Integrative Research Institute for the Sciences

Biannual Report 2017 & 2018

Visualization: Nickl & Partner Architekten AG

Preface

With the establishment of **IRIS Adlershof** in 2009, Humboldt-Universität zu Berlin has created an innovative platform for integrative research in the natural sciences. Today, almost 10 years later, IRIS has become an internationally recognized player in the fields of hybrid inorganic and organic systems for optics and electronics, and also for the physics of space, time and matter.

Started with a small office in HU's Department of Physics in the Lise-Meitner-Haus, IRIS in its present IRIS Building at Zum Großen Windkanal 6 hosts six theoretically oriented research groups, with more than 80 scientists and students, as well as the branch offices of **IRIS Adlershof** and the Collaborative Research Centre 951 Hybrid Inorganic/Organic Systems for Opto-Electronics (HIOS), and also the ProMINT-Kolleg.

Another 120 scientists and students from experimental IRIS research groups are looking forward to the commissioning of the newly constructed IRIS Research building, which is expected to be operational early 2020. The federal government, the state of Berlin and Humboldt-Universität zu Berlin are providing a total of more than 50 million € for this purpose.

The successful acquisition of the funds required for the construction of the research building is considered essential for the future of **IRIS Adlershof**, since the new research building will be an asset for excellent research in its research fields, as well as the promotion of young researchers.

We have learned with great pleasure that outstanding junior scientists who have obtained substantial research funding from the ERC or the German Federal Government to establish independent junior research groups, have moved from abroad to Adlershof to benefit from the integrative research culture at **IRIS Adlershof**, and also from the excellent infrastructure, expected from the new research building.

During the reporting period, **IRIS Adlershof** has considerably enhanced its national and international cooperation and visibility, in particular through large collaborative projects such as Collaborative Research Centers, ERC and EU projects, and also by hosting meetings and conferences. We are pleased to report an increasing number of invited lectures at internationally siginificant conferences as well as highly recognized publications.

It is my pleasure to thank all members and the staff of **IRIS Adlershof** for their dedicated work, and we are all very grateful for the support that we have received from the administrative departments and the President's office of Humboldt-Universität zu Berlin. Certainly, we are very much looking forward to further fruitful collaborations.

Jürgen P. Rabe I Director of **IRIS Adlershof**

Content

1. Executive Summary

IRIS Adlershof can look back on two very successful years in which significant positive growth has been achieved: In 2017 and 2018, the Integrative Research Institute for the Sciences efficiently established its position as an international leader in the research areas Hybrid Systems for Optics and Electronics and Space-Time-Matter, made great progress in the promotion of young scientists and is on the verge of the inauguration of its own research building.

Outstanding Scientific Achievements

A clear indication of **IRIS Adlershof**'s positioning at the center of the scientific scene are the outstanding scientific achievements of its 22 members, three junior research group leaders, and about 120 early career researchers. Their groundbreaking scientific results were presented to the international scientific community in high impact journals and at national and international conferences.

Among the scientific highlights from 2017 is the article "*Beating the thermodynamic limit with photo-activation of n-doping in organic semiconductors using "hyper-reductants"*", published by IRIS member Norbert Koch together with colleagues from Georgia Tech and Princeton in Nature Materials. One of the key highlights from 2018 is the article "*Collective molecular switching in hybrid superlattices for light-modulated two-dimensional electronics*", which was published by IRIS member Stefan Hecht together with international and scientifically enormously recognized colleagues in the journal Nature Communications.

All scientific highlights will be discussed in Chapter Two of this report, a list of key conferences, seminars and outreach activities IRIS members have participated in, can be found in the appendix (pp. 94-100).

That the scientific performance of the **IRIS Adlershof** members takes place at a top level is furthermore particularly illustrated by the high number of peer-reviewed publications in high impact journals, which exceeded 180 in total in the reporting years. A list of selected publications can be found in the appendix (pp. 83-93).

Two Key Objectives In 2017 And 2018

In order to maintain the best possible support and furtherance of the top achievements of its members, **IRIS Adlershof** strongly focused on its two key objectives during the reporting period: to provide outstanding scientists with an excellent infrastructure for interdisciplinary research and to promote young scientists.

Strong Promotion Of Junior Scientists

Following the recommendation of an expert commission and with the aim of continuous further improvement, **IRIS Adlershof** significantly expanded its measures to support young scientists: In December 2017, the IRIS Council was extended to now include two representatives of the young scientists, Julian Miczajka, who is a doctoral student in Jan Plefka's group, and Sven Ramelow, junior research group leader since 2016, as his deputy. This enables the young scientists to participate more actively in the future development of **IRIS Adlershof**. Furthermore, **IRIS Adlershof** organized a series of seminars and supported numerous events addressed to promising young scientists to further encourage those. All support measures and, above all, the outstanding achievements of **IRIS Adlershof**'s young scientists are discussed in detail in Chapter Three.

With regard to the promotion of young talent and the related continuous further enhancement of **IRIS Adlershof**, it is also positive to note that the promising chemist and ERC-grant holder Michael J. Bojdys could be won as a new junior research group leader. Due to his great enthusiasm for the concept of **IRIS Adlershof** and the research carried out here, he joined the Humboldt-Universität zu Berlin in 2018 as leader of the junior research group Functional Nanomaterials. The group's research aims at the development of metal-free, electronic components for transistors and sensors on the basis of functional materials made up of light, covalently-bonded atoms. At the heart of the project lies the challenge to transfer the control mechanisms and modularity known from molecular, organic chemistry to macroscopic structures. Bojdys reinforces the chemical aspect of the Integrative Institute for the Sciences and his collaboration with IRIS Director Jürgen P. Rabe and IRIS member Emil List-Kratochvil will further contribute to the outstanding research at **IRIS Adlershof**.

Bojdys is one of a total of five junior research group leaders related to **IRIS Adlershof** in 2017 and 2018. Compared to previous years, two junior research group leaders have ended their activities during the reporting period to pursue different scientific activities: David Bléger, who established the independent junior research group Photodynamic Molecular Systems and Materials in 2013, left **IRIS Adlershof** in late 2018 to pursue a career in industry and the former junior research group leader Yan Lu was accepted as a full IRIS member after being appointed a W2-S professorship for Polymer-based Hybrid Materials at the University of Potsdam in 2017. An overview of all junior research group leaders can be found in the appendix (p. 46).

5 New IRIS Members

Since the recruitment of new highly qualified scientists as members is of utmost importance for outstanding research results and for the further growth of a research institute, it should be emphasized when looking back on the reporting period, that **IRIS Adlershof** was able to gain a total of five new members:

As mentioned above, in 2017, the junior research group leader Yan Lu became a full member of **IRIS Adlershof**. Her new position is linked to the management of a working group at the Helmholtz-Zentrum Berlin für Materialien und Energie GmbH. There she is researching in the field of colloid chemistry, focusing on the synthesis and characterization of hybrid functional materials. As an expert in the fields of colloid chemistry, she is an essential asset for **IRIS Adlershof**. Yan Lu about her admission to IRIS: "**IRIS Adlershof** is a diverse and high-quality research harbor where my Colloid chemistry team could easily meet and interact with groups with different research expertise, from theory, fundamental studies to applications. Being a member of **IRIS Adlershof** provides a valuable opportunity for the next stage growth of my research activities on a much broader platform."

Since Fall 2016, Kannan Balasubramanian has been a professor for Micro and Nano Analytical Sciences and a member of the Graduate School SALSA at Humboldt-Universität

zu Berlin, and since August 2017, he has been a member of **IRIS Adlershof**. Kannan Balasubramanian's research focuses on nanostructured materials such as graphene, and the realization of nano and micro scale devices as novel analytical tools in a fluidic environment. His expertise is of particularly importance for **IRIS Adlershof**'s research focus on Hybrid Systems, to which the new research building is dedicated.

In the same year, Caterina Cocchi became not only a junior professor at the Department of Physics of Humboldt-Universität zu Berlin but also a member of **IRIS Adlershof**. In the focus of her research interests is light-matter interaction with advanced first principles methods, based on density-functional theory (DFT) and its time-dependent extension (TDDFT) as well as of many-body perturbation theory (MBPT). As a new member of IRIS Adlershof, Caterina Cocchi reinforces the vital link between theoretical and experimental physics. Caterina Cocchi about IRIS: "**IRIS Adlershof** is the home of my research. It provides me and my group with fully equipped office space and cozy common rooms. But IRIS is actually much more than that. By hosting and co-organizing seminars, workshops, and research exchanges, IRIS generates the opportunities to interact with other scientists, no matter whether they are from the other side of Campus Adlershof, the other side of Berlin, or even the other side of the world. IRIS welcomes our guests and makes them feel like at home. It provides us with all the support that is indispensable for a young group to grow and to establish itself in the international scientific scene. I could not imagine any better place to work in science than **IRIS Adlershof**!"

With the appointment of Michael Hintermüller as a new member, the valuable presence of mathematics in the Integrative Research Institute for the Sciences is increased. Hintermüller is a professor for Applied Mathematics at Humboldt-Universität zu Berlin, Director of Weierstrass Institute for Applied Analysis and Stochastics and Chair of the Einstein Center for Mathematics Berlin. He became a member of **IRIS Adlershof** early 2018 and his current research interests lie in the area of mathematical modeling, the analysis of the resulting variational problems or operator equations as well as in the development, analysis and numerical implementation of associated solution methods.

The admission of Igor Michailovitsch Sokolov also provides essential impulses for **IRIS Adlershof**, as it strengthens the link between the research areas Mathematical Physics and Hybrid Systems. Igor M. Sokolov, physics professor at Humboldt-Universität zu Berlin, joined **IRIS Adlershof** in August 2017. The main interest of his research is on statistical physics and the physical chemistry of condensed and soft matter, especially problems in which the discrete, disordered structure and fluctuations play the leading role.

With their expertise, these five new members will contribute immensely to the further expansion and interlinking of the IRIS research areas and thus strengthen the Institute itself. **IRIS Adlershof** is very pleased about this enrichment.

During the reporting period, three members left **IRIS Adlershof** to pursue different scientific activities: Johann-Christoph Freytag, one of **IRIS Adlershof**'s founding members, left the Integrative Institute for the Sciences in 2017 to focus on his new position in the Executive Board of the Einstein Center Digital Future. Regine von Klitzing, who had been an IRIS member since 2012, transferred to Technische Universität Darmstadt in 2017 and and the IRIS-founding member Joachim Sauer became an emeritus professor in 2017. **IRIS Adlershof** would like to express its appreciation for the excellent and fruitful cooperation over the years! A list off all current members of **IRIS Adlershof** can be found in the appendix (pp. 40-46).

IRIS Research Building

With regard to **IRIS Adlershof**'s goal of creating the best possible framework for cutting-edge research, the progress made in completing the IRIS research building during the reporting period can be rated as positive. Construction progressed so far in 2017 and 2018 that the building can be opened in early 2020 – a milestone event for **IRIS Adlershof** which will be addressed in the next annual report. The IRIS research building will provide outstanding scientists with excellent working conditions, it will allow the IRIS research areas to expand and it will further strengthen **IRIS Adlershof**'s international appreciation. This makes it a symbol of the continuous spatial and scientific growth of **IRIS Adlershof**. Details on construction progress and the expansion of the research infrastructure are presented in the appendix (pp. 50-52).

Successfull Collaborative Projects

During the reporting period, members of **IRIS Adlershof** were participating in important coordinated collaborative projects. The Graduate Schools Berlin Mathematical School and School of Analytical Sciences Adlershof (SALSA) as well as the Clusters of Excellence Image Knowledge Gestaltung and Unifying Concepts in Catalysis (UniCat) were particularly successful: Although the Excellence Initiative and thus the projects themselves ended in October 2017, they emerged into the new Clusters of Excellence Matters of Activity, UniSysCat, and Math+ due to their great achievements.

With regard to Collaborative Research Centers, **IRIS Adlershof** focused in particular on the preparation of the application for a third funding period of the CRC 951 Hybrid Inorganic/Organic Systems for Opto-Electronics (HIOS). The proposal was submitted to the German Science Foundation (DFG) in December 2018.

Among the remarkable collaborative projects that launched during the reporting period and in which **IRIS Adlershof**'s members actively participate, are the EU Research Project SAGEX and the BMBF project Q.Link.X. Furthermore, a joint lab between the group Hybrid Devices led by IRIS member Emil List-Kratochvil and the Helmholtz Innovation Lab HySPRINT was established during the reporting period. The collaboration focuses on the generative manufacturing processes for hybrid components. All coordinated collaborative projects with IRIS involvement are addressed in detail in the appendix (pp. 53-82).

HLRN-IV Super-Computer

For the scientists at **IRIS Adlershof**, the signing of the contract for the HLRN supercomputer by the HLRN-Verbund was also a significant change in 2018. The supercomputer HLRN-IV will replace the previous model HLRN-III. IRIS member Alexander Reinefeld explains: "With nearly a quarter of a million cores and computing power of about 16 peta-flops, the new system will be about six times faster than the previous one. This will enable researchers to carry out even more precise model calculations in the future, for example in environmental research, the life sciences, materials and engineering sciences, and in basic research in physics, chemistry and mathematics." The computer is located at the Zuse Institute Berlin and is available to IRIS members.

International Visibility

In order to strengthen its international visibility in the two current IRIS research areas and to further profile the Adlershof campus as a place of international innovative research, **IRIS Adlershof** initiated new and intensified existing fruitful international cooperation with international partner institutions that are world leaders in those research areas during the reporting period.

The long-standing and intensive collaboration with HU's profile partners, Princeton University and National University of Singapore (NUS) in the research area Novel (Opto-) Electronic Materials are particularly important for the Integrative Research Institute for the Sciences. An immensely fruitful collaboration between Andrivo Rusidy from the National University of Singapore and IRIS member Claudia Draxl is based on their common interest on solar-cell materials, investigating their interaction with radiation from two different perspectives, for example experiment on the NUS side and ab initio theory on the HU side. Concerning kersterites, a puzzling seeming discrepancy between different X-ray absorption measurements (K- edge and L2,3-edge, performed on different samples) and theoretical results could be solved by performing both probes (K- and L-edge) on a dedicated new sample at NUS. In-depth analysis based on many-body theory calculations finally revealed the different nature of the used samples, being either disordered or copper-poor. Another focus are 2D hybrid perovskites, where common investigations are dedicated to explore the effect of spin-orbit coupling on the excitation spectra.

To further increase its international visibility and to establish and maintain important international cooperation, **IRIS Adlershof** financially supported the scientifically highly acclaimed Gordon Research Conference: Electronic Processes in Organic Materials in July 2018 within the framework of the Strategic Partnership with Princeton University. Amongst the invited speakers of the conference, which was held in Italy, were the **IRIS Adlershof** members Norbert Koch and Claudia Draxl.

In October 2018, **IRIS Adlershof** strengthened its international cooperation with the HU's third strategic profile partner and one of the consistently top ranked universities in the South American subcontinent, the Universidade de São Paulo (USP). At a very prosperous meeting with the USP's president, Professor Vahan Agopyan, and the USP's vice-president for International Relationships, Professor Raul Machade Neto, in Adlershof, Jan Plefka, the vice dean for research at the HU's Faculty of Mathematics and Natural Sciences and a member of **IRIS Adlershof,** and IRIS's manager Nikolai Puhlmann

emphasized the current study conditions on Humboldt's natural science campus and the research opportunities at **IRIS Adlershof**. The guests from São Paulo were particularly impressed by the progress of the HU's research results and praised the diverse opportunities offered by the Adlershof science location for high-ranking scientific research and the training of international young scientists.

Earlier the same year, **IRIS Adlershof** welcomed a group of students and professors from Morehouse College and Spelman College, two so-called historically black colleges and universities or colleges from the Black Ivy League from Atlanta, Georgia (USA), who were also interested in the outstanding research opportunities provided by the natural science campus and **IRIS Adlershof**.

Welcoming Guest Researchers

Welcoming guest researchers is also very important for the expansion of **IRIS Adlershof**'s international relations, as they provide an important impetus for research conducted at the Institute. During the reporting period, **IRIS Adlershof** not only hosted guest scientists but also laid the foundation for successful future cooperation:

Distinguished Professor Rich Spontak from the Department of Chemical and Biomolecular Engineering of North Carolina State University visited **IRIS Adlershof** as a guest professor of the Cluster of Excellence Image Knowledge Gestaltung within the project Experimental Systems twice during the reporting period, from June to July in 2017 and from November to December in 2018. Professor Spontak's focus areas in research are polymer morphology and phase stability, multifunctional and nanostructured polymers, blends and networks, and the application of microscopy techniques to polymer science and engineering. In winter 2018, he gave a lecture at the **IRIS Adlershof** seminar on Designing selective membranes from the ground-up: A Polymer Scientists Playground.

Humboldt Research Award

Moreover, a total of three internationally acclaimed scientists won the highly renowned Humboldt Research Award during the reporting period, who will then conduct research at **IRIS Adlershof** in the following reporting period:

In October 2017, Lance Jenkins Dixon received the renowned research prize of the Alexander von Humboldt Foundation. Dixon is a professor at the National Accelerator Laboratory Slac, operated by Stanford University, and a leading researcher in theoretical high-energy physics. His contributions range from seminal and mathematically profound papers in the early phase of string theory to very practical high precision calculations in Quantum Chromodynamics (QCD) relevant to collider physics, and to an ever deeper understanding of scattering amplitudes for quantum field theory. The price allowed him to work for a total of one year with scientists at Humboldt-Universität zu Berlin to develop new ways to solve quantum field theory nonperturbatively, and to investigate further the elusive theory of quantum gravity. He was hosted by **IRIS Adlershof** within the research areas Space-Time-Matter and Mathematical Physics.

In March 2018, Seth Marder, Professor of Chemistry and Materials Science and Engineering (courtesy) at the Georgia Institute of Technology, was awarded the Humboldt Research Award. Seth Marder is internationally recognized for his leadership in developing structure-property relationships for organic and metallo-organic materials for optical and electronic applications. Whilst his time as a visiting professor in Adlershof, Seth Marder continued his collaborative studies of the effects of dopants on the properties of both organic and inorganic materials. He was hosted by Nobert Koch at **IRIS Adlershof** and the Department of Physics of Humboldt-Universität zu Berlin.

Niklas Beisert, professor for mathematical physics at the ETH Zürich, Switzerland, also received the Humboldt Research Award in March 2018. Beisert is an internationally known leading researcher in the area of the quantum field theory and integrable models. The research prize gives Beisert the opportunity to explore exact nonperturbative solutions in quantum field theory together with Jan Plefka, Matthias Staudacher, and Dirk Kreimer, his colleagues from **IRIS Adlershof** and the Departments for Physics and Mathematics of the Humboldt-Universität zu Berlin. Beisert also has the opportunity to investigate the hidden symmetries in quantum field theories in depth. He will stay seven months as a guest of **IRIS Adlershof** and strengthen the IRIS research field Space-Time-Material in the academic year of 2018/2019 with his expertise.

Cooperation With Iranian Universities

In order to further enhance and specialize their international profile, the HU and **IRIS Adlershof** endeavored to expand scientific cooperation with Iranian universities during the reporting period. After the first visit to Iran in October 2017 and the participation in the very successful German-Iran Science Day in February 2018, **IRIS Adlershof** hosted a match-finding workshop in Berlin in October 2018. Its aim was to explore the possibility of a promising scientific cooperation with the University of Teheran, the Tarbiat Modares University and Amirkabir University of Technology in **IRIS Adlershof**'s central research field Hybrid Systems for Optics, Electronics and Photonics. The workshop, in which 23 scientists participated, was a success and common interests could be identified. In a next step, the scientists will examine the possibilities of expanding their respective joint project ideas into concrete project proposals. A first concrete resulting cooperation measure is the eight-month-research stay of two Tehran postdocs in the group of IRIS member Emil List-Kratochvil on the subject of Transition Metal Dichalcogenide (TMD)monolayers, which began in February 2019.

Future Goals

In summary, **IRIS Adlershof** had two very successful years and is starting the next reporting period with full verve. **IRIS Adlershof** wants to continue growing and developing and the objectives for the next reporting period are as follows: Moving in and commissioning the new IRIS research building, expanding the IRIS research fields by enlarging existing ones and/or adding new ones and successfully renewing the CRC 951 Hybrid Inorganic/Organic Systems for Opto-Electronics (HIOS).

2. Scientific Highlights

The most outstanding scientific results are regularly presented by **IRIS Adlershof** on its website (www.iris-adlershof.de). In order to communicate the exceptional achievements of its members not only to the international professional public, but also to interested readers without detailed expertise in the fields being discussed, a generally understandable presentation method was chosen. These are the scientific highlights of 2017 and 2018:

"Flying Plasmons": Unprecedented Precision Studies Of Surface Plasmon Polaritons In Levitated Silver Nanowires

The field of plasmonics is motivated by the ever-increasing need to reduce the footprint of optical devices, to enhance their operation speed, and to increase their energy efficiency. Surface plasmon polaritons (SPPs) at metal-dielectric interfaces can tightly confine and guide electromagnetic excitations. This not only allows for guiding energy on small length scales, but also establishes a dramatically enhanced light-matter interaction. In order to understand and even design the functionality of highly integrated devices utilizing SPPs, it is mandatory to exactly know the properties of individual constituents, that is, plasmonic nano wires or nano particles. However, the material parameters of nano particles deviate from bulk properties and mandatory supporting structures are of great influence.

A way to isolate small objects in a clean environment is levitation in vacuum. Researchers from the Department of Physics at Humboldt-Universiät zu Berlin now isolated charged particles ranging in size from a few micrometers using the oscillating electric field in a Paul trap. For the first time, they were able to investigate plasmon propagation in a freely levitated silver nanowire.

The studies allowed for investigations of the optical properties of silver wires without any supporting structure and in an environment, which could be almost completely controlled. Furthermore, the simple and well-defined geometry of the problem, that is, a cylinder surrounded by vacuum or air, renders precise, quantitative comparison to analytical and numerical models possible. The work represents a study of unprecedented coherence, as it was possible to correlate clean transmission spectrograms with wire geometry and a simple Fabry-Pérot model.

Our studies pave the way for quantitative characterization of nearly any trappable plasmonic nano object, even of fragile ones such as droplets of liquids or molten metal and of nearly any nanoresonator based on a finite waveguide with implications for modeling of complex hybrid structures featuring strong coupling or lasing." says Oliver Benson from the Department of Physics and **IRIS Adlershof**.

A goal of follow-up research refers to surface plasmon polaritons as local generators of heat, point-like electron emitters, and local chemical reaction sites. Here again, it would be desirable to work out the properties of a

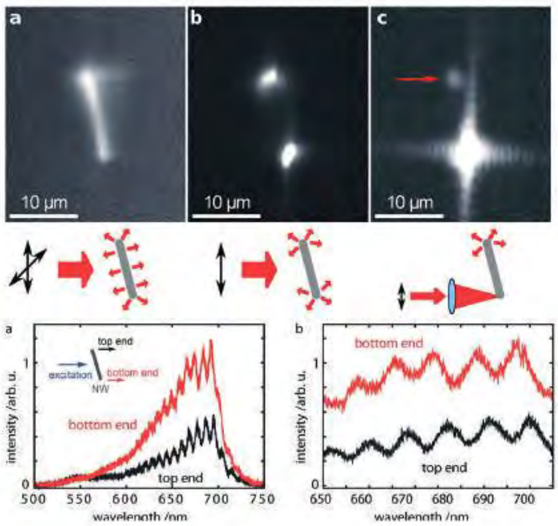


Fig. 1: Optical characterization of a single levitated silver nanowire and white light scattering spectra acquired from levitating nanowires

a) CCD camera image of a Ag nanowire illuminated by unpolarized white light from a halogen lamp.
b) Using white light from the supercontinuum source polarized parallel to the wire strong scattering from the wire's ends is visible.
c) White light from the supercontinuum source is focused onto the lower end of the wire. Besides the large bright spot from the directly reflected light, light also stemming from the distal end of the wire is visible (indicated by an arrow) as a clear indication of surface plasmon polarition being guided along the wire and scattered out at the end. The length of the wire is approximately 12 µm.
d) Optical spectra acquired from the top (black line) and the bottom ends (red line) of a silver nanowire approximately under illumination from the side using the supercontinuum source.
e) Zoom into the region from 650 to 700 nm.

"pure" plasmonic nano particle, for example, in a comparison with theoretical investigations looking for signatures of quantum behavior. Moreover, the configuration studied in the actual experiment has the potential to be complemented by gas sensors to study the impact of hot electrons on catalytic reactions nearby plasmonic particles.

Publication
"Flying Plasmons": Fabry-Pérot Resonances in Levitated Silver Nanowires
A. W. Schell, A. Kuhlicke, G. Kewes, and O. Benson
ACS Photonics 4 (2017) 2719
DOI: 10.1021/acsphotonics.7b00526

Beating The Thermodynamic Limit With Photo-Activation Of N-Doping In Organic Semioconductors Using "Hyper-Reductants"

Doping of semiconductors is a key process for controlling the materials' charge carrier density, which directly impacts the electrical conductivity. Electronic and optoelectronic devices used in information, communication, energy conversion, and energy storage technologies rely on precise and efficient doping, i.e., the admixture of a small amount of a doping agent into the semiconductor.

However, n-type doping of organic semiconductors – electron transfer from the dopant to the semiconductor – is notoriously difficult as the molecular dopants employed presently are highly sensitive to ambient exposure, upon which they react with water and oxygen and are rendered inactive.

In an article that just appeared in Nature Materials, a team of researchers from the Georgia Institute of Technology, the Helmholtz-Zentrum Berlin, Humboldt-Universität zu Berlin, and Princeton University demonstrates a new approach towards n-doping of organic semiconductors, which allows bypassing the dopant sensitivity to the ambient and simultaneously enables doping organic electron transport materials that have been out of reach for n-doping so far.

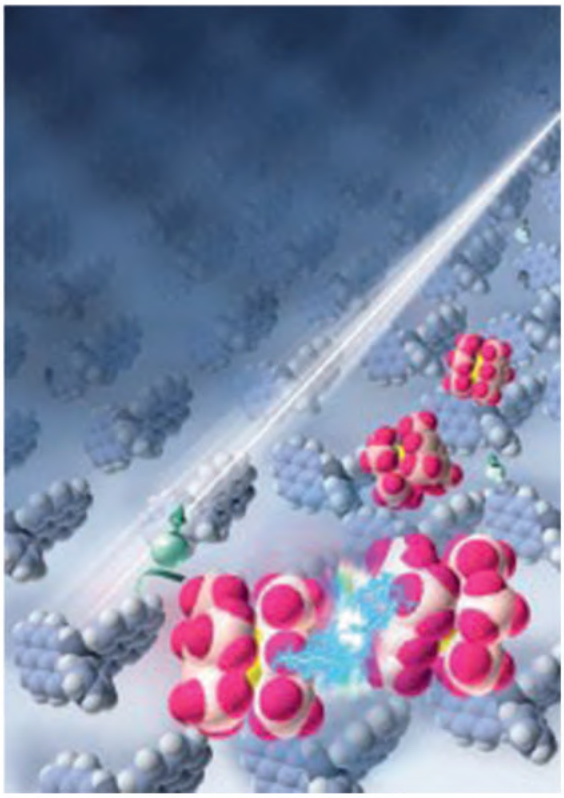
The first step of innovation lies in chemically connecting two organometallic molecular dopants in a dimer that is stable even in air, with reduced ability to dope organic electron transport semiconductors. Consequently, when mixing these into the organic semiconductor, nothing happens at first.

The revolutionary step now involves illuminating the mixture with light. A dimer and a semiconductor molecule in immediate proximity absorb a photon, the dimer can dissociate and unfold the full doping power of each dopant in a multi-step process. "By this optical activation of dopants, we could enhance the conductivity of organic electron transport materials by five orders of magnitude. This boosts the efficiency of organic light emitting diodes and solar cells, using rather simple and technologically relevant processing" says Prof. Antoine Kahn from Princeton University, who coordinated the project.

The choice of the article's title is explained by Prof. Seth Marder from Georgia Tech: "This doping is actually beyond the thermodynamic limit of what the dopant should be able to do, thus once the light is turned off one might naively expect the reverse reaction to occur (rapidly, within seconds perhaps) and the conductivity increase to disappear. However, this is not the case. The reason for this is that the doping process involves multiple steps, and the back-reaction to the starting system involves many uphill intermediate steps creating a kinetic barrier, thus the reverse reaction is extremely slow." Indeed, no indications of a loss in conductivity upon light-activation after hundreds of hours were found. For these reasons, the compounds are referred to as "hyper-reductants".

The fact that the team demonstrated the beneficial effect of their doped electron transport semiconductors in highly efficient light emitting diodes underlines the huge potential of this approach in device applications.

"We believe that our work enables simple processing of n-doped organic semiconductors in numerous device architectures, where the critical step - doping activation - can take place after standard device encapsulation. This will contribute substantially to improved device lifetime and in some case simplify device fabrication" notes Prof. Norbert Koch from Humboldt-Universität, member of **IRIS Adlershof**. The work was part of a project within the strategic partnership program of Princeton University and Humboldt-Universität.



© *Jing Wang and Xin Lin*

Publication

Beating the thermodynamic limit with photo-activation of n-doping in organic semiconductors using "hyper-reductants"
X. Lin, B. Wegner, K.M. Lee, M.A. Fusella, F. Zhang, K. Moudgil, B.P. Rand, S. Barlow, S.R. Marder, N. Koch, and A. Kahn
Nat. Mat. 16 (2017) 1209
DOI: 10.1038/nmat5027

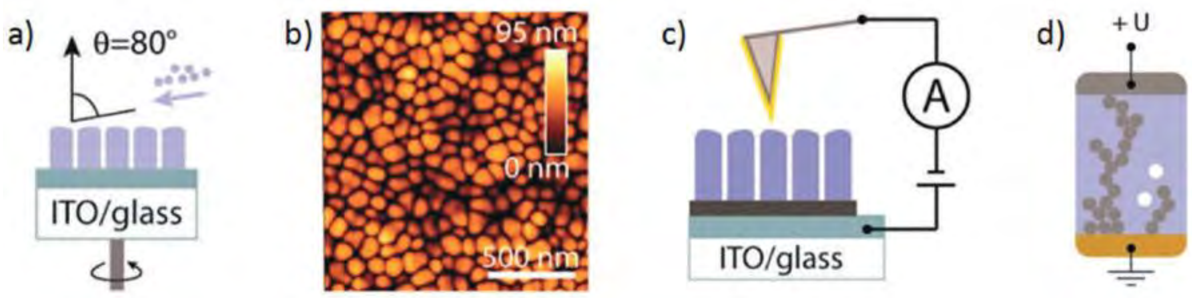
GLAD Makes New Organic Memory Devices Possible

Giovanni Ligorio, Marco Vittorio Nardi, and Norbert Koch, member of **IRIS Adlershof**, have invented a new technique for constructing novel memory devices. The results have now been published in Nano Letters.

Author Dr. Giovanni Ligorio explains: "Novel non-volatile memory devices are currently investigated to overcome the limitation of traditional memory technologies. New materials such as organic semiconductors and new architectures are now considered to address high-density, high-speed, low-fabrication costs and low power-consumption. Usually, nano-devices (traditionally based on inorganic semiconductors) are fabricated via lithography techniques. Here, we show the fabrication of devices with nanometric footprint using a different technique: Glancing Angle Deposition (GLAD). This technique allows the tailoring of nanostructured morphologies through physical vapor deposition via controlling the substrate orientation with respect to the vapor source direction. When thin films are deposited onto stationary substrates under condition of oblique deposition, meaning that the vapor flux is non-perpendicular to the substrate surface, an inclined columnar nanostructured is produced. Upon proper bias applied between the two electrodes of the memory device, it is possible to form a conductive path (or filament). The filament shorts the electrodes and drastically changes the resistivity characteristic of the device. Forcing a high current in the device, the filament can be distrust. This programs the device in the original high resistivity state. Since the process can be repeated consecutively we can program the device in a high or low resistive state (i.e. ON or OFF). We aim for the fabrication of devices in structured arrays (in this publication the nano devices are not ordered in array, but they are randomly distributed.) This allows for connecting via cross bar electrodes, which can be fabricated via printing. This allows fabricating memory devices with a density of roughly 1 GB/cm² employing novel material for electronics, i.e. organic semiconductors."

Publication

Lithography-Free Miniaturization of Resistive Nonvolatile Memory Devices to the 100 nm Scale by Glancing Angle Deposition
G. Ligorio, M. Vittorio Nardi, and N. Koch
Nano Lett. 17 (2017) 1149
DOI: 10.1021/acs.nanolett.6b04794



With GLAD technique, the oblique incident vapour deposition (see the setup schematic in a) results in films with a characteristic columnar nanostructure (as depicted in atomic force microscopy image in b). Each column is considered as a single device on the lateral nanometric scale. Once electrically connected, e.g. via a conductive cantilever (see in c), information can be stored in the column by the formation/disruption of a conductive filament (see d).

Longer Lifetimes For Perowskit Absorber

An international team of scientists has improved greatly the stability of organic-inorganic lead halide perovskites. These materials have enormous potential for photovoltaic applications but still suffer from comparably moderate device lifetime. The scientists, led by researchers from the EPFL, Lausanne, Switzerland, incorporated a large organic cation – guanidinium – into the perovskite crystal structure, in part replacing the traditionally used methylammonium and formamidinium cations.

Overall, the new material delivered average power conversion efficiencies over 19% and stabilized performance for 1,000 h under continuous light illumination. This is a fundamental step within the perovskite field. These groundbreaking research results were recently published in Nature Energy. Among the authors is the member of **IRIS Adlershof**, Norbert Koch.

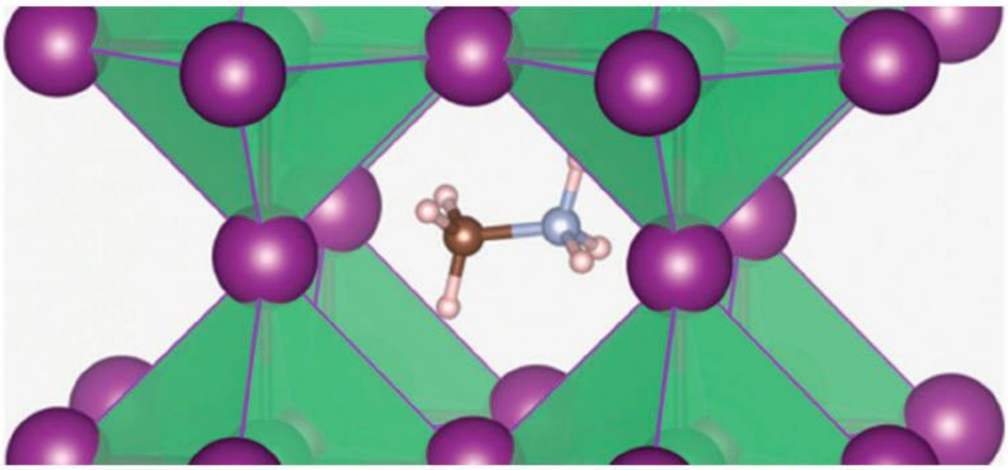
Publication

Large guanidinium cation mixed with methylammonium in lead iodide perovskites for 19% efficient solar cells

A.D. Jodlowski, C. Roldán-Carmona, G. Grancini, M. Salado, M. Ralaiarisoa, S. Ahmad, N. Koch, L. Camacho, G. de Miguel, and M.K. Nazeeruddin

Nature Energy 2 (2017) 972

DOI: 10.1038/s41560-017-0054-3



Spiro-Bridged Ladder-Type Oligo(*para*-phenylene)s: Fine Tuning Solid State Structure And Optical Properties

In this recent research highlight, the authors developed synthetic routes that allow to subsequently replace every pair of symmetry-equivalent alkyl groups in ladder-type quaterphenyl by a spiro-bifluorene group.

With an increasing number of spiro groups, the optical gap for absorption and emission slightly decreases, which is disadvantageous with respect to resonant energy transfer with ZnO. Thus, a synthetic route to a *para*-linked ladder-type quaterphenyl carrying all bridging units on one side of the ribbon was developed, which results in an in-plane bending of the *para*-phenylene. The optival gap increased compared to the linear molecule, however, the absorption coefficient slightly decreased. The authors analyzed the influence of different deposition techniques on the solid state structure by X-ray diffraction of single crystals obtained by crystallization from solution as well as sublimation.

In the cases of L4P-sp2 and L4P-sp3, it could even be shown that sublimation and crystallization from solution result in different crystal structures, of which the ones from sublimation are obviously more relevant in view of the typically employed vacuum deposition and might be advantageous in terms of application in light-emitting devices.

An increasing number of spiro-bifluorene substituents was found to aid thin-film formation on oxide surfaces, such that the optical properties could be preserved in pure, nondiluted thin films.

Finally, promising spiro-L4P derivatives have been employed in energy-transfer devic-

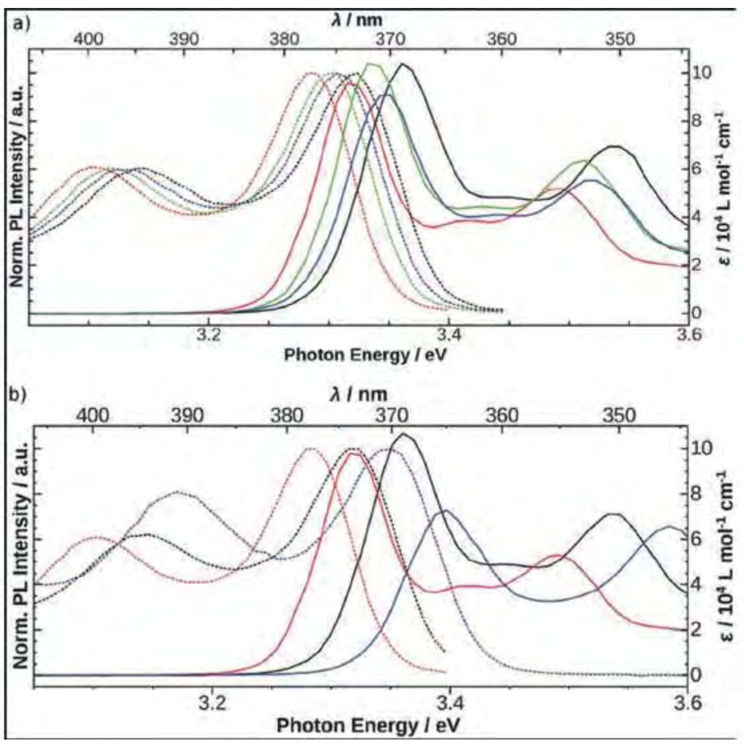


Fig. 1: *Absorption (solid lines) and normalized PL (dotted) spectra of final products 10-6 - 10-5 mol L-1 in CH2Cl2.*
For more details please see the publication text.

es, for which highly efficient energy transfer from an inorganic quantum well to the organic layer followed by efficient light emission could successfully be demonstrated.

Publication

Spiro-Bridged Ladder-Type Oligo(para-phenylene)s: Fine Tuning Solid State Structure and Optical Properties
B. Kobin, J. Schwarz, B. Braun-Cula, M. Eyer, A. Zykov, S. Kowarik, S. Blumstengel, and S. Hecht
Adv. Funct. Mater. 27 (2017) 1704077
DOI: 10.1002/adfm.201704077

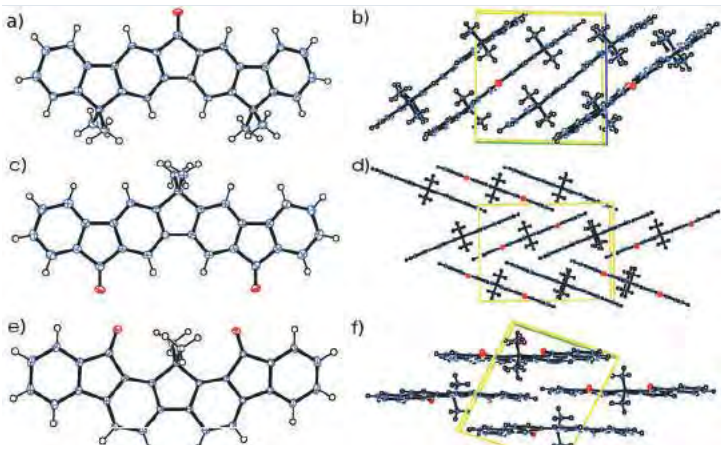


Fig. 2: *Asymmetric units (left) and arrangement of molecules in the crystal (right) of different molecule types. Thermal ellipsoids drawn at 50% probability level, cell edges marked in a: red, b: blue and c: green. For more details please see the publication text.w*

X-Ray "Movie" Provides Insights Into The Formation of Molecular Layers

Thin-film technologies that promise control on the atomic and molecular scale have attracted increasing interest in recent years as traditional manufacturing processes reach their fundamental limits. A team from the Department of Physics at the Humboldt-Universität zu Berlin, led by Anton Zykov, Stefan Kowarik and Jürgen P. Rabe (member of **IRIS Adlershof**) in collaboration with colleagues from the PETRA III Synchrotron at DESY Hamburg has now studied the non-equilibrium growth of molecular layers using innovative, time-resolved X-ray scattering. The movie sequence of the X-ray scattering during the molecular beam deposition was chosen as the cover image of a special topic issue of the Journal of Chemical Physics on "Atomic and molecular layer processing".

Semiconducting organic molecules have significant potential for future applications such as organic light-emitting diodes (OLED), camera sensors or memory devices. Many of these components are based on ultra-thin layers of functional molecular materials. Their preparation by deposition of molecules from the gas phase is a complex process involving molecular adsorption on a substrate, molecular diffusion and self-assembly. Since many of these processes do not proceed under conditions of local thermodynamic equilibrium, these processes and their velocities are still not well understood.

By means of innovative X-ray measurements of diffuse scattering at the P03 Beamline of the PETRA III synchrotron, the researchers were able to record "movies" of the growth processes on the nanoscale. The measurement makes it possible to follow the nucleation, island growth and the roughness evolution of the layer.

The researchers show that the results of the new X-ray technique are consistent with established scanning probe techniques and time-resolved measurements are possible without disturbing the growth.

In the study, a significant improvement in the diffusivity of molecules between the first and the subsequent molecular layers was found and the nucleation energy was determined within the framework of recent growth theories. The application of the new X-ray scattering technique will help to take our understanding beyond a recipe-based perspective to that of sound fundamental understanding of molecular growth.

Publication

Diffusion and nucleation in multilayer growth of PTCDI-C8 studied with in situ X-ray growth oscillations and real-time small angle X-ray scattering

A. Zykov, S. Bommel, C. Wolf, L. Pithan, C. Weber, P. Beyer, G. Santoro, J.P. Rabe, and S.Kowarik

J. Chem. Phys. 146 (2017) 052803

DOI: 10.1063/1.4961460

Water Makes The Proton Shake – Ultrafast Motions And Fleeting Geometries In Proton Hydration

Basic processes in chemistry and biology involve protons in a water environment. Water structures accommodating protons and their motions have so far remained elusive. Applying ultrafast vibrational spectro-scopy, Dahms et al. map fluctuating proton transfer motions and provide direct evidence that protons in liquid water are predominantly shared by two water molecules. Femtosecond proton elongations within a hydration site are 10 to 50 times faster than proton hopping to a new site, the elementary proton transfer step in chemistry.

The proton, the positively charged nucleus H+ of a hydrogen atom and smallest chemical species, is a key player in chemistry and biology. Acids release protons into a liquid water environment where they are highly mobile and dominate the transport of electric charge. In biology, the gradient of proton concentration across cell membranes is the mechanism driving the respiration and energy storage of cells. Even after decades of research, however, the molecular geometries in which protons are accommodated in water, and the elementary steps of proton dynamics have remained highly controversial.

Protons in water are commonly described with the help of two limiting structures (Fig. 1A). In the Eigen complex (H9O4+) (left), the proton is part of the central H3O++ ion surrounded by three water molecules. In the Zundel cation (H5O2+) (right), the proton forms strong hydrogen bonds with two flanking water molecules. A description at the molecular level employs the potential energy surface of the proton (Fig. 1B) which is markedly different for the two limiting geometries. As shown in Fig. 1B, one expects an anharmonic single-minimum potential for the Eigen species and a double minimum potential for the Zundel species. In liquid water, such potentials are highly dynamic in nature and undergo very fast fluctuations due to thermal motions of surrounding water molecules and the proton.

Led by Thomas Elsässer, member of **IRIS Adlershof**, researchers from the Max Born Institute in Berlin, Germany, and the Ben Gurion University of the Negev in Beer-Sheva, Israel, have now elucidated the ultrafast motions and structural characteristics of protons in water under ambient conditions. They report experimental and theoretical results in Science which identify the Zundel cation as a predominant species in liquid water. The femtosecond (1 fs = 10-15 s) dynamics of proton motions were mapped via vibrational transitions between proton quantum states (red and blue arrows in Fig. 1B). The sophisticated method of two-dimensional vibrational spectroscopy provides the yellow-red and blue contours in Fig. 2A which mark the energy range covered by the two transitions. The blue contour occurs at higher detection frequencies than the red, giving the first direct evidence for the double-minimum character of the proton potential in the native aqueous environment. In contrast, the blue contour is expected to appear at smaller detection frequencies than the red one.

The orientation of the two contours parallel to the vertical frequency axis demonstrates that the two vibrational transitions explore a huge frequency range within less than 100 fs, a hallmark of ultrafast modulations of

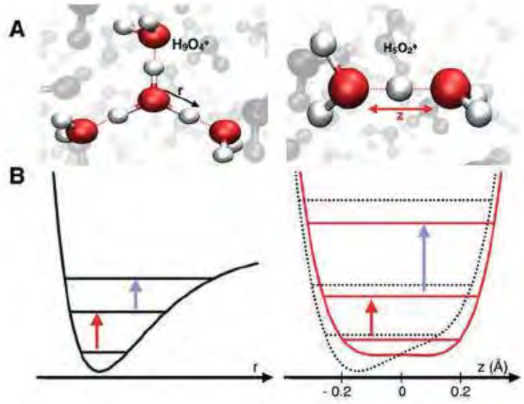


Fig. 1: Chemical structure of hydrated protons in liquid water

A: Schematic of the Eigen cation H9O4+ (left) and the Zundel cation H5O2++ (right). The arrows indicate the O-H bond coordinate r and the (O...H+...O) proton transfer coordinate z. In the Eigen cation a covalent O-H bond localizes the proton whereas in the Zundel cation the proton is delocalized between two water mole-cules.

B: Anharmonic vibrational potential (left) and double minimum potential of the Zundel cation along z (right, red. Distortions by the solvent surrounding impose a modulation of the double minimum potential (right, dotted line). Red and blue arrows indicate transitions between particular quantum states of the proton mo-tion, i.e., the ground-state-to-first-excited-state transition (red) and the first-excited-state-to-second-excited-state transition (blue). The modulation of the potentials leads to spectral shifts of the vibrational transitions which are mapped by two-dimensional infrared spectros-copy.

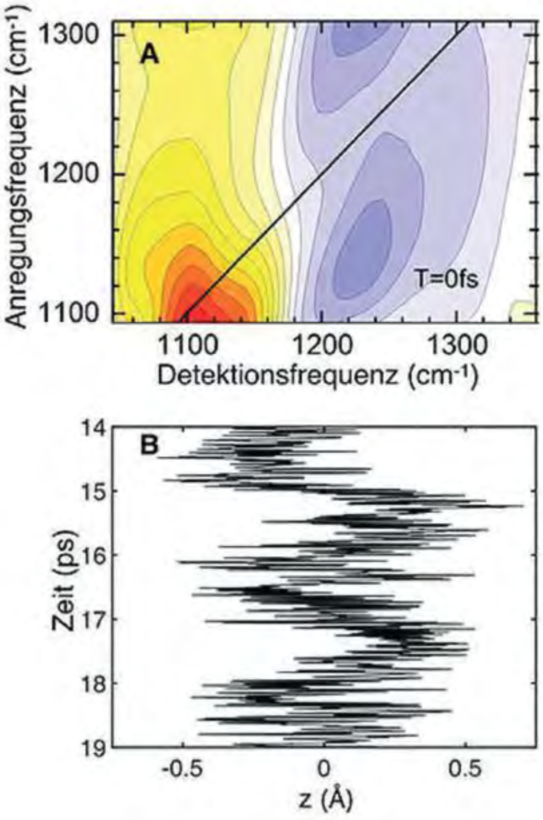


Fig. 2: Femtosecond dynamics of proton motions (1 fs = 10-15 s)

A: Two-dimensional vibrational spectra with the ground-state-to-first-excited-state transition (red) at lower detection frequency than the first-excited-state-to-second-excited-state transition (blue). The orientation of both contours parallel to the excitation frequency axis is due to ultrafast frequency fluctuations and the loss of memory in the proton position.

B: Simulated real-time dynamics of the proton motions in the Zundel cation. Within less than 100 fs, the proton dis-plays large amplitude excursions along z, the coordinate linking the two water molecules in the Zundel cation. Due to the ultrafast modulation of the shape of proton potential by surrounding solvent mole-cules, the proton explores all locations be-tween the two water molecules.

the shape of proton potential. In other words, the proton explores all locations between the two water molecules within less than 100 fs and very quickly loses the memory of where it has been before. The modulation of the proton potential is caused by the strong electric field imposed by the water molecules in the environment. Their fast thermal motion results in strong field fluctuations and, thus, potential energy modulations on a sub100 fs time scale. This picture is supported by benchmark experiments with Zundel cations selectively prepared in another solvent and by detailed theoretical simulations of proton dynamics (Fig. 2B).

A specific Zundel cation in water transforms into new proton accommodating geometries by the breaking and reformation of hydrogen bonds. Such processes are much slower than the dithering proton motion and occur on a time scale of a few picoseconds. This new picture of proton dynamics is highly relevant for proton transport by the infamous von Grotthuss mechanism, and for proton translocation mechanisms in biological systems.

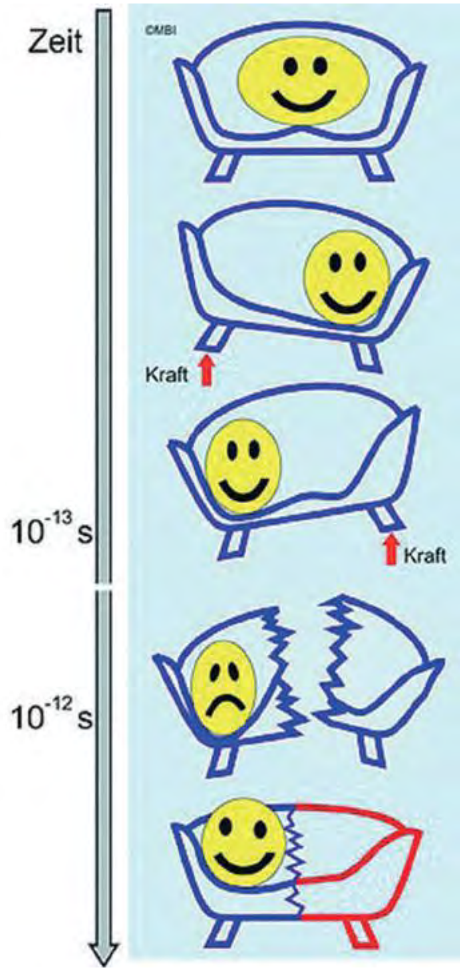


Fig. 3: Cartoon picture of proton hydration dynamics, visualized with the help of classical physics

The proton Smiley is sitting in the middle of a sofa with two seats. When shaking the sofa with a mechanical force, the shape of the seating changes and the proton moves forth and back on the sofa. Such motions occur on a time scale shorter than 100 fs (10-13 s). After an average time of 1 ps = 1000 fs = 10-12 s, the sofa breaks and the proton moves to a new site/sofa, including the red halve on the right.

Publication

Large-amplitude transfer motion of hydrated excess protons mapped by ultrafast 2D IR spectroscopy

F. Dahms, B.P. Fingerhut, E.T.J. Nibbering, E., Pines, and T. Elsaesser

Science 357 (2017) 491

DOI: 10.1126/science.aan5144

A “Bullseye” Antenna Helps To Reads Out A Quantum Sensor

An ideal platform to study the light-matter interaction at the fundamental level consists of single quantum emitters coupled to photonic and plasmonic elements. Such elements are also needed to realize quantum interfaces between stationary and flying quantum bits in quantum networks. Reaching the required nanometer precision for optimum coupling is still a challenge. Approaches for different scenarios have been developed.

A very precise approach uses nanomanipulation with the help of atomic force microscopy (AFM) tips, the so-called pick-and-place approach. Here, single nanoparticles containing quantum emitters are transferred from substrate to substrate. The method is highly accurate and deterministic, and it also allows for pre-characterization of the luminescent particles. Moreover, the placement is not final, and several iterations can be performed by nanomanipulation if required. Finally, very different materials for the emitters or substrates (these may contain complex photonic structures like optical waveguides or microresonators) can be employed in order to assemble hybrid systems.

A joint team of the Department of Physics of Humboldt-Universität and the Hebrew University, Jerusalem, now successfully presented a versatile technique allowing for high accuracy placement of a single quantum emitter an a plasmonic nanoantenna. The antenna operates by collecting light in a two-dimensional dielectric waveguide, which is then scattered into a well-defined narrow solid angle by concentric metallic (Ag) rings. Due to these rings such antennas are called bulleseye antennas. A key advantage of a plasmonic antenna is its broad bandwidth, i.e., even light from emitters with a rather wide

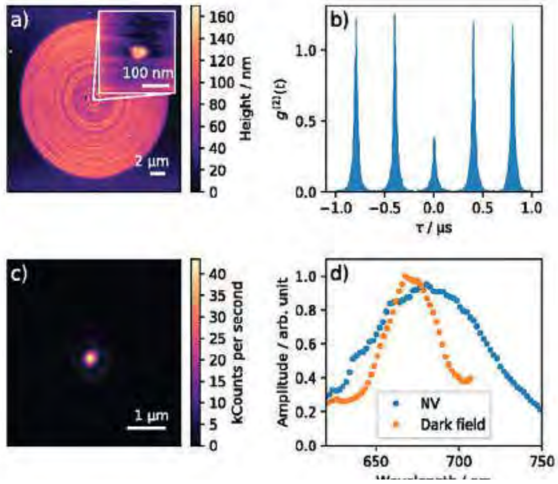


Fig. 1: AFM, confocal scan, and optical characterization of a placed nanodiamond containing a single nitrogen vacancy (NV) center.

a) AFM scans of the placed nanodiamond in the center of the plasmonic bulleseye antenna.

b) Measured normalized photon coincidences (g(2)-function) recorded under pulsed excitation with a repetition rate of 2.5MHz. The strongly reduced probability to find two photons after an excitation pulse (reduced peak height near zero time delay t) proves emission of single photons.

c) Confocal scan of the antenna with the nanodiamond in the middle.

d) Spectrum of the fluorescence from the NV (blue) and a dark field scattering spectrum of the antenna (orange) show a good overlap.

fluorescence spectrum can be concentrated and directed with very high efficiency. Then, simple subsequent collection optics, even optical fibers, may collect more than 90% of all the emitted light.

The quantum emitter was a single nitrogen-vacancy (NV) defect center in a nanodiamond. The NV center can be used a single photon source emitting at room temperature.

On the other hand it hosts an electron spin state, which can be manipulated and read out optically. In this way nanomagnetometry on the level of single spins can be performed even at room temperature.

Prof. Ronen Rapaport and Prof. Oliver Benson, who lead the research teams in Jerusalem and Berlin, respectively, point out: "The coupling of an NV center to a plasmonic antenna dramatically increases the efficiency of the device. This is crucial for its use as quantum light source, and even more for an application as magnetic field quantum sensor. Particularly for applications in biophysics or medicine room-temperature operation and fast non-invasive read out is crucial."

As next steps the researchers want to combine the NV quantum sensor, plasmonic light collecting structures and a microfluidic platform to develop reliable sensors for applications in biophysics.

Publication

Accurate placement of single nanoparticles on opaque conductive structures

N. Nikolay, N. Sadzak, A. Dohms, B. Lubotzky, H. Abudayyeh, R. Rapaport, and O. Benson

Appl. Phys. Lett. 113 (2018) 113107

DOI: 10.1063/1.5049082

Exploring The "Goldilocks Zone" Of Semiconducting Polymer Photocatalysts Via Donor-Acceptor Interactions

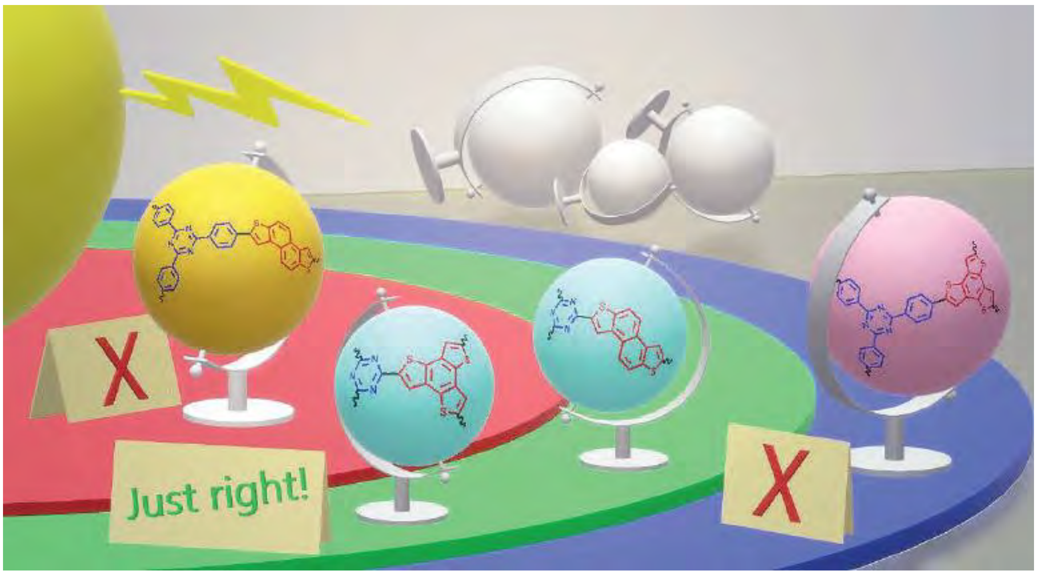
A team of researchers from Germany and Chechia has developed a polymer catalyst that can split hydrogen from water using sun light.

Hydrogen is regarded as the energy source of the future because its combustion e.g. as a car propellant proceeds cleanly to water without the generation of greenhouse gases like carbon dioxide. The novel design principle of these polymer catalysts is not only that they consist of abundant elements like carbon, nitrogen and sulphur. Notably, the researchers realised that the electron interactions between the electron-donor sulphur and the electron acceptor nitrogen can be used for particularly efficient charge separation in photo catalysis.

This leads to materials that achieve – without the need for further chemical or physical modifications – the highest hitherto reported hydrogen evolution rate of 3158 mmol h^{-1} g^{-1}. The lead-author of this work, Michael J. Bojdys, is a junior member of the **IRIS Adlershof** since 2018.

Publication

Exploring the "Goldilocks Zone" of Semiconducting Polymer Photocatalysts by Donor–Acceptor Interactions
Y. S. Kochergin, D. Schwarz, A. Acharjya, A. Ichangi, R. Kulkarni, P. Eliášová, J. Vacek, J. Schmidt, A. Thomas and M. J. Bojdys
Angew.Chem Int. Ed. 57 (2018) 14188
DOI: 10.1002/anie.201809702



Light-Controlled Molecules: Scientists Develop New Recycling Strategy

Robust plastics are composed of molecular building-blocks, held together by tough chemical linkages. Their cleavage is extremely difficult to achieve, rendering the recycling of these materials almost impossible. A research team from the Humboldt-Universität zu Berlin (HU) developed a molecule, which can drive or reverse specific chemical reactions with light of different colors. This enables making and breaking of connections on the molecular scale, even if they are exceptionally strong. The discovery paves the way for the development of novel recycling methods and sustainable materials. Light-driven recovery of individual molecular building-blocks has great potential to enable recycling of yet non-recyclable plastics without compromising on color, quality, or shape.

"*The working principle of our system is quite similar to the one of ready-to-assemble furniture*" explain Michael Kathan and Fabian Eisenreich, the two first authors of this study. "*We are able to repetitively assemble or disassemble molecular architectures, but instead of a hammer and screw-driver, we use red and blue LEDs as tools to control our molecules.*"

The results of their study have been published in Nature Chemistry.

Publication

Light-driven molecular trap enables bidirectional manipulation of dynamic covalent systems

M. Kathan, F. Eisenreich, C. Jurissek, A. Dallmann, J. Gurke, and S. Hecht
Nat. Chem. 10 (2018) 1031

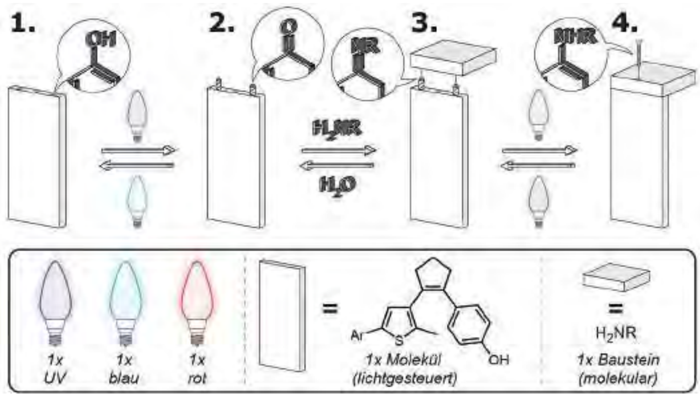


Fig. 1: *A light-controlled molecule in combination with a specific light sequence allows for bond formation (UV and red light; 1. to 4.) or scission (UV and blue light; 4. to 1.) with molecular building-blocks. Visualization: Michael Kathan.*

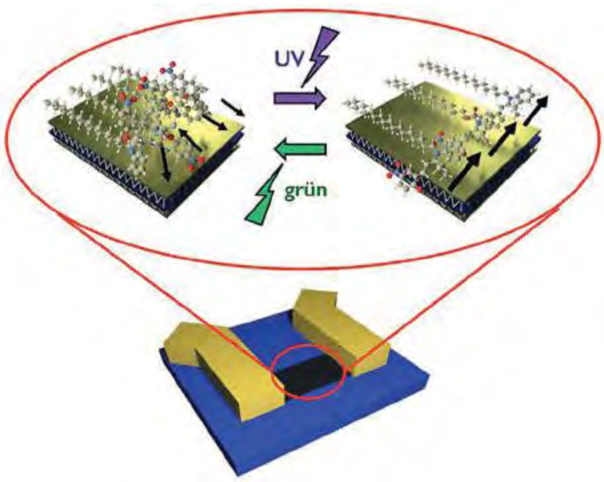
Flipping The Switch On Supramolecular Electronics

For the first time, two-dimensional materials have been decorated with a photoswitchable molecular layer, and electronic components have been fabricated from the resulting hybrid materials that can be controlled by light. The results of this fruitful collaboration of several European research groups have been published in Nature Communications.

Owing to their outstanding electrical, optical, chemical and thermal properties, two-dimensional (2D) materials, which consist of a single layer of atoms, hold great potential for technological applications such as electronic devices, sensors, catalysts, energy conversion and storage devices, among others. Thanks to their ultra-high surface sensitivity, 2D materials represent an ideal platform to study the interplay between nanoscale molecular assembly on surfaces and macroscopic electrical transport in devices.

In order to provide a unique light-responsivity to devices, the researchers have designed and synthesized a photoswitchable spiropyran building block, which is equipped with an anchoring group and which can be reversibly interconverted between two different forms by illumination with ultraviolet and visible light, respectively. On the surface of 2D materials, such as graphene or molybdenum disulfide (MoS2), the molecular photoswitches self-assemble into highly ordered ultrathin layers, thereby generating a hybrid, atomically precise superlattice. Upon illumination the system undergoes a collective structural rearrangement, which could be directly visualized and monitored with sub-nanometer resolution by scanning tunneling microscopy. This light-induced reorganization at the molecular level induces an optical modulation of the energetics of the underlying 2D material, which translates into a change in the electrical characteristics of the fabricated hybrid devices. In this regard, the collective nature of self-assembly allows to convert single-molecule events into a spatially homogeneous switching action, which generates a macroscopic electrical response in graphene and MoS2.

"*With our versatile approach of molecularly tailoring 2D materials, we are taking supramolecular electronics to a new level and closer to future applications,*" says Stefan Hecht, who is researching hybrid materials at **IRIS Adlershof**. The work is groundbreaking for the realization of multifunctional hybrid components powered by nature's primary energy source - sunlight.



Publication

Collective molecular switching in hybrid superlattices for light-modulated two-dimensional electronics

M. Gobbi, S. Bonacchi, J.X. Lian, A. Vercouter, S. Bertolazzi, B. Zyska, M. Timpel, R. Tatti, Y. Olivier, S. Hecht, M.V. Nardi, D. Beljonne, E. Orgiu, and P. Samorì

Nat. Commun. 9 (2018) 266

Light-Controlled Production Of Biodegradable Polymers

A research team from Berlin has developed a novel catalyst system, which enables the regulation of multiple polymerization processes to produce biodegradable plastics solely by illumination with light of different colors. The results of this work have now been published in Nature Catalysis.

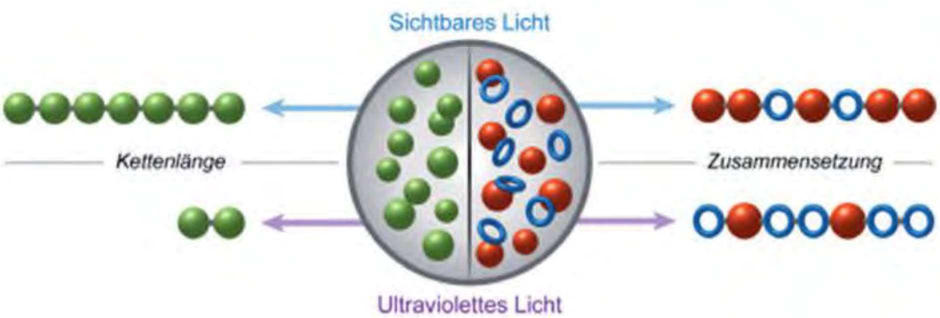
The properties of a polymeric material are highly dependent on factors, such as the connected monomer building blocks as well as the length and composition of the formed polymer chains. Typically, these factors are predetermined by the choice of the employed reaction conditions. In order to overcome this limitation and generate materials with new and unprecedented properties, regulation of polymerizations by means of external stimuli represents an attractive goal. Similarly to dental repair, light serves to precisely control the location and duration of the chemical reaction during polymer formation.

A new method for the light-regulated production of biodegradable polymers has now been developed by chemists of the Humboldt-Universität zu Berlin, the Federal Institute for Materials Research and Testing Berlin, and the Heinrich-Heine-Universität Düsseldorf.

Their work is based on the design of a unique catalyst, which is capable to change its activity reversibly by illumination with light of different wavelength. Using their catalyst, the scientists were able to turn the formation of polylactide on and off on demand, which allowed them to control the chain length of the produced polymer strands. Moreover and for the first time, they were able to regulate the incorporation of two different monomers into the same polymeric backbone with light. Fabian Eisenreich and Michael Kathan, the first authors of the study, are excited: “With our remote-controlled catalyst we are in principle able to program the formation of a desired polymer strand by employing a specific order and duration of light pulses.” Their promising development is an important step toward smart production processes of (biodegradable) polymers with the aim to meet the growing demands of future applications, including light-guided 3D printing and photolithography.

Publication

A photoswitchable catalyst system for remote-controlled (co)polymerization in situ
F. Eisenreich, M. Kathan, A. Dallmann, S.P. Ihrig, T. Schwaar, B.M. Schmidt, and S. Hecht
Nature Catalysis 1 (2018) 516
DOI: 10.1038/s41929-018-0091-8



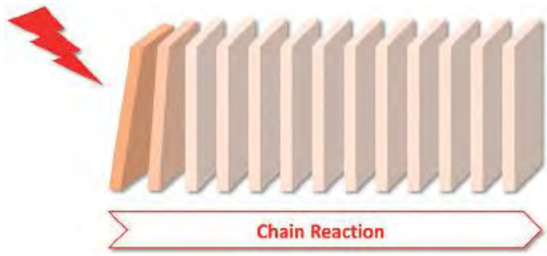
Chain Reaction Switched Molecules In Depth

A new method developed by a team of chemists in Berlin open the door for using optically switchable molecules. The results of the study have been published in Chem.

Smart materials become increasingly common in our daily life as they adapt their properties to their surroundings, such as temperature and light. Think about light-adaptive lenses in sunglasses that change their color in response to brightness or darkness. In these materials, photoswitchable molecules able to change their properties, such as color or the ability to conduct electricity, upon illumination serve as key components. However, photoswitches typically require the use of high-energy UV light and in addition do neither switch quantitatively nor efficiently since many more quanta than molecules are needed. These drawbacks limit the applicability of photoswitches, in particular since the more energy-rich light is, the less it can penetrate into materials.

Now, chemists of Humboldt-Universität zu Berlin and the Universität Potsdam have developed a method, which allows one to efficiently and quantitatively operate photoswitches with the smallest amounts of low-energy red photons, thus solving both issues described above. By coincidence they came across the phenomenon that the oxidation of only a few switch molecules was sufficient to switch the entire sample. Subsequently, they investigated the underlying chain reaction in great detail and optimized it by introducing dyes to allow for the use of red light. The latter allowed them to boost the quantum yield – typically way below 100% – to a record-setting value of almost 200%.

The impact of their discovery is tremendous according to Dr. Alexis Goulet-Hanssens and Prof. Stefan Hecht, who works at the Department of Chemistry and **IRIS Adlershof**: „*With our method, for the first time we can address molecular switches deep in a material. Thus, we can operate optical devices efficiently but also penetrate deep into the skin through the biological window*“ they explain and are excited about possible applications in optoelectronics as well as medicine.



Publication

Hole Catalysis as a General Mechanism for Efficient and Wavelength-Independent Z→E Azobenzene Isomerization

A. Goulet-Hanssens, C. Rietze, E. Titov, L. Abdullahu, L. Grubert, P. Saalfrank, and S. Hecht

Chem 4 (2018) 1740

DOI: 10.1016/j.chempr.2018.06.002

Ab Initio Modeling Of Novel Photocathode Materials For High Brightness Electron Beams

The development of laser-driven photocathode radio-frequency electron injectors has become a significant enabling technology for free electron lasers and for the fourth generation of light sources. Such remarkable progress come with quest for novel materials that are able to operate in the visible region with optimized quantum efficiency and minimized intrinsic emittance. Multi-alkali antimonides have recently emerged as ideal materials for photocathode applications in spite of the little fundamental knowledge regarding their electronic and optical properties. A team composed of scientists from the HU Berlin and HZB carried out a systematic investigation of the electronic structure and excitations of CsK_2Sb, an exemplary and promising multi-alkali antimonide, by means of first-principles many-body methods. The results of their study confirm that this material is an excellent candidate for photocathode applications and pioneers a new research line bridging solid-state theory, material science, and accelerator physics in view of an improved modelling and design of materials for the next-generation electron sources.

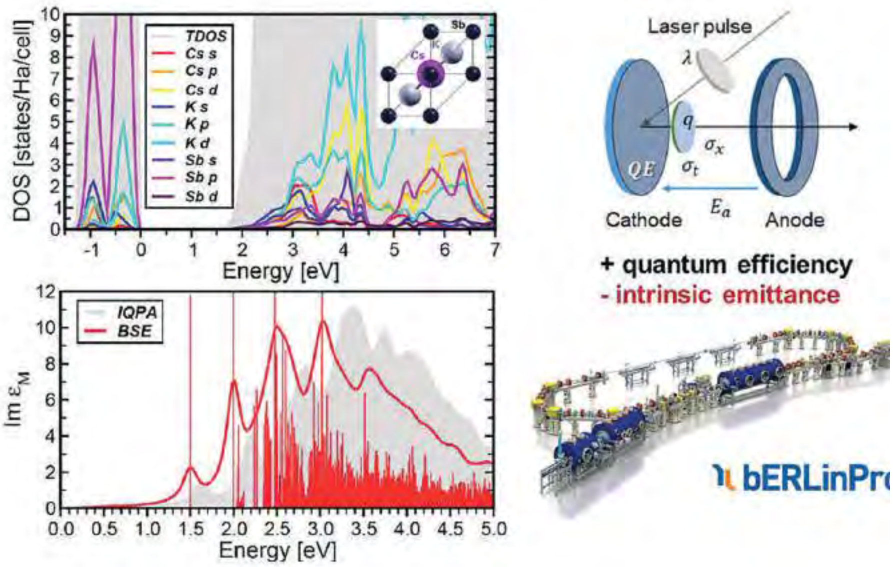
This work was published on The Journal of Physics: Condensed Matter as an invited contribution to Prof. Caterina Cocchi, a member of **IRIS Adlershof** since 2017, to the special issue "Emerging leaders 2018"

Publication

First-principles many-body study of the electronic and optical properties of CsK_2Sb, a semiconducting material for ultra-bright electron sources

C. Cocchi, S. Mistry, M. Schmeisser, J. Kühn, and T. Kamps

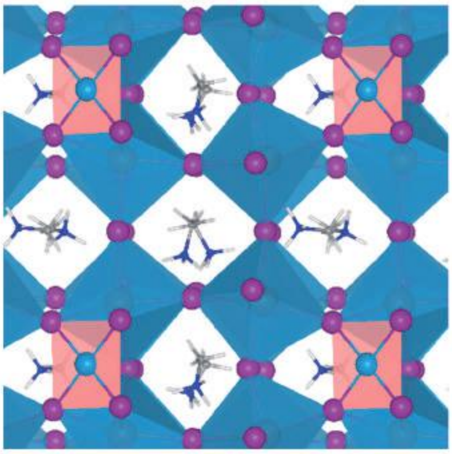
J. Phys. Condens. Mat. 31 (2018) 014002



Hybrid Organic-Inorganic Perovskites: Promising Substrates For Single-Atom Catalysts

Mononuclear metal species are widespread in enzymes and homogeneous catalysts. When such isolated single metal atoms are placed on a solid surface, they can also play an important role in heterogeneous catalysis. In the past few years, great attention has been paid to single-atom catalysts, not only because they can exhibit superior catalytic performance, but also, because they offer a novel way of maximizing the efficiency of utilizing atoms, which is especially desirable in the use of scarce metal elements like platinum. However, single atoms cannot work in isolation but need to be dispersed on suitable substrates.

Qiang Fu and Claudia Draxl have recently demonstrated that hybrid organic-inorganic perovskites - the emerging candidates in solar-cell applications - are highly promising substrates for Pt single atom catalysts. Through systematic first-principles calculations, they found that single Pt atoms are stabilized on such substrates through a synergistic cooperation between covalent bond formation and charge transfer. The generated Pt sites possess excellent catalytic properties in CO oxidation and may be able to play a role in CO_2 reduction. This work not only has promising consequences in single-atom catalysis but also sheds light on potential applications of hybrid perovskites as photocatalysts.



Publication

Hybrid Organic-Inorganic Perovskites as Promising Substrates for Pt Single-Atom Catalysts

Q. Fu and C. Draxl

Phys. Rev. Lett. 122 (2019) 046101

Accepted 2018

DOI: 10.1103/PhysRevLett.122.046101

3. Young Scientists

IRIS Adlershof's enormously successful development since its founding in 2009 was confirmed in 2016 by an external expert commission within the framework of an evaluation. As already stated in the last biannual report, the reviewers concluded that IRIS has succeeded to put the HU's science campus on the international map of research in the fields of Hybrid Systems and Mathematical Physics. However, the promotion of young scientists should be further enhanced, the commission pointed out. Thus, **IRIS Adlershof**'s outstanding goal during the reporting period was to follow this recommendation and to further strengthen and encourage their young scientists.

Classes For Master & Doctoral Students

As a first and essential promotional measure, IRIS members were again involved in teaching classes of their corresponding departmental institutes and gave special lectures that go into detail about the IRIS research areas. In this way, the interest of master and doctoral students in the scientific work of **IRIS Adlershof** and its research areas could be aroused. As in previous years, this measure proved to be very productive.

IRIS Adlershof has furthermore directly supported young scientists during the reporting period: PhD student Bita Rezania, for example, recieved a scholarship financed by **IRIS Adlershof**, which supported her at the end her doctorate.

Expansion Of The IRIS Council

IRIS Adlershof also supported its young scientists through internal modifications: In December 2017, Julian Miczajka and Dr. Sven Ramelow were elected as young scientist representatives in IRIS's committees. The young scientists are now being represented in IRIS general meetings as well on IRIS's board with rights to speak, submit applications, and vote.

Julian Miczajka

Sven Ramelow

Julian Miczajka who is a doctoral student in Prof. Jan Plefka's group, is focusing on an exceptional class of higher spin theories in flat spaces, especially on their relationship with hidden symmetries, integrability, and duality. Dr. Sven Ramelow is the head of the independent Emmy-Noether junior research group Nonlinear Quantum Optics.

Furthermore, as part of the promotion of young scientists, the former junior research group leader Yan Lu was accepted as full IRIS member after being appointed full professor.

Achievements Of IRIS Young Scientists

In this report, however, not only the support measures but also the enormous achievements and impressive accomplishments of the IRIS young scientists are to be highlighted:

First IRIS Roots Day

In December 2017, **IRIS Adlershof** hosted its first IRIS-Roots-Day, a competition in which nine IRIS young scientists took up the challenge to present their current research project in the manner of a science slam within only five minutes. Due to the outstanding performance of all candidates, the jury, consisting of IRIS members and the two new representatives of IRIS's young scientists, found it difficult to decide. The first prize, which was coupled with a travel grant so that the awardee could take an active part at a national or international scientific conference, went to Inna Kviatkovsky who came to Sven Ramelow's IRIS junior scientists group a few months before to do research on infrared quantum imaging. The second prize was awarded to Yuhang Zhao who is doing a doctorate in Prof. Dr. Yan Lu's group at the HZB. Wadim Wormsbecher, a doctoral student in Jan Plefka's group, and Matthias Runge, a master student in Prof. List-Kratochvil's group, share the third place. In addition, the winners were offered a free professional pitch training for participation in Falling Walls Lab 2018.

Falling Walls Lab

In September of the same year, Inna Kviatkovsky and Wadim Wormsbecher then successfully took part in the annual Falling Walls Lab, a competition in which young researchers and young professionals have to present their research projects, ideas and initiatives in only 3 minutes each. The aim of this international event is to promote exceptional ideas and to connect promising scientists and entrepreneurs from all fields on a global level.

IRIS Symposium 2018

In order to give young scientists the opportunity to present their own research results to invited speakers and symposium participants, the IRIS Symposium 2018, held in June was expanded to include a poster competition. The jury consisted of Julian Miczajka, representative of the young researchers as well as the IRIS members Yan Lu and Emil List-Kratochvil. Laura Orphal, a master student in the group Photonics, which is led by IRIS member Oliver Benson, convinced the jury and won the Best-Poster-Award.

Honors & Awards

Furthermore, the dissertation of Michael N. Borinsky was selected to be published in *Springer Thesis*, a dedicated book series to recognize outstanding doctoral research. Michael Borinsky was an IRIS junior scientist and supervised by IRIS member Dirk Kreimer.

In March 2018, IRIS's young scientist Anne Fuhrmann was awarded the Carl Roth Prize by the Gesellschaft Deutscher Chemiker (GDCh). She developed her plastic coatings which can target and heal damage with the help of light for her doctoral work in the research group of Stefan Hecht who is an IRIS member. The damaged site repairs itself only where it has previously been heated up and then lit with a special color of light.

In June 2018, Anne Spiering was awarded the Lise-Meitner Prize of the Vereinigung der Freunde und Förderer des Instituts für Physik der Humboldt-Universität zu Berlin e.V. for her master thesis. Anne Spiering was a master student in the group *Quantum Field and String Theory* led by IRIS member Jan Plefka.

Julian Miczajka, the representative of the junior researchers of **IRIS Adlershof**, was awarded the Physics Study Award of the Physical Society of Berlin in June 2018. The prize goes to outstanding graduates of the diploma or master's degree in physics.

Also in 2018, Stijn van Tongeren, a member of the group Mathematical Physics of Space, Time and Matter, was selected to lead the Emmy Noether Junior Research Group *Exact Results in Extended Holography*. He and his group are currently working on deformations of AdS/CFT and related integrable structures.

Future Goals

In the years to come, **IRIS Adlershof** will continue to make it its goal to further develop the promotion of young talent.

4. Appendices

4. 1. Inner Structure and Members

During the reporting period, **IRIS Adlershof** consisted of 22 full members. In addition, three leaders of young research groups and about 120 early career researchers (graduate students, postdocs) were associated with **IRIS Adlershof**. The main governing bodies of **IRIS Adlershof** are the General Assembly, the IRIS Council, and the Director, which are all supported by the IRIS Branch Office.

IRIS Adlershof is headed by the IRIS Council, which formerly consisted of three members and in 2017 was expanded to five members, now including the head of the research building commission and the representative of the young researchers. The purpose of this addition is to increase support of young researchers as proposed in the 2015 evaluation. The council decides on all important matters that are not in the competence of the general IRIS assembly or of other academic bodies. It is headed by the Director who represents IRIS internally and externally. The General Assembly, as the highest body of **IRIS Adlershof**, is responsible for all decisions concerning the thematic, conceptual, and infrastructural development of **IRIS Adlershof**. The Branch Office is responsible for all administrative matters pertaining to **IRIS Adlershof**. It is the interface to the local and central administrative bodies of the University.

The five elected members of the IRIS Council are:

Prof. Dr. Jürgen P. Rabe
Research Topic: Physics of Macromolecules
Humboldt-Universität zu Berlin, Department of Physics
& Max Planck Institute for Colloids and Interfaces

Prof. Dr. Norbert Koch (Deputy Director)
Research Topic: Supramolecular Systems
Humboldt-Universität zu Berlin, Department of Physics
& Helmholtz-Zentrum Berlin für Materialien und Energie

Prof. Dr. Emil List-Kratochvil (Head of Research Building Commission)
Research Topic: Hybrid Devices
Bridging Professorship Physics/Chemistry
Humboldt-Universität zu Berlin, Department of Physics and Department of Chemistry

Prof. Dr. Matthias Staudacher
Research Topic: Mathematical Physics of Space, Time and Matter
Bridging Professorship Physics/Mathematics
Humboldt-Universität zu Berlin, Department of Physics and Department of Mathematics

Julian Miczajka, M.Sc. (Representative of the Young Researchers)
Research Topic: Quantum Field and String Theory
Humboldt-Universität zu Berlin, Department of Physics

These are the 22 full members of **IRIS Adlershof** during the reporting period:

Prof. Dr. Kannan Balasubramanian (IRIS member since 2017)
Research Topic: Micro & Nano Analytical Sciences
Humboldt-Universität zu Berlin, Department of Chemistry

Prof. Dr. Matthias Ballauff (IRIS member since 2010)
Research Topic: Soft Matter and Functional Materials
Helmholtz-Zentrum Berlin für Materialien und Energie &
Humboldt-Universität zu Berlin, Department of Physics

Prof. Dr. Oliver Benson (IRIS founding member)
Research Topic: Nano Optics
Humboldt-Universität zu Berlin, Department of Physics

Prof. Dr. Jochen Brüning (IRIS founding member)
Research Topic: Geometrical Analysis & Spectral Theory
Humboldt-Universität zu Berlin, Department of Mathematics

Prof. Dr. Caterina Cocchi (IRIS member since 2017)
Research Topic: Theory of excitations in low-dimensional systems
Humboldt-Universität zu Berlin, Department of Physics

Prof. Dr. Dr. h.c. Claudia Draxl (IRIS member since 2012)
Research Topic: Solid-State Theory
Humboldt-Universität zu Berlin, Department of Physics
& Fritz-Haber-Institut der Max-Planck-Gesellschaft

Prof. Dr. Thomas Elsässer (IRIS member since 2010)
Research Topic: Nonlinear Processes in Condensed Matter
Max Born Institute for Nonlinear Optics and
Short Pulse Spectroscopy &
Humboldt-Universität zu Berlin, Department of Physics

Prof. Johann-Christoph Freytag, Ph.D. (IRIS founding member, member until 2017)
Research Topic: Databases and information systems
Humboldt-Universität zu Berlin, Department of Computer Science

Prof. Stefan Hecht, Ph.D. (IRIS founding member)
Research Topic: Chemical Approaches to Nanoscience
Humboldt-Universität zu Berlin, Department of Chemistry

Prof. Dr. Michael Hintermüller (IRIS member since 2018)
Research Topic: Applied Mathematics
Weierstraß-Institut für angewandte Analysis und Stochastik &
Humboldt-Universität zu Berlin, Department of Mathematics

Prof. Dr. Regine von Klitzing (IRIS member from 2012 to 2017)
Research Topic: Applied Physical Chemistry
Before: Technische Universität Berlin, Institute of Chemistry
Now: Technische Universität Darmstadt, Department of Physics

Prof. Dr. Christoph T. Koch (IRIS member since 2016)
Research Topic: Structure Research and Electron Microscopy
Humboldt-Universität zu Berlin, Department of Physics

Prof. Dr. Norbert Koch (IRIS member since 2009 and Deputy Director)
Research Topic: Supramolecular Systems
Humboldt-Universität zu Berlin, Department of Physics
& Helmholtz-Zentrum Berlin für Materialien und Energie

Prof. Dr. Jürg Kramer (IRIS founding member)
Research Topic: Mathematics and Education
Humboldt-Universität zu Berlin, Department of Mathematics

Prof. Dr. Dirk Kreimer (IRIS member since 2011)
Research Topic: Structure of Local Quantum Field Theories
Bridging Professorship Mathematics/Physics
Humboldt-Universität zu Berlin, Department of Mathematics
& Department of Physics

Prof. Dr. Christian Limberg (IRIS member since 2014)
Research Topic: Bioinspired Chemistry and Surface Models for the Activation of Small Molecules
Humboldt-Universität zu Berlin, Department of Chemistry

Prof. Dr. Emil List-Kratochvil (IRIS member since 2015)
Research Topic: Hybrid Devices
Bridging Professorship Physics/Chemistry
Humboldt-Universität zu Berlin, Department of Physics and Department of Chemistry

Prof. Dr. Yan Lu (IRIS member since 2017)
Research Topic: Soft Matter and Functional Materials
Helmholtz-Zentrum Berlin für Materialien und Energie GmbH
& Universität Potsdam, Institute of Chemistry

Prof. Dr. Nicola Pinna (IRIS member since 2016)
Research Topic: Functional Materials
Humboldt-Universität zu Berlin, Department of Chemistry

Prof. Dr. Jan Plefka (IRIS member since 2012)
Research Topic: Quantum Field and String Theory
Humboldt-Universität zu Berlin, Department of Physics

Prof. Dr. Jürgen P. Rabe (IRIS founding Director)
Research Topic: Physics of Macromolecules
Humboldt-Universität zu Berlin, Department of Physics
& Max Planck Institute for Colloids and Interfaces

Prof. Dr. Alexander Reinefeld (IRIS founding member)
Research Topic: Distributed algorithms and inovative computer architecture
Zuse Institute Berlin (ZIB) &
Humboldt-Universität zu Berlin, Department of Computer Science

Prof. Dr. Joachim Sauer (IRIS founding member, member until 2017)
Research Topic: Quantum Chemistry
Humboldt-Universität zu Berlin, Department of Chemistry
& Fritz-Haber-Institut der Max-Planck-Gesellschaft

Prof. Dr. Igor Michailovitsch Sokolov (IRIS member since 2017)
Research Topic: Statistical Physics and Nonlinear Dynamics & Stochastic Processes
Humboldt-Universität zu Berlin, Department of Physics

Prof. Dr. Matthias Staudacher (IRIS member since 2010)
Research Topic: Mathematical Physics of Space, Time and Matter
Bridging Professorship Physics/Mathematics
Humboldt-Universität zu Berlin, Department of Physics and Department of Mathematics

Over the entire reporting period, a total of five junior research groups worked at **IRIS Adlershof,** three of them simultaneously.

Dr. Michael J. Bojdys (junior research group leader since 2018)
Junior Research Group: Functional Nanomaterials
Humboldt-Universität zu Berlin, Department of Chemistry

Dr. David Bléger (junior research group leader from 2013 to 2018)
Junior Research Group: Nanoscale and Photodynamic Systems
Before: Humboldt-Universität zu Berlin, Department of Chemistry
Now: Scientific Consultant at Evonik Creavis GmbH

Dr. Valentina Forini (junior research group leader since 2012)
Junior Research Group: Gauge Fields from Strings
Humboldt-Universität zu Berlin, Department of Physics
& City University of London, Department of Mathematics

Prof. Dr. Yan Lu (junior research group leader from 2009 to 2017)
Junior Research Group: Structure Analysis of Colloidal Particles
Before: Helmholtz-Zentrum Berlin für Materialien und Energie GmbH
Now: Helmholtz-Zentrum Berlin für Materialien und Energie GmbH and Universität Potsdam, Institute of Chemistry

Dr. Sven Ramelow (junior research group leader since 2016)
Junior Research Group: Nonlinear Quantum Optics
Humboldt-Universität zu Berlin, Department of Physics

4. 2. Selected Honors And Awards

During the reporting period, IRIS members and IRIS related young researchers received the following awards and honors for their outstanding scientific work:

2017

Prof. Dr. Norbert Koch
Distinguished Award 2017 for Novel Materials and their Synthesis of the International Union of Pure and Applied Chemistry (IU-PAC) and of the Conference Committee of the IUPAC NMS-XIII Conference

Dr. Raphael Schlesinger
Publication of his outstanding dissertation in the book series Springer Theses

2018

Anne Fuhrmann
Carl Roth Prize of the Gesellschaft Deutscher Chemiker

Prof. Dr. Alexander Reinefeld together with ZIB authors Matthias Noack, Dr. Tobias Kramer and Dr. Thomas Steinke
Best Paper Award at the 19th IEEE International Workshop on Parallel and Distributed Scientific and Engineering Computing (PDSEC 2018) in conjunction with the 32nd IEEE International Parallel and Distrivuted Processing Symposium (IPDPS 2018)

Julian Miczajka
Physics Study Award 2018 of the Physikalische Gesellschaft zu Berlin

Prof. Dr. Claudia Draxl
Election as a member of the Austrian Academy of Sciences

Anne Spiering
Lise-Meitner Prize 2018 of the Vereinigung der Freunde und Förderer des Instituts für Physik der Humboldt-Universität zu Berlin for her outstanding master‘s thesis

Dr. Michael Borinsky
Publication of his outstanding PhD thesis in the book series Springer Theses

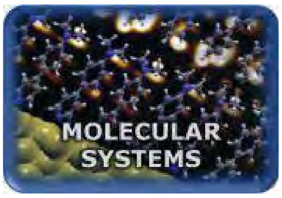
4. 3. Competences and Research Areas

IRIS Adlershof builds on the particular competences of Humboldt-Universität zu Berlin at its Campus Adlershof in the fields of Modern Optics, Molecular Systems, Mathematical Physics and Computation in the Sciences and is currently devoted to two prime areas of research: Hybrid Systems for Optics and Electronics and Space-Time-Matter.

Modern Optics

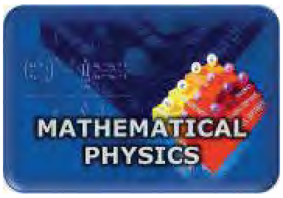
In the competence field Modern Optics, the unique properties of light with very precisely defined time and wavelength structures in a broad spectral range are employed to forge ahead in currently inaccessible terrains in physics by using a combination of modern optical methods. Fundamental processes in nature or in artificial materials will thus be elucidated, and the insights will be employed for novel applications for optical technologies, modern information processing and storage, sensors, material processing, and medicine.

Molecular Systems



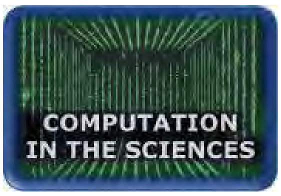
In the competence field Molecular Systems, the interaction of structural, electronic, optical and chemical properties is investigated at different levels of complexity. Inspired by a fundamental understanding of the relationship between structure and physico-chemical function in natural systems, new approaches to artificial systems with unprecedented property profiles are being developed that shall finally lead to new types of energy and resource saving materials and functional systems.

Mathematical Physics



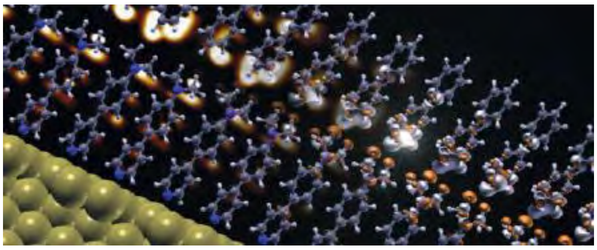
Mathematical Physics investigates the geometry and analysis of mathematical structures at the interface between theoretical physics and pure mathematics, as discussed, e.g., in superstring theories and quantum field theories. With the new Large Hadron Collider (LHC) at CERN, particle physics is at the onset of a new area, which makes this topical field very timely. A related but differently oriented research field is Complex Dynamics which currently finds its most interesting applications in climate research and in the physics of biomacromolecules.

Computation in The Sciences



Computation in the Sciences is dedicated to the computer simulation of real systems that can be analyzed with scientific methodologies. It supplements the traditional approaches in science and mathematics, which are based on collecting empirical evidence, on the one hand, and conceptual and algorithmic modelling on the other. With the rapid development of the architecture of high performance computing, new dimensions of the extraction of quantitative information will be within reach. Additionally, more and more realistic images of reality will be created by using efficient algorithms.

Hybrid Systems For Optics and Electronics



Hybrid inorganic/organic systems structured on atomic, molecular and mesoscopic length scales offer completely new possibilities for the implementation of optical and electronic properties and function approaching fundamental limits. Based on physicochemical concepts and inspired by the extraordinary efficient way functions are implemented in natural systems, the structure-property relationships of these novel hybrid materials will be investigated and explored for their application potential.

Space-Time-Matter

Modern physics strive to understand from first principles the structure of space, time, and matter on very large and very small scales, as well as in complex systems. Therefore, it is necessary to analyze the role of basic symmetries as well as the way they are broken. The ultimate goal is to find the Weltformel, in order to describe the fundamental forces and their interactions by a single coherent theory. Hopefully it will become clear along the way how the "smooth" world that we experience emerges from "chaotic" principles of quantum physics. Mathematicians and theoretical physicists are cooperating to address specific questions of mathematical physics in the described framework. An important structural goal consists in broadening the base of this enterprise by also including fundamental experimental physics.

4. 4. IRIS Research Building

One of **IRIS Adlershof**'s prestige projects is the new IRIS research building dedicated to the research field Hybrid Systems for Optics and Electronics which is currently under construction. Upon completion, it will not only significantly improve **IRIS Adlershof**'s spatial and scientific infrastructure and thus provide its outstanding scientists with excellent working conditions, but it will also contribute to strengthening **IRIS Adlershof**'s position as an international leader in interdisciplinary research in the area of Hybrid Devices.

The IRIS research building's great importance and enrichment for **IRIS Adlershof**, for the scientists working and the cutting-edge research carried out here, and the building's development from the initial idea and the application for funding to the laying of the foundation stone was already addressed in the last biannual report 2015 & 2016.

Celebration Of The Topping Ceremony

During the reporting period 2017 & 2018, construction work on the IRIS research building continued to progress enormously, so that in July 2017 **IRIS Aldershof** was able to celebrate the topping ceremony together with the Governing Mayor of Berlin, Michael Müller, the Senate building director Regula Lüscher, the President of the Humboldt-Universität zu Berlin, Prof. Dr.-Ing. Dr. Sabine Kunst, and the architect Prof. Hans Nickl of Nickl & Partner Architekten AG.

Completion Of The Outer Building Shell

The superstructure and work on the outer building shell were then completed by the end of 2018, including the metal facade of the laboratory building and the installation of the outer windows and doors. This meant that the construction could be sealed against the effects of the weather. In addition, the first landscape measures were carried out.

Interior Design

Furthermore, the interior of the building received its final layout, and considerable efforts have been made to make this building an ideal environment for scientists able to conduct interdisciplinary research in the fields of Electronics, Optoelectronics and Photonics. The building now comprises 2,500 square meter of laboratory space and 2,200 square meters of office space and common rooms. Located in the center of the building are numerous laboratories of various sizes and specializations. They will range from standard physics laboratories with common media supply, wet laboratories with two or more hoods, clean rooms, high-quality optical laboratories with controlled and stable climatic conditions to magnetically shielded and vibration-decoupled, state-of-the-art TEM laboratories upon completion. The offices are located in the immediate vicinity of the laboratories, offering space for more than 160 desks at the end of the construction work. A number of common rooms will give access to coffee and promote informal discussion at whiteboards. To provide opportunities for fruitful informal discussion and exchange, the laboratories and offices are located very close to each other, but at the same time are separated by membrane-like common areas. Researchers from different fields will thus be able to easily interact with each other and even theoreticians will get involved into scientific process close to experiments. Several seminar rooms will be available for discussion, presentation and lectures. The entrance area itself is designed to provide space for poster presentations, which makes this building very suitable for conferences.

Interior work also progressed well during the reporting period. All dry walls were completed and prepared for laboratory requirements. The vast installation of the media supplies such as pressured air, argon, nitrogen and electricity in the laboratories was continued and in some laboratories even completed. Furthermore, the adaption of the vibration-decoupled foundation for the NION TEM was finished. In addition, the middle voltage transformator was installed for a sufficient and stable power supply and the connection to the Adlershof cooling compound (Kälteverbund Adlershof) which ensures the cooling of the air-conditioning and water circuit, as well as to the physics department of the Humboldt-Universität for the helium-recovery was made. The latter two procedures were done beneath ground level and required excavations which made these steps time consuming.

Laboratories

Upon completion, the laboratories will provide scientists access to a variety of top-quality scientific instruments that enable spectroscopic and microscopic examination, manipulation and characterization methods. A clearly outstanding device will be the NION high-resolution TEM with energy filter which will be a very powerful tool for investigation on organic and inorganic structures down to sub nanometer scale. It will be complemented by Cryo-TEM, both mounted on a decoupled foundation for higher performance. Moreover, the IRIS building will offer a SEM, E-Beam and photolithography within the clean room and a 19m long glovebox cluster, UHV-cluster and scanning probe devices, such as AFM and force robots, in close proximity. Numerous wet labs will offer plenty of workspace in BIO-S1 and even BIO-S2 certified settings measuring rooms in different sizes and qualities provide space for short- mid- and long-term research in single usage- or coop-space.

Art Competition

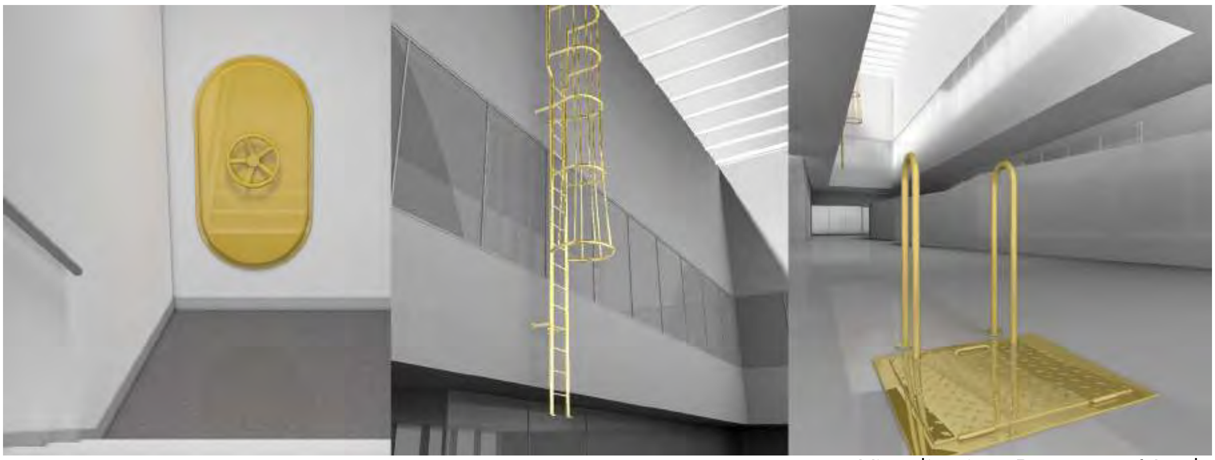
During the reporting period, an art competition was held in order to equip the interior of the research building not only functionally at the highest level, but also aesthetically pleasing. In August 2017, the Senate Department for Culture and Europe, together with the Senate Department for Urban Developing and Housing, announced an art competition with 10 invited artists for the new research building of **IRIS Adlershof**. The goal of the art competition was to develop independent artistic designs that also corresponded with the scope of the institute's cutting-edge research work. The artwork was supposed to reflect and contribute to the ongoing discussion with the architecture, urban environment of the Adlershof campus, and the use of the building as a lively place of research and exchange. In February 2018, a jury chaired by the artist Veronike Hinsberg approved the draft by BORGMAN I Lenk with the title Access. This winning design, which features the installation of gold-colored components and elements that are inconsistent with the functional processes and entrances of the house, was on display at the IRIS house in July 2018. The jury honors the artistic idea of contradicting architecture's functionality. Gold-colored elements like an air lock door, entrance hatch, and elevator display give a new momentum to a "free and searching movement of thoughts." The proposed design has a dry humor and great sensitivity for the used materials.

Opening In 2020

Construction work on the new IRIS research building progressed so far during the reporting period that the building can be commissioned in early 2020.

Institutional funding

IRIS Adlershof annually receives a basic financial support to cover its main office costs from the university's central funding. A further funding was allocated by Humboldt-Universität's Institutional strategy that is being funded through the Excellence Initiative since November 2012. The funds required for the construction of the research building amounting to approx. EUR 52 million were jointly raised by the federal government, the state of Berlin and the university. Concrete research projects are financed through the acquisition of third-party funds.



Visualization: Borgmann I Lenk

4. 5. Coordinated Collaborative Projects

During the reporting period, members of **IRIS Adlershof** were participating in important coordinated collaborative projects. On the following pages these projects are discussed in more detail:

- **IRIS Adlershof** in the Excellence Initiative
- Collaborative Research Centers (CRC)
- Research Training Groups and Graduate Schools
- EU Research Projects
- Funding by the Einstein Foundation
- BMBF Projects
- Collaborative Projects in the Context of Mathematics and Science Teacher Education and Training

© Stephan Pfeiler

IRIS Adlershof In The Excellence Initiative

As part of the Excellence Initiative, **IRIS Adlershof** was involved in numerous Clusters of Excellence and Graduate Schools through its members. The Excellence Initiative's funding period started in July 2005 and ended during the reporting period in October 2017. Projects that were not advised of any continuation in the follow-up program Excellence Strategy could apply for bridge funding of a maximum of 24 months, ending October 2019. The here presented Clusters of Excellence and Graduate Schools in which **IRIS Adlershof** participated through its members, successfully ended during the reporting period. The majority of them emerged into new Clusters of Excellence, funded under the Excellence Strategy. They were launched in January 2019.

Cluster Of Excellence: Image Knowledge Gestaltung. An Interdisciplinary Laboratory

Period of funding: 11/2012 – 10/2017
Spokespersons: Prof. Dr. Horst Bredekamp
& Prof. Dr. Wolfgang Schäffner (both HU Berlin)

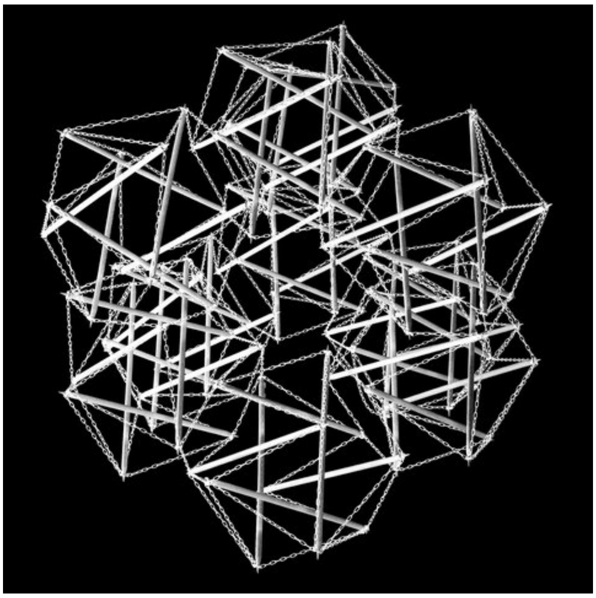
Science can be viewed as a Gestaltung of all its elements, from the laboratory arrangement of the chemical formula and the outline of a study to the theory building. Since time immemorial, knowledge has been designed by architectures, tools and models, and information tools and images. With the development of digital imaging methods, the importance of Gestaltung for the production and perception of knowledge has reached a new level for well over a half century. As a means for visualization and compression, modeling and mediation, evidence, and archiving images have caused a profound change in the sciences and humanities, technology, and medicine. They make vast amounts of data and complexities understandable. By no means are they effective only immaterially, but rather fold the digital and the material, because they are a comprehensive reservoir of forms of knowledge. Images open disciplinary boundaries and transport local styles and aesthetic strategies. "Gestaltung", a paradigm from modern design and production processes, has been moved from the periphery to the core of the research itself.

The Cluster of Excellence Image Knowledge Gestaltung, in which images and knowledge were explored as design processes, played a key role here. Furthermore, an interdisciplinary laboratory was established as a new virtual and physical architecture of knowledge. The humanities, the sciences, and technology as well as the design disciplines were brought together. "Gestaltung" has become a model in terms of scientific activity. With the participation of more than 40 disciplines from numerous university and non-university research institutions and museums, an integrative scientific platform was formed that changed the Humboldt-Universität zu Berlin in a striking manner.

The scholars and scientists participating in the project came from a wide range of institutions: Humboldt-Universität zu Berlin, Technische Universität Berlin, Berlin University of the Arts, the Max Planck Institute of Colloids and Interfaces, the Max Planck Institute for the History of Science, the Ibero-American Institute, the Museum of Decorative Arts, the Bauhaus Dessau Foundation, Berlin Weißensee School of Art, the Museum für Naturkunde (Natural History Museum), the Art Library, Federal Institute for Materials Research and Testing, and the Leibniz-Zentrum für Literatur- und Kulturforschung.

Following a positive application for bridge funding, the Cluster of Excellence ended as a success in November 2017 with a final conference. The initiative submitted a new application for the follow-up program Excellence Strategy which was approved in 2018. The newly formed Cluster Matters of Activity. Image Space Material, in which the old Cluster is merged, started in January 2019. The Cluster will explore materials' own inner activity, which can be discovered as a new source of innovative strategies and mechanisms for rethinking the relationship between the analog and the dig-tal and for designing more sustainable and energy-efficient technologies. More information under www.moa.hu-berlin.de and www.matters-of-activity.de.

Participating IRIS members:
- Prof. Dr. Jochen Brüning
- Prof. Dr. Norbert Koch
- Prof. Dr. Jürgen P. Rabe (also participating in Matters of Activity. Image Space Material)
- Prof. Dr. Matthias Staudacher (also participating in Matters of Activity. Image Space Material)



© NODE Berlin Oslo & Julia Meer

Cluster Of Excellence: Unifying Concepts In Catalysis - UniCat

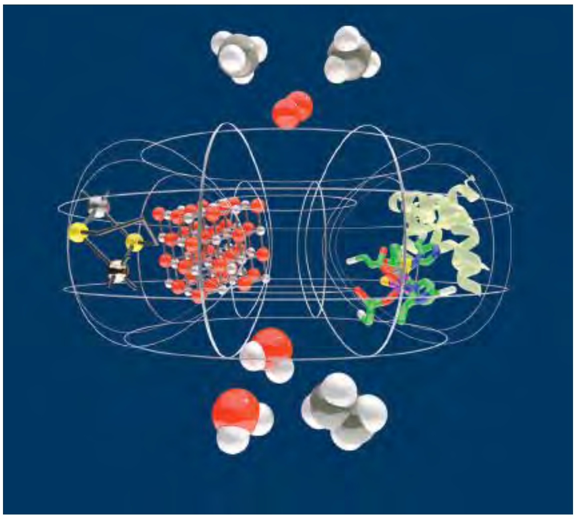
Period of funding 11/2012 – 12/2018
Spokesperson: Prof. Dr. Matthias Drieß (TU Berlin)
www.unicat.tu-berlin.de

More than 50 research groups from chemistry, physics, biology, and engineering from the Technische Universität Berlin (coordinating university), the Freie Universität Berlin, Humboldt-Universität zu Berlin, the University of Potsdam, the Fritz-Haber-Institut der Max-Planck-Gesellschaft, and the Max-Planck Institute of Colloids and Interfaces in Potsdam worked in the Cluster of Excellence UniCat on the research and development of catalysts. This cluster was unique in Germany, as it combined a wide range of scientific expertise with modern methods of engineering sciences, which in turn allowed optimal conditions for the development of new catalytic processes.

Three major areas were linked in this concept: The development and research of catalysts were carried out by both classical chemistry and the biological and materials sciences. The implementation of results into industrial applications required engineers from different disciplines. These researchers presented their results to potential users in demonstration projects, so-called Mini-Plants, after showing the technical and economic viability of the newly developed method. Embedded in the organizational structure of UniCat was the "Berlin International Graduate School of Natural Sciences and Engineering" (BIG-NSE), which was established in May 2007 at the Technische Universität Berlin. The Graduate School was to enable new synergies for a structured doctoral training. The BIG-NSE sees itself as a magnet for young, internationally successful early-stage scientists and scholars from the sciences and engineering.

This Cluster of Excellence also resulted in an application for the Excellence Strategy funding. From early 2019 on, the new founded follow-up initiative Unifying Systems in Catalysis (UniSysCat) works in five interdisciplinary research areas on the elucidation and evolution of catalyc networks. The central scientific objective of this newly founded cluster is to master the next stage of future challenges in catalysis: how to elucidate, create, and control reaction network in chemical and biological catalysis at different levels of complexity in space and time. Participating IRIS members in UniSysCat are Stefan Hecht and Christian Limberg.

Participating IRIS members:
- Prof. Stefan Hecht, Ph.D.
- Prof. Dr. Christian Limberg
- Prof. Dr. Joachim Sauer



Berlin Mathematical School

Period of funding 11/2006 – 12/2018
Spokespersons:
Prof. Dr. Günther M. Ziegler (FU Berlin, until 06/2018),
Prof. Dr. Holger Reich (FU Berlin, from 06/2018),
Prof. Dr. Jürg Kramer (HU Berlin & **IRIS Adlershof**)
& Prof. John M. Sullivan, PhD (TU Berlin)
www.math-berlin.de

The Berlin Mathematical School (BMS) is the joint graduate school of the mathematics departments of the Berlin universities, TU Berlin, FU Berlin, and HU Berlin. It was established in 2006, in the first round of the Excellence Initiative, as a permanent institution for excellent graduate education in all areas of mathematics at the Berlin universities.

As announced on 27th September 2018, the Berlin Mathematics Research Center MATH+ will receive funding as a Cluster of Excellence within the Excellence Strategy until 2025. The BMS is an integral part of MATH+ and provides the framework and environment for graduate education, as well as for the development and support of early career researchers for the Cluster of Excellence MATH+.

The BMS offers:

- a uniform setting for mathematics graduate studies in Berlin,
- a two-phase program modeled on US graduate schools, accepting students completing a Bachelor's degree as well as those completing a Master's,
- an international environment with half the students from outside Germany,
- a coordinated, highly diverse course program in English (so that German language skills are not needed)
- access to all mathematical research groups in Berlin for doctoral training, in particular, to the various DFG Research Training Groups (Graduiertenkollegs), Collaborative Research Centers (SFBs) and other ongoing research projects,
- intensive mentoring during the whole duration of studies, and support on nonmathematical issues ranging from housing and visas to childcare and language courses.

Participating IRIS members:

- Prof. Dr. Jochen Brüning
- Prof. Dr. Michael Hintermüller
- Prof. Dr. Jürg Kramer
- Prof. Dr. Dirk Kreimer
- Prof. Dr. Matthias Staudacher

© Kay Herschelmann/Berlin Mathematical School

School Of Analytical Sciences Adlershof SALSA

Period of funding 11/2012 – 10/2019
Spokespersons: Prof. Dr. Janina Kneipp (HU Berlin) & Prof. Dr. Ulrich Panne (Federal Institute for Materials Research and Testing & HU Berlin)
www.salsa.hu-berlin.de

Analytical Sciences are key technologies at the interface of chemistry, physics and biology. The Graduate School DFG GSC 1013 SALSA has the aim to overcome the fragmentation of Analytical Sciences into different fields and to address problems in basic and applied research in a multidisciplinary fashion.

This has been achieved by an approach that integrates graduate teaching and research, by setting up a new curriculum, and through the close collaboration of experts from different fields ranging from different directions of chemistry to physics, biology, mathematical modelling, and educational sciences.

SALSA has been part of “Analytic City Adlershof”, a competence center that bundles the university, non-university, and industrial expertise available in Adlershof. International partnerships were established with ETH Zürich, University of Oviedo in Spain and Hebrew University of Jerusalem, Israel with the aim to foster scientific exchange and develop a joint curriculum in Analytical Sciences.

SALSA runs two Application Labs, providing facilities for graduate projects and being home to a junior research group in Photonics.

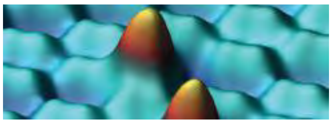
In October 2017, SALSA launched “Initiative Make & Measure”, which is aiming to secure funding for new collaborative research projects in the area of Analytical Sciences in the Berlin research area after the termination of the initial funding as GSC 1013 from November 2019.

Participating IRIS members:
- Prof. Dr. Kannan Balasubramanian
- Prof. Dr. Oliver Benson
- Prof. Stefan Hecht, Ph.D.
- Prof. Dr. Christian Limberg
- Prof. Dr. Jürgen P. Rabe

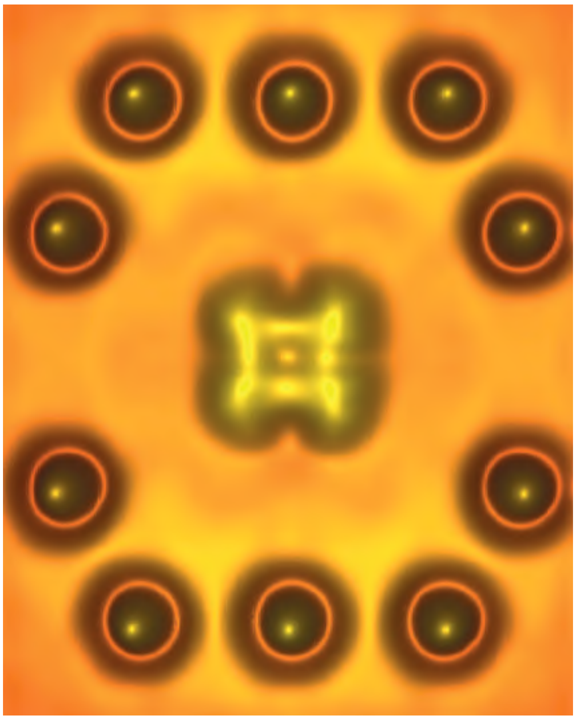
© School of Analytical Sciences Adlershof SALSA

CRC 658: Elementary Processes In Molecular Switches At Surfaces

Period of of funding: 07/2005 – 06/2017
Spokesperson: Prof. Dr. Martin Weinelt (FU Berlin)
www.physik.fu-berlin.de/en/einrichtungen/sfb/sfb658/



The increasing miniaturization and integration in electronic devices and sensors opens the perspective to use molecules as building blocks for functional molecular nanostructures. For applications like molecular electronics it will be essential to control the switching between different molecular states which in nature is often realized by photoinduced conformational changes. Controlled switching of molecular function requires the synthesis and design of appropriate molecular nanosystems and a basic understanding of structural and electronic properties including the interaction with the environment.



In addition, there is a demand for active control by external stimuli like electromagnetic fields, forces and currents. The interaction of molecules with surfaces opens new perspectives: It allows to assemble molecules with defined orientations and to vary the lateral couplings in a systematic manner. The contact of molecules to solid state interfaces is also essential to connect the molecular system with the outside world, in particular for electric transport.

The collaborative research center 658 investigated molecular switching processes driven by external excitations in well-defined molecular systems at solid surfaces. The focus was on reversible conformational changes of individual molecules and ensembles leading to measurable changes of functional properties of the system. After a very successful twelve-year run, the Collaborative Research Center held its final symposium in April 2017.

Participating IRIS members:
- Prof. Dr. Claudia Draxl
- Prof. Stefan Hecht, Ph.D.

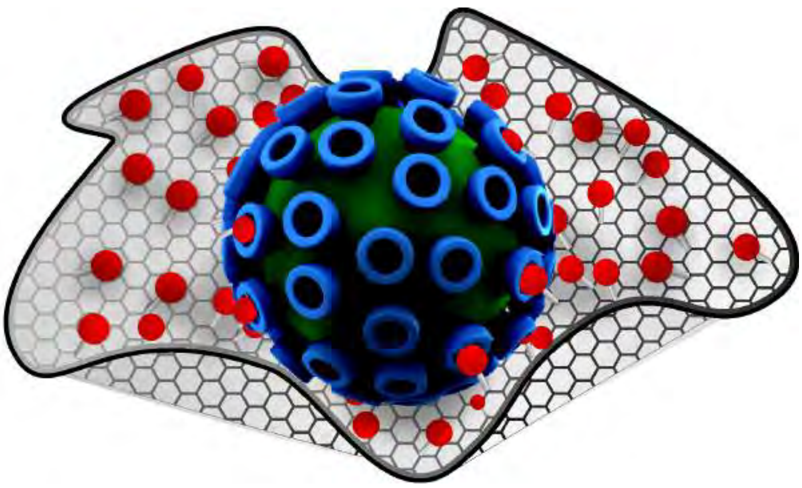
Researchers from the CRC 658 together with colleagues from the U.S. and Japan built a single-molecule transistor.
© Paul-Drude Institute Berlin

CRC 765: Multivalency As Chemical Organizational And Operational Principle: New Architectures, Functions, And Applications

Period of funding: 01/2008 – 12/2019
Spokesperson: Prof. Dr. Rainer Haag (FU Berlin)
www.sfb765.de

Multivalency is of vital significance in the (self)-organization of matter, in cognitive processes and signal transduction going on in biological systems. Thus, the development of new multivalent molecules is of great importance for approaching major biological issues such as the inhibition of inflammatory processes and the prevention of viral infections as well as for the systematical production of functional molecular architectures.

Participating IRIS members:
- Prof. Stefan Hecht, Ph.D.
- Prof. Dr. Jürgen P. Rabe



© Sumati Bhatia, Luis Cuellar Camacho, and Rainer Haag, Pathogen Inhibition by Multivalent Ligand Architectures, J. Am. Chem. Soc. 28 (2016) 8654.

CRC 787: Semiconductor - Nanophotonics: Materials, Models, Devices

Period of funding: 01/2008 – 12/2019
Spokesperson: Prof. Dr. Michael Kneissl (TU Berlin)
www.sfb787.tu-berlin.de

The CRC 787 Semiconductor nanophotonics: materials, models, devices combines three complementary areas of research aiming at the development of novel photonic and nanophotonic devices. The close collaboration between the different research areas and their mutual integration help explore new functionalities of nanophotonic devices and open new dimensions of applications. These include quantum key systems that are based on q-bit and entangled photon emitters, high frequency vertical cavity surface emitting lasers for future multi-terabus systems, quantum dot lasers, and optical amplifiers for ultra-high bit rate Ethernet, as well as high brilliance IR and visible lasers for materials processing and laser displays.

The CRC 787 comprises a total of 17 projects from TU Berlin, which is also the speaker university, the Humboldt Universität zu Berlin, the Otto-von-Guericke Universität Magdeburg as well as the Ferdinand-Braun-Institut (Leibniz Institut für Höchstfrequenztechnik), the Fraunhofer-Institut für Nachrichtentechnik (Heinrich-Hertz-Institute), the Weierstraß-Institute for Applied Analyis and Stochastic, and the Konrad-Zuse-Zentrum für Informationstechnik.

Participating IRIS member:
- Prof. Dr. Oliver Benson

CRC 951: Hybrid Inorganic/Organic Systems For Opto-Electronics (HIOS)

Period of funding: 07/2011 – ongoing
Spokesperson: Prof. Dr. Norbert Koch
(HU Berlin & **IRIS Adlershof**)
www.physik.hu-berlin.de/sfb951

The CRC 951, currently now in its 2nd funding period, is a central part of the IRIS research area "Hybrid Systems for Optics and Electronics". The CRC 951 scientists perform cutting-edge research on hybrid systems that unite inorganic semiconductors, conjugated organic materials and metal nanostructures with the aim of realizing substantially improved and potentially novel opto-electronic functionalities not achievable with any of the individual material classes alone. The CRC's spokesperson and deputy spokesperson, Norbert Koch and Oliver Benson, both members of **IRIS Adlershof**, are delighted with the progress the CRC managed to achieve during the past years. The CRC elucidated the fundamental chemical, electronic, photonic, and plasmonic interactions arising from the different nature of the components combined in HIOS, and uncovered novel hybridized quantum states and coupled excitations at their interfaces. In hand with this, the CRC 951 comprehended the limitations of state-of-the-art bulk inorganic semiconductors for achieving intimate coupling with conjugated molecules. First experiments on emerging 2D materials such as transition metal dichalcogenide monolayers show promising results and may most likely be the ideal inorganic semiconductor component for the goals of the CRC.

Examples of material basis used in the CRC 951. © CRC 951.

At the end of the reporting period, the application for a third funding period was submitted to the DFG. This application has been approved in the meantime. The CRC 951 is looking forward to upcoming years full of exciting HIOS research and the continuing collaboration of 27 principal investigators from physics and chemistry of Humboldt-Universität zu Berlin (coordinating university), Technische Universität Berlin, Universität Potsdam, Helmholtz-Zentrum Berlin für Materialien und Energie, and Fritz-Haber-Institut der Max-Planck-Gesellschaft.

Participating IRIS members:

- Prof. Dr. Matthias Ballauff
- Prof. Dr. Oliver Benson
- Prof. Dr. Caterina Cocchi
- Prof. Dr. Claudia Draxl
- Prof. Stefan Hecht, Ph.D.
- Prof. Christoph Koch, Ph.D.
- Prof. Dr. Norbert Koch
- Prof. Dr. Emil List-Kratochvil
- Prof. Dr. Yan Lu
- Prof. Dr. Jürgen P. Rabe

CRC 1109: Understanding Of Oxide / Water Systems At The Molecular Scale: Structural Evolution, Interfaces And Dissolution

Period of funding: 04/2014 – 12/2018
Spokesperson: Prof. Dr. Christian Limberg
(HU Berlin & **IRIS Adlershof**)
www.chemie.hu-berlin.de/sfb1109

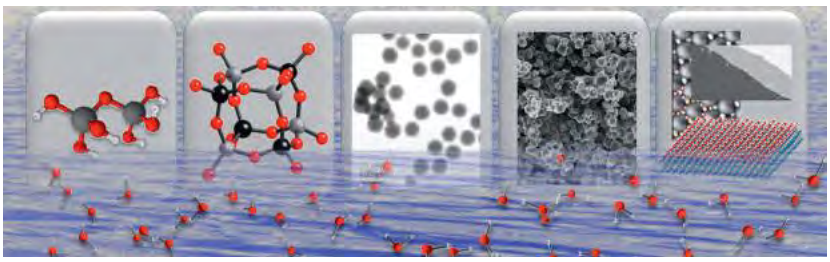
The Collaborative Research Centre 1109 was an interdisciplinary research platform bringing together scientists from four universities and three non-university institutions. It comprised research projects with a diverse expertise in chemistry and physics.

The research aimed at a comprehensive understanding of the complex atomic scale processes underlying oxide formation, structural evolution and dissolution.

Exemplarily, silica, alumina and iron oxides were studied as metal oxides with the highest natural abundance and application relevance. The research results contribute to a basis for a rational synthesis of oxides with desirable properties, such as stability towards corrosion.

After five successful years, the Collaborative Research Center held its final meeting in October 2018.

Participating IRIS members:
- Prof. Dr. Christian Limberg
- Prof. Dr. Nicola Pinna
- Prof. Dr. Joachim Sauer



Atomic-level insights into the multi-scale nature inherent to the metal oxide/water interface.
© CRC1109

Research Training Group 1504: Mass, Spectrum, Symmetry – Particle Physics In The Era Of The Large Hadron Collider

Period of funding: 04/2009 – 03/2018
Spokesperson: Prof. Dr. Heiko Lacker (HU Berlin)
www.masse-spektrum-symmetrie.de

While working in this group, doctoral students familiar with experimenting, on the one hand, or with theory, on the other, became acquainted with the sphere of research they were not used to. For the experimenting contingent, there primarily was research work at the Atlas Detector of the Large Hadron Collider at CERN. Besides the astrophysical groups conducting the IceCube experiments in the Antartic and H.E.S.S., researchers were involved in Namibia. The theoretical physicists, in turn, whose common denominator is the quantum field theory, were working to find new approaches reaching beyond the standard model.

The challenges emerging from the Large Hadron Collider at CERN require a strong integration and communication of the different experimental and theoretical working areas of elementary particle physics, which was precisely the key goal of this research training group. Furthermore, they aimed to unify the broad experimental and theoretical expertise in Berlin (HU Berlin), Dresden (TU Dresden), and Zeuthen (DESY) and to place the common character of elementary particle physics back into the center of the doctoral students' training. The common link between the involved experimental groups was their participation in the Atlas experiment at Large Hadron Collider at CERN and the search for new physics there. The link between the theoretical groups that were in the cooperation is quantum field theory, which was treated perturbatively, nonperturbatively, numerically, and generally in the context of string theory. In addition to the broad spectrum of the participating research groups, which was unique for the eastern part of Germany, the research training group was characterized by a large number of participating junior researchers.

The curriculum was geared for excellent doctoral students, who were trained in lectures and seminars at the Humboldt Universität zu Berlin and the Techniche Universität Dresden as well as in weekly intensive courses on topics in elementary particles that took place twice a year. Further features of the research training group were a secondary advisor concept and a midterm report.

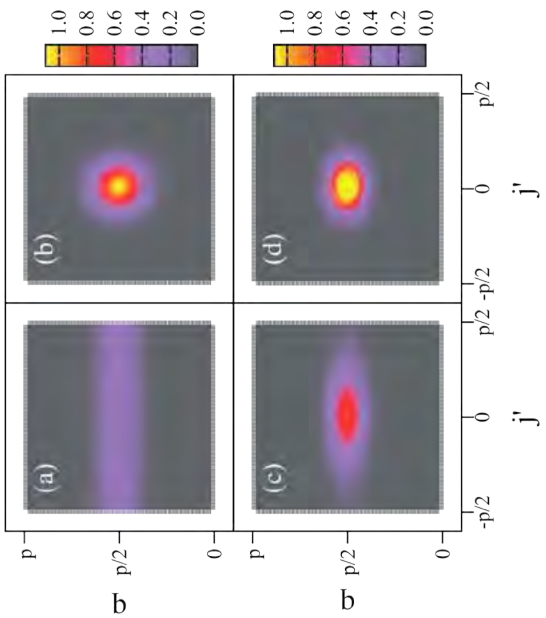
Participating IRIS members:
- Dr. Valentina Forini
- Prof. Dr. Dirk Kreimer
- Prof. Dr. Jan Plefka
- Prof. Dr. Matthias Staudacher

International Research Training Group 1524: Self Assembled Soft Matter Nano-Structures At Interfaces

Period of funding: 04/2009 – 03/2018
Spokesperson: Prof. Dr. Martin Schoen (TU Berlin)
www.ssni.tu-berlin.de

The International Research Training Group was aiming at fundamental properties of self-assembled nanostructures of soft (organic and biomolecular) matter at interfaces. The studies were being devoted to the nature of the structures formed and the driving forces behind their formation. A common objective of the research program was a better understanding of the interplay of the length scales characterizing the substrate and the properties of the self-assembled surface structures formed at the substrate. Research was focusing on three types of systems of different degree of complexity: (i) Systems in which the characteristic length scale results from a surface pattern imposed on an otherwise flat solid surface. Specifically, it was investigated how ''chemical'' patterns ranging from nano- to micrometer dimensions can be formed through self-assembly and how they can be imprinted onto adjacent soft-matter phases. (ii) Systems with curved interfaces, in which the mean radius of curvature of the substrate represents a primary length scale. The self-assembly of amphiphilic molecules at the surface of colloidal particles into surface micelles, bilayers, etc. is an example of such systems. (iii) Biomimetic structures of various length scales within interfaces. Typical issues here are, for example, the size and stability of domains formed in multicomponent biomembranes or field-induced pattern formation of colloidal particles at interfaces. After nine successful years of research activities, the concluding colloquium of the IRTG 1524 was held in December 2017.

Participating IRIS member:
- Prof. Dr. Matthias Ballauff
- Prof. Dr. Regine von Klitzing
- Prof. Dr. Jürgen P. Rabe



Plots of the orientation distribution function P_α (ω) as functions of polar and azimuthal angles θ and φ. The magni- tude of P_α is given by the colour bars attached to each pair of plots. Parts (a) and (c) refer to $\alpha = a$, whereas parts (b) and (d) of the figure pertain to $\alpha = b$; lower panel $T = 1.00$, upper panel $T = 1.20$. The higher temperature pertains to region II, whereas the lower one refers to a state point in region III in Figure 3). The azimuthal angle $\varphi = \varphi' + \pi$ so that $\varphi \in [0, 2\pi]$ according to its standard definition.
© R. A. Skutnik, L. Lehmann, S. Püschel-Schlotthauer, G. Jackson, and M. Schoen
Mol. Phys.,
DOI: 10.1080/00268976.2019.1581292

Research Training Group 1651: SOAMED – Service-Oriented Architectures For The Integration Of Software-Based Processes, Exemplified By Health Care Systems And Medical Technology

Period of funding: 04/2010 – 09/2019
Spokesperson: Prof. Dr. Ulf Leser (HU Berlin)
www.ki.informatik.hu-berlin.de/soamed

Service orientation is a promising architectural concept to quickly and cost efficiently couple encapsulated software components ("services"), and to adapt them to new requirements. Service orientation has mainly been suggested for co-operating business processes. However, its application in embedded systems is increasing. Service orientation has evolved from very pragmatic problems and backgrounds. Little attention has been directed to theoretical and conceptual problems of the area. Furthermore, only rudimentary software technology methods for services are available. Examples of systematically constructed service-oriented architectures are presently visible only to a minor degree.

Informatics is a key technology for the innovative organization of health care systems and of medical technology. In comparison with other organizational and embedded systems, the involved processes are more versatile, and the reliability and correctness requirements are higher. Medical processes are usually loosely coupled. Their integration is as much difficult as important. Theoretical and methodological foundations of both the design process and the structure of service-oriented systems might substantially improve today's information technology

In this situation, this Graduate School starts out with the idea to underpin the currently pragmatically focussed service-oriented approach with theoretical foundations by integrating established as well as emerging software engineering procedures. This approach aims at a decisive improvement of concepts, methods, and tool support for service-oriented system construction.

The scope of innovation of the Graduate School is obvious and far reaching: health care systems as well as medical systems are presently dominated by structures and processes that can substantially be improved by the concepts and methods developed by this Graduate School. The feasibility of the project is guaranteed by all participants' long standing experience in comparable projects.

Participating IRIS member:
- Prof. Johann-Christoph Freytag, Ph.D.

International Research Training Group 1740: Dynamical Phenomena In Complex Networks: Fundamentals

Period of funding: 10/2011 – 09/2020
Spokespersons: Prof. Dr. Jürgen Kurths
(Potsdam Institute for Climate Impact Research & HU Berlin) &
Prof. Dr. Elbert E.N. Macau (Federal University of São Paulo)
https://www.physik.hu-berlin.de/de/irtg1740

During the last decade, networks with complex topology have become a very powerful approach for understanding large complex systems in various fields of applications ranging from Neuroscience, via Engineering to Sociology and Economy. So far, most studies have concentrated on fixed topology, i.e. were strongly restricted in their applicability. Therefore, we intend to study in this IRTG principles of self-organization in evolving complex networks. To bring these principles closer to various applications, we will in addition investigate the influence of heterogeneity in the network structure, multiscale time delays and stochasticity. These theoretical studies will be intimately connected with the investigation of experimental and natural dynamical networks of increasing complexity starting from lasers, via hybrid networks of neurons to the Earth system. The latter one is a special challenge for the network theory and it will be a focus of this IRTG. In this context, the main topic will be to understand the functioning of the Earth´s subsystems under changing conditions, especially global warming and deforestation in Amazonia.

A key goal of this interdisciplinary IRTG will be to develop a structured PhD program which will enable young researchers to work in network theory as well as across various fields of network applications. It comprises education on modern theoretical concepts and training on network applications, even involving "hands-on" experience with the corresponding experiments. The training program includes dual supervision of each student, annual schools, workshops and on-site learning, but innovative forms of learning and communication such as teleconferences, e-learning, or wikiversity will be extensively used too. Special emphasis will be devoted to soft skills education by making use of the Humboldt Graduate School and the University of São Paulo.

Based on the complementary expertise of the participants from the German (HU Berlin and Potsdam Institute for Climate Impact Research [PIK]) and Brazilian (University of São Paulo [USP] and Natioanl Space Institute for Space Research [INPE]) teams and on the various common activities from subgroups of both sides in the past, we will establish this multidisciplinary IRTG consisting of physicists, mathematicians, climatologists, biologists and geographers.

Participating IRIS member:
- Prof. Dr. Igor M. Sokolov

International Max Planck Research School: Functional Interfaces In Physics And Chemistry

Spokesperson: Prof. Dr. Martin Wolf
(Fritz-Haber-Institut der Max-Planck-Gesellschaft)
www.imprs-cs.mpg.de

The physical and chemical properties of material surfaces play an important role in many large scale applications, such as in heterogeneous catalysis and corrosion inhibition. With the shrinking dimensions of electronic and optoelectronic devices, surface properties are becoming increasingly important in many fields of modern technology, such as in thin film growth. In this emerging field, which combines electronic devices with biological applications, the surface properties dominate such issues as biocompatibility. The last two decades have seen a rapid progress in our understanding of fundamental processes on highly idealized surfaces.

The International Max Planck Research School on "Functional Interfaces in Physics and Chemistry" aims at combining the expertise of several strong research groups at the Humboldt Universität zu Berlin, the Freie Universität Berlin, and the Fritz-Haber-Institut der Max-Planck-Gesellschaft in order to create a unique opportunity for foreign and German students in terms of cutting-edge research and a thorough training in the methods, concepts, and theoretical basis of the physics and chemistry of surfaces. The research school provides an interdisciplinary environment, and a wealth of methods using state-of-the-art equipment.

Participating IRIS members:

- Prof. Dr. Claudia Draxl
- Prof. Dr. Norbert Koch
- Prof. Dr. Joachim Sauer

© International Max Planck Research School "Functional Interfaces in Physics and Chemistry"

International Max Planck Research School Multiscale Bio-Systems

Period of funding: 06/2019 - 05/2025
Spokesperson: Prof. Dr. Reinhard Lipowsky
(Max Planck Institute of Colloids and Interfaces)
imprs.mpikg.mpg.de

The IMPRS on Multiscale Bio-Systems addresses the fundamental levels of biosystems as provided by macromolecules in aqueous solutions, molecular recognition between these building blocks, free energy transduction by molecular machines, as well as structure formation and transport in cells and tissues. The research activities are focused on four core areas:

- Recognition of Biopolymers
- Photo-induced Molecular Processes
- Cell-like Systems and Processes
- Tissue-like Systems and Processes

One general objective is to understand, in a quantitative manner, how the processes on supramolecular and mesoscopic scale between a few nanometers and many micrometers arise from the structure and dynamics of the molecular building blocks. To achieve this goal, our interdisciplinary research combines bottom-up with top-down approaches, which are pursued by several groups from theoretical and experimental biophysics, from physical and colloid chemistry, as well as from biochemistry and molecular biology.

The IMPRS on Multiscale Bio-Systems involves the Max Planck Institute of Colloids and Interfaces, which is the main organizational structure, the Universität Potsdam, the Freie Universität and the Humboldt-Universität zu Berlin as well as the Fraunhofer Institute for Biomedical Engineering IBMT.

Participating IRIS members:
- Prof. Stefan Hecht, Ph.D.
- Prof. Dr. Jürgen P. Rabe

© Max Planck Institute of Colloids and Interfaces.

International Max-Planck Research School: Mathematical And Physical Aspects Of Gravitation, Cosmology And Quantum Field Theory

Period of funding: 01/2016 – 12/2021
Spokesperson: Prof. Dr. Hermann Nicolai
(Max Planck Institute for Gravitational Physics)
imprs-gcq.aei.mpg.de/2505/de

The International Max Planck Research School (IMPRS) for Mathematical and Physical Aspects of Gravitation, Cosmology and Quantum Field Theory addresses fundamental questions about the nature of classical and quantum gravity and its links to the fundamental constituents of matter. The research is purely theoretical and brings together some of the most exciting challenges of modern physics and mathematics. The school started operating in January 2016 and replaces the previous IMPRS for Geometric Analysis, Gravitation and String Theory.

Students enroll in a doctoral program at one of the participating universities. Every student is assigned a primary and a secondary adviser by the executive committee. In addition to their research work, students are expected to attend advanced lecture courses that are offered by the school. Moreover, they are required to present progress reports of their work in regular intervals at local seminars. The program, dissertation, and exams are in English or German. The PhD should be completed within 2-3 years.

Participating IRIS members:
- Dr. Valentina Forini
- Prof. Dr. Dirk Kreimer
- Prof. Dr. Jan Plefka
- Prof. Dr. Matthias Staudacher

Graduate School: Hybrid4Energy - Hybrid Materials For Efficient Energy Generation And Information Technologies

Period of funding: 04/2014 – 12/2017
Spokesperson: Prof. Dr. Norbert Koch (HU Berlin & **IRIS Adlershof**)
www.physik.hu-berlin.de/h4e

Hybrid4Energy, a graduate school for Hybrid Materials for Efficient Energy Generation and Information Technologies, is a joint venture of Humboldt-Universität zu Berlin and the Helmholtz-Zentrum Berlin für Materialien und Energie GmbH.

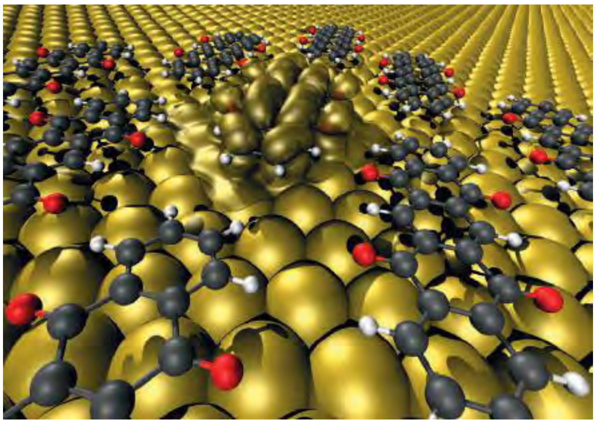
The program offers a structured, three-year period of multidisciplinary research combined with an integrated curriculum in physics and chemistry. The objective of this graduate school is to push interdisciplinary education, training, and research on hybrid organic/inorganic systems for electronic, optoelectronic and photovoltaic devices.

The Campus Adlershof with its wide range of expertise allows doctoral students to grow and benefit from an excellent interdisciplinary environment and research facilities.

The research program focuses on unravelling the electronic, optoelectronic, and photonic properties of organic/inorganic hybrid systems in a concerted experimental and theoretical approach studied, with the goal of predicting and controlling the material properties and functionalities. The knowledge gained will then be applied to the fields of renewable energy and next generation information technology.

Participating IRIS members:

- Prof. Dr. Oliver Benson
- Prof. Dr. Claudia Draxl
- Prof. Stefan Hecht, Ph.D.
- Prof. Dr. Norbert Koch
- Prof. Dr. Yan Lu
- Prof. Dr. Jürgen P. Rabe



Interdisciplinary Master Program Polymer Science

Head of Joint Commission: Prof. Dr. Reinhard Schomäcker (TU Berlin)
http://polymerscience.physik.hu-berlin.de/

Polymer science is an interdisciplinary area comprised of chemical, physical, engineering, processing and theoretical aspects. It also has enormous impact on contemporary materials science. Its goal is to provide the basis for the creation and characterization of polymeric materials and an understanding for structure/property relationships. Polymer science is of increasing importance for everyone's daily life. Many modern functional materials, gears, and devices have polymers as integral parts. Not surprisingly, roughly 30% of all scientists in the chemical industry work in the field of polymers. Despite its importance today and potential for future economic growth, there is no adequate university-level study program for polymer science in Germany.

The Berlin-Brandenburg Polymer Society (Berlin-Brandenburgischer Verband für Polymerforschung e.V.) became aware of this misbalance and initiated a two-year Master of Science polymer program, which started in the winter semester of 1999/2000. It was jointly designed by polymer scientists of the three Berlin universities, Freie Universität Berlin (FU), Humboldt-Universität zu Berlin (HU), Technische Universität Berlin (TU) and the nearby Universität Potsdam (UP) with the goal in mind to be competitive with renowned polymer centers abroad. To make it more attractive to foreign students the program is in English.

This challenging interdisciplinary program benefits from the close proximity of several other Berlin and Potsdam scientific centers such as the institutes of the Max Planck, Fraunhofer, and Helmholtz Societies, as well as the BESSY II synchrotron. The universities are very well equipped with the most state-of-the-art technical equipment and laboratories, spe-cialty workshops, large service units, and modern computer facilities. The work of the polymer scientists in charge of the Polymer Science program is internationally renowned and endowed by industry, state, and private grants and awards.

Participating IRIS members:

- Prof. Dr. Regine von Klitzing
- Prof. Dr. Jürgen P. Rabe (Deputy Head of Joint Commission)
- Prof. Dr. Igor M. Sokolov
- Prof. Dr. Matthias Ballauff

Master Program: Optical Science

Coordinator: Prof. Dr. Kurt Busch (HU)
Opticalsciences.physik.hu-berlin.de

The Optical Sciences comprise the study of the propagation and detection of light and its interaction with matter. Discoveries in optics have had a profound influence on the devel-opment of modern science and the forefront of technology, as demonstrated by more than 20 optics-related Nobel prizes between 1907 and 2014.

With the international MSc in Optical Sciences program, the Humboldt-Universität zu Berlin, together with its cooperation partners in the Science- and Technology-Park Berlin Adlershof, offers an excellent education in this vibrant and exciting field. We seek outstanding students with a bachelor's degree in physics or closely related field who wish to contribute to state-of-the-art optics research and development.

Participating IRIS members:

- Prof. Dr. Oliver Benson
- Prof. Dr. Thomas Elsässer

EU Research Projects

iSwitch – Integrated Self-Assembled Switchable Systems And Materials: Towards Responsive Organic Electronics – A Multisite Innovative Training Action

Period of funding: 01/2015 – 12/2018
Coordinator: Prof. Paolo Samori (Université de Strasbourg)
http://iswitch-network.eu/

iSwitch was a Marie Skłodowska-Curie Action Innovative Training Network (ITN) funded by the EU Framework Programme for Research and Innovation Horizon 2020. It offered top-level multi-disciplinary and supra-sectorial training to a pool of talented young researchers, involving contributions from different scientific and technological fields, such as, supramolecular chemistry, materials, nanoscience, physics and engineering. iSwitch's appointees were trained through lecture courses, dedicated inter- national schools and workshops, topical conferences, secondments to other consor- tium nodes and an ambitious and carefully planned research activities benefiting from the expertise of world-leading senior PIs and of younger but well-established PIs with outstanding track records in training and research.

Additionally, iSwitch generated new ground-breaking S&T knowledge needed to obtain efficient and fast switching in supra- molecular electro- and opto-photoactive materials as a response to external stimuli. This was accomplished via controlled self-assembly of multicomponent architectures incorporating molecular switches, for fabricating responsive and multifunctional optoelectronic supramolecular devices. Special emphasis was laid on developing nano- and macro-scale switchable transistors and light-emitting devices as new solutions to (nanoscale) multi-functional organic-based logics.

Since its launch in January 2015, iSwitch brought together some of the leading European research groups at the interface of chemistry and physics to train the next generation researchers on the emerging topic of smart electronics. iSwitch successfully ended during the reporting period in December 2018 with a final symposium highlighting the key achievements of the project and discussing future perspectives in this burgeoning area of research. The symposium was organized by Prof. Stefan Hecht and Prof. Norbert Koch, both members of **IRIS Adlershof**.

Participating IRIS members:
- Prof. Stefan Hecht, PhD
- Prof. Dr. Norbert Koch

NOMAD - The Novel Materials Discovery Laboratory

Period of funding: 11/2015 – 11/2018
Coordinator: Prof. Dr. Matthias Scheffler
(Fritz-Haber-Institut der Max-Planck-Gesellschaft)
https://nomad-coe.eu/

NOVEL MATERIALS DISCOVERY

The NOMAD Laboratory is a European Centre of Excellence (CoE), funded by the European Union under the Horizon2020 program. Eight complementary research groups of highest scientific standing in computational materials science along with four high-performance computing (HPC) centres form the synergetic core of this CoE.

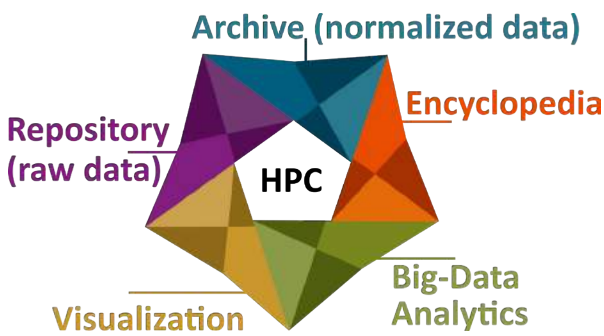
New technological developments are practically always based on better, and often enough completely new, materials. This applies to the next generation of smartphones, fuel-efficient cars or powerful batteries for electric vehicles, as well as to catalysts for the production of methane or liquid fuels and high-performance solar cells. The NOMAD Laboratory develops a Materials Encyclopedia and Big-Data Analytics tools for materials science and engineering. It starts from the NOMAD Repository which contains data and input and output files of many high-quality calculations performed all over the word. The NOMAD Repository is unique in the sense that it is not restricted to one or a few simulation programs ("codes") but it accepts output from all important codes. At the moment, the NOMAD Repository contains input and output files of more than 50 million calculations which corresponds to more than 2 billion CPU-core hours burned on various high-performance computers all over the planet.

A Materials Encyclopedia opens up new opportunities by developing new tools to search and retrieve information from the large materials data pool. It comprehensively characterizes materials by their computed properties. The developed search engine enables to retrieve those materials that exhibit one or more required features.

Although the funding by the European Union ended late 2018, **IRIS Adlershof** and the Fritz-Haber-Institut der Max-Planck-Gesellschaft will continue to work together on this vital project.

Participating IRIS members:

- Prof. Dr. Claudia Draxl
- Prof. Johann-Christoph Freytag, Ph.D.



© C. Draxl and M. Scheffler, NOMAD: The FAIR Concept for Big-Data-Driven Materials Science, Invited Review for MRS Bulletin 43, 676-682 (2018).

SAGEX – Scattering Amplitudes: From Geometry To Experiment

Period of of funding: 09/2018 – 08/2022
Scientific Coordinator: Prof Gabriele Travaglini,
Project Manager: Dr. Jenna Lane
https://www.sagex.org

SAGEX is a Maria Skłodowska-Curie Innovative Training Network funded by the European Union under the European Horizon 2020 research and innovation program. It aims to train the next generation of world-leading scientists in the field of scattering amplitudes.

Scattering amplitudes, describing the observations of high-energy collider experiments, provide a window into the fundamental structures predicted by relativistic quantum theories. By identifying and exploiting seemingly disparate concepts from abstract geometry, symbolic big data, and phenomenological calculations, the SAGEX network will tutor early stage researchers in the new tools, approaches and insights that will make possible previously intractable analyses directly relevant to current and near-future particle physics experiments.

Training of the network's early stage researchers will comprise an integrated curricu-lum of local and intensive network courses, schools, and engagement with active cutting-edge research. They will be seconded to at least one academic and one private sector partner of the project, building bridges between academic and industrial communities.

In February 2020 Humboldt-Univesität zu Berlin will organise and host the 2nd SAGEX training school and workshop, one of the project's main events.

Participating IRIS members:
- Prof. Dr. Jan Plefka
- Prof. Dr. Matthias Staudacher

Early Stage Researchers of SAGEX.
© SAGEX.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 764850 (SAGEX)

Funding By The Einstein Foundation

ECMath - Einstein Center For Mathematics Berlin

Period of of funding: 01/2014 -12/2018
Spokesperson: Prof. Dr. Michael Hintermüller
(HU Berlin & **IRIS Adlershof**)
www.ecmath.de/

The Einstein Center for Mathematics Berlin (ECMath) was founded in 2014. It is supported by the Einstein Foundation Berlin, by the three universities Freie Universität Berlin (FUB), Humboldt-Universität zu Berlin (HU), and Technische Universität Berlin (TUB) and by the two research institutes Weierstraß Institute for Applied Analysis and Stochastic (WIAS) and Zuse Institute Berlin (ZIB).

ECMath was founded to support mathematical research in selected innovation areas (Clinical Research and Healthcare, Metropolitan Infrastructure, Optical Technologies, Sustainable Energies) and to establish and strengthen a network structure of excellent joint initiatives in Berlin.

Founding members of ECMath were the Research Center MATHEON, the Berlin Mathematical School (BMS) and the German Center for Teacher Education in Math-ematics (DZLM). The Research Campus Modal, the DFG Collaborative Research Centers (CRCs) 647, 1114, and Transregional Research Centers (TRs) 109, 154 were additional members.

The main focus of ECMath was to provide support for application-oriented basic research within MATHEON, thus, targeting mathematics for innovation in key applications. By the conception of "Mathematics as a Whole", it fostered a comprehensive approach to mathematics and its applications through the training of young scientists and early-career students. Within this activity, ECMath provided attractive stipends for extraordinarily well-qualified BMS students, and it furthered and supported school activities within MATHEON and DZLM. A particular strength of ECMath was the knowledge transfer from science to industry.

In this way, ECMath supported and created an environment for connecting comprehensive mathematical education, cutting-edge research in pure and applied mathematics, and large-scale applications in industry and society. Thus, ECMath laid the foundation for the newly established Berlin Mathematics Research Center MATH+, which continues and broadens the scientific scope of application-oriented mathematical research in Berlin as a Cluster of Excellence since 01/2019.

Participating IRIS member:

- Prof. Dr. Michael Hintermüller
- Prof. Dr. Jürg Kramer

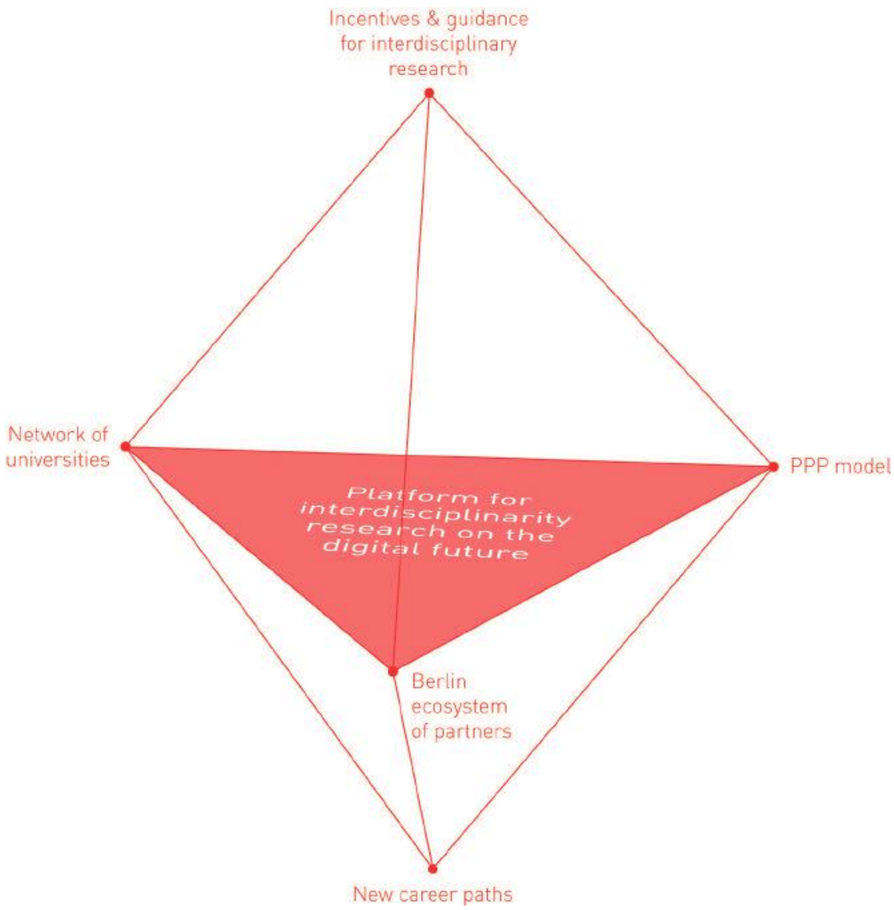
Einstein Center Digital Future

funding since 04/2017
Spokesperson: Prof. Dr. Odej Kao (TU Berlin)
www.digital-future.berlin

Einstein Center Digital Future (ECDF) is the center for digitization research in Berlin. Since its opening in April 2017, scientists have been conducting research in the core area of "Digital Infrastructure, Methods and Algorithms" and in the areas of innovation "Digital Health", "Digital Society and Digital Industry and Services". ECDF is an enabler and accelerator for research in the field of digitalization in Berlin. The project aims to create more links in the field of digitization in Berlin, try out new forms of cooperation, concentrate on innovative interdisci-plinary cutting-edge research and attract excellently trained young scientific talent.

Einstein Center Digital Future is an interdisciplinary project of the four Berlin universities (Humboldt-Universität zu Berlin, Technische Universität Berlin, Freie Universität Berlin and Berlin University of the Arts) and of Charité - Universitätsmedizin Berlin. It is based on a large-scale public-private partnership (PPP model) between companies, organizations and research institutions from Berlin science.

Participating IRIS members:
- Prof. Johann-Christoph Freytag, Ph.D.
- Prof. Dr. Alexander Reinefeld



© ECDF

Quantum Link Expansion (Q.Link.X)

Period of funding: 08/2018 – 07/2021
Spokesperson: Dr. Marianne Lenzen
(Rheinische Friedrich-Wilhelms-Universität Bonn)
www.qlinkx.de

Q.Link.X
Verbundprojekt
Quanten-Link-
Erweiterung

Digitization permeates our entire society - from Industry 4.0 to healthcare applications. Data security and secure communication are becoming increasingly important. Quantum communication is a promising approach for this: It uses quantum states as information carriers, which cannot be copied or unnoticed due to fundamental physical laws. The Federal Ministry of Education and Research (BMBF) is supporting this departure into quantum technology by funding the joint project Quantum Link Expansion (Q.Link.X) with a total of 14.8 million euros over the next three years. The working groups of IRIS member Prof. Oliver Benson and **IRIS Adlershof** young research group leader Sven Ramelow are involved.

The goal of the collaborative project is physically tap-proof fiber optic networking. However, this paradigm shifts in message encryption away from conventional methods and towards quantum technology encounters a technological challenge: transmission of quantum information with light particles (photons) leads to unavoidable line losses, limiting transmis-sion distances to less than 100 kilometers. With quantum repeaters, this limit should be overcome without security restrictions. Repeaters (repeater stations) are signal amplifiers and conditioners in communication technology. Unlike these repeaters, however, the quantum repeater has to connect signals from different sections using quantum processes in order to bridge larger distances.

The joint project Quantum Link Extension (Q.Link.X) is now intended to promote the development of such quantum repeaters, which use quantum memory and quantum cou-plers. In the next three years, the Federal Ministry of Education and Research is supporting this move into quantum technology with a total of 14.8 million euros. With quantum dots, diamond color centers and a combination of atomic and ionic systems as three different technical platforms, transmission distances between ten and 100 kilometers are to be realized and the advantages of the respective systems compared to each other. The work should prepare the technology to bridge much longer distances in later phases. For the first time, Q.Link.X not only researches and develops individual components of a quantum repeater, but also en-tire communication routes.

In the Q.Link.X network, 24 partners from research institutions from universities to industrial laboratories have come together to explore the key technology of quantum repeat-ers. The close involvement of industrial partners and consultants should facilitate the feasibil-ity from an industrial and engineering perspective from the outset. The exploitation of earnings in Germany is to be secured by patents and spin-offs of the consortium.

The following partners are involved in the project: Rheinische Friedrich-Wilhelms-Universität Bonn, Technichel Universität München, Technische Universität Dortmund, High Fi-nesse Laser and Electronic Systems GmbH, Fraunhofer Heinrich Hertz Institute Berlin, Technische Universität Berlin, Universität Stuttgart, Universität Paderborn, Universität des Saarlands, Freie Universität Berlin, Leibniz Institute for Solid State and Materials Research Dresden, Ruhr Universität Bochum, Swabian Instruments GmbH, Leibniz Universität Hannover, Max Planck Institute for Quantum Optics (Garching), Julius-Maximilians-Universität Würzburg, Universität Bremen , Heinrich Heine Universität Düsseldorf, Universität Ulm, Humboldt-Universität zu Berlin, Universität Kassel, Johannes Gutenberg Universität Mainz, Karlsruhe Institute of Technology and Ludwig-Maximilians Universität München.

Participating IRIS members:
- Prof. Oliver Benson
- Dr. Sven Ramelow

Collaborative Projects In The Context Of Mathematics And Science Teacher Education And Training

Graduate School: Humboldt-ProMINT-Kolleg

Period of funding: 08/2010 – 01/2022
Spokespersons: Prof. Dr. Niels Pinkwart (HU Berlin)
www.promint.hu-berlin.de

Initiated in 2010, the Humboldt-ProMINT-Kolleg is an interdisciplinary institution at Humboldt-Universität zu Berlin, that focuses on the further development and evaluation of educational research in mathematics and the sciences as well as STEM teacher education and training.

From 2014 to 2018, the Humboldt-Universität and Freie Universität Berlin have coordinated a national network in "School labs for STEM teacher education and training". Since fall 2018, the Humboldt-Universität zu Berlin and its Humboldt-ProMINT-Kolleg is a member of the national network "The Future of STEM Learning", funded by Deutsche Telekom Stiftung.

The five participating universities (Humboldt-Universität zu Berlin, University of Kaiserslautern, Kiel University, University of Koblenz-Landau and University of Würzburg) will jointly develop and test ideas for teaching high-quality STEM classes in the digital world and then integrate these ideas into STEM teacher training programs.

Deutsche Telekom Stiftung is investing a total of EUR 1.6 million in the project. The universities will be supported in their development efforts by experts from Germany, Estonia, the Netherlands, and Austria.

Participating IRIS member:

- Prof. Dr. Jürg Kramer

Joint Lab With The Helmholtz Innovation Lab HySPRINT

Project Manager: Dr. Stefan Gall (Institute Silicon Photovoltaics)
https://www.HySPRINT.de

In 2018, the first joint lab between IRIS Adlershof and the Helmholtz Innovation Lab HySPRINT was established. HySPRINT stands for Hybrid Silicon Perovskite Research, Integration & Novel Technologies and was founded in 2017. In the joint lab GenFab (Generative Fabrication), the group Hybrid Devices led by IRIS member Prof. Dr. Emil List-Kratochvil closely collaborates with the Young Investigator Group Hybrid Materials Formation and Scaling led by Dr. Eva Unger from HZB. Their long-term collaboration focusses on the Generative manufacturing processes for hybrid components. For IRIS scientists, the collaboration is very advantageous. List-Kratochvil says: "For us, HySPRINT is not only an exemplary research partner, but is a real working vehicle to move outside academia to industry."

Objectives of this research tandem are covering a wide field of topics of scaling and producing of photovoltaic and (opto)electronic components and devices. Unger's group will concentrate on the investigation and improvement of the fabrication processes for the hybrid perovskite materials and their interfaces. List-Kratochvil and his team aim to realize the large scale printed memories, light-emitting diodes (LEDs) and transparent conductive electrodes and interconnects. For testing of the final devices the joint lab employs a large variety of electrical and spectroscopy techniques. To enhance their scientific cooperation, List-Kratochvil and Unger will set up together a new equipped working space, 200 m2 large, in October 2019.

HySPRINT and the Hybrid Devices teams have already developed together an assembly of the single processes and will work further on their improvement in the upcoming two years. Being at the Technology Readiness Level 3 (TRL) of production, common for the research institutions, the joint lab strives to reach TRL 6 (from 9) in the next 5 years. As a result, List-Kratochvil and Unger expect to settle the pilot line of hyrid components and large-size hybrid tandem solar cells.

4. 6. Selected Publications In Important High Impact Journals

The scientific results of IRIS research are communicated to the international scientific community in particular through peer-reviewed publications in high-ranking scientific journals. This is a list of selected publications in some of the most prestigious, relevant scientific journals. A complete overview of all publications can be found on the website of **IRIS Adlershof** (www.iris-adlershof.de).

2017

Analytical representation of dynamical quantities in GW from a matrix resolvent
J. Gesenhues, D. Nabok, M. Rohlfing, and C. Draxl
Phys. Rev. B 96 (2017) 245124
DOI: 10.1103/PhysRevB.96.245124

Large guanidinium cation mixed with methylammonium in lead iodide perovskites for 19% efficient solar cells
A.J.D. Jodlowski, C. Roldán-Carmona, G. Grancini, M. Salado, M. Ralaiarisoa, S. Ahmad, N. Koch, L. Camacho, G. de Miguel, and M.K. Nazeeruddin
Nat. Energy 2 (2017) 972
DOI: 10.1038/s41560-017-0054-3

Beating the thermodynamic limit with photo-activation of n-doping in organic semiconductors
X. Lin, B. Wegner, K. Min Lee, M. A. Fusella, F. Zhang, K. Moudgil, B. P. Rand, S. Barlow, S. R. Marder, N Koch, and A. Kahn
Nat. Mater. 16 (2017) 1209
DOI: 10.1038/nmat5027

Population equations for degree-heterogenous neural networks
M. Kähne, I. M. Sokolov, and S. Rüdiger
Phys. Rev. E 96 (2017) 052306
DOI: 10.1103/PhysRevE.96.052306

Spiro-Bridged Ladder-Type Oligo(para-phenylene)s: Fine Tuning Solid State Structure and Optical Properties
B. Kobin, J. Schwarz, B. Braun-Cula, M. Eyer, A. Zykov, S. Kowarik, S. Blumstengel, and S. Hecht
Adv. Funct. Mater. (2017 1704077
DOI: 10.1002/adfm.201704077

Computational materials: Open data settled in materials theory
C. Draxl, F. Illas, and M. Scheffler
Nature 548 (2017) 523
DOI: 10.1038/548523d

Twinned growth of metal-free, triazine-based photocatalyst films as mixed-dimensional (2D/3D) van der Waals heterostructures
D. Schwarz, Y. Noda, J. Klouda, K. Schwarzová-Pecková, J. Tarábek, J. Rybáček, J. Janoušek, F. Simon, M.V. Opanasenko, J. Čejka, A. Acharjya, J. Schmidt, S. Selve, V. Reiter-Scherer, N. Severin, J.P. Rabe, P. Ecorchard, J. He, M. Polozij, P. Nachtigall, and M.J. Bojdys
Adv. Mater. (2017) 1703399
DOI: 10.1002/adma.201703399

Hybrid Organic–Inorganic Transition-Metal Phosphonates as Precursors for Water Oxidation Electrocatalysts
R. Zhang, P. A. Russo, A. G. Buzanich, T. Jeon, and N. Pinna
Adv. Funct. Mater. 27 (2017) 1703158
DOI: 10.1002/adfm.201703158

Two-Dimensional Nanostructured Materials for Gas Sensing
X. Liu, T. Ma, N. Pinna, and J. Zhang
Adv. Funct. Mater. 27 (2017) 1702168
DOI: 10.1002/adfm.201702168

Large-amplitude transfer motion of hydrated excess protons mapped by ultrafast 2D IR spectroscopy
F. Dahms, B.P. Fingerhut, E.T.J. Nibbering, E. Pines, and T. Elsaesser
Science 357 (2017) 491
DOI: 10.1126/science.aan5144

Limitations of Particle-Based Spasers
G. Kewes, K. Herrmann, R. Rodríguez-Oliveros, A. Kuhlicke, O. Benson, and K. Busch
Phys. Rev. Lett. 118 (2017) 237402
DOI: 10.1103/PhysRevLett.118.237402

General Synthetic Route toward Highly Dispersed Metal Clusters Enabled by Poly(ionic liquid)s
J.-K. Sun, Z. Kochovski, W.-Y. Zhang, H. Kirmse, Y. Lu, M. Antonietti, and J. Yuan
J. Am. Chem. Soc. 139 (2017) 8971
DOI: 10.1021/jacs.7b03357

Evidence for Anisotropic Electronic Coupling of Charge Transfer States in Weakly Interacting Organic Semiconductor Mixtures
V. Belova, P. Beyer, E. Meister, T. Linderl, M.-U. Halbich, M. Gerhard, S. Schmidt, T. Zechel, T. Meisel, A.V. Generalov, A.S. Anselmo, R. Scholz, O. Konovalov, A. Gerlach, M. Koch, A. Hinderhofer, A. Opitz, W. Brütting, and F. Schreiber
J. Am. Chem. Soc. 139 (2017) 8474
DOI: 10.1021/jacs.7b01622

Ultrafast light-driven substrate expulsion from the active site of a photoswitchable catalyst
M. Pescher, L. van Wilderen, S. Grützner, C. Slavov, J. Wachtveitl, S. Hecht, and J. Bredenbeck
Angew. Chem. Int. Ed. 56 (2017) 1
DOI: 10.1002/anie.201702861

Reduced Interface-Mediated Recombination for High Open-Circuit Voltages in $CH_3NH_3PbI_3$ Solar Cells
C.M. Wolff, F. Zu, A. Paulke, L.P. Toro, N. Koch, and D. Neher
Adv. Mater. (2017) 1700159
DOI: 10.1002/adma.201700159

Insight into the wetting of a graphene-mica slit pore with a monolayer of water
H. Lin, A. Schilo, A.R. Kamoka, N. Severin, I.M. Sokolov, and J.P. Rabe
Phys. Rev. B 95 (2017) 195414
DOI: 10.1103/PhysRevB.95.195414

Porous Ti4O7 Particles with Interconnected-Pore Structure as a High-Efficiency Polysulfide Mediator for Lithium–Sulfur Batteries
S. Mei, C. J. Jafta, I. Lauermann, Q. Ran, M. Kärgell, M. Ballauff, and Y. Lu
Adv. Funct. Mater. 27 (2017) 1701176
DOI: 10.1002/adfm.201701176

Addressing elctron-hole correlation in core excitations of solids: A first-principles all-electron approach based on many-body perturbation theory
C. Vorwerk, C. Cocchi, and C. Draxl
Phys. Rev. B. 95 (2017) 155121

Addressing electron-hole correlation in core excitations of solids: An all-electron many-body approach from first principles
C. Vorwerk, C. Cocchi, and C. Draxl
Phys. Rev. B 95 (2017) 155121
DOI: 10.1103/PhysRevB.95.155121

Impact of White Light Illumination on the Electronic and Chemical Structures of Mixed Halide and Single Crystal Perovskites
F.-S. Zu, P. Amsalem, I. Salzmann, R.-B. Wang, M. Ralaiarisoa, S. Kowarik, S. Duhm, and N. Koch
Adv. Opt. Mat. 5 (2017) 1700139
DOI: 10.1002/adom.201700139

Strong Coupling between Surface Plasmon Polaritons and Molecular Vibrations
H. Memmi, O. Benson, S. Sadofev, and S. Kalusniak
Phys. Rev. Lett. 118 (2017) 126802
DOI: 10.1103/PhysRevLett.118.126802

Impact of d-band filling on the dislocation properties of bcc transition metals: The case of tantalum-tungsten alloys investigated by density-functional theory
H. Li, C. Draxl, S. Wurster, R. Pippan, and L. Romaner
Phys. Rev. B 95 (2017) 094114
DOI: 10.1103/PhysRevB.95.094114

Templated bilayer self-assembly of fully conjugated π-expanded macrocyclic oligothiophenes complexed with fullerenes
J.D. Cojal González, M. Iyoda, and J.P. Rabe
Nature Communications 8 (2017) 14717
DOI: 10.1038/ncomms14717

Functionalized graphene as extracellular matrix mimics: Toward well-defined 2D nanomaterials for multivalent virus interactions
M.F. Gholami, D. Lauster, K. Ludwig, J. Storm, B. Ziem, N. Severin, C. Böttcher, J.P. Rabe, A. Herrmann, M. Adeli, and R. Haag
Adv. Funct. Mater. 27 (2017) 1606477
DOI: 10.1002/adfm.201606477

Activation of small molecules at nickel(I) moieties
P. Zimmermann and C. Limberg
J. Am. Chem. Soc. 139 (2017) 4233
DOI: 10.1021/jacs.6b12434

Highly Ordered Self-Assembly of Native Proteins into 1D, 2D, and 3D Structures Modulated by the Tether Length of Assembly-Inducing Ligands
G. Yang, H. Ding, Z. Kochovski, R. Hu, Y. Lu, Y. Ma, G. Chen, and M. Jiang
Angew. Chem. Int. Ed. 56 (2017) 1069
DOI: 10.1002/anie.201703052

Controlled covalent functionalization of thermally reduced graphene oxide to generate defined bifunctional 2D nanomaterials
A. Faghani, I.S. Donskyi, M.F. Gholami, B. Ziem, A. Lippitz, W.E.S. Unger, C. Böttcher, J.P. Rabe, R. Haag, and M. Adeli
Angew. Chem. 129 (2017) 2719
DOI: 10.1002/ange.201612422
Angew. Chem. Int. Ed. 56 (2017) 2675
DOI: 10.1002/anie.201612422

Ultrafast modulation of electronic structure by coherent phonon excitations
J. Weisshaupt, A. Rouzée, M. Woerner, M. J. J. Vrakking, T. Elsaesser, E. L. Shirley, and A. Borgschulte
Phys. Rev. B (R) 95 (2017) 081101
DOI: 10.1103/PhysRevB.95.081101

Lithography-Free Miniaturization of Resistive Nonvolatile Memory Devices to the 100 nm Scale by Glancing Angle Deposition
G. Ligorio, M. V. Nardi, and N. Koch
Nano Lett. 17 (2017) 1149
DOI: 10.1021/acs.nanolett.6b04794

Electrospun Nanomaterials for Supercapacitor Electrodes: Designed Architectures and Electrochemical Performance
X. Lu, C. Wang, F. Favier, and N. Pinna
Adv. En. Mat. 7 (2017) 1601301
DOI: 10.1002/aenm.201601301

Activation of Dioxygen at a Lewis Acidic Nickel(II) Complex - Characterization of a Metastable Organoperoxide complex
P. Holze, T. Corona, N. Frank, B. Braun-Cula, C. Herwig, A. Company, and C. Limberg
Angew. Chem. Int. Ed. 56 (2017) 2307
DOI: 10.1002/anie.201609526

Quantum Interference between Transverse Spatial Waveguide Modes
A. Mohanty, M. Zhang, A. Dutt, S. Ramelow, P. Nussenzveig, and M. Lipson
Nat. Commun. 8 (2017) 14010
DOI: 10.1038/ncomms14010

Light-Activated Sensitive Probes for Amine Detection
V. Valderrey, A. Bonasera, S. Fredrich, and S. Hecht
Angew. Chem. 129 (2017) 1941
Angew. Chem. Int. Ed. 56 (2017) 1914
DOI: 10.1002/anie.201609989

Diffusion and nucleation in multilayer growth of PTCD-C8 studied with in situ X-ray growth oscillations and real-time small angle X-ray scattering
A. Zykov, S. Bommel, C. Wolf, L. Pithan, C. Weber, G. Santoro, J.P. Rabe, and S. Kowarik
J. Chem. Phys. 146 (2017) 052803
DOI: 10.1063/1.4961460

Large-amplitude transfer motion of hydrated excess Protons mapped by ultrafast 2D IR Spectroscopy
F. dahms, B.P. Fingerhut, E.T. Nibbering, E.Pines, and T.Elsaesser
Science 357 (2017) 491
DOI: 10.1126/science.aan5144

2018 Electrocatalytic Z → E Isomerization of Azobenzenes
A. Goulet-Hanssens, M. Utecht, D. Mutruc, E. Titov, J. Schwarz, L. Grubert, D. Bléger, P. Saalfrank, and S. Hecht
J. Am. Chem. Soc. 139 (2017) 335
DOI: 10.1021/jacs.6b10822

Reversible photoisomerization of monolayers of π-expanded oligothiophene macrocycles at solid-liquid interfaces
J. D. Cojal González, M. Iyoda, and J. P. Rabe
Angew. Chem. Int. Ed. 57 (2018) 17038
DOI: 10.1002/anie.201809514
Angew. Chem. 130 (2018) 17284
DOI: 10.1002/ange.201809514

Re- and pre-configurable multi-stable visible light responsive surface topographies
M. Hendrikx, J. ter Schiphorst, E.P.A. van Heeswijk, G. Koçer, C. Knie, D. Bléger, S. Hecht, P. Jonkheijm, D.J. Broer, and A.P.H.J. Schenning
Small 14 (2018) 1803274
DOI: 10.1002/smll.201803274

Exploring the "Goldilocks Zone" of Semiconducting Polymer Photocatalysts via Donor-Acceptor Interactions
Y.S. Kochergin, D. Schwarz, A. Acharjya, A. Ichangi, R. Kulkarni, P. Eliášová, J. Vacek, J. Schmidt, A. Thomas, and M.J. Bojdys
Angew.Chem.Int.Ed. 57 (2018) 14188
DOI: 10.1002/anie.201809702

Oxygen Vacancies Allow Tuning the Work Function of Vanadium Dioxide
R. Wang, T. Katase, K.-K. Fu, T. Zhai, J. Yang, Q. Wang, H. Ohta, N. Koch, and S. Duhm
Adv. Mater. Interfaces 5 (2018) 1801033; DOI: 10.1002/admi.201801033

Macroscopic electric polarization and microscopic electron dynamics: quantitative insight from femtosecond x-ray diffraction
C. Hauf, M. Woerner, and T. Elsaesser
Phys. Rev. B 98 (2018) 054306
DOI: 10.1103/PhysRevB.98.054306

Microstructure and elastic constants of transition metal dichalcogenide monolayers from friction and shear force microscopy
X. Xu, T. Schultz, Z. Qin, N. Severin, B. Haas, S. Shen, J.N. Kirchhof, A. Opitz, C.T. Koch, K. Bolotin, J.P. Rabe, G. Eda, and N. Koch
Adv. Mater. (2018) 1803748
DOI: 10.1002/adma.201803748

Light-driven molecular trap enables bidirectional manipulation of dynamic covalent systems
M. Kathan, F. Eisenreich, C. Jurissek, A. Dallmann, J. Gurke, and S. Hecht
Nat. Chem. 10 (2018) 1031
DOI: 10.1038/s41557-018-0106-8

A multifunctional interlayer for solution processed high performance Indium oxide transistors
A. Kyndiah, A. Ablat, S. Guyot-Reeb, T. Schultz, F. Zu, N. Koch, P. Amsalem, S. Chiodini, T. Y. Alic, Y. Topal, M. Kus, L. Hirsch, S. Fasquel, and M. Abbas
Scientific Reports 8 (2018) 10946
DOI: 10.1038/s41598-018-29220-0

Random Search with Resetting: A Unified Renewal Approach
A. Chechkin, and I.M. Sokolov
Phys. Rev. Lett. 121 (2018) 050601
DOI: 10.1103/PhysRevLett.121.050601

New relations for graviton-matter amplitudes
J. Plefka and W. Wormsbecher
Phys. Rev. D 98 (2018) 026011
DOI: 10.1103/PhysRevD.98.026011

Collective molecular switching in hybrid superlattices for light-modulated two-dimensional electronics
M. Gobbi, S. Bonacchi, J. X. Lian, A. Vercouter, S. Bertolazzi, B. Zyska, M. Timpel, R. Tatti, Y. Olivier, S. Hecht, M. V. Nardi, D. Beljonne, E. Orgiu, and P. Samorì
Nature Commun. 9 (2018) 2661
DOI: 10.1038/s41467-018-04932-z

A photoswitchable catalyst system for remote-controlled (co)polymerization *in situ*
F. Eisenreich, M. Kathan, A. Dallmann, S. P. Ihrig, T. Schwaar, B. M. Schmidt, and S. Hecht
Nature Catalysis 1 (2018) 516
DOI: 10.1038/s41929-018-0091-8

Dimensionality of excitons in stacked van der Waals materials: The example of hexagonal boron nitride
W. Aggoune, C. Cocchi, D. Nabok, K. Rezouali, M. A. Belkhir, and C. Draxl
Phys. Rev. B 97 (2018) 241114
DOI: 10.1103/PhysRevB.97.241114

Carbon nitride supported Fe_2 cluster catalysts with superior performance for alkene epoxidation
S. Tian, Q. Fu, W. Chen, Q. Feng, Z. Chen, J. Zhang, W.-C. Cheong, R. Yu, L. Gu, J. Dong, J. Luo, C. Chen, Q. Peng, C. Draxl, D. Wang, and Y. Li
Nature Commun. 9 (2018) 2353
DOI: 10.1038/s41467-018-04845-x

Area Increase and Budding in Giant Vesicles Triggered by Light: Behind the Scene
V. Georgiev, A. Grafmueller, D. Bléger, S. Hecht, S. Kunstmann, S. Barbirz, R. Lipowsky, and R. Dimova
Adv. Sci. (2018) 1800432
DOI: 10.1002/advs.201800432

Influence of Oxygen Deficiency on the Rectifying Behavior of Transparent-Semiconducting-Oxide–Metal Interfaces
T. Schultz, S. Vogt, P. Schlupp, H. von Wenckstern, N. Koch, and M. Grundmann
Phys. Rev. Applied 9 (2018) 064001
DOI: 10.1103/PhysRevApplied.9.064001

Coupling a Single Nitrogen-Vacancy Center in Nanodiamond to Superparamagnetic Nanoparticles
N. Sadzak, M. Héritier, and O. Benson
Scientific Reports 8 (2018) 8430
DOI: 10.1038/s41598-018-26633-9

Reversible Sodium and Lithium Insertion in Iron Fluoride Perovskites
M.-L. Doublet, E. Kemnitz, and N. Pinna
Adv. Funct. Mater. (2018) 1802057
DOI: 10.1002/adfm.201802057

A Biomimetic Nickel Complex with a Reduced CO_2 Ligand Generated by Formate Deprotonation and Its Behaviour towards CO_2
P. Zimmermann, S. Hoof, B. Braun-Cula, C. Herwig, and C. Limberg
Angew. Chem. Int. Ed. 57 (2018) 12345
DOI: 10.1002/anie.201802655

Sensitive Assays by Nucleophile-Induced Rearrangement of Photoactivated Diarylethenes
S. Fredrich, A. Bonasera, V. Valderrey, and S. Hecht
J. Am. Chem. Soc. 140(2018) 6432
DOI: 10.1021/jacs.8b02982

Phonon-assisted damping of plasmons in three- and two-dimensional metals
F. Caruso, D. Novko, and C. Draxl
Phys. Rev. B 97 (2018) 205118
DOI: 10.1103/PhysRevB.97.205118

Stabilization of β-Diketiminato Nickel(I) with Alkaline Metal Halide Entities for Small Molecule Activation
P. Holze, B. Braun-Cula, S, Mebs, and C. Limberg
Z. Anorg. Allg. Chem. (2018) published online
DOI: 10.1002/zaac.201800100

Ultrafast carrier dynamics in a GaN/$Al_{0.18}Ga_{0.82}N$ superlattice
F. Mahler, J. W. Tomm, K. Reimann, M. Woerner, T. Elsaesser, C. Flytzanis, V. Hoffmann, and M. Weyers
Phys. Rev. B 97 (2018) 161303
DOI: 10.1103/PhysRevB.97.161303

Microhartree precision in density functional theory calculations
A. Gulans, A. Kozhevnikov, and C. Draxl
Phys. Rev. B 97 (2018) 161105
DOI: 10.1103/PhysRevB.97.161105

Dynamic Photoswitching of Electron Energy Levels at Hybrid ZnO/Organic Photochromic Molecule Junctions
Q. Wang, G. Ligorio, V. Diez Cabanes, D. Cornil, B. Kobin, J. Hildebrandt, M. V. Nardi, M. Timpel, S. Hecht, J. Cornil, E. J. W. List-Kratochvil, and N. Koch
Adv. Funct. Mater. (2018) 1800716
DOI: 10.1002/adfm.201800716

Efficient Light-Induced pKa-Modulation coupled to Base-Catalyzed Photochromism
J. Gurke, Š. Budzák, B. M. Schmidt, D. Jacquemin, and S. Hecht
Angew. Chem. Int. Ed. 57 (2018) 4797
DOI: 10.1002/ange.201801270

Frequency multiplexing for quasi-deterministic heralded single-photon sources
C. Joshi, A. Farsi, S. Clemmen, S. Ramelow, and A. L. Gaeta
Nature Communications 9 (2018) 847
DOI: 10.1038/s41467-018-03254-4

Continuously revolving patterns
D. Bléger
Nature Nanotech. 13 (2018) 274
DOI: 10.1038/s41565-018-0076-4

Crystal-phase quantum wires: One-dimensional heterostructures with atomically flat interfaces
P. Corfdir, H. Li, O. Marquardt, G. Gao, M. Molas, J. Zettler, D. van Treeck, T. Flissikowski, M. Potemski, C. Draxl, A. Trampert, S. Fernandez-Garrido, H. Grahn, and O. Brandt
Nano Lett. 18 (2018) 247
DOI: 10.1021/acs.nanolett.7b03997

Direct imaging of the electron liquid at oxide interfaces
K. Song, S. Ryu, H. Lee, T. R. Paudel, C. T. Koch, B. Park, J. K. Lee, S.-Y. Choi, Y.-M. Kim, J. C. Kim, H. Y. Jeong, M. S. Rzchowski, E. Y. Tsymbal, C.-B. Eom, and S. H. Oh
Nature Nanotech.13 (2018) 198
DOI: 10.1038/s41565-017-0040-8

Neural-network-based depth-resolved multiscale structural optimization using density functional theory and electron diffraction data
R. S. Pennington, C. Coll, S. Estradé, F. Peiró, and C. T. Koch
Phys. Rev. B 97 (2018) 024112
DOI: 10.1103/PhysRevB.97.024112

Switching the Proton Conduction in Nanoporous, Crystalline Materials by Light
K. Müller, J. Helfferich, F. Zhao, R. Verma, A. B. Kanj, V. Meded, D. Bléger, W. Wenzel, and L. Heinke
Adv. Mater. 30 (2018) 1706551
DOI: 10.1002/adma.201706551

Taking Photochromism beyond Visible: Direct One-Photon NIR Photoswitches Operating in the Biological Window
K. Klaue, Y. Garmshausen, and S. Hecht
Angew. Chem. Int. Ed. 57 (2018) 1414
DOI: 10.1002/anie.201709554

Electrode Work Function Engineering with Phosphonic Acid Monolayers and Molecular Acceptors: Charge Redistribution Mechanisms
M. Timpel, H. Li, M.V. Nardi, B. Wegner, J. Frisch, P.J. Hotchkiss, S.R. Marder, S. Barlow, J.-L. Brédas, and N. Koch
Adv. Funct. Mater. (2018) 1704438
DOI: 10.1002/adfm.201704438

All rational one-loop Einstein-Yang-Mills amplitudes at four points
D. Nandan, J. Plefka, and G. Travaglini
J. High Energy Physics 2018 (2018) 11
arXiv: 1803.08497 (e-Print)
DOI: 10.1007/JHEP09(2018)011

Accurate placement of single nanoparticles on opaque conductive structure
N. Nikolay, N. Sadzak, A. Dohms, B. Lubotzky, H. Abudayyeh, R. Rappaport, and O. Benson
Appl. Phys. Lett. 113 (2018) 113107
DOI: 10.1063/1.5049082

Hole Catalysis as a General Mechanism for Efficient and Wavelength-Independent Z→E Azobenzene Isomerization
A. Goulet-Hanssens, C. Rietze, E. Titov, L. Abdullahu, L. Grubert, P. Saalfrank, and S. Hecht
Chem 4 (2018) 1740
DOI: 10.1016/j.chempr.2018.06.002

First-principles many-body study of the electronic and optical properties of CsK_2Sb, a semiconducting material for ultra-bright electron sources
C. Cocchi, S. Mistry, M. Schmeisser, J. Kühn, and T. Kühn
J. Phys. Cond. Mat. 31 (2018) 014002

Hybrid Organic-Inorganic Perovskites as Promising Substrates for Pt Single-Atom Catalysts
Q. Fu, and C. Draxel
Phys. Rev. Lett. 122 (2019) 046101
Accepted 2018
DOI: 10.1103/PhysRevLett.122.046101

4. 7. Scientific Conferences, Seminars and Outreach Activities

In order to not only communicate its member's groundbreaking scientific results to the international professional public, to promote its young scientists and to strengthen and expand its national and international visibility and cooperation, but also to present the institute and the cutting-edge research conducted here to a broader audience, **IRIS Adlershof** organized the following scientific events during the reporting period, which IRIS members substantially helped to put together:

IRIS Colloquia

2017

All Optical Control of Solid State Qubits: Towards Platforms for Scalable Quantum Information Processing
Dr. Konstantinos Lagoudakis, E. L. Ginzton Laboratory, Stanford University, USA
January 16, 2017

Directed Self-Assembly as a Route to Hierarchical Superstructures in Soft Matter (joint Colloquium with CRC 951 HIOS)
Prof. Richard J. Spontak, Departments of Chemical & Biomolecular Engineering and Materials Science & Engineering, North Carolina State University, USA
July 21, 2017

Ten years of Nature Photonics
Dr. Oliver Graydon, Chief Editor Nature Photonics, London, GB
August 21, 2017

2018

Measuring photon non-classicality using quantum-dot light sources
Prof. Dr. Glenn S Solomon, Joint Quantum Institute, University of Maryland, USA
February 9, 2018

Single photon emission from defects in 2D hexagonal Boron Nitride
Prof. Mike Ford, Faculty of Science, University of Technology Sydney, Australia
July 5, 2018

Molecular design of azobenzene photoresponsive compounds: from molecular switches to crawling crystals
Prof. Yasuo Norikane, National Institute of Advanced Industrial Science and Technology, Ibaraki, Japan
July 16, 2018

Designing Selective Membranes from the Ground-Up: A Polymer Scientist's Playground
Prof. Richard Spontak, Departments of Chemical & Biomolecular Engineering and Materials Science & Engineering, North Carolina State University, USA
November 19, 2018

International Symposium of the CRC 1109 on Metal Oxide – Water Systems

February 19 – 22, 2017

In February 2017, the CRC 1109 Understanding of Metal Oxide/ Water Systems at the Molecular Scale: Structural Evolution, Interfaces, and Dissolution took the opportunity to report and discuss the results of the past four years with colleagues from all over the world. Among other things, the symposium focused on formation and dissolution of metal oxides, behavior of metal oxides at the interface with water, molecules, gas phase clusters and thin films as oxide models, design of oxide materials for applications and speciation, nucleation and growth. During the three conference days, there were 10 invited talks by leading scientists of the field, and 12 lectures by members of the CRC 1109, including IRIS members Prof. Dr. Christian Limberg, Prof. Dr. Nicola Pinna and Prof. Dr. Joachim Sauer (IRIS founding member, member until 2017)

7th Nano and Photonics meeting

March 22 – 25, 2017

In March 2017, IRIS member Emil List-Kratochvil, Wolfgang Knoll from the Austrian Institute of Technology and Franz Aussenegg from Universität Graz and Erwing-Schrödinger Institute jointly organized the 7th Nano and Photonics meeting in Castle of Mauterndorf, Austria. The annual event's purpose is to organize an international scientific meeting for those, who are interested in photonic application of modern nanotechnology. One goal of this event was also to create an informal European wide discussion platform for state of the art work in basic research done at the various universities as well as industrial based research and development. 2017's program was put together with a topical focus on Sensing applications based on plasmonic nanostructures.

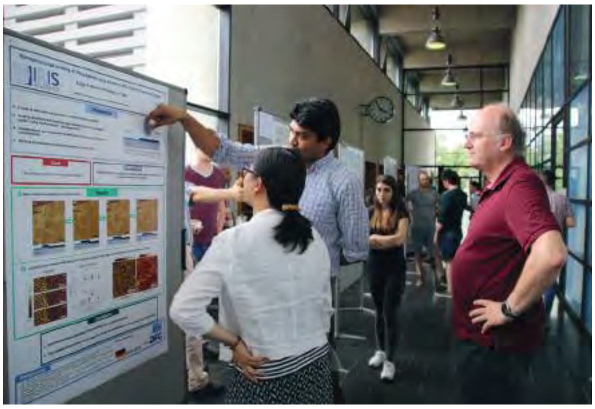
Symposium IRIS 2017 & IRIS 2018

June 29, 2017 & June 21, 2018

After its launch in 2015, the IRIS Symposium has firmly established itself as an annual highlight in the scientific life of **IRIS Adlershof**, and it also has a growing interest beyond the Adlershof location, as the annually increasing number of participants impressively demonstrates. The annual Symposium aims to explore and discuss ideas for the further development of the Integrative Research Institute for the Sciences.

The symposium IRIS 2017 focused on the topics of Charge Density Control, Analytical Sciences, Matters of Compultation and Matters of Activity, whilst at the Symposium IRIS 2018, ideas for the further development in the areas of Advanced Microscopies, Hybrid Materials for Optics and Electronics, Mathematical Physics of Complex Systems, and Quantum Technologies were in the focus of interest. At both symposia, the topics were introduced to an open-minded audience of internationally renowned researchers and representatives of business enterprises.

In order to give young scientists the opportunity to present their own research results to the invited speakers and the symposium participants, IRIS 2018 was expanded to include a poster competition. The jury, consisting of the representative of the young researchers Julian Miczajka, as well as the IRIS members Prof. Dr. Yan Lu and Prof. Emil List-Kratochvil, was visibly struggling to make the choice for the best poster. Finally, Laura Orphal was able to prevail with a total of 30 competitors with her poster. Laura Orphal, master student in the group Photonics, which is currently led by IRIS member Prof. Oliver Benson, received the Best Poster Award and a book voucher at the end of the symposium by IRIS Director Prof. Jürgen P. Rabe before the event ended with grilled and drinks.



Symposium of the CRC 951 on Hybrid inorganic/organic systems for opto-electronics

September 7 – 28, 2018

In September 2018, the CRC 951 HIOS held a symposium on Hybrid inorganic/organic systems for opto-electonics. The symposium focused on hybrid structures comprising inorganic semiconductors, conjugated organic materials, and metal nanostructures. The topics covered included structure and morphology, electronic structure and control of inorganic/organic interfaces, charge and energy transfer, hybrid optical excitations, and plasmonic phenomena. Invited talks were presented by outstanding international experts and by members of the CRC 951, including the IRIS members Prof. Dr. Oliver Benson, Prof. Dr. Caterina Cocchi, Prof. Stefan Hecht, and Prof. Dr. Emil List-Kratochvil. Excellent networking opportunities and room for lively discussions were provided during a poster session and a joint dinner.

iSwitch Final Symposium: Perspectives on Switchable Systems and Materials for Smart Electronics

December 11 – 12, 2018

Since 2015 the EU funded Integrated Training Network iSwitch – integrated self-assembled Switchable systems and materials: towards responsive organic electronics had been bringing together some of the leading European research groups at the interface of chemistry and physics to train the next generation researchers on the emerging topic of smart electronics. It offered top-level multi-disciplinary and supra-sectorial training to a pool of talented young researchers, involving contributions from different scientific and technological fields such as, supramolecular chemistry, materials, nanoscience, physics and engineering. In December 2018, iSwitch successfully ended with a final symposium highlighting the key achievements and discussing future perspectives in this burgeoning area of research. The symposium was organized by Stefan Hecht and Norbert Koch, both members of **IRIS Adlershof.**

22nd Berliner Tag der Mathematik

April 22, 2017

In 2017, the 22nd Berlin Day of Mathematics was held at Humboldt-Universität zu Berlin and took place on the Adlershof campus. The annual event, which has already become a cherished tradition, is organized by the mathematical institutes of the three Berlin universities and the Beuth Hochschule für Technik Berlin, the Zuse Institute Berlin, the Weierstrass Institute for Applied Analysis and Stochastics and the Bertha-von-Suttner Gymnasium in Berlin. The local organization in Adlershof was led by IRIS member Dirk Kreimer with support from the **IRIS Adlershof**'s Branch Office. The Berlin Day of Mathematics is aimed primarily at pupils of all ages and offers a colorful mix of games, a mathematics competition and lectures that show where and how mathematics enters everyday life. The IRIS member Jürg Kramer, for example, spoke about the fascination of prime numbers.

Long Night of the Sciences 2017 & 2018

June 24, 2017 & June 10, 2018

Members from **IRIS Adlershof** were also actively participating in the Long Night of the Sciences 2017 and 2018 and therefore were able to present some of their projects to the broader public. At 2018's event, IRIS member Alexander Reinefeld offered lectures and tours at the Konrad-Zuse-Zentrum für Informationstechnik ranging from the origin of computers and autostereoscopic displays to the computer-supported molecule development. In the Max Born Institute for Nonlinear Optics and Short Pulse Spectroscopy, IRIS member Thomas Elsässer informed visitors about extremely short light impulses and lasers with lab tours, exhibits, and experiments. In the Institute for Physics, IRIS's young researchers gave some interesting insights into molecular physics and IRIS member Jan Plekfa presented some of his current research findings in the lecture The world as a hologram: some news about string theory.

A highlight was the presentation of The cube of physics (#cubeofphysics) from the Excellence Cluster Image Knowledge Gestaltung in the foyer of the Lise-Meitner-Haus. IRIS Director Jürgen P. Rabe and IRIS member Mathias Staudacher presented together with Professor Christian Kassung from the Social Sciences, as well as the scenographer Franziska Paul and several other colleagues some ways to approach a world formula from Newtonian mechanics with an interactive media station and a meter-high installation.

Advanced Materials Competition (AdMaCom) 2017 & 2018
September 25 – October 6, 2017 & September 7 – 21, 2018

ADVANCED MATERIALS COMPETITION

In the fall of 2017 and 2018, the annual Advanced Materials Competition, short AdMaCom, once again brought together ten talented international start-ups to compete against each other. The two-week workshop, which was first held in 2016, is organized by The Network for Advanced Materials (INAM) and held under the patronage of the governing Mayor of Berlin.

The workshop addresses scientific driven startups with outstanding technologies and business models in the area of advanced materials and related digital services. The competitions' underlying aim is for the international start-ups to propel their innovations forward by connecting with potential partners and receiving valuable advice from experts on product and business development.

The participants of AdMaCom 2017 & 2018 were able to draw upon the expertise of mentors from renowned international research facilities and industrial companies like LG Technology Center Europe, BASF Ventures, the London School of Economics, the Imperial College London as well as from Berlin like OSRAM, Fab Lab Berlin and IRIS Adlershof. The competitions' host, the Innovation Network for Advanced Materials, was initiated in 2016 by the Humboldt-Universität zu Berlin, Berlin Partner, OSRAM, IRIS Adlershof and FAB LAB Berlin. Its aim is to diminish the existing gap between research and industry in the field of Material Sciences.

Wissenschaft trifft Wirtschaft
December 7, 2017

In December 2017, IRIS members continued to contribute to the popular event series Wissenschaft trifft Wirtschaft / Science meets Business of the Humboldt-Universität zu Berlin. The events series, which took place for the fifth time, serves as a platform for the interdisciplinary exchange of knowledge and technology between science and business. It aims at bringing together research and application and initiating new innovative ideas in science and industry. This year event was dedicated to the topic of nanoscale analytics. Several businesses presented their research questions regarding the topic in short pitches. In addition, researchers from Humboldt-Universität zu Berlin and **IRIS Adlershof** reported on their current research projects and on their experiences in working in R&D projects carried out jointly with partners from industry. IRIS Adlershof member Kannan Balasubramanian gave a speech on analytical challenges in the use of single carbon nanostructures and IRIS member Chritsoph T. Koch gave insights into nanoanalytics in the electron microscope with high spatial and spectral resolution. The purpose of the presentations and discussions was to develop ideas for possible cooperation and thus to identify and exploit existing innovation potential. At the same time, the exchange should also provide new impulses for one's own work at the university or in the private sector.

Humboldt Children's University

March 15, 2018

Everything should be like a real university at the Humboldt-Kinder-Uni, which means real lectures on interesting topics, smart professors, and a large auditorium.

At the Humboldt Childrend's University 2018, IRIS member Prof. Dr. Emil J. W. List-Kratochvil gave a lecture entitled Bendable screens - fluorescent fish - red beets in front of the elementary students. At the fully booked lecture, it was found that the glow of fish in the deep sea, the color of leaves, and flexible screens are based on very similar material concepts. At the end of the lecture, a solar cell was made from beet juice.

Les Houches – Summer School on Structures in local Quantum Field Theory

June 4-5, 2018

At the renown École de Physique des Houches, IRIS member Prof. Dr. Dirk Kreimer and collaborators organized the Les Houches workshop: 2018 Summer school on structures in local quantum field theory. One focus of the conference was on the connection between the analytic structure of amplitudes and the mathematics of Outer Spaces, which was recently discovered by the two conference organizers, IRIS member Dirk Kreimer and his colleague Spencer Bloch.

Amplitudes are a multivalent function of parameters such as energies, moments and masses for a given scattering experiment. With a variation of these parameters they show monodromy. The discovery of the connection between amplitude and the mathematics of Outer Spaces is a major step towards understanding monodromies, which is a formidable problem in complex analysis and algebraic geometry. This field of research is a main research agenda in Kreimer's group and these rather new developments have already been reviewed in a publication:

Publication

Multi-valued Feynman Graphs and Scattering Theory
Dirk Kreimer
Elliptic Integrals, Elliptic Functions and Modular Forms in Quantum Field Theory (2019)
arXiv:1807.00288

Imprint

Editor: **IRIS Adlershof**
Humboldt-Universität zu Berlin
Zum Großen Windkanal 6
12489 Berlin I Germany
office@iris-adlershof.de
www.iris-adlershof.de

Responsible for the Content: Prof. Dr. Jürgen P. Rabe
Dr. Nikolai Puhlmann

Layout and Design: Victoria Coors
Dr. Annika Scior

Printing: CSV Service-Vertrieb-Kopieren GmbH