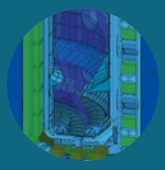
EPFL

SCHOOL OF BASIC SCIENCES FSB ANNUAL REPORT 2018



IPHYS ISIC MATH

DEAN'S FOREWORD

With this second annual activity report of the School of Basic Sciences (FSB), we have now established a tradition that you will hopefully find interesting and valuable.

The School of Basic Sciences remains both healthy and focused on achieving excellence in research, education, and innovation. Five new colleagues have joined us this year, strengthening activities across all three institutes in the School.

Several measures confirm the excellence, and continued growth of the School. During 2018, FSB research groups received almost 20 major international prizes and awards, and we continue to successfully attract the most talented young researchers worldwide. The School also draws an increasing number of students both at the Bachelor and Master level (17 % of EPFL), as well as at the PhD level (29 % of EPFL). Furthermore, thanks to the 14 Massive Open Online Courses (MOOCs) lead by FSB faculty, over 61,000 students worldwide attended our classes.

In 2019, FSB will undergo an ETH-Board mandated academic review. This provides a unique opportunity to get a detailed snapshot of the School's strengths and weaknesses, and will lay the foundation for a long term strategic plan. This will further strengthen FSB and confirm its position as one of the leading schools of Basic sciences worldwide.

I hope you will enjoy browsing through this annual report and experience the broad diversity of activities, the outstanding quality of the research, and the commitment of the member of FSB to the success of the School and EPFL.

With the best wishes for a successful and rewarding 2019,

JAN S. HESTHAVEN
Dean of the School of Basic Sciences, EPFL

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Nominations and Promotions 2018

Maryna Viazovska was promoted to Full Professor of Mathematics from January 2018.

Maryna Viazovska is a highly gifted young academic in the field of pure mathematics. She is particularly interested in problems relating to number theory and discrete optimisation. In spring 2016 she caused an international sensation by solving the sphere-packing problem in dimensions 8 and 24. Since Maryna Viazovska's appointment as an assistant professor in December 2016, her results have appeared in the top publications in her field. By promoting her to a full professorship, EPFL is ensuring that it retains the creativity and innovative energy of a scientist who aims to be one of the best in the world.

Christoph Bostedt was named Full Professor of Physical Chemistry and Head of the Femtochemistry Laboratory at the Paul Scherrer Institute (PSI) starting on the 1st of April 2018.

Christoph Bostedt is an internationally renowned expert on synchrotron radiation and free-electron lasers. His research findings have enabled significant advances to be made. Christoph Bostedt belongs to a new generation of researchers working in the field of physical chemistry on an interdisciplinary basis. His particular interests and outstanding expertise make him ideally qualified to exploit the potential of the X-ray free-electron laser SwissFEL, which is due to come into regular use at the PSI in 2019.

Yimon Aye was named Associate Professor of Chemistry, starting on the 1st of August 2018.

Yimon Aye's research focuses on electrophilic signals and the control of genome replication. Understanding the electrophilic signaling mechanisms that affect proteins function allows the modulation of various biological processes, including cell aging, cell decay, immune reactions and the protection of genetic material. Thanks to her innovative research programs in the fields of organic chemistry, biological chemistry and life sciences, Yimon Aye's laboratory at EPFL will play a global leading role in biological chemistry.

Fabrizio Carbone was promoted to Associate Professor of Physics starting on the 1st of August 2018.

Fabrizio Carbone conducts research into the ultra-fast dynamics of highly correlated systems, particularly in relation to superconductivity and in systems based on carbons such as graphite, graphene, and diamondoids. Having developed innovative procedures for imaging and ultra-fast spectroscopy, he is working at the forefront of research into the dynamic behaviour of low-dimensional materials. EPFL's competence in solid state physics is strengthened by Fabrizio Carbone's research, while EPFL's teaching will also benefit from his dedication.

Kevin Sivula was promoted to Associate Professor of Chemical Process Engineering starting on the 1st of October 2018.

Kevin Sivula's research focuses on the development of engineering methods based on chemical solution-based processes in order to manufacture semiconductor materials for optoelectronic high-performance systems. His particular aim is to develop new technologies for the manufacturing of more stable, more efficient and more cost-efficient semiconductor materials for the fabrication of photovoltaic devices. Kevin Sivula, who received an ERC Starting Grant in 2013, is a very active researcher who will help boost the international standing of EPFL, especially in the field of sustainable development.

Juhan Aru was named Tenure-Track Assistant Professor of Mathematics from the 1st of January 2019.

Juhan Aru is one of the world's most promising scientists of his generation in the field of probability theory. He also has the potential to develop the seminal field of stochastic analysis at EPFL. In his research, he concentrates in particular on Gaussian free fields and the Schramm-Loewner evolution, a single-parameter family of random planar curves. Juhan Aru also has excellent teaching abilities. His research and teaching will enhance the EPFL's reputation in key subject areas.

Victor Panaretos was promoted to Full Professor of Statistics starting on the 1st of January 2019.

Victor Panaretos is one of the world's top specialists in functional data analysis – an area of statistics which concentrates on the analysis of objects as functions of infinite dimension. He has won numerous awards, including an ERC Starting Grant. His research area requires the use of very advanced mathematical and geometrical methods, and a broad spectrum of probability theory. Panaretos has made highly acclaimed contributions to the spectral analysis of function series and the statistical analysis of non-standardized data classes. His results are used for modelling epidemics, for example.

Clément Hongler was promoted to Associate Professor of Mathematics starting on the 1st of January 2019.

Clément Hongler is a promising young scientist who has already been awarded an ERC Starting Grant in 2016 and the EPFL Latsis Prize in 2017. In his research he uses a combination of complex analysis, probability theory, discrete mathematics and statistical mechanics. His specialist area is the Ising model, which is one of the most important models used in statistical physics. Clément Hongler has quickly established himself as a top international scientist in the highly topical field of mathematical physics.

Sofia Olhede was named Full Professor of Statistics from the 1st of April 2019.

Sofia Olhede is an internationally acclaimed expert on stochastic modeling and statistical inference from time series, as well as spatial data analysis and data network analysis. Her work, for which she has been awarded an ERC Consolidator Grant, is of fundamental importance to the development of the statistical sciences and has had a substantial influence on numerous fields, such as oceanography, ecology, neuroscience and finance. Sofia Olhede will make significant contributions to strategic projects at EPFL, and boost its international reputation.

Lesya Shchutska was named Tenure-Track Assistant Professor of High-Energy Physics from the 1st of April 2019.

Lesya Shchutska is an internationally acclaimed and highly innovative young scientist. In 2017 she was awarded an ERC Starting Grant. Her research focuses on the search for physical phenomena beyond the standard model of particle physics. To this end, she is participating in the collaborative CMS experiment at the CERN Large Hadron Collider in Geneva. Lesya Shchutska is one of the world's leading experts in the search for supersymmetric particles. Her work at EPFL will include helping to develop and construct the particle detectors of the future.

Pablo Rivera-Fuentes was named as Tenure-Track Assistant Professor of Chemical Biology starting on the 1st of August 2019.

Pablo Rivera-Fuentes has a broad-ranging knowledge of molecular imaging, organic synthesis and biological chemistry. His current focus is on visualizing intracellular connections in order to acquire a better understanding of the interplay between the processes occurring in cells. In recent years he has attracted considerable international attention, such as for the first small molecular probe capable of imaging esterase activity in living cells with nanometric resolution. His appointment strengthens EPFL's position in the area of chemical biology.

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Nominations and Promotions 2018

NEW ADJUNCT PROFESSORS (PROF. TITULAIRES)

Simone Deparis is an internationally recognized scientist in the field of numerical analysis and computer-aided mathematics. He is regarded as a key mathematics lecturer at EPFL, and in 2018 he won the Credit Suisse Award for Best Teaching at EPFL.

Pascale Jablonka is an internationally recognized scientist in the field of astrophysics and cosmology. Her work focuses on the formation and development of stars in galaxies and galaxy clusters.

Christopher Mudry is a highly acclaimed theoretical physicist, carrying out his research at the Paul Scherrer Institute (PSI). He is regarded as one of the world's leading experts in the quantum field theory of condensed matter and in the rapidly developing field of the topological properties of matter.

Philippe Spaetig is a well-known expert in the field of nuclear reactors. The main focus of his research is the relationship between microstructures and the mechanical properties of high-temperature materials, and works at the Paul Scherrer Institute (PSI).

OTHER APPOINTMENTS

Ambrogio Fasoli, director of the Swiss Plasma Center at EPFL, was recently elected as Chair of the General Assembly of EUROfusion, the European Consortium for the development of fusion energy. He succeeds to the previous Chair, Dr. Jérôme Paméla of France. The General Assembly is the highest decision body of EUROfusion. The EUROfusion Consortium operates in the frame of the 8th Framework Program, the so-called Horizon 2020, with the goal of following the European Roadmap for fusion, to develop it as an abundant, safe, environmentally friendly energy source compatible with sustainable development.

PRIZES AND AWARDS

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ISIC

Clémence Corminboeuf won the 2018 ACS award

Professor Clémence Corminboeuf won the 2018 Early-Career Award in Theoretical Chemistry from the American Chemical Society (ACS).

The Award is given by the Physical Chemistry Division of the ACS to *"recognize outstanding contributions in experimental and theoretical physical chemistry by young investigators."*

With the Award, the ACS honors Professor Corminboeuf for *"her development of novel methods and conceptual tools and their implementation and application to organic systems"*.

Professor Clémence Corminboeuf directs the Laboratory for Computational Molecular Design at EPFL. Her research focuses on the development of electronic structure methods and conceptual tools with applications in organic electronics and catalysis.

IPHYS

Tobias Kippenberg won the ZEISS Research Award

Professor Tobias J. Kippenberg was one of the two winners of the prestigious ZEISS Research Award for 2018.

The ZEISS Research Award is presented every two years and has been allocated prize money totaling 40,000 euros. The selected candidates should have already demonstrated outstanding achievements in the field of optics or photonics, they must still be actively conducting research, and their work should offer major potential for gaining further knowledge and enabling practical applications. Initiated and funded by Carl Zeiss AG, the ZEISS Research Award is the successor to the Carl Zeiss Research Award that honored outstanding achievements in optical research every two years from 1990 onward. Many winners of Carl Zeiss Research Award went on to obtain further awards and distinctions; four of them were even honored with the Nobel Prize.

Tobias Kippenberg directs the Laboratory of Photonics and Quantum Measurements at EPFL. He is a pioneer in the field of cavity optomechanics and microresonator-based optical frequency combs. His research has demonstrated that, by using microresonators – which can confine light in an extremely small space and guide it – the faint forces exerted by light rays can be used to measure and cool mechanical movements in the quantum regime. This means, for instance, that high-precision sensors can be developed to measure mechanical movements that are several orders of magnitude more precise than the currently available position sensors, and that are even sensitive enough to measure the quantum mechanical "zero point motion" of a mechanical oscillator.

Professor Kippenberg is one of the two winners of the 2018 ZEISS award, the other one being Jean-Pierre Wolf, Professor at the Biophotonics Institute at the University of Geneva.

ISIC

Majed Chergui awarded three international excellence distinctions

In 2018, Majed Chergui was elected Foreign Member of the Royal Spanish Academy of Sciences, received the Khwarizmi International Award (KIA), and was voted a Fellow of the American Crystallographic Association.

The Royal Spanish Academy of Sciences (Real Academia de Ciencias) was founded in the 16th century, and currently counts 54 Full Members, 90 National Correspondents, and Foreign Correspondents, which include several Nobel Prize winners. Majed Chergui was elected as successor to Ahmed Zewail (1999 Chemistry Nobel Laureate).

Chergui also received the prestigious Khwarizmi International Award (KIA) in the category of Fundamental Research under the title "Unravelling the fundamentals of solar materials". Awarded each year by the Iranian Research Organization for Science and Technology (IROST), the KIA was established in 1987 in memory of Abu Jafar Muhammad Ibn Musa Al-Khwarizmi (ca. 780-850 AD), the famous Persian mathematician, astronomer, and geographer whose name (latinized into *Algoritmi*) gave us the term "algorithm".

In October, Chergui was voted a Fellow of the American Crystallographic Association, a non-profit, scientific organization of over 1,300 members in more than 35 countries. ACA Fellows act as scientific ambassadors to the broader scientific community and the general public, advancing *"science education, research, knowledge, interaction, and collaboration"*.

An internationally renowned expert in ultrafast spectroscopy, Chergui directs the Laboratory of Ultrafast Spectroscopy, which pursues a variety of ultrafast UV and X-ray spectroscopic studies on chemical and biological systems. He is also a founding Editor-in-chief of the journal *Structural Dynamics*, a flagship journal of the American Institute of Physics and the American Crystallographic Association. His lab is also part of the Lausanne Centre for Ultrafast Science (LACUS).

ISIC

Kumar Agrawal won NAMS Young Membrane Scientist Award

Professor Kumar Varoon Agrawal at EPFL's Institute of Chemical Science and Engineering was awarded a Young Membrane Scientist Award from the North American Membrane Society.

The North American Membrane Society (NAMS) is a professional society in North America whose aim is to promote *"all aspects of membrane science and technology"*, a spectrum that covers fundamental studies of membrane material science to process application and development.

Each year, NAMS awards up to three Young Membrane Scientist Awards *"to outstanding individuals who are starting their professional careers in membrane science and technology"*. The award is open to all Membrane Scientists whose careers are within five years after completing their PhDs, including postdocs, faculty, and even scientists working in industry.

This year, NAMS has given one the awards to Professor Kumar Varoon Agrawal. Professor Agrawal directs the GAZNAT Chair for Advanced Separations at EPFL Valais Wallis, where his team investigates ways of synthesizing "two-dimensional membranes" that significantly exceed the performance limits set by the conventional membranes. The aim is to boost the energy efficiency of molecular separation, e.g. energy-efficient carbon capture.

Every Young Membrane Scientist Award includes a $500 prize, a commemorative plaque, a free one-year membership in NAMS, and free registration to the annual NAMS Meeting, where winners give an oral presentation during a special award session. The winners also write a report on the Meeting, which is published in NAMS *Membrane Quarterly*.

IPHYS

Suliana Manley won the RMS Medal

Professor Suliana Manley has been awarded a Medal for Innovation in Light Microscopy by the Royal Microscopy Society.

The Royal Microscopy Society is a UK-based organization whose purpose is to *"to promote the advancement of microscopical science by such means as the discussion and publication of research into improvements in the construction and mode of application of microscopes and into those branches of science where microscopy is important."* The Society publishes the Journal of Microscopy and the members-exclusive *infocus* magazine.

To celebrate its 175th anniversary, the RMS launched a series of annual Medals, designed *"to recognise and celebrate individuals who make outstanding contributions to the field of microscopy across both the life and physical sciences."* The Medals are divided into five categories: Electron Microscopy, Light Microscopy, Innovation in Applied Microscopy for Engineering and Physical Sciences, Life Sciences, and Scanning Probe Microscopy.

Professor Suliana Manley, who directs the Laboratory of Experimental Biophysics has won the 2019 RMS Medal for Light Microscopy. Manley's research focuses on automated and high-throughput super-resolution fluorescence microscopy (PALM/STORM), high-density single molecule particle tracking (sptPALM), and its application to the structure and dynamics underlying the biophysics of cells and organelles.

With the Medal, the RMS recognizes Professor Manley *"for outstanding scientific achievements applying or developing new forms of light microscopy."*

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Emad Oveisi won the Microscopy Today Innovation Award

An extension to the breakthrough "tilt-less" 3D electron imaging technique, developed by EPFL researchers, has won a Microscopy Today Innovation Award.

Microscopy Today is the official, bimonthly magazine of the Microscopy Society of America (MSA), published since 1992. Each year, the magazine awards ten innovations that *"will make microscopy and microanalysis more powerful, more productive, and easier to accomplish."*

Although transmission electron microscopy (TEM) provides sufficient two-dimensional (2D) resolution for characterizing complex nanoscale specimens, determining the internal 3D structure with a TEM remains a significant challenge.

But in 2017, EPFL's electron microscopy scientists (from the CIME and LSME labs) developed a method that enables 3D imaging of complex curvilinear structures from a single sample orientation. The 3D reconstruction takes place via a proprietary image-processing algorithm that has been developed in collaboration with the Computer Vision Laboratory of EPFL.

In 2018, EPFL researcher Emad Oveisi won an Innovation Award from Microscopy Today for a new technique that enables 3D imaging for *in situ* dynamics, referred to as "Single-shot three-dimensional electron imaging".

"I am very delighted to have contributed to the advancement of the electron microscopy field," says Oveisi. "Our new imaging methodology has the potential to transform certain research areas, as it enables the 3D electron imaging of dynamic processes evolving on a millisecond timescale, such as interaction of crystal defects under mechanical stress, or resolving beam-sensitive biological structures in 3D."

ISIC

Michael Grätzel won the 2018 August Wilhelm von Hofmann Memorial Medal

Professor Michael Grätzel has been awarded the August Wilhelm von Hofmann Memorial Medal from the German Chemical Society.

The German Chemical Society (Gesellschaft Deutscher Chemiker, or GDCh) is a learned society and professional association. It was founded in 1949 to represent the interests of German chemists in both Germany and internationally. The GDCh *"unites those people associated with the chemical and molecular sciences and supports them in their responsible and sustainable endeavors for the good of the public and of our environment."*

Every two years, the GDCh awards August Wilhelm von Hofmann Medal to recognize outstanding achievements in chemistry, particularly by scientists working outside of Germany. Founded in in 1902, the Medal is named after famous organic chemist August Wilhelm von Hofmann, and is represented by a gold coin.

This year, the GDCh has awarded the prestigious Medal to Professor Michael Grätzel, who directs EPFL's Laboratory of Photonics and Interfaces. Grätzel is internationally famous for the invention of dye-sensitized solar cells ("Grätzel cells"), which became the launch pad for the current development of perovskite photovoltaics. Dye-sensitized solar cells are already manufactured on a multi-megawatt scale, and perovskite photovoltaics are poised to conquer the market in the near future.

ISIC

Two wins in SCS Fall Meeting Best Poster Presentation awards

Jovana Milic, a research scientist at EPFL's Laboratory of Photonics and Interfaces, and Shang-Jung Wu, a PhD student at the Laboratory of Nanobiotechnology have won awards for the Best Poster Presentation at the Swiss Chemical Society's 2018 Fall Meeting.

The Swiss Chemical Society (SCS) is an organization that represents chemists and chemistry-related scientists in Switzerland and abroad. It also supports the exchange of scientific and technical know-how, and offers networking possibilities to the academic and industrial community. The SCS counts about 2700 individual and institutional members in more than 50 countries, and publishes the journal CHIMIA.

Every year during their Fall Meeting, the SCS offers Best Poster Awards in nine categories; along with their Best Oral Presentation Awards, these award programs are among of the most highly remunerated in the field.

During the 2018 Fall meeting, held at EPFL, the Best Poster Award for Physical Chemistry went to Jovana Milic, a research scientist with Michael Grätzel's lab at EPFL. The corresponding award in Analytical Sciences went to Shang-Jung Wu, a PhD student at the Laboratory of Nanobiotechnology, headed by Professor Ardemis Boghossian.

Each award includes a certificate, CHF250 in cash, a travel voucher of CHF750 to attend an international conference, and an invitation to each scientist to present their research in the laureates' issue of CHIMIA.

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Oleg Yazyev won a University Latsis Award

Professor Oleg Yazev won a University Latsis Prize for his project "Understanding and discovering materials *in silico*".

The four annual University Latsis Prizes are awarded by the Universities of Geneva and St. Gallen, ETH Zürich, and EPFL. They are funded by the Fondation Latsis Internationale, a non-profit, public-benefit foundation established in 1975, which has been funding Latsis Prizes (University and National) since 1983. The University Latsis Prizes are each worth CHF 25,000 and their purpose is *"to encourage and recognize outstanding work by young researchers under the age of 40 working within the Swiss higher education system."*

One of the 2018 winners was Professor Oleg Yazyev who holds the Chair of Computational Condensed Matter Physics at EPFL's Institute of Physics. The Prize citation reads: *"For his computer-based search for low-dimensional materials with novel electronic and transport properties. He has predicted a novel topological insulator phase in quasi-one-dimensional bismuth iodide, and a robust Weyl semimetal phase in molybdenum and tungsten diphosphides. Both predictions have been confirmed experimentally and created a field of intense research."*

The past decades have been marked by the discoveries of new, paradigm-shifting classes of materials. Two notable examples are 2D materials that are used to realize atomically thin crystals, and topological materials, which emerged following the rigorous topological classification of electronic band structures.

But while it is certain that both types of materials will be used in important technological applications, doing this depends on discovering new materials in each class. Oleg Yazyev and his laboratory tackle this challenge by performing computational, or *in silico*, materials discovery.

Early successes were related to the structure and properties of disorder in graphene – the first 2D material which keeps fascinating researchers. These predictions received full experimental confirmation. But more recently, Yazyev's laboratory revealed a number of new topological insulators and semimetals by performing high-throughput computational screening of known materials.

Some of the new candidate materials (the topological insulator Bi_4I_4 and the Weyl semimetals MoP_2 and WP_2) have already been investigated experimentally by Yazyev's collaborators, confirming predicted topological properties. The remaining predictions awaiting experimental confirmation have been made publicly available via the open-science platform Materials Cloud developed by NCCR-MARVEL.

ISIC

Xile Hu won the Caltech Resonate Award

Professor Xile Hu has won the 2018 Resonate Award from Caltech for his work on for developing abundant and non-precious metal catalysts for the sustainable synthesis of added-value chemicals and the cost-effective production of solar fuels.

The Resonate Awards are given each year by Caltech's Resnick Sustainability Institute to *"honor outstanding achievement in renewable energy and sustainability-focused science and technology."*

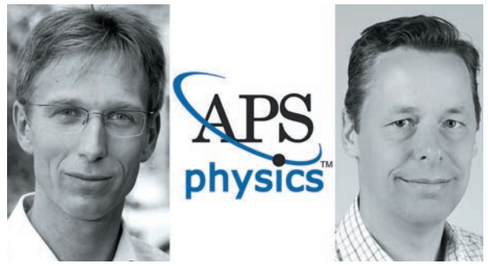
The Awards are given to "up-and-coming" innovating scientists under the age of 40, whose work *"charts new pathways or opens up new areas to solutions with long-term impacts on sustainability challenges such as energy security, climate change and the environment."*

In 2018, the prestigious Award has been given to Xile Hu, Professor of Chemistry at EPFL's Institute of Chemical Sciences and Engineering and founder and director of its Laboratory of Inorganic Synthesis and Catalysis. His research focuses on developing catalysts made of earth-abundant elements for chemical transformations related to synthesis, energy, and sustainability. Professor Hu has distinguished himself by his pioneering research on the production of solar fuels, as well as on the synthesis of molecules with high added value.

The Award was presented to Xile Hu at a special reception following the 2018 Resnick Young Investigators Symposium at Caltech.

ISIC

Rainer Beck and Christoph Bostedt were elected APS Fellows



Professors Rainer Beck and Christoph Bostedt, at EPFL's Institute of Chemical Sciences and Engineering, have been elected Fellows of the American Physical Society.

The American Physical Society (APS) is the world's largest organization of physicists. It was founded in 1899 with the aim *"to advance and diffuse the knowledge of physics"*. Today, the APS numbers some 50,000 members worldwide, and publishes over a dozen scientific journals, including the prestigious *Physical Review* and *Physical Review Letters*.

Despite its size, APS Fellows comprise a mere 0.5% of the Society's membership, making it a distinct honor.

In 2018, the APS has elected into its Fellows Professors Rainer Beck and Christoph Bostedt at EPFL's Institute of Chemical Sciences and Engineering (ISIC).

Beck's research focuses the elementary steps of chemical reactions between gas-phase molecules and solid surfaces. His lab uses molecular beams and laser radiation to probe reaction processes at a molecular level by performing quantum state resolved reactivity measurements. The APS citation for Professor Beck reads: *"For pioneering experimental studies of quantum-state-resolved of gas-surface reaction dynamics"*.

Bostedt is an expert on ultrafast x-ray sciences with applications to physical chemistry. He uses intense, femtosecond x-ray pulses from novel free-electron laser sources to image the structure and non-equilibrium dynamics in nanometer-sized particles, and he develops novel non-linear X-ray spectroscopy approaches to investigate electronic and nuclear dynamics in atoms, molecules, and clusters. The APS citation for Professor Bostedt reads: *"For pioneering studies that elucidate the mechanisms and dynamics of high-intensity x-ray interactions with nanoparticles"*.

ISIC

Two EPFL chemical engineers won the 1st and 2nd Clariant CleanTech Awards

Ydna Marie Questell-Santiago and Dr Amita Ummadisingu, researchers at EPFL's Institute of Chemical Sciences and Engineering (ISIC), won the first and second Clariant CleanTech Awards in 2018.

Clariant is a specialty-chemicals company headquartered in Basel and operating worldwide. Founded in 1995, it currently encompasses 110 companies in 53 countries and is involved in care chemicals, catalysis, natural resources, plastics and coatings.

In 2018, Clariant partnered with the Swiss Chemical Society and the University of Basel to award the Clariant CleanTech Award Switzerland, which was endowed with a total of 10,000 CHF. The Award honors *"outstanding scientific achievements of Master students, PhD students and Postdocs in Switzerland in the field of Sustainable Chemistry, in areas such as resource efficiency, renewable energy, renewable raw materials or green technologies and environmental protection."*

The 2018 Award winners were announced during the annual Clariant Chemistry Day at the University of Basel (October 4th), which highlights outstanding achievements in sustainable chemistry, and which offered the awardees four lecture slots to present their respective projects. Professor Paul Dyson (ISIC) gave the Clariant CleanTech Lecture at the same event.

The First prize (5,000 CHF) was given to Ydna Marie Questell-Santiago, a PhD student from the Laboratory of Sustainable and Catalytic Processing directed by Professor Jeremy Luterbacher. Her project is titled *"New routes toward biomass-derived carbohydrates upgrading"*.

The Second prize (2,500 CHF) was given to Dr Amita Ummadisingu, a scientist with Professor Michael Grätzel's Laboratory of Photonics and Interfaces at EPFL. Her project is titled *"Fundamentals of perovskite formation for photovoltaics"*.

MATH

Maryna Viazovska was an invited speaker at the 2018 ICM

Professor Maryna Viazovska was one of the invited speakers at the 2018 International Congress of Mathematicians (ICM), which is hosted in Rio de Janeiro. She gave a talk about her research on sharp sphere packings.

The International Congress of Mathematicians, the largest conference of mathematics, was founded in the 1890s and is based on an idea of the German mathematicians Klein and Cantor. The first ICM was held in Zürich in 1897 and is since held every four years. The Fields medals and other prestigious awards are delivered during the ICM opening ceremony.

Professor Maryna Viazovska, who holds the Chair of Number Theory at EPFL, has been invited to give one of the *sectional lectures* in Combinatorics and Number Theory. The speakers are chosen by the International Mathematical Union and are representative of major scientific achievements in their mathematical field.

Born in Kiev in 1984, Maryna Viazovska is famous for her solution to the sphere packing problem. She completed her BSc in Mathematics in 2005 at the Taras Shevchenko National University of Kiev, her MSc in 2007 at the University of Kaiserslautern, and her PhD in 2013 at the University of Bonn. It was during her postdoctoral research at the Berlin Mathematical School and at the Humboldt University of Berlin that she took on and resolved the question of sphere packing in dimensions 8 and 24. In December 2016, she accepted EPFL's offer to become an assistant tenure-track professor, and was promoted to full professor in January 2018.

MATH

Victor Panaretos to deliver 2019 Bernoulli Society Forum Lectures

The Bernoulli Society for Mathematical Statistics and Probability elected Professor Victor Panaretos to deliver their prestigious biannual Forum Lectures. Panaretos is the youngest mathematician to receive the honor.

The Bernoulli Society for Mathematical Statistics and Probability was founded in 1975 as part the International Statistical Institute (ISI), itself established in 1885 and one of the oldest scientific associations of the modern world. The Society's objectives are to advance the sciences of probability (including stochastic processes) and mathematical statistics, and promote their application *"to all those aspects of human endeavor which are directed towards the increase of natural knowledge and the welfare of mankind."* The Bernoulli Society Forum Lectures take place every two years at the European Meeting of Statisticians, one of the foremost international meetings on Statistics and Probability. They include two hour-long plenary research talks.

For the 2019 European Meeting of Statisticians, the Bernoulli Society has chosen Professor Victor Panaretos, who holds the Chair of Mathematical Statistics at EPFL. His research focuses on the analysis of random functions and their interactions with stochastic geometry, statistical inverse problems, and mathematical biology.

Panaretos is known for his development of statistical theory and methods for addressing complex data structures arising in the physical and biological sciences. The mathematical description of such structures typically requires abstract formalisms for which many traditional statistical techniques are inadequate, calling for new theory. This has led Panaretos to cross intra- and inter-disciplinary boundaries, looking into problems of random tomography of single particles, analysis of DNA minicircle dynamics, shape homology of biological macromolecules, forecasting the evolution of epidemics, and measuring fundamental particle spectra at the Large Hadron Collider.

ISIC

Jeremy Luterbacher won the 2019 Werner Prize

Jeremy Luterbacher has been awarded the Swiss Chemical Society's Werner Prize for 2019.

The Werner Prize is awarded annually to promising young Swiss scientists or scientists working in Switzerland under 40 to recognize *"their outstanding research in the field of chemistry."*

Jeremy Luterbacher, head of EPFL's Laboratory of Sustainable and Catalytic Processing, has been awarded for *"his original and groundbreaking research on chemical conversion of plant material using protection group chemistry during biomass depolymerization and upgrading."*

"It's wonderful to get this kind of support from the Swiss research community, and especially exciting to join so many friends and mentors on the past winners' list!" says Luterbacher.

The Prize will be awarded on 5 April 2019 during the SCS Spring Meeting in Dübendorf, where Luterbacher will be presenting his research in the Werner Prize Award Lecture.

MATH

Simone Deparis rewarded for his flipped classroom

Simone Deparis was awarded the 2018 Credit Suisse Award for Best Teaching (see p. 6). He introduced a flipped classroom approach in his first-year linear algebra class, which proved highly popular with students.

When it came time to pick a career, Simone Deparis didn't hesitate for a second. He had known he wanted to be a math teacher ever since he was a teenager. Today a linear algebra professor at EPFL, he enjoys everything about math – its beauty, its contradictions and especially its complexity. "In this field you have to be tenacious, because you'll inevitably come across times when you're frustrated. You have to hang in there so you can eventually savor the victories," he says. Originally from the Canton of Ticino, Deparis holds a mathematics degree from ETH Zurich and a PhD from EPFL; he started teaching at EPFL ten years ago. Never one to shy away from a challenge, he even seeks them out – in the 2017–2018 school year he tested a new approach during part of his linear algebra class: the flipped classroom. Students were responsible for learning the theory at home, and the class time was spent doing exercises. In recognition of his bold initiative in the field of mathematics and the quality of his teaching, Deparis won the 2018 Credit Suisse Award for Best Teaching.

Flipped classrooms are being used increasingly at universities worldwide, including EPFL. But the challenge for Deparis was to use the approach in a linear algebra class for first-year students who may not be particularly motivated about math. (The class is for students of all sections except architecture, math and physics.) "I completely revolutionized my class, it was a lot of work but at the same time very stimulating" he says. And that wasn't the first risk he's taken. While at EPFL, he also developed a MOOC on the Octave and MATLAB programming languages; some 40,000 people have signed up for the English version.

A KNACK FOR IMPROVISATION

Simone Deparis tried out the flipped classroom with 100 linear algebra students over five weeks in the middle of the term. "Studies have shown that students learn better in flipped classrooms, and the mathematics section also wanted to see if this new approach would help motivate students who didn't choose to study math." For this trial run, he let students decide whether they wanted to participate, and used it for only a third of the total course. "We wanted to make sure that students who volunteered to try the flipped classroom weren't placed at a disadvantage."

To develop his approach, Deparis worked closely with Cécile Hardebolle, a teaching advisor at EPFL's Teaching Support Center (CAPE), and based it on Donna Testerman's MOOC. "The first lesson was a disaster because I didn't coordinate it with the MOOC. But I quickly fixed the problem, and then the students were really enthusiastic. The experience taught me a lot. With flipped classrooms, you have to be able to respond to questions and comments that might not come up in a conventional classroom. You have to be able to improvise while remaining clear and methodical."

Deparis's students enjoyed this new way of learning, even though it meant they had to do more work at home. The initial feedback indicates that by working on exercises in the classroom, students were able to better assess their level, discuss problems, and help each other out. In fact, once the five weeks of the flipped classroom were over, the students didn't want to return to the conventional approach. Deparis is repeating the experiment this fall but extending it to cover most of the course. And once again, hundreds of students have signed up. Apparently the teacher's bet was right on the mark.

ISIC

Nikolay Golubev received a Branco Weiss Fellowship

The Branco Weiss Fellowship Society in Science

The Branco Weiss Fellowship – Society in Science has selected Dr Nikolay Golubev as one of its six new Fellows in 2018.

Named after Swiss entrepreneur and patron Branco Weiss, the Branco Weiss Fellowship – Society in Science (BWF) is a postdoc program based in ETH Zürich, which offers a platform for exceptionally qualified researchers who are *"willing to engage in a dialogue on relevant social, cultural, political or economic issues across the frontiers of their particular discipline."*

Since 2002, the program aims to award up to ten young researchers around the world each year with generous personal research grants.

This year, the BWF has selected Dr Nikolay Golubev for its prestigious award. Dr Golubev is based at EPFL's Laboratory of Theoretical Physical Chemistry, and the fellowship will allow him to work on the development of a new theoretical approach that can shed light on the fascinating interplay between electronic and nuclear motion in molecules.

Although mathematical equations describing quantum behavior of microscopic particles are known for almost one hundred years, their direct solution remains extremely difficult for systems with more than a few degrees of freedom. In order to overcome these limitations, Dr Golubev aims to develop a new theoretical approach based on the alternative representation of the molecular wavefunction. This new methodology will provide experimentalists the needed conceptual understanding of fundamental principles underlying electron-nuclear interactions and will be indispensable in interpreting the fast-growing data from modern experimental observations of ultrafast electron-nuclear dynamics. His research will help to interpret recent groundbreaking experiments measuring properties of matter at the microscopic level and on fundamental time-scales.

For more information on The Branco Weiss Fellowship, please visit www.brancoweissfellowship.org

IPHYS

Antonio Gentile was awarded the Polysphère d'Or 2018

The Polysphère d'Or was awarded this year to Antonio Gentile of the Physics Section.

Every year, during the Graduation Ceremony, the students honour the best teacher of each faculty with a polysphere. The teacher who obtains the highest mark in the vote receives the Polysphère d'Or. This year, the Polysphère d'Or has been awarded to Antonio Gentile, ET technician at the Physics Section and involved in the course 'Introduction to construction technics' for 3rd year students in the Physics Bachelor. In this course, students learn to design parts, to build them in the mechanical workshop, and to also build electronic circuits. Gentile also supports all the practical work. He has in particular helped the preparation of the team of students who won the International Physicists' Tournament last April in Moscow.

IPHYS

EPFL team won the 2nd prize of the IBM Quantum Computing Award

EPFL Master students using IBM's Q Experience platform
© EPFL

A team of bachelor and master students following courses in quantum optics and quantum information, led by Clément Javerzac-Galy (SB), Marc-André Dupertuis (SB), and Nicolas Macris (IC), has won the second Best Paper Award from IBM Q, given to highest-scientific impact papers by master, PhD student, or postdoctoral researcher.

The objective is to use the first small experimental quantum computers provided by IBM via an online platform (IBM Q Experience), to perform experimental research on quantum algorithms using the IBM Qiskit special software package (open-source). Quantum computing is a totally new paradigm to perform computations by using fragile quantum bits whose states cannot even be copied, but only teleported, through the device. It requires totally new technologies, and the first machines start being available in research labs, and at companies like IBM, Google, Rigetti, Intel. Presently most of these companies try to generate "open source communities" to try and identify new challenges, to foster large-scale collaborations and "ecosystems" for new quantum software and new applications.

The adventure started last spring when interested students had to find a research topic. Some students already had the chance to use the IBM quantum computer in their quantum optics and quantum information class, as EPFL was one of the first universities to use it for teaching. Teachers from the sections of Physics and Communication Systems also joined forces for a collaboration that required a diverse set of skills. It was quickly found that constructing and characterizing different types of complex entangled quantum states could be a good challenge, and each aspect of the enterprise was tackled by small subgroups of students. For instance, Diogo Cruz together with other fellow students, found a way to generate a special class of entangled states more efficiently than previously known. It was also an occasion to test ideas like quantum error correction, which at this stage did not prove efficient. Such entangled quantum states are potentially useful for quantum secret sharing, quantum memories, multiparty quantum network protocols, and universal quantum cloning machines.

Participating in the exploration of the new quantum information world is a lot of work, but also fun and exhilarating, even on machines with as little as 16 Qbits. One does not know yet if the quantum revolution in computing will find its "transistor", the invention that enabled, since 1947, the large-scale miniaturization and diffusion of classical computers in our society, but future engineers and scientists can already be trained on the new experimental quantum machines.

REFERENCE
Efficient quantum algorithms for GHZ and W states, and implementation on the IBM quantum computer, D. Cruz, R. Fournier, F. Gremion, A. Jeannerot, K. Komagata, T. Tosic, J. Thiesbrummel, C.L. Chan, N. Macris, M.-A. Dupertuis, C. Javerzac-Galy, https://arxiv.org/abs/1807.05572

IPHYS

EPFL won the 2018 International Physicists' Tournament

© A. Lomakin (MIPT), supported by MIPT-Union, Abbyy and Pres. Grants Fund

A team of students from EPFL won the 2018 International Physicists' Tournament in Moscow, beating the French and Brazilian teams in the final.

Fifteen teams from around the world gathered for a week at the Moscow Institute of Physics and Technology for the 10th annual International Physicists' Tournament.

At the final on April 7, EPFL edged out its rivals to win the tournament. EPFL's team was selected to represent Switzerland at a national competition held on campus last December. A Swiss team also won the competition in 2013.

This year's scores were very close: Switzerland (47.2 points) narrowly beat France (46.4 points), represented by the Ecole Polytechnique in Paris, and Brazil (39.8 points), represented by the Federal University of ABC (UFABC).

PLAYING THE ROLE OF OPPONENT AND REVIEWER TOO
For this tournament, the teams receive a series of physics problems several months prior to the competition. This year's challenges included: estimating the temperature of a liquid from the sound it makes when poured; determining the statistical distribution of sparks created by an angle grinder; and making a speaker without any moving parts. At EPFL, the third-year physics curriculum for Bachelor's students includes time to prepare for the tournament.

The teams have to come up with solutions, which they present at the competition alongside those of the rival teams. The teams are evaluated by an international panel of professional physicists on the basis of their solutions and their critique of their rivals' work.

UNEXPECTED VICTORY
"A week ago, I would absolutely not have banked on winning," says Alberto Rolandi, EPFL's team captain. "We ran out of time, and so at the start of the tournament we were only ready to present seven of the 17 problems. But we stuck with it and pulled it off."

After a week of intense work, the six members of the Swiss team and the three people who accompanied them returned to Switzerland exhausted but thrilled. They learned a lot from the experience, including the fact that the opponents and jury do not fully appreciate the quality of a team's background research if it's not well presented. "The work done by the Ukrainian team, for example, was clearly a cut above that of the other teams, but their presentations were nowhere near the level required by the tournament," adds Rolandi, who's in the third year of his Bachelor's degree. "It's no different when it comes to publishing articles!"

Next year, Rolandi says he's ready to step aside and let other physics students compete. "It's best to quit while you're ahead. But I would like to join the international executive committee so that I can help organize future tournaments."

Rolandi adds: "I'd really like to thank our three coaches and my teammates for their great work throughout the semester and at the tournament. I'm also grateful to the technical staff in the physics labs for their support in both theoretical and practical matters."

ISIC

Ursula Röthlisberger was elected AAAS fellow

Professor Ursula Roethlisberger has been elected Fellow of the American Association for the Advancement of Science (AAAS).

The American Association for the Advancement of Science (AAAS) is *"the world's largest multidisciplinary scientific society"*, publishing the Science family of research journals.

This year, the AAAS has honored 416 of its members with the lifetime title of Elected Fellow, *"in recognition of their extraordinary achievements in advancing science"*.

One of the new AAAS Fellows in the Section of Chemistry, is Professor Ursula Roethlisberger with EPFL's Institute of Chemical Science and Engineering (ISIC). Professor Roethlisberger directs the Laboratory of Computational Chemistry and Biochemistry, and her research focuses on *ab initio* molecular dynamics methods based on density functional theory (Car-Parrinello simulations) and their application, adaption, and extension to systems of chemical and/or biological interest.

The AAAS Fellows will be recognized at the 2019 AAAS Annual Meeting in Washington D.C. during a Fellows Forum on 16 February 2019. They will be presented with an official certificate and the AAAS Fellows' gold and blue rosette pin, the colors of which represent the fields of science and engineering respectively.

IPHYS - ISIC - MATH

Best Teacher Awards

Sandrine Gerber
Chemistry and Chemical Engineering Section (SCGC)

Simone Deparis
Mathemathics Section (SMA)

Frédéric Mila
Physics Section (SPH)

IPHYS - ISIC - MATH

Best PhD Thesis Awards

CHEMISTRY AND CHEMICAL ENGINEERING (EDCH)

Julia Pedroni
FOR HER THESIS
"Pd(0)-Catalysed C-H Functionalisations for the Enantioselective Synthesis of N-Heterocycles"
THESIS DIRECTOR
Nicolai Cramer

MATHEMATICS (EDMA)

Dimitri Wyss
FOR HIS THESIS
"Motivic and p-adic Localization Phenomena"
THESIS DIRECTOR
Tamàs Hausel

PHYSICS (EDPY)

Mauro Fanciulli
FOR HIS THESIS
"Spin Polarization and Attosecond Time Delay in Photoemission from Solids"
THESIS DIRECTOR
Hugo J. Dil

RESEARCH GRANTS

IPHYS ISIC MATH

ISIC

Kumar Varoon Agrawal won an ERC Starting Grant

Professor Kumar Varoon Agrawal was awarded a Starting Grant from the European Research Council.

The ERC Starting Grants are given each year to researchers of any nationality and in any field of research, with 2-7 years of research experience after the completion of their PhD and who show a promising scientific track record. The application must be made from an EU or associated country, and each Starting Grant can be up to €1.5 million given over a period of five years.

In 2018, Kumar Varoon Agrawal (ISIC) has received a Starting Grant for his project: *"UltimateMembranes: Energy-efficient membranes for carbon capture by crystal engineering of two-dimensional nanoporous materials"*. The project will develop CO_2-selective membranes that are only a few nanometer-thick, cutting down the energy penalty for CO_2 capture from the industrial streams.

"We are extremely excited about the development of these high-performance two-dimensional membranes, which can be a game-changer," says Agrawal.

IPHYS - ISIC

Two SB Professors received ERC Advanced Grants

Professors Thomas Rizzo and Frédéric Courbin have each received European Research Council Advanced Grants.

The ERC Advanced Grants are given each year to established, leading principal investigators to fund long-term funding for *"ground-breaking, high-risk"* research projects in any field. This year, the ERC has awarded several EPFL professors with Advanced Grants, including two from the School of Basic Sciences.

Professor Thomas Rizzo (ISIC-LCPM)
GLYCANAL: High-Throughput Cryogenic Spectroscopy for Glycan Analysis"

Glycans, or oligosaccharides, are ubiquitous in biological systems. Because they decorate the surface of cells, they play a key role in virtually all cellular recognition processes and are implicated in almost every major disease. This project involves designing and constructing an instrument that combines state-of-the-art ion mobility separation, cryogenic ion spectroscopy, and time-of-flight mass spectrometry to perform high throughput analysis of glycan primary structure. The success of this project would represent a tremendous breakthrough for glycoscience.

Professor Frédéric Courbin (IPHYS-LASTRO)
COSMICLENS: Cosmology with Strong Gravitational Lensing

Answering fundamental questions about the expansion of the Universe requires a precise measurement of the Hubble parameter, (H0), which is the prime parameter in the cosmological distance scale. The COSMICLENS project aims to measure H0 using the time-delay method in gravitationally lensed quasars. Capitalizing on the COSMOGRAIL pathfinder program initiated and lead by EPFL, we can fully exploit time delays with an observational, modeling and technical boost, made possible only through ERC funding.

IPHYS - SPC

Christian Theiler received an SNSF Eccellenza Grant and an "Enabling Research" grant from the EUROfusion Consortium

Christian Theiler, Tenure-track assitant professor at the Swiss Plasma Center (SPC), was awarded an Eccellenza Grant for his project 'Alternative divertors for improved tokamak operation'. He is also the recipient of an "Enabling Research Grant" from the EUROfusion Consortium to lead a collaborative research project in the physics of tokamaks.

The Swiss National Foundation's Eccellenza Grants aim at *"researchers in all disciplines who have recently been appointed as tenure-track assistant professors at a Swiss higher education institution."* They are given each year to *"highly qualified young researchers who aspire to a permanent professorship."* The goal is to support these scientists in leading generously funded research projects with their own team at a Swiss higher education institution. The Grants offer project funds up to CHF 1,500,000 over five years.

"In fusion devices, such as tokamaks, the edge region of the magnetically confined plasma has to simultaneously assure good confinement of the core plasma and guarantee acceptable heat fluxes to the surrounding wall structures. We propose to use EPFL's Tokamak à Configuration Variable (TCV) to explore alternative magnetic geometries of the tokamak edge region, a promising path to develop a robust tokamak edge solution."

The Enabling Research Grant is described as *"a key ingredient of the EUROfusion Consortium activities as it provides a special path to bring new ideas and techniques into the programme in ways not easily achieved within the strongly goal-oriented main Work Packages."* The €600,000 grant was awarded after a call and selection by EUROfusion for project proposals in magnetic confinement fusion.

Christian Theiler will lead a collaborative research project with an international team of 21 researchers from EPFL, the French Atomic and Alternative Energy Commission (CEA), the Culham Centre for Fusion Energy (CCFE), the Technical University of Denmark, the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA), and the Max Plank Institute for Plasma Physics (IPP) in Garching. The project is titled *"Towards a first-principles understanding of fluctuations and flows in the X-point region of tokamaks"*, and will run for two years.

"We aim to validate five leading plasma turbulence codes against well-diagnosed experiments in the challenging but highly relevant 'X-point geometry' of tokamak fusion devices," explains Theiler. "It will result in an important step forward in the understanding of X-point physics, in the predictive capabilities of tokamak boundary modelling, and in establishing these codes as standard tools in the main EUROfusion work packages."

IPHYS

ERC grants €14 million to Swiss researchers

The European Research Council (ERC) has given four scientists from the PSI, EPFL, ETH Zurich, and Stockholm University a €14 million grant to look "into the heart of materials" and uncover new quantum effects that have gone overlooked or have just been undetectable by previously employed methods. The so-called HERO project is expected to set off the next quantum revolution.

Seeking to further our understanding of quantum properties of materials, four expert scientists have successfully secured an extraordinary €14 million Synergy Grant, administered by the European Research Council, and the most prestigious award for excellent European research projects.

The team consists of three scientists in Switzerland and one in Sweden: Gabriel Aeppli at the Paul Scherrer Institute (PSI), Henrik M. Rønnow at EPFL, Nicola Spaldin at ETH Zurich, and Alexander Balatsky at Stockholm University's Nordic Institute for Theoretical Physics (Nordita).

With this funding, the scientists will join their respective expertises to look into "the heart of materials" to uncover new, "hidden" quantum properties in known materials, meaning properties that could not be seen by current methods or have perhaps been overlooked.

They will also design new materials with useful quantum properties. Such new properties could be of use for data processing or storage in the future and thus become the backbone of future electronics, which need to be faster, smaller, and more energy efficient.

The scientists will use the the several large research facilities at PSI for complementary investigations, as well as employ the computing power of the Swiss National Supercomputing Centre (CSCS) at ETH Zurich in Lugano for data processing and theoretical calculations.

They researchers called their joint research project HERO which stands for "Hidden, Entangled and Resonating Orders" – all of which are important quantum properties they will look at in order to discover possible materials of the future.

The three scientists in Switzerland all work within the ETH domain. This gave them a notable advantage in joining their expertise, says Henrik Rønnow, neutron scientist at EPFL's Institute of Physics. The four experts teaming up now will greatly advance the field: "Every time we sit together, we notice that we all come from very different angles but are often looking at the same thing," continues Rønnow. "Already in the past, listening to the viewpoints of the other three has given me new ideas on how to better find the things I am searching. I am therefore very much looking forward to expanding this collaboration."

Authors: EPFL and Paul Scherrer Institute (PSI)

ISIC - IPHYS

Three FSB Professors won ERC Consolidator Grants

Christophe Galland (IPHYS)
QTONE
"Quantum plasmomechanics with THz phonons and molecular nano-junctions"

Clémence Corminboeuf (ISIC)
PUSHQCHEM
"Pushing quantum chemistry by advancing photoswitchable catalysis"

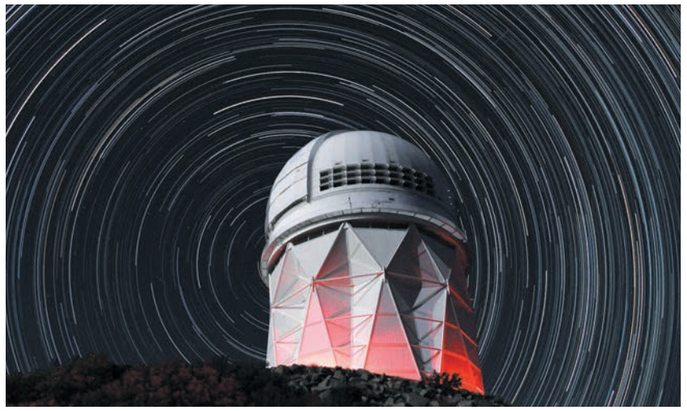
Suliana Manley (IPHYS)
PIKO
"Revealing the adaptive internal organization and dynamics of bacteria and mitochondria"

RESEARCH HIGHLIGHTS

IPHYS ISIC MATH

IPHYS

Mayall telescope gets ready for the largest 3D map of the universe



The Mayall Telescope
© NOAO

The 45-year-old Nicholas U. Mayall Telescope, is temporarily closing for the installation of the Dark Energy Spectroscopic Instrument (DESI), which will allow it to build the largest 3D map of the universe, and help solve the mystery of how dark energy drives the accelerating expansion of the universe. EPFL is full partner of the DESI project through key contributions to its unique fiber positioner robotic system.

The Mayall Telescope is housed in the Kitt Peak National Observatory (KPNO) in Arizona and operated by the National Optical Astronomy Observatory. Named after US astronomer and KPNO director Nicholas U. Mayall (1906-1993), it is a four-meter reflector telescope built at an altitude of 2,120 meters, and has been operating since 1973.

Since then, the Mayal Telescope has contributed to many discoveries in astrophysics, including dark energy and the role of dark matter in the universe. Equipped with with a wide-field imager camera, the CCD Mosaic, the Mayall produces color pictures of astronomical objects such as Messier 101, but also wide field observations that will help to map structure of the universe.

The Mayall will be temporarily closed to begin what is described as "the largest overhaul" in its history, preparing the stage for the installation of the Dark Energy Spectroscopic Instrument (DESI). The work involves more than 465 researchers from about 71 institutions, and according to KPNO Director Lori Allen, the entire top end of the telescope - which weighs as much as a school bus and houses the telescope's secondary mirror and a large digital camera - will be removed with a crane and replaced with DESI instruments.

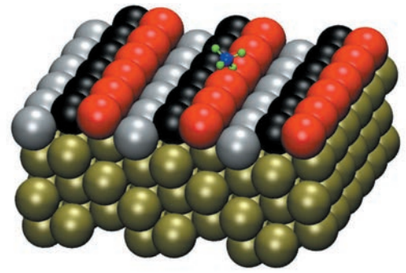
Once installed, the DESI will begin a five-year observation run to provide new insights about the universe's expansion and large-scale structure. In addition, it will also help to set limits on theories related to gravity and the formative stages of the Universe, perhaps even providing new mass measurements for a variety of neutrinos.

EPFL scientists have contributed to the DESI project through the development of the targeting strategy of the DESI survey, as well as through the development of the robotic fiber positionner system. The latter work as been conducted as part of the "astrobots" group, which includes EPFL's Laboratory of Astrophysics (LASTRO), Laboratory of Robotic Systems (LSRO) and the Coordination & Interaction Systems Group (REACT). EPFL and the Swiss National Science Foundation have contributed almost 1 million CHF to the DESI project, and the scientists are standing by to process the enormous amount of data that will be coming in.

"The focal plane of the Mayall telescope will be equipped with a fully automated robotic fiber positioner system co-developed by the Berkeley Lab, the University of Michigan, and EPFL. This high-precision system will place 5,000 optical fibers to 5-micron accuracy within less than one minute," says LASTRO director **Jean-Paul Kneib**.

ISIC

Locating precise catalytic sites in steam reforming



The Pt(211) surface model with the methane molecule on it
© Rainer Beck/EPFL

Using infrared spectroscopy and a quantum theory model, EPFL scientists have gained a more complete understanding of methane dissociation reactions on platinum.

Transition metals, such as nickel and cobalt, are known for their superior chemical bonding capabilities. Because of this, these are widely used in the industrial production of hydrogen and other useful compounds from natural gas. The most common method for achieving this transformation is "steam reforming": methane, which is the main constituent of natural gas, is heated with steam in the presence of the transition-metal catalyst, and is converted into hydrogen and carbon monoxide.

There is always the search for better transition-metal catalysts, and the search is largely based on trial and error. Scientists know that the most significant reactions occur at the surface of the catalysts, but much of the guesswork is based on the assumption that catalyzed reactions take place on atomic defect sites of the metal crystals.

The group of **Rainer Beck** at EPFL, with colleagues at the University of Massachusetts, combined infrared techniques with quantum theory to explore these reactions in unprecedented detail. Their work reveals for the first time exactly where the most significant reactions occur on the catalyst's surface.

The researchers focused on platinum (Pt) as the catalyst for breaking down methane. At the atomic scale, the surface of a platinum catalyst, as well as other metal crystals, can consist of various defects such as steps and terraces, all of which are thought to be important "sites" in the catalytic process.

Using infrared laser pumping, the researchers excited methane molecules into selected rotational and vibrational quantum states. They then detected methane dissociation on the various sites of the Pt(211) crystal by using reflection-absorption infrared spectroscopy (RAIRS), a non-intrusive technique that allows researchers to monitor chemical reactions in real time during the deposition of, in this case, methane on the platinum's surface. This is done by recording site-specific uptake curves for chemisorbed methyl species on steps and terraces sites, which can then be used to determine the reactivity levels of methane on each of the sites.

"We demonstrated that it is possible to use RAIRS detection for state- and surface-site specific measurements of methane reactivity and to compare the effect of vibrational excitation on reactivity on the steps and terraces of a catalyst surface," says Rainer Beck. "This new area of study provides another level of detail in detecting methane's dissociation products."

The researchers combined RAIRS with a quantum theory framework (Reaction Path Hamiltonian model) to calculate the potential energy surface and explore the dynamics during the chemical reactions. The approach showed that dissociation reactions are at least two orders of magnitude more efficient on the atomic steps than on the terraces. A third type of surface site located between steps and the terrace, referred to as "corner atoms", saw no reactions taking place.

Although the study looked at platinum, the model can be applied to other transition-metal catalysts, such as nickel. "A tested predictive theory with chemical accuracy could change the way one searches for new catalysts and make the search more efficient and cheaper," says Beck.

FUNDING
- **Swiss National Science Foundation (FNS)**
- **Ecole Polytechnique Fédérale de Lausanne (EPFL)**

REFERENCE
Helen Chadwick, Han Guo, Ana Gutiérrez-González, Jan Paul Menzel, Bret Jackson, Rainer D. Beck. **Methane dissociation on the steps and terraces of Pt(211) resolved by quantum state and impact site.** *The Journal of Chemical Physics* **148**, 014701 (2018). DOI: 10.1063/1.5008567

ISIC

Standardizing perovskite aging measurements

© 2017 EPFL

EPFL scientists have produced a data-driven proposal for standardizing the measurements of perovskite solar cell stability and degradation. The work aims to create consensus in the field and overcome one of the major hurdles on the way to commercializing perovskite photovoltaics.

Perovskite solar cells are an alternative to conventional silicon solar cells, and are poised to overtake the market with their high power-conversion efficiencies (over 22% now) and lower capital expenditure and manufacturing costs. But one of the greatest obstacles on this road is stability: to be commercially viable, perovskite solar cells must also be able to maintain their efficiency over time, meaning that they must not degrade significantly over 25 years of service.

"As a first-order approximation, we are talking about stabilities of several years for the most stable perovskite solar cells," says Konrad Domanski, first author on the paper. "We still need an increase of an order of magnitude to reach the stabilities of silicon cells."

While research efforts are continuously made to improve perovskite stability, the community is hamstrung by the fact that there are no general standards by which scientists can measure the stability of perovskite solar cells. Consequently, the results coming in from different laboratories and companies cannot be easily compared to each other. And even though dedicated stability measurement standards have been developed for other photovoltaic technologies, they have to be adapted for perovskite solar cells, which show new types of behavior.

Now, the labs of **Michael Grätzel** and **Anders Hagfeldt** at EPFL's Institute of Chemical Sciences and Engineering have carried out a study that proposes to standardize the measurements of perovskite solar cell stability across the entire field. The researchers investigated the effects of different environmental factors on the ageing of perovskite solar cells, looking at the impact of illumination (sunlight-level light), temperature, atmospheric, electrical load, and testing a systematic series of combinations of these.

"We designed and built a dedicated system to carry out this study," says Domanski. "It is state-of-the-art for measuring stability of solar cells – we can vary light intensity over samples and control temperature, atmosphere etc. We load the samples, program the experiments, and the data is plotted automatically."

The study shows how certain behaviors specific to perovskite solar cells can distort the results of experiments. For example, when the cells are left in the dark, they can recover some of the losses caused by illumination and "start fresh in the morning". As solar cells naturally undergo day-night cycles, this has important implications on how we define that a solar cell degrades in the first place. It also changes our perception on the metrics used by industry to describe lifetime of solar cells.

"The work can lay the foundations for standardizing perovskite solar cell aging," says Wolfgang Tress, last author on the paper. "The field can use it to develop objective and comparable stability metrics, just like stabilized power is now used as a standard tool for assessing power-conversion efficiency in perovskite solar cells. More importantly, systematically isolating specific degradation factors will help us better understand degradation of perovskite solar cells and improve their lifetimes."

"We are not trying to impose standards on the community," says Domanski. "Rather, being on the forefront on perovskite solar cells and their stability research, we try to lead by example and stimulate the discussion on how these standards should look like. We strongly believe that specific protocols will be adopted by consensus, and that dedicated action groups involving a broad range of researchers will be formed for this purpose."

FUNDING

- **Swiss National Science Foundation (FNS)**
- **King Abdulaziz City for Science and Technology (KACST)**

REFERENCE

Konrad Domanski, Essa A. Alharbi, Anders Hagfeldt, Michael Grätzel, Wolfgang Tress. Systematic Investigation of the Impact of Operation Conditions on the Degradation Behaviour of Perovskite Solar Cells. ***Nature Energy*** 01 January 2018. DOI: 10.1038/s41560-017-0060-5

IPHYS

EPFL helps the International Cycling Union combat technological fraud

X-ray unit for the detection of technological fraud in cycling events

© UCI

The Union Cycliste Internationale (UCI) has unveiled new X-ray methods to detect technological fraud in biking competitions. EPFL's Institute of Physics offered scientific and technological support to the project.

Advances in the performance of batteries and electric motors has provided new technological possibilities including drones and transport devices like hoverboards, e-bikes and e-scooters – technologies that solve the door-to-door challenge may help a greener future where more people abandon cars to commute by public transport.

However, the possibility to hide performant motors in bicycles has led to a challenge for cycling as a sport. Since 2010, rumors and speculations have circulated of so called technological fraud in professional cycling races. In 2016, a bicycle with motor and battery hidden in the carbon-fiber frame was discovered at the Cyclocross world championships, and in 2017, a cyclist was caught using a hidden motor at a French amateur race. There is hope these were isolated cases, but cyclists and fans alike deserve assurance that the outcomes of bicycle races are not influenced by "mechanical doping".

To this end, the UCI revealed in Geneva an X-ray inspection unit designed to scan bicycles for hidden motors. This tool will be deployed at up to 50% of race-days at the top level of the sport – the UCI Protour. EPFL's Institute of Physics and the University of Lausanne's REDs unit assisted UCI to realize the solution. Initial X-ray tests were performed at EPFL, and the instutute's expertise in radiation safety was employed to ensure a completely safe operation that has been approved by the national health authorities.

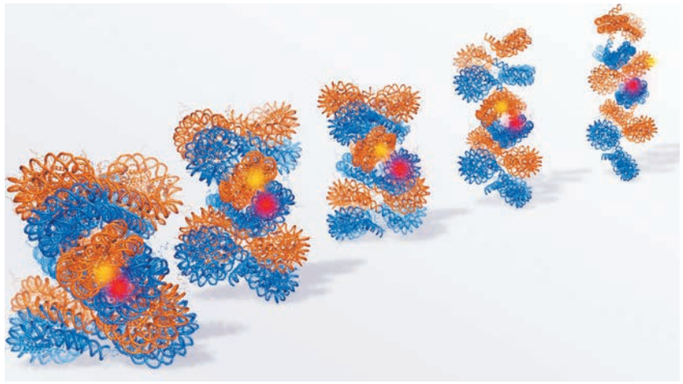
"While other tools, including magnetic inspection and thermal imaging make it very difficult for someone to hide a motor without being caught, X-ray inspection of bicycles at the arrival ensures without doubt that there is no motor, and it is this certainty both riders and fans of the sport need," says EPFL's Professor **Henrik Rønnow** from EPFL, who took part in the press conference.

"One downside highlighted by some of the journalists present is that the machine is heavy (1500 kg), expensive, and that there is only one – which means that only the most important cycling races can be controlled," he adds. "But this is only the beginning. By using a special X-ray source that emits only 50-nanosecond short pulses, our lab was able to design and construct a setup weighing less than 100 kg, which can be transported in a regular car. Each national cycling federation could have such a setup to ensure efficient controls at all levels of the sport."

This is one of many examples where EPFL and University of Lausanne have lent their broad expertise to benefit sports. UNIL's Institute of Sport Sciences (ISSUL) hosts world-leading experts in the physiology of sports, while EPFL's engineering advances range from better skis, to speeding up America's Cup-winning sailing boats, to advanced big-data analysis of NBA games.

ISIC

A new, dynamic view of chromatin movements



An illustration of chromatin (on the left) opening up to individual nucleosomes (right).
© Beat Fierz/EPFL

In cells, proteins tightly package the long thread of DNA into pearl necklace-like complexes known as chromatin. Scientists at EPFL show for the first time how chromatin moves, answering longstanding questions about how its structure helps regulate gene expression.

The total length of DNA inside a single cell is between 2-3 meters. In order to fit inside cells, DNA is wrapped around small protein spindles, forming strings of molecules called nucleosomes. The nucleosomes then coil up to form intertwined fibers. This complex is called chromatin and it organizes and compacts DNA inside the cell's nucleus, but it also makes it hard for the cellular machinery to access DNA.

Structural studies of chromatin so far have only given us a static view of how DNA is organized in cells. But how can the gene-expression machinery access the DNA buried in chromatin? Answering this requires a more dynamic view of genetic material.

The lab of **Beat Fierz** at EPFL, in collaboration with the group of Claus Seidel at the University of Düsseldorf, was now able to observe actual chromatin motions, using a unique combination of protein and DNA chemistry, along with two complementary single-molecule fluorescence spectroscopy approaches. The work reveals, for the first time, the internal structure and movements of chromatin, thereby addressing an unsolved question in chromatin research.

The researchers found that the nucleosomes within chromatin fibers form short stacks that quickly fall apart and reform within a matter of milliseconds. These short nucleosome packages contain four nucleosomes and about 800 base pairs of DNA, thus forming the basic unit of chromatin organization. A protein that is responsible for gene silencing (heterochromatin protein 1α), can lock nucleosome interactions and compact chromatin even more, thereby preventing the gene expression machinery to access the DNA.

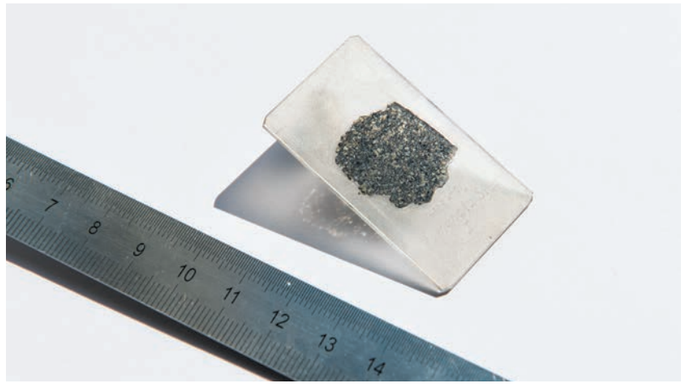
Together, the discovery of such rapid dynamic modes within chromatin fibers provides new insight into how processes can gain access to DNA (or are prevented to do so), such as transcription factors, or the machinery for transcription, replication, or DNA repair.

FUNDING
- **Sandoz Family Foundation**
- **Swiss National Science Foundation**
- **European Research Council (Consolidator Grant 2017, chromo-SUMMIT)**
- **EPFL**
- **Boehringer Ingelheim Foundation**
- **European Research Council (Advanced Grant 2015, hybridFRET)**

REFERENCE
Sinan Kilic, Suren Felekyan, Olga Doroshenko, Iuliia Boichenko, Mykola Dimura, Hayk Vardanyan, Louise C. Bryan, Gaurav Arya, Claus A. M. Seidel, Beat Fierz. **Single-molecule FRET reveals multi-scale dynamics of chromatin modulated by HP1α.** *Nature Communications* 16 January 2018. DOI: 10.1038/s41467-017-02619-5

IPHYS

Meteorite diamonds tell of a lost planet



A thin slice of the meteorite sample used in the study.
© EPFL/Hillary Sanctuary

Using transmission electron microscopy, EPFL scientists have examined a slice from a meteorite that contains large diamonds formed at high pressure. The study shows that the parent body from which the meteorite came was a planetary embryo of a size between Mercury to Mars.

On October 7, 2008, an asteroid entered Earth's atmosphere and exploded 37 km above the Nubian Desert in Sudan. The asteroid, now known as "2008 TC_3", was just over four meters in diameter. When it exploded in the atmosphere, it scattered multiple fragments across the desert. Only fifty fragments, ranging in size from 1–10 cm, were collected, for a total mass of 4.5 kg. Over time, the fragments were gathered and catalogued for study into a collection named Almahata Sitta (Arabic for "Station Six", after a nearby train station between Wadi Halfa and Khartoum).

The Almahata Sitta meteorites are mostly ureilites, a rare type of stony meteorite that often contains clusters of nano-sized diamonds. Current thinking is that these tiny diamonds can form in three ways: enormous pressure shockwaves from high-energy collisions between the meteorite "parent body" and other space objects; deposition by chemical vapor; or, finally, the "normal" static pressure inside the parent body, like most diamonds on Earth.

The unanswered question, so far, has been the planetary origin of 2008 TC_3 ureilites. Now, scientists at **Philippe Gillet**'s lab at EPFL's Institute of Physics, with colleagues in France and Germany, have studied large diamonds (100-microns in diameter) in some of the Almahata Sitta meteorites and discovered that the asteroid came from a planetary "embryo" whose size was between Mercury to Mars.

The researchers studied the diamond samples using a combination of advanced transmission electron microscopy techniques at EPFL's Interdisciplinary Centre for Electron Microscopy. The analysis of the data showed that the diamonds had chromite, phosphate, and iron-nickel sulfides embedded in them – what scientists refer to as "inclusions". These have been known for a long time to exist inside Earth's diamonds, but are now described for the first time in an extraterrestrial body.

The particular composition and morphology of these materials can only be explained if the pressure under which the diamonds were formed was higher than 20 GPa (giga-Pascals, the unit of pressure). This level of internal pressure can only be explained if the planetary parent body was a Mercury- to Mars-sized planetary "embryo", depending on the layer in which the diamonds were formed.

Many planetary formation models have predicted that these planetary embryos existed in the first million years of our solar system, and the study offers compelling evidence for their existence. Many planetary embryos were Mars-sized bodies, such as the one that collided with Earth to give rise to the Moon. Other of these went on to form larger planets, or collided with the Sun or were ejected from the solar system altogether. The authors write: "This study provides convincing evidence that the ureilite parent body was one such large 'lost' planet before it was destroyed by collisions some 4.5 billion years ago."

FUNDING
- **Swiss National Science Foundation**

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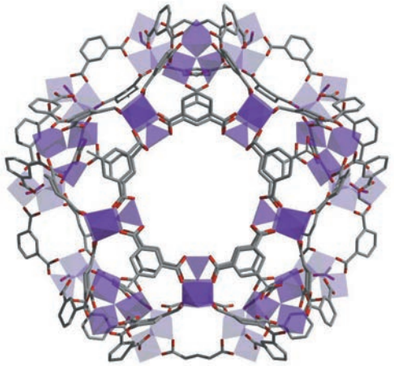
Farhang Nabiei, James Badro, Teresa Dennenwaldt, Emad Oveisi, Marco Cantoni, Cécile Hébert, Ahmed El Goresy, Jean-Alix Barrat, Philippe Gillet. A large planetary body inferred from diamond inclusions in a ureilite meteorite. *Nature Communications* **9**, 1327 (17 April 2018). DOI:10.1038/s41467-018-03808-6.

ISIC

A “sponge” that can get gold out of waste water



© 2018 EPFL/Wendy Queen

A material developed by EPFL scientists can rapidly extract trace amounts of gold from waste water, fresh water, ocean water, and even sewage sludge.

Gold has been the basis of currency for many civilizations throughout history. Despite this, only ~190,000 tons of gold have been mined to-date, an amount that readily fits into a box ~20 meters on each side.

Nowadays gold is primarily used in electronics, where it is irreplaceable due to its unique properties. However, diminishing gold supplies and a continuous rise in the production of electronics have led the European Union to label this precious metal as a critical resource. Considering it can take as much as a ton of ore to yield enough gold for 40 cell phones, it is no surprise that extracting this commodity from sources other than virgin mines is becoming increasingly important.

While gold can be found in a number of different sources, such as electronic waste, sea water, fresh water, waste water, and sewage sludge, there are currently no materials reported that can selectively extract gold from such complex media.

Recently the laboratory of Professor **Wendy L. Queen** at the Institute of Chemical Sciences and Engineering of EPFL Valais Wallis developed a “sponge” that can mine gold from a variety of complex liquids. The porous material, referred to as Fe-BTC/PpPDA, is constructed by a metal-organic framework (MOF) and polymer building blocks, and has a very large internal surface area, which allows it to adsorb up to 1 gram of gold per gram of material.

In this work, published in the *Journal of the American Chemical Society*, the new material was tested in highly complex real-world samples. The PhD student responsible for the work, Daniel T. Sun, in collaboration with Dr Natalia Gasilova, has shown that these materials can remove gold in as little as two minutes from river water, sea water, and solutions obtained from electronic waste. Further, the sponge can be destroyed after metal extraction, leaving behind 23.9-karat gold, the highest purity reported to date for such an extraction method.

Last, due to recent reports that suggest that ~1.5 million euros worth of gold goes into the Swiss sewage system annually, the group has also obtained waste water and sewage sludge ash from a local waste water treatment plant. The group has demonstrated that the sponge can effectively remove the gold, leaving all other metals behind. The group is now exploring other MOF-Polymer composites for the extraction of a variety of contaminates and other high value commodities from water.

FUNDING

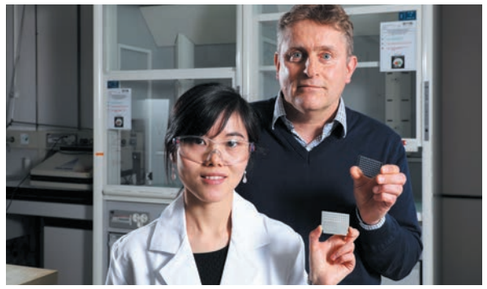
- **Swiss National Science Foundation**

REFERENCE

Rapid, Selective Extraction of Trace Amounts of Gold from Complex Water Mixtures with a MOF/Polymer Composite, Daniel T. Sun, N. Gasilova, S. Yang, E. Oveisi, and Wendy L. Queen, *Journal of the American Chemical Society*, November 5, 2018, DOI: 10.1021/jacs.8b09555

ISIC

Electrochemistry flushes out antibiotic-resistant proteins



EPFL 2018 – Yingdi Zhu, Horst Pick © Alain Herzog/EPFL

EPFL scientists, working with the Valais Hospital in Sion and Fudan University in Shanghai, have developed a method for analyzing bacteria that – for the first time ever – lets doctors quickly see exactly which proteins are associated with antibiotic resistance.

Some bacteria contain proteins that indicate resistance to antibiotics. But to spot those proteins, doctors need to be able to open the bacteria membranes and analyze the proteins inside – something that until now has been impossible, since mass spectrometry can identify only small proteins. However, scientists at EPFL’s Sion campus working with colleagues at Fudan University in Shanghai have developed a single method that can be used to analyze a large spectrum of proteins and identify both the bacteria and their resistance to antibiotics. The process combines titanium dioxide nanoparticles with the energy emitted by UV light rays. Their research has been published in *Chemical Science* (an open-access journal of the Royal Society of Chemistry).

The WHO has named bacterial resistance to antibiotics as the single biggest threat to human health. It is the result of doctors excessively prescribing antibiotics, which has accelerated bacteria’s regular defense mechanisms, weeding out the weakest microbes and allowing the strongest to survive. Over time, these bacteria have evolved to protect themselves against antibiotics by genetic mutation, passing genetic mutations on to their offspring or exchanging DNA with other bacteria.

Today, scientists are trying to slow this process by better targeting specific bacteria to prevent new multi-resistant strains from forming. That means they must be able to precisely identify which bacteria they are dealing with. The main method used in hospitals to detect antibiotic resistance involves growing bacteria cultures in the presence of antibiotics, but this technique can take several hours or even days. Another method entails using mass spectrometry to analyze bacteria strains grown in a Petri dish; doctors place the bacteria on a steel plate and irradiate them with a laser. That generates a cloud of proteins that can be analyzed to determine the bacteria’s phenotype. But neither method is capable of identifying larger proteins – which is why the research team set out to develop a new one.

STEEL PLATES IMPRINTED WITH TITANIUM DIOXIDE

The EPFL scientists, working at the school’s Laboratory of Physical and Analytical Electrochemistry (LEPA), and their colleagues in Shanghai used steel plates that had been imprinted with titanium dioxide nanoparticles. “Titanium dioxide is a white powder that absorbs light. When hit with UV rays, the powder triggers an electrochemical reaction that enhances the laser’s effects by literally exploding open the bacteria membranes,” says **Hubert Girault**, head of LEPA.

This method opens up the bacteria much more than existing ones, releasing an array of biological molecules including protein, DNA, RNA, and lipids. “We looked mainly at proteins, since they are what can potentially alter or deteriorate the antibiotics,” says Horst Pick, a biologist who helped develop the method. “But we also found that we could use the same mass spectrometry technique to analyze all the other types of molecules released and obtain the bacteria’s ‘fingerprint.’ That can help doctors identify the specific type of bacteria.”

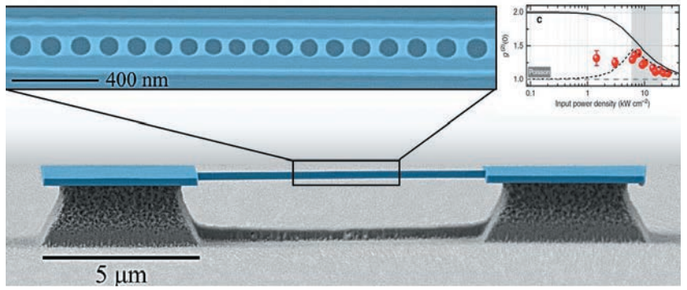
As a next step, the scientists hope to be able to work with the bacteria directly, without having to first grow cultures. That would shrink the analysis time to 30 minutes – a huge benefit since time is of the essence when fighting an infection – and ensure that doctors were targeting the right microbes. Highly promising trials have already been carried out.

REFERENCE

Yingdi Zhu, Natalia Gasilova, Milica Jović, Liang Qiao, Baohong Liu, Lysiane Tissières Lovey, Horst Pick and Hubert H. Girault. **Detection of antimicrobial resistance-associated proteins by titanium dioxide-facilitated intact bacteria mass spectrometry.** http://pubs.rsc.org/en/Content/ArticleLanding/2018/SC/C7SC04089J

IPHYS

Revealing the properties of nanolasers with quantum optics



Side view scanning electron microscopy image of GaN nanobeams suspended in air over a silicon substrate. Insets: (top left) Overhead view of the central part of the nanobeam with the optical cavity defined by the smallest hole region. (top right): Second-order autocorrelation function as obtained from experiment (red data points) and theory.

Researchers from EPFL, the Technical University of Berlin, and the University of Bremen have investigated nanolasers made from a gallium nitride semiconductor material and revealed their optical properties, paving the way for applications ranging from photonic circuits to optogenetics.

The laser is one of the most seminal inventions of the second half of the 20th century with applications ranging from telecommunications to eye surgery. But although it was invented in 1960, the properties of the laser are still investigated by scientists.

Among the various types of lasers, semiconductor-based nanolasers form a fascinating class on their own. These lasers are made from dielectric materials and can be engineered using techniques available in clean room facilities and reach a size where the active volume responsible for light emission is of the order of one cubic wavelength.

Using the nanofabrication tools available at EPFL's Center of MicroNanoTechnology (CMi) and Institute of Physics, the laboratory of **Nicolas Grandjean** teamed up with researchers from the Technical University of Berlin (optical spectroscopy) and the University of Bremen (microscopic theory) to investigate nanolasers made from gallium nitride (GaN) material: the semiconductor behind white-light emitting diodes (LEDs) used for solid-state lighting. This work unveils the emission features of nanolasers.

The scientists found that the compact, low-threshold nanolasers that emit in the blue spectral range under continuous wave optical pumping are ideally suited for exploring the ultimate properties of lasing in dielectric media thanks to the efficient photon funneling offered by their geometry. These are referred to as "high-β nanolasers".

Beyond engineering light-matter interactions at the nanoscale and the emergence of coherent light at the few-photon level, the study illustrates the potential of such a platform for a number of practical uses, such as small-footprint, low-threshold coherent emitters for photonic integrated circuits, lab-on-a-chip light sources, and biocompatible light emitters that are suitable for single-cell optogenetic experiments.

FUNDING

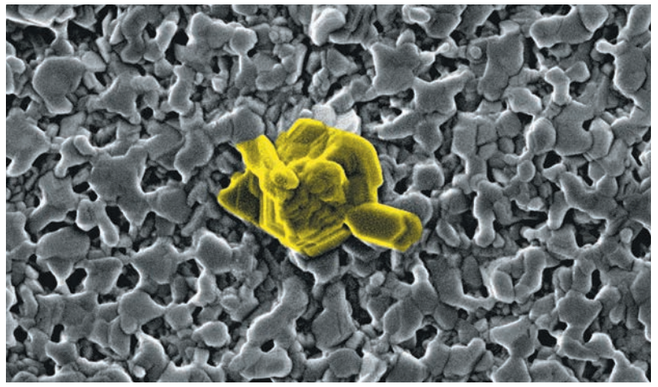
- German Research Foundation
- European Research Council
- Swiss National Science Foundation

REFERENCE

S. T. Jagsch, N. Vico Triviño, F. Lohof, G. Callsen, S. Kalinowski, I. M. Rousseau, R. Barzel, J.-F. Carlin, F. Jahnke, R. Butté, C. Gies, A. Hoffmann, N. Grandjean, and S. Reitzenstein. **A quantum optical study of thresholdless lasing features in high-β nitride nanobeam cavities**. *Nature Communications* **9**, 564 (08 February 2018). DOI: 10.1038/s41467-018-02999-2

ISIC

Revealing the hidden path of perovskite formation



Scanning electron microscope (SEM) image showing the formation of methylammonium lead iodide perovskite ($CH_3NH_3PbI_3$) by the reaction of lead iodide (PbI_2) films with methylammonium iodide (CH_3NH_3I) solution for 2 seconds in the dark. The growth of a PbI_2 crystal (highlighted in yellow) from the partly amorphous PbI_2 film is visible. Image shows an area of 2.77 microns x 2.08 microns.

EPFL scientists systematically study the path of the sequential deposition reaction used to build perovskite solar panels. The study offers much-needed, fundamental understanding of perovskite formation and its different stages.

Perovskite solar cells are an alternative to conventional silicon solar cells, poised to enter the market with their high power-conversion efficiencies (above 22% now) and lower capital expenditure and manufacturing costs. One of the main methods for depositing perovskite films onto panel structures is a process known as sequential deposition, which was developed in 2013 by Michael Grätzel and coworkers at EPFL. Many studies have attempted to control this process with additives, compositional changes, and temperature effects. However, none of these have provided a complete understanding of the entire sequential deposition reaction. This prevents adequate control over film quality, which determines the performance of the solar cell.

A study by **Michael Grätzel** and Amita Ummadisingu at EPFL now offers the most systematic and full study of the sequential deposition reaction to-date. The scientists began with X-ray diffraction analysis and scanning electron microscopy (SEM) to study in depth the crystallization of lead iodide (PbI_2), which is the first stage of the reaction. They then used, for the first time, SEM-cathodoluminescence imaging to study the nano-scale dynamics of perovskite film formation.

"We have combined two powerful tools to obtain compositional information about the surface of the film during perovskite formation," says Ummadisingu. "This technique enables us to achieve stunning nano-scale resolution meaning that we can see, for the first time, that mixed crystalline aggregates composed of perovskite and PbI_2 are formed during the reaction."

Next, the scientists used cross-sectional photo-luminescence mapping, which revealed the directionality of the conversion reaction. This kind of information has so far been unattainable with standard surface imaging because layers lying beneath one another are inaccessible. But with the aid of state-of-the-art hybrid high-definition photon detectors, the researchers were able to simultaneously image PbI_2 and perovskites in these cross-sections. "We identified trapped, unreacted PbI_2 inside the perovskite film using this technique, which is very useful," says Ummadisingu.

"Our findings finally answer several open questions regarding the location and role of residual PbI_2 in perovskite solar cells," says Grätzel. "On a broader note, our innovative demonstration of this technique's uses opens the door for understanding the properties of perovskites in vertical cross sections of solar cells, not just the perovskite surface as currently shown in the literature."

FUNDING

- Swiss National Science Foundation (SNSF)

REFERENCE

A. Ummadisingu, M. Grätzel, **Revealing the detailed path of sequential deposition for metal halide perovskite formation.** *Science Advances* **4**, e1701402 (02 February 2018). DOI: 10.1126/sciadv.1701402

ISIC

The world's first formic acid-based fuel cell

Gabor Laurenczy
© E. Barraud/EPFL

Scientists at EPFL's Institute of Chemical Sciences and Engineering and GRT Group have built the world's first integrated power supply unit that can produce electricity from formic acid, using a fuel cell in an energy-efficient, safe, cost-effective, and sustainable way.

When it comes to renewable energy storage solutions, hydrogen is one of the most promising energy carriers. Using hydrogen to produce heat or electricity produces no carbon or particle emissions, meaning that it has no negative environmental impact. The problem is that hydrogen has a very low energy content by volume. This makes it very difficult to store and transport in its natural form (gas).

The alternative solution is to use a hydrogen carrier such as formic acid, which is the simplest combination of hydrogen and CO_2. One liter of formic acid can carry 590 liters of hydrogen. This is the basis for the project carried out by GRT Group, a company that focuses on energy transition with energy-storage development solutions, and Professor **Gabor Laurenczy**'s research group at EPFL, who have developed a new, integrated formic acid-hydrogen fuel cell device.

EASY TO STORE AND TRANSPORT

Formic acid is liquid at normal conditions, easy to store, transport, and handle, and is produced from sustainable sources in hundreds of thousands of tons globally: it is already used widely in agriculture, and the leather, rubber, chemical, and pharmaceutical industries.

The device used to extract the hydrogen from formic acid consists of two main parts, a hydrogen reformer (HYFORM) and a proton-exchange membrane fuel cell (PEMFC). The reformer uses a ruthenium-based catalyst to extract hydrogen, although the scientists are currently developing catalysts based on even cheaper materials.

This unit can produce 7000 kWh yearly, and its nominal power is 800 Watts – roughly the equivalent of 200 smartphones being recharged simultaneously. Its electrical efficiency is currently up to 45%. As long as the formic acid used is produced sustainably, the fuel cell is completely environmentally friendly and allows long-term storage of renewable energy. It is quiet, emits clean gas, has zero carbon dioxide balance, and produces neither particles nor nitrogen oxides.

At the same time, the HYFORM-PEMFC is low-maintenance, needing no sulfur treatment, and features stable and long-term catalyst performance. Its technology is scalable, so it can be used in both households and industrial settings. Since it only needs to be fueled with formic acid, the system does not require connection to power grids, which makes it ideal for remote or inaccessible areas.

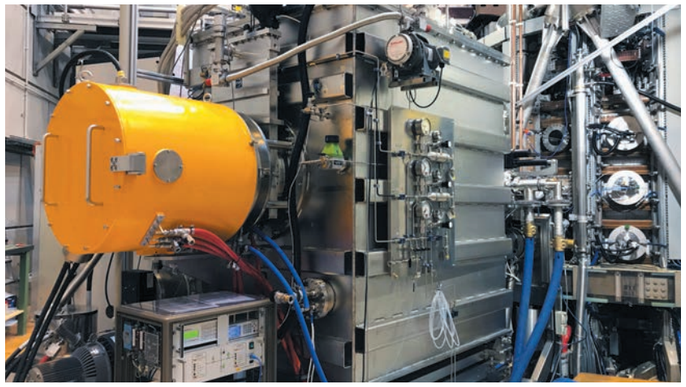
"The chemical transformation of CO_2, a greenhouse gas, into useful products becomes increasingly important as its atmosphere levels continue to rise because of human activity," says Laurenczy. "For this reason, producing formic acid in a sustainable way – using CO_2 as a hydrogen-energy vector – is very important. Worldwide demand for formic acid is growing, especially in the context of renewable energy. Hydrogen carriers, and their production from CO_2, either through hydrogenation or from bio-waste or biomass, are considerably more sustainable than existing routes."

The HYFORM-PEMFC is the result of a project co-financed by the Swiss Federal Office of Energy and GRT Group.

FUNDING
- **SNSF**
- **GRT Group**

IPHYS - SPC

A fruitful year of TCV tokamak operation



Neutral beam system to heat fusion plasmas in the tokamak TCV
© SPC

The largest fusion energy experimental facility on the EPFL campus, the "Tokamak à Configuration Variable" (TCV) at the Swiss Plasma Center, had a very intense operational period during 2018, with experiments conducted both in the frame of the EUROfusion Consortium, which significantly funds these experiments, and for its own domestic program, of which an important fraction is devoted to PhD students. Thousands of plasma discharges of a few seconds were achieved, in which matter hotter than the core of the sun was created, confined, controlled and studied. The TCV research program ranges from conventional to advanced-tokamak scenarios and alternative divertor configurations, exploiting the device's unique shaping capabilities. New results were obtained on how to control in real-time instabilities that can lead to disruptions, sudden losses of plasma confinement that could be deleterious for reactors, and on how to use gas injection to dissipate the runaway electrons that could still result from these violent events. The new 1-MW Neutral Beam Injector has expanded the parameter range, now encompassing plasma scenarios that are akin to those foreseen for the ITER fusion reactor project, and stationary discharges sustained by the current driven by electron cyclotron waves and neutral beams.

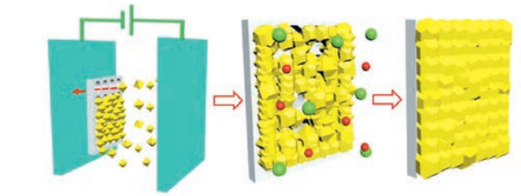
It was observed that turbulence is reduced in the core of plasmas with negative triangularity, i.e. with an inverted D-shape. This is consistent with increased confinement and in accord with global gyrokinetic numerical simulations, and confirms the potential of these plasma shapes to improve the tokamak fusion performance. Crucial questions were also addressed on the dynamics and control of the plasma edge, the region of interface between the hot plasma core and the surrounding material walls.

Plasma detachment from the walls, energy and particle transport, and turbulence were studied in standard and alternative edge magnetic configurations. Among the latter, we created and preliminarily investigated in TCV the so-called doublet, in which a large, relatively cold plasma mantle surrounds two separate plasma channels, independently heated and controlled.

A major shutdown is presently ongoing to implement infrastructure upgrades that will further enhance the capabilities of the TCV tokamak to investigate crucial issues for ITER, DEMO and the fusion reactor. An important element of the TCV upgrade plan is the construction of an in-vessel structure with mechanical baffles, several gas injection valves and an enhanced pumping system, together with an updated set of diagnostic systems. This will create a divertor volume of variable closure with a high degree of control of the plasma and neutral gas conditions. The divertor upgrade will also capitalise on the installation of additional, multi-MW electron cyclotron wave and neutral beam heating systems. This will enable us to investigate important aspects of the plasma exhaust issue in conventional, i.e. ITER-like, and innovative magnetic configurations for DEMO, the step that will demonstrate the industrial potential of fusion power plants.

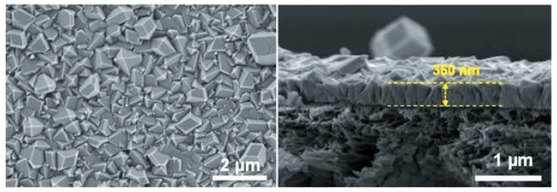
ISIC

Metal-organic frameworks cut energy consumption of petrochemicals



Electrophoretic nuclei assembly for an energy-efficient separation membrane

© K.V. Agrawal/EPFL



Ultrathin MOF membrane on commercial polymer support

© K.V. Agrawal/EPFL

Chemical Engineers at EPFL have developed a new method for making metal-organic framework membranes that can be used to considerably improve energy-expensive processes such as propylene-propane separation, which accounts for 40% of energy used in the global petrochemical industry.

In the chemical and the petrochemical industries, separating molecules in an energy-efficient way is one of the most important challenges. Overall, the separation processes account for around 40% of the energy consumed in the petrochemical industry, and reducing this can help addressing anthropogenic carbon emissions.

One of the most important products in the petrochemical industry is propylene, which is widely used in fibers, foams, plastics etc. Purifying propylene almost always requires separating it from propane. Currently this is done by cryogenic distillation, where the two gases are liquefied by being cooled to sub-zero temperatures. This gives the propylene-propane separation process a very large energy footprint.

A solution is to use "metal-organic frameworks" (MOF's). These are porous, crystalline polymers made of metal nodes that are linked together by organic ligands. The pores in their molecular structure allow MOFs to capture molecules so efficiently that they are now prime candidates in carbon-capture research.

In terms of separating molecules, MOF-based membranes are among the highest performers, and can carry out the propylene-propane separation at ambient temperature. One MOF called ZIF-8 (zeolitic imidazolium frameworks-8), allows propylene to diffuse through its pores 125 times more efficiently than propane at 30°C, offering high selectivity without the need for sub-zero temperatures.

"The main challenge with this approach is to synthesize high-quality, ultrathin, MOF films on commercial porous substrates without complicated substrate modifications," says Professor **Kumar Varoon Agrawal**. "Such high-quality films have fewer defects and are necessary for obtaining the highest possible separation selectivity." His lab at EPFL Valais Wallis has now developed a straightforward MOF crystallization approach called *"electrophoretic nuclei assembly for crystallization of highly-intergrown thin-films"* (ENACT).

The ENACT method allows simple regulation of the heterogeneous nucleation on unmodified (as-obtained) porous and nonporous substrates. This in turn facilitates the synthesis of ultrathin, highly intergrown polycrystalline MOF films.

The lab used the ENACT method to synthesize 500-nm-thick MOF membranes. When they tested them, the membranes yielded one of the best separation performances in propylene/propane separation recorded to date. The ultrathin film yielded large propylene permeance (flux normalized with pressure difference), which will help reduce the membrane area needed for industrial applications.

The group concludes that the versatile, straightforward ENACT method can be extended to a wide-range of nanoporous crystals.

FUNDING

- **European Union (Horizon 2020)**

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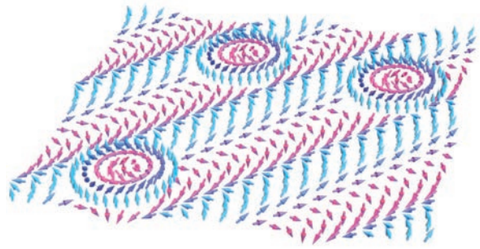
G. He, M. Dakhchoune, J. Zhao, S. Huang, K. V. Agrawal. **Electrophoretic Nuclei Assembly for Crystallization of High Performance Membranes on Unmodified Supports.** *Advanced Functional Materials*, 12 March 2018. DOI: 10.1002/adfm.201707427

IPHYS

Controlling skyrmions with lasers



EPFL scientists have produced controllable stable skyrmions using laser pulses, taking a step towards significantly more energy-efficient memory devices.

A skyrmion is a collection of electron spins that look like a vortex in certain magnetic materials. Skyrmions can exist individually or in patterns referred to as lattices. Named after British physicist Tony Skyrme who first theorized the existence of their elementary-particle counterparts in 1962, skyrmions have attracted attention for their potential in being used in so-called "spintronic" devices, which would use the spin rather than the charge of electrons, thus becoming significantly more miniaturized and energy-efficient.

Most interest has been focused on memory-storage technologies. Skyrmions can be rather stable and require very little energy for writing or erasing them: some studies have shown that creating and annihilating skyrmions could be almost 10,000 times more energy-efficient than conventional data-storage devices. However, this would require a fast and reliable way of controlling and manipulating individual skyrmions.

Now, the labs of **Fabrizio Carbone** and **Henrik M. Rønnow** at EPFL's Institute of Physics have been able to write and erase stable skyrmions using laser pulses. The scientists used an iron-germanium alloy, which can host skyrmions at around 0°C, not too far from room temperature. This is important, since many of these fundamental experiments usually take place at temperatures too low to ever be commercially meaningful.

The researchers took advantage of the supercooling effect that follows an ultrafast temperature jump, which is itself induced in the alloy by an ultrashort laser pulse. During the supercooling, skyrmions can be frozen-in in places where they would not occur in conventional equilibrium conditions.

The forming skyrmions were imaged by using time-resolved cryogenic Lorentz electron microscopy, which can "see" magnetic domain structures and magnetization reversal mechanisms in real space and real time. This technique is an evolution of static cryo-electron microscopy, for which Jacques Dubochet won the Nobel Prize in Chemistry in 2017.

"What we did was apply a laser pulse to the alloy while it was kept at a temperature and external magnetic field that normally forbids the appearance of skyrmions," says Fabrizio Carbone. "Individual skyrmions were seen to appear near the edges of the sample at every light flash. Furthermore, once the skyrmions were established, by adjusting the parameters in proximity to the transition between having the skyrmions and not having them anymore, laser pulses can be used to erase them via local heating-induced demagnetization."

The researchers were able to write and erase skyrmions on the alloy within a few hundred nanoseconds to a few microseconds. However, the results also suggest routes to engineer the super-cooling rates for faster control of the skyrmions, down to picoseconds.

"The energy barriers for manipulating skyrmions can be very small," says Carbone. "This means that, if this was a memory-storage device, the energy consumption estimated by our experiments, in which the light properties were not yet tailored to optimize this parameter, is in the region of femtojoules (quadrillionths of a joule) per bit, already comparable to the most energy-efficient prototypes available."

Despite being a proof-of-principle study, the researchers couldn't resist thinking in terms of applications. "We actually calculated the energy it requires, without any optimization in our experiment," says Carbone. "And we found that it was already at the level of the least energy-consuming data-storage device to-date. If implemented into devices, this would mean something like your laptop's battery lasting for about a month before needing to charge."

CONTRIBUTORS

- **University of Glasgow**
- **Osaka Prefecture University**
- **Hiroshima University**
- **EPFL Interdisciplinary Centre for Electron Microscopy (CIME)**

FUNDING

- **NCCR MUST**
- **Swiss National Science Foundation (Ambizione and Advanced Postdoc Mobility grants)**

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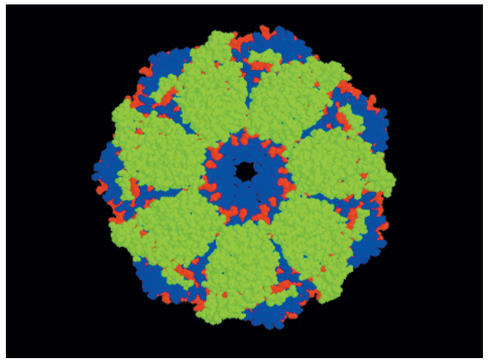
IPHYS

Chaperones can hold proteins in non-equilibrium states



A top-view of the GroES/GroEL bacterial chaperone complex model © Wikipedia

Chaperones are specialized proteins in the cell that help other proteins to reach their functional 3D shapes, which correspond to the states preferred at thermodynamic equilibrium. But a new study by EPFL, UNIL and INSERM (France) scientists shows that chaperones can also maintain proteins in non-equilibrium states, potentially altering their fate.

After translation, proteins must fold to their functional 3D shape and keep it while under attack by various perturbations: external stress such as temperature changes, wrong interactions with other proteins in the cell, and even deleterious mutations. To ensure that proteins stay functional, the cell uses a particular class of proteins, the chaperones. These are present in all organisms and are among the most abundant proteins in cells, emphasizing how crucial they are to sustain life.

The current view is that the functional 3D shape of a protein is also its most thermodynamically stable state, and that chaperones help proteins reach this state by keeping them from aggregating and by allowing them to escape so-called "kinetic traps" – points where the protein may get "stuck" in a non-functional state. And to do all this, chaperones need energy, which in the cell comes in the form of adenosine triphosphate, or ATP.

The labs of **Paolo De Los Rios** at EPFL and Pierre Goloubinoff at UNIL, in collaboration with Alessandro Barducci (INSERM – Montpellier), have now shown that the energy from ATP is used by chaperones to actively maintain the proteins they are working on in a non-equilibrium but transiently stable version of the functional form, even under conditions upon which the functional form should not be thermodynamically stable.

"What we found is that chaperones can actively repair and revert the proteins they act upon in a non-equilibrium steady-state," says De Los Rios. "In this state, the proteins are in their native state even if, from an equilibrium thermodynamics perspective, they should not."

The researchers combined theoretical and experimental approaches to prove that chaperones are molecular motors, capable of performing work and extending the stability range of proteins. The results may challenge parts of the prevalent view that evolution has designed amino acid sequences so that the functional state of the protein they belong to is thermodynamically optimal.

"In the presence of chaperones, even thermodynamically sub-optimal proteins might be able to reach their functional form, facilitating evolution in its endless exploration of chemical possibilities," says De Los Rios.

FUNDING

- **Swiss National Science Foundation (SNSF)**
- **Swiss State Secretariat for Education Research and Innovation**
- **French Agence Nationale de la Recherche (ANR)**

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ISIC

Removing heavy metals from water

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EPFL chemists have developed a new material that can remove heavy metals from water and make it drinkable in seconds.

According to the World Health Organization almost 1 billion people do not have access to clean drinking water, and that number is expected to increase with climate change. Meanwhile, our endlessly rising energy needs and use of heavy metals in industrial processes have maximized our exposure to toxic materials in water.

Current commercial methods to remove heavy metals including lead from municipal drinking water tend to be costly and energy-consuming, without being sufficiently efficient. Less conventional approaches might be more efficient, but are single-use, difficult to regenerate, or produce significant toxic waste as a side-product.

Now, the lab of Professor **Wendy Lee Queen** at EPFL's Institute of Chemical Sciences and Engineering, with colleagues at the University of California Berkeley and Lawrence Berkeley National Laboratory have found a solution using metal organic frameworks (MOFs), which are materials made up of metal nodes interlinked by organic chemical "struts". Their unprecedented internal surface areas and easy chemical tunability allow MOFs to "pull" water vapor and other gases from air. These same features make them promising materials also for selectively removing heavy metals from water.

A PhD student at EPFL Valais Wallis, Daniel T. Sun, has designed a water-stable MOF/polymer composite using cheap, environmentally and biologically friendly materials. The scientists treated a MOF, known as Fe-BTC, with dopamine, which polymerized to polydopamine (PDA) pinning the polymer inside the MOF.

The final composite, named Fe-BTC/PDA, can quickly and selectively remove high amounts of heavy metals like lead and mercury from real-world water samples. In fact, it can remove over 1.6 times its own weight of mercury and 0.4 times of its weight of lead.

Fe-BTC/PDA was then tested in solutions as toxic as some of the worst water samples found in Flint, Michigan. The tests showed that the MOF can, in a matter of seconds, reduce lead concentrations to 2 parts per billion, a level that the U.S. Environmental Protection Agency and World Health Organization deem drinkable.

The scientists also removed lead from various real-world water samples obtained from the Rhone River, the Mediterranean Sea, and a wastewater treatment plant in Switzerland. They also showed how the material could be regenerated easily.

There are multiple sources of exposure to toxic heavy metals. For example, lead is used in paint, ceramic glazes, jewelry, toys, and pipes. Considering this, the approach with the new MOF shows much promise for solving current limitations of water-cleaning systems. The authors of the study are now testing other new specially designed MOFs to remove other types of trace contaminants in water and air.

FUNDING

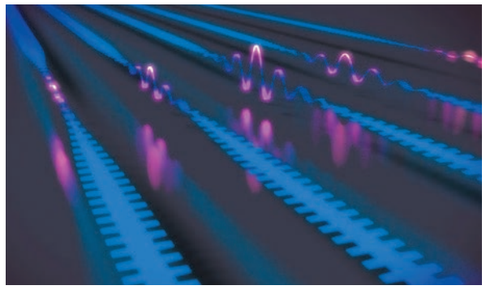
- **Swiss National Science Foundation**
- **German Research Foundation**
- **US Department of Energy**
- **Swiss National Supercomputing Center**

REFERENCE

Daniel T. Sun, Li Peng, Washington S. Reeder, Seyed Mohamad Moosavi, Davide Tiana, David K. Britt, Emad Oveisi, Wendy L. Queen. **Rapid, selective heavy metal removal from water by a metal-organic framework/polydopamine composite.** *ACS Central Science* 14 March 2018. DOI: 10.1021/acscentsci.7b00605

IPHYS

One string to rule them all



Artist's rendition of vibrating nanostrings © Woogieworks

EPFL scientists have engineered a tiny guitar string that vibrates 1 billion times when plucked. They would like to use it as a microphone for light.

Strain can be used to engineer unusual properties at the nanoscale. Researchers in **Tobias Kippenberg**'s lab at EPFL have harnessed this effect to engineer an extremely low loss nanostring. When plucked, the string vibrates for minutes with a period of a microsecond (equivalent to a standard guitar note playing for a month). Using it as an ultrasensitive microphone, the researchers hope to be able to "hear" the sound of photons in a laser beam. The work is published in *Science*.

For a mechanical engineer, stress is usually a nuisance. Properly managed, however, it can also be a powerful tool: An elastic body responds to stress by adjusting the distance between its atoms (strain), which can be used to control the properties of its electrons. One example of such "elastic strain engineering" is the modern transistor, whose operating speed is enhanced by stressing its silicon gate material.

Stress can also be used to engineer the properties of an elastic body. Stretching a guitar string, for example, will change not only its sound (its vibrational frequency), but also its quality factor (the number of vibrations produced by a single pluck). This effect, known as "dissipation dilution," in undesirable in many musical circles, but in other fields can be a tremendous advantage.

One such field is nanomechanics, where the quality factor an oscillator dictates its utility for applications such as force sensing. Over the last decade, strained nanomechanical oscillators have emerged as an important paradigm owing to their anomalously high quality factors; however, this trend is not as much a design choice as an artifact of large stresses naturally produced at the nanoscale.

Armed with a powerful set of tools at EPFL's Center of MicroNanoTechnology, researchers in Kippenberg's lab set about engineering nanomechanical devices with deliberately enhanced stress and dissipation dilution. They found that a string is an ideal geometry for this, although its motion must be localized away from its supports and co-localized with its internal stress profile. To meet these requirements, the researchers patterned the string into a periodic structure in which vibrations could be trapped around a central defect: a phononic crystal. To co-localize strain, the defect is carefully tapered, and the entire pattern is printed onto a string of roughly 10 nm thick and 1 cm long (the equivalent of stretching the Golden Gate bridge across the Pacific ocean).

Measurements made on nanostring devices at room temperature reveal localized modes that vibrate at 1 MHz for tens of minutes, corresponding to a quality factor of 800 million. Transposed onto a standard guitar string, an equivalent "note" would play for a month.

By dint of their small mass and extreme quality factors, nanostrings similar to those developed in the Kippenberg lab are expected to have an important impact on traditional sensing applications. One intriguing application is to detect weak light forces. By coupling a nanostring to an optical waveguide, Kippenberg's lab recently demonstrated the ability to "hear" the gentle sound of photons flowing in a laser beam (each imparting a tiny radiation pressure force to the string). In a surprising twist, they showed how this measurement could be used to generate a nonclassical state of light known as squeezed light, which can be used to enhance the sensitivity of an optical interferometer.

They are now asking a different question: is it possible to use the same light field to "see" the vacuum fluctuations of the nanostring (a consequence of its *phonon*-like nature)? "Heisenberg's uncertainty principle predicts that the two capabilities are commensurate," says Dalziel Wilson, one of the paper's authors. "Operating at this so-called standard quantum limit offers the possibility of cooling a tangibly-sized mechanical object from room temperature to absolute zero (its motional ground state), the starting point for myriad quantum experiments."

FUNDING

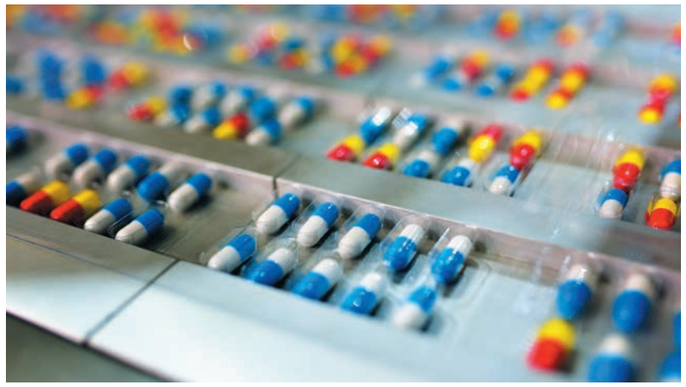
EU Horizon 2020 Research and Innovation Program
SNF Cavity Quantum Optomechanics
MSCA ETN-OMT
ERC AdG (QuREM)

REFERENCE

A. H. Ghadimi, S. A Fedorov, N. J. Engelsen, M. J. Bereyhi, R. Schilling, D. J. Wilson, T. J. Kippenberg. **Elastic Strain Engineering for Ultra-Low Mechanical Dissipation.** *Science* 12 April 2018. DOI: 10.1126/science.aar6939

ISIC

Light and copper catalysis improve amine synthesis



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EPFL chemists have developed a novel and efficient method to make amines, which are among the most important structural compounds in pharmaceuticals and organic materials.

Amines are molecules that contain a basic nitrogen atom. They are derived from ammonia, where one or its hydrogen atoms has been replaced with a carbon group, most commonly an aryl (ring-structured hydrocarbons) or alkyl group.

Amines are used widely in bioactive molecules, drugs, and various organic materials, and preparing them is one of the most important tasks for synthetic chemists in both academia and industry. While many methods are now available for synthesizing amines containing aryl groups, the synthesis of amines containing alkyl groups still pose a challenge.

Now, the lab of **Xile Hu** at EPFL's Institute of Chemical Sciences and Engineering has developed a new method that can efficiently produce alkyl amines by using photocatalysis alongside copper catalysis. The photocatalysis allowed the chemists to start with alkyl redox-active esters instead of the usual alkyl halides, which are limited in terms of availability, stability, and are sometimes toxic.

The esters can be easily prepared from alkyl carboxylic acids, which are readily available, stable, and non-toxic. The copper catalysis was then used to link the alkyl unit generated in photocatalysis with a nitrogen-containing coupling partner to generate alkyl amines.

"Although metal-catalyzed cross coupling reaction has completely revolutionized the synthesis of aryl amines, it can hardly be used to synthesize alkyl amines," says Hu. "The reason is that the necessary metal alkyl intermediates tend to decompose, and the alkyl-nitrogen ligation becomes difficult."

The work provides a new and efficient approach for the synthesis of alkyl amines, which has potential applications in the pharmaceutical and fine chemical industries. It offers high selectivity, compatibility with a large number of functional groups, and broad scope. In addition, the reactions are carried out at an ambient temperature, much milder than traditional methods. "And because many amino acids, natural products, and pharmaceuticals contain the alkyl carboxylic acid structural motif, our method can be used to rapidly functionalize these molecules," says Hu.

The researchers also provided over 50 examples where their new method is used for the synthesis of a diverse set of alkyl anilines with high chemoselectivity and functional group compatibility.

FUNDING

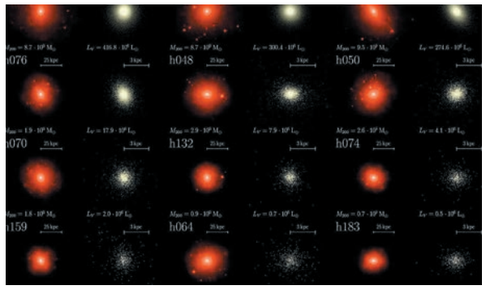
- **European Union (Horizon 2020 Program NoNoMeCat Marie Skłodowska-Curie training network)**

REFERENCE

Runze Mao, Adrian Frey, Jonathan Balon, Xile Hu. **Decarboxylative C(sp3)–N cross-coupling via synergetic photoredox and copper catalysis.** *Nature Catalysis* 07 February 2018. DOI: 10.1038/s41929-017-0023-z

IPHYS

Studying dwarf galaxies to get the big picture



Calalog of the studied dwarf galaxies' haloes © 2018 EPFL/LASTRO

EPFL scientists have completed the fastidious task of analyzing 27 dwarf galaxies in detail, identifying the conditions under which they were formed and how they've since evolved. These small-scale galaxies are perfect for studying the mechanisms of new star formation and the very first steps in the creation of the universe.

Dwarf galaxies don't emit much light and are therefore hard to observe, but they have a lot to teach us about how the universe was created. Scientists from EPFL's Laboratory of Astrophysics (LASTRO) meticulously studied 27 such galaxies and found a surprising degree of variation in the mechanisms by which their stars were formed. The results of their painstaking work was published in *Astronomy & Astrophysics*.

"Dwarf galaxies are the smallest and probably the oldest galaxies in the universe. Under standard cosmology theory, larger galaxies are formed by the merger of these smaller ones," says Yves Revaz, a galaxy dynamics expert at LASTRO.

While they may be called "dwarves," they are in fact huge and can weigh anywhere between hundreds of thousands and several million times as much as the sun. They are also the galaxies with the most dark matter. The LASTRO team therefore had to develop highly sophisticated computer models to study these galaxies' properties, size and temporality – all of which go well beyond our basic understanding.

Their models take into account each of the galaxies' components – gases, stars and dark matter – as well as the relationship between dark matter and visible matter (called "baryonic matter" in astrophysics). The models also factor in the conditions under which matter was formed when the universe was first created some 14 billion years ago – conditions that are now known thanks to recent space missions carried out to discover the signatures of the Big Bang.

To analyze the dwarf galaxies, the scientists first took each model and went step by step through the galaxies' key characteristics like how much gas (mainly hydrogen) they contain, the heating and cooling of their interstellar mediums, their compression and expansion processes, the successive generations of their stars, those stars' supernovae, and the resulting release of an array of chemicals. The scientists then compared the results of their models with data obtained by observing dwarf galaxies – more specifically, those orbiting our galaxy, the Milky Way, and its neighboring galaxy, Andromeda (M31) – using eight-meter optical telescopes, the biggest out there. These dwarf galaxies form part of what is called the Local Group and are close enough for astrophysicists to be able to obtain accurate information on the ages and chemical components of individual stars.

This is the first time that dwarf galaxies have been examined in such detail and under cosmologic conditions – that is, not by considering them as isolated systems but rather by taking into account all the interactions among the very first galactic systems.

"The advantage of dwarf galaxies is that they respond very well to even minor changes in conditions, making them excellent guinea pigs for studying galaxies in general," says Professor **Pascale Jablonka**, a co-author of the study. For instance, by analyzing the light that stars emit, she was able to determine their chemical composition and how long it took them to form.

"Our models enabled us to create a database of many different types of stellar activity and gave us valuable insight into the factors that can cause star formation to speed up, slow down or even stop altogether," says Revaz.

Based on the data they collected – which include an impressive number of different star-formation mechanisms given how "small" dwarf galaxies are – the LASTRO team found that the specific mechanism used depends on the density of the galaxy's dark and baryonic matter. If a dwarf galaxy's matter is too dispersed, then its hydrogen will get too hot and evaporate, meaning it can no longer form stars. If on the other hand a dwarf galaxy has a dense halo of dark matter protecting it, then star formation will continue apace.

REFERENCE

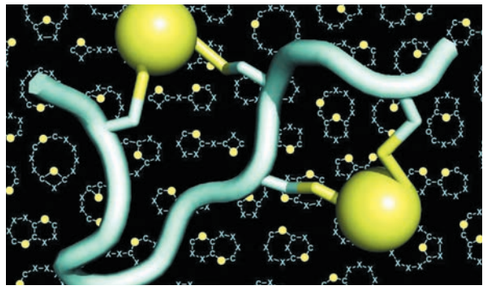
Yves Revaz and Pascale Jablonka: Pushing back the limits: detailed properties of dwarf galaxies in a LCDM universe, EPFL

SCIENTIFIC ARTICLE: **https://arxiv.org/abs/1801.06222**

MORE SIMULATIONS: **https://lastro.epfl.ch/page-153441.html**

ISIC

Double-bridged peptides bind any disease target



A model of a double-bridged peptide (the peptide in light blue, the two bridges in yellow). The background of the figures shows many examples of skeletons (also named "scaffolds" or "backbones") of double-bridged peptides © C. Heinis/EPFL

EPFL scientists have developed a new type of "double-bridged peptide" that can be tailored to bind tightly to disease targets of interest. The peptides' highly efficient binding, combined with their small size and high stability make them ideal for drug therapies.

Peptides are short chains of amino acids that can bind to proteins and change their function. They show high binding affinity, low toxicity, and are easy to synthesize, all of which makes peptides ideal for use in drug development, and many naturally occurring peptides such as insulin, oxytocin, somatostatin and the antibiotics vancomycin or polymyxin B, are already successfully used like that.

However, using peptides as drugs faces two challenges. First, binding affinity: Good binding requires difficult peptide architectures and amino acid sequences that are perfectly complementary in shape and charge to the surface of their target proteins. Second, peptide stability: peptides can potentially be cut by enzymes (proteases) into smaller and useless fragments or even single amino acids.

The lab of **Christian Heinis** at EPFL's Institute of Chemical Sciences and Engineering has now addressed both of these challenges by developing the new peptide format that they call "double-bridged peptides". These are chains of 10-15 amino acids, four of which are chemically connected by two bridges. Each bridge links a pair of two cysteine amino acids – four in total.

Because the four cysteines can be placed in many different ways along the sequence of amino acids, the double-bridging strategy allowed the researchers to generate an enormously large number of structurally diverse peptide architectures. They expanded the diversity even further by using different chemical reagents that increased the number of bridges. The scientists also found that the four cysteines could be bridged by two linkers in three different ways, giving rise to three different architectures from each single peptide sequence.

Using this strategy, the researchers produced an enormous diversity of peptide structures, all with different "skeleton" structures. In addition, the chemists systematically changed the amino acids between the cysteines and generated libraries of billions of different double-bridged peptides. After screening the libraries, the researchers were able to isolate high-affinity binders to important protein targets.

One of these targets was kallikrein, a plasma protein associated with hereditary angioedema, a rare swelling disorder. Another was interleukin-17, a cytokine protein implicated in several inflammatory disorders such as rheumatoid arthritis and psoriasis. Using the double-bridge approach for both these protein targets, the scientists developed peptides that could bind them efficiently at nanomolar concentrations. In the case of kallikrein, the peptides could bind it for more than an hour before dissociating.

Stability was also a highly attractive feature of the new peptide format. The double-bridged peptides are hardly degraded by proteases in the blood, which is a great advantage because it keeps the peptides from being eliminated too quickly, thus extending their therapeutic effects.

Based on the results, Heinis's lab is now applying the peptide format to many other disease targets. They have already developed new, even larger double-bridged peptide libraries and screened them against a range of disease-relevant targets. One of these peptides is already undergoing pre-clinical evaluation.

FUNDING

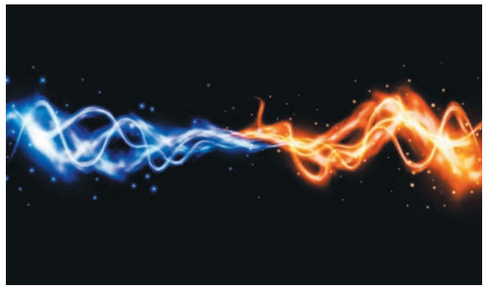
- **Swiss National Science Foundation (NCCR Chemical Biology)**

REFERENCE

Sangram S. Kale, Camille Villequey, Xu-Dong Kong, Alessandro Zorzi, Kaycie Deyle, Christian Heinis. **Cyclization of peptides with two chemical bridges affords large scaffold diversities.** *Nature Chemistry* 30 April 2018. DOI: 10.1038/s41557-018-0042-7

IPHYS

Detecting the birth and death of a phonon



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EPFL physicists have developed a new technique to probe elementary quantum excitations of atomic vibrations inside a diamond crystal under ambient conditions. The technique uses ultra-short laser pulses and detectors sensitive to single photons.

Phonons are discrete units of vibrational energy predicted by quantum mechanics that correspond to collective oscillations of atoms inside a molecule or a crystal. When such vibrations are produced by light interacting with a material, the vibrational energy can be transferred back and forth between individual phonons and individual packets of light energy, the photons. This process is called the Raman effect.

In a new study, the lab of **Christophe Galland** at EPFL's Institute of Physics has developed a technique for measuring, in real time and at room-temperature, the creation and destruction of individual phonons, opening exciting possibilities in various fields such as spectroscopy and quantum technologies.

The technique uses ultra-short laser pulses, which are bursts of light that last less than 10^{-13} seconds (a fraction of a trillionth of a second). First, one such pulse is shot onto a diamond crystal to excite a single phonon inside it. When this happens, a partner photon is created at a new wavelength through the Raman effect and is observed with a specialized detector, heralding the success of the preparation step.

Second, to interrogate the crystal and probe the newly created phonon, the scientists fire another laser pulse into the diamond. Thanks to another detector, they now record photons that have reabsorbed the energy of the vibration. These photons are witnesses that the phonon was still alive, meaning that the crystal was still vibrating with exactly the same energy.

This is in strong contradiction with our intuition: we are used to seeing vibrating objects progressively lose their energy over time, like a guitar string whose sound fades away. But in quantum mechanics this is "all or nothing": the crystal either vibrates with a specific energy or it is in its resting state; there is no state allowed in between. The decay of the phonon over time is therefore observed as a decrease of the probability of finding it in the excited state instead of having jumped down to the rest state.

Through this approach, the scientists could reconstruct the birth and death of a single phonon by analyzing the output of the two photon detectors. "In the language of quantum mechanics, the act of measuring the system after the first pulse creates a well-defined quantum state of the phonon, which is probed by the second pulse," says Christophe Galland. "We can therefore map the phonon decay with very fine time resolution by changing the time delay between the pulses from zero to a few trillionths of a second (10^{-12} seconds or picoseconds)."

The new technique can be applied to many different types of materials, from bulk crystals down to single molecules. It can also be refined to create more exotic vibrational quantum states, such as entangled states where energy is "delocalized" over two vibrational modes. And all this can be performed in ambient conditions, highlighting that exotic quantum phenomena may occur in our daily life – we just need to watch fast enough to see them.

FUNDING

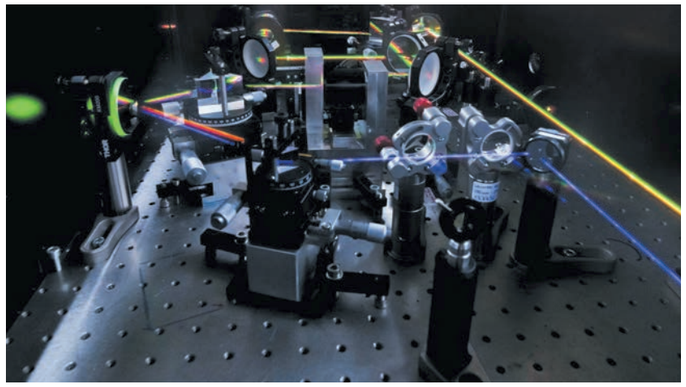
- **Swiss National Science Foundation (SNSF)**

REFERENCE

Mitchell D. Anderson, Santiago Tarrago Velez, Kilian Seibold, Hugo Flayac, Vincenzo Savona, Nicolas Sangouard, Christophe Galland. **Two-color pump-probe measurement of photonic quantum correlations mediated by a single phonon.** *Physical Review Letters* **120**, 233601 (2018). DOI:10.1103/PhysRevLett.120.233601

ISIC

Titanium dioxide as a nanoscale sensor of mechanical stress



The ultrafast two-dimensional deep-ultraviolet spectroscopy setup at EPFL used for the experiments on anatase TiO nanoparticles.

© Francesco Pennacchio

Scientists from EPFL, Germany and France have revealed a new property of the cheap and abundant material anatase titanium dioxide, which promises applications as a medium for room-temperature nanosensors of mechanical stress with an optical read-out.

Measuring mechanical stress in the nano-world is a major challenge in materials science and engineering. Key to this advancement is the ability to combine cheap nano-sized materials that react to mechanical stress and simple detection schemes. A promising route would involve the development of sensors with an optical read-out. However, there are no known nano-materials that change their light-absorbing properties upon application of mechanical stress in a simple and predictable way, especially at room temperature. Such materials would be extremely useful in a number of sensing applications, ranging from bioscience to metrology.

In a twist, the lab of **Majed Chergui** at EPFL within the Lausanne Centre for Ultrafast Science, in collaboration with the theoretical groups of Angel Rubio at Max-Planck (Hamburg) and Pascal Ruello at the Université de Le Mans, showed that nanoparticles of the anatase polymorph of titanium dioxide can revolutionize the field.

Titanium dioxide is a cheap and abundant material that is already used in a wide variety of applications such as photovoltaics, photocatalysis, transparent conductive substrates, sunscreen, paints, water and air purification. With their recent discovery, published in Nano Letters, Chergui and his colleagues show that titanium dioxide is the most promising candidate for the development of room-temperature sensors of strain at the nanoscale and with an optical read-out.

In their experiments, the researchers launched a mechanical stress wave inside titanium dioxide nanoparticles at room temperature and monitored their optical response in the vicinity of the main absorption band of the material, called an "exciton". They found that the latter undergoes a change of intensity under the applied mechanical stress. This simple response is at odds with the behavior of all known materials, whose optical responses to mechanical stress are complex and unpredictable. These new findings pave the way to the development of sensors with an optical read-out based on a single laser frequency tuned to the exciton resonance.

Considering that titanium dioxide is already embedded in a large range of devices and that there is broad expertise available for combining it with other systems, these findings promise a new generation of optical sensors of mechanical stress at the nanoscale.

"This observation was made possible thanks to our novel ultrafast laser techniques in the deep-ultraviolet. We expect our experimental method to lead to even more exciting discoveries in the nano-world in the near future," says Edoardo Baldini, first author of the article, now at MIT.

FUNDING

- **Swiss National Science Foundation (NCCR:MUST)**
- **European Research Council (Advanced Grants DYNAMOX and QSped-NewMat)**

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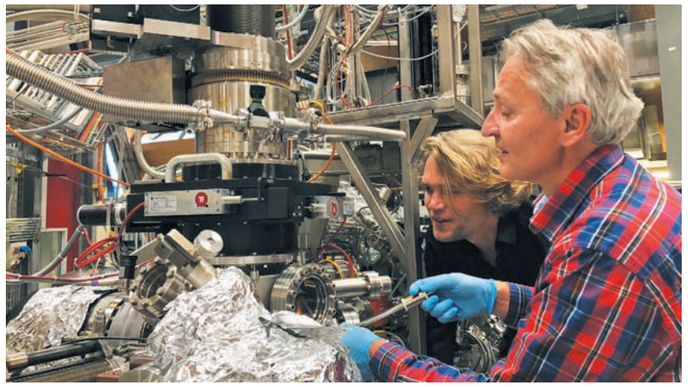
IPHYS

Spintronics: Controlling magnetic spin with electric fields



Hugo Dil and Juraj Krempaský with the experimental set-up at the Paul Scherrer Institut
© H. Dil/EPFL

EPFL physicists have found a way to reverse electron spins using electric fields for the first time, paving the way for programmable spintronics technologies.

Spintronics is a field of physics that studies the spin of electrons, an intrinsic type of magnetism that many elementary particles have. The field of spintronics has given rise to technological concepts of "spintronic devices", which would run on electron spins, rather than their charge, used by traditional electronics.

In order to build programmable spintronic devices we first need to be able to manipulate spins in certain materials. So far, this has been done with magnetic fields, which are not easy to integrate into everyday applications.

In a new set of experiments, an international team of physicists led by **Hugo Dil** at EPFL's Institute of physics have now demonstrated the ability to control what they call "the spin landscape" using electric fields. They accomplished this in a new class of materials based on germanium telluride (GeTe), which is the simplest ferroelectric material operating at room temperature.

The scientists used a technique called spin- and angle-resolved photoemission spectroscopy (SARPES), which can measure the spin of electrons, and has been perfected by Dil's lab. By combining SARPES with the possibility to apply an electric field, the physicists demonstrate electrostatic spin manipulation in ferroelectric α-GeTe and multiferroic (GeMn)Te.

In addition, the scientists were able to follow the spins' switching pathway in detail. In (GeMn)Te, the perpendicular spin component switches due to electric-field-induced magnetization reversal. This provides firm evidence of magneto-electric coupling, which opens up the possibility of programmable semiconductor based spintronics.

"Our previous work showed that magnetic fields can control spins in these materials," says Dil. "And now we've shown that spin manipulation is also possible using electric fields. Our experimental findings open up a promising path to only use electric fields in a spintronics device, strongly reducing the energy consumption."

OTHER CONTRIBUTORS
- **Paul Scherrer Institute**
- **New Technologies-Research Center University of West Bohemia**
- **Kharkiv Polytechnic Institute**
- **University of Regensburg**
- **Pavol Jozef Šafárik University**
- **ETH Zurich**
- **Johannes Kepler Universität**

FUNDING
- **Swiss National Science Foundation (SNSF)**
- **Austrian Science Funds Project**
- **German Research Foundation (DFG)**
- **European Regional Developmental Fund**

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J. Krempaský, S. Muff, J. Minár, N. Pilet, M. Fanciulli, A.P. Weber, E.B. Guedes, M. Caputo, E. Mueller, V.V. Volobuiev, M. Gmitra, C. A. F. Vaz, V. Scagnoli, G. Springholz, and J. H. Dil. **Operando imaging of all-electric spin texture manipulation in ferroelectric and multiferroic Rashba semiconductors.** *Phys. Rev.* X 8, 021067. 18 June 2018. DOI:10.1103/PhysRevX.8.021067

ISIC

Chemical "Caryatids" improve stability of metal-organic frameworks

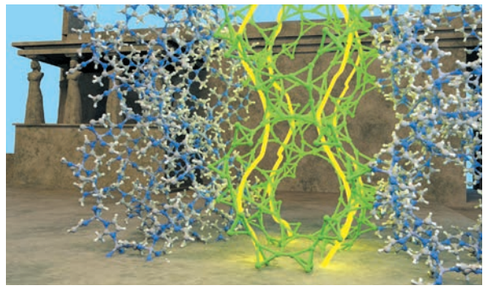

Illustration of the "Chemical Caryatids" © B. Smit/EPFL

Metal-organic frameworks (MOFs) are porous materials that can change the way we capture carbon, filter water, and an array of other applications. EPFL chemists have now found the link between mechanical stability and structure, thus overcoming a significant obstacle in optimizing MOFs.

Metal-organic frameworks" (MOFs) are materials with nano-sized pores in their crystal structure. These pores allow MOFs to capture molecules so efficiently that they are now prime candidates in applications like carbon capture and water filtering.

The challenge with MOFs is their mechanical stability. The materials are vulnerable to physical and chemical stress, which can affect their structure and, ultimately, their performance. Because many MOF applications involve cycling between different temperatures, varying pressures, and other chemical molecules exerting capillary forces, it has become paramount to the field that MOFs feature sufficient mechanical stability.

Now, the lab of **Berend Smit** at EPFL Valais Wallis with Lev Sarkisov of the University of Edinburgh have discovered how the mechanical properties of MOFs relate to their structure, which has long been an obstacle in optimizing the stability of the materials.

For this study, the scientists focused on a popular type of MOFs called "zeolitic imidazolate frameworks", which are used in carbon capture, catalysis, and even some drug delivery strategies. The team developed software that generates chemical structures to design large numbers of these MOFs with different molecular structures. By studying these, they extracted principles that connect the mechanical properties of a MOF to its structure, and design materials with enhanced mechanical stability.

The researchers then "decorated" the organic parts of the MOFs with a variety of functional groups, a term that refers to groups of atoms that give the molecule (in this case, the MOF) specific characteristic properties. This part of the study showed that, depending on the pore structure, the same functional groups can either harden a MOF's structure and enhance its mechanical stability, or soften it and make it unstable.

The key to the effects of functional groups lies in what are called "nonbonded interactions", which occur between atoms with no chemical bonding. Nonbonded interactions include electrostatic and Van der Waals interactions – the latter governs the formation of water droplets.

The EPFL scientists found that nonbonded interactions play an important role in the stiffness of MOFs. This means that strategically placed functional groups can help tune the mechanical stability of a MOF by introducing extra connectivity between its atoms via nonbonded interactions.

The authors describe the functional groups that help carry the mechanical load applied to the MOF as "chemical Caryatids", referring to the statues of women that acted as supporting columns for structures in ancient Greece, most famously those of the Erechtheion on the Acropolis in Athens.

"The addition of a functional group may look a decoration, but if it is strategically placed, it provides an essential reinforcement of the MOF structure," says Berend Smit "In our lab, we have developed the software that experimental groups can use to predict whether adding different functional groups enhances the mechanical stability of their material."

OTHER CONTRIBUTORS
- **University of Edinburgh**
- **University of California Berkeley**

FUNDING
- **European Research Council (ERC) Horizon 2020**

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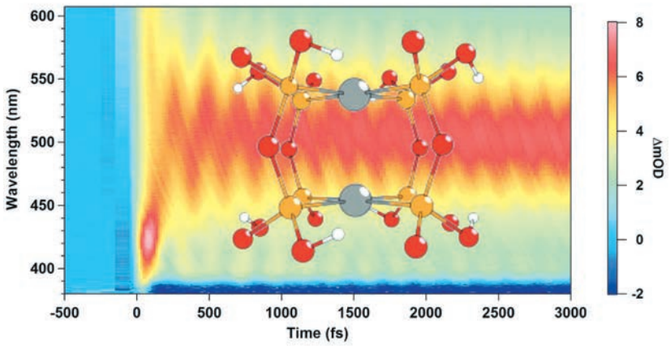
ISIC

Staying coherent while spinning



The diplatinum complex studied by the Chergui group. In the background, evidence for coherent oscillations of the complex in solution

© M. Chergui/EPFL

Scientists from EPFL show that photo-excited polyatomic molecules maintain their coherence in motion while undergoing spin changes within ultrashort timescales.

Electron spin is an important property of molecules. It determines processes such as chemical reactivity, and lifetime of the electron state. Spin is exploited in several applications such as luminescent materials, phototherapy, photochemistry, solar energy conversion, etc. for which bringing the system to a long-lived high spin state is crucial.

When large molecules absorb light their energy dissipates. This happens through several electron states that are characterized by a difference in electron configurations and spins.

In following pathways of energy flow, vibrational coherence plays a crucial role. It is at the birth of femtochemistry, the field that studies chemical reactions on extremely short timescales, approximately 10^{-15} seconds – or one femtosecond. When exciting an assembly of molecules using a short pulse, from tens to few hundreds of femtoseconds), the molecules oscillate in phase at their characteristic vibrational frequencies. In this way, the response of the assembly of excited molecules is like that of a single molecule. Vibrational coherence is therefore an ideal way of tracking where and how the molecular configuration is at a given instant in time.

Transfer of vibrational coherence between electronic states of molecules has been reported since the early years of femtochemistry. However, none of these studies has ever involved states of different spins.

The lab of **Majed Chergui** at EPFL's Institute of Chemical Sciences and Engineering within the Lausanne Centre for Ultrafast Science has now reported for the first time a transfer of vibrational coherence in the case of a diplatinum complex in solution.

The scientists used their advanced femtosecond transient absorption set-up to follow step-by-step the transfer of vibrational coherence during a spin switch between the lowest two electronic states of the molecule.

The clear and unambiguous passage between these two states is even more remarkable considering that the solvent usually destroys coherence. The experimental results are supported by quantum mechanical simulations showing the importance of the solvent in driving and modifying pathways and efficiency of energy flow in polyatomic molecules.

"The solvent is not just a spectator in photobiology and photochemistry but it can strongly affect the outcome of a function or reaction. Understanding its role is crucial for our description of nature and for future applications," says Chergui.

FUNDING

- **Swiss National Science Foundation via the NCCR:MUST**

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IPHYS

A step closer to single-atom data storage

A magnetic hard drive © iStock

Physicists at EPFL successfully used Scanning Tunneling Microscopy to test the stability of a magnet made up of a single atom.

Despite the rise of solid-state drives, magnetic storage devices such as conventional hard drives and magnetic tapes are still very common. But as our data-storage needs are increasing at a rate of almost 15 million gigabytes per day, scientists are turning to alternative storage devices.

One of these are single-atom magnets: storage devices consisting of individual atoms stuck ("adsorbed") on a surface, each atom able to store a single bit of data that can be written and read using quantum mechanics. And because atoms are tiny enough to be packed together densely, single-atom storage devices promise enormous data capacities. But although they are no longer science fiction, single-atom magnets are still in basic research, with many fundamental obstacles to be overcome before they can be implemented into commercial devices. EPFL has been at the forefront of the field, overcoming the issue of magnetic remanence, and showing that single-atom magnets can be used to read and write data.

In a new study published in Physical Review Letters, physicists at EPFL's Laboratory of Nanostructures at Surfaces, directed by **Harald Brune**, have used Scanning Tunneling Microscopy to demonstrate the stability of a magnet consisting of a single atom of holmium, an element they have been working with for years.

"Single-atom magnets offer an interesting perspective because quantum mechanics may offer shortcuts across their stability barriers that we could exploit in the future," says EPFL's Fabian Natterer who is the paper's first author. "This would be the last piece of the puzzle to atomic data recording."

The scientists exposed the atom to extreme conditions that normally de-magnetize single-atom magnets, such as temperature and high magnetic fields, all of which would pose risks to future storage devices.

Using a Scanning Tunneling Microscope, which can "see" atoms on surfaces, the scientists found that the holmium atoms could retain their magnetization in a magnetic field exceeding 8 Tesla, which is around the strength of magnets used in the Large Hadron Collider. The authors describe this as "record-breaking coercivity", a term that describes the ability of a magnet to withstand an external magnetic field without becoming demagnetized.

Next, they turned up the heat: The researchers exposed a series of Holmium single-atom magnets to temperatures of up to 45 Kelvin, (-233.15 degrees Celsius), which, for single atoms, is like being in a sauna. The Holmium single-atom magnets remained stable up to a temperature of 35K. Only at around 45K, the magnets began to spontaneously align themselves to the applied magnetic field. This showed that they can withstand relatively high temperature perturbations and might point to the way forward for running single-atom magnets at more commercially viable temperatures.

"Research in the miniaturization of magnetic bits has focused heavily on magnetic bistability," says Natterer. "We have demonstrated that the smallest bits can indeed be extremely stable, but next we need to learn how to write information to those bits more effectively to overcome the magnetic 'trilemma' of magnetic recording: stability, writability, and signal-to-noise ratio."

OTHER CONTRIBUTORS

- **Institute for Basic Science (Korea)**
- **Ewha Womans University (Korea)**

FUNDING

- **Swiss National Science Foundation (FNS)**

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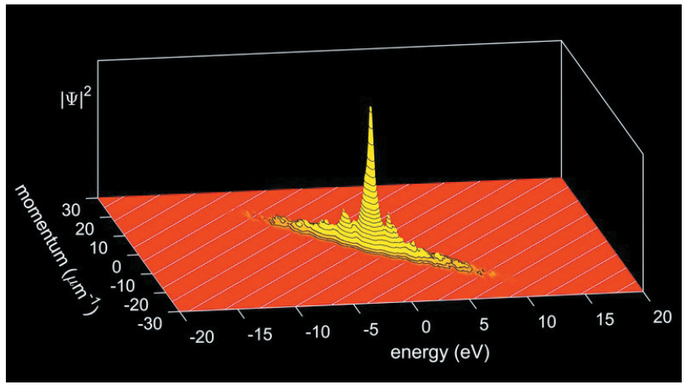
IPHYS

Can ultrashort electron flashes help harvest nuclear energy?



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EPFL physicists have now demonstrated experimentally the ability to coherently manipulate the wave function of a free electron down to the attosecond timescale (10^{-18} of a second). The team also developed a theory for creating zeptosecond (10^{-21} of a second) electron pulses, which could also be used to increase the energy yield of nuclear reactions.

The lab of **Fabrizio Carbone** at EPFL's Institute of Physics and their international colleagues have used ultrafast Transmission Electron Microscopy to take attosecond energy-momentum resolved snapshots (1 attosecond = 10^{-18} or quintillionths of a second) of a free-electron wave function. Though unprecedented in itself, the scientists also used their experimental success to develop a theory of how to create electron flashes within zeptosecond (10^{-21} of a second) timeframes, using already existing technology. This breakthrough could allow physicists to increase the energy yield of nuclear reactions using coherent control methods, which relies on the manipulation of quantum interference effects with lasers and which has already helped advance fields like spectroscopy, quantum information processing, and laser cooling.

In fact, one of the most elusive phenomena in physics is the excitation of an atom's nucleus by absorption of an electron. The process, known as "nuclear excitation by electron capture" (NEEC), was theoretically predicted fourty years ago, though it proved difficult to observe experimentally.

But in February 2018, US physicists finally caught a glimpse of NEEC in the lab. The work was hailed as ushering in new nuclear energy-harvesting systems, as well as explaining why certain elements like gold and platinum are so abundant in the universe.

The EPFL researchers in their publication suggest a way of potentially exploiting the several orders of magnitude in energy harvesting possibly present in the nucleus of an atom via the coherent control of the NEEC effect. Such a method would be enabled by the availability of ultrashort (as to zs) electron flashes. "Ideally, one would like to induce instabilities in an otherwise stable or metastable nucleus to prompt energy-producing decays, or to generate radiation," says Carbone. "However, accessing nuclei is difficult and energetically costly because of the protective shell of electrons surrounding it."

The authors state: "Our coherent control scheme with ultrashort electron pulses would offer a new perspective for the manipulation of nuclear reactions with potential implications in various fields, from fundamental physics to energy-related applications."

OTHER CONTRIBUTORS
- **Technion - Israel Institute of Technology**
- **University of Glasgow**
- **Ripon College (US)**
- **The Barcelona Institute of Science and Technology**
- **Catalan Institution for Research and Advanced Studies (ICREA)**

FUNDING
- **Swiss National Science Foundation (NCCR:MUST and Advanced Postdoc Mobility Grants)**

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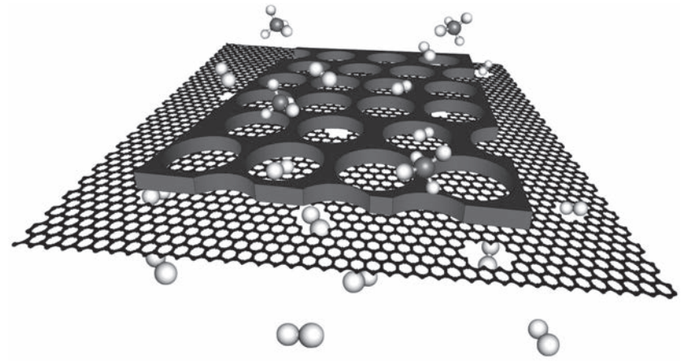
ISIC

An atom-thick graphene membrane for industrial gas separation



A single-layer nanoporous graphene reinforced with a nanoporous carbon film for the separation of hydrogen from methane

© K. V. Agrawal/EPFL

Chemical engineers at EPFL have shown for the first time that an atom-thick graphene membrane can separate gas mixtures with a high-efficiency. The "ultimate" membrane is scalable, making it a breakthrough for industrial gas separation.

Separating mixed gases, such as air, into their individual components is a process with multiple industrial applications, including biogas production, air enrichment in metal working, removal of toxic gases from natural gas, and hydrogen recovery from ammonia plants and oil refineries.

Gas separation usually takes place with the use of synthetic membranes made from polymers (e.g. cellulose) or other materials. In recent years, research has turned to what many refer to as the "ultimate" membrane: a layer of graphene, a single atom in thickness, which has been now shown to be the thinnest molecular barrier and hence the most efficient membrane, offering excellent permeance combined with robustness and scalability.

However, progress with developing graphene has met with two "bottlenecks": first, a lack of methods for incorporating molecular-sized pores into the layer of graphene, and second, a lack of methods for manufacturing mechanically robust, crack- and tear-free, large-area membranes.

Now, in a breakthrough that solves both problems, the team of **Kumar Varoon Agrawal** at EPFL Valais Wallis has developed a large-area, single-layer graphene membrane that can separate hydrogen from methane with a high-efficiency (separation factor up to 25), and an unprecedented hydrogen permeance from a porosity that was only 0.025%.

The membrane contains nanopores to allow hydrogen to permeate through, for what is known as "gas-sieving". The membrane was stable at industrial pressures and temperatures (at least up to 7 bar and 250 °C). But more importantly, the team was able to produce a surface area of 1 square millimeter – significantly larger than previous reports, where only a few square micrometers could be synthesized without cracks. Agrawal's group is now working to incorporate higher density of nanopores in graphene, to make graphene realize its true potential.

"The novel technique to produce crack-free graphene layer will go a long-way in realizing the ultimate performance of the atom-thick graphene membranes for a number of important chemical separations including carbon capture, hydrogen recovery and the purification of clean drinking water," says Agrawal.

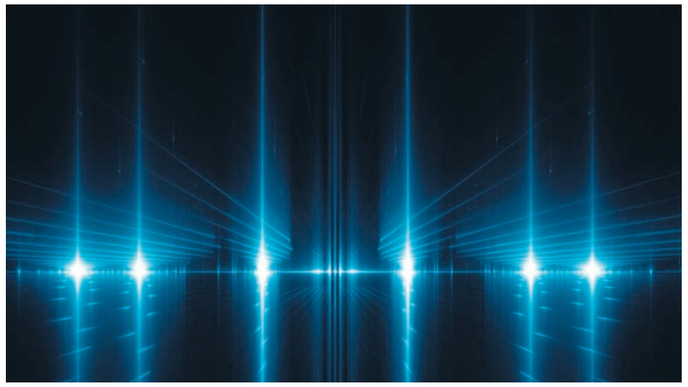
OTHER CONTRIBUTORS
- **EPFL Laboratory of Materials for Renewable Energy (LMER)**
- **EPFL Interdisciplinary Centre for Electron Microscopy (CIME)**
- **Massachusetts Institute of Technology (MIT)**

FUNDING
- **EPFL**
- **GAZNAT**
- **Swiss Competence Center of Energy Research – Efficiency in Industrial Processes (SCCER-EIP)**
- **ETH Board**

REFERENCE
Shiqi Huang, Mostapha Dakhchoune, Wen Luo, Emad Oveisi, Guangwei He, Mojtaba Rezaei, Jing Zhao, Duncan T. L. Alexander, Andreas Züttel, Michael S. Strano, Kumar Varoon Agrawal. **Single-layer graphene membranes by crack-free transfer for gas mixture separation.** *Nature Communications* **9**, 2632 (6 July 2018). DOI: 10.1038/s41467-018-04904-3

IPHYS

Quantum interference opens up a new source for single photons



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The predictions of EPFL physicists for a new kind of single photon source have come to life in a recent collaboration with the universities of Leiden and Santa Barbara. The so-called Unconventional Photon Blockade was experimentally realized with a semiconductor quantum dot embedded in a micropillar optical cavity.

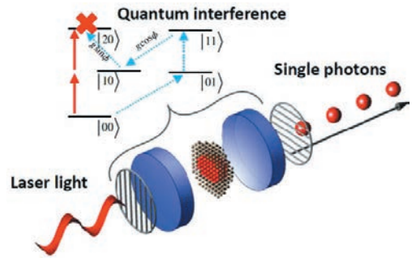
Thanks to massive investment from the high-tech giants, emerging quantum technologies have recently made the leap onto industry. While the first quantum computers rely on superconducting circuits, photonics stand as the most promising platform for integrable quantum chips, and already lie at the heart of quantum encryption devices available on the market.

Processing quantum information with light relies on extracting the individual photons that encode the information from the random stream of a laser source. The most conventional approach involves trapping the laser light inside an optical cavity characterized by a strongly nonlinear response.

This trapping is referred to as "strong light-matter coupling". During this, the cavity cannot absorb more than one photon at a time and therefore re-emits them, behaving like a turnstile for the laser: the so-called Photon Blockade. However, experimentally realizing a strongly nonlinear optical cavity remains a very challenging and expensive engineering task.

The Unconventional Photon Blockade (UPB) is another paradigm, first proposed in 2010. It relaxes the need for strong nonlinearity and results from a quantum interference effect that minimizes the chances of having two photons trapped at the same time in the cavity thanks to an auxiliary element, such as a second cavity of a quantum dot.

In a new study published in *Physical Review Letters*, the UPB was experimentally implemented by the groups of Wolfgang Loffler (University of Leiden) and Dirk Bouwmeester (University of Santa Barbara) with theoretical support from Hugo Flayac and **Vincenzo Savona** at EPFL. The effect was measured after a laser light was sent to a micropillar cavity hosting a semiconductor quantum dot far away from the strong coupling regime.



The work opens the way to considerably cheaper and flexible single-photon sources. Flayac and Savona are now attempting to adapt the mechanism to photonic crystal cavities, which are simple and cheap pieces of silicon with suitably arranged arrays of holes operating at room temperature.

FUNDING

- **Netherlands Organisation for Scientific Research (NWO) and Ministry for Education, Culture and Science (OCW)**
- **Swiss National Science Foundation (FNS)**

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ISIC

Improving biosensors for implantable sensing

Alice Gillen and Nils Schürgers, two of the paper's authors, making sensor gels out of the new DNA-nanotube complexes.

© Alessandra Antonucci

EPFL scientists have developed new nanotube biosensors using synthetic biology, which improves their sensing capabilities in complex biofluids, such as blood and urine.

Biosensors are devices that can detect biological molecules in air, water, or blood. They are widely used in drug development, medical diagnostics, and biological research. The growing need for continuous, real-time monitoring of biomarkers in diseases like diabetes is currently driving efforts to develop efficient and portable biosensor devices.

Some of the most promising optical biosensors currently being developed are made using single-walled carbon nanotubes. The near-infrared light emission of the carbon nanotubes lies within the optical transparency window of biological materials. This means water, blood, and tissue such as skin do not absorb the emitted light, making these biosensors ideal for implantable sensing applications. These sensors can thus be placed underneath the skin and the optical signal can still be detected without the need to have electrical contacts piercing through the surface.

However, the omnipresence of salts in biofluids creates a pervasive challenge in designing the implantable devices. Fluctuations in salt concentrations that naturally occur in the body have been shown to affect the sensitivity and selectivity of optical sensors based on single-walled carbon nanotubes wrapped with single-stranded DNA.

In order to overcome some of these challenges, a team of researchers from the lab of **Ardemis Boghossian** at EPFL's Institute of Chemical Sciences and Engineering engineered stable optical nanotube sensors using synthetic biology. The use of synthetic biology imparts increased stability to the optical biosensors, making them more suitable for use in biosensing applications in complex fluids such as blood or urine and even inside the human body.

"We wrap nanotubes with 'xeno' nucleic acids (XNA), or synthetic DNA that can tolerate the variation in salt concentrations that our bodies naturally undergo, to deliver a more stable signal," says Ardemis Boghossian. Alice Gillen led the efforts in studying how certain salts affect the optical emission of the biosensors.

The study covers varying ion concentrations within the physiological ranges found in common biofluids. By monitoring both the intensity of the nanotubes' signal and shifting of the signal's wavelength, the researchers were able to verify that the bioengineered sensors showed greater stability over a larger range of salt concentrations than the DNA sensors traditionally used in the field.

"This is really the first time a true synthetic biology approach is being used in the field of nanotube optics," says Boghossian. "We think these results are encouraging for developing the next generation of optical biosensors that are more promising for implantable sensing applications such as continuous monitoring."

FUNDING

- **Swiss National Science Foundation (SNSF)**

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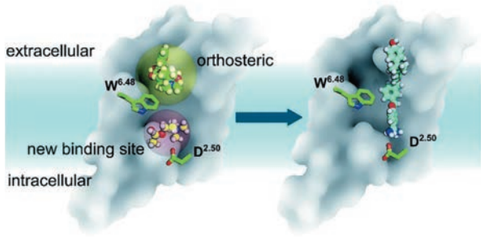
ISIC

Computer simulation of receptors reveals a new ligand-binding site



The receptor model, indicating the new site. © RSC

Using a computer simulation of an important receptor, EPFL scientists have discovered a novel binding site for natural ligands and drugs. The new site might be present on other receptors and can be exploited in novel treatments for multiple diseases.

Most biological processes in a cell go through receptors. These are specialized proteins that are activated when a ligand binds to them. Ligands can be all sorts of molecules (e.g. hormones, nucleic acids, neurotransmitters etc), and by binding receptors – and other proteins – they run complex processes such as cell maintenance, immune responses, genetics and others.

These normal cell processes involve complex "dominoes" of biochemical signals that are carried across the cell through protein-ligand interactions. On the other hand, they also lie at the core of a vast number of diseases. An entire branch of research known as "receptor pharmacology" is dedicated to exploiting these interactions with synthetic ligands (drugs), attempting to find ligand-binding sites that can exploited as a drug target.

Now, scientists led by Professor **Horst Vogel** have developed a computer simulation of the widespread muscarinic acetylcholine receptor. Specifically, the scientists examined the M3 and M4 subtypes of the receptor, which are majorly involved in the function of the lungs (M3) and the central nervous system (M3 and M4).

The receptors belong to the large family of so-called "G protein-coupled receptors" (GPCRs), which generally detect signals coming from outside the cells, such as light, hormones, or neurotransmitters. Upon activation, GPCRs change their structure in such a way that they can bind and activate other proteins inside the cell and ultimately turn on the appropriate process.

GPCRs are the target of more than a third of modern therapeutic compounds, meaning that finding new ligand binding sites can help design more efficient GPCR-targeted drugs.

The team used what are known as "molecular dynamics simulations", which is a method for simulating studying the physical movements of atoms and molecules in a computer. The method can reveal details down to the level of individual atoms, thus offering a high-resolution way to look at how various ligands bind on the receptor – and, more importantly, where.

The study revealed a new binding site on the acetylcholine receptors, which can be exploited pharmacologically to understand ligand binding and activation processes. The site seems capable of binding small ligands and cause different effects to the receptor than the "main" ligand would.

Looking at more than 200 ligand-bound GPCR structures, the researchers discovered that most ligands bind the traditional ("orthosteric") sites on the receptors. However, one receptor that binds leukotriene (LTB4) and directs immune cells to sites of infection seemed to bind a "double" ligand, which binds the new site discovered in the two acetylcholine receptors. The new site was detected in many others of the over 200 receptors that the scientists examined.

The study shows that the new binding site might exist in other GPCRs, opening a new opportunity for GPCR drug discovery. "The study shows the power of computational methods to resolve in atomic detail central receptor-mediated signaling reactions," says Horst Vogel. "The challenging next step is to use computational methods to design novel compounds that would fit into the newly found binding sites to activate or deactivate the receptor in a defined mode and thus design novel medicines."

OTHER CONTRIBUTORS
- **University of Bradford**
- **ShanghaiTech University**
- **Case Western Reserve University**
- **University of Warsaw**

FUNDING
- **Interdisciplinary Centre for Mathematical and Computational Modelling (Poland)**
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- **European Community (project SynSignal)**
- **EPFL**
- **Arnold and Mabel Beckman Foundation**

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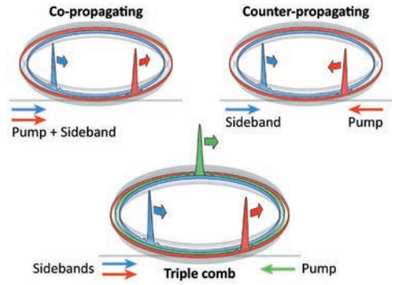
IPHYS

Microresonators offer a simpler approach to sensing with light pulses



An illustration of the concept behind the new method
© Erwan Lucas/EPFL

Researchers at EPFL have found a way to implement an optical sensing system by using spatial multiplexing, a technique originally developed in optical-fiber communication. The method, which produces three independent streams of ultrashort optical pulses using a single continuous-wave laser and a single optical microresonator, is far simpler than existing technologies.

Ultrashort optical pulses are becoming more and more relevant in a number of applications including distance measurement, molecular fingerprinting and ultrafast sampling. Many of these applications rely not only on a single stream of pulses – also known as "optical frequency combs" – but require two or even three of them. Nonetheless, these multi-comb approaches significantly speed up acquisition time over conventional techniques.

These trains of short optical pulses are typically produced by large pulsed laser sources. Multi-comb applications therefore require several such lasers, often at prohibitive costs and complexity. Furthermore, the relative timing of pulse trains and their phases must be very well synchronized, which requires active electronics that synchronize the lasers.

In a paper published in Nature Photonics, the research team of **Tobias J. Kippenberg** at EPFL's Institute of Physics, together with the group of Michael Gorodetsky at the Russian Quantum Centre, has developed a much simpler method to generate multiple frequency combs. The technology uses small devices called "optical microresonators" to create optical frequency combs instead of conventional pulsed lasers.

The microresonator consists of a crystalline disk of a few millimeters in diameter. The disk traps a continuous laser light and converts it into ultrashort pulses – solitons – thanks to the special nonlinear properties of the device. The solitons travel around the microresonator 12 billion times per second. At every round, a part of the soliton exits the resonator, producing a stream of optical pulses.

This type of microresonator has a special property in that it allows the light to travel in the disk in multiple different ways, called spatial modes of the resonator. By launching continuous lightwaves in several modes at the same time, multiple different soliton states can be obtained simultaneously. In this way, the scientists were able to generate up to three frequency combs at the same time.

The working principle is the same as spatial multiplexing used in optical fiber communication: the information can be sent in parallel on different spatial modes of a multimode fiber. Here, the combs are generated in distinct spatial modes of the microresonator.

The method has several advantages, but mainly it does not require complex synchronization electronics. "All the pulses are circulating in the same physical object, which reduces potential timing drift, as encountered with two independent pulsed lasers," explains Erwan Lucas, first author of the paper. "We also derive all the continuous waves from the same initial laser by using a modulator, which removes the need for phase synchronization."

Using this multiplexing scheme, the team demonstrated several applications, such as dual-comb spectroscopy, or rapid optical sampling. The acquisition time could be adjusted between a fraction of a millisecond to 100 nanoseconds.

The authors are now working on developing a new demonstration with the triple-comb source.

The technology can be integrated with both photonic elements and silicon microchips. Establishing multi-comb generation on a chip may catalyze a wide variety of applications such as integrated spectrometers or LIDAR, and could make optical sensing far more accessible.

FUNDING
- **Swiss National Science Foundation**
- **US Air Force Office of Scientific Research**
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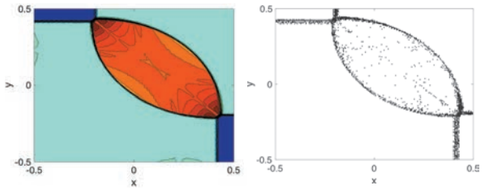
- **European Space Technology Centre**

REFERENCE
E. Lucas, G. Lihachev, R. Bouchand, N. G. Pavlov, A. S. Raja, M. Karpov, M. L. Gorodetsky, T. J. **Kippenberg. Spatial multiplexing of soliton microcombs.** *Nature Photonics* 01 October 2018. DOI: 10.1038/s41566-018-0256-7

MATH

Training an artificial neural network to detect discontinuities in solutions to conservation laws



Left panel Representation of the density in a solution of the Euler equation of gas dynamics. Right panel Black dots represent cells identified as troubled cells in the left panel by the neural network © EPFL

EPFL mathematicians have developed a new way to detect discontinuities by training an artificial neural network using supervised learning to classify cells as troubled-cells or good-cells. The network is trained offline and can be easily integrated into existing code frameworks.

When an aircraft reaches the speed of sound, a shockwave is formed. If a shockwave carries energy, like an ordinary wave, it is characterized by an abrupt change in the features of the medium, such as pressure or temperature. Due to that brutal transition, shockwaves must be treated as a discontinuous transition.

We know that solutions – the shockwave for example – of special time-dependent partial differential equations (PDEs), known as conservation laws, often develop discontinuities. Another typical example is the shallow water equations describing flow dynamics in water bodies. However, while approximating these discontinuities, numerical algorithms suffer from spurious oscillations that can lead to numerical instabilities, resulting in unphysical results.

A popular technique to overcome this issue is by limiting the numerical solution in problematic cells of the mesh used to decompose the physical domain. However, in order to use this method, one must locate the problematic cells. This is achieved via a suitable troubled-cell indicator, an algorithm that flags the cells in which the solution is unstable. Although several such indicators have been developed over the years, most of them need problem-dependent parameters to be prescribed. A non-optimal choice of these parameters can either lead to the reappearance of the oscillations or the loss of accuracy in regions of the domain where the solution is smooth.

Professor **Jan S. Hesthaven**, head of the Chair of Computational Mathematics and Simulation Science (MCSS), and his postdoc Deep Ray are investigating the effectiveness of deep-learning techniques to resolve issues of parameter-tuning when computationally solving partial differential equations. Their research has been published in the *Journal of Computational Physics*.

OVERCOMING ALGORITHMIC BOTTLENECKS WITH DEEP NEURAL NETWORKS

Their new approach for detecting discontinuities involves training an artificial neural network, during an offline stage, with data generated from simple canonical functions. The advantage of this strategy is that it is parameter-free, computationally efficient, problem-independent, and can be integrated into existing code frameworks. Furthermore, the network was demonstrated to outperform traditional troubled-cell indicators. Combining these properties, the network is attractive as a universal troubled-cell indicator for general conservation laws.

Deep learning has great potential to solve problems that arise in the computational sciences, and there has recently been an active interest in the use of such networks. However, the philosophy of Hesthaven and his team is that deep learning should not completely replace existing, well-established numerical methods, but should rather support them to enhance their performance.

The EPFL mathematicians are now working on suppressing the oscillations by introducing an artificial viscous term in the underlying partial differential equation. Still aiming to make their method parameter-free, they have trained neural networks to predict the required viscosity. The results are promising, as the networks beat existing methods on both structured and unstructured meshes.

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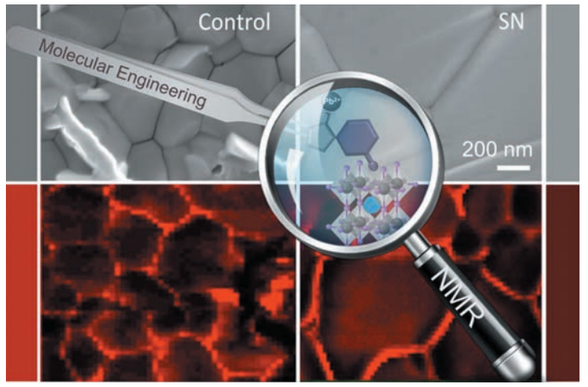
Deep Ray and Jan S. Hesthaven, 2018, **"An artificial neural network as a troubled-cell indicator,"** *J. Comput. Phy.*, vol. 367,166–191.

ISIC

A novel avenue to high-performance, stable perovskite solar cells



Schematic representation of the MMM concept using molecular engineering in conjunction with solid-state NMR spectroscopy for advancing perovskite solar cell research. The background shows plane-view scanning electron microscopy images (grey) and cathodoluminescence mapping (red) of pristine (control, left) and molecularly modulated (SN, right) double-cation pure-iodide perovskite films.
© LPI-EPFL

EPFL researchers show how stable, scalable, and efficient perovskite solar cells can be produced through molecular engineering of multifunctional molecular modulators and using solid-state nuclear magnetic resonance to investigate their role in double-cation pure-iodide perovskites.

Some of the key challenges for hybrid organic-inorganic perovskite solar cells, one of the most promising thin-film photovoltaic technologies, are their limited stability, scalability, and molecular level engineering. Researchers at the Laboratory of Photonics and Interfaces (LPI) and Laboratory of Magnetic Resonance (LMR) at EPFL's Institute of Chemical Sciences and Engineering demonstrate in their *Nature Communications* article how molecular engineering of multifunctional molecular modulators (MMMs) and using solid-state nuclear magnetic resonance (NMR) to investigate their role in double-cation pure-iodide perovskites can lead to stable, scalable, and efficient perovskite solar cells.

There has been an ongoing effort to overcome some of the limitations associated with perovskite solar cells by using organic additives, however, their microscopic role in the perovskite structure was mostly speculative. The objective of the team lead by **Michael Grätzel** (LPI), in collaboration with the group of **Lyndon Emsley** (LMR) was to tackle these challenges through rational molecular design in conjunction with solid-state NMR, as a unique technique for probing interactions within the perovskite material at the atomic level.

The team designed a series of organic molecules equipped with specific functions that act as molecular modulators (MMs), which interact with the perovskite surface through noncovalent interactions, such as hydrogen bonding or metal coordination. While hydrogen bonding can affect the electronic quality of the material, coordination to the metal cation sites could ensure suppression of some of the structural defects, such as undercoordinated metal ions. Combining the two traits provided the way to simultaneously address the performance and stability, leading to the development of a multifunctional molecular modulator (MMM) with the capacity to interact with the perovskite surface and suppress the defects. As a result, the perovskite solar cells demonstrated performances with power conversion efficiencies exceeding 20% for active areas above 1 cm^2, which came alongside operational stability even under ambient conditions.

Drs. Jovana V. Milić (LPI) and Dominik J. Kubicki (LMR), are excited to apply this approach to more advanced MMMs for stable, scalable, and efficient perovskite solar cells in the future, hoping that this stimulates wider application of atomic-level characterization techniques, such as solid-state NMR, for unraveling the mechanisms of their operation.

FUNDING

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- **ERC PRINTSolar**
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- **National Natural Science Foundation of China**
- **King Abdulaziz City for Science and Technology (KACST)**

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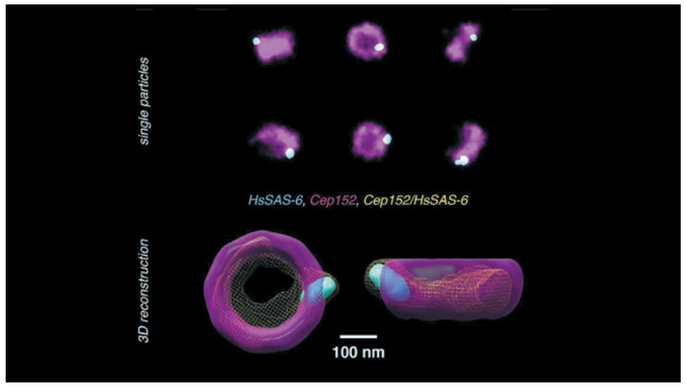
Dongqin Bi, Xiong Li, Jovana V. Milić, Dominik J. Kubicki, Norman Pellet, Jingshan Luo, Thomas LaGrange, Pierre Mettraux, Lyndon Emsley, Shaik M. Zakeeruddin, Michael Grätzel. **Multifunctional molecular modulators for perovskite solar cells with over 20% efficiency and high operational stability.** *Nature Communications* **9**: 4482 (26 October 2018). DOI: DOI: 10.1038/s41467-018-06709-w

IPHYS

Super-resolution microscopy builds multicolor 3D from 2D



Human centrioles labelled with antibodies against two proteins (Cep152, HsSAS-6) and imaged using super-resolution microscopy. From many individual particles showing projections of the centriole complex in various orientations (upper panel), by using a fused intermediate (yellow, lower panel), the newly developed method allows to reconstruct a multicolor 3D model (lower panel)
© Christian Sieben/EPFL

A new technique developed by EPFL overcomes the noise and color limitations of super-resolution microscopy by creating three-dimensional reconstructions from single-color, two-dimensional images of protein complexes.

Super-resolution microscopy is a technique that can "see" beyond the diffraction limit of light. The technique has garnered increasing interest recently, especially since its developers won the Nobel Prize in Chemistry in 2014. By exploiting fluorescence, super-resolution microscopy now allows scientists to observe cells and their interior structures and organelles in a way never possible before.

Many of the molecular complexes inside cells are made up of multiple proteins. Since current techniques of super-resolution microscopy typically can only use one or two fluorescent colors, it is difficult to observe different proteins and decipher the complex architecture and underlying assembly mechanisms of the cell's interior structures. An even greater challenge is to overcome the noise inherent to the super-resolution methods and fluorescent labeling, to achieve the full resolution potential.

Scientists from the lab of **Suliana Manley** at EPFL's Institute of Physics have now solved both problems by developing a new method to analyze and reconstruct super-resolution images and re-align them in a way that multiple proteins can be placed within a single 3D volume. The method works with images taken with large field-of-view super-resolution microscopy, with each image containing hundreds of two-dimensional projections of a labeled structure in parallel.

Each 2D view represents a slightly different orientation of the structure, so that with a dataset of thousands of views, the method can computationally reconstruct and align the 2D images into a 3D volume. By combining information from a large number of single images, the noise is reduced and the effective resolution of the 3D reconstruction is enhanced.

With the help of **Pierre Gönczy**'s lab at EPFL's School of Life Sciences, the researchers tested the method on human centriole complexes. Centrioles are pairs of cylindrical molecular assemblies that are crucial in helping the cell divide. Using the new multicolor super-resolution reconstruction method, the researchers were able to uncover the 3D architecture of four proteins critical for centriolar assembly during organelle biogenesis.

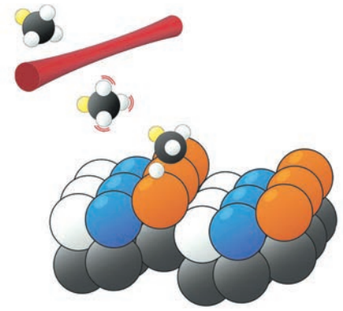
The new approach allows for unlimited multiplexing capabilities. "With this method, if the proteins in the structure can be labeled, there is no limit to the number of colors in the 3D reconstruction," says Suliana Manley. "Plus, the reconstruction is independent of the super-resolution method used, so we expect this analysis method and software to be of broad interest."

FUNDING
- **European Research Council (ERC)**
- **EPFL**
- **Horizon 2020 (MSCA-COFUND)**
- **NCCR Chemical Biology**

REFERENCE
Christian Sieben, Niccolò Banterle, Kyle M. Douglass, Pierre Gönczy, Suliana Manley. **Multicolor single particle reconstruction of protein complexes.** *Nature Methods* 01 October 2018. DOI: 10.1038/s41592-018-0140-x

ISIC

Vibrational spectroscopy dissects a surface reaction



The bond-selective and surface-site-specific dissociation of deuterated methane on a Pt(211) surface © R. Beck/EPFL

When a metal surface catalyzes a chemical process, the surface atoms aren't all the same. EPFL scientists have bridged the gap between lab and plant by studying methane dissociation on the (211) crystal face of platinum.

In 1909, Fritz Haber made a discovery that would change the world: With the help of a solid iron catalyst, he could break atmospheric nitrogen into its constituent atoms and combine them with hydrogen to make ammonia. The fertilizers produced from that synthetic ammonia increased agricultural productivity several-fold and allowed Earth's growing population to be fed.

Industrial surface catalysis—now extended to many more reactions—is a messy process. The catalytic surfaces are rough and irregular, and hot reactant molecules jostle one another and move in all directions. Chemical physicists get a handle on the reactions by simplifying them: the craggy catalysts and pressurized reaction vessels in a chemical plant are replaced with smooth crystalline surfaces and rarefied atmospheres in the lab. The experiments have yielded some important results, including the detailed mechanism of the Haber process, but they're a far cry from real-world conditions.

Rainer Beck, of the Swiss Federal Institute of Technology in Lausanne, and his colleagues are bridging the gap between lab and plant by studying methane dissociation on the (211) crystal face of platinum. With its regularly spaced steps, Pt(211) has three distinct types of surface sites, shown in the figure in orange, blue, and white. Previously, experiments could measure only the average reaction output of the whole surface. But earlier this year, Beck and company showed that the reaction product, CH_3, had measurably different vibrational resonances depending on the surface site where it was located. By monitoring the vibrational spectrum of the whole surface and resolving it into site-specific components, the researchers probed the catalytic activity of each type of site. Qualitatively, the results fit with expectations: The step sites (orange) are more active than the terrace sites (blue), and the corner sites (white) don't contribute to the reaction at all.

Now, Beck and colleagues have added a new layer of complexity. By replacing CH_4 with deuterated methane, CH_3D, they have created a system in which more than one dissociation reaction is possible: The bond that breaks could be either C–H or C–D. The ability to steer such a reaction toward a desired set of products is a long-standing goal. In the case of deuterated methane, one can create a preference for C–H bond dissociation by preparing the reactant molecules in a state in which the C–H bonds vibrate strongly but the C–D bond does not. But the degree of that preference exhibits a complicated dependence—which Beck and colleagues have now disentangled—on both the reaction site and the reactant speed.

The Lausanne experimenters are working with several theory groups to convert their results into a better predictive understanding of surface reactions. And they're extending their experiments to even more complicated surfaces, such as Pt(531), whose steps are zigzag-shaped.

Reproduced from J. L. Miller, 'Vibrational spectroscopy dissects a surface reaction,' Physics Today Online, 26 July 2018, with the permission of the American Institute of Physics. [https://doi.org/10.1063/PT.6.1.20180726a].

FUNDING
- **Fonds national suisse de la recherche scientifique (FNS)**
- **École Polytechnique Fédérale de Lausanne (EPFL)**

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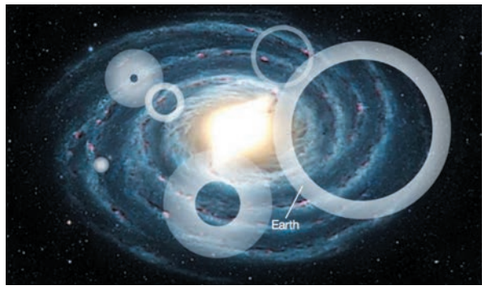
IPHYS

New tool helps scientists better target the search for alien life



Schematic view of the Milky Way showing six isotropic extraterrestrial emission processes forming spherical shells filled by radio signals. The outer radii of the spherical shells are proportional to the time at which the signals were first emitted, while the thicknesses are proportional to the duration of the emissions. In this example, the Earth is illuminated by one of these signals © Claudio Grimaldi

An EPFL scientist has developed a novel approach that boosts the chances of finding extraterrestrial intelligence in our galaxy. His method uses probability theory to calculate the possibility of detecting an extraterrestrial signal (if there is one) at a given distance from Earth.

Could there be another planet out there with a society at the same stage of technological advancement as ours? To help find out, EPFL scientist Claudio Grimaldi, working in association with the University of California, Berkeley, has developed a statistical model that gives researchers a new tool in the search for the kind of signals that an extraterrestrial society might emit. His method – described in an article appearing today in *PNAS** – could also make the search cheaper and more efficient.

Astrophysics initially wasn't Grimaldi's thing; he was interested more in the physics of condensed matter. Working at EPFL's Laboratory of Physics of Complex Matter directed by **László Forró**, his research involved calculating the probabilities of carbon nanotubes exchanging electrons. But then he wondered: if the nanotubes were stars and the electrons were signals generated by extraterrestrial societies, could we calculate the probability of detecting those signals more accurately?

This is not pie-in-the-sky research; scientists have been studying this possibility for nearly 60 years. Several research projects concerning the search for extraterrestrial intelligence (SETI) have been launched since the late 1950s, mainly in the United States. The idea is that an advanced civilization on another planet could be generating electromagnetic signals, and scientists on Earth might be able to pick up those signals using the latest high-performance radio telescopes.

Despite considerable advances in radio astronomy and the increase in computing power since then, none of those projects has led to anything concrete. Some signals have been recorded, like the Wow! signal in 1977, but scientists could not pinpoint their origin. And none of them has been repeated or seems credible enough to be attributable to alien life.

But that doesn't mean scientists have given up. On the contrary, SETI has seen renewed interest following the discovery of the many exoplanets orbiting the billions of suns in our galaxy. Researchers have designed sophisticated new instruments – like the Square Kilometre Array, a giant radio telescope being built in South Africa and Australia with a total collecting area of one square kilometer – that could pave the way to promising breakthroughs.

"In reality, expanding the search to these magnitudes only increases our chances of finding something by very little. And if we still don't detect any signals, we can't necessarily conclude with much more certainty that there is no life out there," says Grimaldi.

The advantage of Grimaldi's statistical model is that it lets scientists interpret both the success and failure to detect signals at varying distances from the Earth. His model employs Bayes' theorem to calculate the remaining probability of detecting a signal within a given radius around our planet. For example, even if no signal is detected within a radius of 1,000 light years, there is still an over 10% chance that the Earth is within range of hundreds of similar signals from elsewhere in the galaxy, but that our radio telescopes are currently not powerful enough to detect them. However, that probability rises to nearly 100% if even just one signal is detected within the 1,000-light-year radius. In that case, we could be almost certain that our galaxy is full of alien life.

After factoring in other parameters like the size of the galaxy and how closely packed its stars are, Grimaldi estimates that the probability of detecting a signal becomes very slight only at a radius of 40,000 light years. In other words, if no signals are detected at this distance from the Earth, we could reasonably conclude that no other civilization at the same level of technological development as ours is detectable in the galaxy. But so far, scientists have been able to search for signals within a radius of "just" 40 light years. So there's still a way to go.

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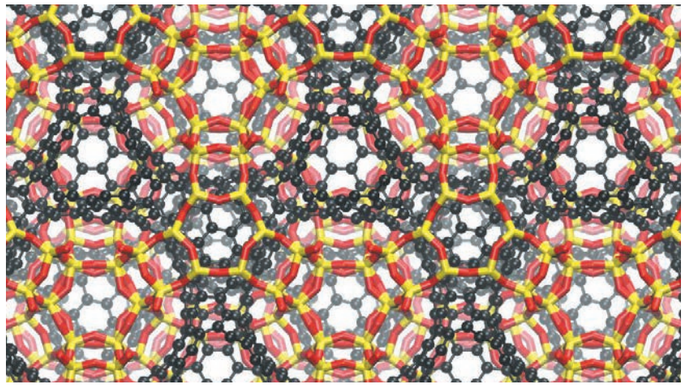
ISIC

A computational method for designing a new type of 2D carbons



Schwarzite generated by computationally-templating the zeolite FAU. Black spheres are deposited carbon atoms, yellow ribbons are zeolite silicon atoms, and red ribbons are zeolite oxygen atoms. After the carbon surface is generated the zeolite atoms are removed.
© Yongjin Lee and Efrem Braun (UC Berkeley)

Scientists from EPFL and Berkeley have developed a computational method for designing a new type of two-dimensional carbon materials called Schwarzites.

Zeolites are porous minerals that occur both naturally but also are being synthesized artificially. Because of their stability and durability, they are used in industrial water purification, catalysis, adsorption, and even in blood-clotting powders (e.g. QuickClot used by the US military).

A recent application of zeolites is to use them as templates for "growing" carbon surfaces inside the pores of zeolites. Now, the lab of **Berend Smit** at EPFL Valais Wallis, working with their colleagues at the University of California Berkeley, have developed a computational method to grow these carbon surfaces.

To the surprise of the authors a detailed analysis of these carbon structures resembles negatively curved surfaces called Schwarzites. "For a long time Schwarzites have been only a mathematical concept of a new form of two-dimensional carbon," says Berend Smit. "Like graphene, they have potentially many unique properties and interesting applications." The unique electronic, magnetic, and optical properties of Schwarzites make them ideal for supercapacitors, battery electrodes, catalysis, gas storage, and chemical separations.

"Our work allowed us to generate a library of Schwarzites that can be obtained from all known zeolite structures," says Smit. "We can now suggest to experimental groups which zeolite to use as a template for making a new two-dimensional carbon, described by a particular Schwarzite."

The work has proven so promising that EPFL and Berkeley have filed a joint patent application on the computational method.

OTHER CONTRIBUTORS

- **ShanghaiTech University**
- **Technische Universität Dresden**
- **Università degli Studi di Milano**
- **Samara State Technical University**

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- **ShanghaiTech University**
- **Deutsche Forschungsgemeinschaft (DFG)**
- **NCCR MARVEL**
- **European Research Council (ERC)**
- **EU graphene program**

REFERENCE

Efrem Braun, Yongjin Lee, Seyed Mohamad Moosavi, Senja Barthel, Rocio Mercado, Igor A. Baburin, Davide M. Proserpio, Berend Smit. **Generating carbon schwarzites via zeolite-templating.** *PNAS* 13 August 2018. DOI: 10.1073/pnas.1805062115

IPHYS

A rare star opens a window on the beginning of time

Dedicated to the search of the most ancient stars in the Milky Way, the Pristine survey recently identified an extremely rare object. © iStock

EPFL astrophysicists actively participated in the discovery of a very rare star, which is particularly old and metal-poor. As a messenger from the distant past, it will allow the scientists to learn more about the young Universe, right after the Big Bang.

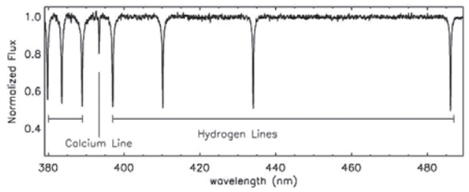
"We made a major discovery, which questions our understanding of the formation of the first generations of stars in the universe". Researcher at EPFL Laboratory of astrophysics (LASTRO), **Pascale Jablonka** is a founding member of the Pristine survey, an international project dedicated to the search of the most ancient and metal-poor stars. It allowed the recent identification of an extremely rare object. Called Pristine 221, it is among the 10 most metal-poor stars known to date in the halo of our Galaxy. Moreover, it is one out of two outstanding stars that are almost totally carbon free. This breakthrough has recently been published in the journal *Monthly Notices of the Royal Astronomical Society (MNRAS)*.

For the study of the early universe, astronomers have different methods at their disposal: One is to look far into the Universe and back in time, to see the first stars and galaxies growing. Another option is to examine the oldest surviving stars of our home galaxy, the Milky Way, for information from the early universe. The Pristine survey, led by the Leibniz Institute for Astrophysics Potsdam (AIP) and the University of Strasbourg, is looking for exactly these pristine stars.

To find these oldest messengers among the overwhelming population of younger stars is no easy task. Just after the Big Bang, the Universe was filled with hydrogen and helium and a bit of lithium. No heavier elements were around, as these are only synthesized in the hot interior of stars - and those did not exist yet. Our Sun has about 2% of heavier elements in its atmosphere: for this reason, astrophysicists can conclude that the sun has emerged as part of a later generation of stars - and has "recycled" in its atmosphere the products of the stars that lived long before it and have since died out. In searching for the oldest stars, scientists look for stars with much more pristine atmospheres than our Sun. Studying stars of different generations allows us to understand the formation history of the Galaxy - an area of research that therefore is also called near-field cosmology.

CHEMICAL ABUNDANCE

The Pristine team used a special narrow band filter on the Canada-France-Hawaii Telescope to preselect candidate stars with pristine atmospheres. This step was then followed by a detailed spectroscopic campaign with the telescopes of the Isaac Newton Group in Spain and the European Southern Observatory in Chile. EPFL's researchers Pascale Jablonka and Carmela Lardo formed one out of three teams, with the Paris Observatory and the Instituto de Astrofísica de Canarias, in charge of the spectroscopic analysis and the chemical abundance measurements, that led to the identification of this very special star. They could demonstrate that the star had indeed very few heavy elements in its atmosphere.



"Pristine 221 spectrum shows a lot of hydrogen lines and very few other elements except a small amount of calcium. This tells us that the star is ultra metal-poor. This unusual lack of heavier elements in its atmosphere means that it probably belongs to an early generation of stars formed in the Galaxy."

"Most elements are depleted by factors 10,000 to 100,000 compared to the Sun. Additionally, its detailed pattern of different elements stands out. Whereas usually extremely metal-poor stars show a very large enhancement in carbon, this star does not. This makes this star the second of its kind and an important messenger from the early Universe", says Else Starkenburg, researcher at AIP and first author of the study.

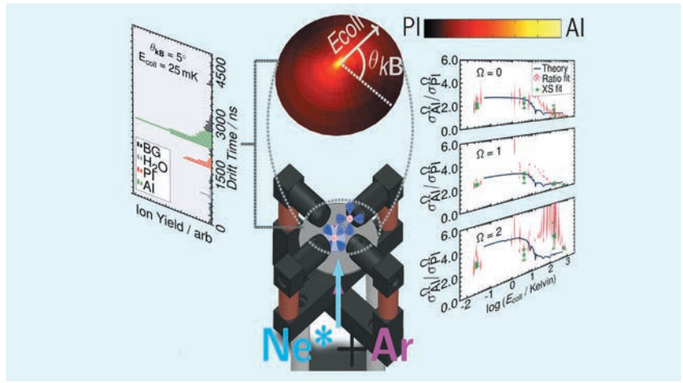
"Scientists used to think that carbon was a necessary cooling agent, enabling small fragmentation of the gas cloud from which stars form, and leading to the subsequent formation of low-mass stars in the high-redshift universe, Pascale Jablonka explains. With now two examples of such old and carbon-poor stars, models need to be revised."

REFERENCE

"The Pristine Survey IV: Approaching the Galactic metallicity floor with the discovery of an ultra metal-poor star", Else Starkenburg *et al*, in: *Monthly Notices of the Royal Astronomical Society.* Volume 481, Issue 3, 2018, p. 3838–3852. Doi: 10.1093/mnras/sty2276

ISIC

Controlling chemical reactions near absolute zero



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EPFL chemists have demonstrated complete experimental control over a chemical reaction just above absolute zero.

It is an understatement to say that chemical reactions take place everywhere and constantly. In both nature and the lab, chemistry is ubiquitous. But despite its advances, it remains a fundamental challenge to gain a complete understanding and control over all aspects of a chemical reaction, such as temperature and the orientation of reacting molecules and atoms. This requires sophisticated experiments where all the variables that define how two reactants approach, and ultimately react with, each other can be freely chosen. By controlling things like the speed and the orientation of the reactants, chemists can study the finest details of a particular reaction mechanism.

In a new study, a team led by **Andreas Osterwalder** at EPFL's Institute of Chemical Sciences and Engineering, working with theorists from the University of Toronto, have built an apparatus that allows them to control the orientation and energies of reacting atoms, down to nearly absolute zero. "It's the coldest formation of a chemical bond ever observed in molecular beams," says Osterwalder. A molecular beam is a jet of gas inside a vacuum chamber, frequently used in spectroscopy and studies in fundamental chemistry.

The scientists have used two such beams that merge into a single beam to study chemi-ionization, a fundamental energy-transfer process that is used in several applications, e.g. in mass spectrometry. During chemi-ionization, an atom or molecule in the gas phase reacts with another atom or molecule in an excited state and creates an ion. The identity of the resulting ion depends on the reaction, a new bond can be formed during the collision, resulting in a molecular ion, or else an atomic ion can be formed.

The researchers studied the reaction between two gases: an excited neon atom and an atom of argon. Their apparatus contains a pair of solenoid magnets that is used to precisely tune the direction of a magnetic field wherein the reaction takes place, which allowed the researchers to control the actual orientation of the two atoms relative to each other. "Even though atoms often are represented as tiny balls, they are not normally spherical objects," says Osterwalder. "Exactly because they are not, they have specific orientations, and this can affect their reactivity."

But even though the experiment could control the orientation which, in turn, controlled the amount of atomic vs molecular ions formed from the chemi-ionization, the researchers found that below a temperature of around 20 Kelvin (-253,15°C), the inter-atomic forces took over and the atoms re-oriented themselves irrespective of the applied field.

"This is the first time anyone has done this at such a low temperature," says Osterwalder. "With this level of control, we can study some of the most fundamental models at the core of chemistry, such as the relationship between orientation and reactivity."

OTHER CONTRIBUTOR

- **University of Toronto**

FUNDING

- **EPFL**
- **Swiss National Science Foundation (FNS)**
- **Natural Sciences and Engineering Research Council of Canada (NSERC)**

REFERENCE

Sean D. S. Gordon, Juan J. Omiste, Junwen Zou, Silvia Tanteri, Paul Brumer, Andreas Osterwalder. **Quantum-state-controlled channel branching in cold Ne($^3P_2$)+Ar chemi-ionization.** *Nature Chemistry* 2018. DOI: 10.1038/s41557-018-0152-2.

ISIC

New method more than doubles sugar production from plants

Beech wood undergoing deconstruction.
© Ydna Questell-Santiago / EPFL Laboratory of Sustainable and Catalytic Processing

EPFL chemists have developed a method that can significantly increase the yield of sugars from plants, improving the production of renewable fuels, chemicals, and materials.

Producing fuels and chemicals from biomass (wood, grasses, etc.) is one of the most promising solutions for building a renewable economy. The process involves breaking down, or "deconstructing", plants to produce single carbohydrates, mostly in the form of simple sugars like xylose and glucose. But even though these sugars are valuable, current processes for plant deconstruction often end up degrading them.

Now, the lab of **Jeremy Luterbacher** at EPFL's Institute of Chemical Sciences and Engineering has developed a chemical method that stabilizes simple sugars and prevents them from being degraded. This method could mean that chemists no longer have to balance deconstruction of the plant with avoiding degradation of the product.

The new method changes the chemical susceptibility of the sugars to dehydration and degradation by latching aldehydes onto them. The process is reversible, meaning that that the sugars can be retrieved after deconstruction.

The chemists tried their method on beechwood. First, they turned it into pulp using a paper-making technique called organosolv, which solubilizes wood into acetone or ethanol. But in order to latch aldehydes onto the sugars, the scientists mixed the beechwood with formaldehyde.

With this approach, they were able to recover over 90% of xylose sugars as opposed to only 16% xylose without formaldehyde. When they broke down the remaining pulp to glucose, the carbohydrate yield was over 70%, compared to 28% without formaldehyde.

"Before, people had always been looking for often expensive systems that limited sugar degradation," says Jeremy Luterbacher. "With stabilization, you worry less about this degradation and this frees you up to develop cheaper and faster transformations for plants, potentially accelerating the emergence of renewable consumer products."

FUNDING

- **Swiss National Science Foundation**
- **Swiss Competence Center for Energy Research: Biomass for a Swiss Energy Future (Swiss Commission for Technology and Innovation)**
- **EPFL**

REFERENCE

Ydna M. Questell-Santiago, Raquel Zambrano-Valera, Masoud Talebi Amiri, Jeremy S. Luterbacher. **Carbohydrate stabilization extends the kinetic limits of chemical polysaccharide depolymerization.** *Nature Chemistry* 17 September 2018. DOI: 10.1038/s41557-018-0134-4

MATH

Euler Course celebrates ten years of coaching gifted math students

Cassandre Renaud and Yannis Ulrich, both Euler Course's students. ©A.Herzog / 2018 EPFL

EPFL's Euler Course – the only one of its kind in Switzerland – is designed to help junior-high and high-school students with a high aptitude in mathematics fulfill their potential. 110 students are currently enrolled in the course, which will celebrate its tenth anniversary on 21 November.

Every Wednesday, a group of students aged 10 to 18 from across French-speaking Switzerland meet on the EPFL campus for an intensive afternoon of mathematical problem solving. They are enrolled in the Euler Course – an advanced program for junior-high and high-school students whose avid interest in mathematics means they don't mind sacrificing their otherwise free Wednesday afternoons. And on Wednesday of this week, the course will celebrate its tenth anniversary.

"Every math teacher dreams of giving a class like this, where students enroll voluntarily because they want to learn more and are happy to be there," says **Jérôme Scherer**, a senior scientist at EPFL and the Euler Course coordinator. Scherer manages the course alongside **Kathryn Hess Bellwald**, the EPFL professor who started the program.

"Patrick Aebischer talked to me about setting up the program because I participated in a similar program that my parents created in the US. It was a lot of work, but in the first year we already had 180 students sign up for the entrance exam. We didn't expect it to be so popular!" says Hess Bellwald, who obtained a PhD from MIT when she was just 21. Getting into the Euler Course isn't easy: the entrance exam – a grueling multiple-choice test – is open to any child between the ages of 10 and 13, but only around 30 are selected to enroll each year. "The exam is designed to evaluate how intuitively students grasp mathematical concepts," says Hess Bellwald. Around 350 signed up for this year's entrance exam.

DEVELOPING ANALYTICAL THINKING SKILLS AND SELF-CONFIDENCE

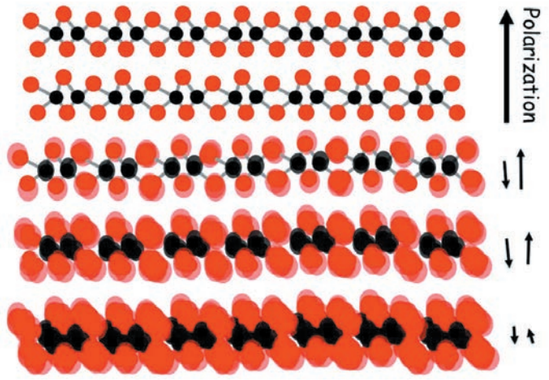
Renaud Rivier, currently a PhD student in mathematics at the University of Geneva, is one of the 20-odd members of the program's first class, which started in the fall of 2008. He was just 10 years old at the time, got good grades and "didn't see any downside" to trying his luck. He completed all six years of the program; the first three focus on high-school-level mathematics and the last three on university-level topics. "It's nice to be able to master a subject so thoroughly when you're so young. That helped me in my science classes, and doing well in such a difficult subject really boosted by self-esteem." The program moves twice as fast as regular classes and requires a major commitment from the students. "But they all enjoy being here and want to put in the effort," says Michèle Honsberger, an educational consultant who works with the program organizers to make sure the students aren't feeling too much pressure.

Today a total of 110 students are enrolled in the six levels of the program, and they span the social spectrum. "I really wanted the program to be open to everyone. That's why tuition is just 100 francs per year," says Hess Bellwald. EPFL and private-sector organizations provide the rest of the funding. Students who take part in the program are exempted from math classes at their regular school. "I liked math in junior high but the classes bored me, so I didn't make much of an effort," says Cassandre Renaud, who is now 16 and in the fourth year of the program. "The Euler Course taught me how to work methodically and introduced me to people who understand me – in junior high I was a nerd, but here I'm just like everyone else."

Yannis Ulrich, a 17-year-old in the sixth year of the program, also enjoys the course's ambiance and the opportunity to talk with like-minded students. But what he really appreciates is being able to "dig into topics deeply" – which helps quench his thirst for knowledge. He used that knowledge to develop a robot for his high-school project and plans to study physics at EPFL. "Half the students who complete the program go on to pursue a degree in math, and the other half a degree in a scientific field. But even if they switch majors or decide not to continue their studies, it's still a useful experience," says Scherer. Shirley Ye, a fifth-year medical student at the University of Lausanne, changed her career goals after completing the program. But she still draws on the skills she learned. "The program changed the way I think. In school I was bored, but the Euler Course gave us stimulating exercises that challenged us. It taught me to look hard for an answer myself before asking for help. And you remember a solution to a problem better if you have to find it on your own," she says.

IPHYS

A dynamic material with a polar shell



An illustration of the effect discovered in this study
© A. Weber/EPFL

A new study shows that the phase transitions of the exotic material molybdenum ditelluride – a candidate for future electronics – are more complex than previously thought.

First-order phase transitions, wherein an amount of heat is lost or gained by a system, are a part of our everyday lives. A typical example is the freezing of water into ice or boiling of water into steam.

A team scientists led by **Hugo Dil** at EPFL's Institute of Physics have now studied how electrons respond to such a first-order phase transition in molybdenum ditelluride ($MoTe_2$), a metal with exotic properties that could be useful for future electronic devices.

The scientists studied the transitions of $MoTe_2$ where its crystal structure changes from one without electric polarization (a measure of the separation of negative and positive charges) to one with electric polarization after cooling the metal down to −23°C.

This is a unique phenomenon because electric polarization causes the conducting electrons to orient their spins according to their momentum. The scientists observed this using a technique called spin- and angle-resolved photoemission spectroscopy, which they carried out at the Swiss Light Source.

Physicists generally think of first-order transitions as happening suddenly at the transition temperature (e.g. 100°C for boiling water). But the scientists observed that the electrons near the surface of $MoTe_2$ respond more gradually near the transition, and interact much more strongly than expected with vibrations in the crystal structure.

The researchers concluded that, at room temperature, the first nanometers of crystal have an ordered polar structure lying on top of a region of dynamically fluctuating electric polarization. The whole of the crystal becomes ordered only after cooling through the transition.

"This discovery furthers our understanding of the everyday phenomenon of first-order transitions and how electric polarization in materials is switched on," says Andrew Weber, the first author of the study. "The transition in $MoTe_2$ is clearly more than a simple, on-off switch."

OTHER CONTRIBUTORS
- **Donostia International Physics Center**
- **Peter Grünberg Institute and Institute for Advanced Simulation**
- **National and Kapodistrian University of Athens**

FUNDING
- **Swiss National Science Foundation**
- **NCCR-MARVEL**
- **Deutsche Forschungsgemeinschaft**
- **Helmholtz Association (VITI project)**

REFERENCE
Andrew P. Weber, Philipp Rüßmann, Nan Xu, Stefan Muff, Mauro Fanciulli, Arnaud Magrez, Philippe Bugnon, Helmuth Berger, Nicholas C. Plumb, Ming Shi, Stefan Blügel, Phivos Mavropoulos, J. Hugo Dil. **Spin-resolved electronic response to the phase transition in $MoTe_2$.** *Physical Review Letters* **121**, 156401. DOI: 10.1103/PhysRevLett.121.156401

ISIC

New symmetry-breaking method opens way for bioactive compounds

A demonstration of chirality © J. Waser/EPFL

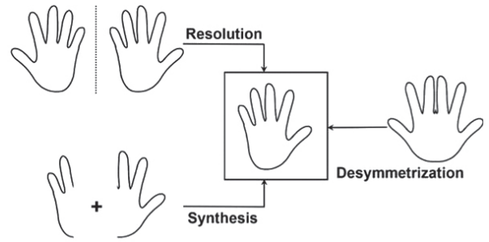
EPFL chemists have developed a new catalytic method for symmetry breaking. The method can help synthesize important building blocks for bioactive compounds such as anticancer drugs.

Many chemical molecules can exist in nature together with their mirror counterparts; like hands, two compounds can be made up of the same atoms in the same overall structure but in opposite orientations, i.e. left-handed and right-handed. This phenomenon of symmetry is called "chirality", and can give mirror counterparts ("enantiomers") entirely different chemical properties. A famous and tragic example of chirality is thalidomide, which was originally sold as a mixture of both enantiomers. The problem was that one was a harmless sedative and the other highly toxic to fetuses, resulting in disturbing congenital deformities.

So today it has become imperative to synthesize compounds with what is known as high "optical purity", which is a measurement of chiral purity: the degree to which a sample contains one enantiomer in greater amounts than the other. But because enantiomers have very small structural differences and identical stability, synthesizing one over the other is a very challenging task.

One way to do this is what chemists call "desymmetrization" of a non-chiral compound that is similar to the target molecule. This involves modifying a molecule so that it loses the symmetry elements that prevented it to be chiral.

Researchers at **Jérôme Waser**'s Laboratory of Catalysis and Organic Synthesis at EPFL have now developed a new desymmetrization strategy to access chiral building blocks containing urea sub-structures. Urea derivatives are important components of biomolecules such as biotin (vitamin B7) or bioactive natural products, such as the anticancer agelastatin A.



The three main approaches to accessing one enantiomer selectively: 1) Separate a mixture of the two enantiomers (resolution), wasting one of the enantiomers. 2) Synthesize selectively only one of the two enantiomers. 3) Use a "desymmetrization" of a non-chiral compound similar to the target. This is used less often, but it is particularly elegant as it can reveal chirality from an already relatively complex precursor by breaking the symmetry in only one simple transformation.
© J. Waser/EPFL

The researchers made two crucial innovations. First, they designed a non-chiral cyclopropane (three-membered carbon ring) precursor. This molecule offers enhanced reactivity and is ideal for reactions under mild conditions.

Second, the researchers engineered a new copper catalyst that can form an enantiomer of the desired product with high selectivity. The copper center binds and activates the cyclopropane precursor, causing its bonds to break. The precursor is then attacked by an indole, a molecule very important as structural element of bioactive compounds. As a result, the precursor loses its symmetry – and therefore becomes chiral – and can be used to selectively make the desired enantiomer.

FUNDING
- **Swiss National Science Foundation (SNSF)**

REFERENCE
Daniele Perrotta, Ming-Ming Wang, Jérôme Waser. **Lewis Acid Catalyzed Enantioselective Desymmetrization of Donor-Acceptor Meso-Diaminocyclopropanes.** *Angewandte Chemie International Edition* DOI: 10.1002/anie.201800494 and *Angewandte Chemie* DOI: 10.1002/ange.201800494

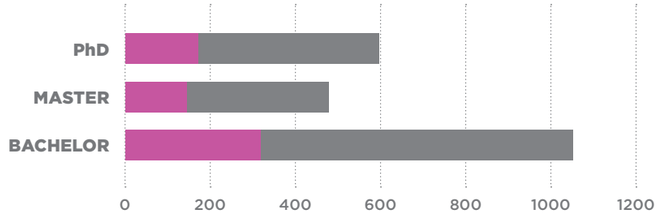
2018 IN FIGURES

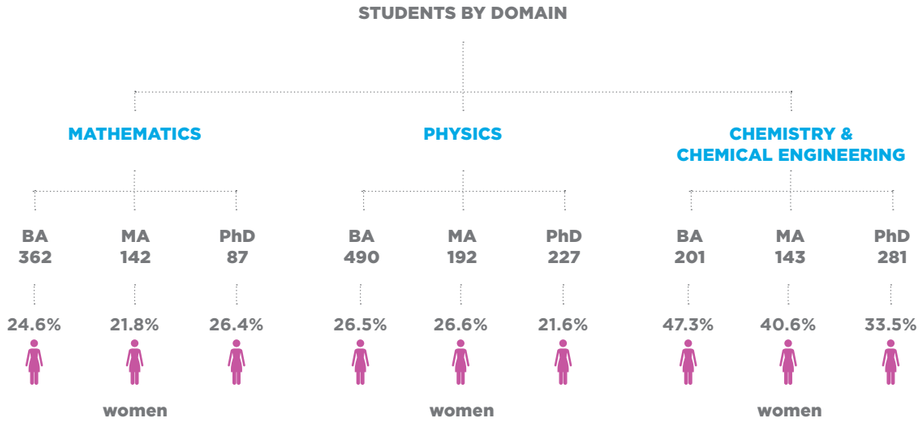
PEOPLE
FUNDING
RESEARCH
KEY FIGURES

IPHYS ISIC MATH

PEOPLE

FSB students



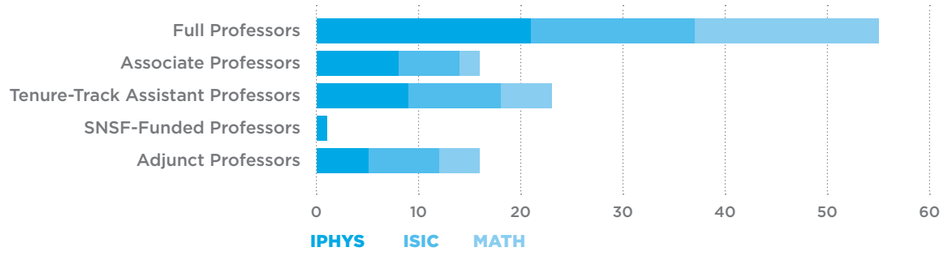


FSB staff

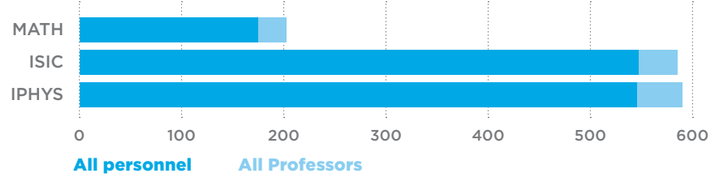
	IPHYS	ISIC	MATH	ALL
Full Professors	21	16	18	55
Associate Professors	8	6	2	16
Tenure-Track Assistant Professors	9	9	5	22
SNSF-funded Professors	1	0	0	1
Adjunct Professors	5	7	4	16
Senior Scientists / MER	20	7	2	29
Scientific staff / postdocs	169	182	67	418
Administrative staff	35	35	16	93 *
Technical staff	95	42	3	146 *
PhD students	227	281	87	595
Apprentices				37
Emeriti Professors				62

* includes the FSB Deanship

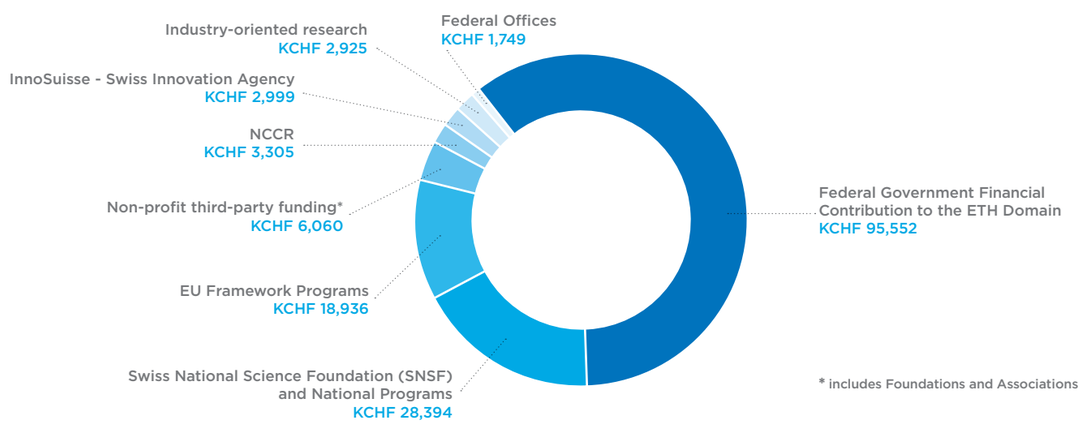
FSB PROFESSORS



FSB STAFF



FUNDING



RESEARCH

1034	Journal articles
31	Conference papers
24	Reviews
4	Book chapters
1093	Total peer-reviewed publications
92	Theses
3	Patents

KEY FIGURES

118	Research groups
3	Research Institutes
1	Research Center
2	Campuses
3	Doctoral Programs
2125	Students
110	Professors
686	Staff

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School of Basic Sciences FSB

EPFL
Bâtiment PH
Station 3
CH-1015 Lausanne
sb@epfl.ch

sb.epfl.ch

@epflSB