) Holomorphic -systems with Fuchsian monodromy (with an appendix by Takuro Mochizuki). arXiv:2104.04818
» (with Cheikh Birahim Ndiaye) First explicit constrained Willmore minimizers of non-rectangular conformal class. Advances in Mathematics 386, 107804, 2021
» (with Sebastian Heller) Higher solutions of Hitchin's self-duality equations, Journal of Integrable Systems 5 (1), xyaa006, 2020.
» (with Sebastian Heller and Nicholas Schmitt) Navigating the Space of Symmetric CMC Surfaces, Journal of Differential Geometry, 110 (3), pp 413-455, 2018.
» Constrained Willmore Tori and Elastic Curves in 2-Dimensional Space Forms. Communications in Analysis and Geometry, 22 (2), pp 343-369, 2014.

Prof. Dr. Knut Smoczyk

Prof. Dr. Knut Smoczyk

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My research interests within Differential Geometry are Geometric Evolution Equations, Kähler- and Sasaki Geometry as well as Geometric Analysis. In particular, geometric evolution equations and elliptical partial differential equations are examined, which are related to sections in vector space bundles over differentiable manifolds and with the help of which statements about the existence and uniqueness of objects with special geometric properties can be derived.

These include the mean curvature flow, especially in higher codimensions and of Lagrange subman-ifolds, the Sasaki-Ricci flow and flows of mappings between Riemannian or symplectic manifolds. The main focus is on understanding the modular space of special Lagrangian submanifolds in Cala-bi-Yau manifolds and their relation to mirror symmetry and the Thomas-Yau conjecture.

In recent projects of the working group, questions about the existence in connection with harmonic and minimal mappings between Riemannian and Kählerian manifolds are investigated.

Institute's logo

Important professional positions

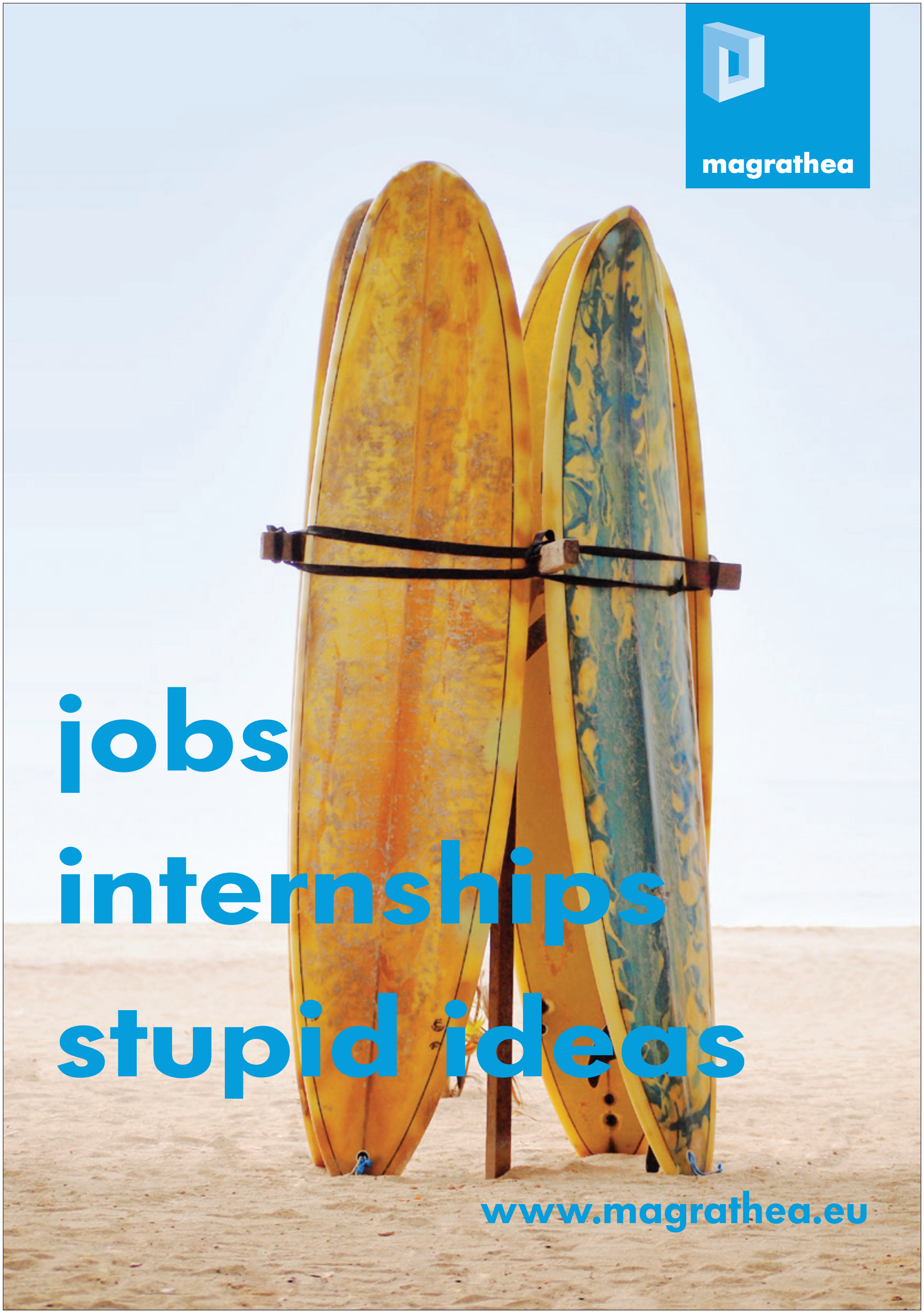
since 2018	spokesperson of the Riemann Center for Geometry and Physics
since 2006	Managing director of the Institute for Differential Geometry
since 2005	Professor for Differential Geometry, Leibniz University Hannover
2004 - 2005	Heisenberg fellow at the Albert Einstein Institute in Golm with Gerhard Huisken
1996 - 1998	Postdoc in Michael Struwe's group, ETH Zurich
1995 - 1996	Feodor Lynen fellow in the working group of S.-T. Yau, Harvard University

Important research projects

» DFG SM 78/4-1, Selfsimilar solutions of the mean curvature flow
» DFG SM 78/6-1, Mean curvature flow in higher co-dimensions
» DFG SM 78/7-1, Singularities of the Lagrangian mean curvature flow (Subproject number 76 in the priority program 2026, Geometry at Infinity)

Important publications

» (with Andreas Savas-Halilaj) Lagrangian mean curvature flow of Whitney spheres. Geometry & Topology 23 (2019), 1057–1084
» (with Francisco Martin, Jesus Perez-Garcia and Andreas Savas-Halilaj) A characterization of the grim reaper cylinder. J. reine angew. Math. 746 (2019), 209–234
» Self-shrinkers of the mean curvature flow in arbitrary codimension. International Mathematics Re-search Notices 48 (2005) 2983–3004
» Angle theorems for the Lagrangian mean curvature flow. Math. Z. 240 (2002), no. 4, 849-883
» (with Mu-Tao Wang) Mean curvature flows of Lagrangians submanifolds with convex potentials. J. Differential Geom. 62 (2002), no. 2, 243–257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Institute of Actuarial and Financial Mathematics

private

Prof. Dr. Gregor Svindland
Executive Director

C. Wyrwa

Bettina Peine-Bertram
Office

Actuarial and financial mathematics are essential to insurance and banking:

- profits and associated risks have to be balanced,
- investment strategies have to be optimized,
- financial and insurance products have to be priced and their risks have to be controlled.

The regulation of financial and insurance markets is of great importance to our society. An important aim on a national and global level is to maximize social welfare which is significantly affected by activities in the financial system. Successful regulation requires a proper control of various types of risk, in particular of systemic risk. Suitable models and methods for this purpose are provided by modern actuarial and financial mathematics, a vivid field of research. There are strong ties to other areas of mathematics such as stochastic optimization, stochastic analysis, statistics, functional/convex analysis and numerical analysis.

The research of the Institute of Actuarial and Financial Mathematics focuses mainly on optimal decisions and strategies in the face of risk and uncertainty. Modeling, quantifying, and controlling risk and uncertainty is key to any decision-making process in insurance, banking, and beyond. Recent research at the institute covers topics such as

- risk management, risk measures, preferences,
- robust portfolio optimization,
- economic equilibria and game theory,
- efficient Monte Carlo methods,
- market consistent valuation and optimal balance sheet management,
- systemic risk and network models,
- emerging risks such as cyber risk, risk in critical infrastructure and new technologies.

Hannover is one of Germany's centers in the field of insurance. Hannover's insurance industry is a major employer of graduates in mathematics. The Institute of Actuarial and Financial Mathematics offers a comprehensive program in actuarial

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and financial mathematics and prepares students for a career in both academia and industry. This includes various courses that are approved by the Deutsche Aktuarvereinigung (DAV) as part of the German actuarial exam.

Actuarial sciences at Leibniz University Hannover encompasses actuarial mathematics, insurance law, and insurance economics in the House of Insurance, an interdisciplinary research center. The House of Insurance offers students a unique interdisciplinary research environment and closely co-operates with the insurance industry in Hannover.

For more information, please consult: https://www.insurance.uni-hannover.de

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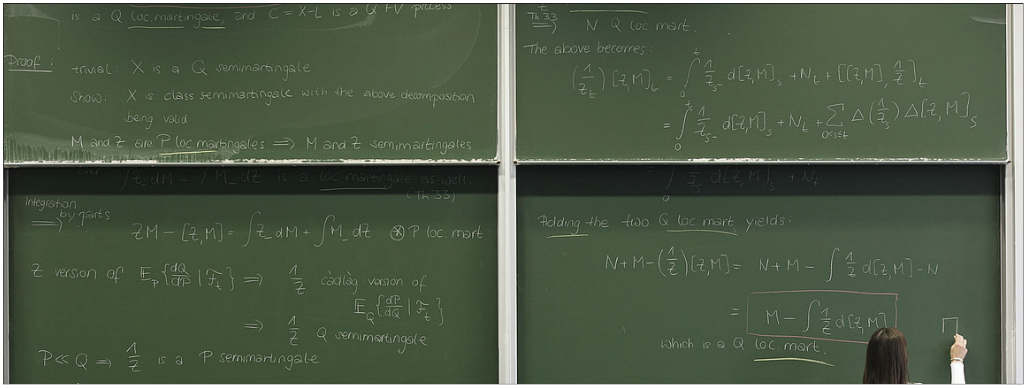

C. Wyrwa

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Prof. Dr. Gregor Svindland

private

My main area of research are risk measures and preferences and related topics in risk management and mathematical economy such as optimal risk transfer and equilibrium models. Moreover, I am interested in constructive mathematics where I in particular study a constructive approach to optimization theory.

Prof. Dr. Gregor Svindland

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Important professional positions

since 2019	Member of the managing board of the House of Insurance
since 2019	Professor of actuarial mathematics at Leibniz University Hannover
2015 - 2019	Lecturer (akademischer Rat) at Ludwig-Maximilians-Universität München
2011 - 2015	Assistent Professor at Ludwig-Maximilians-Universität München
2010 - 2011	Senior Researcher at École Polytechnique Fédéral de Lausanne

Important research projects

» Risk Management
» House of Insurance

Important publications

» Efficient allocations under law-invariance: a unifying approach (with F.-B. Liebrich), Journal of Mathematical Economics, 84, 28-45, 2019.
» Brouwer's fan theorem and convexity (with J. Berger), Journal of Symbolic Logic, 83(4), 1363-1375, 2018.
» Comonotone Pareto optimal allocations for law invariant robust utilities on L1 (with C. Rav-anelli), Finance and Stochastics, 18(1), 249-269, 2014
» On the lower arbitrage bound of American contingent claims (with B. Acciaio), Mathematical Finance, 24(1), 147-155, 2014.
» Dual representation of monotone convex functions on L0 (with M. Kupper), Proceedings of the AMS, 139(11), 4073-4086, 2011.

Risk and uncertainty are key characteristics of our interconnected world which create multiple challenges for individual actors, firms and regulatory authorities. The research group focuses on the analysis of actions of agents and on regulatory policies, their improvement and their optimal design.

Solvency regulation aims at the protection of creditors of firms, such as banks and insurance companies, and constitutes an essential ingredient when building resilient financial systems. One important instrument are capital requirements that are computed from stochastic balance sheet projections. Main research challenges are the suitable design of risk measures in complex, interacting financial systems, efficient Monte Carlo methods for applications in practice, tools for model validation in the face of uncertainty, and implications for financial markets and their evolution.

Complex systems and systemic risk in interacting networks extend beyond financial markets. Further important application domains are cyber networks, new technologies and critical infrastructures. We study – jointly with collaborating researchers from other disciplines such as law, engineering, and computer science – risk, robustness, resilience, and efficiency of such systems and develop strategies for their improvement and control.

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Stock Exchange Frankfurt

private

Prof. Dr. Stefan Weber

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Important research projects

- Risk management and regulation of banks and insurance companies
- Complex systems and systemic risk
- House of Insurance

Important professional positions

2019 - today	Executive Board, House of Insurance
2011 - 2019	Executive Board, Kompetenzzentrum Versicherungswissenschaften
2009 - today	Full Professor of Insurance and Financial Mathematics, Leibniz University Hannover
2006 - 2009	Assistant Professor (tenure track), Cornell University, Ithaca, NY
2004 - 2006	Postdoctoral Associate, Berlin & New York
2001 - 2004	Doctoral Researcher, Humboldt-Universität zu Berlin

Important publications

- Pricing of Cyber Insurance Contracts in a Network Model (with M. Fahrenwaldt & K. Weske), ASTIN Bulletin, 48(3), 1175-1218, 2018
- Measures of Systemic Risk (with Z. Feinstein & B. Rudloff), SIAM Journal on Financial Mathematics, 8(1), 672-708, 2017
- The Axiomatic Approach to Risk Measures for Capital Determination (with H. Föllmer), Annual Review of Financial Economics, 7, 2015
- Stochastic Root Finding and Efficient Estimation of Convex Risk Measures (with J. Dunkel), Operations Research, 58(5), 1505-1521, 2010
- Distribution-Invariant Risk Measures, Information, and Dynamic Consistency, Mathematical Finance, 16(2), 419-442, 2006

Institute of Mathematics and Physics Education

private

Prof. Dr. Reinhard Hochmuth
Executive Director

S. Gerhard

Anja Krampe
Office Mathematics Education

C. Wyrwa

Nadine Bischof
Office Physics Education

With its professorships and working groups, the Institute of Mathematics and Physics Education is responsible for the didactics of „mathematics" and „physics". It therefore scientifically focuses on the teaching and learning of these two subjects.

As a field of research, didactics as a whole is a rather young field. It develops in close relation to the subjects and, among others, to pedagogy, psychology, general didactics and educational research. A central task is to systematically research the teaching and learning of the subjects with regard to their goals, conditions and methods.

The main focus of the Institute's mathematics didactics research is on the study of mathematical teaching-learning processes in the areas of problem solving and argumentation, the description and analysis of epistemological-institutional aspects of mathematical practices, their linkage with subject-scientific approaches and, last but not least, the didactics of mathematics in higher education.

The investigation of epistemological-institutional facets of mathematics-related teaching and learning from a subject-scientific perspective follows internationally established research directions in didactics and is integrated into their current developments through an intensive exchange. Methodologically, the research efforts are oriented towards approaches of the so-called Anthropological Theory of Didactics and cultural-historical or social-scientific concepts. Thematically, it deals with questions of external didactic transposition, the design and implementation of digital teaching units, the development of teaching units that enable inquiry-oriented learning or the analysis of mathematics-related practices of electrical engineering students in advanced courses and, last but not least, the effects and conditions for success of current projects in higher education didactics in mathematics.

The research on the development of problem solving and mathematical reasoning in schools is based on the findings of the TIMS and PISA studies, which suggest that these process competencies, which are anchored in the core curriculum, should be promoted more intensively in the classroom. The research data consist mainly of videotaped problem-solving processes from training and control classes, where we test self-developed support materials. Further research topics are empirical studies on the development stages of mathematical thinking and to analyze the success of special tuition in cases of dyscalculia.

The current research and development focus of the Physics Education Group is on problem solving in physics, the usage of learning tasks in physics lessons, practical work in physics, learning with worked-out examples, learning with simulations / new media, inquiry learning, formative and summative assessment and learning in out-of-school contexts. For example, we are looking into the question of how to work in physics lessons with the experimental boxes used in Abitur examinations, how pupils learn to research and solve problems, or how methods from computer science such as machine learning or learning analytics can be used in physics lessons. In addition, we offer teacher trainings, work on specific teaching projects in university didactics (including tutor training, "Qualitätsoffensive Lehrerbildung") and are active in various science competitions.

The Institute's working groups are substantially involved in several projects funded by foundations, the Ministry of Science and Culture, the EU and the BMBF: khdm - Competence Centre for Higher Education Didactics in Mathematics; WiGeMath - Effect and Conditions for Success of Support Measures for Mathematics-Related Learning in the Initial Study Phase; MOVE & MINT - Development and provision of interactive self-learning modules for the Mathematics for Engineers I lecture; Quality+ project - development and implementation of digital tasks for first-year courses; EU-project PLATINUM-Partnership for Learning and Teaching in University Mathematics; MWK-Research Training Group GINT (Lernen in informellen Kontexten), MWK-Research Training Group LernMINT – Data-assisted classroom teaching in STEM (MINT) subjects, EU-Projekt Erasmus+ Projekt Digital Distance Learning in University Teaching, VW-Stiftung SomeClics – Social Media and Climate Change: Usage, Literacies and Interventions from the Perspective of Science Education; participation in various sub-projects of the Leibniz University Hannover project „Theoria cum praxi. Promoting Reflective Capacity for Action as a Leibniz Principle of Teacher Education".

Members of the Institute are also involved in the organisation and implementation of working groups and national and international conferences, e.g. Annual meeting of the GDM working groups on university mathematics didactics, mathematics and education, problem solving, mini-symposium „Engineering Mathematics" of the GDM 2021, mini-symposium „Didactic Aspects and Functions of Pictorial Representations" within the framework of the DMV annual meeting (Hamburg, September 2015), Conference of Mathematical Views (MAVI), the International Conference Didactics of Mathematics in Higher Education as a Scientific Discipline (Hannover, December 2015), the Conferences of the International Network for Didactic Research in University Mathematics (Agder, 2018; Tunis, 2020; Hannover 2022), International Congress on Mathematical Education (2016, 2021), Mathematics Education and Society Conferences (2018, 2021), Annual Meeting of the Society for Didactics of Chemistry and Physics (Hannover, 2012), General Assembly of the SAILS project (Hannover, 2015), Spring Meeting of the German Physical Society / Didactics of Physics (2010, 2016).

There are closer international collaborations with research groups in the USA (e.g. University of San Diego, Arizona State University), Norway (MatRIC - Centre for Research, Innovation and Coordination of Mathematics Teaching) and other European countries (e.g. INDRUM - International Network for Didactic Research in University Mathematics, DIAM - la didactique et informatique pour apprentissage des mathématiques) and the SAILS network (universities in Ireland, England, Denmark, Sweden, Poland, Slovakia, Portugal, Belgium, Greece, Hungary) as well as cooperations with the universities of Braunschweig, Kassel, Paderborn, Darmstadt, Duisburg-Essen, FU Berlin, Oldenburg, Osnabrück, Ulm, Stuttgart, the Institute for Science Education (IPN) and the Studienseminars in the Hanover region.

In teaching, the Institute covers in particular the subject didactic contents within the scope of the teacher training courses (interdisciplinary Bachelor's degree, Bachelor's degree in Technical Education, Master's degree in Education - Gymnasium teacher training, Master's degree in Technical Education, Science / Physics and Technology, Sprint-Ing) and conducts seminars, lectures, practicals in schools, practical labwork and preparatory seminars for Bachelor's and Master's theses. Finally, 16 PhDs in subject didactics are currently in preparation.

Logo of the AG Physics Didactics

Prof. Dr. Gunnar Friege

C. Wyrwa

Prof. Dr. Gunnar Friege

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The Physics Education Group focuses on the learning and teaching of physics in lower and upper secondary schools. In addition, projects are carried out in the field of university didactics and there are established project connections with the field of primary education at LUH.

The investigation of knowledge and problem solving of learners with the help of expert-novice comparisons and against the background of the model of knowledge-centered problem solving forms the starting point of various research activities of the Physics Education Group on the varied usage of tasks in physics classes, on learning with worked-out-examples or on teaching with the productive failure approach.

Digital education plays a major role in the Physics Education Group in teaching, development and research. For example, seminars and training courses on the use of new media are offered, a digital lab book and a wide range of OER material are developed, the use of AR and VR is tested and the flipped classroom approach in schools and at the university is researched. The Physics Education Group is part of the LUH research initiative Digital Education and is active in the doctoral program LernMINT; both are research networks of educators in the STEM subjects and computer scientists.

Outreach projects such as the MasterClasses in quantum optics, material development and advanced training in the field of hearing or the development and testing of teaching materials on the topic of repair and recycling are also part of the fields of work of physics education as well as the participation and implementation of science competitions.

Important research projects

» Quality Offensive Teacher Education (Phase I and II) (BMBF project, since 2016).
» GINT - learning in informal spaces, together with the universities of Oldenburg and Vechta (MWK doctoral program (Lichtenberg scholarships), 2016-2021)
» LernMINT - data-supported teaching in STEM subjects (MWK doctoral program (Lichtenberg scholarships), 2019-2024)
» MasterClasses, together with the didactics of physics at the TU Braunschweig within the Cluster of Excellence Quantum Frontiers (DFG, since 2019)
» SomeClics - Social Media and Climate Change: Usage, Literacies, and Interventions from the Perspective of Science Education, with Dr. A. Büssing, Prof. K. Kremer, Prof. A. Nehring, Prof. W. Nejdl (VW Foundation, since 2021)

Important professional positions

since 8/2008	professor for didactics of physics at Leibniz University Hannover
until 7/2008	scholarship holder of the state of Schles wig-Holstein and research assistant at the IPN, research assistant (C1) at the University of Kiel and at the IPN, school service in Schleswig-Holstein

Important publications

» Lind, G. & Friege, G. (2003). Wissen und Problemlösen. Eine Untersuchung zur Frage des „trägen Wissens". Empirische Pädagogik, 17 (1), 57 – 86.
» Friege, G. & Lind, G. (2003). Allgemeine und fachspezifische Problemlösekompetenz. Zeitschrift für die Didaktik der Naturwissenschaften, 9. Jahrgang, S. 63 – 74.
» Friege, G. & Lind, G. (2006). Types and qualities of knowledge and their relations to problem solving in physics. International Journal of Science and Mathematics Education, 4(3), S. 437 – 465.
» Rode, H. & Friege, G. (2017). Nine optical black-box experiments for lower-secondary students. Physics Education, 52, 035009
» Hiniborch, J., Wille, K. & Friege, G. (2020). Fehler als Auslöser von Lernprozessen. Unterricht Physik, 177/178, S. 78-81.
» Weber, K.-A., Friege, G. & Scholz, R. (2020). Quantenphysik in der Schule - Was benötigen Lehrkräfte? Eine Delphi-Studie, Zeitschrift für Didaktik der Naturwissenschaften, 26. Jahrgang, S. 173 - 190.
» Weiß, L.-F., Friege, G. (2021). The Flipped Classroom: Media Hype or empirically based Effectiveness? Problems of Education in the 21st Century 79(2):312-332

TIMSS and PISA have shown a need for school-based support in the areas of problem solving and reasoning. Despite subsequent anchoring in the core curricula, this need persists, as our longitudinal study HeuRekAP showed. On the positive side, we were able to show that an integrated instructional concept with explicit heuristic training units achieved a significant increase in performance without diminishing performance in other areas (as measured by VERA 8).

The analysis of videographed problem solving processes in TIMSS item K10 by use of the self-developed analysis tools temple representation, barrier and directional band showed that beyond the application of the trained heurisms, the greater success in the experimental class was based on the fact that due to an increased ability to act in a stable-flexible manner, the expectable barrier in the solution path could be overcome significantly more often by combining working forward and backward. This is in line with the „principle of the effect of heuristic education": if learners learn to know and flexibly apply suitable heurisms, this can largely compensate for lower mental agility. In the LeduPro project, we are currently working on condensing the findings from HeuRekAP into training sequences that can also be used in regular classes. In addition to the classical tools, electronic worksheets for the utilisation of Dynamic Geometry Software (DGS) are a proven means to initiate heuristically rich learning processes.

Moreover, our interest is directed towards a theoretical penetration of the empirical findings by linking them to mathematics-related developmental theories: The van Hiele levels are suitable to describe the development of mathematical thinking, especially reasoning, along the educational chain, because they are on the one hand empirically demonstrable and on the other hand interpretable in terms of content. For this purpose, a multimodal placement test was developed. With respect to problem solving, a theoretically grounded description of developmental processes based on Piaget's developmental theory is provided by operationalizing the central concepts of assimilation and accommodation.

Furthermore, we developed tools for teaching diagnostic and remedial concepts for dyscalculia to secondary mathematics teachers and for analyzing the success of such measures.

S. Gerhard

Prof. Dr. Thomas Gawlick

Problem Solving and the Development of Mathematical Thinking
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Important research projects

- Scientific investigation of MALU (Maths project group at Leibniz University Hannover for fifth graders, continued in cooperation with Forschergeist e.V.)
- HeuRekAP (Heuristic Reconstruction of Problem Solving Tasks, in cooperation with Bismarckschule Hannover and Medienberatung NRW)
- LeduPro (Learning by Problem Solving, in cooperation with schools in Hannover and surroundings)

Important professional positions

2007 - today	W3-Professorship for Didactics of Mathematics, Leibniz University Hannover
2003 - 2007	Lecturer at the Institute of Mathematics, University of Koblenz-Landau, Landau site
2002 - 2003	Research Assistant Professor at the Institute for Didactics of Mathematics, University of Bielefeld University
2001 - 2002	Lecturer at the Oberstufen-Kolleg of the University of Bielefeld
1998 - 2001	Assistant Professor for Didactics of Mathematics at the University of Vechta

Important publications

- (with D. Lange) General vs. Mathematical Giftedness as Predictors of the Problem Solving Competence of Fifth-Graders: Proceedings of PME 35, Ankara 2011
- »Click, drag, think« Utilizing Dynamic Geometry Software to pose and explore Conjectures. Habre, S. (Ed.): Dynamical mathematical software and visualization in the learning of mathematic. Hershey, PA: IGI Global 2013
- (with B. Rott) Explizites oder implizites Heurismentraining – was ist besser? mathematica didactica 37, 2014
- (with A. Hilgers): Rechenschwäche diagnostizieren und fördern – ein zentraler Baustein des inklusiven Mathematikunterrichts. In: Zeitschrift für Inklusion, 2017 Online unter https://www.inklusion-online.net/index.php/inklusion-online/article/view/448
- Attributional Beliefs During Problem-Solving. In B. Rott, G. Törner, J. Peters-Dasdemir, A.Möller, Safrudiannur (Eds.) Views and Beliefs in Mathematics Education; The Role of Beliefs in Classroom (S. 89-101), Springer 2018

Prof. Dr. Reinhard Hochmuth

private

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Mathematics didactics
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The research topics of the working group focus on professional, in particular epistemological-institutional, and psychological aspects of teaching and learning mathematics at school and at university. A part of the research relating to the transition from school to university is located in the Competence Centre for Higher Education Didactics in Mathematics (khdm), which was established in close cooperation with colleagues at the universities of Kassel and Paderborn. The khdm is one of three internationally acknowledged European centres in higher education mathematics. There are cooperative relationships with the two other centres in Great Britain (the Sigma Network founded by the Mathematics Education Centre of Loughborough University together with Coventry University) and Norway (Centre for Research, Innovation and Coordination of Mathematics Teaching (MatRIC)), which are manifested in jointly organised international workshops, conferences and professional development courses in higher education didactics. The professorship also plays a major role in the European network INDRUM (International Network for Didactic Research in University Mathematics) as well as in the survey team on university didactics of the International Congress on Mathematical Education, which takes place every four years. Methodologically, the research efforts are based on approaches of the so-called Anthropological Theory of Didactics and on cultural-historical and social science concepts. Thematically, the focus is on questions of external didactic transposition, the design and implementation of digital teaching units or the analysis of mathematics-related practices of electrical engineering students in advanced courses such as signal theory and, last but not least, the analysis of effects and conditions for success of current projects in higher education didactics in mathematics. A current focus is on the development of teaching units that enable research-based learning and a link to advanced mathematics content. Another current focus is on the subject-scientific reconstruction and further development of up-to-date international didactics discourses, which pursue the claim of linking social and mathematical aspects in a teaching-learning perspective.

Important research projects

- Competence Centre for Higher Education Didactics in Mathematics hematik (Cooperation with A. Eichler/Kassel, M. Liebendörfer/Paderborn u. a.)
- PLATINUM" (Partnership for Learning and Teaching in University Mathematics): European project in cooperation with colleagues from Norway, England, Spain, the Netherlands, the Czech Republic and Ukraine.
- Teaching Mathematics in Everyday Life Online (MiAou) in cooperation with Prof. Dr. Frühbis-Krüger. and Prof. Dr. May (Carl von Ossietzky University Oldenburg) and PD Dr. Michael Gruber.
- Effect and conditions for success of support measures for mathematics-related learning in the introductory phase of studies (cooperation with R. Biehler, M. Liebendörfer, N. Schaper/Paderborn and others).

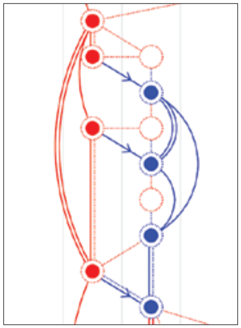
Important professional positions

2014 - today	Professor, Leibniz University of Hanover
2013 - today	Co-editor of the book series Konzepte und Studien zur Hochschuldidaktik und Lehrerbildung Mathematik published by Springer-Verlag
2011 - today	Director, Competence Centre for Higher Education Didactics in Mathematics
2011 - 2014	Professor of Mathematics, Leuphana University Lüneburg
2005 - 2011	Professor of Analysis, University of Kassel

Important publications

- Hausberger, T., Derouet, C., Hochmuth, R., & Planchon, G. (2021). Compartmentalisation of mathematical sectors: the case of continuous probability distributions and integral. International Journal of Research in Undergraduate Mathematics Education. (im Druck)
- Hochmuth, R., Broley, L., & Nardi, E. (2021). Transitions to, across and beyond university. V. Durand-Guerrier, R. Hochmuth , E. Nardi and C. Winsløw (Eds.), Research and Development in University Mathematics Education (S. 193 - 215). New York: Routledge.
- Hochmuth, R., & Peters, J. (2021). On the analysis of mathematical practices in signal theory courses. International Journal of Research in Undergraduate Mathematics Education, 7(2), 235-260.

The focus of the research group lies in the empirical investigation of mathematical teaching and learning processes. The main concern is the study of mathematical thinking processes in central topics in mathematics. In particular, the role of language in mathematics learning is of interest. From a semiotic perspective, mathematical sign activities and speaking about them are considered as essential aspects of mathematical practice and learning. From a perspective of the philosophers Wittgenstein and Peirce, mathematics can be seen as a sign game on the one hand, and on the other hand, experiments with signs enable observable, communicable and describable reasoning. For this purpose, a qualitative method of analysis was developed to visualize the interplay of learners' sign activities with their speaking about them and, in particular, to reconstruct the student's line of reasoning. In addition, the method of imaginary dialogues, a form of writing in mathematics education, was developed and explored to analyze mathematical thinking processes. In addition to theoretical research on the use of this method in research and teaching, the practical use of imaginary dialogues in classroom settings is investigated. Further research refers to characteristics of mathematics learning in sign language. Differences of learning mathematics in spoken or sign language are explored and practical, digitally supported learning environments are designed. This research is relevant for sign-language-oriented learners as well as for learners who use mainly a spoken language, here in relation to the role of gestures in mathematics learning. In addition to the above research topics, mathematical picture books are being developed as an early approach to mathematics.



Analysis of mathematical sign activity and speaking about it

Bernhard Horst

Prof. Dr. Annika Wille

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Important professional positions

2022 - today	Professor, Leibniz University Hannover
2019 - 2022	Associate Professor, Universität Klagenfurt, Austria
2011 - 2019	Postdoc Assistant and Assistant Professor, Universität Klagenfurt, Austria
2007 - 2009	PhD in Mathematics, Technische Universität Darmstadt

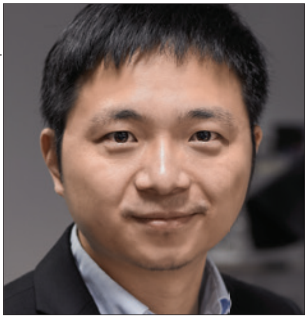
Important research projects

» Interaction of mathematical sign activity and talking about it (cooperation with B. Ott/St. Gallen, Switzerland)
» Development of a method to investigate mathematical thinking processes (cooperation with E. Müller-Hill/Rostock)
» Characteristics of learning mathematics in sign language (cooperation with Chr. Krause/Graz, Austria, Chr. Schreiber/Gießen, et al.)
» Picture books as an early access to mathematics (cooperation with B. Ott/St. Gallen, Switzerland)

Important publications

» Imaginary dialogues in mathematics education. Journal für Mathematik-Didaktik, 38(1) (2017), 29–55
» Activity with signs and speaking about it: exploring students' mathematical lines of thought regarding the derivative. International Journal of Science and Mathematics Education, 18 (2020), 1587–1611
» Sign language in light of mathematics education: an exploration within semiotic and embodiment theories of learning mathematics (with Chr. Krause). American Annals of the Deaf, 166(3) (2021), 352–377
» Diagrammatic activity and communicating about it in individual learning support: patterns and dealing with errors (with B. Ott): Proceedings of CERME 12, Bozen 2022

Institute of Solid State Physics



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Prof. Dr. Fei Ding
Executive Director

Yvonne Griep
Office

Heike Kahrs
Office

Anna Braun
Office

Solid state physics is omnipresent for everyone in everyday life. However, it is often not always apparent in which systems the achievements of modern solid-state physics are hidden. These include, for example, the integrated and highly efficient systems of information processing, telecommunications, and current-to-light or light-to-current conversion, which range from computer chips to high-mobility transistors in cell phones to future quantum information processing, or from LED flashlights to high-efficiency solar cells to high-tech semiconductor lasers. In the Institute of Solid State Physics a correspondingly broad spectrum of solid state-based systems is investigated, ranging from applied research of solar based power supply to fundamental research of complex quantum phenomena in low-dimensional systems. The methods of the working groups collaborating in the institute complement each other and include optical and electronic spectroscopy of complex multi- and zero-dimensional artificial and self-assembled atomic nanostructures.

Networking:

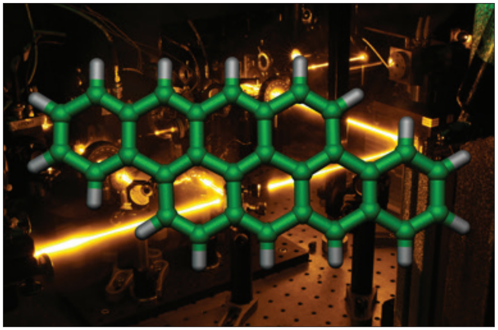
The Institute of Solid State Physics is well integrated into the research and education landscape at Leibniz Universität and beyond. In addition to the collaboration with the Cluster of Excellence „QuantumFrontiers", coordinated doctoral programs such as the „Hannover School for Nanotechnology" contribute to this. There is an integral connection to the Laboratory for Nano and Quantum Engineering, to the Hannover Institute of Technology and to the Institute for Solar Energy Research in Hameln.

Equipment:

The groups of the Institute of Solid State Physics conduct cutting-edge research at an international level and accordingly pay attention to state-of-the-art equipment. In the various laboratories, this includes modern laser systems, ultra-low temperature measuring stations, magnet systems up to 20 Tesla, high vacuum apparatus, equipment for material growth and characterization, and industrial plant prototypes for solar process technology.

Teaching:

The research groups of the Institute of Solid State Physics actively participate in high-quality education in undergraduate physics and nanotechnology. This includes regular events such as lectures on introduction in solid state physics and advanced solid state physics, seminars on quantum effects in nanostructures, proseminars with a focus on solid state physics, practical courses and additional in-depth special lectures, which represent an optimally coordinated preparation

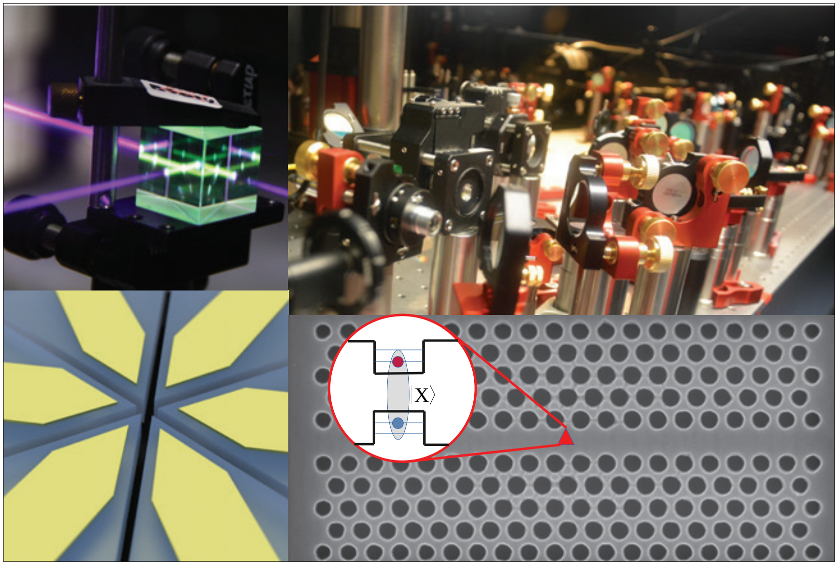


Single molecules

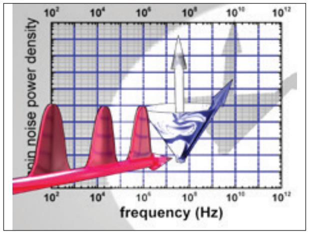
and accompaniment to bachelor and master studies in the fields of physics and nanotechnology.

Working groups in the institute (2021):

Prof. Dr.-Ing. Rolf Brendel (Solar Energy Research)
Prof. Dr. Fei Ding (Quantum Engineering)
Prof. Dr. Rolf Haug (Quantum Transport)
Prof. Dr. Michael Oestreich (Optical Spectroscopy)
Prof. Dr. Herbert Pfnür (Atomic Structures)
Prof. Dr. Andreas Schell (Quantum Technology)
Prof. Dr. Jan Schmidt
(Photovoltaic Materials Research)
Prof. Dr. Lin Zhang (Energy Storage)



Picture of entrance of institute



Michael Römer/Oestreich

Semiconductor physics

Prof. Dr. Rolf Brendel

U. Salzmann

Prof. Dr.-Ing. Rolf Brendel

Solar Energy Research
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Physical laws have always determined the functioning of our energy technology. This was true for the steam engines of the industrial revolution and it is true today for our emission-free energy technologies that use solar radiation and wind. The heating of the world's climate by the greenhouse effect is a major threat that we are countering by rapidly expanding renewable energy technologies. We are developing improved and new silicon-based solar cells that convert sunlight directly into electricity. The semiconductor silicon is a fascinating solid, about which we know a lot from microelectronics. We apply this knowledge to the development of more efficient and cost-effective solar cells and continue to expand it. To this end, we simulate the electrical and optical properties of photovoltaic modules. New manufacturing processes with higher efficiencies and reduced material requirements are developed with the understanding that we gain from comparing simulation and experiment. This is done in collaboration with the Institute for Solar Energy Research Hameln (ISFH), which operates a research line on which photovoltaic modules can be manufactured. We develop rapid calculation methods for predicting energy yields of building-integrated photovoltaics and determine the solar potentials of entire cities or counties based on optical simulations and machine learning. We use the results to simulate the energy transition of Lower Saxony and Germany in a European context.

U. Salzmann

Firing oven in our research line for fabricating Si solar cells.

Important professional positions

2004 - today	Professor at the Institute for Solid State Physics at Leibniz University Hanover and Scientific Director of the Institute for Solar Energy Research (ISFH)
1997 - 2004	Head of Department at the Bavarian Center for Applied Energy Research (ZAE-Bayern) in Erlangen
1992 - 1997	PostDoc at the Max Planck Institute for Solid State Research, Stuttgart
1988 - 1992	PhD in Materials Science, University of Erlangen-Nuremberg

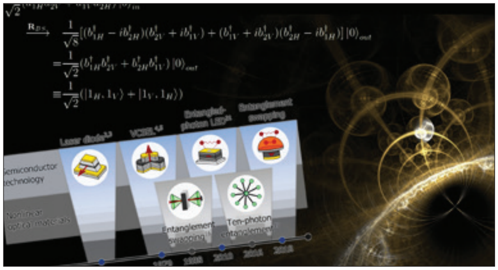
Important research projects

» Modeling the transformation of the energy system
» Optics of photovoltaic modules
» High-efficiency silicon solar cells with polycrystalline silicon contacts

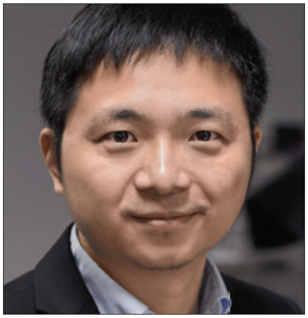
Important publications

» Kruse, C.N., Schäfer, S., Haase, F., Mertens, V., Schulte-Huxel, H., Lim, B., Min, B., Dullweber, T., Peibst, R., Brendel, R., Simulation-based roadmap for the integration of poly-silicon on oxide contacts into screen-printed crystalline silicon solar cells, Scientific Reports (2021), 11 (1), art. no. 996.
» Min, B., Wehmeier, N., Brendemuehl, T., Haase, F., Larionova, Y., Nasebandt, L., Schulte-Huxel, H., Peibst, R., Brendel, R., 716 mV Open-Circuit Voltage with Fully Screen-Printed p-Type Back Junction Solar Cells Featuring an Aluminum Front Grid and a Passivating Polysilicon on Oxide Contact at the Rear Side, Solar RRL (2021), 5 (1), art. no. 2000703
» Folchert, N., Peibst, R., Brendel, R., Modeling recombination and contact resistance of poly-Si junctions, Progress in Photovoltaics: Research and Applications (2020), 28 (12), pp. 1289-1307.
» Schulte-Huxel, H., Blankemeyer, S., Morlier, A., Brendel, R., Köntges, M., Interconnect-shingling: Maximizing the active module area with conventional module processes, Solar Energy Materials and Solar Cells (2019), 200.
» Brendel, R., Peibst, R., Contact Selectivity and Efficiency in Crystalline Silicon Photovoltaics, IEEE Journal of Photovoltaics (2016), 6 (6), pp. 1413-1420

We focus on the phenomena resulting from the interaction of light and nanomaterials, and the research of photon statistics based on such effects. Our study spans a variety of nanomaterials, such as epitaxial quantum dots, colloidal quantum dots, and two-dimensional materials. Besides of discovering the underlying physical principles of these materials, we are interested to obtain single photon sources for quantum information science with high single-photon purity, indistinguishability and brightness.



A particular emphasis lies on the development of epitaxial quantum dots for quantum science and technology, for example, semiconductor based quantum communication. Semiconductor quantum dots are the leading candidate for generating polarization-entangled photons deterministically. Such sources, together with efficient quantum memories, are a key component for a so-called quantum repeater which is proposed to allow for long-haul quantum communication. The entangled photon sources developed by us are used in the necessary quantum optical protocols, such as entanglement swapping between entangled photon pairs generated by semiconductor quantum dots. Furthermore we investigate the tuning of the quantum dot emission to quantum memory frequencies.



privat

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Important research projects

» ERC Starting Grant »Elementary quantum dot networks enabled by on-chip nano-optomechanical systems«
» BMBF Project» "Q.Link-X": Quanten-Link-Erweiterung«
» DFG Sachbeihilfe» Verschränkungsbereite Photonenquellen bei Telekommunikationswellenlängen«
» DFG Sachbeihilfe» Einfang von null-dimensionalen Polaritonen in Sub-Mikrometer Regionen in einem Mikroresonator«
» DFG Schwerpunktprogramm» 2D Heterostrukturen mit durch anisotrope Verspannung abstimmbaren Moire-Potentialen«

Important professional positions

From 2016	Professor (W3) for Experimental Physics, Leibniz University Hannover
2012 - 2019	Group leader, Leibniz-Institut für Festkörper- und Werkstoffforschung (IFW), Dresden
2010 - 2012	Marie Curie Postdoc, IBM Zurich Laboratory, Zürich
2009 - 2010	Postdoc, IFW Dresden
2007 - 2008	Guest researcher at Kavli Institute of Nanosciences, Technical University of Delft
2004 - 2009	PhD candidate at Chinese Academy of Sciences / Max-Planck-Gesellschaft

Important publications

» M. Zopf, R. Keil, Y. Chen, J. Yang, D. Chen, F. Ding, O. G. Schmidt: Entanglement Swap- ping with Semiconductor-Generated Photons Violates Bell's Inequality. Phys. Rev. Lett. 123, 160502 (2019)
» Y. Chen, M. Zopf, R. Keil, F. Ding, O. G. Schmidt: Highly-efficient extraction of entangled photons from quantum dots using a broadband optical antenna. Nat. Commun. 9, 2994 (2018)
» E. A. Chekhovich, A. Ulhaq, E. Zallo, F. Ding, O. G. Schmidt, M. S. Skolnick: Measure- ment of the spin temperature of optically cooled nuclei and GaAs hyperfine constants in GaAs/AlGaAs quantum dots. Nat. Mater. 16, 982 (2017)
» R. Keil, M. Zopf, Y. Chen, B. Höfer, J. Zhang, F. Ding, O. G. Schmidt: Solid-state ensem- ble of highly entangled photon sources at rubidium atomic transitions. Nat. Commun. 8, 15501 (2017)
» Y. Chen, J. Zhang, M. Zopf, K. Jung, Y. Zhang, R. Keil, F. Ding, O. G. Schmidt: Wavelength- tunable entangled photons from silicon-integrated III-V quantum dots. Nat. Commun. 7, 10387 (2016)

Prof. Dr. Rolf Haug

S. Gerhard

Prof. Dr. Rolf Haug

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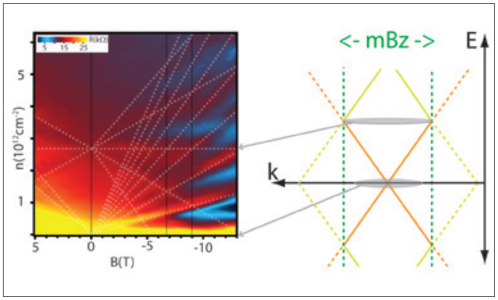
The research of the group focuses on quantum effects in smallest semiconductor systems. In order to be able to produce such smallest systems, the group deals with the nanotechnology of semiconductor materials. In addition to III-V heterostructures, two-dimensional materials such as graphene and one-dimensional systems such as carbon nanotubes are used as semiconducting materials. Semiconductor nanostructures are fabricated from these materials using exfoliation methods, electron beam lithography, and direct writing techniques with an atomic force microscope. These structures are characterized by means of very sensitive measurements at temperatures down to 10mK and in high magnetic fields (in the group up to 20T). Measurement techniques used include electronic transport measurements, noise measurement techniques, and single electron counting. The effects studied include the quantum Hall effect, the fractional quantum Hall effect, superlattice effects in twisted bilayers of graphene, condensation effects in bilayer systems, ballistic transport in one dimension, spectroscopy of single and coupled quantum dot systems, spin structures, and Kondo physics in quantum dots. The work represents fundamental research, but is carried out with applications in nanoelectronics, quantum information processing, quantum metrology, and quantum sensing in mind.



J. Rode

Example of a measurement showing superlattice effects in a folded graphene structure together with a schematic image of the bandstructure

Important professional positions

1995 - today	Professor for Experimental Physics at Leibniz University Hannover
1990 - 1995	research associate at the MPI-FKF in Stuttgart, Germany
1989 - 1990	Postdoctoral researcher at the IBM Research Laboratory in Yorktown Heights, USA, Group L. Esaki
1985 - 1988	PhD student at the MPI-FKF in Stuttgart, Department v. Klitzing
1978 - 1984	Studies of Physics, University of Tübingen, Université Scientific e Medicale in Grenoble

Important research projects

» Work within the framework of the Cluster of Excellence „QuantumFrontiers"
» Work within the framework of the "Hannover School for Nanotechnology"
» Work in the framework of the DFG Priority Program SPP 2244 „2D Materials"

Important publications

» Controlled emission time statistics of a dynamic single-electron transistor, F. Brange, A. Schmidt, J.C. Bayer, T. Wagner, C. Flindt, R.J. Haug, Science Advances 7, eabe0793 (2021)
» Quantum stochastic resonance in an a.c.-driven single-electron quantum dot, T. Wagner, P. Talkner, J.C. Bayer, E.P. Rugeramigabo, P. Hänggi, R.J. Haug, Nature Physics 15, 333 (2019)
» Linking interlayer twist angle to geometrical parameters of self-assembled folded graphene structures, J.C. Rode, D. Zhai, C. Belke, S.J. Hong, H. Schmidt, N. Sandler, R.J. Haug, 2D Materials 6, 015021 (2019)
» Interaction-induced spin polarization in quantum dots, M.C. Rogge, E. Räsanen, R.J. Haug, Phys. Rev. Lett. 105, 046802 (2010)
» Partitioning of on-demand electron pairs, N. Ubbelohde, F. Hohls, V. Kashcheyevs, T. Wagner, L. Fricke, B. Kästner, K. Pierz, H.W. Schumacher, R.J. Haug, Nature Nanotechnology 10, 46 (2015)
» Superlattice structures in twisted bilayers of folded graphene, H. Schmidt, J.C. Rode, D. Smirnov, R.J. Haug, Nature Communications 5, 5742 (2014)

Prof. Dr. Michael Oestreich

The research group of Michael Oestreich studies the spin and charge dynamic in low dimensional semiconductor nanostructures. The detailed understanding of this dynamic is the foundation for refined physical concepts and modern quantum mechanical semiconductor devices. The research employs highly advanced optical methods which allow for microscopic spatial resolution at high magnetic fields and extremely low temperatures. The relevant timescale spans from a few femtoseconds in ultrafast processes up to a day for spin relaxation times in isotopically enriched ^{28}Si.

Oestreich

Ultrafast spectroscopy on GaN quantum wells for blue LEDs

One core research area is the study of the complex spin dynamics of electrons, holes, and nuclei in semiconductor nanostructures in view of entanglement and manipulation of semiconductor spin systems. The research lays the foundation for a prospective spin-based quantum information technology and is based to a large extend on the modern technique of optical spin noise spectroscopy. This method has been successfully transferred for the first time from quantum optics to solid state physics by this group and by now allows ultra-sensitive, quasi demolition free measurements on single carriers localized in semiconductor quantum dots.

Further research fields of the group are basic research on modern, two-dimensional solid-state systems and the physics using intense laser pulses for nonlinear spectroscopy.

private

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Important research projects

» Exzellenzcluster QuantumFrontiers »Spin dynamic in low dimensional semiconductor nanostructures«
» DFG-Projekt »Spinrauschspektroskopie an nulldimensionalen Halbleiterstrukturen«
» DFG-Projekt » Spin and Valley Dynamics in Novel Transition Metal Dichalcogenide 2D Materials« (PI PD Dr. Jens Hübner)

Important professional positions

2021 - today	Elected member of the senate of the LUH
2000 - today	Full professor of experimental physics at the Leibniz University Hannover
1997 - 2000	Group leader at the Philipps-Universität Marburg
1995 - 1996	Postdoc at the Max Planck Institute for Solid State Research
1994 - 1995	Postdoc at the University of California Santa Barbara, USA
1991 - 1994	Ph.D. student at the Max Planck Institute for Solid State Research
1984 - 1991	Study of physics, Universität Münster, Heriot-Watt University in Edinburgh

Important publications

» Sauter, E., Abrosimov, N. V., Hübner, J., Oestreich, M., Low Temperature Relaxation of Donor Bound Electron Spins in ^{28}Si:P, Phys. Rev. Lett. 126, 137402 (2021).
» Berski, F., Hübner, J., Oestreich, M., Luwig, A., Wiek, A. d., Glazov, M., Interplay of Electron and Nuclear Spin Noise in n-Type GaAs, Phys. Rev. Lett. 115, 176601 (2015).
» Dahbashi, R., Hübner, J., Berski, F., Pierz, K. & Oestreich, M., Optical Spin Noise of a Single Hole Spin Localized in an (InGa)As Quantum Dot, Phys. Rev. Lett. 112, 156601 (2014).
» Müller, G., Römer, M., Schuh, D., Wegscheider, W., Hübner, J. & Oestreich, M., Spin noise spectroscopy in GaAs (110) quantum wells: Access to intrinsic spin lifetimes and equilibrium electron dynamics, Phys. Rev. Lett. 101, 206601 (2008).
» Oestreich, M., Römer, M., Haug, R. J. & Hägele, D., Spin noise spectroscopy in GaAs, Phys. Rev. Lett. 95, 216603 (2005).
» Döhrmann, S., Hägele, D., Rudolph, J., Bichler, M., Schuh D., Oestreich, M., Anomalous Spin Dephasing in (110) GaAs Quantum Wells: Anisotropy and Intersubband Effects, Phys. Rev. Lett. 93, 147405 (2004).

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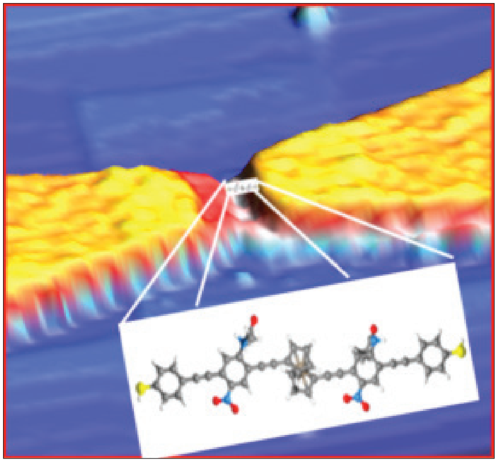
Experimentally, access to all kinds of condensed matter is possible only through surfaces and interfaces. For very small objects in the nano and sub-nano range the properties of surfaces and interfaces domininate those of the whole object in conjunction with the interaction with the substrate. The focus of my research is on quasi-one dimensional systemes and the connection between one and two-dimensional properties. Prominent examples are bundles of atomic wires that are stabilied by an insulating substrate. Furthermore, collective plasmonic excitations are investigated in clusters, wires and 2D-layers. In all these systems, correlations between charge and spin play an important role for electronic scattering in strongly spin polarized surface layers like topological insulators. Emphasis is also put on electrical and electronic properties of insulator-metall-semiconductor interfaces at the atomic scale, as well as on metallic atomic contacts with single organic molecules that offer attractive perspectives towards molecular electronics.



C. Tegenkamp

Scheme of contacting of a single molecule between metallic contacts (yellow-red) on insulator (blue).

Important research projects

» DFG research unit »Metallic nanowires on the atomic scale« (Chairman)
» Projects within the graduate schools »Nanoschool Contacts in nanosystems« (plasmons in one and two dimensions) and »Hannover School of Nanotechnology« (molecular electronics)
» SPP 1165 »Correlation of geometric and electronic properties in metallic nanowires«
» DFG research unit »Adsorbatwechselwirkungen an Ionenkristallen und Metallen«

Important professional positions

1990 - 2020	Professor of Experimental Physics at the Institute of Solid State Physics, Leibniz University Hannover
1984 - 1989	Hochschulassistent (Akad. Rat a. Z.), Physics department E20, TU München
1982 - 1983	IBM research fellow at IBM research labs San Jose

Important publications

» Enforced long-range order in 1D wires by coupling with higher dimensions, Z. Mamiyev, C. Fink, K. Holtgrewe, H. Pfnür, S. Sanna, Phys. Rev. Lett. 126, 106101 (2021)
» Thickness dependent coherent and incoherent scattering in electronic transport through epitaxial nontrivial Bi quantum films, D. Abdelbarey, J. Koch, C. Tegenkamp, H. Pfnür, Phys. Rev. B 102, 115409 (2020)
» Matching different symmetries with an atomically sharp interface: Epitaxial Ba2SiO4 on Si(001), J. Koch, K. Müller-Caspary, H. Pfnür, Phys. Rev. Mat. 4, 013401 (2020)
» How one-dimensional are atomic gold chains on a substrate? S. Sanna, Z. Mamiyev, T. Lichtenstein, C. Tegenkamp, H. Pfnür, J. Phys. Chem. C 122, 25580-25588 (2018).
» Acoustic surface plasmons on stepped surfaces: Au(788), M. Smierieri, L. Vattuone, L. Savio, T. Langer, C. Tegenkamp, H. Pfnür, M. Rocca, Phys. Rev. Lett. 113, 186804 (2014).
» Fermi nesting between atomic wires with strong spin-orbit coupling C. Tegenkamp, D. Lükermann, H. Pfnür, B. Slomski, G. Landolt, J. H. Dil, Phys. Rev. Lett. 109, 266401 (2012).

Quantum technologies are concerned with the use of quantum systems to develop new and improve existing technical applications. In this context, individual quantum mechanical states (e.g., the states of individual atoms or photons) are specifically manipulated and read out in order to make quantum mechanical phenomena usable. Prominent examples of these technologies are quantum information, quantum cryptography, and quantum-based sensors that exceed conventional digital measurement techniques in their precision.

In the Quantum Technologies group we investigate the development and implementation of concepts to exploit quantum mechanical effects. One of our research topics is the characterization of single photon emitters and their integration into quantum circuits to fabricate chip-based quantum optical devices. Furthermore, we deal with the application of tailored quantum states such as single photons in metrological applications.

The Quantum Technologies Group is a cooperation of Leibniz Universtiy Hannover together with the Physikalisch Technische Bundesanstalt in Braunschweig.

Prof. Dr. Andreas Schell

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Important research projects

» Spectroscopy of quantum emitters
» Integration of quantum emitters into photonic devices
» Spectroscopy and manipulation of levitating nanoparticles
» Development of photonic micro- and nanostructures

Important professional positions

2019 - today	Group Leader of the Quantum Technology Group at PTB
2019 - today	Junior professor for quantum technologies at Leibniz University Hannover, Germany
2018 - 2019	Group leader at CEITEC, Brno, Czech Republic
2016 - 2018	Postdoctoral researcher at ICFO, Barcelona, Spain
2014 - 2016	Postdoctoral researcher at Kyoto University, Japan
2009 - 2014	PhD student at Humboldt-Universtät zu Berlin, Germany

Important publications

» Conangla, G. P., Ricci, F., Cuairan, M. T., Schell, A. W., Meyer, N., & Quidant, R. Optimal feedback cooling of a charged levitated nanoparticle with adaptive control. Physical review letters, 122(22), 223602 (2019)
» Schell, A. W., Engel, P., Werra, J. F., Wolff, C., Busch, K., & Benson, O. Scanning single quantum emitter fluorescence lifetime imaging: quantitative analysis of the local density of photonic states. Nano letters, 14(5), 2623-2627 (2014)
» Schell, A. W., Kaschke, J., Fischer, J., Henze, R., Wolters, J., Wegener, M., & Benson, O. Threedimensional quantum photonic elements based on single nitrogen vacancy-centres in laser-written microstructures. Scientific reports, 3(1), 1-5 (2013)
» Schell, A. W., Kewes, G., Schröder, T., Wolters, J., Aichele, T., & Benson, O. A scanning probebased pick-and-place procedure for assembly of integrated quantum optical hybrid devices. Review of Scientific Instruments, 82(7), 073709 (2011)

Prof. Dr. Jan Schmidt

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Prof. Dr. Jan Schmidt

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In the „Photovoltaics Materials Research" group, new methods for identifying and electrically characterising defects in semiconductor materials for photovoltaics are developed and applied, such as lifetime spectroscopy or photoluminescence imaging. The aim is to develop a comprehensive understanding of the impact of defects and defect reactions on solar cell properties. With the help of targeted „defect engineering", we also actively improving the material quality of the materials used in photovoltaics.

Another focus of our work is the analysis of new materials, processes and concepts for application to next-generation solar cells. On the one hand, the focus is on carrier-selective contact systems, on the other hand, novel dielectric passivation layers are developed with different methods (e.g. by means of atomic layer deposition) and the fundamental electronic properties of the interfaces with semiconductors are investigated. From our fundamental findings, novel concepts for highly efficient solar cells are derived and solar cell prototypes are fabricated and characterised in our lab.

Important research projects

» Impact of defects and defect reactions in semiconductors on solar cell properties
» Analysis of novel materials for photovoltaic applications
» Novel thin films for the surface passivation and as passivating contacts for solar cells

Important professional positions

2016 - today	Professorship for „Photovoltaics Materials Research", Institute of Solid-State Physics, Leibniz University Hannover
2010 - 2016	apl. Professor, Leibniz University Hannover
2001 - today	Head of the „Photovoltaics Materials Research" group at ISFH
1998 - 2000	Feodor-Lynen Fellowship, Australian National University, Canberra, Australien

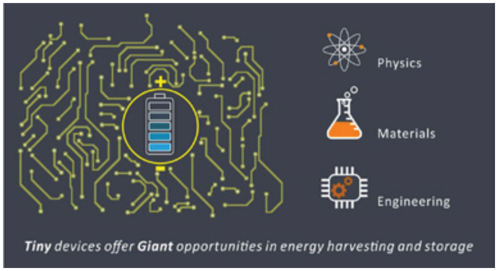
Important publications

» J. Schmidt, K. Bothe, V. V. Voronkov, and R. Falster, Fast and slow stages of lifetime degradation by boron-oxygen centres in crystalline silicon, Phys. Status Solidi B 257, 1900167 (2020).
» J. Schmidt, D. Bredemeier, and D. C. Walter, On the defect physics behind light and elevated temperature-induced degradation (LeTID) of multicrystalline silicon solar cells, IEEE J. Photovolt. 9, 1497-1503 (2019).
» M.-U. Halbich, D. Zielke, R. Gogolin, R. Sauer-Stieglitz, W. Lövenich, and J. Schmidt, Improved surface passivation and reduced parasitic absorption in PEDOT:PSS/c-Si heterojunction solar cells through the admixture of sorbitol, Scientific Reports 9, 9775 (2019).
» J. Schmidt, R. Peibst, and R. Brendel, Surface passivation of crystalline silicon solar cells: Present and future, Sol. En. Mat. Sol. Cells 187, 39-54 (2018).
» D. Zielke, A. Pazidis, F. Werner, and J. Schmidt, Organic-silicon heterojunction solar cells on n-type silicon wafers: the BackPEDOT concept, Sol. En. Mat. Sol. Cells 131, 110-116 (2014).

Prof. Dr. Lin Zhang

Renewable energies are abundant in our environment. The critical problem is how to harvest and store them efficiently. We aim to tackle this great challenge by developing micro-/nanoscale materials and devices. The multidisciplinary research, which covers physics, materials and engineering, will provide solutions to create energy harvesting and storage devices that are safer, smaller, more efficient and durable.

An important focus is the development of novel nanomaterials. Nanomaterials are very attractive in developing high performance energy harvesting and storage devices. The electrochemical reactions occur at nanometer scales, leading to a number of interesting effects which do not occur in conventional materials. Our goal is to perform fundamental investigations on new nanomaterials developed in recent years, and to identify their potential in energy related applications.



Another important research direction is the fabrication of miniaturized energy devices. Development of microsized energy harvesting and storage devices plays an important role in the design of small-scale, and even on-chip integrated electronic devices. A number of challenges exist in the electrode design, the development of solid electrolyte, and the device packaging/integration. Addressing these challenges is an important part of our research.

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Jun.-Prof. Dr. Lin Zhang

Energy harvesting and storage
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Important research projects

» Hannover School for Nanotechnology Project »hsn-digital«
» DFG-Projekt » Verspannungen in Batterieanoden basierend auf Nanomembranen «
» VolkswagenStiftung und MWK -Projekt » Stärkung des Batterieclusters Region Braunschweig «

Important professional positions

Since 2017	Junior professor, Institute for solid state physics, Leibniz University Hannover
2012 - 2017	postdoc and project leader in IFW Dresden
2011	postdoc in Max-Planck Institute for solid state research, Stuttgart
20017 - 2010	PhD candidate in Leibniz Institute for solid and material research Dresden

Important publications

» Y. Liu, S. Ma, L. Liu, J. Koch, M. Rosebrock, T. Li, F. Bettels, T. He, H. Pfnür, N. C. Bigall, A. Feldhoff, F. Ding and L. Zhang: Nitrogen Doping Improves the Immobilization and Catalytic Effects of Co9S8 in Li-S Batteries, Adv. Funct. Mater. 30, 2002462 (2020)
» S. Huang, L. Liu, Y. Zheng, Y. Wang, D. Kong, Y. Zhang, Y. Shi, L. Zhang, O. G. Schmidt and H. Yang: Efficient Sodium Storage in Rolled-Up Amorphous Si Nanomembranes, Adv. Mater., 30, 1706637 (2018)
» L. Liu, Q. Wen, X. Lu, L. Zhang, O. G. Schmidt, Advances on Microsized On-Chip Lithium-Ion Batteries, Small 13, 1701847 (2017)
» J. Deng, X. Lu, L. Liu, L. Zhang, O. G. Schmidt Introducing Rolled-Up Nanotechnology for Advanced Energy Storage Devices, Adv. Energy Mater. 6, 1600797 (2016).
» L. Zhang, J. Deng, L. Liu, W. Si, S. Oswald, L. Xi, M. Kundu, G. Ma, T. Gemming, S. Baunack, F. Ding, C. Yan, O. G. Schmidt, Hierarchically designed SiOx/SiOy bilayer nano-membranes as stable anodes for lithium ion batteries, Adv. Mater. 26, 4527 (2014).

Prof. Dr. Ilja Gerhardt

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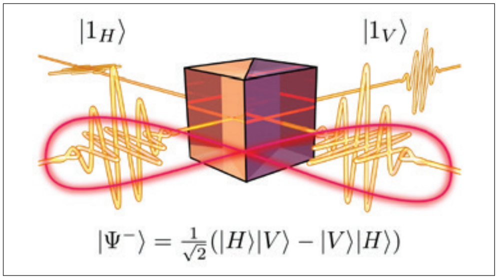
The research on single fluorescing emitters in the solid state allows for the highly sensitive sensing of, for example, magnetic, or electric fields. This allows for the sensing at the nano-scale, even below the wavelength of light. Therefore, the research group works on high resolution microscopy and the precise and accurate localization of single emitters.

Single emitters can also be used as excellent single photon sources which emit after their excitation exactly one single photon. A prime example are single organic molecules which are researched at liquid helium temperatures – they deliver many millions of single photons per second, and are spectrally narrow-band. The photons have ideal properties and can interact well with other quantum systems, such as atomic vapors.

The description of the photon statistics allows for insights into the quantum optical and spectroscopic properties. Special photonic states are realized in the lab.

The optical interaction of the generated photons with hot atomic vapors allows for the implementation of narrow-band optical filters, but also quantum memories which allow to store a single photon for later experiments. Hot atomic vapors are also utilized as highly sensitive magnetometers in the research group.

The single photon sources are utilized in quantum cryptography and in quantum networks.



The optical superposition of two single photons on a simple beam-splitter leads to a new quantum state which is their quantum entanglement.

Important research projects

» Single Emitter Spectroscopy
» Quantum Sensors
» **Spectroscopy & magnetometry hot atoms**
» Cryptography

Important professional positions

2001 - 2006	PhD, Uni Konstanz & ETH Zürich
2007 - 2009	Research Fellow, NUS Singapur
2010 - 2011	Guest professorship, UBC Vancouver
2012 - 2020	Group Leader, MPI Stuttgart
2021 - today	Professorship, LUH

Important publications

» C. Toninelli, I. Gerhardt, A. S. Clark, et al., “Single organic molecules for photonic quantum technologies”, Nature Materials, 2021, 1-14
» Mohammad Rezai, Jörg Wrachtrup, Ilja Gerhardt, “Polarization-entangled photon pairs from a single molecule”, Optica, 2019, 6, 34-40
» Petr Siyushev, Guilherme Stein, Jörg Wrachtrup, Ilja Gerhardt, “Molecular photons interfaced with alkali atoms”, Nature, 2014, 509, 66-70
» I. Gerhardt, Q. Liu, A. Lamas-Linares, J. Skaar, C. Kurtsiefer, V. Makarov, “Full field implementation of a perfect eavesdropper on a quantum cryptography system”, Nature Comm., 2011, 2, 349
» I. Gerhardt, G. Wrigge, P. Bushev, G. Zumofen, M. Agio, R. Pfab, V. Sandoghdar, “Strong Extinction of a Laser Beam by a Single Molecule”, Physical Review Letters, 2007, 98, 4

Institute for Gravitational Physics

S. Gerhard

Prof. Dr. Karsten Danzmann
Executive Director

S. Gerhard

Kirsten Labove
Office

The Institute for Gravitational Physics at Leibniz University Hannover collaborates closely with the Max Planck Institute for Gravitational Physics (Albert Einstein Institute; AEI) in Hannover. Together, the two institutes play a leading role in gravitational physics and gravitational-wave astronomy. This includes the development of sensitive measurement technology and highly efficient data analysis methods. The institutes are responsible for the construction, operation and further development of the GEO600 gravitational-wave detector. Researchers from the institutes lead the preparation of LISA, the gravitational-wave observatory in space, and are important partners in the GRACE Follow-on satellite mission. To analyze the data from the international network of gravitational-wave detectors, they develop efficient mathematical methods and operate the powerful computer cluster Atlas. The distributed computing project Einstein@Home involves volunteers from around the world in the search for neutron stars and gravitational waves.

B. Knispel/ AEI

The Institute for Gravitational Physics at Leibniz Universität Hannover and the Max Planck Institute for Gravitational Physics in Hannover closely collaborate.

The Institute for Gravitational Physics originally emerged from the Institute for Atomic and Molecular Physics of the University of Hannover. On April 1, 1993, Prof. Dr. Karsten Danzmann became head of the section for spectroscopy. He was appointed with the aim of establishing a center for experimental gravitational physics in Hannover. From 1997 to 2001, Prof. Danzmann was also the head of the Hannover branch of the Max Planck Institute of Quantum Optics (MPQ).

On January 1, 2002, the Max Planck Institute for Gravitational Physics was founded in Hannover and since then both institutes have been working together under one roof on theoretical and experimental challenges in gravitational astronomy.

The AEI in Hannover has two departments: "Observational Relativity and Cosmology" led by Prof. Dr. Bruce Allen and "Laser Interferometry and Gravitational Wave Astronomy" led by Prof. Dr. Karsten Danzmann.

Observational Relativity and Cosmology
The department employs a data-driven approach to make new discoveries in relativity, astronomy, and cosmology.

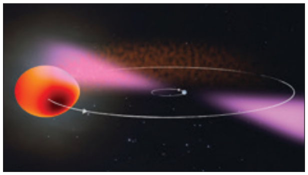
The worldwide network of Earth-based gravitational-wave observatories collects very large amounts of data. Analyzing their public data with advanced methods and detecting gravitational waves from different astronomical sources is the central research focus of the Observational Relativity and Cosmology department at AEI. The department has the skills, experience, and computational resources to independently search and analyze data from gravitational-wave detectors. To this end, novel sophisticated mathematical methods are developed here and a computer cluster is operated. The custom-built "Atlas" computer cluster is the world's most powerful dedicated resource for the analysis of gravitational-wave data. It has more than 23 petabytes of total storage and about 99,000 logical CPU cores and 2,400 GPUs housed in 3,200 compute servers.

A second focus is the application of novel methods for the search for unknown neutron stars. Data from electromagnetic observatories as well as gravitational-wave data are used for this purpose. The department also operates the volunteer distributed computing project Einstein@Home in collaboration with the University of Wisconsin-Milwaukee. As part of this worldwide project, anyone can participate in the search for previously unknown neutron stars at home using their PC, laptop or smartphone. More than 80 new neutron stars have already been discovered in data from radio telescopes and the Fermi satellite. The institute also carries out the most sensitive searches for (as yet undetected) continuous gravitational waves.

Laser Interferometry and Gravitational Wave Astronomy

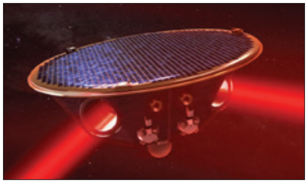
After decades of research, gravitational-wave research has finally reached its goal: Today's observatories have achieved the sensitivity required for direct detection of gravitational waves. Ninety signals observed as of now and completely new insights into our universe are witnesses to this success. Scientists of the "Laser Interferometry and Gravitational Wave Astronomy" department are world leaders in this area. Together with British colleagues, they operate the GEO600 gravitational-wave detector and develop new state-of-the-art technology. Many of the methods developed at AEI – such as the high-power laser systems of the detectors – are used in all major gravitational-wave observatories in the world. In this international collaboration, the institutes are making key contributions to the technology of future detectors. The AEI is also significantly involved in the development of the "Einstein Telescope", the European third-generation gravitational-wave detector.

The most spectacular project for gravitational-wave detection is certainly LISA, the "Laser Interferometer Space Antenna" - a gravitational-wave observatory led by the European Space Agency ESA, which is scheduled to be launched into space in 2034. The institutes are the world's leading research institutions in the development of the project, which will span laser arms millions of kilometers long between three satellites. This will make LISA sensitive enough to hear gravitational-wave signals from across the entire universe. LISA Pathfinder, an ESA test mission for LISA, involved researchers from both institutes and demonstrated the viability of key LISA technologies. The institutes are contributing a laser interferometer to the gravimetry mission GRACE Follow-On, making available gravitational-wave technology from basic research for climate research already today.



Knispel/Clark/MPI für Gravitationsphysik/NASA GSFC

The Division „Observational Relativity and Cosmology" develops methods to efficiently analyze very large amounts of data from gravitational-wave detectors and other telescopes. Many astronomical discoveries have already been made, including PSR J2039-5617, which is a rapidly rotating neutron star in an exotic binary system.



AEI/Milde Marketing/ exozet

The Institute for Gravitational Physics plays a leading role in the planned LISA mission. Three satellites, separated by millions of kilometers, will measure their mutual distances so precisely that tiny ripples in spacetime – gravitational waves – can be detected. LISA will be able to detect gravitational waves from the entire Universe.

Prof. Dr. Bruce Allen

S. Gerhard

Prof. Dr. Bruce Allen

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Bruce Allen studied physics at the Massachusetts Institute of Technology and received his PhD at Cambridge University under the supervision of Stephen Hawking. Following his postdoc fellowships at the University of California Santa Barbara, Tufts University and Observatoire de Paris-Meudon, he was appointed Assistant Professor at the University of Wisconsin-Milwaukee in 1989. He is currently a Director of the Max Planck Institute for Gravitational Physics (Albert Einstein Institute) in Hannover and Honorary Professor at Leibniz University Hannover. He is Head of the »Observational Relativity and Cosmology« Division of the Max Planck Institute, which is the leading research institute dedicated to the development and implementation of data analysis algorithms to aid in the search for gravitational waves. Allen's group develops methods for the – often very compute-intensive – search for weak signals in all known gravitational-wave sources. The group operates the ATLAS computing cluster, which contains about 99,000 CPU cores and 1.7 M GPU cores and which is the world's largest and most powerful resource dedicated to gravitational-wave data analysis. Bruce Allen established the distributed volunteer computing project Einstein@Home in 2005. Today he is the project leader, working with partners in the USA. Einstein@Home uses idle computing time donated by volunteers on their smartphones and home or office PCs for astrophysical data analysis. Einstein@Home has already made a large number of astronomical discoveries.

M. Fiorito/AEI

Bruce Allen's Division operates the ATLAS computing cluster, which is essential for the development of innovative data analysis methods.

Important professional positions

Since	2008	Honorary Professor of Physics, Leibniz University Hannover
Since	2007	Director of the Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Hannover
Since	2007	Adjunct Professor of Physics (part time), University of Wisconsin-Milwaukee
1997 - 2006		Full Professor of Physics, University of Wisconsin-Milwaukee
1992 - 1997		Associate Professor of Physics, University of Wisconsin-Milwaukee
1989 - 1992		Assistant Professor of Physics, University of Wisconsin-Milwaukee

Important research projects

- Development of methods for the detection of gravitational waves in binary systems of neutron stars and black holes with significant spin; their implementation on CPUs and GPUs
- Utilization and expansion of Einstein@Home to aid in the search for gravitational-wave, radio and gamma signals from rapidly rotating neutron stars
- Real-time searches for short, transient gravitational-wave signals

Important publications

- B Allen, E Agrell, The Optimal Lattice Quantizer in Nine Dimensions, Annalen der Physik, 2100259 (2021)
- L Nieder, C J Clark, D Kandel, R W Romani, C G Bassa, B Allen, et al, Discovery of a gamma-ray black widow pulsar by GPU-accelerated Einstein@Home, arXiv:2009.01513 [astro-ph.HE], 2020
- B Abbott, R Abbott, T D Abbott, M R Abernathy, F Acernese, K Ackley, C Adams, T Adams, P Addesso, R X Adhikari, V B Adya, C Affeldt, M Agathos, K Agatsuma, N Aggarwal, O D Aguiar, L Aiello, A Ain, P Ajith, B Allen et al., Observation of gravitational waves from a binary black hole merger, Phys. Rev. Lett. 116, 061102, 2016
- B Allen, JD Romano, Detecting a stochastic background of gravitational radiation: Signal processing strategies and sensitivities, Physical Review D 59 (10), 102001, 1999
- B Allen, Vacuum states in de Sitter space, Physical Review D 32 (12), 3136, 1985

Karsten Danzmann studied, got his PhD, and worked in Clausthal-Zellerfeld, Hannover, Berlin, Stanford, and Garching before he was appointed in 1993 as a Professor at the Leibniz University Hannover. Today he is Director of the Institute for Gravitational Physics of the Leibniz University Hannover und Director at the Max Planck Institute for Gravitational Physics (Albert Einstein Institute) in Hannover. He is Chair of the division »Laser Interferometry and Gravitational Wave Astronomy«. Prof. Danzmann is PI of the laser interferometric earth based Gravitational Wave Detector GEO600 in Sarstedt near Hannover. He is Chair of the space-based LISA International Science Team. The LISA Mission will consist of three satellites at a relative distance of Millions of kilometers. It will be the largest Gravitational Wave Interferometer ever built. The rocket launch will be around the year of 2034. Prof. Danzmann is Co-PI of the satellite mission LISA Pathfinder, that was launched in the year 2015. It has demonstrated the central LISA technologies until the mission finalization in 2018.

H. Lück/ AEI

GEO600 Gravitational wave detector (in Ruthe/Sarstedt)

He is Speaker of the International Max Planck Research School on Gravitational Wave Astronomy, educating the newest generation of gravitational wave scientists at the Albert Einstein Institute since 2005.

Karsten Danzmann is co-Speaker of the DFG special project SFB1464 Relativistic and Quantum-based Geodesy (TerraQ) since 2021. It provides disciplinary research in the basics for the earth shape and the variations of climate change. Danzmann is also Speaker of the Excellence Cluster QuantumFrontiers EXC2123 of the DFG since 2019.

S. Gerhard

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Important professional positions

2002 - today	Director at the Max Planck Institute for Gravitational Physics
1993 - today	Professor (C4, now W3), Director of the Institute for Gravitational Physics, Leibniz University Hannover

Important research projects

- » GEO600
- » LISA and LISA Pathfinder
- » GRACE Follow-On

Important publications

» Physical Review Letters 59 (1987) 1885, 180 -Correlated Equal-Energy Photons From 5.9-MeV/Nucleon U+Th Collisions, K. Danzmann, et al.
» Optics Communications 134, (1997) 431-439, White-light cavities, atomic phase coherence, and gravitational wave detectors, A. Wicht, K. Danzmann et al.
» G. Heinzel, K.A. Strain, J. Mizuno, K.D. Skeldon, B. Willke, W. Winkler, R. Schilling, A. Rüdiger, K. Danzmann. Experimental demonstration of a suspended dual recycling interferometer for gravitational wave detection. Physical Review Letters 81, (1998) 5493-5496.
» H. Grote, K. Danzmann, K.L. Dooley, R. Schnabel, J. Slutsky, H. Vahlbruch. First Long-Term Application of Squeezed States of Light in a Gravitational-Wave Observatory. Physical Review Letters, 110: 181101. (2013) doi:10.1103/PhysRevLett.110.181101.
» M. Armano, H. Audley, G. Auger, J. Baird, M. Bassan, … , K. Danzmann, et. al. Sub-Femto- g Free Fall for Space-Based Gravitational Wave Observatories: LISA Pathfinder Results. Physical Review Letters, 116: 231101. (2016) doi:10.1103/PhysRevLett.116.231101.
» B. P. Abbott, … , K. Danzmann, …, J. Zweizig, et. al. Observation of Gravitational Waves from a Binary Black Hole Merger. Physical Review Letters, 116(6), (2016) 061102. doi:10.1103/PhysRevLett.116.061102.

apl. Prof. Dr. Gerhard Heinzel

private

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Laser interferometry in space
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The group of Prof. Heinzel deals with the application of laser interferometry on satellites in the field of gravitational physics. This includes the planned gravitational wave observatory LISA as well as the observation of the Earth gravity field with GRACE Follow-On and its successors, for climate reasearch. The group works mainly experimentally, with optics and electronics, but also develops and uses computer simulations, data processing techniques and project management.

The group played a pivotal role in the first two laser interferometers in space, the one on LISA Pathfinder within one satellite (2015-2017) and the Laser Ranging Instrument on GRACE Follow-On (since 2018), measuring nm variations between two satellites 200km apart. Moreover it is central in the development of LISA, which will measure gravitational waves between three satellites 2.5 million km apart. Our emphasis in each case is the laser interferometry. The group naturally works closely together with international partners such as NASA, ESA, space agencies and industry, and participated in the design, prototyping, testing and operation of the actual instruments that fly on these satellites.

In addition we develop instruments that can also be used on Earth, such as compact optical accelerometers or a torsion balance to test such equipment.

Important professional positions

Since 2015	Professor
2009	Venia legendi in experimental physics
Since 2001	Scientist and group leader at the Max Planck institut for gravitational physics (Albert-Einstein Institut) and the Institute for gravitational physics of Leibniz University Hannover
1999 - 2001	Post-Doc at the National Astronomical Observatory in Japan
Until 1999	studies at the university of Hannover; diploma and doctoral theses at the Max-Planck institut for quantum optics, Garching

Important research projects

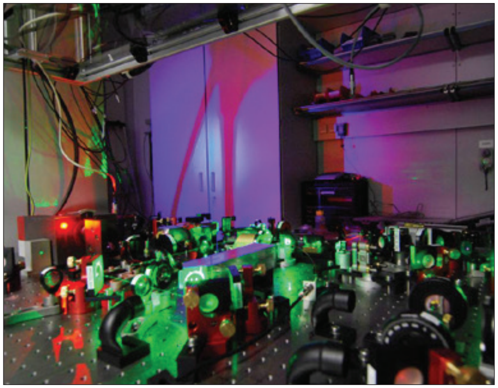
» Design, test and operation of the laser interfeometer on LISA Pathfinder
» Design, test and operation of the laser interfeometer on GRACE Follow-On
» Design and development of numerous aspects of the laser interferometry for LISA
» Compact accelerometers with optical readout
» Planning the instrumentation for future geodesy missions

Important publications

» Heinzel, G et al.: „Experimental demonstration of a suspended dual recycling interferometer for gravitational wave detection", PHYSICAL REVIEW LETTERS Vol. 81 Issue 25 p. 5493-5496 (1998)
» Heinzel, G et al.: „The LTP interferometer and phasemeter", CLASSICAL AND QUANTUM GRAVITY Vol. 21 Issue 5 p. S581-S587 (2004)
» Sheard, B. S.; Heinzel, G. et al.: „Intersatellite laser ranging instrument for the GRACE follow-on mission", JOURNAL OF GEODESY Vol. 86 Issue 12 p. 1083-1095 (2012)
» Abich, Klaus et al.: „In-Orbit Performance of the GRACE Follow-on Laser Ranging Interferometer", PHYSICAL REVIEW LETTERS Vol. 123 Issue 3 031101 (2019)
» M. Armano et al.: „Sensor Noise in LISA Pathfinder: In-Flight Performance of the Optical Test Mass Readout", Phys. Rev. Lett. 126, 131103 (2021)

The group „Quantum Control" at the Institute for Gravitational Physics was founded in July 2010 as a Junior Research Group within the Centre of Excellence QUEST (Centre for Quantum Engineering and Space-Time Research) of Leibniz University Hannover. We work on complex (mostly quantum optical) systems that exhibit noise at or below the quantum limit.

Maximilian Wimmer



Optical table in the Quantum Control Laboratory

Our research areas encompass sources of nonclassical light at high frequencies for applications in precision metrology, as well as the investigation of coherent destructive interference of quantum noise in optomechanical experiments (e.g. in interferometric gravitational wave detectors).

These research areas are joined in their goal of reducing or even fully eliminating quantum noise effects in complex (quantum)optical systems – this is the biggest challenge for next-generation interferometric gravitational wave detectors, but also in many areas of quantum optics and in quantum technologies.

private

Prof. Dr. Michèle Heurs

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Important professional positions

Since Dez. 2016	professor
2010 - 2016	junior professor
2005 - 2010	PostDoc
2000 - 2004	PhD student

Important research projects

» Coherent quantum noise reduction in optomechanical systems (e.g. for next-generation gravitational wave detectors) in cryogenic environment
» Non-classical light (high-frequency optical parametric oscillators)
» Precision metrology: Laser interferometry, stable high-finesse resonators, high-frequency low-noise photo detection with high bandwidth
» Simulation of micro-optomechanical oscillators / membranes

Important publications

» J. Junker, D. Wilken, E. H. Huntington, and M. Heurs, High-Precision Spectroscopy Using High-Frequency Squeezed Light, accepted for publication in Optics Express (2021)
» A. Evlyukhin, M. Matiushechkina, V. A. Zenin, M. Heurs, and B. N. Chichkov: Lightweight metasurface mirror of silicon nanospheres [Invited], Optical Materials Express 10 10 (2020)
» M. Heurs, Gravitational wave detection using laser interferometry beyond the standard quantumlimit, Philosophical Transactions of the Royal Society A Mathematical Physical and EngineeringSciences 376 2120 (2018)
» LSC paper: B. P. Abbott, . . . , M. Heurs, . . . , A gravitational-wave standard siren measurement of the Hubble constant, Nature 551 (7678) (2017)
» LSC paper: B. P. Abbott, . . . , M. Heurs, . . . , Multi-messenger Observations of a Binary Neutron Star Merger, The Astrophysical Journal Letters 848 (2) (2017)
» LSC paper: B. P. Abbott, . . . , M. Heurs, . . . , Observation of gravitational waves from abinary black hole merger, Phys. Rev. Lett. 116 (6) (2016).
» T. Denker, D. Schütte, M. H. Wimmer, T. A. Wheatley, E. H. Huntington, M. Heurs, Utilizing weak pump depletion to stabilize squeezed vacuum states, Opt. Express 23 132 (2015)
» M. H. Wimmer, D. Steinmeyer, K. Hammerer, and M. Heurs, Coherent cancellation of backaction noise in optomechanical force measurements, Phys. Rev. A 89, 053836 (2014)
» H. Song, H. Yonezawa, K. B. Kuntz, M. Heurs, and E. H. Huntington, Quantum teleportation in space and frequency using entangled pairs of photons from a frequency comb, Phys. Rev. A 90, 042337 (2014)

Prof. Dr. M. Alessandra Papa

private

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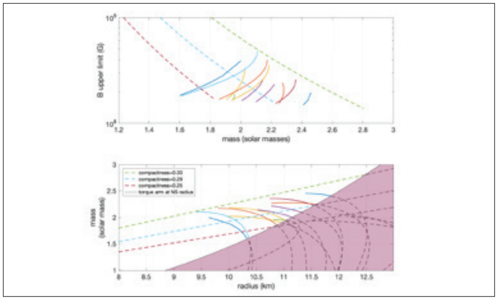
The goal of my research is to detect a continuous gravitational wave signal. These are very weak ripples in space-time generated, for instance, by rotating neutron stars, although also other more exotic sources could generate similar signals. My group has consistently deployed the deepest surveys for these types of signals and has provided the tightest constraints on the amplitude of continuous wave signals at the Earth.

Hand in hand with this work on the data, goes the improvement of the search methods, the development of optimisation techniques to pick the most promising signals to search for, and investigations to explore different emission mechanisms.

Continuous wave searches are computationally limited. For this reason we use the Einstein@Home volunteer computing project, with its Petaflop performance, as our main work-horse. There is a non-trivial overhead associated to setting-up each Einstein@Home search, which must run flawlessly on hundreds of thousands of different computer architectures and operating systems. We are also constantly scoping out how we can leverage new computing hardware and optimise our searches to run on the fastest machines.

Searching LIGO data is an amazing opportunity to detect a continuous gravitational wave signal. Directly through my own work and by coordinating the work of my group, this is what I strive to achieve.



Scorpius X-1 surface magnetic field strength and mass-radius exclusion regions.

Important research projects

- » Continuous Wave Searches, MPI PQP10004, PI
- » Einstein@Home Searches, MPI PQP10003, PI
- » Searches for new neutron stars, NFS grant Nr.1816904 Collaborative Research, U. Wisconsin Milwaukee, co-PI
- » 3G Science Case: Neutron-star Physics Group co-Chair

Important professional positions

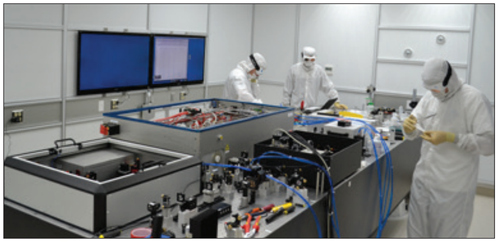
2018 - today	Independent Research Group Leader, MPI for Gravitational Physics, Hannover
2017	Visiting professor at La Sapienza University, Rome, Italy
2007 - 2018	Research Group Leader, MPI for Gravitational Physics, Potsdam
2005 - 2007	Senior Scientist University of Wisconsin Milwaukee

Important publications

- » Y. Zhang, M. A. Papa, B. Krishnan, A. L. Watts "Search for Continuous Gravitational Waves from Scorpius X-1 in LIGO O2 Data", The Astrophysical Journal Letters 906, L14 (2021)
- » B. Steltner, M. A. Papa, H.-B. Eggenstein, B. Allen, V. Dergachev et al. "Einstein@Home all-sky search for continuous gravitational waves in LIGO O2 public data", The Astrophysical Journal, Volume 909, Number 1, 79 (2021)
- » V. Dergachev, M. A. Papa "Results from the first all-sky search for continuous gravitational waves from small-ellipticity sources", Phys. Rev. Lett. 125, 171101 (2020)
- » M. A. Papa, J. Ming, E. V. Gotthelf, B. Allen, R. Prix, V. Dergachev, H. B. Eggenstein, A. Singh and S. J. Zhu, "Search for Continuous Gravitational Waves from the Central Compact Objects in Supernova Remnants Cassiopeia A, Vela Jr. and G347.3-0.5," The Astrophysical Journal, Volume 897, Number 1 (2020)
- » B. P. Abbott et al ,"Observation of Gravitational Waves from a Binary Black Hole merger", Phys. Rev. Lett 116, 061102 (2016)

Prof. Willke's research group at the Albert Einstein Institute is concerned with methods of laser stabilization that can in particular meet the extremely high requirements of Gravitational Wave interferometers. This involves the stabilization of the laser's power, frequency, beam position and beam geometry. Known stabilization methods are optimized on lasers with a power of up to 400 Watts. Furthermore, novel methods are developed at and below the quantum limit and tested in laboratory experiments.

B. Willke



Installation of the stabilized 200W laser system at the Advanced LIGO gravitational wave detector in Hanford (USA)

Due to the rapid development in fiber optic technologies for applications with high light powers, the group has recently focused on the investigation and stabilization of high-power fiber lasers.

Furthermore, Prof. Willke's group works on so-called squeezed light sources. In these non-classical light sources, the quantum statistic of light is manipulated to achieve a better sensitivity of optical measurements.

Another area of activity is the application of lasers and optical resonators in particle physics. In the ALPS collaboration with the DESY research center in Hamburg, the group is responsible for the light source of a light-shining-through-a-wall experiment. Here, high-finesse optical resonators are paired with superconducting magnets to search for theoretically and astrophysically motivated novel particles outside the Standard Model of particle physics.

S. Gerhard

apl. Prof. Dr. Benno Willke

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Important professional positions

2014 - today	associate professor
2009	Habilitation
1992 - today	Scientist and group leader at the Institute for Gravitational Physics, Leibniz University Hannover and at the Max Planck Institute for Gravitational Physics
1997 - 1998	Feodor-Lynen- Scholarship Holder (Alexander von Humboldt Foundation), Stanford University (USA)
1983 bis 1992	Studies and doctorate at the University of Hanover

Important research projects

» Design, construction and operation of the GEO600 Gravitational Wave detector
» Stabilization and installation of the high-power lasers at the Advanced LIGO gravitational wave detectors
» Development of stabilized high-power lasers for the third generation of Gravitational Wave detectors
» Development of new methods for laser stabilization including squeezed-light techniques
» Design, test, installation and operation of the optical setup of the ALPS experiment at DESY for the search for novel particles
» Development of novel squeezed-light sources

Important publications

» F. Wellmann et al., »Low noise 400 W coherently combined single frequency laser beam for next generation gravitational wave detectors«, Optics Express 29 10140-10149 (2021)
» N. Bode et al., »Advanced LIGO Laser Systems for O3 and Future Observation Runs«, Galaxies No.4 8 84 (2012)
» M. Nery et al., »Fundamental limits of laser power stabilization via a radiation pressure transfer scheme«, Optics Letters 45 3969-3972 (2020)
» B. Willke, »Lasers for high optical power interferometers«, in »Advanced Interferometric Gravitational-Wave Detectors « 459-489 World Scientific Publishing Co (2019)
» P. Kwee et al., »Stabilized high-power laser system for the gravitational wave detector advanced LIGO«, Optics Express 20 10617-10634 (2012)
» K. Ehret et al., »New ALPS results on hidden-sector lightweights«, Physics Letters B 689 149-155 (2010)

Institute of Meteorology and Climatology

S. Gerhard

Prof. Dr. Günter Groß
Executive Director

C. Wyrwa

Petra Kraege
Office

The Institute for Meteorology and Climatology (IMuK) at Leibniz University Hannover was founded in 1949 and has been part of the newly founded Faculty of Mathematics and Physics since April 2005. It is the only institution in Lower Saxony where a consecutive Bachelor-Master study of meteorology is possible. In addition to the training offered in the subject of meteorology for students at the institute, there is a range of courses for other subjects with meteorology as a minor. Furthermore, events are offered in the context of public relations and adult education.

The research topics worked on at the IMuK are oriented towards the major challenges of our time in the context of global problems such as climate change, water scarcity and the development of alternative energy sources such as the sun, water and wind.

The study of meteorology imparts the knowledge of how to record the processes observed in the atmosphere by means of physical laws and equations and how to investigate their causes. Due to their complexity, the mathematical-physical equations for describing such atmospheric processes can usually only be solved by means of a computer. Therefore, the intensive teaching of programming skills as well as the development of algorithms to solve a problem is also an essential part of the study.

Since the atmosphere is closely linked by many interactions with other components of the climate system such as hydrosphere, biosphere or cryosphere, there are a number of interdisciplinary connections e.g. to chemistry, geophysics, oceanography, biology or also engineering sciences. This is expressed in the study program by the possibility for corresponding minor subjects.

Special emphasis is placed at the IMuK on training in the classical discipline of actual weather forecasting. For this purpose, a computer-based system for the visualization and processing of meteorological data has been established completely parallel to the equipment at the German Weather Service (DWD). The institute's own weather room serves the students as an information center for the preparation of weather forecasts and as a forum for weather discussions. The training is

M. Gryschka

Weather briefing in the weather room of the ImuK supplemented by practical courses given by a meteorologist working in weather forecasting.

Meteorological processes usually take place outside the laboratory, and therefore field measurements, instrument practicals and measurement campaigns are firmly integrated components of the course. For this purpose, the IMuK has two measurement fields, a roof platform and several large instruments at its disposal. In close cooperation with the DWD, experiments are carried out at DWD observatories in order to learn in practice how to use the latest instrument developments already during the studies. These experiments are supplemented by measurement campaigns under completely different climatic conditions such as in the high mountains or at the sea.

Research at the institute is carried out in the various working groups and deals with current issues in applied meteorology and atmospheric physics on the topics of weather, climate and environment. Through numerous research projects and cooperations in the scientific and industrial environment, the institute is networked worldwide. As a partner and contact point for authorities and industry, it performs important public tasks in the state of Lower Saxony and in Germany.

In the working group „Applied Meteorology „, under the direction of Prof. Gross, topics from the areas of regional climate change, wind energy, dispersion of pollutants, odors and noise are worked on. The WG Radiation and Remote Sensing, headed by Prof. Dr. Gunther Seckmeyer, pursues research topics such as the detection of the spatial and temporal distribution of solar radiation or the assessment of the biological and medical effects of solar radiation. Prof. Dr. Siegfried Raasch heads the working group „PALM", which is mainly concerned with the investigation of turbulent atmospheric and oceanic boundary layer flows by means of coarse structure simulation (Large-Eddy Simulation, LES).

M. Sauer

Students at the advanced practical course at the DWD Observatory Lindenberg

Prof. Dr. Günter Groß

S. Gerhard

Prof. Dr. Günter Groß

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The fields of work of environmental meteorology concern the immediate living space of man. For an assessment of the effects of weather, weather conditions, climate and air hygiene on the human organism, several specific complexes are of importance: thermal effect complex, actinic effect complex, air-hygienic effect complex including odor, noise and wind comfort.

These aspects are especially investigated in the area of urban agglomerations above ground and underground (e.g. subway stations), but also for the interior. Due to legal requirements, these factors influencing people are fixed components of spatial planning and must therefore be taken into account accordingly.

For such planning tasks, special numerical models have been developed in the working group, which are able to calculate local and regional distributions of the different meteorological variables. The differential equations underlying the models are solved by numerical methods on a computational grid. Due to the task, very fine spatial mesh sizes of 1 m-100 m are used.

Such models provide the opportunity to examine not only current conditions, but also the effects of changes in conditions such as:

- Land use changes (urbanization, forest clearing).
- Changes in the composition of the air (smog)
- local effects of global climate change (urban climate 2100)

Agnes Straaten

Meteorological measurements in a subway station

Important research projects

» KFM – Regional Management of Climate Impacts in the Metropolitan Region Hannover-Braunschweig-Göttingen
» KURAS – Concepts for urban stormwater management and wastewater systems
» Investigation of the effect of immission control plantings in the vicinity of livestock buildings

Important professional positions

1990 - today	Professor for Meteorology, University of Hannover
1988 - 1990	Professor for Climatology University of Trier
1984 - 1988	University Assistant Technical University Darmstadt

Important publications

» Gross, G. (2014): Observations and numerical simulations of the train-induced air flow in a subway station. Meteorologische Zeitschrift, DOI 10.1127/metz/2014/0615
» Gross, G. (2014): On the estimation of wind comfort in a building environment by micro-scale simulation. Meteorologische Zeitschrift, DOI 10.1127/0941-2948/2014/0577
» Gross, G. (2012): Numerical simulation of greening effects for idealised roofs with regional climate forcing, Meteorologische Zeitschrift 21, DOI: 10.1127/0941-2948/2012/0291
» Heimann, D., Gross, G. (1999): Coupled simulation of meteorological parameters and sound level in a narrow valley. Appl. Acoustics 56, 73-100.
» Gross, G. (1995): Optimum time step and remerging Feigenbaum trees in a one-dimensional boundary-layer model. Beitr.Phys.Atmosph. 68, 271-273

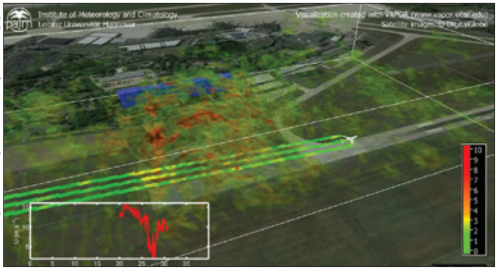
apl. Prof. Dr. Siegfried Raasch

My research focus is on the numerical investigation of atmospheric turbulence with large-eddy simulation models (LES) and direct numerical simulation (DNS).

My interests range from basic research, e.g. about the origin of dust devils or the turbulence induced growth of cloud and rain droplets, up to applied questions like turbulence effects on air quality in the urban environment, the behaviour of commercial aircraft and unmanned aerial vehicles (UAVs) under strong turbulence, or the effects of turbulence on the energy production and the lifetime of wind energy systems. Respective simulations require large amounts of computational resources and that is why they need to run on the world's biggest computers.

Therefore, a further focus of my work is on development and optimization of LES models and relevant numerical methods for massively parallel computers and accelerator boards (GPUs). Visualization of complex flow phenomena is another field of work, not only for research purposes, but also to communicate research results to a broader public.

Helge Knoop/Christoph Knigge



Influence of turbulence generated by a building (blue) on a landing aircraft. Red/green areas mark areas with high/low turbulence intensity.

S. Gerhard

apl. Prof. Dr. Siegfried Raasch

PALM working group
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E-Mail raasch@meteo.uni-hannover.de

Important professional positions

2008 - today	„außerplanmäßiger" professor at the Leibniz University Hannover
1993 - today	Scientific staff, Institute of Meteorology and Climatology, Leibniz University Hannover
1990 - 1993	Temporary academic consult, "Fachbereich Physik", University Hannover
1985 - 1990	Research associate at the University Hannover

Important research projects

» Turbulence structure of the urban canopy layer: LES reference studies and comparisons with data from wind tunnel, scale models, and field observations (DFG core research program »Multiple Scales in Fluid Mechanics and Meteorology«)
» Entrainment of aerosols and their activation in shallow cumulus clouds – Large-eddy simulations with an embedded Lagrangian particle model (DFG)
» Evolution and features of dust devils in convective boundary layers – A comparative study using DNS/LES and laboratory experiments (DFG)

Important publications

» Raasch, S. und M. Schröter, 2001: A large-eddy simulation model performing on massively parallel computers, Meteorol. Z., 10, 363-372
» Letzel, M.O., M. Krane und S. Raasch, 2008: High resolution urban large-eddy simulation studies from street canyon to neighbourhood scale, Atmos. Env., 42, 8770-8784
» Raasch, S. und T. Franke, 2011: Structure and formation of dust devil-like vortices in the atmospheric boundary layer: A high-resolution numerical study. J. Geophys. Res., 116, D16120, DOI: 10.1029/2011JD016010
» Hoffmann, F., Y. Noh und S. Raasch, 2017: The route to raindrop formation in a shallow cumulus cloud simulated by a Lagrangian cloud model, J. Atmos. Sci., 74, 2125-2142, DOI: 10.1175/JAS-D-16-0220.1
» Maronga, B., C. Knigge und S. Raasch, 2020: An improved surface boundary condition for large eddy simulations based on Monin-Obukhov similarity theory: Evaluation and consequences for grid convergence in neutral and stable conditions, Boundary-Layer Meteorol., 174, 297-325, DOI: 10.1007/s10546-019-00485-w

Prof. Dr. Gunther Seckmeyer

private

Prof. Dr. Gunther Seckmeyer

Radiation and remote sensing
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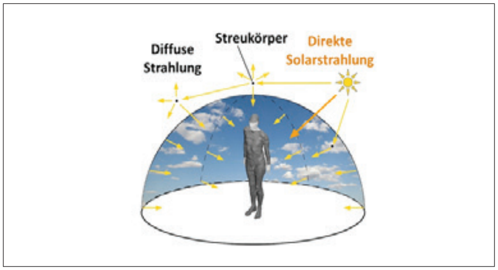
seckmeyer@meteo.uni-hannover.de

My objective is to contribute to the most urgent and important issue of mankind: the accelerating climate crisis. I want to communicate the existing knowledge to the members of the university as well as the general public. My main field of expertise is solar radiation, which has energetic, biological and medical impacts. My interest is to improve measurements, modelling and usage of solar energy.

My special focus is the development and the application of novel instruments for the measurement of solar radiation. With these data both positive (e.g. Vitamin D) and negative effects (e.g. skin cancer) on human health shall be investigated and better described. The Climate Change has various impacts on the solar radiation and human health, e.g. by creating new record losses of ozone both in the Arctic and in Antarctica. A better understanding of solar radiation is also important for a better utilization of solar energy, which is the key technology for fighting the climate crisis. To enable an application of the knowledge for larger areas, there is also a need to validate data from satellites by ground based measurements.

Because the challenges are of world-wide importance it is necessary to coordinate the science on a world-wide basis. Therefore I am cooperating on a national, European and world-wide scale and nearly since 30 years I am member of international committees, such as the Network for the Detection of Atmospheric Composition Change or the Global Atmosphere Watch Program of the World Meteorological Organization.



Michael Schrempf

3-D model human in solar radiation field.

Important research projects

- Seckmeyer G., Blumthaler M., Putz E., Weihs P., Gillotay D., Taalas P., Lenoble J., Dehne K., Gardiner B., Bais A., Cappellani F., Siani A., Kelder H., Slaper H., Kylling A., Kjeldstad B., Redondas A., Josefsson W.: Scientific UV Data Management (SUVDAMA), CEC, 1996-1999
- Seckmeyer G., Blumthaler M., Putz E., Weihs P., Taalas P., Lenoble J., Slaper H., Kylling A., Kjeldstad B., Gardiner B., Bais A., Engelsen O., Webb A.R., Gillotay D., Siani A., Feister U., Steinmetz M., de la Casiniere, van Weele M., Rembges D.: European database for Ultraviolet Climatology and Evaluation (EDUCE), Commission of European Communities, 2000-2004
- Multispektralradiometer, Großgerät finanziert von der Deutschen Forschungsgemeinschaft und dem Land Niedersachsen

Important professional positions

2000 - today	Professor for Meteorology at the Leibniz University Hannover
1992 - 2000	scientist at the Fraunhofer Institute for atmospheric environmental research, Garmisch-Partenkirchen, Germany, leader of the research group on "radiative transfer"
1987 - 1992	Physicist at the company PRC Krochmann, Berlin in cooperation with the research center on environment and health (GSF), Munich, Germany

Important publications

- Seckmeyer G.; McKenzie R.: Increased ultraviolet radiation in New Zealand (45°S) relative to Germany (48°N), Nature, Vol. 359, pp 135-137, September 1992
- Seckmeyer G., Schrempf M., Wieczorek A., Riechelmann S., Graw K., Seckmeyer S., Zankl M.: A novel method to calculate solar UV exposure relevant to vitamin D productionin humans, Photochemistry&Photobiology, 89: 974–983, Juli, 2013
- Riechelmann S., Schrempf M., Seckmeyer G.: Simultaneous measurement of spectral sky radiance by a non-scanning multidirectional spectroradiometer (MUDIS), Measurement Science and Technology, 24, 125501, http://dx.doi.org/10.1088/0957-0233/24/12/125501, Oktober, 2013New J. Phys., 14, 065008, DOI: 10.1088/1367-2630/14/6/065008

The focus of my research is the investiation of small-scale processes in the atmospheric boundary layer. More specifically, I am interested in phenomena related to the interaction between the Earth's surface and the surface-layer. My main tool for this research is the turbulence-resolving large-eddy simulation model PALM. PALM has been developed and used in our work group, supervised by Prof. Dr. Siegfried Raasch and myself.

Above all, my research focuses on the further development of PALM for application in urban environments and investigations related to the urban micro-climate. We are here dealing with questions like: how does building retrofitting affect indoor and outdoor temperatures during summer heat waves? How can cities adapt to climate change? What is the effect of traffic-produced turbulence on the dispersion of particulate matter and air pollutants?

Pollutant concentation (red: high values) at street level in Hannover's old town district. PALM simulation of a virtual hazardous accident at Steintor place.

Moreover, my work is dedicated to the simulation of stable boundary layers, which typically occur during nighttime or in the polar regions in the winter half year. Due to the low turbulence intensity and strong static stability of the boundary layer, simulating stable conditions remains a huge challenge. In the case of fog formation, the turbulence structure is further complicated by the complex interaction between vegetation and radiation processes as well as the cloud microphysics. The forecasting of fog is thus a major weakness of numerical weather prediction models. LES models such as PALM can resolve these processes and thus support the improvement of numerical weather prediction. Due to the small size of the relevant energy-containing eddies, very small grid spacings are required, so that LES of such situations require enormous computational power on the world's leading supercomputers.

private

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Important research projects

- Model-based city planning and application in climate change (BMBF)
- High-resolution numerical studies on the effect of turbulence on nocturnal radiation fogs (DFG)
- Large-eddy simulation study on the effect of vehicle-induced turbulence and exhaust fumes on wind flow and pollutant dispersion in urban street canyons

Important professional positions

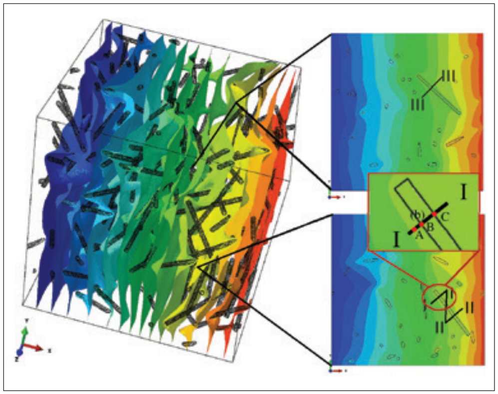
Since 2021	Full Professor for Meteorology and Climatology, Leibniz University Hannover
2017 - 2021	Adjunct Associate Professor, Geophysical Institute, University of Bergen, Norway
2016 - 2021	Junior Research Group Leader, Institute of Meteorology and Climatology, Leibniz University Hannover
2010 - 2016	Research Associate, Institute of Meteorology and Climatology, Leibniz University Hannover

Important publications

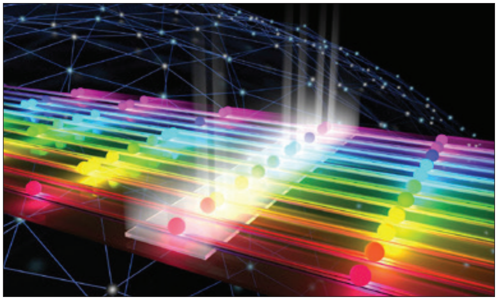
- Kral, S.T., G. H. Urbancic, B. Greene, K. Flacké Haualand, L. Båserud, P. B. Chilson, A. A. M. Holtslag, M. O. Jonassen, R. Kouznetsov, T. Lorenz, B. Maronga, S. Mayer, E. A. Pillar-Little, A. Rautenberg, J. Schwenkel, A. Seidl, G.-J. Steeneveld, I. Suomi, T. Vihma, B. Wrenger, J. Reuder (2020): Innovative Strategies for Observations in the Arctic Atmospheric Boundary Layer Project (ISOBAR) — Unique fine-scale observations under stable and very stable conditions, Bull. Am. Meteor. Soc. DOI: 10.1175/BAMS-D-19-0212.1
- Schwenkel, J. and B. Maronga (2020): Towards a better representation of fog microphysics in large-eddy simulations based on an embedded Lagrangian cloud model, Atmosphere, 11 (5), 466. DOI: 10.3390/atmos11050466
- Maronga, B., C. Knigge, S. Raasch (2020): An improved surface boundary condition for large eddy simulations based on Monin-Obukhov similarity theory: Evaluation and consequences for grid convergence in neutral and stable conditions, Boundary-Layer Meteorol., 174, 297-325. DOI: 10.1007/s10546-019-00485-w

Institute of Photonics

The Institute of Photonics at Leibniz University Hannover was founded in late 2020. It's aim is pursuing research and teaching in the growing interdisciplinary field of photonics. The Institute of Photonics deals with basic and application-oriented research of photonic effects and systems, using both experimental and numerical / theoretical methods. The research ranges from the study of new photonic phenomena to the design of optical fiber-based and integrated systems and phonic nanostructures. Here effects and structures are taken into account that are on the order of the wavelength of the light. Another focus of the institute's research is the application of these new systems in e.g. sensor technology and information processing.



The institute currently has two professorships. Prof. Xiaoying Zhuang PhD deals with the application of machine learning processes and numerical mechanics to calculate and design new types of nanostructures, metamaterials and photonic systems. Prof. Dr. Michael Kues researches photonic quantum systems with a focus on technology development. Examples are the implementation of quantum-enhanced measurement methods, e.g. resolution improvement, and the implementation of quantum information processing systems, e.g. the implementation of optimization algorithms. Both professors have been



awarded an ERC Starting Grant and have excellent networks throughout the institutes, nationally and internationally. The institute is significantly involved in the excellence cluster „PhoenixD" and has collaborations with universities in Germany (e.g. KIT, Ruhr University Bochum, University of Leipzig) and with research institutions worldwide (e.g. Glasgow University, Aarhus University).

The Institute for Photonics offers lectures on modern simulation technologies as well as experimental methods in photonics. The simulation courses cover multiscale problems, multiphysics problems and the modeling of nanomaterials. Further courses on machine learning and "data driven computing" will be offered in 2021. The experimental courses cover topics on applied quantum photonic technologies and integrated optics. Furthermore, contemporary Bachelor and Master theses themes are offered in current topics of photonics, numerical optics and photonic quantum systems. Dissertation projects are also offered and implemented within the framework of third-party funded projects within these topics.

IOP Institute of Photonics

CSST Chair of Computational Science and Simulation Technology

Prof. Dr. Michael Kues

private

Prof. Dr. Michael Kues

Photonic quantum technologies
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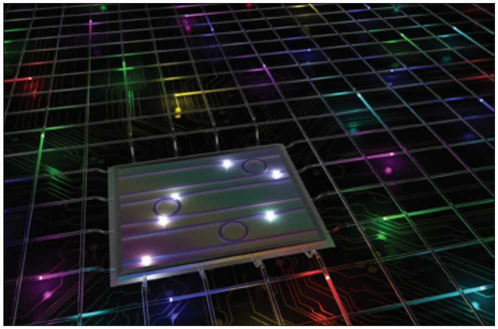
Quantum physical effects such as superposition and entanglement allow new and interesting possibilities with a plethora of new applications e.g. the total secure telecommunications (quantum communication), enhanced computing (quantum computing), and quantum improved measurements (quantum sensing). Photons, that is, the particles of light, are of high interest for the realization of suitable quantum systems, as photons can be transmitted over long distances and their systems can be operated at room temperatures.

A focus of our research group is the investigation and development of novel, scalable and compact photonic quantum systems based on fiber and integrated optical circuit technology. This encompasses e.g. the generation of complex optical quantum states in integrated photonic waveguide structures, the specific manipulation and control of the states, as well as their full characterization and detection. The approaches exploit advances in the sophisticated telecommunications technology (ultra-fast signal processing) and in chip fabrication industry. We work at the intersection of nonlinear optics, integrated photonics, quantum science and information processing with the aim to enable quantum technologies in real world scenarios. The photonic quantum systems are robust and compact and of interest for further projects in research and industry.



M. Kues

Photonic quantum circuits

Important professional positions

2019 - today	Professor for experimental physics at Hannover University
2018 - 2019	Assistant Professor, Aarhus University, Denmark
2018 - 2019	Marie-Skłodowska Curie Fellow, University of Glasgow, UK
2015 - 2018	Group leader "Nonlinear integrated quantum optics" at the National Scientific Research Institute, Montreal, Kanada
2014 - 2018	Marie-Skłodowska Curie Fellow at National Scientific Research Institute, Montreal, Kanada

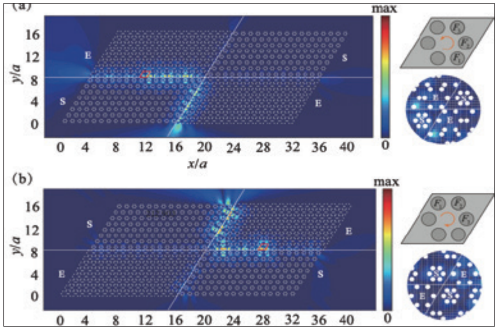
Important research projects

» BMBF Quantum Futur Program - PQuMAL
» ERC Starting Grant - QFreC
» VW-Vorab Israel-Niedersachsen Cooperation

Important publications

» A. Khodadad Kashi and M. Kues, "Spectral Hong–Ou–Mandel interference between independently generated single photons for scalable frequency-domain quantum processing," Laser and Photonics Reviews, https://doi.org/10.1002/lpor.202000464 (2021).
» M. Kues, et al., "Quantum Optical Microcombs," Nature Photonics 13, 170–179 (2019).
» C. Reimer, ..., M. Kues and R. Morandotti, "High-dimensional one-way quantum processing implemented on d-level cluster states," Nature Physics 15, 148–153 (2019).
» M. Kues, et al., "On-chip generation of high-dimensional entangled quantum states and their coherent control," Nature 546, 622 (2017).
» M. Kues, et al., "Passively mode-locked laser with an ultra-narrow spectral width," Nature Photonics 11, 159 (2017).
» C. Reimer, M. Kues, et al., "Generation of multiphoton entangled quantum states by means of integrated frequency combs," Science 351, 1176 (2016).

Prof. Xiaoying Zhuang's key research area is machine learning and computational mechanics for the modelling and design of novel photonic systems, metamaterials and nanostructures. She has developed numerous innovative and robust numerical methods including level-set methods, partition-of-unity methods (such as mesh-free methods, XFEM formulations, phantom node methods and finite cover methods), multiscale methods, phase field models and error-driven adaptive methods developed and implemented. She also has experience with coupled (hydro-mechanical, thermo-mechanical, thermo-hydro-mechanical and electro-mechanical) problems, uncertainty analyzes/uncertainty quantification as well as inverse methods and optimization processes. She has applied innovative numerical methods to solve complex problems in engineering, solid state physics, and materials science. The research focus funded by the Humboldt Foundation is the modeling, optimization and development of polymer composite materials. Her onging ERC Starting Grant is focused on the optimization and development of piezoelectric and flexoelectric nano-energy converters.



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Prof. Dr. Xiaoying Zhuang

Chair of Computatioanl Science and Simulation Technology
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Phone +49 511 762 17535
E-Mail zhuang@iop.uni-hannover.de

Important research projects

- Marie Curie Global Fellow 2020, "Triboelectrification muscle dynamics†framework for developing triboelectric nanogenerators TENGS implantable bio applications (TEMD)" European Research Council, Horizon2020, 1.2022-12.2023.
- ERC Starting Grant 2018, Horizon2020, European Research Council, PI, 8.2019-7.2024.
- Heisenberg-Professur Programme, DFG, ZH 459/5-1, 2019.
- Cluster of Excellence „PHOENIXD –"Photonics, Optics, Engineering Innovations Across Disciplines" for the Simulation, Manufacturing und Application of Optical System, PI, 01.2019-12.2025.

Important professional positions

2021- today	W3-Professor, Faculty of Physics and Mathematics, Leibniz University Hannover
2020	Offer of W3-Professor, Faculty of Mechanical Engineering, KIT
2020	Offer of W2-Professur, Faculty of Civil Engineering, Ruhr-University Bochum
2015 - 2021	Sofja-Kovalevskaja Prize Winner und Research Group Leader, Institute of Continuum Mechanics, Faculty of Mechanical Engineering, Leibniz University Hannover (www.sofja-zhuang.ikm.uni-hannover.de).
2014 - 2015	FP7 Marie Curie International Incoming Fellow at Institut of Struktural Mechanics, Bauhaus-University Weimar, Germany
2014	Offer of Senior Lecturer, Durham University, University of Durham (QS World Top Universities Rankings 2019 in 74th place), the UK

Important publications

- K.M. Hamdia, X. Zhuang, T. Rabczuk. An efficient optimization approach for designing machine learning models based on genetic algorithm. Neural Computing and Applications 33 (6), 1923-1933, 2021.
- B. Mortazavi, B. Javvaji, F. Shojaei, T. Rabczuk, A.V. Shapeev, X. Zhuang. Exceptional piezoelectricity, high thermal conductivity and stiffness and promising photocatalysis in two-dimensional Mo-Si2N4 family confirmed by first-principles. Nano Energy 82, 105716, 2021.
- **X. Zhuang, Q. Wang, H. Zhu. Multiscale modelling of hydro-mechanical couplings in quasi-brittle materials, International Journal of Fractures, 204:1-27, 2017.**
- **S. Nanthakumar, X. Zhuang, H. Park, T. Rabczuk. Topological optimization of flexoelectric nano energy harvester, Journal of the Mechanics and Physics of Solids, 105: 217-234, 2017.**

Institute of Quantum Optics

S. Gerhard

Prof. Dr. Silke Ospelkaus
Executive Director

Dr. Malte Niemann
Management

Anne-Dore Göldner-Pauer
Office

Stephanie Kaisik
Office

Madeleine-Yasmin Miltsch
Office

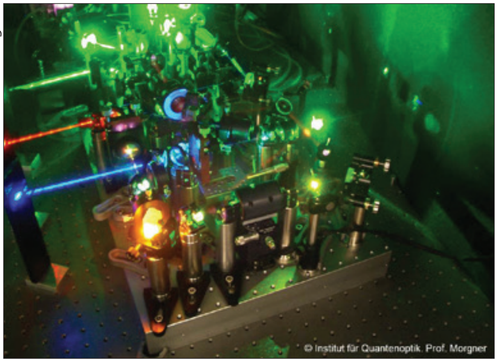
Marina Rückert
Office

Bianca Thiel
Office

The Institute for Quantum Optics at Leibniz University Hannover focuses on fundamental and application-oriented research in the field of laser physics and the interaction of laser light with matter. Thematically, the work ranges from the coldest matter produced so far (Bose-Einstein condensation) to the hottest plasmas achievable by laser radiation with the shortest laser pulses on femto- and attosecond time scales. A wide variety of systems are studied: from individual ultracold atoms to molecules to living biological systems. The research extends to quantum information processing and satellite-based research of phenomena of general relativity. „How can we improve lasers?", „Where can we use laser light?" Or „What can I learn from the interaction of laser light with matter?" are some of the central questions that are being studied. Complementary to the basic research, application aspects are always in the focus of interest. New imaging methods for tissue and technical surfaces are being worked on. Research is being carried out how atomic clocks and atomic inertial sensors with unprecedented accuracy can be built, how atom-molecule reactions (chemical processes) can be controlled using new methods of atom and molecule manipulation, how laser surgery will make glasses obsolete in the future or how even individual cells can be manipulated extremely gently; In the long term, it is aimed for the building of a quantum computer using individual atoms or to achieve lasers with ever shorter wavelengths, including X-ray lasers.

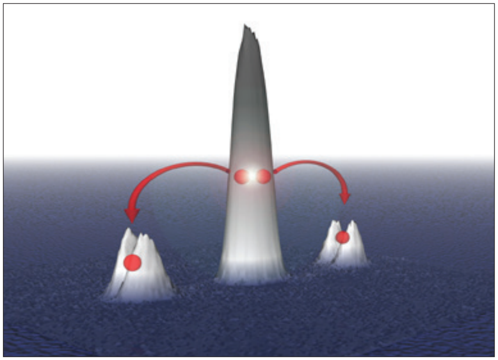
The research of the Institute of Quantum Optics takes place in established local, national and international collaborations. The institute has established collaborations with the Laser Center Hanover (LZH), other faculties at Leibniz University Hanover, the Physikalisch-Technische Bundesanstalt in Braunschweig, NIFE (Lower Saxony Center for Biomedical Technology, Implant Research and Development), the DLR-SI (Institute for Satellite Geodesy and Intertial Sensors) as well as with other nationally and internationally leading

U. Morgner



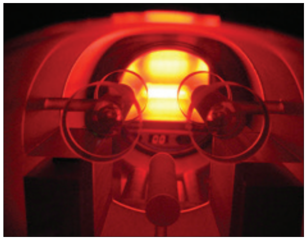
RGB laser through nonlinear frequency conversion processes

C. Klempt

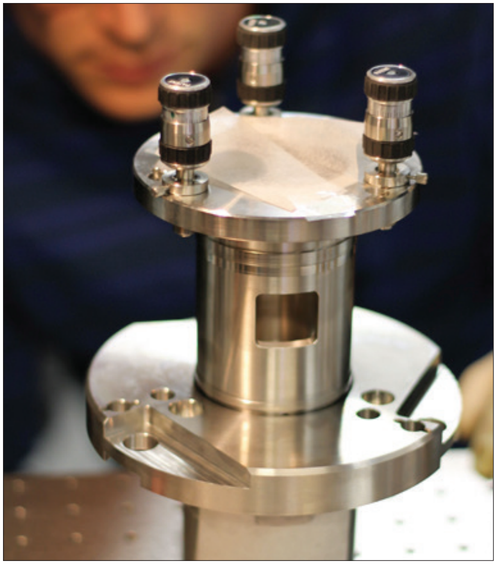


Matter waves from ultracold, entangled rubidium atoms universities and research institutions. Particularly important are the collaborations within the framework of the QUEST Leibniz Research School and the Cluster of Excellence PhoenixD: „Photonics, Optics, Engineering and Innovation across Disciplines", QuantumFrontiers: „Light and matter at the quantum limit", and Hearing4all: „Models, technology and solutions for diagnostics, restoration and support of hearing" as well as many national and multinational projects funded by the German Research Foundation, federal and state ministries, the EU Commission or the ESA. The institute contributes significantly to the quantum technology network QVLS „Quantum Valley Lower Saxony". The international exchange of knowledge and scientists is very important. After completing a master's degree or doctoral thesis, IQ graduates find interesting career prospects in global research and / or in research-related industry.

Teaching offered by the Institute of Quantum Optics includes introductory seminars, basic experimental physics lectures (experimental physics I-IV) and advanced lectures within the bachelor's degree such as Atomic and Molecular Physics and Coherent Optics. The lectures and seminars are aimed at undergraduate students in physics, mathematics, computer science and meteorology as well as students enrolled in teacher training courses. Advanced lectures and seminars directly related to research (photonics, atomic optics, quantum optics, optical layers, etc.) are offered for master's students. All groups of the institute offer demanding theses on current research topics for both Bachelor and Master students in physics and the teacher training courses. Great emphasis is placed on intensive and committed support. Dissertation projects are mostly integrated into national and multinational third-party funded projects. A large part of the doctoral students are also involved in a structured doctoral training program funded by the German Research Foundation, the EU or the State of Lower Saxony. In addition to training in the laboratory, research-related lectures and seminars as well as job-oriented seminars are offered.


A. Zenesini

High finesse resonator in vacuum


S. Ospelkaus

Assembly of a high-resolution lens for the detection of single molecules

Prof. Dr. Boris Chichkov

S. Gerhard

Prof. Dr. Boris Chichkov

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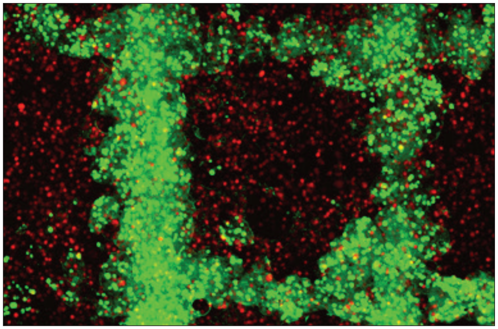
Boris Chichkov's Nanoengineering group deals with the development of laser-based nanotechnologies for 3D additive manufacturing, laser printing, nanoparticle generation; the development of new nanomaterials and biofabrication. An important focus in our research form interdisciplinary applications and collaborations in the fields of nanophotonics, new materials, tissue engineering, and biomedicine.

This work takes place in close cooperation with international and national scientists and industry. In the context of biomedical research, there are close collaborations with the Hannover Medical School, the Faculty of Natural Sciences, the Lower Saxony Center for Biomedical Engineering, Implant Research and Development, and the Faculty of Mechanical Engineering at Leibniz University Hannover.

Important pioneering work in femtosecond laser material interaction and material processing, twophoton polymerization, nanophotonics, the development of novel biomedical implants and the laser printing of nanoparticles, microorganisms, and living cells originated from this Nanoengineering group.

The working group consists of an international and interdisciplinary team of scientists and engineers working together at the interfaces of physics, chemistry, biology and medicine, with a strong focus on the translation of research results into industry and clinical applications.



Andrea Deiwick

Laser cell print of endothelial cells (green) and smooth muscle cells (red).

Important professional positions

2009 - today	Professor at Leibniz University Hannover
2004 - 2017	Head of the Nanotechnology Department, Laser Zentrum Hannover e.V.
1981 - 2004	Research activities in Moscow, Garching, Osaka, Darmstadt, Göttingen, Jena and Hannover Editorial board member von "Materials Science and Engineering: C Materials for Biological Applications"; "International Journal of Bioprinting", "Journal of 3D Printing in Medicine – Future Medicine", "Nanomaterials".

Important research projects

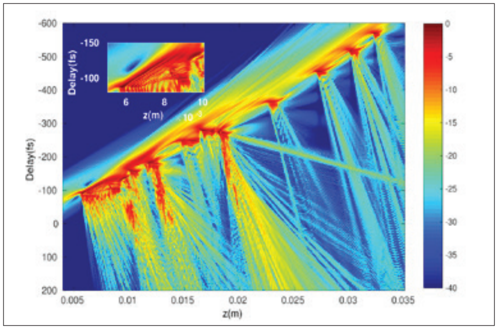
» Excellence cluster »QuantumFrontiers«
» Excellence cluster »PhoenixD«
» Excellence cluster »REBIRTH: From regenerative Biology to rekonstructive Therapy«
» Excellence cluster »QUEST: Quantum engineering and space-time research«
» Biofabrication for NIFE, Low Saxony Project
» RESPONSE: BMBF funded Konsortium

Important publications

» U. Zywietz, A.B. Evlyukhin, C. Reinhardt, B.N. Chichkov, Laser printing of silicon nanoparticles with resonant optical electric and magnetic responses, Nature communications 5:3402 (2014)
» L. Koch, M. Gruene, C. Unger, B. Chichkov, Laser assisted cell printing, Current pharmaceutical biotechnology 14, 91 (2013)
» A.B. Evlyukhin, S. M. Novikov, U. Zywietz, R. Lynge Eriksen, C. Reinhardt, S. I. Bozhevolnyi, and B.N. Chichkov, Demonstration of Magnetic Dipole Resonances of Dielectric Nanospheres in the Visible Region, Nano Lett. 12, 3749 (2012)
» M. Farsari and B.N. Chichkov, Materials processing: Two-photon fabrication, Nature photonics 3, 450 (2009)

apl. Prof. Dr. Ayhan Demircan

The group focuses on theoretical and computational investigations of light-matter interaction in complex optical and photonic systems. The investigations include the theoretical analyses modeling of the fundamental effects, development of suitable numerical methods and their application. A wide range of methods are applied, ranging from spectral and statistical methods to finite-difference time-domain methods. Our research area includes modern nonlinear optics and quantum optics, laser physics, photonics in condensed matter, and micro- and nanophotonics. One focus is the manipulation and control of light pulses, both in ultrafast optics and strong-field phenomena and in the generation and control of single photons.



Simulation of the nonlinear propagation of an intense laser light pulse in glass with an energy close to the destruction limit, which causes a self-induced refractive index change via photo-ionization.

The research projects are very well connected through national and international collaborations. In particular, due to the integration into the PhoenixD Cluster of Excellence, a close interdisciplinary collaboration with other faculties at Leibniz University Hannover is given, such as the Faculty of Natural Sciences, the Faculty of Mechanical Engineering and the Faculty of Electrical Engineering and Computer Science.

private

apl. Prof. Dr. Ayhan Demircan

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Important research projects

» Cluster of Excellence »PhoenixD: Photonics, Optics, and Engineering – Innovation Across Disciplines«
» Niedersachsen Vorab und Volkswagen Stiftung »HYMNOS: Hybrid Numerical Optical Simulation«
» DFG-Project »Pulse shaping in hollow fiber compressors: simulation and experiment«

Important professional positions

2019 - today	extracurricular Professor at the Leibniz University Hannover
2013 - today	Research Scientist, Institute for Quantum Optics, Leibniz University Hannover
2003 - 2011	Research Scientist, Weierstrass Institute for Applied Analysis and Stochastics, Berlin

Important publications

» O. Melchert, S. Willms, S. Bose, A. Yulin, B. Roth, F. Mitschke, U. Morgner, I. Babushkin, A. Demircan, Soliton molecules with two frequencies, Physical Review Letters 123, 243905 (2019)
» I. Babushkin, A. Tajalli, H. Sayinc, U. Morgner, G. Steinmeyer, A. Demircan, Simple route toward efficient frequency conversion for generation of fully coherent supercontinua in the mid-IR and UV regime, Light: Science & Applications 6, e16218 (2017)
» C. Brée, I. Babushkin, U. Morgner, A. Demircan, Regularizing Aperiodic Cycles of Resonant Radiation in Filament Light Bullets, Physical Review Letters 118, 163901 (2017)
» A. Demircan, S. Amiranashvili, C. Brée, G. Steinmeyer, Compressible octave spanning supercontinuum generation by two-pulse collisions, Physical Review Letters 110, 233901 (2013)
» A. Demircan, S. Amiranashvili, G. Steinmeyer, Controlling light by light with an optical event horizon. Physical Review Letters, 106, 163901 (2011).

Prof. Dr. Wolfgang Ertmer

S. Gerhard

Prof. Dr. Wolfgang Ertmer

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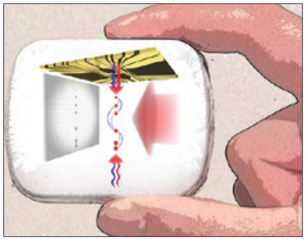
The atom optics group conducts research with ultracold gases, so-called Bose-Einstein con-densates. In this unique system, the majority of atoms are indistinguishably in the same quan-tum mechanical state.

The focus of the research is on the one hand on the investigation of fundamental concepts of quantum mechanics such as the entanglement of atoms. Entanglement of two or even many atoms among each other is a fundamental quantum phenomenon that can only be realized and used in extremely low-noise quantum systems. Here, colli-sions between ultracold atoms are used to entang-le up to 68 atoms with each other. In addition to the fundamental study of such phenomena, this non-classical state also allows extremely precise measurements to be made that are not limited by the standard quantum limit of interferometry.

On the other hand, the further development of methods for the preparation of ultracold quan-tum gases and Bose-Einstein condensates is being explored. In particular, with respect to precision interferometry with matter waves, fast generati-on of large, cold ensembles is of great interest. For this purpose, the advantages of variable magnetic fields of microchips are com-bined with the lar-ge trap volumes of conventional atom traps. The resulting sequential genera-tion and storage of many ultracold ensembles provide an ideal star-ting point for a variety of different applications.

These investigations form the basis for innova-tive quantum sensors, such as inertial sensors, gravimeters, or gradiometers for terrestrial and space-based gravity field measurements for Earth observation. The drop tower in Bremen, the Ein-stein Elevator in HITec and ballistic rocket flights are used for tests under zero gravity conditions.

Part of the research is also now carried out at the DLR Institute for Satellite Geodesy and Iner-tial Sensing.



Important professional positions

Since 2019	Founding director of the DLR Institute for Satellite Geodesy and Inertial Sensing
1994 - 2020	Professor of Experimental Physics at Leibniz University Hannover
1985 - 1994	Professor for Experimental Physics at the Rheinische Friedrich-Wilhlems-University, Bonn
1983 - 1985	Visiting Scientist at the Joint Institute for Laboratory Astrophysics, Boulder, CO, USA

Important research projects

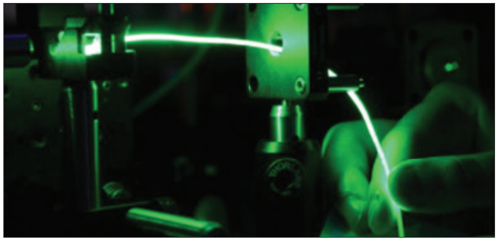
» QUANTUS (Quantum gases under zero gravity)
» MAIUS (Material wave interferometry under zero gravity)
» BECCAL (Bose Einstein Condensate and Cold Atom Laboratory)

Important publications

» The Bose-Einstein condensate and cold atom laboratory. Frye Kai, Abend Sven, Wolfgang Bartosch, Bawamia Ahmad, Dennis Becker, Blume Holger, Braxmaier Claus, Chiow Sheng-Wey, Maxim A Efremov, Wolfgang Ertmer, Peter Fierlinger, Tobias Franz, Gaaloul Naceur, Grosse Jens, Grzeschik Christoph, Hellmig Ortwin, Victoria A Hen-derson, Herr Waldemar, Israelsson Ulf, James Kohel, Krutzik Markus, Kürbis Christian, Lämmerzahl Claus, Daniel Lüdtke, Nathan Lundblad, Marburger J Pierre, Matthias Meister, Mihm Moritz, Müller Holger, Müntinga Hauke, Ayush M Nepal, Oberschulte Tim, Papakonstan-tinou Alexandros, Perovsek Jaka, Achim Peters, Prat Arnau, Ernst M Rasel, Albert Roura, Sbroscia Matteo, Wolfgang P Schleich, Christian Schubert, Stephan T Seidel, Jan Sommer, Spindeldreier Christian, Stamper-Kurn Dan, Benjamin K Stuhl, Marvin Warner, Wendrich Thijs, Wenzlawski André, Andreas Wicht, Patrick Windpassinger, Nan Yu, Lisa Wörner. EPJ Quantum Technology 8 (1), 1-38, 2021
» Einstein-Elevator: A New Facility for Research from µg to 5 g. C Lotz, T Froböse, A Wanner, L Overmeyer, W Ertmer. Gravitational and Space Research 5 (2), 11-27, 2020

Prof. Dr. Alexander Heisterkamp

The research group from Alexander Heisterkamp is working on the application of optical technologies in the field of Medicine and Biology. Within these interdisciplinary areas, the group uses high resolution optical imaging on the one hand for visualization and diagnostics at the cellular and tissue level. On the other hand, using laser systems at higher power, therapeutic effects or highly resolved manipulation can be achieved. The research is conducted in close collaboration with other researchers from the biomedical field within the Leibniz University Hannover, such as Chemistry, Cell Biology, Electrical Engineering or other engineering disciplines. Moreover, close interactions and joints research exists together with the Medical School Hannover (MHH), like the excellence cluster "Hearing for all", the center for lung research (DZL) or the research center REBIRTH (From Regenerative Biology to Reconstructive Therapy) and the collaborative research center SIIRI.



In detail, the group applies optical technologies at cell cultures or organoid systems and artificial tissue, to visualize, study or diagnose certain cell or tissue states. Furthermore, highly resolved manipulation or even surgery of single cells can be achieved, like for example in the field of optogenetics, in which cells can be excited by specific optical pulses, allowing excitation of neuronal cells or contraction of heart muscles cells for next generation optical implants. Additionally, effects like Brillouin scattering or multiphoton excitation are used to allow optical diagnostics of cells and tissues.

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Important research projects

- Cluster of excellence »HEARING4ALL: Models, technology and solutions for diagnostics, restoration and support of hearing«
- German Center for Lung Research (DZL)
- Collaborative research cluster SFB-Transregio SIIRI
- Research center »REBIRTH: From Regenerative Biology to Reconstructive Therapy«

Important professional positions

Since 2021	Vice Dean of the Faculty of Mathematics and Physics
Since 2019	Speaker of the Board of Directors of NIFE – Lower Saxony Centre for Biomedical Engineering, Implant Research and Development
2018 - 2019	Distinguished Guest Professor at Keio University Tokyo, Japan
Since 2014	Member of the Scientific Directorate at the Laser Zentrum Hannover
Since 2014	Professor for Biophotonics (W3) at Leibniz University Hannover
2011 - 2014	Professor for Applied Physics and Optics (W2) at Friedrich-Schiller-University Jena
2009 – 2011	Professor for Biophotonics (W2) at Leibniz University Hannover
2006 - 2011	Junior-Professor for Biophotonics (W1) at Leibniz University Hannover
2003 - 2004	Postdoc at the Harvard University, USA

Important publications

- Machida, W. Shen, H. Onoe, Y. Hiruta, A. Heisterkamp, E. Mazur, M. Terakawa, Anionic fluorophore-assisted fabrication of gold microstructures inside a hydrogel by multiphoton photoreduction, Opt. Mat. Expr., 11, 1, 48-58, 2021
- J. Bahlmann, N. Madrahimov, F. Daniel, D. Theidel, D. Detemple, M. Buettner, A. Bleich , A. Haverich, A. Heisterkamp, S. Kalies, Establishment of a guided, in vivo, multichannel, abdominal, tissue imaging approach, Sci Rep. (2020) 10:9224, doi.org/10.1038/s41598-020-65950-w
- S. Johannsmeier, M. Thanh Truc Nguyen, R. Hohndorf, G. Dräger, D. Heinemann, T. Ripken, A. Heisterkamp, PEGDMA hydrogels for cell adhesion and optical waveguiding, ACS Applied Bio Materials, 3, 10 7011-7020, 2020

apl. Prof. Dr. Milutin Kovacev

S. Gerhard

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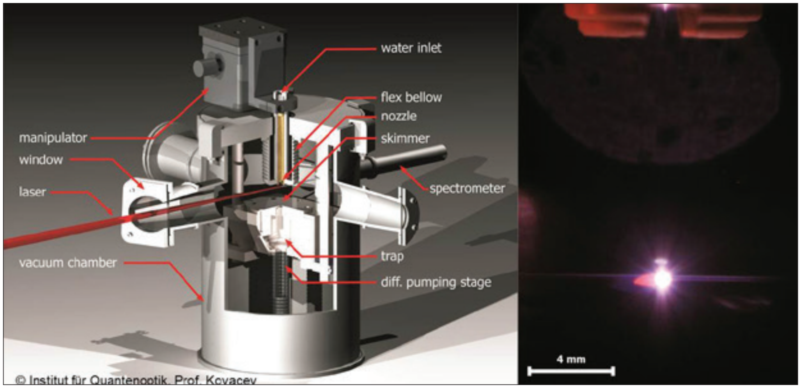
The focus of my research activities is the investigation of intense laser fields and their interaction with matter. The aim of my work is the investigation of XUV radiation sources with special regard to the generation of high harmonics and their applications in attosecond physics. This still very young field allows the time-resolved study of electronic processes and thus the direct observation of fascinating physical strong-field effects. Current research projects include phase matching of harmonics with respect to electronic quantum paths, generation of attosecond pulses in filaments, generation of harmonics in liquid jets and on nanostructures.

Milutin Kovacev



Experimental setup for the generation of harmonics in liquid jets. The intense laser pulse generates a plasma when interacting with a water droplet.

Important research projects

» Probing the spatio-temporal properties of strong field harmonic emission in the liquid phase.
» Investigating the filamentation dynamics using strong field processes
» Ultrafast imaging using plasmon enhanced generation of EUV radiation

Important professional positions

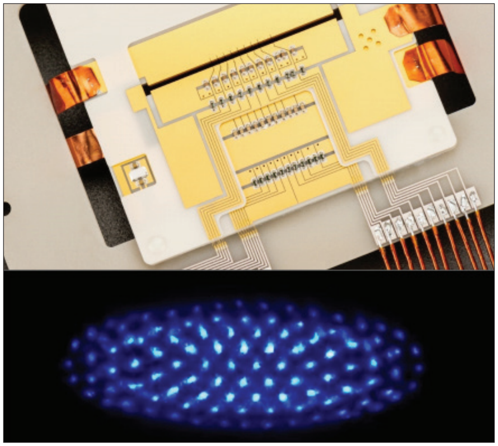
2014 - today	apl. professor, Leibniz University of Hannover, Germany
2006 - 2014	Junior Professor, Leibniz University of Hannover, Germany
2004 - 2006	Post-Doc IESL, Heraklion
2000 - 2003	Ph.D. Université Paris XI (Orsay)

Important publications

» Attosecond synchronization of high-harmonic soft x-rays, Mairesse Y., De Bohan A., Frasinski L. J., Merdji H., Dinu L. C., Monchicourt P., Breger P., Kovacev M., Taïeb R., Carré B., Muller H. G., Agostini P., Salières P., Science, 302, 1540 (2003)
» Extreme-ultraviolet high-order harmonic pulses in the microjoule range, J.-F. Hergott, M. Kovacev, H. Merdji, C. Hubert, Y. Mairesse, E. Jean, P. Breger, P. Agostini, B. Carré, and P. Salières, Phys. Rev. A 66, 021801 (2002)
» Extreme Ultraviolet Fourier-Transform Spectroscopy with High Order Harmonics, M. Kovacev, S. V. Fomichev, E. Priori, Y. Mairesse, H. Merdji, P. Monchicourt, P.Breger, J. Norin, A. Persson, A. L'Huillier, C.-G. Wahlström, B. Carré, P. Salières, Phys. Rev. Lett. 95, 223903 (2005)
» High-order harmonic generation directly from a filament, D. S. Steingrube, E. Schulz, T. Binhammer, M. B. Gaarde, A. Couairon, U. Morgner and M. Kovacev, New J. Phys., 13, 043022 (2011)
» L. Shi, J.R.C. Andrade, A. Tajalli, J. Geng, J.M. Yi, T. Heidenblut, F.B. Segerink, I. Babushkin, M. Kholodtsova, H. Merdji, B. Bastiaens, U. Morgner, M. Kovacev, Generating Ultrabroad-band Deep-UV Radiation and Sub-10 nm Gap by Hybrid-Morphology Gold Antennas, Nano Letters 19, 4779-86 (2019)

Trapped and laser-cooled ions represent ideal quantum systems for precision experiments due to their excellent storage conditions. In particular, the study of multi-particle systems, so-called ion Coulomb crystals, opens up research fields ranging from the observation of nanofriction on the smallest atomic scale to very precise optical atomic clocks. However, such tailored ion crystals, which show strong similarities to a classical solid-state crystal, place high demands on the trap environment in which they are stored.

In my research group „Quantum Clocks and Complex Systems", we develop precision ion traps that provide a platform for state-of-the-art quantum experiments. These include realising the world's first optical clock based on a multi-ion system, and creating topological defects in Coulomb crystals and investigating their quantum dynamics. Considering ion traps as a future of quantum technology, we are pursuing approaches to integrate light-guiding optics such as optical fibres, lenses, and waveguides into ion traps to realise compact and robust setups for portable quantum sensors in the future.



Top: Precision ion trap made of AlN ceramics with a total of eight trap segmentations. Bottom: laser-cooled ion Coulomb crystal of ytterbium ions stored in one of the trap segments.

private

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Important research projects

- Cluster of Excellence „Quantum Frontiers"
- Collaborative Research Center „Designing the Quantum States of Matter"
- Joint Research Lab „TRIAC" with Osaka University, Trapped Ion Integrated Atomic-Photonic Circuits
- BMBF Verbundprojekt „ATIQ" (Quantencomputer-Demonstrationsaufbauten)

Important professional positions

2020 - today	Professor at Leibniz University Hannover, Germany
2018 - today	Visiting Professor at the University in Osaka, Japan
2016	Habilitation in physics „Quantum sensors with laser-cooled atoms and ions"
2009 - 2015	Junior research group leader at the Physikalisch-Technische Bundesanstalt, Braunschweig, Germany
2008	Postdoctoral researcher at the Physikalisch-Technische Bundesanstalt, Braunschweig
2006 - 2007	Postdoc at the Observatoire de Paris/SYRTE, France

Important publications

- H. A. Fürst, C.-H. Yeh, D. Kalincev, A. P. Kulosa, L. S. Dreissen, R. Lange, E. Benkler, N. Huntemann, E. Peik, and T. E. Mehlstäubler, "Coherent Excitation of the Highly Forbidden Electric Octupole Transition in ^{172}Yb+," Phys. Rev. Lett., 125, 163001 (2020).
- J. Keller, D. Kalincev, T. Burgermeister, A. P. Kulosa, A. Didier, T. Nordmann, J. Kiethe, and T. E. Mehlstäubler, "Probing Time Dilation in Coulomb Crystals in a High-Precision Ion Trap," Phys. Rev. Applied, 11, 011002 (2019).
- J. Keller, T. Burgermeister, D. Kalincev, A. P. Kulosa, A. Didier, T. Nordmann, J. Kiethe, and T. E. Mehlstäubler, "Controlling systematic frequency uncertainties at the 10-19 level in linear Coulomb crystals," Phys. Rev. A 99, 013405 (2019).
- T. E. Mehlstäubler, G. Grosche, C. Lisdat, P. O. Schmidt, H. Denker, "Atomic clocks for geodesy," Rep. Prog. Phys. 81, 064401 (2018).
- J. Kiethe, R. Nigmatullin, D. Kalincev, T. Schmirander and T. E. Mehlstäubler, "Probing nanofriction and Aubry-type signatures in a finite self-organized system, Nature Communications," 8, 15364 (2017).

Prof. Dr. Uwe Morgner

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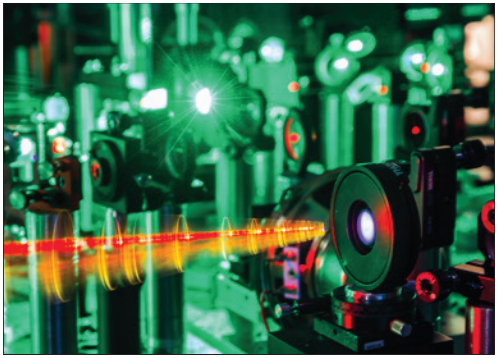
Laser physics is extreme physics. In no other field of research are the magnitudes stretched to the outer edges of the unit scales from Atto- to Peta-. In the foci of high-intensity laser pulses, we find extreme conditions: Peak powers of terawatts, field strengths of gigavolts/cm or thousands of Teslas, light pressures of gigapascals, and temperatures of megakelvin are already achievable today with manageable commercial laser sources. Laser optics spans the gamut from single-photon experiments to strong-field physics; and thus, there are just few scientific and engineering areas that do not benefit in a substantial way from coherent photons for focused manipulation or as a sensitive sensor.

Research on new sources of femto- and sub-femtosecond laser pulses is the focus of the group, both experimentally and in theory/numerics. This is followed by investigations of fundamental questions about the interaction of such short light pulses with matter. Current work is related to optical parametric amplifiers, high power disk laser concepts and coherent generation of X-rays. Many follow-on and collaborative projects in spectroscopy, microscopy, sensing and manipulation of matter benefit from the innovative beam sources.



Uwe Morgner

Two-color-pumped optical parametric amplifier for the generation of single cycle laser pulses

Important research projects

- Cluster of Excellence »PhoenixD: Photonics, Optics, and Engineering – Innovation Across Disciplines«
- Cluster of Excellence »QUEST: Quantum engineering and space-time research«
- Cluster of Excellence »HEARING4ALL: Models, technology and solutions for diagnostics, restoration and support of hearing«
- Collaborative Research Center »Planar optronic Systems«
- BMBF Network Project »NEXUS«, »Next Generation of Ultrafast Sources«
- BMBF Network Project »METAPHOR«, »Spectrally sensitive microscopy via excitation fingerprinting based on a non-collinear optic-parametric oscillator«
- EU Network Project »HIBISCUS«, »Hybrid integrated biophotonic sensors created by ultrafast laser systems"

Important professional positions

Since 2020	Founding Dean of the Leibniz Research School of Optics & Photonics
Since 2019	Speaker of the Cluster of Excellence PhoenixD
2013 - 2017	Dean of the Faculty for Mathematics and Physics
Since 2006	Scientific Director at Laser Zentrum Hannover e.V., LZH
Since 2004	Professor for Experimental Physics at Leibniz University of Hannover
2002 bis 2004	Research group head at Max-Planck-Institute for Nuclear Physics in Heidelberg

Important publications

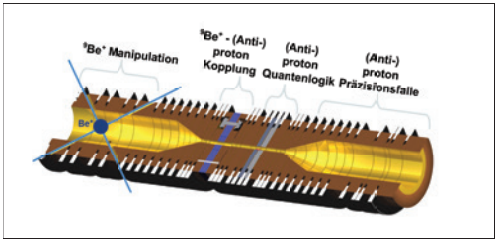
- V. Tamuliene, G. Juskeviciute, D. Buozius, V. Vaicaitis, I. Babushkin, U. Morgner, Influence of tunnel ionization to third-harmonic generation of infrared femtosecond laser pulses in air, Scientific Reports 10, 17437 (2020)
- L. Shi, J.R.C. Andrade, A. Tajalli, J. Geng, J.M. Yi, T. Heidenblut, F.B. Segerink, I. Babushkin, M. Kholodtsova, H. Merdji, B. Bastiaens, U. Morgner, M. Kovacev, Generating Ultrabroadband Deep-UV Radiation and Sub-10 nm Gap by Hybrid-Morphology Gold Antennas, Nano Letters 19, 4779-86 (2019)
- I. Babushkin, A. J. Galan, J. R. C. Andrade, A. Husakou, F. Morales, M. Kretschmar, T. Nagy, V. Vai aitis, L. Shi, D. Zuber, L. Bergé, S. Skupin, I.A. Nikolaeva, N.A. Panov, D.E. Shipilo, O. G. Kosareva, A. N. Pfeiffer, A. Demircan, M. J. J. Vrakking, U. Morgner, and M. Ivanov, „All-optical attoclock for imaging tunnelling wavepackets,", Nature Physics, in press (2021)

Prof. Dr. Christian Ospelkaus

This joint research group of LUH (Institut für Quantenoptik) and PTB (Quest-Institut für experimentelle Quantenmetrologie) studies single trapped ions for applications in quantum computing and for quantum logic inspired precision measurements.

We use single trapped ions as a qubit platform for future scalable quantum computers. The quantum information is encoded in extremely long-lived hypferfine states of the atoms. The qubits are held above a scalable chip structure by electric fields. The structure realizes quantum registers with all the required functionalities (preparation, logic gates and readout). In contrast to the widespread laser-based approach to the ion-trap quantum computer, quantum gates are carried out using chip-integrated microwave components. So far, we have implemented single-qubit gates with residual infidelities of order 10^{-4} and two-qubit gates approaching 10^{-3} gate infidelity. This puts the fault tolerance threshold of 10^{-4} error per gate, which is important for being able to scale quantum computing, within experimental reach. We further have developed a patented microfabrication process to realize produce the required chip structures.

M. Niemann



Concept of a Penning trap for cooling and manipulation of single (anti-)protons through 9Be+ „qubit" ions for fundamental physics tests

Furthermore we develop methods to use these ion qubits to cool and manipulate other quantum systems, such as single protons and antiprotons [Heinzen and Wineland, 1990]. This is motivated by the fundamental CPT symmetry which can, for example, be tested in a very sensitive way by comparing the magnetic moment of the proton and the antiproton. This project is part oft the BASE collaboration which operates an antiproton beamline at CERN.

The research group has laboratories at the Institut für Quantenoptik, at LNQE and HITec as well as at QUEST Institut für experimentelle Quantenmetrologie.

C. Wyrwa

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Important professional positions

2010 - today	Professor, Leibniz University Hannover
2007 - 2010	Guest Researcher, National Institute of Standards and Technology, Boulder, CO (USA)
2002 - 2006	Promotion, Universität Hamburg

Important research projects

- BMBF collaborative projects „ATIQ" (Quantencomputer-Demonstrationsaufbauten, coordinator). 44.5 M€ project volume, LUH funding 6.4 M€
- BMBF collaborative project „MIQRO - Skalierbarer Quantencomputer mit Hochfrequenz-gesteuerten gespeicherten Ionen", since 2021 (Anteil: 8.5 M€)
- QVLS-Q1 »Quantum Computing for Lower Saxony«, c-speaker, since 2021 (25 M€)
- EU QT Flagship project »MicroQC«, since 2018
- SFB 1227 »DQ-mat«, member of board and projects A01 und B06, since 2016
- ERC Starting Grant »QLEDS«, 2013 - 2020 (1.6 M€)

Important publications

- A. Bautista-Salvador, C. Ospelkaus, M. Wahnschaffe, and J. Morgner: »Verfahren zum Herstellen einer Atomfalle sowie Atomfalle«, Patent DE 10 2018 111 220 B3 (2019).
- G. Zarantonello, H. Hahn, J. Morgner, M. Schulte, A. Bautista-Salvador, R. F. Werner, K. Hammerer, and C. Ospelkaus: »Robust and Resource-Efficient Microwave Near-Field Entangling 9Be+ Gate«, Phys. Rev. Lett. 123, 260503 (2019)
- C. Smorra, Y. V. Stadnik, P. E. Blessing, M. Bohman, M. J. Borchert, J. A. Devlin, S. Erlewein, J. A. Harrington, T. Higuchi, A. Mooser, G. Schneider, M. Wiesinger, E. Wursten, K. Blaum, Y. Matsuda, C. Ospelkaus, W. Quint, J. Walz, Y. Yamazaki, D. Budker, and S. Ulmer: »Direct Limits on the Interaction of Antiprotons with Axion-like Dark Matter«, Nature 575, 310 (2019)
- H. Hahn, G. Zarantonello, M. Schulte, A. Bautista-Salvador, K. Hammerer, and C. Ospelkaus: »Integrated $^9Be^+$ Multi-Qubit Gate Device for the Ion-Trap Quantum Computer«, Npj Quantum Inf 5, 70 (2019)

Prof. Dr. Silke Ospelkaus

S. Gerhard

Prof. Dr. Silke Ospelkaus

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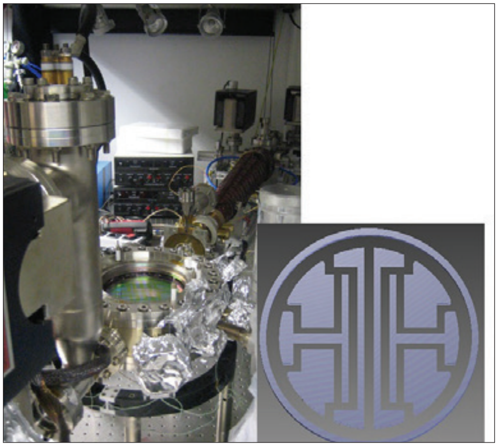
During the last 20 years, spectacular progress has been made in the preparation and control of atomic quantum systems. In particular, atomic ensembles have been cooled to unprecedented temperatures in the nano-Kelvin range close to absolute zero and collective quantum phenomena such as Bose-Einstein condensation have been observed.

The research group „Ultracold Molecular Quantum Gases" is now working on preparing and manipulating molecular systems at temperatures close to absolute zero. At these extreme temperatures, all molecular degrees of freedom are subject to the laws of quantum mechanics. Together with the peculiarities of the molecular interaction, which is mostly dipolar in character and is therefore anisotropic and long-range, a wide field of possibilities opens up: Dipolar interacting many-body systems are expected to reveal novel quantum phases and are traded as candidates for quantum information. Precision spectroscopy on molecules offers possibilities for testing fundamental laws of physics. Furthermore, the precise control of all external and internal degrees of freedom of the molecules promises to give access to a new regime on the border with chemistry, in which quantum effects in chemical reactions can first be observed and later used to control chemical reactions.



S. Ospelkaus / Gruppe S. Ospelkaus

Left: UH vacuum apparatus for the generation of ultracold NaK molecules. Right: Electrode structure of the main chamber for control of molecular interactions by E-fields.

Important professional positions

2011 - today	Professor at Leibniz University Hannover
2009 - 2010	Head of Minerva Research Group at the Max Planck Institute of Quantum Optics, Garching
2007 - 2009	Postdoctoral researcher at JILA, Boulder, USA
2002 - 2006	Doctorate at the University of Hamburg (Group Prof. Dr. K. Sengstock)

Important research projects

- Quantum Valley Lower Saxony (QVLS), T5.5: Quantum chemistry, 2021-2026
- CRC DQ-mat 1227 of the DFG, Project A03: „Detection and analysis of non-classical quantum many-body states of polar molecules", 2016-2024

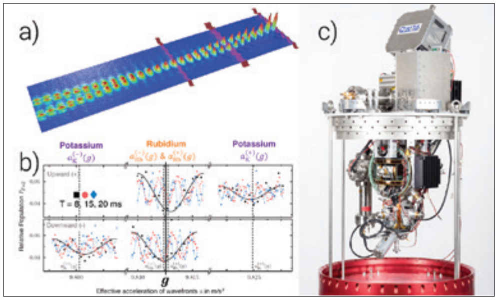
Important publications

- K. K. Voges, P. Gersema, M. Meyer zum Alten Borgloh, T. A. Schulze, T. Hartmann, A. Zenesini, and S. Ospelkaus, Ultracold Gas of Bosonic 23Na39K Ground-State Molecules, Physical Review Letters 125, 083401 (2020)
- M. Petzold, P. Kaebert, P. Gersema, M. Siercke, S. Ospelkaus, A Zeeman slower for diatomic molecules, New Journal of Physics 20, 042001 (2018)
- T. A. Schulze, T. Hartmann, K. K. Voges, M. W. Gempel, E. Tiemann, A. Zenesini, and S. Ospelkaus, Feshbach spectroscopy and dual-species Bose-Einstein condensation of 23Na–39K mixtures, Phys. Rev. A 97, 023623 (2018)
- S. Ospelkaus, K.-K. Ni, D. Wang, M. H. G. de Miranda, B. Neyenhuis, G. Quemener, P. S. Julienne, J. L. Bohn, D. S. Jin, J. Ye, Quantum-State Controlled Chemical Reactions of Ultracold KRb Molecules, Science 327, 853 (2010)
- S. Ospelkaus, K. -K. Ni, G. Quéméner, B. Neyenhuis, D. Wang, M. H. G. De Miranda, J. L. Bohn, J. Ye, D. S. Jin, Controlling the hyperfine state of rovibronic ground-state polar molecules, Phys. Rev. Lett. 104, 030402 (2010)

Prof. Dr. Ernst Maria Rasel

My research group studies the fundamental aspects of matter wave optics, innovative sources for (ultra) cold matter waves as well as for non-classical states, the manipulation of matter waves using light, and their applications for precision metrology. In the past, we have pioneered the use of matter wave optics for optical clocks as well as the development of a compact Sagnac interferometer and a quantum gravimeter based on (ultra)cold atoms. High-precision tests at the interface between quantum mechanics and gravity as well as novel quantum sensors for gravimetry and navigation are current foci of my group and my collaborations with groups in the USA, France and UK, among others. Recently, we realized the first quantum test of the universality of free fall with two different chemical elements. Experiments in space and over long baselines in the testbed VLBAI (Very Large Base- line Atom Interferometry) are promising approaches to increase the sensitivity of our sensors. For example, the QUANTUS project at the drop tower in Bremen demonstrated the first Bose-Einstein condensate under zero gravity and explored interferometry with Bose-Einstein condensates in extended fall. In 2017, very successful experiments were performed on a sounding rocket in the MAIUS project. The generation of Bose-Einstein condensates was demonstrated for the first time in space and this macroscopic quantum state was studied interferometrically marking the begin of ultra-cold atom interferometry in space. Further sounding rocket missions are planned for the next years on quantum gas mixtures. Our work is enriched by many (inter) national collaborations, e.g. in the framework of the SFBs dq-mat and terra-Q, the QUEST-LFS and the Excellence Cluster Quantum Frontiers, as well as NASA collaborations for the use of the Cold Atom Laboratory, the planning of the Bose-Einstein-Condensate-and-Cold-Atom-Laboratory, and experiments at the Einstein Elevator at HITEC together with JPL.

a) Naceur Gaaloul / b) Dennis Schlippert / c) Stephan Seidel



a) Interference of a Bose-Einstein condensate; b) Signals of a two-species interferometer with rubidium and potassium; c) MAIUS-A apparatus for sounding rocket mission.

private

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Important research projects
- QUANTUS QuantenGase Unter Schwerelosigkeit
- VLBAI Very Long Baseline Atom Interferometry
- Optischer Frequenzstandard basierend auf ultrakaltem Magnesium

Important professional positions

2008 - today	Professor, IQ and QUEST, Leibniz University Hannover
1999 - 2008	Assistant Professor, Leibniz University Hannover
1996 - 1999	Postdoc, Ecole Normal Supérieure, Paris
1991 - 1996	Physics dissertation, Leopold- Franzens-Universität Innsbruck

Important publications
- Müntinga, H., Ahlers, H., Krutzik, M.,Wenzlawski, A., Arnold, S., Becker, D., Bongs, K., Dittus, H., Duncker, H., Gaaloul, N., Gherasim, C., Giese, E., Grzeschik, C., Hänsch, T.W., Hellmig, O., Herr, W., Herrmann, S., Kajari, E., Kleinert, S., Lämmerzahl, C., LewoczkoAdamczyk, W. , Malcolm, J., Meyer, N., Nolte, R., Peters, A., Popp, M., Reichel, J., Roura, A., Rudolph, J., Schiemangk, M., Schneider, M., Seidel, S.T., Sengstock, K., Tamma, V., Valenzuela, T., Vogel, A., Walser, R., Wendrich, T., Windpassinger, P., Zeller, W., van Zoest, T., Ertmer, W., Schleich, W.P., Rasel, E. M. (2013): Interferometry with BoseEinstein Condensates in Microgravity. Phys. Rev. Lett. 110(9), 093602
- Schlippert, D., Hartwig, J., Albers, H., Richardson, L. L., Roura, A., Schleich, W. P., Ertmer, W., Rasel, E. M. (2014), Quantum Test of the Universality of Free Fall, Phys. Rev. Lett. 112, 203002
- P. Berg, S. Abend, G. Tackmann, C. Schubert, E. Giese, W.P. Schleich, F.A. Narducci, W. Ertmer, and E.M. Rasel, Phys. Rev. Lett. 114, 063002 (2015)

Prof. Dr. Detlev Ristau

C. Wyrwa

Prof. Dr. Detlev Ristau

Optical Coatings and Fibres
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Today, photonic components play an essential role in research and industry as well as in our daily life. We owe to these key-elements enormous progresses in semiconductor technology for the production of chip structures in the range below 10 nanometers, in modern data transmission via optical fibres with TB/s-speed, or in medical diagnostics, to mention only a few innovative fields. The group "Laser Components and Fibres", LCF, can only cover small aspects in this extremely comprehensive and dynamic research area: the optimization of optical fibres with specific doping concepts and structures as well as investigations in optical coating components of highest quality, complexity and precision. As an example, the group has available a 12 m fibre drawing tower and a laboratory for the production of preforms, which are necessary for fibre drawing, with an MCVD (Modified Chemical Vapor Deposition)-plant equipped with different doping systems in clean rooms at the HiTec building. On this basis, the research group can work with a complete production chain for optical fibres supported by adapted characterisation laboratories. Recent research activities in optical thin film technology are concentrated on nonlinear effects and laser induced damage phenomena in coating systems. These approaches in fundamental research are complemented by application-oriented studies on the precise control and quality optimisation of deposition processes für coatings systems with several thousand single layers as well as photonic integration.

Dr. Marco Jupé

Ion beam sputtering plant for fundamental research in deposition processes within the framework of QUEST

Important professional positions

2018 - today	member of the scientific directorate at LZH
2016 - today	leader of the group LCF
2010 - today	professorship at the LUH
1991 - 2018	leader of the Lasercomponents Department at LZH
1983 - 1991	assistant and leader of the „Aufdampfgruppe" at the IQO
1982 - 1983	research grant at the Rice University in Houston, USA

Important research projects

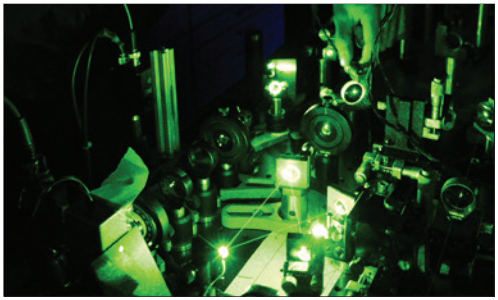
- » Exzellenzcluster PheonixD, TG M3 2019 – today
- » Quanomet, FG NL 5 Integrierte Photonik 2016 – today
- » EFRE-Projekt, DEHERA 2016 – 2020
- » Exzellenzcluster QUEST 2007 – 2014
- » BMBF-Projekte, Pluto 2010-2017, THG-Schicht 2016 – 2020
- » BMWi-Projekte, InnoNet, ZIM, AIF

Important publications

- » Steinecke, M.; Badorreck, H.; Jupé, M.;...Ristau, D. (2020): Quantizing nanolaminates as versatile materials for optical interference coatings, Applied Optics 59 (5), A236-A241, 2020
- » Ristau, D.; (2015): Laser Damage in Optical Materials, Book CRC Press, ISBN 9781439872161.
- » Ristau, D.; Jupé, M.; Starke, K.; (2009): Laser damage thresholds of optical coatings, Thin Solid Films, 518: pp. 1607–1613
- » Mero, M., Liu, J., Rudolph, W., Ristau, D., and Starke, K.; (2005): Scaling laws of femtosecond laser pulse induced breakdown in oxide films, Phys. Rev., B71: p. 115109
- » Ristau, D.; Ebert, J.; (1986): Development of a thermographic laser calorimeter, Applied Optics 25(24), 4571-4578.

The research of the Quantum Logic Spectroscopy Group revolves around fundamental questions such as the constancy of natural constants and the validity of our physical laws. A change in natural constants can be detected, for example, via a precise measurement of the shift of energy levels in trapped and laser-cooled atomic and molecular ions. Building on laser-based quantum engineering techniques, we are developing new spectroscopy methods that allow us to study previously inaccessible species with unprecedented accuracy. Using these so-called quantum logic spectroscopy techniques, we are developing optical clocks based on singly charged aluminum ions, molecular ions, and highly charged ions. Due to their insensitivity to external fields, these are particularly well suited as references for future frequency standards. By comparing the clocks with each other, a change in the fine-structure constant, dark matter or deviations from relativity can be investigated. In addition to fundamental research, applications for these high-precision clocks are being developed: The frequency difference between clocks at different altitudes predicted by Einstein is being used in geodetic missions for precise measurement of altitude differences between distant locations. The development of transportable optical clocks for terrestrial and future space-based applications is an important research topic in our group. In addition, we are developing quantum engineering techniques, such as dynamic decoupling via radio frequency fields or entanglement, to realize frequency references with multiple ions that have lower uncertainty and therefore allow shorter averaging times.

P. O. Schmidt



Alignment of a frequency doubler that generates light at 280 nm for the detection of Magnesium ions

S. Gerhard

Prof. Dr. Piet O. Schmidt

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Important professional positions

2009 - today	Professor at the Leibniz University Hannover and head of the QUEST Institute at the Physikalisch-Technische Bundesanstalt Braunschweig
2005 - 2008	PostDoc and junior research group leader at the University of Innsbruck (Austria)
2003 - 2005	Feodor-Lynen PostDoc at NIST, Boulder (USA)

Important research projects

- » Exzellenzcluster EXC 2123 QuantumFrontiers
- » SFB 1227 „Designed Quantum States of Matter" (DQ-mat)
- » SFB 1464 „Relativistic and Quantum-based Geodesy" (terraQ)
- » Quantum Valley Lower Saxony (QVLS-Q1): Building a 50-qubit quantum computer
- » Quantum logic spectroscopy of highly charged ions in collaboration with A. Surzhykov (TUBS & PTB) and J. Crespo López-Urrutia (Max-Plank-Institut for nuclear physics in Heidelberg)
- » ERC Advanced Grant „FunClocks". Quantum logic spectroscopy of highly charged ions

Important publications

- » P. Micke, T. Leopold, S. A. King, E. Benkler, L. J. Spieß, L. Schmöger, M. Schwarz, J. R. Crespo López-Urrutia, P. O. Schmidt, Coherent laser spectroscopy of highly charged ions using quantum logic, Nature 578, 60 (2020).
- » F. Wolf, C. Shi, J. C. Heip, M. Gessner, L. Pezzè, A. Smerzi, M. Schulte, K. Hammerer, and P. O. Schmidt, Motional fock states for quantum-enhanced amplitude and phase measurements with trapped Ions, Nat. Commun. 10, 2929 (2019).
- » M. G. Kozlov, M. S. Safronova, J. R. Crespo López-Urrutia, and P. O. Schmidt, Highly charged ions: Optical clocks and applications in fundamental physics, Rev. Mod. Phys. 90, 045005 (2018).
- » F. Wolf, Y. Wan, J. C. Heip, F. Gebert, C. Shi, and P. O. Schmidt, Non-destructive state detection for quantum logic spectroscopy of molecular ions, Nature 530, 457–460 (2016).
- » A. D. Ludlow, M. M. Boyd, J. Ye, E. Peik, and P. O. Schmidt, Optical atomic clocks, Rev. Mod. Phys. 87, 637–701 (2015).

Prof. Dr. Andrea Trabattoni

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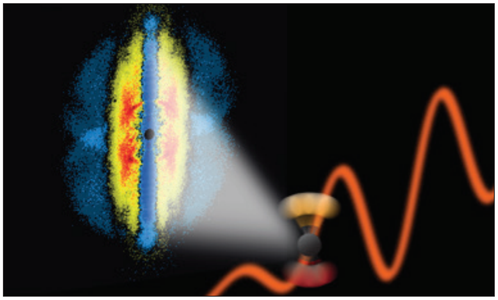
In the ultrafast photoelectron science group, we aim at solving the role of the photo-induced electron dynamics in matter. To do so, we develop tailored laser light with ultrashort duration between few femtoseconds (1 fs = 10-15 s) and attoseconds (1 as = 10-18 s), and use it for the real-time tracking of electronic motion in atomic nuclei, biochemically relevant molecules, and nano-systems. In such studies, we are particularly interested to exploit the interaction between light and electrons as a knob to control the functionality of the target under study.

In molecules, for example, we investigate charge migration processes as a way of driving chemistry at the attosecond timescale. In nano-systems, we trigger collective electron dynamics with tailored laser pulses, with applications in the field of ultrafast plasmonics. In atomic nuclei, efficient energy exchange occurs between the nuclei and the surrounding electron shell during nuclear transitions. In our laboratories, we study how initiating and controlling such energy exchange via laser excitation.

Our research activity is performed as a joint effort between the Institute of Quantum Optics (IQ) at Leibniz University Hannover and the Deutsches Elektronen-Synchrotron (DESY) in Hamburg, where our laboratories are located. This scientific bridge between IQ and DESY represents an excellent opportunity to perform cutting-edge research in the field of advanced laser technology and ultrafast photoelectron science.



Important research projects

- »"Time-resolved spectroscopy of photo-induced electron dynamics in nuclear transitions", Helmholtz Young Investigator grant.
- »"Attosecond x- ray spectroscopy for the study of biorelevant molecules", in collaboration with CNR (Italy).
- »"Ultrafast molecular stabilization mediated by electronic correlations", Collaborative research center SFB925.
- »"Study of carrier transport in MAterials by time-Resolved specTroscopy with ultrashort soft X-ray light", Innovative Training Networks.

Important professional positions

2022 - today	Professor at IQ, LUH (Hannover)
2021 - today	Helmholtz Young Investigator Group Leader, DESY (Hamburg).
2018 - 2021	Scientist, Attosecond science group, DESY (Hamburg).
2016 - 2018	Alexander von Humboldt Fellow, Controlled Molecule Imaging group, DESY (Hamburg).
2011 - 2015	Doctoral researcher, Attosecond science group, Politecnico di Milano (Milan, Italy).

Important publications

» Trabattoni, A., Wiese, J., De Giovannini, U., Olivieri, J.-F., Mullins, T., Onvlee, J., Son, S.-K., Frusteri, B., Rubio, A., Trippel, S., and Küpper, J., "Setting the photoelectron clock through molecular alignment", Nat. Comm. 11, 2546 (2020).

» Trabattoni, A., Colaizzi, L., Ban, L., Wanie, V., Saraswathula, K., Månsson, E. P., Rupp, P., Liu, Q., Seiffert, L., Herzig, E. A., Cartella, A., Yoder, B. L., Légaré, F., Kling, M. F., Fennel, T., Signorell, R. and Calegari, F., "Photoelectron spectroscopy of large water clusters ionized by an XUV comb", J. Phys. Photonics 2, 035007 (2020).

» Pedatzur, O., Trabattoni, A., Leshem, B., Shalmoni, H., Castrovilli, M. C., Galli, M., Lucchini, M., Månsson, E., Frassetto, F., Poletto, L., Nadler, B., Raz, O., Nisoli, M., Calegari, F., Oron, D., and Dudovich, N., "Double-blind holography of attosecond pulses", Nat. Photonics 13, 91–95 (2019).

Institute of Radioecology and Radiation Protection

private

Prof. Dr. Clemens Walther
Executive Director

Karl-Heinz Iwannek

Bettina Weiler
Office

private

Jessica Hahne
Office

The Institute of Radioecology and Radiation Protection (IRS) works on detection and speciation of radionuclides in the environment, dose assessments due to exposure by anthropogenic and natural radionuclides, work on the disposal of high-level radioactive waste, practical radiation protection and regularly conducts courses on radiation protection training (acquisition and updating of expertise). For the successful accomplishment of these tasks, the IRS employs 50 members from the disciplines of physics, chemistry, geology, soil science, biology, mathematics, psychology and sociology.

The IRS operates a controlled area for the handling of radioactive materials and has at its disposal all common radiometric methods. In addition, highly sensitive mass spectrometric, laser spectroscopic and chemical methods for speciation are

Clemens Walther

The illustration shows the so-called „Red Forest" in the immediate vicinity of the damaged reactor block 4 in Chernobyl. The name comes from the red discolored needles of the trees due to radiation exposure as a direct result of the accident. In the meantime, the forest has completely regenerated. Locally, however, the gamma dose is still increased by more than a factor of 1000 in some cases due to Cs-137 contamination.

applied and developed in-house. For example, a commercial secondary ion mass spectrometer was upgraded for imaging ultratrace detection of radionuclides in environmental samples by means of self-designed three-stage laser resonance ionization. This experimental setup, which is unique in Germany, makes it possible to better understand the complex behavior of radionuclides in the environment. This includes studies in the contaminated areas around Fukushima and Chernobyl, in particular on the release and mobilization of actinides (e.g. plutonium), also in particulate form. By non-invasive analysis of individual particles only micrometers in size, conclusions on their origin are drawn and their hazard potential for humans is assessed. Furthermore, the IRS investigates radionuclide uptake in plants with respect to a process understanding on the microscopic level. The IRS carries out broadly based work on trace analysis and investigates transfer of radionuclides in all relevant exposure pathways, but especially to drinking water, also in Germany. In addition to radiation protection aspects, and forensic investiagaitons, radionuclides are used as tracers in the environment. One radionuclide of interest is the long-lived iodine-129, which is released during nuclear fuel reprocessing, e.g., at Sellafield (UK) and La Hague (F), and dispersed throughout Europe by liquid and gaseous discharges and atmospheric dispersion. Using ultra-high sensitivity accelerator mass spectrometry, transport pathways are traced to the Arctic Ocean in the north and the Zugspitze in the south. As a further field of work, the still existing influences of the former uranium mining in Saxony on alluvial soils along the river Mulde are regularly quantified and assessed with regard to agricultural use.

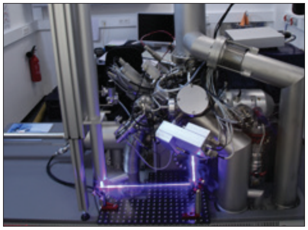
An important focus is the research on the disposal of radioactive residues (so-called „nuclear waste") within the framework of the joint project TRANSENS (see www.transens.de), in which the IRS plays a leading role. The question of safe disposal of these materials can only be solved by interdisciplinary approaches, i.e., the cooperation not only of natural and engineering sciences, but also, for example, of humanities, law and social sciences. As an important new approach, transdisciplinary research is carried out in this SFB-like network, i.e. citizens are involved. On the one hand, to elicit their opinions and views and, on the other hand, to optimize the interaction with scientists and stakeholders in terms of trust and productive collaboration.

The IRS is involved in education and training for all aspects of radioactivity and radiation protection. In addition, students are offered the opportunity to acquire the technical qualification in radiation protection, so that it is possible to work as a radiation protection officer for various applications of ionizing radiation.

Karl-Heinz Iwannek

The Institute for Radioecology and Radiation Protection at the Herrenhausen Campus

In addition to students, the IRS also offers courses to employees from industry, research, public authorities or teachers at general education schools to acquire and maintain expertise in radiation protection. With more than 1000 course participants per year, the IRS has established an important training and further education program at Leibniz University Hannover, which is valued throughout Germany as a competent training center in radiation protection. The courses held cover radiation protection in the use of X-rays as well as in the handling of radioactive materials and accelerator facilities.



Michael Franzmann

The secondary ion mass spectrometer allows the element- and isotope-selective imaging of a surface with a resolution of up to 70nm by sputtering with fast ions. Depending on the element, however, the vast majority of all products are not ionized and cannot be detected. not be detected. Here, three tunable lasers are used to resonantly post-ionize these neutral atoms in a highly selective manner, increasing the sensitivity by several orders of magnitude.

Jan-Willem Vahlbruch

In the technical field, the IRS offers radiation protection courses recognized by the Lower Saxony Ministry for the Environment, Climate Protection and Energy for the acquisition and updating of expertise in radiation protection. The illustration shows the seminar room during a radiation protection course.

Prof. Dr. Clemens Walther

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Clemens Walther studied physics in Mainz and Seattle, then earned his doctorate and habilitation in radiochemistry. Both disciplines are of equal relevance to the field of radioecology. In addition to the highly sensitive detection of radionuclides (in some cases a few atoms per gram of sample material), the chemistry of radionuclides is equally relevant for understanding migration and hazard potential. Investigations include radioactivity released after nuclear accidents (e.g. Fukushima and Chernobyl; the picture shows the market place of Prypjat), contaminated sites in Germany (uranium mining in Saxony) or research on the disposal of highly radioactive waste. Therefore, besides the application of all common radiometric methods, techniques from the fields of mass spectrometry and laser spectroscopy are developed or adapted for this purpose. Examples in the figure (above) are, from left to right, resonance ionization, secondary ion mass spectrometry and SEM for single particle analysis. Clemens Walther has been head of the Mass Spectrometry (MS) Association of the German Physical Society (DPG), is chairman of the Nuclear Chemistry Division of the German Chemical Society (GDCh), spokesman of the Competence Network for Radiation Research (KVSV), and member of the Radiation Protection Commission (SSK) of the BMU and chairman of the SSK Radioecology Committee.

Important research projects

» TRANSENS (Transdisciplinary Research on the Management of High-Level Radioactive Waste in Germany)
» TRANS-LARA (Transport and transfer behavior of long-lived radionuclides along the causal chain groundwater-soil-surface-plant considering long-term climatic changes)
» RADEKOR (speciation and transfer of radionuclides in humans with special reference to decorporation agents)
» Studies of formation, stability and radiolysis of colloids of different plutonium isotopes, forensic investigation of actinide-containing hot particles
» A-CINCH (Augmented Cooperation in Education and Training in Nuclear and Radiochemistry).

Important professional positions

2012 - today	Head of the IRS, Leibniz University Hannover
2019 - 2021	Dean of the Faculty of Mathematics and Physics
2001 - 2011	Deputy Head of the Department Actinide Speciation and Group Leader Colloid Analytics (KIT-INE)
1995 - 1999	PhD, then staff member, Institute of Nuclear Chemistry, JoGU Mainz
1992 - 1994	Diplomarbeit, Institut für Physik, JoGU Mainz
1991 - 1992	Diploma thesis, Institute of Physics, JoGU Mainz

Important publications

» Mandel, M., Holtmann, L., Raiwa, M., Wunnenberg-Gust, A., Riebe, B., & Walther, C. (2021). Imaging of I, Re and Tc plant uptake on the single-cell scale using SIMS and rL-SNMS. Journal of Hazardous Materials, 127143. doi:https://doi.org/10.1016/j.jhazmat.2021.127143
» Bosco, H., Hamann, L., Kneip, N., Raiwa, M., Weiss, M., Wendt, K., & Walther, C. (2021). New horizons in microparticle forensics: Actinide imaging and detection of 238Pu and 242mAm in hot particles. Science Advances, 7(44)doi:doi:10.1126/sciadv.abj1175
» Mühr-Ebert, E.L., Wagner, F., Walther, C. (2018): Speciation of uranium: Compilation of a thermodynamic database and its experimental evaluation using different analytical techniques, Applied Geochemistry, Volume 100, January 2019, Pages 213-222 DOI: 10.1016/j.apgeochem.2018.10.006
» Tanha, M. R., Vahlbruch, J.-W., Riebe, B., Irlinger, J., Rühm, W., Khalid, F. R., Storai, A., Walther, C. (2017): Measurements in Afghanistan using an active Radon exposure meter and assessment of related annual effective dose, Radiat Prot Dosimetry 1-9. DOI: 10.1093/rpd/ncx086
» Pönitz, E., Walther, C. (2017): Calculation of dose rates at the surface of storage containers for high-level radioactive waste, Radiat Prot Dosimetry (2017) pp. 1-12 DOI: 10.1093/rpd/ncx054

The Steinhauser group is concerned with physical and chemical aspects of anthropogenic radioactivity in the environment. The main areas of work include environmental radioactivity after Fukushima and Chernobyl as well as nuclear forensic investigations, especially related to environmental issues. The goal of this work is to understand and classify the history of a contamination, for example its origin, identification of various sources, its age, etc. A particular focus of the group's work is on „forgotten" radionuclides from reactor accidents - those radioactive materials that are either difficult to measure, or were released in minimal quantities and are therefore easily overlooked. The use of stable isotopes and chemical characteristics can also help reveal important forensic information about a contamination. Steinhauser is a member of several professional associations, the Radiation Protection Advisory Board of the Austrian Ministry of Health, and an editor of the journal Environmental Science and Pollution Research.

Katsumi Shozugawa

The exclusion zone, which was established after the Fukushima accident, is still difficult to access today due to strict authority allowances. In 2013, Prof. Steinhauser was granted access to the zone for the first time and was able to take samples for scientific investigations.

private

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Important research projects

» Drying of the Chernobyl cooling pond and its implications for the aquatic environment (Prof. Joachim Lenz Foundation)
» Forensic investigations of the release of radioactive ruthenium in the fall of 2017 (VolkswagenStiftung)
» Environmental nuclear forensics with radiocesium isotopes (DFG)

Important professional positions

2021	Visiting Scientist, Los Alamos National Laboratory, USA
Since 2015	Professor of Physical Radioecology, Leibniz University Hannover, Germany
2014	Visiting Professor, Fukushima University, Japan
2013 - 2015	Assistant Professor, Colorado State University
2008 - 2012	University Assistant, Atominstitut, Vienna University of Technology
2007 - 2008	Erwin Schrödinger Fellow, group of Prof. T.M. Klapötke, LMU München
2005	PhD, then Post-Doc, Atominstitut, Vienna University of Technology

Important publications

» R. Querfeld, et al. Radioactive Games? Radiation Hazard Assessment of the Tokyo Olympic Summer Games. Environ. Sci. Technol. 54 (2020) 11414–11423.
» T. Hopp, D. Zok, T. Kleine, G. Steinhauser. Non-natural atmospheric Ru isotope ratios of the undeclared 2017 release consistent with civilian nuclear activities. Nature Communications 11 (2020) 2744.
» G. Steinhauser, A. Koizumi, K. Shozugawa (eds.), Nuclear Emergencies: A Holistic Approach to Preparedness and Response, Springer-Nature, Singapore, (2019).
» O. Masson, G. Steinhauser, et al. Airborne concentrations and chemical considerations of radioactive ruthenium from an undeclared major nuclear release in 2017. PNAS 116 (2019) 16750-16759.
» G. Steinhauser. Environmental nuclear forensics: The need for a new scientific discipline. Environ. Sci. Pollut. Res. 26 (2019) 16901-16903.
» J.M. Welch, et al. Picomolar traces of Am^{III} introduce drastic changes in the structural chemistry of Tb^{III}: a break in the “gadolinium break”. Angew. Chem. Int. Ed. 56 (2017) 13264-13269.

Institute of Theoretical Physics

S. Gerhard

Prof. Dr. Luis Santos
Executive Director

Gina Gerlach
Office

Birgit Gemmeke
Office

Wiebke Möller
Office

Gitta Richter
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Tanja Wießner
Office

At the Institute of Theoretical Physics (ITP), various research groups work in a wide spectrum of modern topics of theoretical physics, offering as well a broad set of lectures on forefront areas. The Institute is part of many Graduate Colleges, organizes an active seminar program, and forms together with mathematical Institutes the Riemann Center of Geometry and Physics.

The ITP is organized in four sections:

Condensed Matter Theory
In Condensed Matter Theory (groups Frahm and Jeckelmann) methods from quantum many-body theory, statistical physics, quantum field theory and computational physics are applied to describe the different states of interacting macroscopic systems. Just as the solid and liquid phases differ by the presence of spatial order many forms of matter with very different properties - such as metals, insulators, superconductors, superfluids, and the numerous magnetic systems - can be characterized based on a quantum mechanical description of the correlated degrees of freedom. These states of matter are realized not only in solids but also in synthetic many-body systems such as ultracold Fermi and Bose gases.

String theory, Gravitation und Particle Physics
DString theory constitutes a promising candidate for a unified theory of all elementary particles and interactions, including a quantum theory of gravitation.

The group of Prof. Lechtenfeld analyzes the structure of fundamental models of space, time and matter, which unify the established theories of gravitation (Relativity) and particle physics (Quantum Field Theory). A special topic of interest is given by the investigation of super string theory, especially the construction and classification of new compactifications of ten into four space-time dimensions. Special attention is paid to gauge theories on different manifolds. A side-product are electromagnetic knot fields. Another topic of interested in that of classical and quantum integrable many-body models, their deformation and supersymmetric extensions.

The group of Prof. Giulini is devoted to problems of General Relativity, including new exact solutions of Einstein's equations, the influence of gravitation on the dynamics of quantum systems, and the related scenarios of violation of Lorentz invariance in the phenomenology of quantum gravitation.

Helge Krückeberg

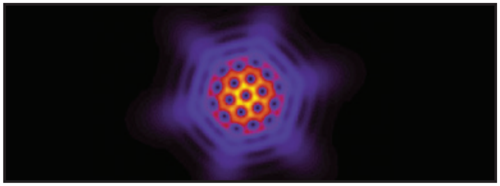
Lecture at the Institute of Theoretical Physics.

Quantum optics
The group of Prof. Lein is devoted to the time-dependent phenomena in atom and molecules under the influence of short intense laser pulses. This research, which is strongly numeric, is in close relation to current experiments in femto- and attosecond physics. The group works at the moment especially on the dynamics of tailored fields formed by many frequency components, with the goal of achieving a precise control of the microscopic electron dynamics.

The group of Prof. Santos works on the theory of ultracold gases, an active field at the interface between AMO physics, statistical physics and condensed-matter physics. Ultracold gases are very controllable, and hence offer interesting possibilities for the study of many-body systems. Current research topics include spinor and dipolar Bose-Einstein condensates, strongly-correlated gases in optical lattices, one-dimensional quantum gases, and synthetic magnetism.

The group of Prof. Hammerer works on the implementation of concepts of quantum computing, quantum communication, and quantum simulation with atoms, molecules, optics and solid-state devices. The goal is to employ the extraordinarily precise quantum control of these systems to observe and use quantum effects in a macroscopic scale. At the moment the activities of the group include, for example, micromechanical oscillators strongly coupled with light, and new quantum algorithms, based on trapped ions, for atomic clocks, and simulations of quantum field theories with cavity QED systems.

Luis Santos



Lattice phase of a two-dimensional Bose-Einstein condensate with synthetic spin-orbit coupling

The group of Dr. Weimer explores the dynamics of open quantum systems, working at the interface between quantum optics, solid-state physics, and quantum information. In this work, play a key role both fundamental questions, as the properties of phase transitions in open systems, and applications in quantum technologies such as quantum simulation and quantum sensorics. For the analysis of these systems the group develops and implements numerical methods, including variational techniques for open systems, tensor-network methods, and Monte-Carlo techniques.

Quantum information
The group of Prof. Osborne works on problems linking quantum information theory with solid-state physics and quantum field theory. The group focuses on quantum information methods, such as tensor-network techniques and entanglement theory, which are employed for the study of complex quantum systems. Two important research topics include the dynamics of correlated quantum fields, and the development of effective theories.

PD Dr. Michael Flohr


private

PD Dr. Michael Flohr

Special Mentoring
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Many first year students perceive the lecture courses in theoretical physics as their biggest challenge.This applies in particular students of the multidisciplinary Bachelor's degree for education, also students of the Bachelor's degree in meteorology, but also students who start their studies after continuation education. Especially these students feel overstrained by the combination of high requirements in mathematics and complex problems in physics. But even students of the Bachelor in physics experience theoretical physics often as some kind of cultural shock, because this aspect of physics is almost completely absent in schools. That is one of the reasons why these study courses have particular high dropout rates. Very often, the requirements for the courses in theoretical physics tipped the balance towards the decision, to abandon one's studies.

In order to reduce the number of dropouts, Prof. emeritus Norbert Dragon and PD Dr. Michael Flohr, both affiliated with the Institute for Theoretical Physics, founded a project together with the Leibniz University Society Hannover in the Fall 2012, which aims specifically at students who are in present danger to abandon their studies. The project offers an intensive one-to-one-mentoring programme for a limited time with made-to-measure assistance. Each year, about ten students can be supported within this programme. Almost always we succeed, such that the students continue their studies. In most cases, students can complete their study courses on their own and rather successfully, once the mentoring has finished.

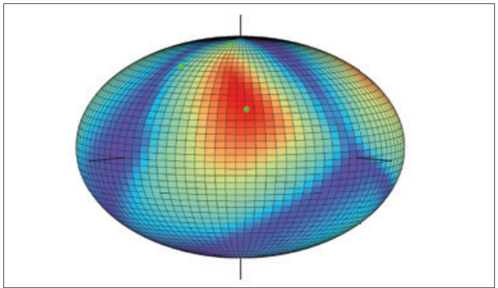
PD Dr. Michael works as lecturer at the Institute for Theoretical physics. One of his main responsibilities is the supervision and organisation of all tutorials for courses in theoretical physics for first year undergraduates. This position is ideal to identify students who are in danger to discontinue their studies, to approach them and, if applicable, to mentor them. Meanwhile the existence of this programme got around, and students started to seek out help with PD Dr. Michael Flohr of their own accord. Depending on the severity of their technical deficiencies and of their precise problems in learning and understanding, students admitted to the programme will be offered a few hours, maximally up to twelve, of intensive special one-to-one mentoring. This is not just coaching or private lessons, but a comprehensive mentoring, which also addresses working techniques, work organisation and scheduling, motivation techniques, and self-development, all individually tailored.

The project now runs prosperous for more than eight years, the success rate is well at 85%. Since quite often students participating in the programme come from families with a rather uneducated background, and who attempt educational advancement, this projects simultaneously serves as a real improvement in equality of opportunity.

We regularly report to the Leibniz University Society Hannover, who accompanies the project. Out of the collected data, a lot of important conclusions can be drawn, which in turn are used by PD Dr. Michael Flohr to continually improve the teaching courses in theoretical physics for all students. For example, he introduced so called supplemental tutorials, which help to compensate deficiencies in their professional qualifications of mathematical skills. In 2018, he launched the HelpDesks, a weekly meeting point where students can get immediate help with problems in their home works or computer exercises, without appointments and waiting time.

Strong correlations and quantum fluctuations in low spatial dimensions facilitate the formation of unconventional phases in many-body systems. Among the particularly interesting aspects of these phases are the physical properties of the corresponding elementary excitations or quasi-particles, which may carry fractions of the electronic charge or show non-Abelian statistics under permutation. Another problem which needs to be addressed is the characterization of the possible phase transitions between states with different topological properties. The theoretical description of these phenomena requires methods which allow for an unbiased approach beyond perturbation theory. Apart from numerical methods – usually limited to systems with few degrees of freedom – integrable quantum systems in one dimension and closely related two-dimensional models of statistical physics allow for an largely analytical approach to study observables and their correlation functions. This allows for important insights into the properties under variation of coupling constants of the effect of external fields.

H. Frahm



Phase diagram of a chain of interacting non-Abelian anyons

Prof. Frahm has used these methods to study systems of strongly correlated electrons in one dimension and the collective behaviour of interacting spins or non-Abelian anyons. One focus of his recent work are supersymmetric vertex models which allow, e.g., to study the quantum critical behaviour of electrons in disordered systems. Their continuum limits are conformal field theories with non-compact degrees of freedom and a continuous spectrum of critical exponents. More recently, he began to investigate the algebraic structures of correlation functions in integrable quantum systems.

private

Prof. Dr. Holger Frahm

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Important research projects
- Correlations in integrable quantum many-body systems
- Spin chains and vertex models based on superalgebras
- Non-Abelian anyons

Important professional positions

Since 2004	Professor of Theoretical Physics at Leibniz University Hannover
1992 - 1993	Acting Professor, Lehrstuhls für Theoretische Physik, Universität Bayreuth
1992	Habilitation in Theoretical Physics, Universität Hannover
1988 - 1991	Postdoc, University of Virginia, Charlottesville (USA)

Important publications

- Fabian H.L. Essler, Holger Frahm, Frank Göhmann, Andreas Klümper, and Vladimir E. Korepin: The One-Dimensional Hubbard Model, Cambridge University Press (2005)
- Peter E. Finch, Michael Flohr and Holger Frahm: Integrable anyon chains: from fusion rules to face models to effective field theories, Nucl. Phys. B 889 [FS] (2014) 299-332 [arXiv:1408.1282]
- Holger Frahm, Jan H. Grelik, Alexander Seel, and Tobias Wirth: Functional Bethe ansatz methods for the open XXX chain ,J. Phys. A: Math. Theor. 44 (2011) 015001 [arXiv:1009.1081]
- Fabian H. L. Essler, Holger Frahm and Hubert Saleur: Continuum limit of the integrable sl(2|1) 3x3 superspin chain, Nucl. Phys. B 712 [FS] (2005) 513-572 [cond-mat/0501197]
- Holger Frahm: Doped Heisenberg chains: Spin-S generalizations of the supersymmetric t-J model, Nucl. Phys. B 559 [FS] (1999) 613-636 [cond-mat/9904157]

Prof. Dr. Domenico Giulini

S. Gerhard

Prof. Dr. Domenico Giulini

Gravitation and Relativity

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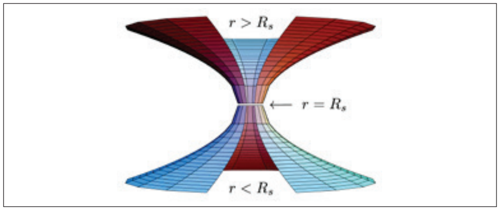
Subject of my research are problems in gravitational physics, relativistic field theory, and the interface between quantum- and gravitational physics. One focus is on exact solutions of Einstein's field equations of General Relativity (GR), in particular their global differential-geometric and topological properties. Another focus is on the as yet insufficiently understood relation of GR and Quantum Mechanics (QM) and also Quantum-Field Theory. A typical question concerning exact solutions to GR is how compact ob-jects, e.g., black holes, fit into a cosmological solutions describing an expanding universe. The difficulty is that, due to the non-linear nature of Einstein's equations, we cannot simply superpose the exact solu-tions known for black holes with that of cosmology. Hence we need to employ other methods to embed such an object in an ambient universe, but those methods are usually not easy to interpret as regards their physical implications. As regards the interface GR-QM, I like to focus on apparently simple ques-tions which, as it turns out, already provide considerable challenges to our current understanding. One such question concerns the precise formulation of Einstein's Equivalence Principle (EEP) so as to also apply to quantum matter. Can we use non-classical states to perform more precise tests of EEP? How does a non-classical (delocalised) state of matter gravitate? What is the influence of gravitational self-coupling onto the dynamics of quantum states? Such questions I enjoy to discuss with colleagues from experimental groups working in Atom-Interferometry and Quantum-Optics. Another strand of my re-search is concerned with the Hamiltonian formulation of relativistic field theories, their symmetries, and the construction of initial data for the Cauchy problem. Recent work with MA and Ph.D. students con-cerns asymptotic symmetries of scalar electrodynamics, Yang-Mills- and Yang-Mills-Higgs-Theory.



D. Giulini

This two-dimensional surface illustrates the spatial geometrical relations of the space in a spacetime with black hole. In the center is a minimal surface (here represented as a circle) where the two funnel-shaped parts are glued together. This represents a so-called apparent horizon.

Important professional positions

2009 - today	Professor, Leibniz University Hannover
2006 - 2009	Researcher at Max-Planck-Institute for Gravitational Physics (Albert-Einstein-Institute) at Golm near Potsdam
2000 - 2006	Adjunct Professor at University of Freiburg

Important research projects

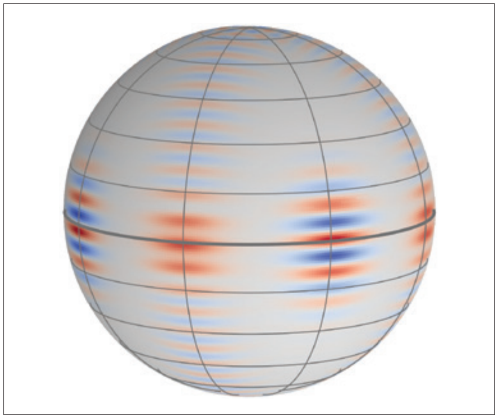
» Solutions to Einstein's equations and their properties
» Gravitation and Quantum Mechanics
» Symmetries in Hamiltonian field theory

Important publications

» R. Tanzi und D. Giulini: Asymptotic symmetries of Yang-Mills fields in Hamiltonian formulation. Journal of High Energy Physics (2020) article number 94
» M. Fennen und D. Giulini: Lie sphere-geometry in lattice cosmology. Classical and Quantum Gravity 37 (2020) 065007
» P. Schwartz und D. Giulini: Post-Newtonian Hamiltonian description of an atom in a weak gravitational field. Physical Review A 100 (2019) 052116
» D. Giulini: Dynamical and Hamiltonian formulation of General Relativity. In: A. Ashtekar und V. Petkov (Editoren), Springer Handbook of Spacetime (Springer Verlag 2014)
» D. Giulini: Equivalence principle, quantum mechanics, and atom-interferometric tests. In: F. Finster et al. (Editoren), Quantum Field Theory and Gravity (Birkhäuser Basel 2012) 345-370
» D. Giulini und A. Großardt: Gravitationally induced inhibitions of dispersion according to the Schrödinger-Newton Equation, Classical and Quantum Gravity 28 (2011) 195026

Prof. Dr. Klemens Hammerer

The group of Klemens Hammerer conducts research in the field of theoretical quantum optics. We deal with physical systems that can be described, controlled and used in quantum technology at the level of single quanta. Examples of such systems we are currently working on are (i) cold ions in ion traps, which can be used to realise novel atomic clocks or quantum computers, (ii) cold atoms in Bose-Einstein condensates, which can be used for matter wave interferometry, (iii) correlated quantum states of the electromagnetic field in resonators and waveguides, and (iv) (quantum) mechanical degrees of freedom of meso- and macroscopic structures in precision measurements such as gravitational wave detectors. We apply a wide range of analytical and numerical methods to describe the quantum dynamics of open systems (i.e. systems interacting with the environment) and to treat complex quantum correlations. The theoretical questions addressed in our group are usually closely related to current quantum optical experiments.



Wigner function of a spin state of an ensemble of entangled clock atoms. The entanglement of atoms can improve the stability of an atomic clock.

private

Prof. Dr. Klemens Hammerer

Theoretical quantum optics
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Important research projects

» SFB 1227 (DQmat) (seit 2016)
» Exzellencluster EXC 2123 (QuantumFrontiers) (seit 2019)
» Quantum Valley Lower Saxony (seit 2021)

Important professional positions

2010 - today	Professor, Leibniz University Hannover
2010 - 2010	Senior Scientist at the Institute for Quantum Optics and Quantum Information, Austrian Academy of Sciences, Innsbruck
2006 - 2009	University Assistant, Institute for Theoretical Physics, Innsbruck
2002 - 2006	Doctorate at the Technical University of Munich

Important publications

» Ramsey interferometry with generalized one-axis twisting echoes, Marius Schulte, Victor J. Martínez-Lahuerta, Maja S. Scharnagl, Klemens Hammerer, Quantum 4, 268 (2020)
» Prospects and challenges for squeezing-enhanced optical atomic clocks, Marius Schulte, Christian Lisdat, Piet O. Schmidt, Uwe Sterr, Klemens Hammerer, Nature Communications 11, 5955 (2020)
» Light-mediated strong coupling between a mechanical oscillator and atomic spins one meter apart, Thomas M. Karg, Baptiste Gouraud, Chun Tat Ngai, Gian-Luca Schmid, Klemens Hammerer, Philipp Treutlein, Science 369, 174 (2020)
» Analytic theory for Bragg atom interferometry based on the adiabatic theorem, Jan-Niclas Siemß, Florian Fitzek, Sven Abend, Ernst M. Rasel, Naceur Gaaloul, Klemens Hammerer, Phys. Rev. A 102, 033709 (2020)
» Dynamics of many-body photon bound states in chiral waveguide QED, Sahand Mahmoodian, Giuseppe Calajó, Darrick E. Chang, Klemens Hammerer, Anders S. Sørensen, Phys. Rev. X 10, 031011 (2020)

Prof. Dr. Eric Jeckelmann

S. Gerhard

Prof. Dr. Eric Jeckelmann

Condensed matter theory
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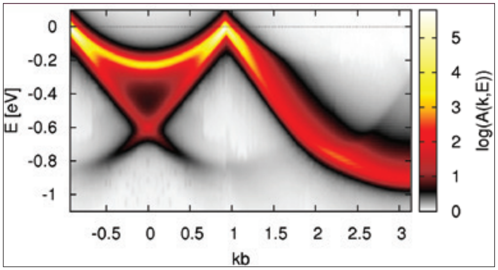
My area of experise is condensed matter theory. My research activities are focused on low-dimensional materials such as atomic chains and ladder systems, the dynamics of complex quantum systems, the interplay between electrons and phonons in solids as well as computational methods for quantum many-body systems. In the field of quantum many-body theory there is a great need for better computational tools and thus the developement of new methods is a main goal of my research group. The focus lies on numerical matrix-product-state methods and other approches based on reduced density matrices. I supervise bachelor and master research projects on theses topics. Prior experience with computers and a programming language such as C/C++ or Python is the main requirement. Condensed matter theory is based, among others, on solid state physics, statistical physics and computational physics. Therefore, I regularly teach basic and advanced courses as well as seminars on these subjects.



E. Jeckelmann

Photoemission spectrum of the (two-band) Hubbard model for the quasi-one-dimensional organic conductor TTF-TCNQ as a function of wave number k and energy E

Important professional positions

2017 - 2019	Dean of studies in the Faculty of Mathematics and Physics
2015 - 2017	Vice dean of studies in the Faculty of Mathematics and Physics
2005 - today	Professor of Theoretical Physics at the Leibniz University Hannover
2003 - 2005	Hochschuldozent (Senior lecturer) at the University of Mainz
1998 - 2003	Wissenschaftlicher Assistent (Postdoc) at the University of Marburg

Important research projects

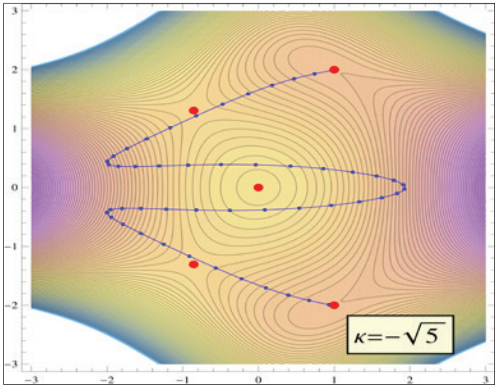
» Embedded one-dimensional electron-phonon systems (DFG FOR1700)
» Time evolution using DMRG methods for systems with bosonic degrees of freedom (DFG FOR1807)

Important publications

» Luttinger liquid and charge-density-wave phases in a spinless fermion wire on a semiconducting substrate, Anas Abdelwahab and Eric Jeckelmann, Phys. Rev. B 98, 235138 (2018)
» Grand canonical Peierls transition in In/Si(111), Eric Jeckelmann, Simone Sanna, Wolf Gero Schmidt, Eugen Speiser, and Norbert Esser, Phys. Rev. B 93, 241407(R) (2016)
» Matrix-product-state method with a dynamical local basis optimization for bosonic systems out of equilibrium, C. Brockt, F. Dorfner, L. Vidmar, F. Heidrich-Meisner, and E. Jeckelmann, Phys. Rev. B 92, 241106(R) (2015)
» Ground-state and spectral properties of an asymmetric Hubbard ladder, Anas Abdelwahab, Eric Jeckelmann, and Martin Hohenadler, Phys. Rev. B 91, 155119 (2015)
» Spectral function of the one-dimensional Hubbard model away from half filling, H. Benthien, F. Gebhard, and E. Jeckelmann, Phys. Rev. Lett. 92, 256401 (2004)
» Dynamical density-matrix renormalization-group method, E. Jeckelmann, Phys. Rev. B 66, 045114 (2002)

Prof. Lechtenfeld's work group analyzes the structure of fundamental models of space, time and matter, with the goal of combining the established theories of gravity (general relativity) and elementary particles (quantum field theory). Prominent are investigations of superstring theory, in particular the construction and classification of new types of compactifications from ten to four spacetime dimensions, by employing modern algebro-geometric and differential-geometric methods. A central part of this program is the detection of solitonic solutions of the Yang-Mills equations on manifolds of dimension four to eight as well as the adiabatic reduction of gauge field theory to specific sigma (Skyrme) models. A byproduct is a novel construction method and classification of rational electromagnetic fields -- knot solutions -- in four-dimensional Minkowski space. A key property of many theoretical building blocks is the so-called integrability, which allows analytic solutions. Our work group investigates the classical and quantum properties of integrable multi-particle systems with conformal invariance and/or supersymmetry and constructs new variants and their integrable deformations.

Maike Tormählen



Plane trajectory of a particle in special potential, describes solution of Yang-Mills equation with torsion kappa on a cylinder above the 5-sphere

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Important professional positions

1992 - today	Professor (C4) at the Leibniz University of Hannover
1985 - 1992	Postdoctoral researcher at CERN (Geneva), in New York (CUNY), in Princeton (IAS)
1977 - 1984	Studies and doctorate, Theoretical Physics, University of Bonn

Important research projects

» Heterotic flux vacua (classical solutions to heterotic string theory): construction, instantons, moduli spaces, brane interpretation
» Adiabatic reduction of Yang-Mills theory: diverse geometries, infrared limit, special sigma models
» Electromagnetic knots: rational Maxwell solutions, construction, classification, properties
» Conformal integrable multi-particle systems: Calogero-type models and their reduction, classical and quantum, PT deformations

Important publications

» V.A. Kostelecky, O. Lechtenfeld, W. Lerche, S. Samuel, S. Watamura, Conformal techniques, bosonization and tree-level string amplitudes, Nucl. Phys. B 288 (1987) 173-232
» M. Dine, W. Fischler, O. Lechtenfeld, J. Polchinski, B. Sakita, Baryon number violation at high temperature in the Standard Model, Nucl. Phys. B 342 (1990) 381-408
» O. Lechtenfeld, A.D. Popov, Noncommutative multi-solitons in 2+1 dimensions, JHEP 0111 (2001) 040,arXiv: hep-th/0106213
» D. Harland, T.A. Ivanova, O. Lechtenfeld, A.D. Popov, Yang-Mills flows on nearly Kähler manifolds and G2-instantons, Commun. Math. Phys. 300 (2010) 185-204, arXiv: 0909.2730 [hep-th].
» T.A. Ivanova, O. Lechtenfeld, A.D. Popov, Solutions to Yang-Mills equations on four-dimensional de Sitter space, Phys. Rev. Lett. 119 (2017) 061601, arXiv:1704.07456 [hep-th].

Prof. Dr. Manfred Lein

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Prof. Dr. Manfred Lein

Theoretical Quantum Dynamics
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The Lein group is located in the Institute of Theoretical Physics. It works on laser-induced quantum dynamics of small systems, mostly atoms and molecules, under the influence of short intense laser pulses. The group is especially interested in the behaviour induced by tailored light fields consisting of more than one colour. Such processes are a central topic in the Priority Programme Quantum Dynamics in Tailored Intense Fields (QUTIF), which has been funded by the German Research Foundation since 2015 and which is coordinated by Professor Lein.

The research of the group falls within the area of attosecond physics as the relevant microscopic processes take place on ultrashort time scales below one femtosecond (1 femtosecond = 10^{-15} seconds, 1 attosecond = 10^{-18} seconds).

Research on nonperturbative quantum dynamics has a strong numerical component and hence it takes advantage of the scientific computing at the Leibniz University IT Services

A large part of this work is in direct connection to experiments carried out at the Institute of Quantum Optics and elsewhere. The group has active collaborations with the Goethe University Frankfurt, the University of Jena and the Huazhong University of Science and Technology, Wuhan.

Besides, the Lein group works on the foundations of time-dependent density functional theory

Research group Quantum Dynamics

Important professional positions

2009 - today	W3 Professor at the Leibniz University Hannover
2006 - 2009	W2 Professor at the University of Kassel
2004 - 2006	Research Group Leader at the Max Planck Institute for Nuclear Physics, Heidelberg
2001 - 2004	Postdoc at Imperial College London and at the Max Planck Institute for the Physics of Complex Systems, Dresden
1998 - 2001	PhD at the University of Würzburg

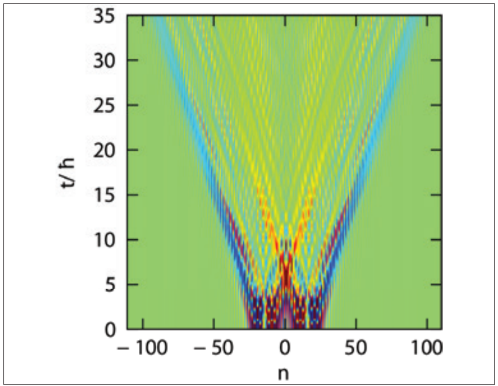
Important research projects

» The HeH^+ molecule in strong laser fields
» Quantum dynamics in two-colour fields

Important publications

» M. Lein, Attosecond probing of vibrational dynamics with high-harmonic generation, Phys. Rev. Lett. 94, 053004 (2005)
» S. Baker, J. Robinson, C.A. Haworth, H. Teng, R.A. Smith, C.C. Chirila, M. Lein, J.W.G. Tisch, J.P. Marangos, Probing proton dynamics in molecules on an attosecond timescale, Science, 312, 424 (2006)
» J. Zhao, M. Lein, Determination of Ionization and Tunneling Times in High-Order Harmonic, Generation, Phys. Rev. Lett. 111, 043901 (2013)
» A. Hartung, S. Eckart, S. Brennecke, J. Rist, D. Trabert, K. Fehre, M. Richter, H. Sann, S. Zeller, K. Henrichs, G. Kastirke, J. Hoehl, A. Kalinin, M.S. Schöffler, T. Jahnke, L.Ph.H. Schmidt, M. Lein, M. Kunitski, and R. Dörner, Magnetic fields alter strong-field ionization, Nature Physics 15, 1222 (2019)
» N. Eicke, S. Brennecke, and M. Lein, Attosecond-Scale Streaking Methods for Strong-Field Ionization by Tailored Fields, Phys. Rev. Lett. 124, 043202 (2020)

Recently, there have been many exciting new developments in the study of many body physics and quantum field theory. It has become clear that an understanding of quantum entanglement leads directly to better variational classes, which are ideal for studying non-equilibrium dynamics using the time-dependent variation principle.



Prof. Dr. Tobias J. Osborne

Simulation of the real time scattering of the dynamics of two excitations of the Heisenberg chain

These variational classes are known as tensor network states (TNS). Prominent examples include matrix product states, projected pair-entangled states, and the multiscale entanglement renormalisation ansatz. The application of application of these TNS within the variational method leads to fascinating new results in many areas of quantum many-particle physics.

Our group is dedicated to the development of theoretical tools for studying large strongly interacting quantum systems. We have effective theories for the practical study of the dynamics of large coherent interacting quantum quantum systems. The development of TNS for complex quantum systems has also been a core area of research, to which we have made numerous contributions, including the development of TNS for strongly interacting quantum fields and for low-energy physics.

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Important professional positions

2010 - today	Professor, Leibniz University Hannover
2009 - 2010	Reader, Royal Holloway, University of London
2005 - 2009	Lecturer, Royal Holloway, University of London
2003 - 2005	Research Assistant, University of Bristol
2002 - 2003	Research Assistant, The University of Queensland

Important research projects

» ERC starting grant, 2011-2016
» EPSRC first grant scheme, 2009-2011
» Vollzeit-Forschungsstipendium am Wissenschaftskolleg zu Berlin, 2009-2010

Important publications

» J. Haegeman, T. J. Osborne, H. Verschelde, F. Verstraete, Entanglement renormalization for quantum fields in real space, Phys. Rev. Lett. 110, 100402 (2013)
» K. Temme, T. J. Osborne, K. G. Vollbrecht, D. Poulin und F. Verstraete, Quantum Metropolis Sampling, Nature 471, 87-90 (2011)
» T. J. Osborne, Efficient approximation of the dynamics of one-dimensional quantum spin systems, Phys. Rev. Lett. 97, 157202 (2006)
» T. J. Osborne, F. Verstraete, General monogamy inequality for bipartite qubit entanglement, Phys. Rev. Lett. 96, 220503 (2006)
» T. J. Osborne, M. A. Nielsen, Entanglement in a simple quantum phase transition, Phys. Rev. A 66, 032110 (2002)

Prof. Dr. Luis Santos

S. Gerhard

Prof. Dr. Luis Santos

Theory of ultracold gases
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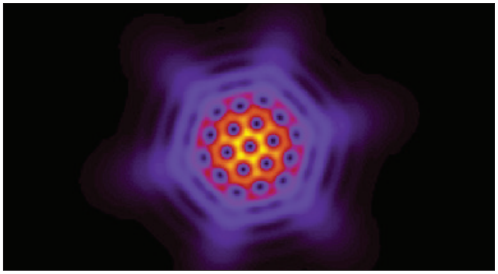
E-Mail santos@itp.uni-hannover.de

The research group of Prof. Santos is devoted to the theory of ultracold gases, a very active research field at the interface between AMO physics, statistical physics, and condensed-matter physics.

When gases are cooled down to very low temperatures, their particles are not any more distinguishable, and as a result, quantum statistics plays a crucial role. In particular, bosons form a so-called Bose-Einstein condensation, which is characterized by many interesting properties.

Ultracold gases constitute a very well controllable system, optimal for the detailed study of many-body physics. For example, particles may be loaded in the periodic potential exerted by a laser standing wave, a so-called optical lattice. The physics of ultracold gases in optical lattices resembles that of electrons in solids. As a result, these systems may be employed for the quantum simulation of interesting condensed-matter problems, as for example quantum magnetism and superconductivity.

The group of Prof. Santos works since years at the forefront of research in the theory of ultracold gases. Current topics of interest include spinor and dipolar condensates, strongly-correlated gases in optical lattices, one-dimensional quantum gases, and synthetic magnetism. The group works closely together with groups at the Institute of Quantum Optics.



L. Santos

Density plot showing the lattice phase of density minima in a trapped 2D two-component Bose-Einstein condensate with spin-independent interactions in the presence of isotropic spin-orbit coupling

Important research projects

» SFB 1227 (DQmat) (since 2016)
» Exzellencluster EXC 2123 (QuantumFrontiers) (since 2019)
» Quantum Valley Lower Saxony (since 2021)

Important professional positions

Since 2006	W3 Professor at the Leibniz University of Hannover
2004 - 2006	C3 Professor at the University of Stuttgart
2001 - 2005	Sofja Kovalevskaja-Awardee of the AvH-Foundation

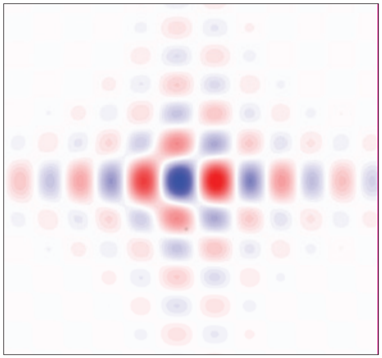
Important publications

» Universal algebraic growth of entanglement entropy in many-body localized systems with power-law interactions, X. Deng, G. Masella, G. Pupillo, and L. Santos, Phys. Rev. Lett. 125, 010401 (2020).
» Deconfining disordered phase in two-dimensional quantum link models, L. Cardarelli, S. Greschner, and L. Santos, Phys. Rev. Lett. 124, 123601 (2020).
» Heralded Generation of Macroscopic Superposition States in a Spinor Bose-Einstein Condensate, L. Pezz_e, M. Gessner, P. Feldmann, C. Klempt, L. Santos, and A. Smerzi, Phys. Rev. Lett. 123, 260403 (2019).
» Observation of a dipolar quantum gas with metastable supersolid properties, L. Tanzi, E. Lucioni, F. Fama, J. Catani, A. Fioretti, C. Gabbanini, R. N. Bisset, L. Santos, and G. Modugno, Phys. Rev. Lett. 122, 130405 (2019).
» Observation of Roton Mode Population in a Dipolar Quantum Gas, L. Chomaz, R. M. W. van Bijnen, D. Petter, G. Faraoni, S. Baier, J. H. Becher, M. J. Mark, F. Wächtler, L. Santos, and F. Ferlaino, Nature Phys. 14, 442 (2018).

PD Dr. Hendrik Weimer

Unterstanding open quantum systems, i.e., quantum systems coupled to an external environment, is the central focus of my research. A large part concerns fundamental questions in many-body systems such as the properties of phase transitions or the realization of topologically ordered states of matter in open quantum systems. We use a combinations of analytical and numerical tools like a variational principle for open systems, tensor network methods, and Monte-Carlo simulations, and we actively advance the development of these methods.

Applications of open systems within quantum technologies is the second important topic investigated in my group. For a long time, the prevalent view was that a perfect isolation of a quantum system from its environment would be necessary to realize these applications. In recent years, however, it became increasingly clear that engineering the interaction between a quantum systems and its environment can result in exactly the type of quantum correlations required to build such quantum technological devices. In my group, we develop new fields of applications within quantum simulation, quantum computing, and quantum sensing. For this, we have a close collaboration with experimental partners, especially in the area of trapped ions, Rydberg atoms, and NV centers in diamond.



Tim Pistorius

Quasi-probability distribution of an open quantum system. Blue areas indicate non-classical behavior having a negative propability density.

Mirko Krenzel für VolkswagenStiftung

PD Dr. Hendrik Weimer

Institute of Theoretical Physics
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Important professional positions

2014 - today	Research group leader, Leibniz University Hannover
2014 - today	Freigeist Fellow of the Volkswagen Foundation
2012 - 2014	Postdoc, Leibniz University Hannover
2010 - 2012	ITAMP Postdoctoral Fellow, Harvard University
2007 - 2010	PhD student, University of Stuttgart

Important research projects

» Cluster of Excellence QuantumFrontiers - Light and Matter at the Quantum Frontier
» SFB 1227 Designed states of quantum matter (DQ-mat)
» Quantum Valley Lower Saxony QVLS-Q1
» Quantum States on Demand (Freigeist Fellowship)
» Open system quantum simulation with Rydberg atoms (SPP 1929)

Important publications

» Simulation methods for open quantum many-body systems, H. Weimer, A. Kshetrimayum, R. Orús, Rev. Mod. Phys. 93, 015008 (2021).
» Initialization of Quantum Simulators by Sympathetic Cooling, M. Raghunandan, F. Wolf, C. Ospelkaus, P. O. Schmidt, H. Weimer, Science Adv. 6, eaaw9268 (2020).
» A simple tensor network algorithm for two-dimensional steady states, A. Kshetrimayum, H. Weimer, R. Orus, Nature Commun. 8, 1291 (2017).
» Variational Principle for Steady States of Dissipative Quantum Many-Body Systems, H. Weimer, Phys. Rev. Lett. 114, 040402 (2015).
» A Rydberg quantum simulator, H. Weimer, M. Müller, I. Lesanovsky, P. Zoller, H. P. Büchler, Nature Phys. 6, 382 (2010)

Prof. Dr. Reinhard F. Werner

S. Gerhard

Prof. Dr. Reinhard F. Werner

Quantum Information Theory
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The Quantum Information Theory group was founded in 1997 at the TU Braunschweig and moved to Hannover in 2009, where it has since been jointly led by Prof. Reinhard F. Werner and Prof. Tobias J. Osborne. The group investigates mathematical aspects of quantum mechanics, especially quantum information theory and the theory of complex many-body quantum systems.

Quantum information theory is a relatively recent area of quantum mechanics, in which, analogous to Shannon's classical information theory, quantum systems are regarded as carriers of information. According to this theory, quantum systems are suitable both for physically secure transmission of secret messages as well as for a considerably accelerated solution of complex tasks with quantum computers. Even if practical quantum computers are still a long way off, research in this field has already made impressive experimental and theoretical progress.

About 20 years ago, one could say that quantum many-body systems were much more difficult to treat than classical ones, if only because some pieces were missing in the toolkit of quantum mechanics. In particular, the relation of subsystems to the whole was insufficiently understood. With the deepened understanding of entanglement from quantum information theory, this gap has narrowed considerably. This has resulted in a very active research area in which the group plays an internationally recognized role.

Important research projects

» Dynamics, propagation and topological classification of quantum walks (collaboration with Dieter Meschede, Applied Physics Bonn)
» Exact uncertainty relations for measurement and preparation in quantum mechanics (collaboration with Paul Busch, York and Pekka Lahti, Turku)
» Methods of quantum information theory for the description of complex quantum systems

Important professional positions

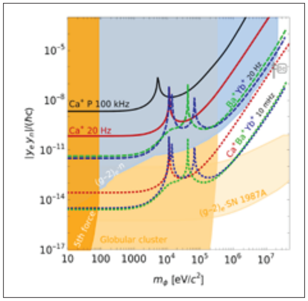
2009 - today	Professor at Leibniz University Hannover
1997 - 2009	Professor at the TU Braunschweig
1988 - 1990	research stay at the Dublin Institute for Advanced Studies
1980 - 1997	Staff member, university assistant and professor on a temporary basis at the University of Osnabrück

Important publications

» P. Busch, P. Lahti und RFW: Proof of Heisenberg's error-disturbance relation, Phys. Rev. Lett. 111(2013) 160405
» C. Cedzich, T. Rybár, A. H. Werner, A. Alberti, M. Genske und RFW: Propagation and spectral properties of quantum walks in electric fields, Phys. Rev. Lett. 111(2013) 160601
» RFW: All teleportation and dense coding schemes, J. Phys. A 34(2001) 7081-7094
» M. Fannes, B. Nachtergaele und RFW: Finitely correlated states on quantum spin chains, Commun. Math. Phys. 144(1992) 443-490
» RFW: Quantum harmonic analysis on phase space, J. Math. Phys. 25(1984) 1404-1411

The research group 'Theoretical particle physics' works on extensions of the Standard Model and their phenomenology at the Large Hadron Collider (LHC), future colliders and at the interface with atomic physics.

We address fundamental questions like the origin for the stability of the Higgs boson mass against quantum corrections, the baryon asymmetry of the universe, and candidates for Dark Matter. As most of the well-motivated extensions of the Standard Model modify the properties of the Higgs boson, a precise analysis of its coupling structure opens a window to effects of New Physics. On the one hand, we consider specific models like extended Higgs sectors with CP violation or the relaxion framework, on the other hand effective field theories that are to a large extent model-independent.



Phys. Rev. Lett. 125 (2020) no.12, 123003

A special focus lies on searches for new, light, weakly interacting particles that can serve as a portal to Dark Sectors and may modify the spectra of atoms and ions. Therefore we develop methods to make in particular the very precise measurements of isotope shifts useable for particle physics purposes.

In both thematic fields, we derive precise theory predictions for processes beyond the Standard Model and develop innovative methods to confront these with experimental data and to suggest new, sensitive measurements. The complementarity of high-energy colliders and high-precision spectroscopy allows us to analyse different models of New Physics.

Jun.-Prof. Dr. Elina Fuchs

Theoretical particle physics with cold atoms and colliders
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elina.fuchs@itp.uni-hannover.de

Important research projects
- Searches for physics beyond the Standard Model with cold atoms and ions
- CP violation in the Higgs sector, electroweak baryogenesis
- Collider phenomenology at the LHC and future colliders
- Member of the excellence cluster QuantumFrontiers, leader of the Topical Group "Fundamental physics with spectroscopy"

Important professional positions

Since 2021	Junior Professor for theoretical particle physics at LUH and PTB
Since 2021	Senior Research Fellow, CERN, Switzerland
2019 - 2021	Postdoc at University of Chicago and Fermilab, USA (from 2020 as Feodor-Lynen-Fellow of the Alexander von Humboldt Foundation)
2015 - 2019	Postdoc at Weizmann Institute of Science, Israel (from 2018 as Minerva Fellow of the Minerva Foundation/Max Planck Society)
2012 - 2015	PhD at DESY Hamburg

Important publications

- C. Solaro, S. Meyer, K. Fisher, J. C. Berengut, E. Fuchs and M. Drewsen, "Improved isotope-shift-based bounds on bosons beyond the Standard Model through measurements of the 2 D3/2–2D5/2 interval in Ca+", Phys. Rev. Lett. 125 (2020) no.12, 123003..
- E. Fuchs, M. Losada, Y. Nir and Y. Viernik, "Implications of the upper bound on h ->μ+μ– on the baryon asymmetry of the Universe", Phys. Rev. Lett. 124 (2020) no.18, 181801.
- J. Berengut, D. Budker, C. Delaunay, V. Flambaum, C. Frugiuele, E. Fuchs, C. Grojean, R. Harnik, R. Ozeri, G. Perez and Y. Soreq, "Probing light new physics with isotope shifts", Phys. Rev. Lett. 120 (2018) 091801.
- E. Fuchs and G. Weiglein, "Breit-Wigner approximation for propagators of mixed unstable states," JHEP (2017) 079.
- T. Flacke, C. Frugiuele, E. Fuchs, R. S. Gupta, and G. Perez, "Phenomenology of relaxion-Higgs mixing," JHEP 06 (2017) 050.

DLR Institute for Satellite Geodesy and Inertial Sensing (DLR-SI)

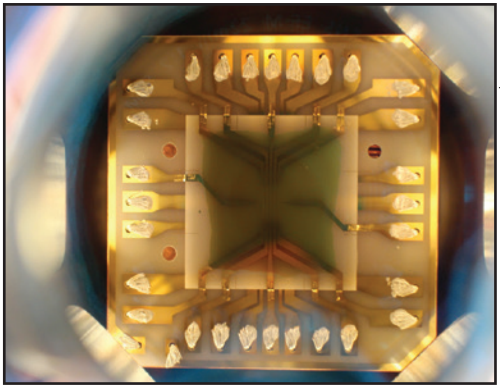
S. Gerhard

Prof. Wolfgang Ertmer
Commissarial management

Quantum-based measurement techniques will revolutionize satellite sensing in the future. Quantum sensors based on Bose-Einstein condensates, novel atomic clocks, laser and matter-wave interferometry are just some of the quantum technologies that are about to make the leap to routine application in space. In the wake of a „second quantum revolution," an unprecedented increase in the precision of metrology and sensing is taking place in space, with previously untapped applications. In the summer of 2019, the DLR Senate had agreed to create an Institute for Satellite Geodesy and Inertial Sensing funded by the German federal government and the state of Lower Saxony. In close cooperation with Leibniz University Hannover, the establishment of the new institute with a total of seven departments is underway. By the end of the decade, it will be established in the university's planned „Quantum Quarter" with a new building to be constructed for around 100 employees. The DLR institute will thus fit in perfectly with nearby facilities such as the Max Planck Institute for Gravitational Physics (Albert Einstein Institute), the Hannover Institute of Technology (HITec) and the Laboratory for Nano and Quantum Engineering (LNQE).

A laboratory building and an associated office building are to be constructed at the corner of Schneiderberg and Appelstraße. Temperature stabilized laser optics and atom optics laboratories and clean rooms, as well as workshops and measuring stations, will provide the necessary infrastructure for quantum technology experiments and development work in the fields of quantum sensing, quantum gravimetry and quantum optical sensors for terrestrial and satellite geodesy applications, such as relativistic geodesy, atom optics-based navigation solutions, or future mobile optical atomic clocks of the highest accuracy. Worldwide, quantum technologies are expected to be a major driver of innovation and growth in the future.

Inertial sensors can be accelerometers or angular sensors, which are used, for example, for flight stabilization and navigation. Quantum sensors based on matter-wave interferometry enable rotation and acceleration to be measured with unprecedented long-term stability. Ultracold quantum gases such as Bose-Einstein condensates can be used for this purpose. In the immediate vicinity of absolute temperature zero, an atomic cloud behaves like a single „giant atom". This socalled BoseEinstein condensate can be observed macroscopically. A further development of this

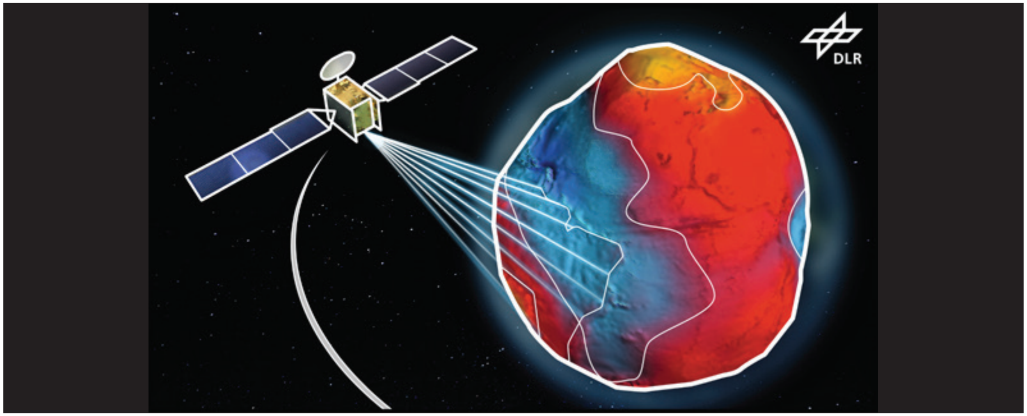


LUH/J. Matthias

Miniaturized chip applications are being developed to be used as atom traps in quantum sensors.

technology promises future high-precision attitude control of satellites, for distance control during formation flights of a satellite swarm or also for precise gravity field measurement of the earth or other celestial bodies. Promising quantum optical methods of laser interferometry will also be further developed at the new DLR institute.

The activities of the new institute will be integrated into DLR-wide projects and collaborations with partners from research and industry in Germany, Europe and the world. For example, DLR is already collaborating with NASA on the BECCAL project, in which Bose-Einstein condensates (BEC) are studied under microgravity conditions in the Cold Atoms Lab (CAL) on the International Space Station (ISS). A core partnership exists with Leibniz University Hannover, where the new institute will initially rent office and laboratory space. A strong collaboration with the PhysikalischTechnische Bundesanstalt (PTB) in Braunschweig is foreseen within the planned department „Optical Frequency Measurement". The „Relativistic Modeling" department will be located at DLR's Bremen site near the Center for Applied Space Technology and Microgravity (ZARM).



DLR

The DLR Institute for Satellite Geodesy and Inertial Sensing (DLR-SI) is primarily dedicated to research questions in the context of the use of quantum technologies and develops quantum measurement techniques for innovative geodetic applications, up to the realization of prototype solutions.

Gravitational-wave detector GEO600


private

Dr. James Lough
Lead Scientist GEO600


private

Dr. Christoph Affeldt
Operations Manager GEO600

For thousands of years, mankind has been gazing at the night sky, and for hundreds of years, it has been building ever more powerful telescopes. But only in the past few years have we also been able to observe the dark, entirely invisible side of the universe through gravitational waves. This breakthrough, which has already led to new insights into black holes, neutron stars and the universe, is also thanks to the German-British gravitational-wave detector GEO600.

New astronomy

On September 14, 2015, humanity for the first time directly observed gravitational waves. GEO600 was crucial for this success, as it is here that key technologies for detecting gravitational waves are being developed and tested. The first detection opened a new window into the universe and ushered in the age of gravitational-wave astronomy. As of today, 90 gravitational-wave signals from mergers of black holes and neutron stars have been observed.

Technology think tank GEO600

GEO600 is the technology think tank of international gravitational-wave research. Technology developed and tested in the GEO project is used in all major gravitational-wave detectors in the world. The laser-based measurement techniques have also found their way into earth observation, climate research and the aerospace industry.

Gravitational waves – ripples in space-time

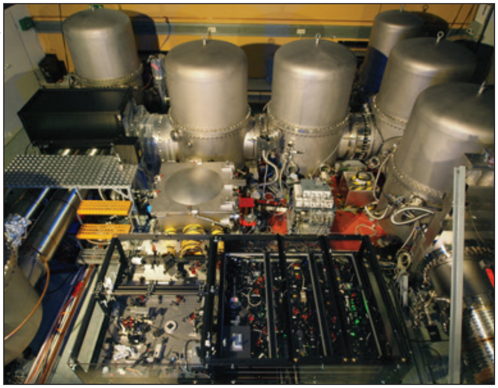
In 1915, Albert Einstein's theory of general relativity provided a completely new view of our universe. For Einstein, gravity is no longer a force as it was for Isaac Newton, but a property of the geometry of space and time. Large masses like stars and galaxies produce, so to speak, dents in space-time. If other objects move through such areas, they are deflected from their original path and seemingly attracted by the large mass. But in fact, they follow the shortest distance in space-time, which results in a certain orbit depending on the deformation. If the masses follow an accelerated motion, then the resulting disturbances in the space-time propagate at the speed of light into all directions. These gravitational waves alternately squeeze and stretch space – the distances between objects contained in space change.

Detecting gravitational waves – how GEO600 works

The tiny length changes caused by gravitational waves are measured using a laser interferometer. The principle: A semi-transparent mirror splits an incident laser beam; the two partial beams, which are perpendicular to one another, travel along measurement paths, are reflected, and superimposed on a photodetector. Since the interferometer is set up such that the two returning light waves oscillate with almost exactly opposite phases, they nearly cancel each other out. The output of the interferometer remains almost completely dark. However, a gravitational wave changes the length of the two measurement paths: it stretches one and compresses the other. As a result, the partial beams get out of sync and the brightness at the output changes.

High-tech under a corrugated metal roof: concentrating on the essentials
From the outside, GEO600 looks inconspicuous. However, the container buildings and the two 600-meter-long trenches covered with corrugated metal conceal state-of-the-art technology. The focus here has been on the essentials, creating a large-scale physical experiment of the first order in a simple guise. Technologies are being pushed to their limits and further developed: Laser stabilization, absorption-free optics, control technology, vibration damping, and data processing are given new impulse from the GEO600 scientists.

Not only did they develop novel types of mirror suspensions on glass fibers and other refinements in detector technology. The GEO600 team is pioneering and holding world records in the field of squeezed-light, which changes the quantum mechanical noise in the detector and thus makes the measurement more accurate.



H. Grote/AEI

View of the central cleanroom at GEO600, which brings together high-precision measurement technology in a very small space.

GEO600 in the worldwide interferometer network
GEO600 is part of a worldwide collaboration of gravitational-wave observatories. This includes the two LIGO instruments in the United States, the Virgo detector in Italy, KAGRA in Japan, and the planned LIGO India detector.

Operator and funding
GEO600 is operated jointly by the Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Leibniz University Hannover, and British researchers from Cardiff and Glasgow Universities. The German Federal Ministry of Education and Research, the State of Lower Saxony, the Max Planck Society, the UK Science & Technology Facilities Council (STFC) and the Volkswagen Foundation are additional funding partners.

M. Brinkmann

GEO600 is part of a worldwide collaboration of gravitational-wave observatories in which measurement data are jointly collected, analyzed and evaluated.

H. Lück

The container buildings look inconspicuous from the outside but contain state-of-the-art technology. Technologies are being pushed to their limits and further developed: Laser stabilization, absorption-free optics, control technology, vibration damping, and data processing are given new impulse from the GEO600 scientists.

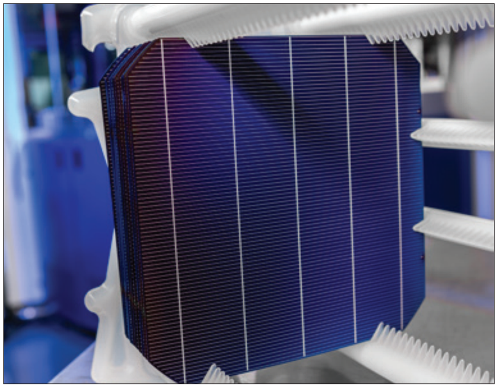
Institute for Solar Energy Research Hamelin

U. Salzmann

Prof. Dr. Rolf Brendel
Executive Director

The Institute for Solar Energy Research Hameln (ISFH) is an affiliated institute of Leibniz University Hannover and home to the Solar Energy Department of the Institute for Solid State Physics. About 160 employees work at the institute on the development of components for the photovoltaic and solar thermal use of solar energy. Converting solar to electricity and heat helps reducing the emission of climate-damaging CO2. In 2019, for example, greenhouse gas emissions of around 28 megatons of CO2 equivalents could be avoided in Germany through the use of solar energy. ISFH researches for the further expansion of this renewable form of energy through scientific understanding, innovation and cost reduction. The institute works with partners from academic research and industry to achieve these goals and offers students the opportunity to write their bachelor's, master's and doctoral theses in a highly interesting environment. The scientific director of the ISFH is Prof. Dr. Rolf Brendel, who, as head of the Solar Energy Department, is also a university professor at the Institute of Solid State Physics. The ISFH is divided into the departments "Photovoltaics" and "Solar Systems Technology".

U. Salzmann



PERC solar cell in 5-busbar design with 21.2% efficiency. This value was the world record for screen printed solar cells in April 2015.

The Photovoltaics (PV) department is engaged in application-oriented research for the industrial implementation of laboratory developments. Fundamental materials research and the analysis of individual solar cells using physical methods are just as much a focus as research into concepts for interconnecting several cells in a module or the manufacturing implementation of individual semiconductor processes. Another area of work is the simulation of the energy transition in Lower Saxony, Germany and Europe. The seven working groups (WGs) consist of interdisciplinary teams with scientists, engineers and technicians from the fields of physics, mechanical engineering and chemistry. They pave the way for technologies with which highly efficient solar cells can be manufactured industrially. Most recently in 2018, for example, ISFH succeeded in setting a world efficiency record of 26.1% for p-type silicon solar cells. The department includes the Hamelin-based WGs "Solar Cell Characterization" (Head: Dr. Karsten Bothe), "Photovoltaic Materials Research" (Prof. Dr. Jan Schmidt), "Future Technologies Photovoltaics" (Dr. Sarah Kajari-Schröder), "Emergent Solar Cell Technologies" (Prof. Dr. Robby Peibst), "Industrial Solar Cells" (Dr. Torsten Dullweber) and "Module Technologies" (Dr. Marc Köntges).

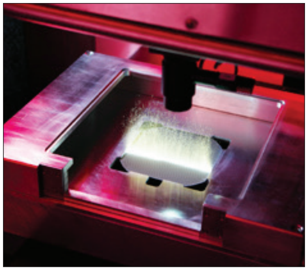
The research activities of the "Solar Systems" department include the integration of solar-generated energy into cost-effective and reliable systems for supplying buildings, processes and entire neighborhoods. We carry out measurements in the field and in the laboratory and analyze them using computer simulations. Research and development focus on heat pump systems, solar collectors and their integration into the building envelope, storage tanks, and efficient domestic hot water preparation. An important point for the integration of solar generated energy is the interaction between solar and non-solar components in energy systems. For this purpose, innovative concepts and control strategies are developed and their implementation is scientifically accompanied. A new field of work is the development of materials and components for hydrogen technologies. The department consists of the working groups "Solar Thermal Materials" (Dr. Rolf Reineke-Koch), "Collectors" (Dr. Federico Giovannetti), "System Components" (Dipl.-Ing. Carsten Lampe), "Thermal Energy Systems" (Dipl.-Ing. Peter Pärisch) and "Electrical Energy Systems" (Dr. Tobias Ohrdes). The simulation work on the energy transition takes place at LUH (Prof. Dr. Rolf Brendel).

The ISFH has extensive equipment: In the field of PV, there are clean room laboratories for 6" silicon technology (wet chemical cleaning, furnace processes, plasma processes), an 800 m² pilot plant (SolarTeC) for the processing of solar cells on industrial machines (PECVD, ICP-CVD, ALD), a laser laboratory with eight laser material processing systems and laboratories for interconnection and module technology (soldering technology, stringing technology). All process steps from the silicon wafer to the finished solar module can be researched. In addition, the institute has a variety of solid-state physical methods for optical and electronic characterization of surfaces and bulk material. These include, for example, a large goniometer for measuring light scattering and various IR-NIR cameras for measuring solar cells and modules.

The Solar Systems Department has indoor and outdoor test stands for extensive performance and serviceability measurements of solar technology components, a climate chamber for investigating heat pumps, and test facilities for aging studies of solar thermal systems. In the new research building "Integrated Solar System Technology (ISS)", research is carried out on the integration of solar energy into existing energy systems on an area of 620 m². Here, the focus is on the dynamic analysis of components and subsystems under realistic operating conditions (hardware-in-the-loop). An overview of all available equipment and methods at the institute as well as possible topics for theses can be found on the institute homepage (www.isfh.de). Visit us! ...on our website or directly in the laboratory in Hamelin: We are happy to offer more information to groups of students (contact: info@isfh.de).


U. Salzmann

Testing a solar thermal vacuum collector


U. Salzmann

Laser processing of SI wafers: Drilling holes into the wafer.


Carsten Janssen

Building of the Institute of Solar Energy Research in Hameln (ISFH).

Laser Zentrum Hannover e. V. – Light for Innovation

J. Leschke/LZH

Dr. Dietmar Kracht
Scientific-Technical Director

private

Prof. Dr.-Ing. Stefan Kaierle
Scientific-Technical Director

Light for innovation - since 1986, the Laser Zentrum Hannover e.V.. (LZH) has been dedicated to the progress of laser technology.

Funded by the Lower Saxony Ministry of Economics, Labor, Transport, and Digitalization, the LZH is dedicated to selflessly promoting applied research in the field of laser technology.

Research, development, consulting as well as education and training in the fields of photonics and laser technology are the central tasks of the LZH with the main research areas:

- Optical components and systems
- Optical production technologies
- Biomedical photonics

The work in the funded research projects is always oriented to the current and future requirements of the industry. In industrial contracts, the focus of the LZH's work is on direct customer benefits.

In addition to these forms of technology transfer, the LZH transmits knowledge in the form of bright minds to industry and research and has thus built up an extensive network across a wide range of industries.

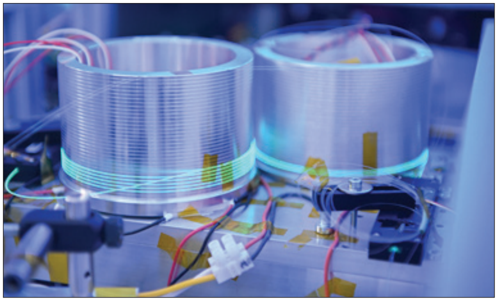
18 successful spin-offs have emerged from the Laser Zentrum Hannover e. V. to date. Approximately 500 jobs have been created in this way, mainly in the Hannover region. Scientists who decide to become self-employed can „grow out" of the institute by renting space and laboratory capacities from the LZH during the start-up phase. If the premises are no longer sufficient, the spatial detachment and establishment occur - preferably in the immediate vicinity.

The LZH creates a substantial transfer between basic science, applied research, and industry. A central prerequisite for this is the intensive regional networking of the LZH: cooperations with various universities in Lower Saxony such as Leibniz University Hannover, Hannover

Photo: LZH

Laser material processing of glass surfaces, among others.

Photo: LZH



Laser systems for gravitational wave detection.

Medical School, Hannover University of Veterinary Medicine, TU Braunschweig, TU Clausthal, and Carl von Ossietzky University Oldenburg.

Participations in the clusters of excellence PhoenixD, QuantumFrontiers, and Hearing-4all as well as in various special research areas such as „Tailored Forming", „Oxygen-free Production", and „Regeneration of Complex Capital Goods" distinguish the LZH.

Furthermore, the LZH is a partner in the Hanover Center for Optical Technologies (HOT), as well as in the Clausthal Center for Materials Engineering of the Clausthal University of Technology, acts as a cooperation partner of the Leibniz University of Hanover at the HITec (Hanover Institute of Technology) and is involved in the interdisciplinary Laboratory for Nano and Quantum Engineering (LNQE), in the research building „SCALE - Scalable Production Systems of the Future", the Lower Saxony Center for Biomedical Engineering, Implant Research and Development (NIFE) and in the „OPTICUM – Optics University Center and Campus".

The interdisciplinary collaboration of natural scientists and engineers enables innovative approaches in various fields: from component development for specific laser systems to process developments for laser applications, such as medical technology or lightweight construction in the automotive sector.

The LZH offers young scientists numerous lectures and a wide range of opportunities for internships, student research assistantships, and theses.

Facts and figures

» Non-university, non-profit research institute for photonics and laser technology.
» Located in the Marienwerder Science and Technology Park
» Total area ~10.000 m²
» Lab ~1.400 m²
» Clean room 300 m²
» 28 laboratories
» Nearly 200 employees, 140 of them scientists

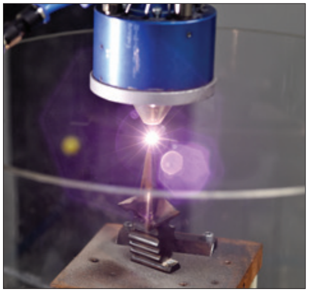


Photo: LZH

Additive manufacturing with powder materials, but also with wire.

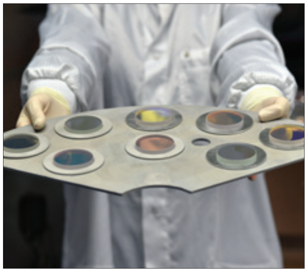


Photo: LZH

Development of special optics.

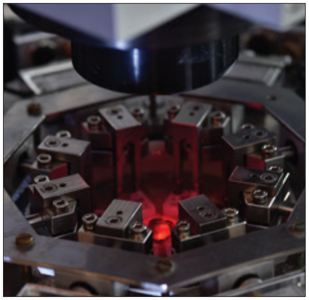


Photo: LZH

Biomedical optics for new laser treatments.

Max Planck Institute for Gravitational Physics

S. Gerhard

Prof. Dr. Bruce Allen
Director

S. Gerhard

Prof. Dr. Karsten Danzmann
Director

The Max Planck Institute for Gravitational Physics (Albert Einstein Institute; AEI) in Hannover collaborates closely with the Institute for Gravitational Physics at Leibniz University Hannover. Together, the two institutes play a leading role in gravitational physics and gravitational-wave astronomy. This includes the development of sensitive measurement technology and highly efficient data analysis methods. The institutes are responsible for the construction, operation and further development of the GEO600 gravitational-wave detector. Researchers from the institutes lead the preparation of LISA, the gravitational-wave observatory in space, and are important partners in the GRACE Follow-on satellite mission. To analyze the data from the international network of gravitational-wave detectors, they develop efficient mathematical methods and operate the powerful computer cluster Atlas. The distributed computing project Einstein@Home involves volunteers from around the world in the search for neutron stars and gravitational waves.

The Max Planck Institute for Gravitational Physics
has established itself as a leading international research center since its foundation in 1995. Here, the entire spectrum of gravitational physics is investigated in five departments (two in Hannover and three in Potsdam) and in several independent junior research groups. The unification of all these important research branches under one roof is unique worldwide.

In 2002, the Albert Einstein Institute established a sub-institute in Hannover, which is dedicated to data analysis and the development of gravitational-wave detectors on Earth and in space. At the "Center for Gravitational Physics", the Max Planck Institute for Gravitational Physics works closely with Leibniz University Hannover. The sub-institute in Hannover has two departments: "Observational Relativity and Cosmology" led by Prof. Dr. Bruce Allen and "Laser Interferometry and Gravitational Wave Astronomy" led by Prof. Dr. Karsten Danzmann.

Observational Relativity and Cosmology
The department employs a data-driven approach to make new discoveries in relativity, astronomy, and cosmology.

The worldwide network of Earth-based gravitational-wave observatories collects very large amounts of data. Analyzing their public data with advanced methods and detecting gravitational waves from different astronomical sources is the central research focus of the Observational Relativity and Cosmology department at AEI. The department has the skills, experience, and computational resources to independently search and analyze data from gravitational-wave detectors. To this end, novel sophisticated mathematical methods are developed here and a computer cluster is operated. The custom-built "Atlas" computer cluster is the world's most powerful dedicated resource for the analysis of gravitational-wave data. It has more than 23 petabytes of total storage and about 99,000 logical CPU cores and 2,400 GPUs housed in 3,200 compute servers.

A second focus is the application of novel methods for the search for unknown neutron stars. Data from electromagnetic observatories as well as gravitational-wave data are used for this purpose. The department also operates the volunteer distributed computing project Einstein@Home in collaboration with the University of Wisconsin-Milwaukee. As part of this worldwide project, anyone can participate in the search for previously unknown neutron stars at home using their PC, laptop or smartphone. More than 80 new neutron stars have already been discovered in data from radio telescopes and the Fermi satellite. The institute also carries out the most sensitive searches for (as yet undetected) continuous gravitational waves.

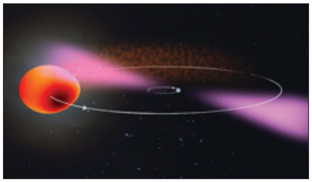
Laser Interferometry and Gravitational Wave Astronomy

After decades of research, gravitational-wave research has finally reached its goal: Today's observatories have achieved the sensitivity required for direct detection of gravitational waves. Ninety signals observed as of now and completely new insights into our universe are witnesses to this success. Scientists of the "Laser Interferometry and Gravitational Wave Astronomy" department are world leaders in this area. Together with British colleagues, they operate the GEO600 gravitational-wave detector and develop new state-of-the-art technology. Many of the methods developed at AEI – such as the high-power laser systems of the detectors – are used in all major gravitational-wave observatories in the world. In this international collaboration, the institutes are making key contributions to the technology of future detectors. The AEI is also significantly involved in the development of the "Einstein Telescope", the European third-generation gravitational-wave detector.

The most spectacular project for gravitational-wave detection is certainly LISA, the "Laser Interferometer Space Antenna" - a gravitational-wave observatory led by the European Space Agency ESA, which is scheduled to be launched into space in 2034. The institutes are the world's leading research institutions in the development of the project, which will span laser arms millions of kilometers long between three satellites. This will make LISA sensitive enough to hear gravitational-wave signals from across the entire universe. LISA Pathfinder, an ESA test mission for LISA involved researchers from both institutes and demonstrated the viability of key LISA technologies. The institutes are contributing a laser interferometer to the gravimetry mission GRACE Follow-On, making available gravitational-wave technology from basic research for climate research already today.

B. Knispel/AEI

The Institute for Gravitational Physics of the Leibniz University Hannover and the Max Planck Institute for Gravitational Physics collaborate closely together.



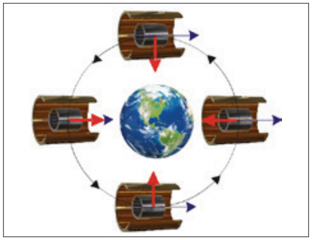
Knispel/Clark/MPI für Gravitationsphysik/NASA GSFC

The Division „Observational Relativity and Cosmology" develops methods to efficiently analyze very large amounts of data from gravitational-wave detectors and other telescopes. Many astronomical discoveries have already been made, including PSR J2039-5617, which is a rapidly rotating neutron star in an exotic binary system.

Center of Applied Space Technology and Microgravity (ZARM)

S. Gerhard

Prof. Dr. Domenico Giulini
Leader of Research Group »Quantum Theory and Gravity« and PI in the Research Training Group »Models of Gravity«



In the MICROSCOPE mission, the free fall of two cylindrical masses on a platinum-rhodium alloy and titanium, respectively, is studied. From measurements of the relative acceleration, the equivalence principle can be tested more precisely than before.

The center for Applied Space Technology and Microgravity (ZARM) is a scientific institute within the Faculty of Production Engineering at the University of Bremen. Its central large-scale laboratory is the Bremen Drop Tower with a height of 146 meters. It is used for earth-bound experiments under high-quality weightlessness conditions of almost 5 seconds. Using the in-ground catapult the free-fall time span may be doubled. The expertise of ZARM sci-entists was, and still is, essential for the design, planning, and operation of the »Einstein-Elevator« at the Hannover Institute of Technology (HITec).

A central field of scientific activity at ZARM concerns fundamental gravitational physics. This includes the conduction of high-precision free-fall experiments, the development of tech-nologies for space science, and the collaboration at planning stages as well as the actual conduction of experiments in space. Theoretical gravity-research mainly concerns problems of General Relativity and its generalisations, in particular questions concerning the relation between theories of gravity one one side, and Quantum Mechanics as well as Quantum Field Theory on the other.   Research activities at ZARM are strongly linked with internation-al research-networks. They comprise the construction of small satellites, high-precision steering and navigation, the development of navigational systems, and, at the fundamental-physics-end of the spectrum, the planning, conduction, and evaluation of experiments on Einstein's equivalence principle.

ZARM is a partner of the space mission LISA (Laser Interferometer Space Antenna) and LISA Pathfinder of ESA/NASA. As part of its PhD program it runs, together with the University of Oldenburg, the Research Training Group »Models of Gravity« in which the ITP Hannover is represented with own research groups and PhD positions. Moreover, ZARM scientists are part of the Collaborative Research Centre »Relativistic and quantum-based geodesy« (Prof. Müller) of the Institute of Geodesy at Leibnitz University and also of the Cluster of Excel-lence »Quantum Frontiers« of the Leibnitz University of Hanover and the University of Braunschweig.

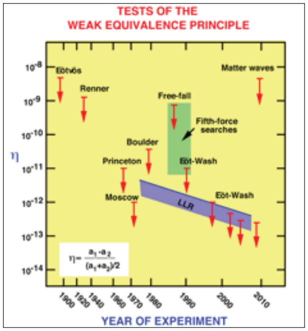
Scientist at ZARM and at the University of Hannover share common interests and research projects, as shall now be explained in some more detail. Our current understanding of gravi-ty rests on Einstein's General Theory of Relativity, formulated in 1915. An essential ingredi-ent of this theory is the so-called Equivalence Principle, according to which the ratio of iner-tial and gravitational mass is a universal constant, independent of the other properties of matter. The purely geometric formulation for gravity that General Relativity achieves, in which all gravitational phenomena relate exclusively to the geometry of spacetime for all matter components, rests essentially on the validity of this principle. Any violation of it would necessitate fundamental revisions in our understanding of gravity. On the other side, such violations may be accommodated in extended theories, like String-Theory or certain models of Quantum Gravity. Hence, any phenomenological hint towards such violations may give us valuable insights into the yet insufficiently understood relation between gravity and Quantum Theory, as well as on the structure of possible higher-order theories. Theoret-ical investigations into such possibilities and theories are conducted by groups at the ITP of the Leibnitz University of Hannover (Professors Giulini, Lechtenfeld).

ZARM has been part of ESA's MICROSCOPE mission in the years 2016-2018, which aims to improve existing tests of the Equivalence Principle by two orders of magnitude. Currently the evaluation of the data is still ongoing, but it can already be said that the mission has been a successfully accomplished and that expectations are high. This satellite-based ex-periment used macroscopic test-masses of different composition that can be described without involving any Quantum Mechanics. This will change in future-planned tests in col-laboration with scientists from the IQO at Leibnitz University of Hannover (group Professor Rasel), in which just the typical quantum-mechanical properties of matter, in particular those exhibited in matter-wave interferometry, shall be exploited. Preliminary studies for this are the QUANTUS (Quantengase unter Schwerelosigkeit) project, which is ongoing since 2004, as well s its follow-up project QUANTUS II. The aim of these projects is to serve as a feasibility study, partly already successfully, that ultra-cold quantum gases (Bose-Einstein condensate) made from atoms of Rubidium-87 can be used as high-precision quantum sen-sors for tiny inertial forces. Moreover, the more recent PRIMUS (Präzisionsinterferometrie mit Materiewellen unter Schwerelosigkeit) project investigates the possibility of matter-wave interferometry in free-fall for matter waves of different matter components. Their high sensitivity concerning violations of the Equivalence Principle in combination with sufficient-ly long periods of free-fall are expected to open up new possibilities for tests of the Equiva-lence Principle, though these would have to be space-based (satellite of Space-Station). First steps towards space tests were taken with the MAIUS (Matter-Wave Interferometry in Mi-crogravity) mission, which successfully demonstrated the feasibility of creating a Bose-Einstein condensate and performing atom interferometry aboard a sounding rocket with Rubidium 87 atoms. Looking ahead, a common DLR-NASA Mission to the ISS is planned in order to conduct experiments at its »Cold Atom Lab« under conditions of long-time weightlessness.

In oder to exemplify the many cross-border activities we finally mention some recent exper-imental work that took advantage of the misguided satellites Galileo 5 und 6 in oder to im-prove on the currently best tests of the effect of gravitational-redshift by a factor of 5. This effect is one of the integral predictions of General Relativity which has recently also been employed as a novel measurement device for practical geodesy. These new techniques give rise to a new and rigorously general-relativistic formulation of geodesy by theoreticians at ZARM and Leibnitz University of Hannover.

Stefan Schmidbauer

View of the inside of the drop tube with a typical a typically shaped drop capsule.



Clifford M. Will

Since the first precision experiments by the Hungarian Baron Lorand Eötvös in 1906-09, the equality of heavy and inertial mass has been verified with an accuracy increased by five orders of magnitude. The MICROSCOPE mission adds another two orders of magnitude.

Leibniz Universität Hannover

Structures MaPhy

Handbook of the Faculty of Mathematics and Physics

Laboratory of Nano and Quantum Engineering (LNQE)

GEML

Prof. Dr.-Ing. Stefan Zimmermann
Speaker of the LNQE Board

O. Kerker

Dr. Fritz Schulze-Wischeler
Chief Operating Officer

The Laboratory of Nano and Quantum Engineering (LNQE) is an interdisciplinary research centre of Leibniz University Hannover in the field of nanotechnology. Leibniz Research Centres stand for an international and high scientific visibility of interdisciplinary research areas. Cooperation extends across subject and faculty boundaries and also includes the participation of external research institutions. Currently, more than 30 research groups from physics, chemistry and engineering are involved. To realise its goals, the LNQE operates a jointly used research building in Hannover with laboratories, equipment, etc., and especially clean rooms. In teaching, the LNQE is in charge of the B. Sc. and M. Sc. degree programmes in nanotechnology and the nanotechnology doctoral programme "Hannover School for Nanotechnology".

The working groups of the LNQE collaborate interdisciplinarily across disciplinary boundaries in the field of nanotechnology. The terms nanoengineering, nanoanalytics and nanomaterials characterise the research of the LNQE. In addition, the LNQE focuses on (currently) four application fields of nanotechnology: energy research, sensor technology, digitalisation and biomedical technology & nanomedicine.

Nanotechnology describes the exploration and manipulation of things on the smallest dimensions. It deals with structures in the size range of 1-100 nanometres in at least one spatial direction. 100 nanometres are approximately one thousandth of the diameter of a normal human hair. At these small dimensions, surface properties increasingly come to the fore compared to the volume properties of the materials, and in addition, quantum physical effects often have to be taken into account.

Nanoengineering is engineering on the nanoscale, i.e. the targeted artificial production of nanotechnology structures, such as tiny transistors on computer chips. The term quantum engineering, which is closely related to nanoengineering, aims at the creation and manipulation of a defined quantum state, such as the realisation of a Bose-Einstein condensate or a device with specifically adjusted electron spin. The size of such systems is often also in the nanometre range.

The artificially created structures and materials are examined and analysed in many different ways. Nanoanalytics, i.e. analysis in the nanometre range, requires the most diverse and latest equipment and procedures. The necessary technological equipment is available to the working groups centrally in the LNQE research building and is supplemented by the equipment in the institutes.

Nanomaterials are substances of various shapes and compositions with sizes in the nanometre range. Such materials are produced and investigated in a wide variety of ways at the LNQE. Due to their small dimensions, individual particles of nanomaterials, often referred to as nanoparticles, possess special chemical and physical properties that differ from the properties of macroscopic particles and solids. The production of nanoparticles with specifically adjustable properties, the utilisation of nanoparticles for specific applications and the basic physical understanding of nanoparticles and their mode of action are at the forefront of the work at the LNQE.

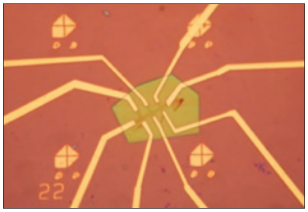
The conversion, transport and storage of energy are fundamental issues for the future of our society. Research into these processes on the nanoscale is a research focus of the LNQE. In the field of sensor technology, nanotechnology is playing an increasingly important role. Sensors with nanoscale surfaces, sensors that transfer information from the nanoscopic world to the macroscopic world and sensors that use nanoeffects as a sensor principle can be defined collectively as nanosensors. With digitalisation, the need for low-cost highly integrated data and computing storage continues to grow. New materials are needed to realise structures in the nanometre range and, in particular, to arrange them in order to use them as data and computing memories. The LNQE researches how quantum mechanical states for quantum computing can be realised with nano and quantum technologies.

To realise its goals, the LNQE operates its own research building in Hannover. The laboratories, the research clean room and the office space are used for interdisciplinary projects, especially from successfully acquired, larger third-party funded projects of the members. The new building was specially funded with federal funds following a recommendation by the German Science Council as a research building (according to Art. 91b of the German Basic Law).

The nanotechnology degree programme initiated by the LNQE teaches the basics in the core subjects of chemistry, electrical engineering, mechanical engineering, and physics (supplemented by mathematics), with special attention paid to the requirements arising from nanotechnology. Already in the course of the Bachelor's degree programme, students then specialise in one scientific and one engineering core subject. In the Master's programme, students have a wide range of options with various elective fields of competence to qualify themselves in current research areas of nanotechnology. In total, the two degree programmes together have over 300 students.

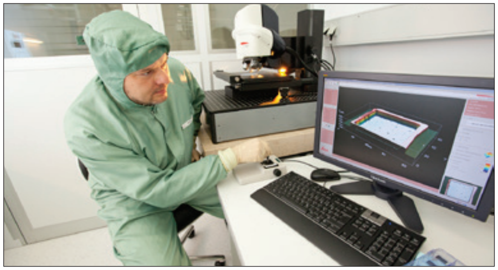
Harke, Haug

A quantum dot created with an atomic force microscope. Electrical measurements at the quantum dot show the charge transport of individual electrons.



Lüdtke, Haug

Quantum physics in bilayer graphene. The graphene is structured in a Hall bar geometry and is electrically characterized at low temperatures and high magnetic fields.


B. Kremmin

The central component of the LNQE research building is the clean room. It is certified according to ISO5/RK 100 in the work areas and ISO6/RK1000 in the corridors. The main area (409 square meters) of the clean room is divided into several subrooms, where the technology for nanostructuring. Due to the division into two lithography areas allows the processing of elemental semiconductors as well as compound semiconductors.


L. David

LNQE Research Building at Schneiderberg 39, 30167 Hannover, Germany.

Hannover Institute of Technology – HITec

C. Wyrwa

Prof. Dr. Christian Ospelkaus
Speaker of the HITec Board

S. Gerhard

Alexander Wanner
Management

S. Gerhard

Tobias Froböse
Technical management

The Hannover Institute of Technology, HITec, was established at Leibniz University Hannover as a unique research center with a cross-topic infrastructure for quantum technologies. With the participation of the physics, geodesy and engineering sciences, the topics focus on fundamental and applied research as well as technology development in the fields of quantum physics and geodesy.

At HITec, fundamental questions of physics are investigated, such as „Are the constants of nature really constant?" For Earth observation, novel sensors and methods are being developed to detect both local and global mass changes, for example ice mass loss due to the consequences of global warming, with previously unattainable quality.

On an area of approx. 1,500 sqm state-of-the-art laboratories are available for 100 to 120 researchers equipped to the highest technological standards. In addition to laser laboratories as well as measurement rooms on the roof, the HITec building is home to three large scale facilities. A twelve-meter-high fiber-drawing apparatus is used for the production of laser-active fibers for space-applications. The ten-meter atomic fountain „Very Large Baseline Atom Interferometer" (VLBAI) is a multifunctional experimental platform for atom-interferometric inertial sensors for geodesy and fundamental research in physics. In the Einstein-Elevator, a 40 meter drop tower, not only fundamental physics experiments but also engineering experiments for new technologies are carried out under zero-gravity conditions.

The development and testing of highly accurate quantum sensors require special laboratory conditions, especially with respect to temperature stability, vibration decoupling of building components and the ground, and a dedicated clean room environment. In addition, a measurement roof is available which provides a direct view to satellites.

This infrastructure does not yet exist in this form either at Leibniz University Hannover or at HITec partner institutions, or in the national environment, were realised by the new research building. This secures Hannover a prominent position in the world's scientific competition worldwide in the medium and long term and creates a highly attractive platform for international researchers in Germany as an interdisciplinary science center.

Carpus+Partner AG

HITec is an interdisciplinary research facility of the QUEST Leibniz Research School and unites under one roof laboratories from the fields of physics, geodesy and engineering sciences. The laboratory building is connected to the office building by a glass passageway to ensure short distances to the measuring stations and laboratories.

Lower Saxony Centre for Biomedical Engineering, Implant Research and Development (NIFE)

NIFE, the Lower Saxony Centre for Biomedical Engineering, Implant Research and Development, emerged from a scientific initiative of the Hannover Medical School (MHH), Leibniz University Hannover (LUH) and the Foundation of the University of Veterinary Medicine Hannover (TiHo) in cooperation with the Laser Zentrum Hannover (LZH).

The NIFE research programme aims to develop biological, biofunctionalised and infection-resistant implants for the reconstruction and functional restoration of failed organ functions in the cardiovascular, audio-neurological, musculoskeletal and dental fields.

Figure 1 shows the interlocking of the various disciplines and subject areas. By applying laser structuring methods (Chichkov LUH), the colonisation of surfaces with fibroblasts can be promoted. In the context of material development, materials are being developed that promote rapid ingrowth but suppress biofilm formation at the penetration site. Within the framework of in-vitro investigations (non-invasive observation, Heisterkamp, LUH, LZH) and in-vivo investigations at the MHH, a rapid translation of the researched implant technologies can be achieved.

In the field of biohybrids, the colonisation of implants with cells represents a special focus. In close methodological connection with the focus on tissue engineering, cell sources are to be found here, adhesion mechanisms developed and tests undertaken in order to develop optimal healing. Figure 2 shows an example of the carrier matrix of native lung tissue (red: elastin fibres, green: collagen matrix), which is to be imitated by corresponding artificial carrier structures, so-called scaffolds, and colonised with cells.

Infections caused by bacterial biofilms play a decisive role in the development of innovative implants. Implants to which bacteria can adhere result in inflammatory reactions, and the associated processes lead to loss of function of the implant and considerable impairment of the patient. Figure 3 shows a metallic dental implant after colonisation with a biofilm in vitro (Heisterkamp LUH/LZH, Stiesch MHH). Through the development of suitable optical laser scanning microscopy techniques, metallic surfaces can also be measured in 3D with high resolution and the fouling of structured implants can be modelled and examined in the laboratory over longer periods of time.

Meike Stiesch

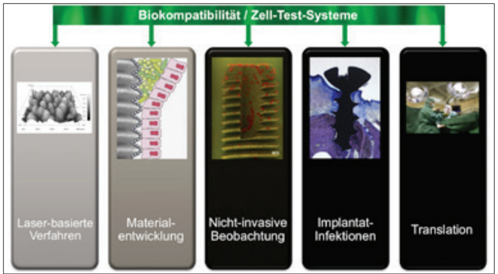


Figure 1

Tobias Ehmke

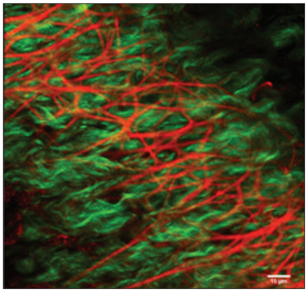


Figure 2

Marko Heidrich

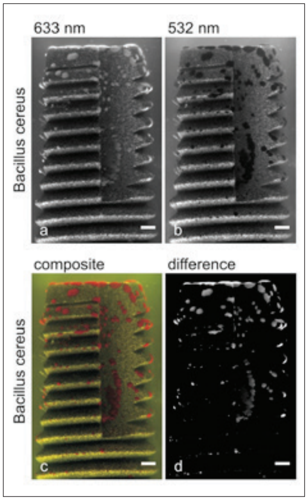


Figure 3

Leibniz
Universität
Hannover

Research MaPhy

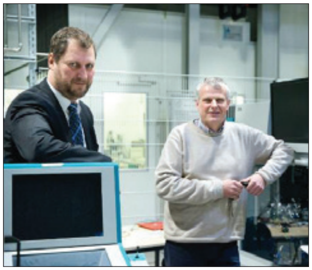
Handbook of the Faculty of Mathematics and Physics

Opticum – University Center and Campus

Henn

The planned, four-storey building of the OPTICUM has a usable floor space of app. 4,000 square metres. Construction is scheduled to begin in 2022. Completion is planned for 2026.

Sonja Smalian/PhoenixD



They jointly manage the OPTICUM: Prof. Dr. Uwe Morgner (left), spokesman of the board of the Cluster of Excellence PhoenixD and chairman of the Leibniz Research School of Optics and Photonics (LSO), and Prof. Dr.-Ing. Ludger Overmeyer, member of the board of PhoenixD and deputy chairman of the LSO.

On 23.04.2021, the German Science Council (Wissenschaftsrat) recommended the funding of the research building „OPTICUM - Optics University Center and Campus" at Leibniz University Hannover (LUH).

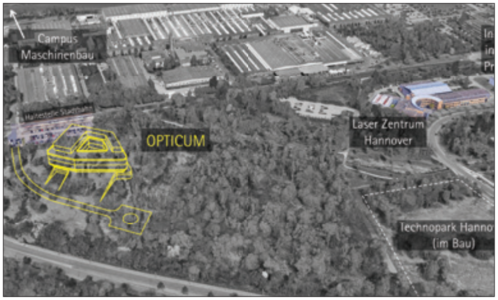
The Cluster of Excellence PhoenixD: Photonics, Optics, and Engineering - Innovation across Disciplines at LUH had applied for the new research building. In the OPTICUM, 120 researchers from physics, mechanical engineering, electrical engineering, mathematics, computer science and chemistry will develop the precision optics of the future in an interdisciplinary manner under one roof. Together, the optics researchers are investigating how complex optical systems can be realised for a fraction of today's price in a short development time using modern manufacturing processes - for example, 3D printing.

The Leibniz School of Optics & Photonics (LSO), founded in spring 2020, manages the OPTICUM. It is closely linked to the Cluster of Excellence PhoenixD and is equivalent to a faculty in its structure.

The research building, which costs around 54 million euros, is financed half by the federal government and half by Lower Saxony. Construction of the 4,000 square metre building is scheduled to begin in 2022. Completion is planned for 2026. Even during the construction phase, LUH is procuring large-scale equipment for the production halls worth twelve million euros, among other things from funds from its Cluster of Excellence PhoenixD and the European Structural Fund.

With the OPTICUM, LUH is bundling the research activities of optics, production technology, materials development and computer science that have existed for decades in one location near the Mechanical Engineering Campus of Leibniz University Hannover in Garbsen.

The members of the Leibniz Research School for Optics & Photonics are recruited from four faculties – Mathematics and Physics, Electrical Engineering and Computer Science, Mechanical Engineering and the Faculty of Natural Sciences. Together with the participating institutions and facilities, the Leibniz Research School of Optics & Photonics conducts appointment and doctoral procedures. It also initiates and designs the establishment of new study programmes. One of the Leibniz School of Optics & Photonics strengths is the integration of both university and non-university institutions. In addition to the various institutes and facilities of the LUH, the Laser Zentrum Hannover e.V., the Max Planck Institute for Gravitational Physics (Albert Einstein Institute), the Technical University of Braunschweig and the Physikalisch-Technische Bundesanstalt (Braunschweig) are also involved.



Henn and Reinhard Caspary/LUH with materials from Google Maps

The OPTICUM research building will be constructed in the Hannover-Marienwerder Science Park. The location on Pascalstraße will be accessible via a tram stop and is near the Laser Zentrum Hannover e. V. and the participating institutes on the mechanical engineering campus of the LUH in Garbsen. The Technology Centre, the Institute for Integrated Production and the Technopark Hannover, currently under construction, is also located in the neighbourhood.

The PhoenixD Cluster of Excellence

Smartphone cameras, online streaming via optical fibre, laser welding of car bodies and 3D imaging in medicine - optical technologies make our everyday digital life possible. Further developing these key technologies' performance is the goal of the Cluster of Excellence PhoenixD: Photonics, Optics, and Engineering - Innovation across Disciplines at Leibniz University Hannover (LUH). The German federal government and Lower Saxony are jointly funding the Cluster of Excellence PhoenixD through the German Research Foundation (DFG) with around 52 million euros from 2019 to 2025.

More than 110 researchers from the six disciplines of physics, mechanical engineering, chemistry, electrical engineering, computer science, and mathematics are developing the future's precision optics. The optics researchers are investigating how complex optical systems can be realised for a fraction of today's price in a short development time using modern manufacturing processes - for example, 3D printing. The desired paradigm shift in optics production is made possible by two trends: more powerful data processing and improved additive manufacturing methods. They enable the researchers to realise a digitally and physically networked production platform for optical components and systems.

At LUH alone, the cluster of excellence's members come from the four faculties of Mathematics and Physics, Electrical Engineering and Computer Science, Mechanical Engineering, and the Faculty of Natural Sciences. Numerous facilities and institutes are involved in the cluster, including the Institute of Quantum Optics (IQ), the Institute of Photonics (IOP), the HOT – Hanover Centre for Optical Technologies, the Institute of Inorganic Chemistry, Institute of Physical Chemistry and Electrochemistry (PCI) as well as the production technology institutes of Transport and Automation Technology (ITA), for Product Development (IPeG), of Assembly Technology (match), of Materials Science (IW), of Production Engineering and Machine Tools (IFW) and of Micro Production Technology (IMPT).

Other collaborative institutions in the cluster are the Max Planck Institute for Gravitational Physics (Albert Einstein Institute), the Laser Zentrum Hannover e.V., the Technische Universität Braunschweig and the Physikalisch-Technische Bundesanstalt. To further bundle its scientific expertise in the field of optics, LUH founded the Leibniz School of Optics & Photonics (LSO) in spring 2020. The LSO is closely linked to the Cluster of Excellence PhoenixD and is equivalent to a faculty in its structure. Initially, the PhoenixD members will still work at different locations in Hannover and Braunschweig. At the end of 2021, some research areas will move into two buildings on the Welfengarten campus. From the end of 2026, the scientists will then work together under one roof in the new LUH research building OPTICUM - Optics University Center and Campus in Marienwerder Science Park.

With the PhoenixD graduate school, the cluster offers the opportunity to do a doctorate and enter a scientific career. The Master's degree programme Optical Technologies, which is also provided in English, prepares students for a job in the optical technologies' growth industry. A subject-specific Bachelor's programme is being planned. In cooperation with the Hannover Medical School, the cluster is a partner in the „Voluntary Scientific Year" programme to inspire the next generation of scientists for STEM subjects and enable them to make a well-founded study decision.

Further information: www.phoenixd.uni-hannover.de


PhoenixD

Speaker
Prof. Dr. Uwe Morgner


PhoenixD

Board of Directors
Prof. Dr.-Ing. Ludger Overmeyer


PhoenixD

Board of Directors
Prof. Dr. Wolfgang Kowalsky


PhoenixD

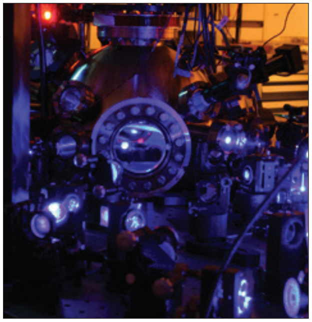
Managing Director
Dr. Sebastian Dikty

The Cluster of Excellence QuantumFrontiers

S. Gerhard

Prof. Dr. Karsten Danzmann
Speaker

Chr. Lisdat/PTB



Strontium atom cloud at a few millikelvin above absolute zero in PTB's optical lattice clock

In QuantumFrontiers, we use light and matter to extend fundamental research and application of metrology beyond the quantum limits. Leibniz University Hannover, TU Braunschweig and Physikalisch-Technische Bundesanstalt (PTB), as well as the Center for Applied Space Technology and Microgravity (ZARM) in Bremen, Laser Zentrum Hannover and Max Planck Institute for Gravitational Physics (Albert Einstein Institute) are participating in the cluster.

The mission of QuantumFrontiers is to combine quantum metrology and nanometrology to advance to the next level of measurement sensitivity and precision, and to push the boundaries of knowledge at the largest and smallest scales: from gravitational wave astronomy to the manipulation of light and matter at the quantum level. QuantumFrontiers researchers benefit from an internationally unique infrastructure of regional facilities and contributes to the technical progress of large international research collaborations in a wider range of disciplines. More than 300 researchers from the disciplines of geodesy, quantum optics, laser science, solid-state physics, electrical engineering, gravitational physics, nanotechnology, and quantum metrology study light and matter at the quantum frontier. This means that they are using quantum metrology and nanometrology to improve the sensitivity and precision of measurements, i.e., the fundamentals of metrology. These advances in the fundamentals of metrology enable new precision measurements and measurement techniques that allow us to better understand nature at the smallest and largest scales.

The QuantumFrontiers consortium has state-of-the-art laboratories with extensive infrastructure facilities such as the GEO600, the Hannover Institute of Technology (HITec), Laboratory of Nano and Quantum Engineering (LNQE), clean room and equipment of the Institute of Micro Production Technology (IMPT) at Leibniz University Hannover, as well as the Epitaxy Competence Center (ec2) of the TU Braunschweig, the Clean Room Center of the PTB and, in the future, the newly founded DLR Institute for Satellite Geodesy and Inertial Sensing (DLR-SI).

Structured PhD programs of the participating institutions are organized and supported in the QuantumFrontiers International Research School (QFIRS). QFIRS provides early career researchers with specific support in quantum and nanosciences and an intensive program for team building, teaching scientific skills and transferable skills.

QuantumFrontiers MasterClasses offer one-day workshops on current topics in quantum metrology for high school students. The learners are introduced to topics of current research based on their skills acquired in physics and mathematics classes.

The QuantumFrontiers Entrepreneur Excellence Program (QuEEP) ensures that cutting-edge research from QuantumFrontiers can be quickly and efficiently transferred into application. Only when research results promise progress for society, they become visible and usable on a broad scale.QuEEP identifies researchers in the cluster and motivates them to view their basic research results through the eyes of potential users. The aim is to turn cutting-edge research into „real" products.

Further information: www.quantumfrontiers.de

The Cluster of Excellence Hearing4all

In the Cluster of Excellence Hearing4all (H4a), the Oldenburg and Hannover sites are working on improving hearing in various fields of hearing aids and hearing implants. The goal of the cluster is literally „hearing for all"!

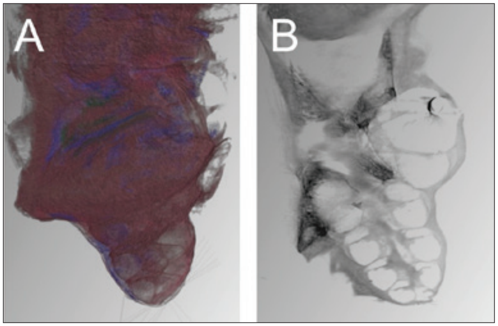
This includes improving diagnostics and care for those affected with regard to personal hearing aids.

At the Hannover site in particular, new technologies for so-called cochlear implants and other hearing implants are being researched in cooperation between Leibniz University and the Medical University. In addition to the use of optical technologies for surface structuring or even direct stimulation of auditory impressions (optical cochlea implant), various optical methods for characterising and analysing tissue samples are used in this research network. Prof. Heisterkamp's research group at Leibniz University Hannover uses optical methods, such as Raman-based methods, to optically evaluate the composition of the fluid in the cochlea (perilymph) and correlate it with disease patterns. The imaging procedures established at the LZH are used in various areas for 3D measurement of the cochlea (optical tomography after clearing/decalcification). These images are used on the one hand for construction space analysis as a basis for model calculations, and on the other hand for the development of new cochlear implants that better adapt to the anatomical conditions. Within the current 2nd phase of funding, the cluster is particularly investigating further procedures for optical excitation and extended diagnostic procedures via photonic technologies, which are to be established on site at NIFE.

Hearing4All logo

Kaiser/MHH, Montage HNO der MHH

The researchers from H4A at the ENT Clinic of the MHH, such as Prof. Dr. Athanasia Warnecke here, are working on the protection and regeneration of the hair cells in the inner ear.

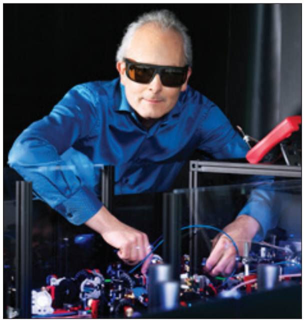


Cochlea including arch canals with silicone implant, reconstructed and rendered data (A) and sectional imaging (B) using SLOT

H. Meyer, LZH, O. Madjdani, MHH

Collaborative Research Centre 1227 – Designed Quantum States of Matter (DQ-*mat*)

PTB



DQ-*mat* Spokesperson Prof. Piet Schmidt aligning a spectroscopy laser system for highly charged Argon

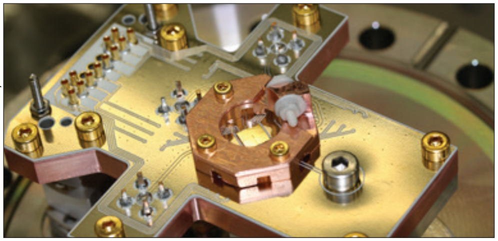
Leibniz University Hannover

Generation, manipulation, and detection for metrological applications and tests of fundamental physics

The vision of DQ-mat is to redefine the limits of conventional physics by entering the world of quantum mechanics and its fascinating properties such as entanglement or superposition. It was only the understanding of the principles of quantum effects that enabled researchers to develop numerous technologies that are now an inherent part of our lives - such as lasers or navigation systems.

Research in understanding and controlling quantum systems comprising single atoms or molecules is quite advanced. DQ-mat researchers intend to apply this knowledge to larger, interacting systems. Controlling many-body effects will enable them to develop quantum sensors - including atomic clocks for measuring time or atom interferometers for measuring accelerations - with an accuracy and resolution not feasible to date. In addition, the researchers aim to look into new levels of fundamental physics such as exploring the possibility of changing universal constants or determining candidates for dark matter.

Leibniz University Hannover



Prototype of an ion trap with integrated microwave circuits

During the first funding period, DQ-mat laid the essential foundations. For example, the members tested a new sensor concept with linked light fields while developing a novel cooling procedure simplifying quantum simulators, as well as preparing initial steps for building quantum computers using ions or proving the entanglement of several thousand atoms. In order to gain a better understanding of fundamental physics, these activities are continued and applied in new contexts in the ongoing second funding period.

By establishing the foeXlab for school pupils, the collaborative research centre aims to fill the gap between actual research and the public perception of quantum physics. While quantum physics is a highly-relevant topic for the future, schools often focus on imparting theoretical knowledge. The foeXlab provides hands-on experiments in the field of interferometry with real quantum states of light and has been successfully established within the „Bildungsregion Hannover".

The collaborative research centre 1227 "Designed Quantum States of Matter (DQ-mat)" is a cooperation between Leibniz University Hannover and the Physikalisch Technische Bundesanstalt in Braunschweig. Speaker is Prof. Dr. Piet O. Schmidt. It was launched in July 2016 and has been extended until June 2024. It may be extended one more time for a further four years.

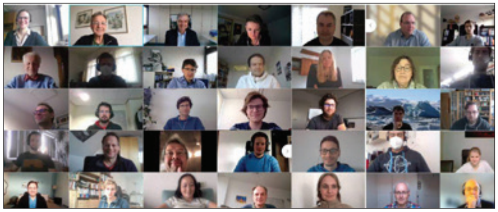
Collaborative Research Center 1464 "Relativistic and Quantum-based Geodesy (TerraQ)"

Climate change processes are widely imprinted in gravitational data. But better temporal and spatial resolution and higher accuracy are required to monitor the related mass changes, which can only be achieved by employing innovative quantum technology concepts. This shall be achieved by our collaborative research center (CRC) TerraQ.

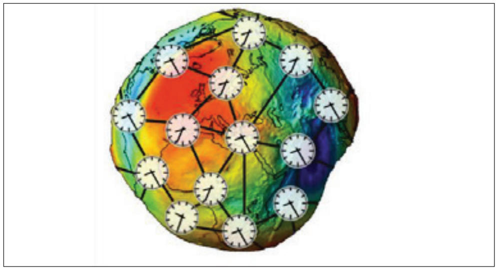
Since the start of TerraQ on January 1st, 2021, scientists from Leibniz University Hannover, DLR-Institut für Satellitengeodäsie und Inertialsensorik Hannover, Physikalisch Technische Bundesanstalt Braunschweig, Zentrum für angewandte Raumfahrttechnologie und Mikrogravitation Bremen, GeoForschungsZentrum Potsdam, HafenCity Universität Hamburg und Technische Universität Graz are facing that challenge together.

The Leibniz University Hannover is the leading partner with the institutes of Geodesy, Quantum Optics, and Gravitational Physics being involved and the spokesperson of the CRC Prof. Dr. Jürgen Müller coming from the Institute of Geodesy.

TerraQ integrates expertise from geodesy and physics in a unique constellation to develop fundamentally new sensors, measurement techniques and analysis methods. Optical ranging between test masses and satellites, atom-interferometric accelerometry and gradiometry, and chronometric levelling with clocks are the required approaches to overcome the problems of classical concepts. Dedicated geodetic and relativistic modelling of the various involved gravity field quantities will be performed to firmly show the superior performance of the new approaches compared to the conventional ones.



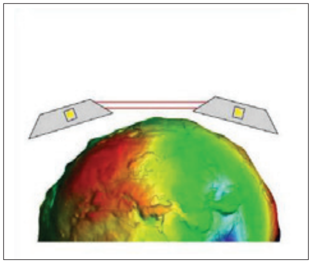
Some TerraQ members during the first general assembly of the CRC 1464.



Networks of optical clocks

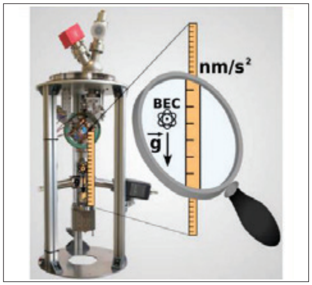
TerraQ pioneers the concept of chronometric levelling for the realisation of physical height systems and gravity field observations

With these novel techniques, mass variations on almost all spatial and temporal scales can be observed with unprecedented accuracy and will serve as input for a multitude of applications in the geosciences, from the monitoring of local groundwater basins to the observation of the complex global mass transport processes in the oceans.



Laser interferometry for satellite gravimetry

TerraQ investigates laser-interferometric systems for ranging between test masses in Earth orbits to advance satellite gravimetry.

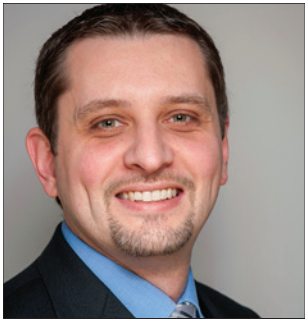


Atomic gravity sensors

TerraQ develops quantum sensors based on atomic interferometry for terrestrial based on atomic interferometry for fast fast and precise gravity measurement.

QUEST Leibniz Research School

S. Gerhard



Alexander Wanner
Managing Director

private

Prof. Dr. Michèle Heurs
Chair

In line with the future strategy of the Leibniz University of Hannover, the QUEST Leibniz Research School was established as the first of its kind. It continues the research topics of the Cluster of Excellence QUEST (Centre for Quantum Engineering and Space-Time Research, 2007-2014) in the Cluster of Excellence QuantumFrontiers (2019-2025) and provides a cross-structure to the existing faculties.
Members of the QUEST Leibniz Research School are recruited from the following faculties:

- Faculty of Mathematics and Physics,
- Faculty of Civil Engineering and Geodesy,
- Faculty of Electrical Engineering and Computer Science,
- Faculty of Mechanical Engineering

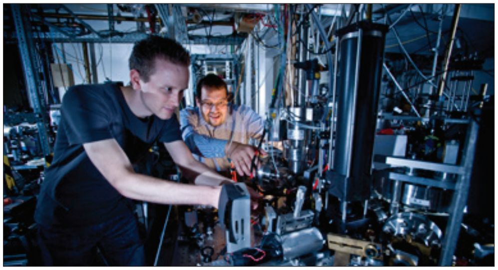
The participating institutes of Leibniz University of Hannover are:

- Institute of Quantum Optics,
- Institute for Gravitational Physics,
- Institute for Earth Measurement,
- Institute for Theoretical Physics,
- Institute for Applied Mathematics,
- Institute of Solid State Physics,
- Institute for Transport and Automation Technology,
- Institute for Drive Systems and Power Electronics.

One of the strengths of the QUEST Leibniz Research School is the integration of both university and non-university institutions and non-university institutions. In addition to eight institutes of Leibniz University Hannover , other institutions in Hanover Hannover, Braunschweig and Bremen are involved:

- the Laser Zentrum Hannover e.V.,
- the Max Planck Institute for Gravitational Physics (Albert Einstein Institute),
- the gravitational wave detector GEO600,
- the Physikalisch-Technische Bundesanstalt (Braunschweig),
- the Center for Applied Space Technology and Microgravity (Bremen),
- the Laboratory for Nano- and Quantum Engineering (LNQE).

Together with the participating institutions the QUEST Leibniz Research School carries out appointment and doctoral procedures, establishes its own study programs and expands existing cooperations with external partners. It focuses and accelerates decision-making processes and strategic developments through its own organizational structure. Developments, on the one hand to help shape international research efforts in a



QUEST/ Michalke

The researchers at the QUEST Leibniz Research School have to invest of the QUEST Leibniz Research School to achieve scientific results. But the effort is worth it: QUEST scientists are in the top league of research worldwide.

QUEST/ Cieluch

The members of the QUEST Leibniz Research School pursue a common goal: the continuation of the interdisciplinary research program of the Cluster of Excellence QUEST - Centre for Quantum Engineering and Space-Time Research.

more targeted manner, and on the other hand to strengthen interdisciplinary areas. The QUEST scientists are scientists are conducting joint research door-to-door in the Hannover Institute of Technology (HITec), a state-of-the-art interdisciplinary state-of-the-art interdisciplinary research building of the QUESTLeibniz Research School. This not only increases the national and international visibility of the of the lighthouses of Leibniz University Hannover, but also the anchoring of interdisciplinary research within the university.

Furthermore the QUEST Leibniz Research School is an attractive „anchor point is an attractive „anchor point" to the outside world, in which external external partners can and should participate.

The QUEST Leibniz Research School pursues the expansion and strengthening of the interdisciplinary teaching and research activities and promotes interfaculty student exchange through interdisciplinary courses at the interfaces of physics, mathematics and geodesy. and geodesy. In cooperation with the Hannover Medical School, the QUEST Leibniz Research School organizes the Voluntary Scientific year in order to attract the next generation of young scientists for STEM subjects and to enable them to make an and to enable them to make a well-founded decision about their studies.

Through the QUEST Leibniz Research School a model project for future new institutions at Leibniz University Hannover has been realized, which provides the structural framework for excellent, interfaculty research and sets the course and sets the course for future interdisciplinary large-scale research projects.

QUEST/ Cieluch

The next generation of scientists, especially young women, for to inspire young scientists, especially young women, to take up STEM subjects. main tasks of public relations at the QUEST Leibniz Research School.

QUEST/ Cieluch

The QUEST Leibniz Research School strengthens teaching and research activities in the subject areas of physics, mathematics and geodesy through specially adapted interdisciplinary teaching programs

Quantum Valley Lower Saxony (QVLS)

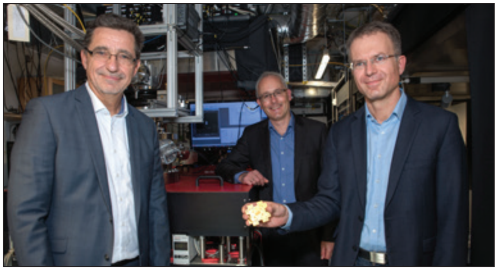
private

Dr. Bernd Jungbauer
Managing Director

More than 400 researchers are working at Leibniz University Hannover, TU Braunschweig, and the PhysikalischTechnische Bundesanstalt on quantum research and the key enabling technologies. Together, they have already acquired two successful clusters of excellence: QuantumFrontiers and PhoenixD. Three recently opened research buildings (HITec, LENA, LNQE) are directly dedicated to nano- and quantum technologies. New clean room laboratories for semiconductor and nanotechnology form an outstanding infrastructure and enable the use of microelectronics production processes, atom and ion trap chips.

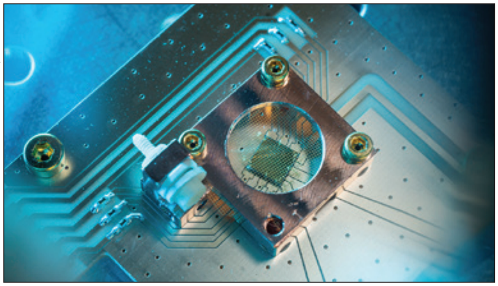
The Quantum Valley Lower Saxony (QVLS) launched in November 2020, with the goal of realizing a 50 qubit quantum computer based on surface ion traps by the end of 2025. This technology is currently considered one of the world's most promising approaches for scalable quantum computers, as it allows operation at room temperature and with the lowest error rates. For the construction of QVLS-Q1, the world-class expertise established in Lower Saxony will be bundled with engineers and industry, thus encompassing the entire chain for the construction of a quantum computer. The combination of all necessary expertise under one umbrella - from nanotechnology to quantum algorithms or the production of ion trap chips - is a convincing unique selling point of the ambitious project even in a worldwide comparison.

Further information about the QVLS can be found at www.qvls-q1.de.

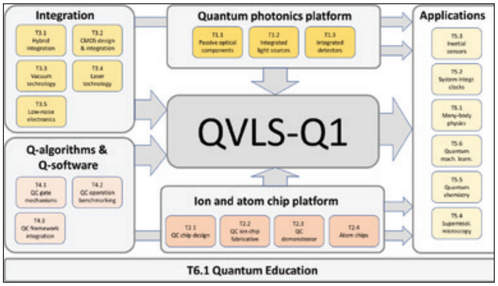


from left to right: Prof. Dr. Andreas Waag TUBS, Prof. Dr. Piet Schmidt PTB-LUH, Prof. Dr. Christian Ospelkaus LUH-PTB

Source: TUBS / Hosan



In surface traps like this one, the quantum bits of tomorrow will be switched with microwaves.



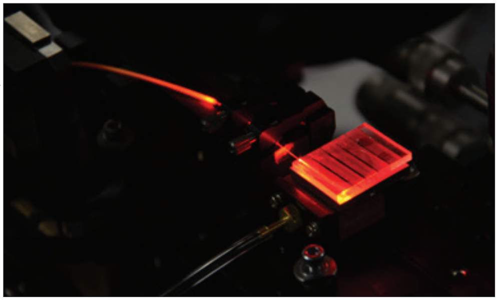
Overview of the different platforms and teams (Tx.y) contributing to QVLS-Q1 and target applications.

Hannover Centre for Optical Technologies (HOT)

The Hannover Centre for Optical Technologies (HOT) is an interdisciplinary research center of the Leibniz University Hanover having the higher goal to join the individual competences in the field of optics and photonics in the different disciplines, create new branches of research and disseminate them in research, teaching, and knowledge transfer. The HOT conducts both basic and applied research in the fields of optical technologies and photonics. It also promotes the transfer of knowledge and technology between the institutions involved and to industry.

The research activities in the five working groups established at the HOT are strategically conceived and focus on (i) computational photonics (Prof. Antonio Cala Lesina), (ii) phytophotonics (Prof. Dag Heinemann), (iii) photonic quantum technologies (Prof Michael Kues), (iv) mesh-free multiscale simulations (Prof. Xiaoying Zhuang) and (v) micro- and nano-optical sensors, biomedical optics and laser analytics (Prof. Bernhard Roth).

C. Kelb, HOT 2020



Fiber-optic measurement configuration for the validation of integrated optical foil sensors created by additive manufacturing (C. Kelb, HOT 2020).

Typical fields of application are in the area of environmental monitoring, medical diagnostics and point-of-care testing, quantum information technology, material science and the investigation and control of processes in nature using coherent light. Thereby, the HOT researchers are increasingly relying on concepts of digitization and artificial intelligence that are linked to optics research and functional optical systems.

The activities of the center benefit from a strongly interdisciplinary team from physics, engineering, biology, mathematics and computer science. The center conducts both own and collaborative research and development projects with its members from the faculties of mathematics and physics, mechanical engineering and electrical engineering and computer science as well as the Laser Zentrum Hannover e. V., the PTB and external partners from industry and universities. It is involved in various joint and large-scale research projects such as the Cluster of Excellence PhoenixD: Photonics, Optics, and Engineering - Innovation Across Disciplines, which was initiated by the HOT. The HOT contributes in many ways to teaching in the participating faculties through a variety of own courses, in particular to the cross-faculty master's course Optical Technologies and the Leibniz School of Optics (LSO) at Leibniz University Hannover. Its tasks also include the training of experts for the optical industry. The center promotes young academics at any stage of their scientific career by giving them the opportunity to work independently, for example, in student projects as well as bachelor, master and PhD theses.

private

Prof. Dr. Uwe Morgner
Speaker of the Board of Directors

S. Gerhard

apl. Prof. Dr. Bernhard Roth
Scientific and Managing Director
Contact:
bernhard.roth@hot.uni-hannover.de

Optical Technologies.

International Max Planck Research School on Gravitational Wave Astronomy

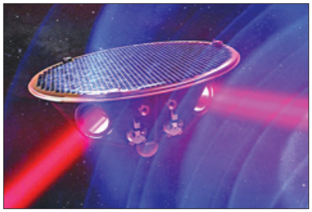
S. Gerhard

Prof. Dr. Karsten Danzmann
Spokesperson

S. Gerhard

Sandra Bruns
Coordinator

AEI/Milde Marketing/exozet, GW-Simulation: NASA/C. Henze



IMPRS PhD students are also conducting research on the LISA mission, the first gravitational-wave observatory in space.

More than 96 percent of our universe is dark and cannot be observed with conventional astronomical methods. Since September 2015, we have been able to take our first glimpses of this dark side of the universe and thus gain entirely new information. Merging black holes and neutron stars reveal themselves through the gravitational waves they emit. The kilometer-sized interferometric detectors on Earth have already detected 90 such events.

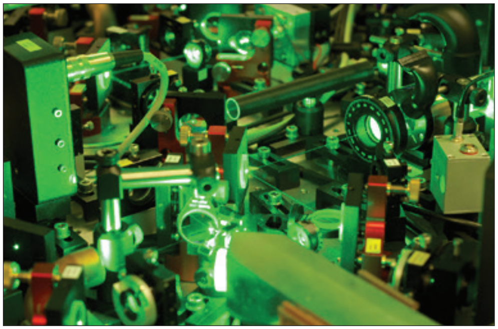
The "International Max Planck Research School on Gravitational Wave Astronomy" (IMPRS-GW) offers the unique opportunity to learn modern gravitational physics in its theoretical and experimental subfields at the same time. The university's collaboration with leading research institutions and the GEO600 gravitational-wave detector allows participating students to become familiar with all areas of this exciting and promising field of research.

Research in this graduate school ranges from laser development, interferometry, and quantum optics to data analysis, theoretical astrophysics, and numerical simulations of gravitational-wave signals. More than 60 students from around the world are currently being trained at IMPRS-GW to become the next generation of gravitational physicists.

The curriculum of the school includes lectures and seminars at affiliated universities and three one-week block courses per year. These "lecture weeks" consist of special courses by renowned scientists and practical seminars, leaving enough time for exchanges between lecturers and students.

Furthermore, the IMPRS-GW offers additional "soft skill" seminars to prepare students for their future careers. These include seminars on how to successfully write scientific articles and research proposals, as well as presentation trainings, trainings for leadership positions, on project management and planning one's research career, and seminars on intercultural communication and other topics.

The following institutions are involved in the IMPRS-GW: the Max Planck Institute for Gravitational Physics (Albert Einstein Institute) in Hannover, the Institute for Gravitational Physics and the Institute for Quantum Optics at Leibniz University Hannover and the Laser Zentrum Hannover e. V.



B. Knispel/AEI

More than 2000 square meters of modern laboratory space are available to researchers at the Institute for Gravitational Physics and the Max Planck Institute for Gravitational Physics in Hannover.

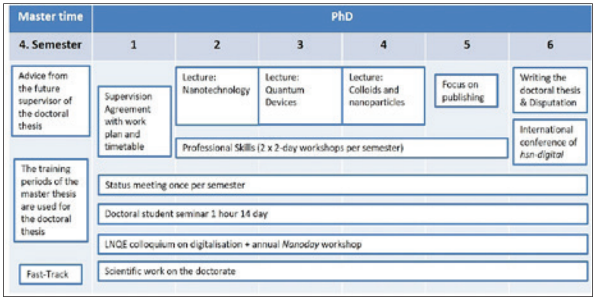
Hannover School for Nanotechnology

The Hannover School for Nanotechnology (hsn) is a coordinated doctoral programme of the Laboratory of Nano and Quantum Engineering at Leibniz University Hannover together with the Hannover University of Applied Sciences and Arts, funded as a Lower Saxony doctoral programme by the Lower Saxony Ministry of Science and Culture. The aim of the doctoral programme is the interdisciplinary training of young scientists in the highly topical field of nanotechnology.

The hsn has been funded three times in a row so far, which is unique overall within the framework of this funding line. In hsn-energy (2012-2016), energy processes were investigated in the nanometre range. Nanomaterials and nanoengineering are used to improve these processes in order to find revolutionary new ways of energy conversion, energy storage and energy transport. hsn-sensors (2016-2020) dealt with nanosensors, i.e. sensors with nanoscale surfaces, sensors that transfer information from the nanoscopic world to the macroscopic world and sensors that use nanoeffects as a sensor principle. hsn-digital (2020-2025) researches nanomaterials and concepts to realise qubits that can be integrated in miniaturised form in the electronic devices of everyday life.

Nanotechnology is a very interdisciplinary science, it requires knowledge in chemistry, physics, electrical and mechanical engineering. The LNQE has been creating a basis for interdisciplinary joint research activities for years and is particularly committed to training a new generation of researchers whose interdisciplinary skills will enable them to communicate effectively between the subjects. Under the aegis of the LNQE, the B. Sc. and M. Sc. degree programmes in nanotechnology have therefore been offered for several years. With the hsn, interdisciplinary education is consistently continued at the doctoral level.

The hsn specifically targets excellent young students from all over the world in order to train them in the best possible way in the field of nanotechnology. An important goal is to achieve the shortest possible doctoral period, also for international students, and at the same time to achieve top research results. In addition to the actual doctoral topic, the scholarship holders are offered a tailor-made teaching programme. This includes nanotechnology lectures, seminars, colloquia, courses to promote personal skills and, in particular, special events on the responsible use of nanotechnology. In addition, a special focus is the promotion of young female scientists.



Schulze-Wischeler (LNQE)

Semester overview of the PhD program Hannover School for Nanotechnology.


S. Gerhard

Prof. Dr. Rolf Haug
Coordinator


O. Kerker

Dr. Fritz Schulze-Wischeler
Chief Operating Officer

foeXlab – A Physics Lab for Senior Level Secondary School Students

Experimenting close to curricular physics
interdisciplinary projects & inquiry learning
training for inservice teachers
teaching/learning lab for teachers to be

Since January 18th 2018 **foeXlab**, the students lab of the CRC 1227 (DQ-mat) at the Leibniz University Hannover, has opened the door for inquiry learning projects for senior class secondary school students. After one and a half year preliminary work the foeXlab team around JProf.' Susanne Weßnigk (AG Physikdidaktik, IDMP) and Dr. Rüdiger Scholz (IQO) started their offer of out-of-school courses on advanced optics.

Science communication –
physical science – educational research

Based on established expertise in contemporary physics and led by theoretical and practical knowledge of science education foeXlab reaches the aimed target groups:

- foeXlab$^{\text{classic}}$: Experimenting close to the curriculum for **senior level secondary school students**
- foeXlap^{+}: Inquiry learning for "specialists"
- foeXlab$^{\text{LLL}}$: The teaching/learning lab for **teachers-to-be** is built to train experimental skills and follows the Leibniz principle of fostering the "reflektierte Handlungsfähigkeit" (supported by Studienqualitätsmitteln of the Leibniz School of Education)
- foeXlab$^{\text{Physik-Café}}$: **In-service teachers'** training and professional advice (science and science education).

The students lab foeXlab is at the core of the outreach project of the CRC 1227 and thus part of the science communication of the Leibniz University. The foeXlab science communication is based on three pillars:

Science foeXlab strives for an in-depth look at current research and the scientific work at a university centred around and contemporary understanding of quantum physics and relevant applications.

Science education foeXlab is aimed to foster interest in science not at least to develop learning, creating, critical participating in the understanding and usage of quantum science and technology.

Science communication Based on experimental projects for the general public and following basic ideas of "Public Engagement with Science (PES)", foeXlab is aimed to develop confidence in scientific methods and the ability for a fair and unbiased discussion.

Active learning close to science and physics research
The concept of foeXlab is based on a connection of selected issues of the CRC-1227-research with typical classroom physics. foeXlab allows for active "hands-on" learning in an university research environment. And, finally, conceptual work at foeXlab enriches the development of the curriculum with new ideas for an experimental supported "pedestrian" approach to quantum physics at secondary schools.

In return, studying physics at the Leibniz University Hannover may profit from new experimental ideas, from an increasing publicity profile. Educational research may be enriched by innovative areas of activity. Young academics and researchers are invited to talk about their topics training their presentation skills.

The course program of foeXlab 10 workstations each for 2 students with the topics

- Maxwell's theory of light: Diffraction and interference
- Classical interferometry (Michelson I Mach–Zehnder interferometer)
- Statistical optics: Experiments with binary detectors
- Coincidences at the optical beam splitter, the interferometer of Hanbury Brown/Twiss
- Experiments with single-photon states
- The BB84 (Quantum-) key distribution scheme

foeXlab evaluation, quality control and the creation of new ideas relies on the awarding of bachelor-and master-theses. Since the beginning of 2018 experimental key phenomena and their relevance for an effective learning of quantum physics is the topic of a phd-thesis.

The scope of outreach measures and specific networking

Scientific network of foeXlab: MeXlab Münster (Prof. Cornelia Denz); Currenta, Leverkusen (Karl-Heinz Wagner); KIT/PSI Schülerlabor (Dr. Antje Bergmann); Quantumlab, Friedrich-Alexander-Universität (Prof. Jan Peter Meyn); CAU Kiel (Prof. Ilka Parchmann); SCIphyLAB/TPÖ SFB 917 (Prof. Heidrun Heinke, RWTH Aachen); NUN-Arbeitskreis (Peter Kroekel, Wolfsburg); qubit EDU (Prof. Rainer Müller, TU Braunschweig, Prof. Stefan Heusler, WHU Münster).

The foeXlab school network ensures a good fit between teachers needs and foeXlab courses: St. Ursula Schule (Hannover), Schillerschule (Hannover), Ricarda-Huch Schule (Hannover), Gymnasium Goetheschule (Hannover), Goethegymnasium (Hildesheim), Helene-Lange Schule (Hannover), Gymnasium Sarstedt, Gymnasium Burgdorf.

	foexlab classic		foeXlab +		foeXlab LLL		General
Date	**Events**	**Participants**	**Events**	**Participants**	**Events**	**Participants**	**Events**
2016	2	38					2
2017	10	183	6	10			1
2018	15	265	5	5	1	20	4
2019	8	125			6	40	2
Sum	**35**	**611**	**11**	**15**	**7**	**60**	

Stand 09. 2019

Riemann Center for Geometry and Physics

Prof. Dr. Knut Smoczyk
Spokesperson

The Riemann Center for Geometry and Physics (Riemann Center for short) is a Leibniz research initiative at the Faculty of Mathematics and Physics that has existed since 2012. The purpose of the Riemann Center is to bundle the joint research activities of mathematicians and physicists at the faculty on the subject of „Geometry and space-time" and to give them a forum for discourse among themselves as well as with guest scientists from all over the world and the public. It brings together activities of the former QUEST excellence cluster and the Research Training Group 1463 »Analysis, Geometry and String Theory« that had existed at Leibniz University since 2007 and 2008, respectively. There are 18 professors with their working groups at the Riemann Center from the institutes for

- Algebra, Number Theory und Discrete Mathematics (Bessenrodt, Cuntz, Derenthal, Holm)
- Algebraic Geometry (Ebeling, Hulek, Schreieder, Schütt)
- Analysis (Bauer, Schrohe)
- Differential Geometry (Bielawski, Heller, Smoczyk)
- Theoretical Physics (Dragon, Giulini, Lechtenfeld, Osborne, Werner)

The current spokesperson for the Riemann Center is Prof. Dr. Knut Smoczyk from the Institute of Differential Geometry. The basic research carried out at the Riemann Center is supplemented and presented externally through various activities, in particular through

- Awarding of »Riemann Fellowships« to young scientists for research stays of a few months at the Riemann Center
- Awarding of »Riemann Instructorships« to young scientists for research and teaching activities of at least three years at the Riemann Center
- Invitation of top-class guests for short stays as »Riemann Visitors«
- Organization of international conferences and schools such as the »Riemann Master School«
- Lectures called »Riemann Lectures« for the general public
- Teacher training and offers for schoolchildren.

Further information on the activities mentioned can be found on the Riemann Center website: www.riemanncenter.de

Willmore-Torus

Helge Krückeberg/Olaf Lechtenfeld

Young scientists are an essential target group of the activities of the Riemann Center.

Leibniz
Universität
Hannover

Studies and Teaching MaPhy

Handbook of the Faculty of Mathematics and Physics

Studying Mathematics

Prof. Dr. Knut Smoczyk
Chair of the examination board

In mathematics, basic research and applications are more closely connected than in most other sciences. Mathematical research thrives on questions within mathematics as well as on challenges posed by practical questions in applications. Enthusiasm for mathematical problems, combined with a willingness to familiarize oneself with the abstract basics of the subject, are important prerequisites for studying mathematics.

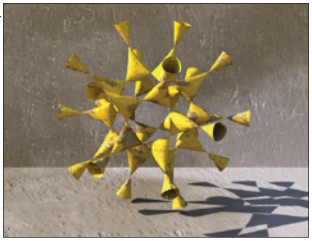
With its bachelor's and master's degree programs in mathematics, the faculty offers a well-founded and broad-based study of mathematics in a research- and application-oriented environment. The mathematical institutes of Leibniz University Hannover cover the important basic mathematical disciplines in Pure and Applied Mathematics, with fruitful cross-references between the research areas represented at the faculty.

The mathematics education in the first year is mainly devoted to calculus and linear algebra. Here the foundation is laid for the good cohesion among students, which is also supported by the activities of the student council. Starting in the second year of the bachelor's program, students can set their own individual focus in the elective area. Possible areas include algebra and number theory, discrete mathematics, various areas of geometry, analysis, numerical analysis or stochastics. An application subject such as computer science, physics or economics is mandatory in order to give students an insight into other sciences and impulses for cross-connections. In the subsequent Master's program, students can deepen their focus according to their own inclinations; for this purpose, a diverse range of courses is available, in which students are supervised in small groups. This also prepares students for the research project of the master's thesis.

In both study phases there is the possibility of a studying at a foreign university, e.g. with the ERASMUS program. The faculty strives to constantly expand the existing network of partner universities.

After successfully completing their studies, mathematics graduates have excellent career prospects. They are ideally qualified for employment in a wide variety of fields, both for starting a career in science and for working, for example, in banking, insurance, consulting or industrial research departments.

Knut Smoczyk



The Barth Sextic

Knut Smoczyk

Representation of the Hopf fibration

Studying Physics

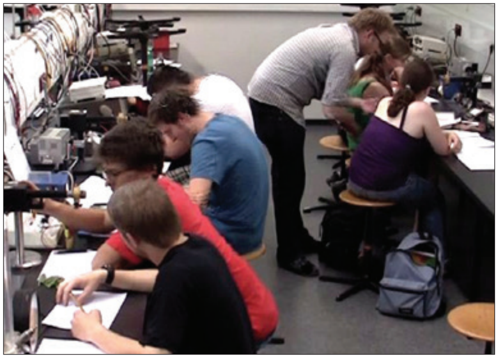
Our faculty offers the degree programmes physics (BSc) and physics (MSc). Already within the BSc programme, our students acquire in-depth knowledge in mathematics, theoretical and experimental physics. Laboratory classes and experiments are carried out in state-of-the art laboratory facilities.

When asked what makes their studies at our university special, students typically highlight the strong team spirit among students. Also, the excellent and productive atmosphere, student-professor relationship as well as the relation to the scientific staff is emphasized. Our students feel that they are well advised in their learning process and cherish their possibility to participate in current fundamental research at the forefront of physics. The main vehicle to ensure this participation is to embed students directly into the numerous research groups. Within the MSc programme with its comprehensive set of possibilities for specialization, the strong focus on research in physics at Leibniz University is highly beneficial. This focus is evident from the clusters of excellence QuantumFrontiers and PhoenixD, several DFG collaborative research centres, the Quantum Valley Lower Saxony (QVLS) initiative of Lower Saxony as well as from the close collaboration with mathematics, e.g. in the Riemann centre. A one-year research phase is an integral part of the MSc programme.

International exchange visits can be incorporated into both degree programmes, e.g. through the Erasmus programme. Our faculty is constantly expanding its network of partner universities and is happy to advise students concerning the planning of semesters abroad.

The MSc programme is also offered in English, an increasingly popular choice. This has made the programme even more attractive both for national and international students and puts a particular emphasis on the international dimension of physics right at the beginning of the MSC programme.

R. Scholz

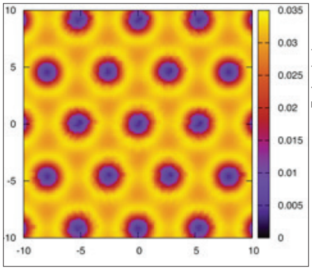


Work in the Laboratory classes

S. Gerhard

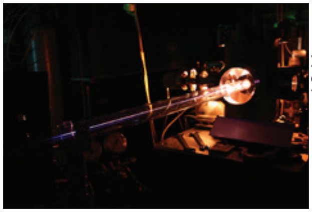
Prof. Dr. Christian Ospelkaus
Chair of the examination board

E. Jeckelmann



Solution of the Schrödinger equation for the density distribution of valence electrons in aluminium (metallic bond)

AG Morgner

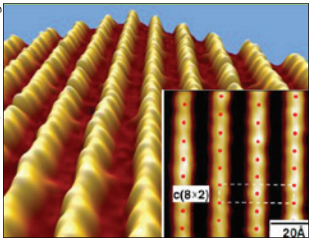


Laser physics – nonlinear optics with laser

Studying Nanotechnology

Prof. Dr. Franz Renz
Audit Committee Chairman

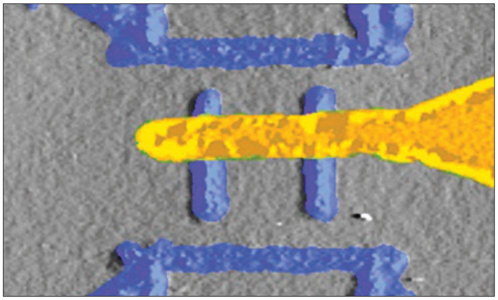
J. Schäfer, Uni Würzburg



Arrangement of atomic gold chains on a silicon (111) surface

The nanotechnology study programs are part of the recent history of the faculty. The bachelor's program was launched in the winter semester 08/09, the master's program in the winter semester 11/12. The attractiveness of the programs has increased steadily since their inception, so that the bachelor's program exceeded the mark of 100 first-year students for the first time in the winter semester 14/15. The number of master's students is also rising accordingly. One reason for the steadily growing interest in studying nanotechnology is certainly the combination of a seminal general topic with innovative approaches, interdisciplinarity and the linking of scientific and technical content, as well as excellent career opportunities after graduation. The special challenge for the organization is to be seen in the strongly interdisciplinary character of the study program, which extends over four faculties. The combined courses offered by the faculties of Natural Sciences, Mathematics and Physics, Electrical Engineering and Information Technology, and Mechanical Engineering cover the curriculum of the program in equal proportions. The Faculty of Mathematics and Physics is in charge. Four professors from the individual faculties, affectionately known as „caretakers", ensure the quality of studies and teaching. Also worthy of mention is the Nanotechnology student body, which has been independently involved in the further development and maintenance of the study program for the past three years. These structures provide students with a particularly effective and close-knit advisory structure. The Laboratory for Nano- and Quantum Engineering (LNQE) offers students a study program with a practical connection directly on site. This research building, which was constructed in 2009, has state-of-the-art equipment in the field of nanotechnology. Core elements are the clean room and several research laboratories. Here, students can analyze the world „in miniature", write their final theses or gain an insight into research during poster sessions. The LNQE is the central place where students and the professors involved in the program meet for (not only) study committee meetings and work on the further development of this unique nanotechnology program.

The nanotechnology study programs were successfully accredited in January 2021. There was much praise from the assessors for the commitment of both the program leaders and the students.



Prof. Dr. Rolf Haug

Semiconductor devices

Studying Meteorology

The consecutive Bachelor- and Master Courses (formerly Diplom) in meteorology have a history of more than 5 Decades in Hannover. It is of growing importance and actuality. The ongoing climate change requires sound and comprehensive knowledge about physics and chemistry of the atmosphere. The necessary change from fossil fuel based energy towards renewable energies – in Germany mostly driven by the highly volatile solar- und wind power – is an additional important field for meteorology. The challenges of these applications are tackled by a sound education in meteorology.

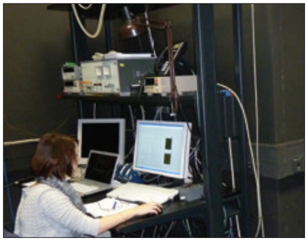
Since the processes in the atmosphere can only be understood by understanding physics, the first six semesters are focused on the basic mathematical and physical methods. These topics are complemented by the education in the broad applications of meteorology. Classical topics like weather analysis and forecast are essential parts as well as modern measurement techniques and the development of numerical models. The cooperation with the other 9 locations in Germany that offer a full education in meteorology is strengthened by a project of the Volkswagen foundation. Meteorology has many neighboring disciplines like physics, chemistry, botany, medicine, geography, geodesy, land sciences, machine and electrical engineering, informatics, environmental engineering, hydrology and so on. The knowledge and methods of these disciplines is important for meteorologists. In return meteorologists share their knowledge with these disciplines.

During the Bachelor and Master phase actual research topics are investigated and there is a close connection to the research groups of the institute. The bachelor degree enables a professional employment especially at the German Weather Service. However, the great majority of students continues their study with the master course in Hannover. The master course is based on the skills acquired during the Bachelor phase. Presentation and discussion of meteorological research topics are integrated in the master phase. Joint work during meteorological excursions and field campaigns strengthen the team building and cooperation amongst the students. Due to numerous international contacts there are manifold possibilities for internships abroad. The list of destinations is long, for example to many European countries, New Zealand, USA, South Korea, Japan and Hongkong. A very good IT infrastructure is enabling to learn relevant meteorological know-how. Many master students are starting a PhD at the institute. In most cases the PhD thesis are funded by external grants.

As part of a reorganization, it is planned to close the BA Meteorology in WS 22/23 and at the same time to allow enrollment in a new program „Environmental Meteorology".

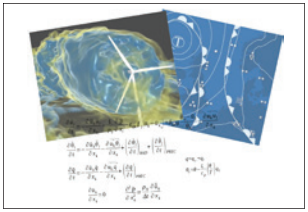
privat

Prof. Gunther Seckmeyer
Audit Committee Chairman



Katharina Isensee

Laboratory work of a student



Micha Gryschka

Top left: Flow simulation of a wind turbine, top right: weather map, bottom: System of equations for the description of atmospheric processes

Mathematical Courses in other degree programmes

In modern life, we take many things for granted which would not exist without the use of elaborate mathematical methods: safety systems in cars, processing and storage in consumer electronics, credit card PINs, digital signatures, and secure data transmission in the internet to name just a few. Other applications of mathematics are in areas which may be hidden from our eyes, but still affect our life in profound ways: Just in time delivery in production chains, DNA sequencing, or risk management in the financial industry.

This makes mathematics into an indispensable tool for those who develop these products now, and in the future. A solid mathematical education is a central part in our study programmes in natural, engineering and economic sciences.

Contact persons regarding the mathematical teaching in the various study programmes are (as of April 2021):

Biologie, Molekulare und Angewandte Pflanzenwissenschaften; Life Science und Geowissenschaften: Michael J. Gruber (gruber@math.uni-hannover.de)

Informatik: Axel Köhler (koehler@maphy.uni-hannover.de)

Geodäsie (2nd year of study): Lutz Habermann (habermann@math.uni-hannover.de)

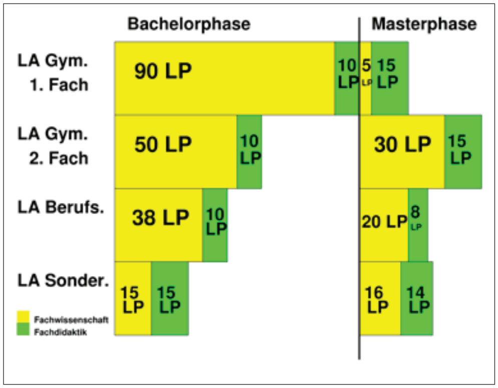
Ingenieurwissenschaften, Geodäsie (1st year of study): Andreas Krug (krug@math.uni-hannover.de)

Ingenieurwissenschaften (2nd year of study); Wirtschaftswissenschaften: Florian Leydecker (leydecker@ifam.uni-hannover.de)

Teacher training programs

For students who want to become teachers at grammar schools or vocational schools with the subjects mathematics and/or physics, or who decide to study mathematics as a subject in the context of special education, the corresponding courses are offered by our faculty. The career prospects are very good for each of these directions.

In the interdisciplinary bachelor's program, in which a minor and a major subject must be chosen, students learn the basic content of their subjects together with the subject students; in addition, they are trained in subject didactics. This is followed by the master's program for the teaching profession at grammar schools, in which the subject didactic training is deepened and the weighting in the subject combination is reversed. After graduating with a bachelor's degree, students can alternatively study the corresponding subject-related master's program.



Study components

The bachelor's degree program in Technical Education serves to prepare students for the teaching profession at vocational schools; here, too, the fundamentals of the subject initially play a major role in the program. This is followed by the master's program in vocational education. For students with a degree in engineering, the MA SprintIng is a good alternative to the combination of BA Technical Education and MA Teacher Training at Vocational Schools.

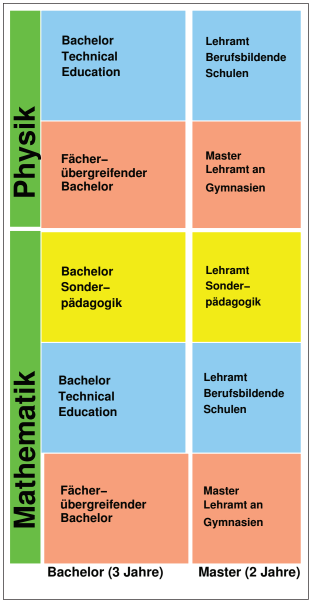
Students of Special Education learn the elementary basics of mathematics and first aspects of subject didactics in the Bachelor's program. This is supplemented and deepened in the master's program.

All teaching-related master's programs include a school internship in which students can test their skills in teaching their subjects. The curriculum also includes educational science and psychology in addition to subject-specific and subject-didactic content.

The proportion of students with an orientation towards the teaching profession is high at the faculty. Therefore, many measures have been taken in recent years to improve the study situation there, e.g. by increasing the equipment of the subject didactics or by introducing special courses for student teachers.


private

Axel Köhler
Program Coordinator



Study options

Student Representatives Mathematics and Physics

Student Representatives Mathematics and Physics

Welfengarten 1, 30167 Hannover
Room D 414
Phone +49 511 762 7405
info@fsr-maphy.uni-hannover.de

Between professors, institutes and deanery every university faculty needs another really important component: The student body. We do not want to name every single student but rather introduce their representation, the so called student representatives, or 'Fachschaftsrat'.

The student representatives serve as the representation of all students of the faculty adverse the university. It keeps itself busy with all kind of problems regarding the students and works as an intersection between professors, committees and students. We as voluntary members take care of the freshmen since at least their first day at university. For them not to get lost at the big new university we organize, in addition to the preparatory classes in mathematics, orientation units where experienced students help the first semesters to build their class schedule, explain how to organize their workaday life in their studies and answer all questions emerging. Through a manifold program subsequent to the preparatory classes we provide the possibility to get to know the fellow students, the city Hannover, the university and the student body itself. We remain as contact persons after the week of orientation – in fact as long as they study.

Beside the assistance through active members the student body provides rooms for collective learning and homework solving. Five of those rooms are located in the main building, the so

At the ralley for first semesters at the foyer in front of the lecture hall E001 in 2019
From top left: Alja Baumann, Tomke Berenbold, Patrizia De Luca Ramírez, Merten Demitz, Wolfgang „Lyon" Dorgelo, Pascal Engelhardt, Erin Feldkemper, Felix Geerken, Hanna Goeda, Leonard Heinze, Anastasija Kartamysheva, Moritz Heumann, Jana Klinger, Pia Koopmann, Sidney Krämer, Benjamin Krüger, Balduin Makko, Nils Maasjost, Tim Ramaker, Finn Jonas Rolf, Kai Schickantanz, Imke Spykman, Tim Winzer

called 'Welfenschloss'. An additional one is determined in Appelstraße 2. With those rooms we not only provide space for learning but also a lot of important books and subsistence by hot and cold drinks. You will find students of every semester, so you can find nearly at all time contact persons to concern regarding content and organization.

During the Covid-19 pandemic you can find the main activities and a large part of inter collegiate exchange at our internal Discord server. Students meet in different vice channels to learn and solve homeworks. Our representatives conferences also take place in a special channel open to all members.

We do our best in solving every problem students have as fast as possible. We discuss all concernings in our weekly conferences and hand problems we cannot solve to the next higher authority. Therefore there are representatives in the advisory board of study affairs, in the board of the faculty and in the students council. It works as an intersection between students and professors. In addition we can cooperate in the configuration of the examination regulations and help with the employment of new professors in appeal boards.

Of course you can find us also online. At our website www.fsr-maphy.uni-hannover.de you can find hints on how to receive old exams and scripts of nearly all courses. There is also every old and current edition of our newspaper 'Der Phÿsemathent' and when our partys like the 'Z4hlend3h3r' take place. You can find there our E-Mail address whereby you can contact us. The mails are discussed every Monday at 18:15 in our conference in our room in the main building. Everbody is invited to our conferences, we are always happy about new faces.

At the rally of the OE- Week 2013 in the atrium

Final photo at the OU preparation in Goslar 2013

Undergraduate Physics Laboratory

private

Dr. Kim-Alessandro Weber
Head of Laboratory

PhysikPraktikum

With currently 200 workplaces, the physics lab course offers basic hands-on training in experimental physics. Every year, about 1,000 students participate the lab course. In addition to physics, it is an integral part of numerous other natural science and engineering degree programmes as well as some interdisciplinary Bachelor's degree programmes. Depending on the discipline, three to ten experiments are performed each semester.

More than 40 assistants supervising the experiments and support selfguided experimentation. In cooperation with the ZQS, training courses are held to ensure the high standards of tutorial support and to make it easier for new tutors to get started.

The aims of the physics lab course are:

- getting access to basic knowledge of physics;
- fostering of experimental skills;
- learning and practising modern physical measurement methods;
- practising the analysis and presentation of measurement data.

Special demands of the Bachelor's phase:

- Already one year after completing the undergraduate lab course, many students begin experimental Bachelor's theses. In order to better support the ability to work in this study phase, experiments in the physics lab course are strongly adapted to measurement method requirement.
- The special training requirements for the teaching profession include a focus on the development of contextual knowledge. To this end, special experiments and working methods are developed in the physics lab course.

A close Network with lab courses at other universities and an active participation in current educational research ensure lab quality, especially with regard to contemporary measurement methods and experiments. [1]

Literature

» [1] Nagel, C., Scholz, R., Weber, K. (2018): Umfrage zu den Lehr/Lernzielen in physikalischen Praktika. PhyDid B - Didaktik der Physik - Beiträge zur DPG-Frühjahrstagung.

Computer workstations for students

For students with a major, minor, or elective in mathematics, meteorology, or physics, computer workstations are available at several locations in the Department of Mathematics and Physics.

The PC pools are run on Linux. Therefore, if you want to work in the pools, you should acquire basic knowledge of Linux, e.g. by taking a Unix/Linux course or reading appropriate literature. In the pools, the corresponding user regulations of the faculty as well as the IT security regulations and the network operation regulations of Leibniz University Hannover apply. LibreOffice and (La)TeX are installed on the computers for word processing, Maple, Mathematica, Sage and Matlab for computer algebra, the GNU Compiler Collection (C, C++, FORTRAN, Java) for programming, and Gimp, Gnuplot and Inkscape for image processing.

The largest pool has 60 workstations and is operated jointly with the Faculty of Electrical Engineering and Computer Science. This room is located in the main building (room F411) and is equipped with two beamers (can also be used in parallel).

Dr. F. Attia

CIP-Pool in the main building

The pool at Appelstraße 2 (room 034) is located in a smaller room with an electronic whiteboard. The computers located there and running continuously can also be accessed from outside the LUIS VPN via ssh.

Logging in to use one of the aforementioned pools is done through the university's central Identity Management (IdM) system. Access to the two rooms is controlled by a PIN, which you will receive in one of the assigned courses.

The smallest pool is located in the Institute of Meteorology and Climatology. There, instead of algebra software, programs for the calculation of thermal and solar radiation are available, as well as the server-client system NinJo, developed by national weather services, with which worldwide current meteorological data can be visualized and analyzed. This pool is currently not connected to the IdM system; access can be requested directly from the Institute of Meteorology and Climatology.

In addition, Windows workstations in the ITS pool of the Faculty of Natural Sciences, Institute of Biostatistics (Herrenhäuser Straße 2) can be used.

Contact persons of the pools are Dr. T. Block, Dr. F. Attia and Dr. N. Fechner as well as C. Buczilowski.

S. Gerhard

Dr. Frank Attia
Supervisor of the CIP-Pool in the main building

private

Dr. Tammo Block
Supervisor of the CIP-Pool Appelstraße 2

S. Gerhard

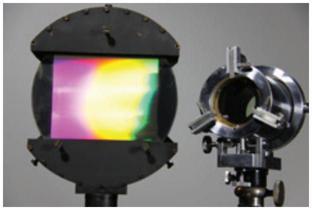
Dr. Notker Fechner
Supervisor of the CIP-Pool Meteorology

Great Physics Hall

M. Schlenk

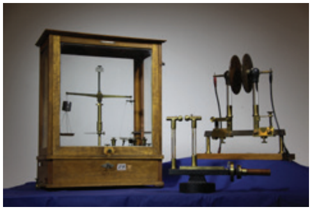
Dipl.-Phys. Matthias Schlenk
Head of lecture hall and collection

M. Schlenk



Wave optics with diffraction grating

M. Schlenk



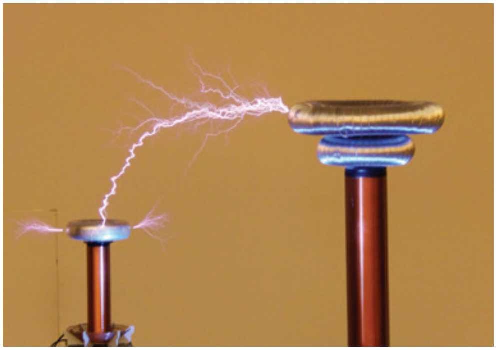
Apparatus for electricity

The Great Physics Hall is the second largest lecture hall of the university and is located in the east wing of the main building (Welfenschloss) directly below the Audimax. It has 555 seats, 532 of which have writing space. Due to the adjoining preparation rooms, the spatial proximity to the Audimax and the technical equipment, it is not only suitable for teaching and examination events, but also for events of various kinds. These include first-semester welcomes and graduation ceremonies as well as Christmas lectures, Saturday Morning Lectures and children's university events.

The installed presentation technology allows audio and video transmissions to and from the Audimax as well as the third largest lecture hall in the main building, e001. This allows for events with up to 1,600 visitors. For the presentation of demonstration experiments, the 80 square meter stage of the lecture hall is equipped with experimental tables as well as the necessary infrastructure.

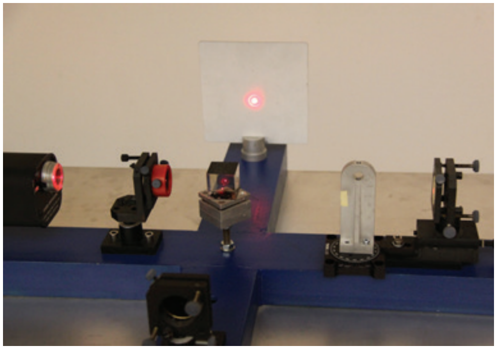
The attached physics collection has almost 500 demonstration experiments from the fields of mechanics, electricity, acoustics and wave theory, thermodynamics as well as atomic physics and quantum phenomena. This can be used to accompany introductory lectures on experimental physics as well as some special lectures. The collection builds on a basic set of experiments already proposed by Robert W. Pohl in Göttingen at the beginning of the last century. It is constantly being expanded and updated to meet today's requirements for modern lectures.

The lecture hall team, headed by Matthias Schlenk, accompanies all experimental physics lectures and provides equally active advice and support for special events.



M. Schlenk

High voltage experiments with Tesla coil



M. Schlenk

Michelson interferometer

PEX – Experiments and Experimentation in Physics Classes

PEX is a course for all student teachers of physics in the master's programs. It follows on from the experimental study components in the subject courses and was redesigned a few years ago specifically for student teachers. The PEX differs from traditional practical courses, among other things, in that a (digital) laboratory book is kept and experimental homework is set regularly.

Promoting the competent use of typical school teaching equipment, experimental materials and the ability to select, plan, conduct and evaluate experiments from a didactic perspective is a central goal of the PEX.

Typical elements include:

- Students learn common student experiment materials for all areas of school physics (optics, mechanics, electricity...), and try out student experiments for grades 5 to 13 themselves.
- They experiment in a course of „classical" and selected high school experiments (e.g. Franck-Hertz experiment, tube experiments, cloud chamber), which are set up and evaluated independently.
- They solve experimental problems (e.g. problems of the black box type).
- They deal with experiments in the field of technology (e.g. construction and operation of electric motors).
- They deal with instrumentation.
- They experiment with the use of modern sensor systems.
- They practice demonstrating experiments and receive feedback based on video recordings of the demonstration experiment, among other things.

The material basis for the PEX is the collection of the Physics Education Group, which has been modernized and extensively expanded in recent years. It is at the same time important for research work, all didactic courses and experimental bachelor and master theses in physics education.

G. Friege

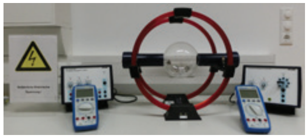
Experiment to illustrate magnetic field lines

Kim Weber

Experiment boxes

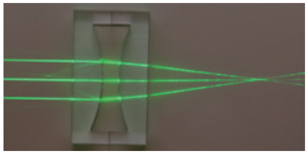
Prof. Dr. G. Friege
responsible for PEX and collection

G. Friege



Teltron tube

G. Friege



Adhesive board optics

Leibniz Universität Hannover

Administration MaPhy

Handbook of the Faculty of Mathematics and Physics

Dean's Office

C. Wyrwa

Prof. Dr. Ulrich Derenthal
Dean

S. Gerhard

Prof. Dr. Alexander Heisterkamp
Vice Dean

The Dean's Office manages the faculty and is the interface between the institutes and the central bodies of the University. The deans are responsible for strategic planning concerning the faculty, the management of centrally allocated funds, appointment matters and much more. In particular, the deans represent the interests of the faculty to the governing bodies of the university.

Currently, the following deans belong to the faculty: The Dean Prof. Ulrich Derenthal, the Dean of Studies Prof. Detlev Ristau, the Vice Dean Prof. Alexander Heisterkamp and the Vice Dean of Studies Prof. Wolfram Bauer.

Faculty Manager Christel Tschernitschek heads the faculty administration. She is primarily responsible for central financial management; she also supports the deans in strategic planning.

The tasks of the Dean's Office range from the coordination of appointments, doctoral and habilitation procedures to the preparation and follow-up of faculty council meetings.

Franziska Lorenz is the first contact person in the office for all matters concerning faculty administration. Among other things, she supervises appointment procedures and helps with inquiries of all kinds. She is supported by Nadine Bischof.

The specialist for all aspects concerning personnel cost budgeting is Birgit Gemmeke. She advises the institutes and is the contact person for hiring, contract extensions, and the like.

Petra Kraege is responsible for financial processing. Madeleine Mohammad and Melisa Mocevic assist with various deanery tasks.

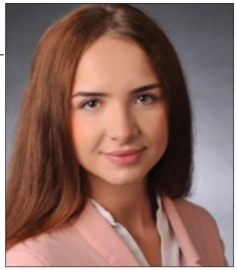
In the doctoral and habilitation office, Brigitte Weskamp helps doctoral and postdoctoral candidates to process the formal aspects of their doctorate or postdoctoral qualification correctly and on time.

C. Wyrwa

Christel Tschernitschek
Faculty Manager

S. Gerhard

Franziska Lorenz
Office



private

Melisa Mocevic
Office

C. Wyrwa

Petra Kraege
Finance office

C. Wyrwa

Birgit Gemmeke
Personnel cost budgeting

Dean of Studies

Within the Dean's Office, the Office of the Dean of Studies, under the direction of the Dean of Studies, is responsible for numerous tasks related to teaching and studying. These include ensuring and coordinating the courses offered and related examinations, as well as advising students. The Dean of Studies also chairs the Faculty's Study Commission, which advises on study matters, discusses course evaluations as part of quality assurance, makes recommendations to the Faculty Council for its resolutions on teaching and learning, and decides on the distribution of study quality funds. In addition, there is a dean of studies; this ensures that there is one person in the Dean's office for each of the two major teaching units, Mathematics and Physics, and that there is a suitable successor to the Dean of studies.

The area of the Dean's office includes the study secretariat and the study office with the study program coordination. In the Study Secretariat, Ms. Stateva-Andonova is responsible for many tasks such as the preparation of the course catalog, the coordination of room and examination planning and the updating of the study guides and module catalogs, but also the organization of, for example, the first semester welcome and the Faculty Day.

In the Office of Student Affairs, Mr. Köhler and Ms. Dr. Radatz are the central contact persons for students and are available for advice and support. They are responsible for the regular teaching evaluations. The central support for students during study abroad is also provided by the Office of Student Affairs; the network of partnerships with foreign universities is being further expanded. The Office of the Dean of Studies is also responsible for monitoring and implementing changes to examination regulations, and in particular for coordinating the process of reaccrediting degree programs. In addition, the Office of the Dean of Studies accompanies projects that serve to improve the study program.


C. Wyrwa

Prof. Dr. Detlev Ristau
Dean of Studies


S. Gerhard

Prof. Dr. Wolfram Bauer
Vice Dean of Studies


private

Brigitte Weskamp
Doctoral and habilitation office


private

Axel Köhler
Program Coordinator


private

Dr. Katrin Radatz
Program Coordinator


private

Miriam Redlich
Program Coordinator


C. Wyrwa

Mariana Stateva-Andonova
Office

Saturday Morning Lecture

S. Gerhard

Prof. Dr. Alexander Heisterkamp
Organizer

Since the winter semester 2002/2003, Saturday morning lectures under the motto „Frühstart - Physik für Aufgeweckte" offer the public insights into fundamental questions and current research topics in physics.

Thematically strongly represented are lectures on the main research topics of the institutes of this faculty, such as astro- and gravitational physics, quantum optics and solid state physics. Traditionally, however, contributions on socially relevant topics such as the so-called energy turnaround also meet with great interest. In these cases, the factual and scientifically based expert knowledge offered in addition to information from the general media is intended to enable the audience to participate competently and responsibly in the respective discussions.

Of course, aspects of related natural sciences and engineering are also taken into account.

The events usually take place on Saturdays from 11 a.m. to 1 p.m. in the Large Physics Lecture Hall (Room E 214) in the main building (Welfenschloss). They each comprise a lecture of about one hour and an always very lively discussion and Q&A session. Careful answers to the lecture questions on the quiz sheets on display can be worthwhile, as there are valuable prizes to be won.

The lectures are aimed particularly at schoolchildren, teachers, students of all disciplines, but also at anyone who wants to experience the fascination of science live.

Among many others, Prof. Dr. Harald Lesch, Prof. Dr. Hanns Ruder, Prof. Dr. Wolfgang Ertmer, Prof. Dr. Karsten Danzmann, Prof. Dr. Uwe Morgner as well as a Nobel Prize winner, Prof. Dr. Klaus von Klitzing, have already given lectures.

The series of events is sponsored by the Wilhelm and Else Heraeus Foundation, the German Physical Society and phaeno. Prof. Dr. Alexander Heisterkamp, Institute of Quantum Optics, and Matthias Schlenk, Lecture Hall and Collection Manager, are responsible for the organization.

M. Schlenk/ Hörsaalteam

M. Schlenk/ Hörsaalteam

uniKIK – connecting schools with the university

uniKIK stands for communication, innovation and cooperation between schools and the university and was founded in 1999 in the Institute of Applied Mathematics. In 2009 uniKIK was integrated into the Student Advice Office. In 2019 uniKIK became part of the Leibniz School of Education. uniKIK aims to inspire highschool students to study the STEM disciplines, help them eliminate inaccurate ideas about these disciplines and introduce them to scientific work. We also aspire to give highschool students a realistic insight into various degree courses to help lower dropout rates.

We achieve these goals with the help of projects targeted at a variety of subjects and age groups such as:

- JuniorSTUDIUM (trial courses)
- Gauß-AG (workshops during the holidays)
- Gauß-AG plus & Einsteins Enkeltöchter (highschool students can work on a long-term scientific project)
- B!G B4NG Challenge (STEM-themed online contest)
- uni:fit (preliminary courses in mathematics for freshmen students)

uniKIK Schulprojekte

- Leibniz (Junior)Lab (mobile experiments for elementary and highschool classes)
- professional training for elementary and highschool teachers
- symposiums in mathematics and physics for highschool teachers

Our newly designed „school projects web portal" (www.schulprojekte.uni-hannover.de) provides an overview of the various school projects of Leibniz University Hannover. Not only the uniKIK projects but also the numerous projects offered by the faculties can be found on the new website.

While our activities traditionally focus on the STEM subjects, the range of projects has continuously been expanded during the past few years. Nowadays, all faculties take part in the uniKIK projects.

Dr. Florian Leydecker (Institute of Applied Mathematics) is the scientific advisor for uniKIK and the contact person for our faculty.

Please find further information on www.uni-hannover.de/unikik or in the school projects portal: www.schulprojekte.uni-hannover.de

C. Wyrwa

Dr. Florian Leydecker

Contact person

uniKIK Schulprojekte

uniKIK Schulprojekte

List of retired professors since 1994

Name	Institute	Office/Service Designation	Entry date	Leaving date
Dieter Meschede	IQO	University Professor	01.06.90	31.03.94
Jürgen Misfeld	IFM	University Professor	01.11.73	06.01.95
Waldemar Bötticher	Plasmaphy	University Professor	01.04.70	31.03.95
Klaus Heilig	IFATMOP	University Professor	01.01.73	30.09.95
Herbert Welling	IQO	University Professor	22.07.74	30.09.96
Rainer Roth	IMUK	University Professor	25.06.75	31.03.98
Dieter Müller	IFINF	University Professor	01.01.73	30.09.98
Alexander Mielke	IFAM	University Professor	01.10.92	31.03.99
Georg Rieger	IFM	University Professor	04.10.74	30.09.99
Frank Demmig	IFATMOP	University Professor	01.12.78	30.09.99
Jürgen Duske	IFINF	University Professor	27.05.74	15.01.00
Klaus Kopfermann	IFM	University Professor	02.05.72	30.09.00
Wolfgang Mader	IFM	University Professor	02.04.79	30.09.01
Helmut Pfeiffer	IFM	University Professor	23.10.75	30.09.01
Burkhard Brehm	IFATMOP	University Professor	13.09.73	30.09.01
Mario Liu	ITP	University Professor	01.01.83	30.09.01
Klaus-Peter Podewski	IFM	University Professor	01.12.78	30.11.01
Erwin Mues	IFM	University Professor	28.03.79	31.03.02
Martin Henzler	FKP	University Professor	01.05.76	31.03.02
Hans-Ulrich Everts	ITP	University Professor	14.02.73	30.09.03
Dietrich Zawischa	ITP	University Professor	22.12.78	30.09.03
Peter Ulrich Sauer	ITP	University Professor	14.10.74	30.09.03
Rudolf Hezel	FB Phy	University Professor	15.09.93	30.09.03
Hans-Jürgen Mikeska	ITP	University Professor	28.01.71	31.03.04
Manfred Kock	IFATMOP	University Professor	01.12.78	30.09.04
Peter Forster	IFAM	University Professor	01.08.80	31.03.05
Maciej Lewenstein	ITP	University Professor	16.02.98	31.03.05
Heinrich Wippermann	IDMP	University Professor	26.03.81	30.09.05
Klausjürgen Schnoege	IFAM	University Professor	06.07.87	30.09.05

Name	Institute	Office/Service Designation	Entry date	Leaving date
Nicole Bäuerle	IMS	University Professor	01.10.02	15.01.06
Günter Mühlbach	IFAM	University Professor	29.03.74	31.03.06
Joachim Engel	IDMP	University Professor	01.10.04	30.09.06
Ursula Schmidt-Westphal	Analysis	University Professorin	27.11.79	31.03.07
Claudia von Aufschnaiter	IDMP	Junior Professor	01.10.05	29.04.07
Karsten Steffens	IAZD	University Professor	22.12.78	30.09.07
Herbert Hotje	IAZD	University Professor	01.07.71	30.09.07
Hans-Christian Graf von Bothmer	IAG	Junior Professor	15.12.05	30.09.08
Jürgen Heine	IFAM	University Professor	22.06.83	31.03.09
Jörg Seiler	IFAM	Junior Professor	01.10.08	31.01.10
Jan Arlt	IQO	Junior Professor	01.11.05	28.02.10
Dieter Etling	IMUK	University Professor	15.03.79	31.03.10
Joachim Reineke	IDG	University Professor	01.06.83	04.08.10
Klaus Hasemann	IDMP	University Professor	01.08.99	31.03.11
Martin Rubey	IAZD	Junior Professor	01.10.08	30.09.11
Karina Morgenstern	FKP/ATMOS	University Professor	10.02.05	31.03.12
Stefan Wewers	IAZD	University Professor	01.10.07	31.03.12
Andreas Ruschhaupt	ITP	Junior Professor	01.04.09	31.08.12
Gerhard Starke	IFAM	University Professor	15.09.00	31.03.13
Maike Tesch	IDMP	Junior Professor	01.04.10	31.07.13
Roman Schnabel	IGP	University Professor	01.04.03	31.08.14
Thomas Hauf	IMUK	University Professor	01.08.98	31.03.15
Teimuraz Vekua	ITP	Junior Professor	16.04.09	15.0415
Marco Zagermann	ITP	Junior Professor	01.09.09	31.08.15
Marcel Erné	IAZD	University Professor	01.04.75	30.09.15
Ernst Peter Stephan	IFAM	University Professor	01.09.89	30.09.15
Lilian Matthiesen	IAG	Junior Professor	01.04.15	29.02.16
Norbert Dragon	ITP	University Professor	01.04.86	31.03.16
Eberhard Tiemann	IQO	University Professor	29.10.82	31.03.16
Stefan Tappe	IVFM	Junior Professor	01.04.11	31.03.17
Ghislain Fourier	IAZD	University Professor	01.10.16	23.07.18
Emil Frederick Wiedemann	IFAM	Univ.-professor a. Z.	01.09.16	31.08.18
Rudolf Grübel	IVFM	University Professor	01.04.94	30.09.18
Wolfgang Ebeling	IAG	University Professor	09.07.90	31.03.20
Wolfgang Ertmer	IQO	University Professor	01.09.94	31.03.20
Herbert Pfnür	FKP	University Professor	01.01.90	30.09.20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Herrenhäuser Straße
Herrenhäuser Kirchweg
Franziusweg
An der Strangriede
Appelstraße
Callinstraße
Kniestraße
Schneiderberg
Nienburger Straße
Georgengarten
Welfengarten
Bodestraße
Asternstraße
Im Moore

Location plan and aerial photos

1 – Welfengarten 1 (main building)
- Institute of Algebraic Geometry
- Institute of Algebra, Number Theory and Discrete Mathematics
- Institute of Analysis
- Institute of Applied Mathematics
- Institute of Mathematics and Physics Education
- Institute of Differential Geometry
- Institute of Quantum Optics
- Institute of Actuarial and Financial Mathematics
- Leibniz School of Optics

2 – Appelstraße 2
- Institute of Solid State Physics
- Institute of Theoretical Physics

3 – Callinstraße 38
- Institute for Gravitational Physics

4 – Herrenhäuser Straße 2
- Institute of Meteorology and Climatology

5 – Herrenhäuser Straße 2
- Institute of Radioecology and Radiation Protection

6 – Appelstraße 11 / 11 A
- Dean's Office
- Dean of Studies
- Institute for Gravitational Physics
- Institute of Photonics

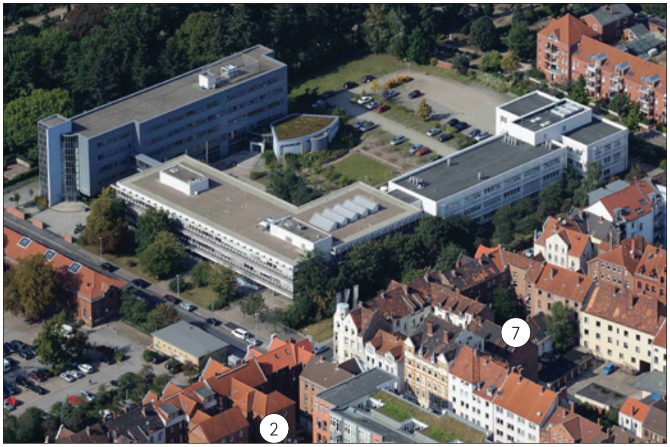
7 – Schneiderberg 32
- Institute of Theoretical Physics

8 – Callinstraße 36
- Quest: Centre for Quantum Engineering and Space-Time Research

9 – Nienburger Straße 17
- Institute of Photonics

Otto-Brenner-Straße 1
- Institute of Actuarial and Financial Mathematics

View of the Welfenschloss - the main building of Leibniz University Hannover



View of the institute buildings Appelstraße 2 and Schneiderberg 32

Overview of the institutes of the Faculty of Mathematics and Physics

	Name	Function	Address	Phone	Room	Page
Institute of Algebraic Geometry						
	Prof. Dr. Wolfgang Ebeling	Professor	Welfengarten 1, 30167 Hannover	0511/762 2248	G316, Building 1101	26
	Prof. Dr. Klaus Hulek	Professor	Welfengarten 1, 30167 Hannover	0511/762 3593	G315, Building 1101	27
Executive Director	Prof. Dr. Stefan Schreieder	Professor	Welfengarten 1, 30167 Hannover	0511/762 2248	G316, Building 1101	24, 28
	Prof. Dr. Matthias Schütt	Professor	Welfengarten 1, 30167 Hannover	0511/762 3593	G131, Building 1101	29
	Natascha Krienen	Office	Welfengarten 1, 30167 Hannover	0511/762 4485	G012, Building 1101	24
	Ute Szameitat	Office	Welfengarten 1, 30167 Hannover	0511/762 3206	G312, Building 1101	24
Institute of Algebra, Number Theory and Discrete Mathematics						
Executive Director	Prof. Dr. Christine Bessenrodt († 24. Januar 2022)	Professor	Welfengarten 1, 30167 Hannover			16, 18
	Prof. Dr. Michael Cuntz	Professor	Welfengarten 1, 30167 Hannover	0511/762 4252	A414, Building 1101	19
	Prof. Dr. Ulrich Derenthal	Professor	Welfengarten 1, 30167 Hannover	0511/762 4478	A413, Building 1101	13, 20, 174
	Prof. Dr. Ziyang Gao	Professor	Welfengarten 1, 30167 Hannover	0511/762 3209	C411, Building 1101	21
	apl. Prof. Dr. Thorsten Holm	apl. Professor	Welfengarten 1, 30167 Hannover	0511/762 4484	C402, Building 1101	22
	Hiltrud Trottenberg	Office	Welfengarten 1, 30167 Hannover	0511/762 3337	A411, Building 1101	16
Institute of Analysis						
	Prof. Dr. Wolfram Bauer	Professor	Welfengarten 1, 30167 Hannover	0511/762 2361	F125, Building 1101	32, 175
Executive Director	Prof. Dr. Elmar Schrohe	Professor	Welfengarten 1, 30167 Hannover	0511/762 3515	F123, Building 1101	30, 33
	Susanne Rudolph	Office	Welfengarten 1, 30167 Hannover	0511/762 3563	F124, Building 1101	30
Institute of Applied Mathematics						
	Prof. Dr. Sven Beuchler	Professor	Welfengarten 1, 30167 Hannover	0511/762 19973	B412, Building 1101	36
	Prof. Dr. Joachim Escher	Professor	Welfengarten 1, 30167 Hannover	0511/762 4472	C406, Building 1101	37
	Prof. Dr. Johannes Lankeit	Professor	Welfengarten 1, 30167 Hannover	0511/762 4977	F120, Building 1101	38
	Prof. Dr. Marc Steinbach	Professor	Welfengarten 1, 30167 Hannover	0511/762 2359	E336, Building 1101	39
	Prof. Dr. Christoph Walker	Professor	Welfengarten 1, 30167 Hannover	0511/762 17203	E340, Building 1101	40

	Name	Function	Address	Phone	Room	Page
Executive Director	Prof. Dr. Thomas Wick	Professor	Welfengarten 1, 30167 Hannover	0511/762 3360	F122, Building 1101	34, 41
	Roswitha Behrens	Office	Welfengarten 1, 30167 Hannover	0511/762 2230	F119, Building 1101	34
	Antje Günther	Office	Welfengarten 1, 30167 Hannover	0511/762 3251	C407, Building 1101	34
	Natascha Krienen	Office	Welfengarten 1, 30167 Hannover	0511/762 19972	B411, Building 1101	34
Institute of Mathematics and Physics Education						
	Prof. Dr. Gunnar Friege	Professor	Welfengarten 1A, 30167 Hannover	0511/762 17223	105, Building 1109	54
	Prof. Dr. Thomas Gawlick	Professor	Welfengarten 1, 30167 Hannover	0511/762 19007	F403, Building 1101	55
Executive Director	Prof. Dr. Reinhard Hochmuth	Professor	Welfengarten 1, 30167 Hannover	0511/762 4752	F405, Building 1101	52, 56
	Prof. Dr. Annika Wille	Professor	Welfengarten 1, 30167 Hannover			57
	Nadine Bischof	Office	Welfengarten 1A, 30167 Hannover	0511/762 17282	104, Building 1109	52
	Anja Krampe	Office	Welfengarten 1, 30167 Hannover	0511/762 5952	F402, Building 1101	52
Institute of Differential Geometry						
	Prof. Dr. Roger Bielawski	Professor	Welfengarten 1, 30167 Hannover	0511/762 2315	C401, Building 1101	44
	Prof. Dr. Lynn Heller	Junior Professorship	Welfengarten 1, 30167 Hannover	0511/762 3895	A421, Building 1101	45
Executive Director	Prof. Dr. Knut Smoczyk	Professor	Welfengarten 1, 30167 Hannover	0511/762 4253	A415, Building 1101	42, 46, 155, 160
	Melanie Eggert	Office	Welfengarten 1, 30167 Hannover	0511/762 2894	A449, Building 1101	42
Institute of Solid State Physics						
Department of Atomic and Molecular Structures						
	Prof. Dr. Fei Ding	Professor	Appelstraße 2, 30167 Hannover	0511/762 4820	139, Building 3701	61
	Prof. Dr. Ilja Gerhardt	Professor	Appelstraße 2, 30167 Hannover	0511/762 4820	143, Building 3701	68
	Prof. Dr. Herbert Pfnür	Professor	Appelstraße 2, 30167 Hannover	0511/762 4819	136, Building 3701	64
	Prof. Dr. Lin Zhang	Junior Professorship	Appelstraße 2, 30167 Hannover	0511/762 4820	143, Building 3701	67
	Anna Braun	Office	Appelstraße 2, 30167 Hannover	0511/762 2581	123, Building 3701	58
	Heike Kahrs	Office	Appelstraße 2, 30167 Hannover	0511/762 4820	142, Building 3701	58
Department of Nanostructure						

	Name	Function	Address	Phone	Room	Page
Executive Director	Prof. Dr. Rolf Haug	Professor	Appelstraße 2, 30167 Hannover	0511/762 2901	122, Building 3701	58, 62, 153
	Prof. Dr. Michael Oestreich	Professor	Appelstraße 2, 30167 Hannover	0511/762 3493	021, Building 3701	63
	Prof. Dr. Andreas Schell	Junior Professorship	Appelstraße 2, 30167 Hannover	0511/762 14890	032, Building 3701	65
	Yvonne Griep	Office	Appelstraße 2, 30167 Hannover	0511/762 2902	124, Building 3701	58
Deaprtment of Solar Energy						
	Prof. Dr.-Ing. Rolf Brendel	Professor	Am Ohrberg 1, 31860 Emmerthal	05151/999100	402	60, 126
	Prof. Dr. Jan Schmidt	Professor	Am Ohrberg 1, 31860 Emmerthal	05151/999 425	425	66
	Yvonne Griep	Office	Appelstraße 2, 30167 Hannover	0511/762 2902	124, Building 3701	58
PTB Group Quantum Technology						
	Prof. Dr. Andreas Schell	Junior Professorship	Appelstraße 2, 30167 Hannover	0511/762 14890	032, Building 3701	65
Institute for Gravitational Physics						
	Prof. Dr. Bruce Allen	Professor	Callinstraße 38, 30167 Hannover	0511/762 17145	165, Building 3401	72, 130
Executive Director	Prof. Dr. Karsten Danzmann	Professor	Callinstraße 38, 30167 Hannover	0511/762 2356	123, Building 3401	70, 73, 130, 144,152
	apl. Prof. Dr. Gerhard Heinzel	apl. Professor	Callinstraße 38, 30167 Hannover	0511/762 19984	C023, Building 3406	74
	Prof. Dr. Michèle Heurs	Professor	Callinstraße 36, 30167 Hannover	0511/762 17037	C127, Building 3406	75, 148
	Prof. Dr. M. Alessandra Papa	Professor	Callinstraße 38, 30167 Hannover	0511/762 17160	133, Building 3401	76
	apl. Prof. Dr. Benno Willke	apl. Professor	Callinstraße 38, 30167 Hannover	0511/762 2360	L107, Building 3401	77
	Kirsten Labove	Office	Callinstraße 38, 30167 Hannover	0511/762 2229	126, Building 3401	70
Institute of Actuarial and Financial Mathematics						
Executive Director	Prof. Dr. Gregor Svindland	Professor	Otto-Brenner-Straße 1-3, 30159 Hannover	0511/762 14812	902	48, 50
	Prof. Dr. Stefan Weber	Professor	Welfengarten 1, 30167 Hannover	0511/762 2312	F440, Building 1101	51
	Bettina Peine-Bertram	Office	Welfengarten 1, 30167 Hannover	0511/762 4250	F439, Building 1101	48
	Sabine Erdmann	Office	Welfengarten 1, 30167 Hannover	0511/762 4250	F439, Building 1101	49
Institute of Meteorology and Climatology						

	Name	Function	Address	Phone	Room	Page
Executive Director	Prof. Dr. Günter Groß	Professor	Herrenhäuser Str. 2, 30419 Hannover	0511/762 5408	F126, Building 4105	78, 80
	apl. Prof. Dr. Sigfried Raasch	apl. Professor	Herrenhäuser Str. 2, 30419 Hannover	0511/762 3253	F231, Building 4105	81
	Prof. Dr. Gunther Seckmeyer	Professor	Herrenhäuser Str. 2, 30419 Hannover	0511/762 4022	F113, Building 4105	82, 163
	Prof. Dr. Björn Maronga	Professor	Herrenhäuser Str. 2, 30419 Hannover	0511/762 4101	F 236, Building 4105	83
	Petra Kraege	Office	Herrenhäuser Str. 2, 30419 Hannover	0511/762 2677	F124, Building 4105	78
Institute of Quantum Optics						
	Prof. Dr. Boris Chichkov	Professor	Welfengarten 1, 30167 Hannover	0511/762 17 771		90
	apl. Prof. Dr. Ayhan Demircan	apl. Professor	Welfengarten 1, 30167 Hannover	0511/762 17219	B104, Building 1104	91
	Prof. Dr. Wolfgang Ertmer	Professor	Welfengarten 1, 30167 Hannover	0511/762 3242	D108, Building 1101	92
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