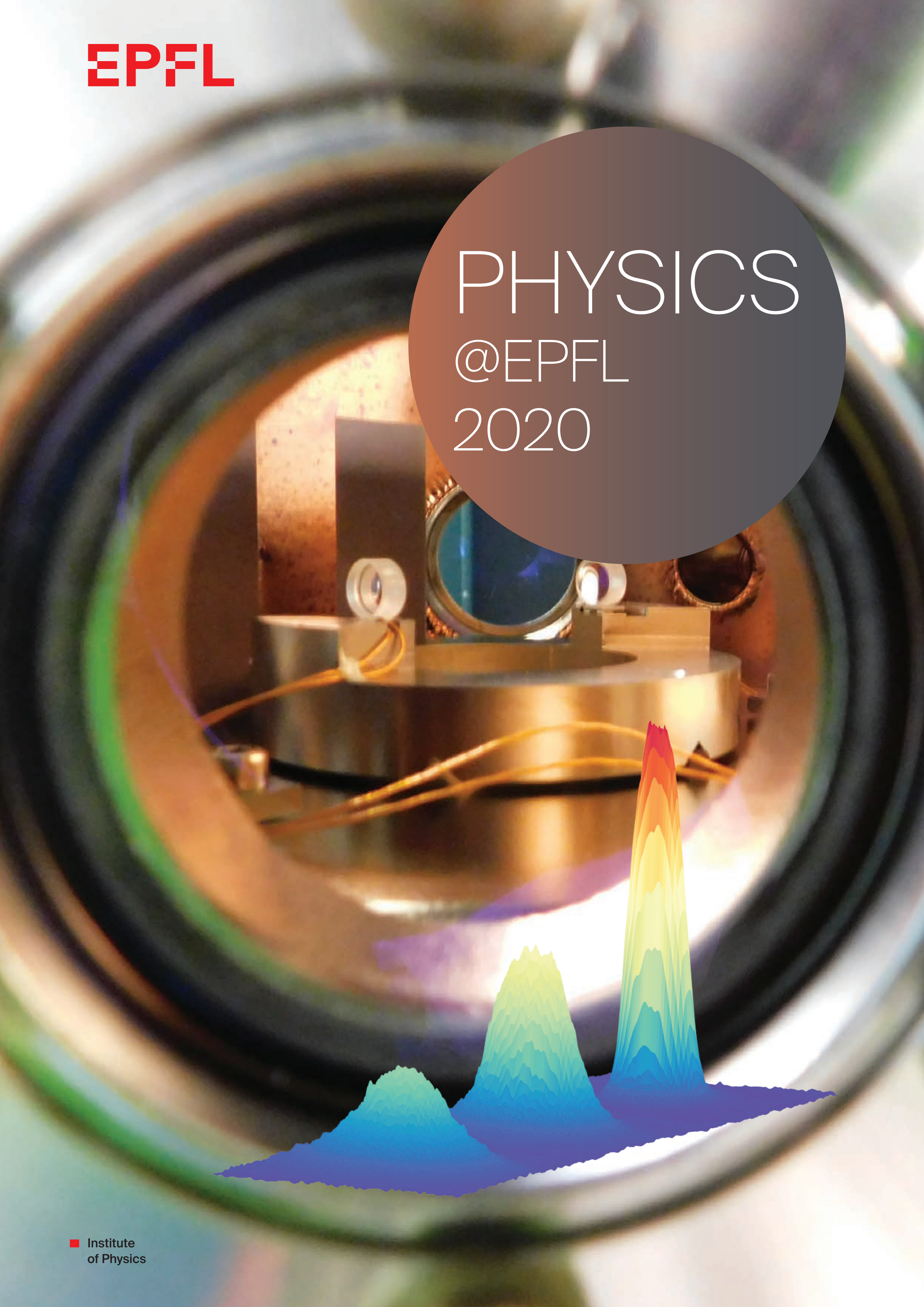
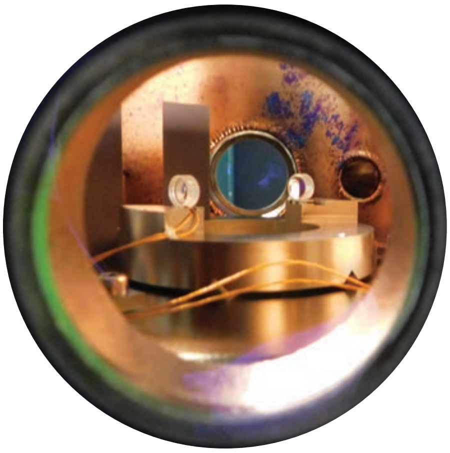


# PHYSICS @EPFL 2020

Institute
of Physics



# CONTENTS 2020


3
Letter from the director

## NOMINATIONS

4
Mitali Banerjee

5
Mike Seidel

6
Henning Stahlberg

## PROMOTION

7
Anna Fontcuberta i Morral

## TEACHING

8
Students meet their heroes

8
Innovation in teaching

12
Graduation Day

15
Apprentices education

## OUTREACH

18
Open Days

## AWARDS

7
Enrico Fermi Prize for Nakada

9
Two ERC grants for Kippenberg

9
Charpak-Ritz Prize for Deveaud

12
EPS HEPP Prize for Shchutska

17
Hébert Teacher of the Year

17
Craie d'Or for Testerman

17
Polysphère d'Or for Magrez

18
Physics Thesis Award for Jorge

## INNOVATION

7
Hexisense

19
Swissto12

## RESEARCH

10
How slip nucleates

11
Basic plasma physics for fusion

13
Neural networks quantum systems

14
Measuring astronomical distances

16
Illuminating the "wet" electron

## INSTRUMENTATION

15
Innovative copper coils

18
Diaphragm installed at TCV

## FAREWELL

19
Retirements

## IN BRIEF

20-21
Publications, nominations and awards

22-23
Physics in figures


**FRONT COVER**
Formation of a molecular Bose-Einstein condensate of lithium atoms and the cavity used to study the condensate.

# LETTER FROM THE DIRECTOR

Dear Reader,

writing these lines, we all live an exceptional situation impacting our private and work lives. Our campus is closed, any experimental activity has ceased, and we work from home as well as possible, ensuring teaching duties online, maintaining motivation in our teams, taking time to analyse or write up research results. As Direction team, we are doing our best to cope with various plans for shutdown, but more importantly to keep the Institute evolving, to put all faculty hires into place at the foreseen dates and to host all new faculty members in the best possible way, given the present circumstances.

Looking back to the time before the SARS-CoV-2 crisis, our institute was able to attract the following new faculty members. In January 2020 we were very happy to welcome Mitali Banerjee, Mike Seidel, and Henning Stahlberg, whose activities you can discover in these pages. Other colleagues, to be presented in our next edition, have been or will be starting later in 2020. Christian Rüegg joined on April 1st as Full Professor in solid-state physics, while becoming the new Director of the Paul Scherrer Institute. Giuseppe Carleo and Pasquale Scarlino, both working in Quantum Science and Technology, have accepted our offers as Tenure Track Assistant Professor and will reinforce this strategic area starting in Autumn 2020. Following our call in Statistical Physics of Complex Systems, we are looking very much forward to the nomination of Lenka Zdeborová (75 % IPHYS, 25 % IC) and her husband Florent Krzakala (50 % IPHYS, 50 % STI). Two SNSF professors have left for faculty positions elsewhere, Peter Maurer at the University of Chicago and Alessandro Vicci at the University of Pisa.

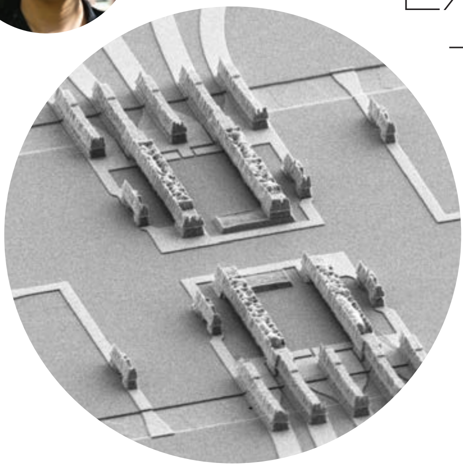
Teaching distinctions recognize every year the dedication of the teaching staff, particularly needed in these hard times. These distinctions were awarded last year to Cécile Hébert, Arnaud Magrez, and Donna Testerman. You will find many other outstanding achievements in the following pages. Among them, we would like to congratulate Tobias Kippenberg for his ERC Advanced and Proof of Concept Grants, and Anna Fontcuberta i Morral for her promotion to Full Professor.

Let me close by expressing my sincere hope that the partial and then full return to operation of our institute and campus go well, that our experimental science will smoothly get up to pace, and that we can swiftly take out all the construction and refurbishing for hosting new faculty members. I am grateful to my team, Olivier Schneider as vice-head, Blandine Jérôme for scientific assistance, and Claire-Lyse Rouiller and Valérie Schaerer Businger for administrative assistance.

In thanking you for your interest in IPHYS and in wishing you a good reading,

**Ecole Polytechnique Fédérale de Lausanne**
EPFL SB IPHYS Direction
Bâtiment PH, Station 3, CH-1015 Lausanne

# MITALI BANERJEE EXPLORES TOPOLOGICAL STATES OF MATTER



**Mitali Banerjee was named as Tenure Track Assistant Professor of Physics as of the 1st of January 2020.**

As a child, Mitali Banerjee was always fond of books, and as she grew, she very naturally gravitated towards mathematics and physics. As an undergraduate, she took physics major and then specialised in condensed matter physics for her masters. During the first couple of years of her PhD, she was working in theory, followed by doing experiments in order to "match" her calculations. "Since then I fell in love with experimental physics," says Mitali Banerjee, "to discover how simple conductance measurements can teach us so much about a system. I always keep my eyes open for new emerging phenomena, allowing me to end up addressing different physics problems in my PhD and postdocs studies." After getting her PhD at the S. N. Bose National Centre for Basic Sciences in Kolkata in 2012, Mitali Banerjee has been a postdoctoral fellow successively at the Indian Institute of Science in Bangalore, the Weizmann Institute of Science in Rehovot, and Columbia University in New York.

Condensed matter physics has markedly evolved in the last decade and one key idea that took the field by storm is topological quantum states, a new class of materials characterised by global topological properties induced by purely local degrees of freedom. Mitali Banerjee also got excited to learn of new kinds of interactions and her work at the Weizmann Institute exploited studies of heat flow as the tool to identify such exotic states, thus opening a wider avenue for future work.

The research of Mitali Banerjee focuses on the understanding of fundamentals of emergent quantum many-body physics. Strong correlations in solid-state systems often make the regular electrons behave differently, and sometimes the resultant quantum states host quasi-particles that are rather immune to local environmental disturbance. These quasi-particles are fundamentally different from electrons or any other fundamental particles. Being fragile, they are elusive and experiments to detect them are much more challenging; yet their understanding may change the way we presently look at advanced technology. "Doing challenging experiments is a driving force in my work," confesses Mitali Banerjee. "I am in love with physics. It gives me immense happiness every time that I chase a goal – either failing or successful."

## *Elusive quasi-particles in quantum many-body systems*

Her group will focus on contributing to and redefining the understanding of topological states of matter, one of the most intriguing strongly correlated systems. New measurement techniques, based on nano-electronic circuits, have to be adapted to invade the depth of these fascinating phases of matter. "With my previous postdoc experiences," she explains, "I am aware of the knowhow needed to unveil the new mysteries. Above all, I have a spectrum of collaborators who will be joining hands in my endeavours."

Mitali Banerjee regards teaching as an important aspect in research. "What can we do without young talents coming and joining the force?" she asks. "I feel that teaching is the only way that I can infuse interest for fundamental science in younger generations."

"It is amazing how much EPFL has to offer to an experimentalist," adds Mitali Banerjee. "Not only its world class facilities, but also the various departments with all kinds of cutting-edge technologies under one roof, make EPFL an exciting place to study and work. The possibilities of inter-departmental, as well as interdisciplinary collaborations, is a dream come true for any experimentalist, and I am looking forward to actively contribute here."

# MIKE SEIDEL DEVELOPS ENERGY-EFFICIENT ACCELERATORS


**Mike Seidel was named as Full Professor of Physics as of the 1st of January 2020. He is also Head of the Division Large Research Facilities at the Paul Scherrer Institute (PSI).**

As the new Head of the Particle Accelerator Physics Laboratory (LPAP) at the Institute of Physics, Mike Seidel engages with accelerator R&D at the energy frontier for particle physics, which is particularly exciting through the connection with CERN. Today the Large Hadron Collider (LHC) is the most powerful, but also the most energy hungry accelerator in the world. A high goal for his research is to develop optimised concepts for a next generation collider facility. The challenge for a future collider facility is to find the best compromise between performance, cost and energy consumption. The LPAP will contribute through beam dynamics studies aiming at maximizing luminosity per grid power, but perhaps also through efficient technology R&D like radio-frequency sources.

## *Maximizing luminosity per grid power*

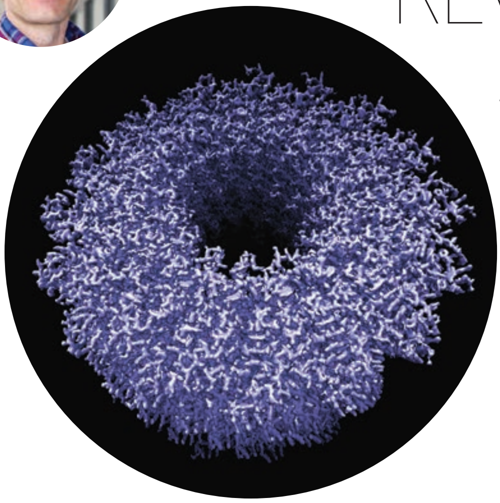
The LPAP is open for studies in a broad range of technological and theoretical topics. A larger project is the development of a unified accelerator design and simulation framework, an activity submitted for co-funding to the Swiss Accelerator Research and Technology Program (CHART). This project can be developed into a long-term activity at EPFL with strong relevance for Future Circular Collider (FCC) studies, but also with impact on other fields of accelerator R&D like synchrotron light sources. With CERN and PSI, Switzerland has two outstanding institutions that perform their research based on particle accelerators. The connection with their large accelerator facilities allows the LPAP to engage in challenging development projects.

"The use of advanced technology in combination with basic physics concepts was always a topic that interested me," says Mike Seidel. "Particle accelerators are a fascinating playground for the application of technology, while at the same time, beam dynamics has many theoretical aspects." After studying nuclear physics in Dresden, Mike Seidel started his accelerator physicist career at DESY in Hamburg. Design and commissioning of a multi-stage beam collimation system for HERA, a 6.3 km ring collider, was his main project there, with pioneering aspects for later machines like the LHC. After that Mike Seidel worked on a variety of topics, including at PSI, since 2006, on the high intensity proton accelerator HIPA, the cancer therapy facility PROSCAN, and more recently, coordinating the design effort for an achromatic superconducting proton therapy gantry.

In the past, Mike Seidel has taught courses at the CERN accelerator school, and he always felt that explaining accelerator concepts in a simple, didactic way is a challenging but also rewarding activity. There is a shortage of physicists and engineers specialised on accelerators, and teaching courses is an obvious way to attract young people to the field. "Discussions with students are always enjoyable," adds Mike Seidel, "and I am very motivated to teach an accelerator physics course."

Today's forefront accelerators utilise advanced technologies like superconducting magnets or cavities. "I strongly believe," asserts Mike Seidel, "that we have not used all opportunities to profit from the fast development in other branches of science and technology, such as computing, material science, advanced manufacturing, plasma physics or energy management. I will work towards establishing such connections with other laboratories to fully utilise the opportunities at a renowned research institution like EPFL."

# HENNING STAHLBERG REVEALS PROTEIN STRUCTURES



**Henning Stahlberg was named as Full Professor of Physics as of January 2020. He will hold a dual professorship with the University of Lausanne (UNIL).**

After graduating in solid state physics at the Technical University of Berlin, Henning Stahlberg did his PhD in the groups of Prof. Horst Vogel at EPFL (Chemistry) and Prof. Jacques Dubochet at UNIL (Biology), analysing membrane proteins by cryo-electron microscopy (cryo-EM). After working for five years as a postdoc at the University of Basel, he opened his own research lab in 2003 at UC Davis, where his group developed and used a software system for the automated structure determination of membrane proteins from cryo-EM images of 2D crystals. In 2009, Henning Stahlberg moved back to the University of Basel, where he became the director of the Center for Cellular Imaging and NanoAnalytics. There, his group implemented a fully automated cryo-EM data collection and online processing pipeline, and developed microfluidic sample preparation technology, allowing them to determine the atomic structure of purified proteins from only few nL of sample.

Since January 2020, Henning Stahlberg is in charge of setting up and directing the newly created Centre d'Imagerie Dubochet (CID), shared between UNIL, EPFL, and other institutions as well as pharmaceutical industry. The CID will serve the Lake Geneva community with high-performance high-resolution structural investigations, using primarily cryo-EM, and will further advance the imaging technology. "The Lausanne strength in deep learning, advanced other microscopies, and the imaging@EPFL initiative will be important contributors to the success of the CID, and vice-versa," stresses Henning Stahlberg,

Cryo-EM has experienced dramatic improvements in resolution and structure analysis speeds in recent years. A remaining major bottleneck is sample preparation: how to extract a protein from its cellular environment and quick-freeze it in a thin water layer without disturbing its structure? "Only a hand-full of laboratories," says Henning Stahlberg, "further advance the method by working at the interface between physics, materials sciences, deep learning, and the application to life sciences cryo-EM. For such projects, EPFL and IPHYS will be a wonderful home for me."

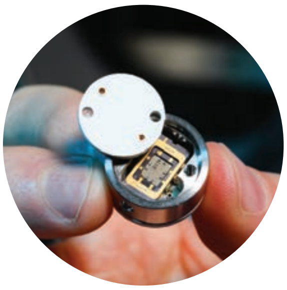
## *Sample preparation remains the main hurdle*

Henning Stahlberg's research focuses on EM method development and Parkinson"s Disease. For the first, his group will setup a prototype cryo-transmission electron microscope aiming for improvements in resolution, reduction of beam damage, and acceleration of structure determination of biological molecules. For the second, they will investigate the molecular players of Parkinson's Disease, their atomic structure and function, and study where and how these proteins contribute to neurodegeneration in the human brain.

Quite expectedly, Henning Stahlberg likes teaching interdisciplinary topics: "I enjoy presenting basic technical concepts together with their application to life sciences or medicine." And further: "Future teaching will likely benefit from the experiences we are now gathering in online teaching with the Corona crisis, but will not replace classroom or laboratory contacts. A combination of online courses with class-room group discussions could be an effective way to harvest the best of both teaching styles."

And he concludes: "In my research lab in IPHYS, I am looking forward to learning from my new colleagues to commonly advance cryo-EM technology. And the CID will implement our newly developed technologies, and employ these to answer the biological questions of the life sciences community at the two Lausanne high-schools and beyond."

INNOVATION



# A chip to measure vacuums

**An EPFL spin-off, Hexisense, is bringing to market a gallium nitride-based chip that can measure the quantity of certain gas molecules cheaply and with unrivalled precision.**

Vacuums are a vital part of the processes – such as freeze-drying – used to make and preserve countless everyday items and must be measured with precision. But vacuum systems contain various residual gases. To measure them, manufacturers currently have two options. The cheap one involves various methods to measure the total pressure of all those gases. The other, mass spectrometry, distinguishes between the gases, but is expensive. The small 0.4 $cm^2$ gallium nitride chip, developed by the Laboratory of Advanced Semiconductors for Photonics and Electronics, aims to offer an affordable way of measuring individual gases in all vacuum systems.

In a vacuum vessel, when gas molecules become less numerous, they move towards the walls and stick there. The gallium nitride mini-sensor is exposed to the light of a LED and repels certain gas molecules, like oxygen. Once the light goes off, gallium nitride's semiconductor properties allow the chip to measure how quickly gas molecules return to the walls. Specific algorithms then analyse the number of molecules on the surface along with the partial pressure of each gas.

The two inventors, Ian Rousseau and Pirouz Sohi, supported by various startup programs, are now starting to produce these chips with the spin-off company Hexisense.

AWARDS

# Tatsuya Nakada wins Enrico Fermi Prize

**Tatsuya Nakada has been awarded the Enrico Fermi Prize from the Italian Physical Society.**

Given by the Italian Physical Society (IPS) since 2001, the prestigious Enrico Fermi Prize is awarded to commemorate the great physicist and Nobel laureate, Enrico Fermi. The Prize is awarded yearly to one or more Members of the Society.

In 2019, one Enrico Fermi Prize has been awarded to Professor Tatsuya Nakada, co-director of the High Energy Physics Laboratory. The IPS states that Tatsuya Nakada is being recognised *"for the conception and crucial leading role in the realization of the LHCb experiment that led this year to the discovery of the CP violation in D mesons with charm quarks."*

Tatsuya Nakada was the first spokesperson of the LHCb experiment at CERN between 1995 and 2008 throughout its design, development and construction phase. Subsequently, with the data collected during the first two operating periods of the Large Hadron Collider (LHC), the LHCb experiment was a huge success, exceeding all expectations. It makes the most precise measurements in its field, making it possible to indirectly seek New Physics beyond the Standard Model with a better sensitivity than that of the other experiments on the LHC. LHCb also made several discoveries, the most recent being in 2019 the CP violation in D mesons.

Another Enrico Fermi Prize was given to Professor Marcello Giorgi at the University of Pisa.

PROMOTION

# Anna Fontcuberta i Morral develops novel nanowires

**Anna Fontcuberta i Morral, associate professor at the Institute of Materials Science and Technology and co-affiliated to the Institute of Physics was named as full professor as of the 1st of October 2019.**

Anna Fontcuberta i Morral obtained her PhD at the Ecole Polytechnique in Paris in 2001. After a postdoctoral period at the California Institute of Technology, she obtained a permanent CNRS researcher position at the Ecole Polytechnique in 2003. In 2004 she co-founded the company Aonex Technologies, spin-off from CalTEch. Thanks to a Marie Curie Excellence Grant, she was a Team Leader at the Technical University of Munich from 2005 to 2010. In 2008, she was appointed Tenure Track Assistant Professor at the Institute of Materials of EPFL, and promoted to Associate Professor in 2014. She was awarded an ERC Starting Grant in 2009 and an SNSF Back-up Schemes Consolidator Grant in 2015.

An internationally renowned scientist, Anna Fontcuberta i Morral specialises in the synthesis of nanostructures within semiconductors and, in particular, in nanowire crystal growth techniques. Her laboratory is well-known for innovations in wires involving hetero-structures of interest for solar cells and quantum computing. The results of her research aid in the development of innovative materials with optimal optical and electronic properties.

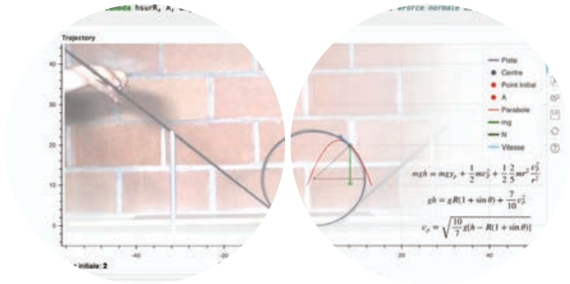
# Students meet their heroes

**The Physics student association -Les Irrotationnels- with the support of the Physics section, organises each semester a topical conference for undergraduates. In 2019, two Nobel laureates, Klaus von Klitzing and Hiroshi Amano, participated to this conference series.**

2019 is a revolutionary *millésime* for physicists with the introduction of brand-new International System base units, especially with a new definition of the kilogram. Four out of seven units have been redefined: the kilogram, ampere, kelvin, and mole are now linked to the electron charge, the Planck constant, the Boltzmann constant, and the Avogadro constant. On April $15^{th}$, after an enlightening talk in the framework of the $50^{th}$ anniversary Campus lectures (and organised by Oleg Yazyev for IPHYS), Prof. von Klitzing (1985 Nobel laureate) met in the evening with undergraduate students and answered questions spanning over a broad spectrum of topics.

"Energy and research" was another topic suggested by the students. To address this question, we received on October $14^{th}$ Prof. Amano who explained the foundation of solid-state lighting based on blue light emitting diodes (for which he was awarded the 2014 Physics Nobel prize). He summarised the current research activities on power electronics, which may dramatically contribute to energy saving in the future. After the conference, a spontaneous discussion started with students asking various questions, as for instance the role of theoretical models in experimental physics or research in Japan.

TEACHING



# Innovation in teaching: DRIL projects

**Digital education is nowadays developing rapidly across EPFL. The vice-presidency for education created the Digital Resources for Instruction and Learning (DRIL) fund to support teachers willing to implement digital tools in their teaching material. IPHYS is very active in promoting digital education with several on-going DRIL projects.**

A recurrent difficulty for $1^{st}$ year students is to understand basic but somewhat complex concepts in classical mechanics like forces, velocities, or the relationship between acceleration and trajectories. Interactive graphics allow students to perform virtual experiments and get a feeling of physical phenomena. The "Jupyter Notebooks for first year physics" project granted to Cécile Hébert offers a digital toolbox where the underlying models and calculations are visible. Students learn to question those tools instead of using them as a black box. They can analyse exercises with graphical tools and play with parameters to get a better understanding of the physical concepts at play.

Another DRIL initiative entitled "Computational thinking tools for solid state physics courses" was granted to Henrik Rønnow and Oleg Yazyev. This Jupyter Notebook project is part of a coherent initiative to strengthen a line of courses for students wishing to specialise in solid-state physics. Solid-state physics is one of the physics education pillars in $3^{rd}$ year Bachelor and Master. Many concepts in solid-state physics are difficult to learn without proper demonstration and experimentation, which is out of reach in traditional courses. Thus, this Jupyter Notebook project, in collaboration with Fabrizio Carbone, aims at offering a set of digital tools with graphical illustrations and numerical experimentations in which parameters can be freely changed by the students. This project clearly helps improving the content of the lectures by bridging the gap between theory and experiments in solid-state physics.

A third DRIL fund was awarded to Christophe Galland. His project is to create a series of Jupyter notebooks aimed at facilitating the conceptual understanding of electromagnetism by the students. This digital resource also promotes "computational thinking" by offering a transparent and modifiable code, which the students can experiment with and build upon. This Jupyter Notebook could be used in all $1^{st}$ and $2^{nd}$ year courses covering electrostatics, electricity, magnetism, electromagnetic waves, and optics. This may benefit to about 1,000 students every year.

# Tobias Kippenberg receives ERC Advanced and Proof of Concept Grants

**Tobias Kippenberg has been awarded an Advanced Grant and a Proof of Concept grant from the European Research Council (ERC).**

The ERC Advanced Grants are given each year to established, leading principal investigators to provide long-term funding for *"ground-breaking, high-risk"* research projects in any field. Tobias Kippenberg was awarded the grant for his project entitled *"Extremely Coherent Mechanical Oscillators and circuit Cavity Electro-Optics."*

The quest for mechanical oscillators with ultralow dissipation is motivated by classical and quantum sensing and technology, as well as precision measurements. The project proposes a new generation of strain-engineered crystalline and superconducting mechanical oscillators, whose Q-factors are predicted to exceed 100 billion in up to 2 dimensions. The aim is to reach this theoretical limit, probe new dissipation mechanisms, and utilise these oscillators for quantum optomechanics in new regimes, and achieve room temperature ground state cooling and ponderomotive squeezing. Likewise, these techniques will be applied to create highly coherent superconducting electromechanical devices at milli-Kelvin temperatures, enabling quantum-enhanced force sensing and 1 second decoherence times.

Secondly, the project will explore a fundamentally new method for the measurement and manipulation of microwave fields with optical fields – the nascent field of circuit Cavity-Electro-Optics (cCEO). First recognised over a decade ago, it is possible with optical fields to cool, amplify or interferometrically read out microwaves. Yet to date this regime has remained inaccessible due to insufficient coupling strength between the microwave and optical fields. This challenge will be overcome with a new circuit architecture. Taken together, the study can open cCEO to usher in a new era of mechanical coherence within classical and quantum domains.

Tobias Kippenberg was also awarded a Proof of Concept Grant entitled *"Photonic Integrated Microcombs as Multi-wavelength Sources for Edge Data Centers."* These grants are given annually to researchers who already hold other ERC grants. Worth up to €150,000, they can be used for different purposes, including establishing intellectual property rights, investigating business opportunities, or conducting technical validation.

Over the past ten years the Laboratory of Photonics and Quantum Measurements (LPQM) has developed and pioneered microcombs – photonic integrated optical frequency combs (OFC) – providing access to equidistant optical carriers. It has also developed unique proprietary $Si_3N_4$ microfabrication processes for ultra-low power microcombs, and allowed in-house photonic packaging. Taken together, the laboratory is now able to implement the full cycle production of a packaged microcomb ready for integration into a commercial product. The project aims to bring the technology to the market.



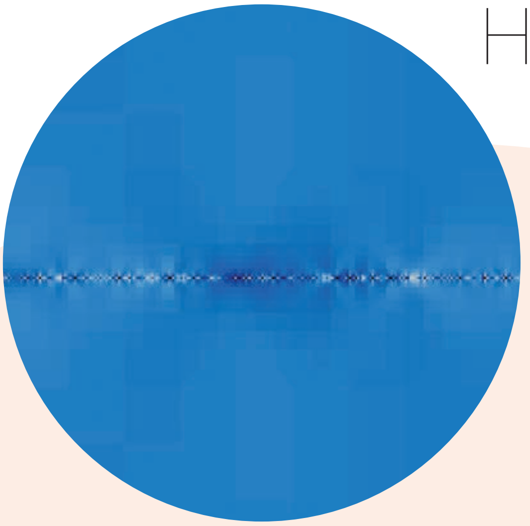
# Benoît Deveaud wins Charpak-Ritz Prize

**Benoît Deveaud, Professor emeritus with the Institute of Physics, has been awarded the 2019 Charpak-Ritz Prize from the Swiss and French Physical Societies.**

The Charpak-Ritz Prize was created in 2016 by the Swiss Physical Society (SPS) and the Société Française de Physique (SFP) to *"highlight the tight relationship between the two societies and to keep the memory alive of Georges Charpak and Walther Ritz who both have profoundly contributed to physics in their respective times"*. The prize distinguishes exceptional contributions in physics or in its development, to honour physicists who have made significant contributions in France and Switzerland.

In 2019, the SPS and SFP have awarded the Charpak-Ritz Prize to Benoît Deveaud, now Professor Emeritus with the Institute of Physics and Vice-Provost for Research at the École Polytechnique (France). Professor Deveaud is honoured for his *"pioneering optical spectroscopy studies dedicated to the ultrafast and quantum optical properties of semiconductor nanostructures."*

Benoît Deveaud's achievements in the field cover a wide range of subjects, including the luminescent properties of deep chromium and transition metal impurities in GaAs, the study of vertical carrier transport in superlattices, the study of the exciton luminescence in semiconductor quantum wells, the physics of microcavity polaritons, and the demonstration of polariton amplification and Bose-Einstein condensation of these polaritons in microcavities.



# HOW COLLECTIVE ASPERITY DETACHMENTS NUCLEATE SLIP

**Friction between solids is ubiquitous but still poorly understood. IPHYS theoretical physicists are using numerical models to build a microscopic theory for friction.**

Understanding how slip at a frictional interface initiates is important for a range of problems including earthquake prediction and precision engineering. Even though this question dates back to Leonardo da Vinci, at present we lack a microscopic theory. The current understanding is mostly phenomenological, with an engineering relation calibrated at the macroscopic scale. Problematically, however, the calibrated values were shown to be system dependent and poorly reproducible.

This engineering relation is based on the friction coefficient. It is defined as the ratio of the applied tangential force at which the sliding of a block that rests on a flat surface starts (or continues to slide), and the normal force acting on the block. The friction coefficient typically decreases with increasing sliding velocity when the latter is small. This phenomenology can lead to stick-slip, whereby driving a system quasi-statically results in periods of loading that are punctuated by sudden macroscopic slip events.

Experimental observations support the fact that these macroscopic slip events proceed by a zipper-like opening of the interface. In particular, it has been observed that after a nucleation phase in which slip appears locally and evolves slowly, a well-defined rupture front appears, that travels ballistically across the frictional interface, unzipping it. This front is accompanied by a stress field in the elastic bulk that is well described by that of a propagating crack. By contrast, the nucleation phase is much less understood.

Physicists in the Physics of Complex Systems Laboratory (PCSL) have proposed a description of frictional interfaces that captures disorder at the asperity level, long-range elastic interactions between local slip events, and inertia. Using a large number of numerical simulations, they have proposed a microscopic prediction for the onset of sliding. It shows that the “friction coefficient” is stochastic even for very large system sizes: sliding is nucleated when, by chance, an avalanche of microscopic detachments reaches a critical radius, beyond which slip becomes unstable and propagates along the interface. When sliding stops, a small fraction of microscopic contacts are left at the onset of detaching again.

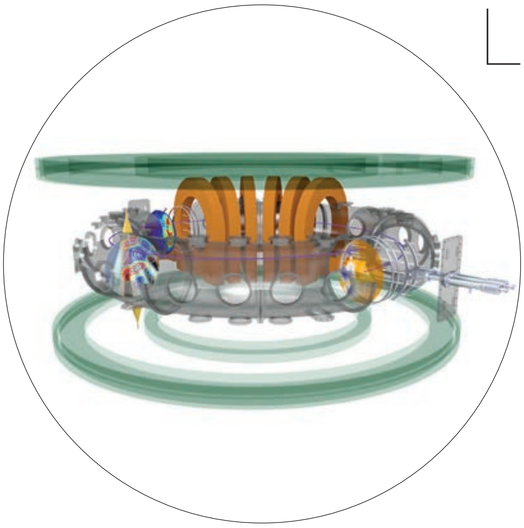
## *Sliding results from an avalanche of microscopic detachments*

Scientists of the PCSL base their microscopic theory on the stability distribution of the interface, *i.e.* the fraction of contacts that will detach when the system moves forward, and the critical radius beyond which an avalanche of detachments nucleates macroscopic slip, that follows a classical prediction from fracture mechanics. They predict that under certain conditions, stick-slip friction is an extremely slowly decaying finite size effect.

With their model they plan to push forward to formulate a microscopic theory for friction that includes the effects of temperature and long-range heterogeneities.

**REFERENCE**

T.W.J. de Geus, M. Popović, W. Ji, A. Rosso, M. Wyart, **How collective asperity detachments nucleate slip at the frictional interfaces**, *Proc Natl Acad Sci* **166**, 23977 (2019). DOI: 10.1073/pnas.1906551116



# LINKS BETWEEN BASIC PLASMA PHYSICS AND FUSION

**In the efforts to demonstrate the feasibility of fusion power, basic plasma physics research and numerical simulations, as performed at the Swiss Plasma Center, are very valuable.**

The road to fusion as a viable energy source is a succession of large scale facilities with increasing power generated by plasmas maintained at temperatures higher than those of the Sun. Presently, the Joint European Torus tokamak holds the record for the highest fusion performance, with 16 MW of fusion power generated from 24 MW of input heating power. The next-generation tokamak known as the International Thermonuclear Reactor (ITER) aims for a 10-fold net energy gain of 500 MW from 50 MW heating power. The next step towards the first commercial power plants, the DEMOnstration Power Station, is already in the conception phase.

In parallel to developing reactor technology, the fusion community needs to refine its physical understanding of fusion plasmas. Basic plasma physics and theoretical models are necessary to define the characteristics of future fusion reactors and certain technological obstacles can be overcome by improving our basic knowledge. A substantial contribution in this direction can be achieved by conducting experiments in simplified plasma devices, and transferring the results to tokamaks or stellarators.

An example of simplified plasma devices is TORPEX, operated at the Swiss Plasma Center. The focus of research carried out with TORPEX lies on turbulence, which is a ubiquitous feature of magnetised plasmas. Turbulence plays a crucial role in the transport of energy and particles both in the core and at the edge of the plasma. The experiments made on the TORPEX installation make it possible to isolate a number of phenomena occurring in the plasmas in order to study them in detail.

Examples include the characterization of the dynamics of “blobs”, macroscopic structures resulting from the turbulent evolution of plasma instabilities, and the possibility of controlling them as well as their influence on the propagation of microwaves in their vicinity.

## *Study isolated phenomena in simplified plasma devices*

TORPEX plays an important role in the validation of numerical simulations based on first principles, since the measurements of modelled quantities are easier to carry out in small, dedicated devices rather than in more complex fusion facilities. For instance, a model describing the propagation of microwaves in the vicinity of blobs could be validated with the help of TORPEX.

Addressing such plasma physics questions in simplified configurations will help define the optimal operation conditions for ITER. For the steps after ITER, fundamental discoveries can influence the conceptual design of future fusion power facilities.

**REFERENCE**
A. Fasoli, I. Furno, P. Ricci, **The role of basic plasmas studies in the quest for fusion power**, *Nature Phys* **15**, 872 (2019). DOI: 10.1038/s41567-019-0622-5

# Lesya Shchutska wins EPS Young Experimental Physicist Prize

**Lesya Shchutska has been awarded a Young Experimental Physicist Prize from the European Physical Society (EPS).**

Each year, the EPS High Energy Particle Physics Board awards a Young Experimental Physicist Prize *"for outstanding work by one or more young physicists (less than 35) in the field of Particle Physics and/or Particle Astrophysics."*

In 2019, one of the awardees is Lesya Shchutska, Tenure-Track Assistant Professor at the High Energy Physics Laboratory. She is an internationally acclaimed and highly innovative young scientist whose research focuses on the search for physical phenomena beyond the standard model of particle physics.

She had been exploring energy frontier with the collaborative CMS experiment at CERN's Large Hadron Collider (LHC) in Geneva. With no evidence for new heavy particles produced at the LHC, Shchutska initiated searches for light feebly interacting particles (like heavy neutrinos) within the large volumes of data delivered by the LHC, and she came to EPFL and the LHCb experiment to challenge standard model predictions with the precision measurements in bottom quarks, and is searching heavy neutrinos in B meson decays.

The EPS has recognised Lesya Shchutska *"for outstanding contributions to experimental activities in particle physics, from the design and simulation of novel experiments, test-beam operations and analyses, to data analyses and their final theoretical interpretations."* The Prize's other winner is Josh Bendavid (CERN).

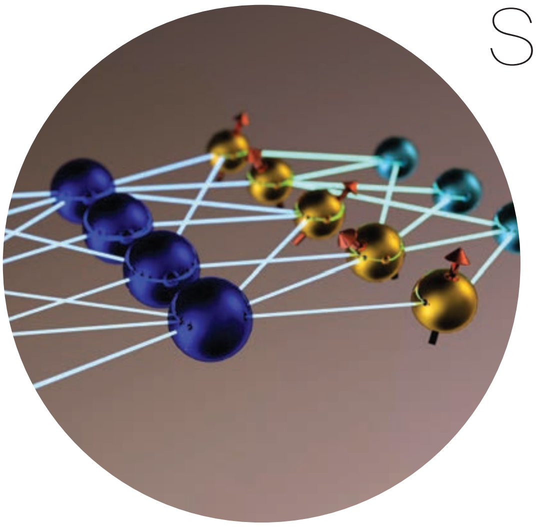
# Graduation Day

**On October 5th 2019, took place the Magistrale, the traditional graduation day at EPFL. This year, 1028 Master students were honored in the presence of the Federal Councilor Alain Berset, the EPFL President Martin Vetterli, and nearly 3'000 relatives who experienced this emotional event where students turned toward new horizons.**

In 2019, the graduation day was marked by EPFL's 50th anniversary celebration. President Martin Vetterli traced the history of EPFL over the last five decades and stressed the key societal role of the graduates for the next 50-year period, where they will face gigantic challenges related to food, health, and energy issues. The Federal Councilor Alain Berset acknowledged the fruitfulness of interdisciplinarity and underlined the successful mission of EPFL in the innovation and education domains. Maria Leptin, Head of the European Molecular Biology Organization, received a Doctor Honoris Causa degree.

The Award ceremony also featured the third highest Master's grade average going to Aurélien Dersy, a physics student with 5.94 out of 6. Arnaud Magrez from IPHYS received the *Polysphère d'Or* award from the student association AGEPoly (see p. 17). The Physics section wishes to thank Arnaud for his engagement in teaching, especially for his contribution in animating and supervising the bachelor hands-on.

After the Magistrale, the physics students and their family were invited to participate to the physics graduation ceremony, chaired by Prof. Paolo De Los Rios. After an introductory speech by Prof. Jan Hesthaven, the Dean of the School of Basic Sciences, 74 Master degrees (43 in physics, 29 in applied physics, and 2 in nuclear engineering) were handed out by Prof. Nicolas Grandjean, Head of the Physics section. The best teacher Award delivered by the Physics section went to Prof. Cécile Hébert for her dedication to develop numerical tools, *i.e.* Jupyter Notebook, for general physics courses (see p. 17).



# SIMULATING QUANTUM SYSTEMS WITH NEURAL NETWORKS

**A new computational method, based on neural networks, can simulate open quantum systems with unprecedented versatility. The method was independently developed by physicists at IPHYS, France, the UK, and the US.**

Even on the scale of everyday life, nature is governed by the laws of quantum physics. These laws explain common phenomena like light, sound, heat, or even the trajectories of balls on a pool table. But when applied to a large number of interacting particles, the laws of quantum physics actually predict a variety of phenomena that defy intuition.

In order to study quantum systems made of many particles, physicists must first be able to simulate them. This can be done by solving the equations describing their inner workings on supercomputers. But while Moore's Law predicts that the processing power of computers doubles every couple of years, this is a far cry from the power needed to tackle the challenges of quantum physics.

The reason is that predicting the properties of a quantum system is enormously complex, demanding a computational power that grows exponentially with the size of the quantum system – an "intrinsically complex" task, according to Vincenzo Savona, who directs the Laboratory of Theoretical Physics of Nanosystems.

"Things become even more complicated when the quantum system is open, meaning that it is subject to the disturbances of its surrounding environment," Vincenzo Savona adds. And yet, tools to efficiently simulate open quantum systems are much needed, as most modern experimental platforms for quantum science and technology are open systems, and physicists are constantly in search of new ways to simulate and benchmark them.

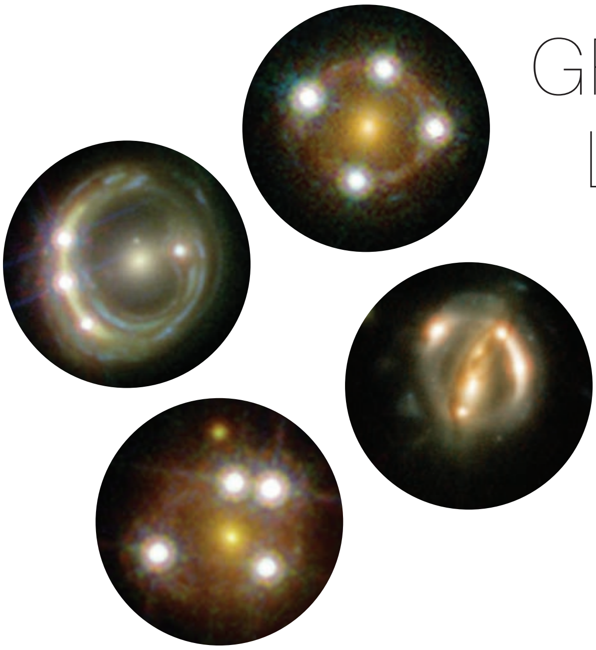
But significant progress has been made thanks to a new computational method that simulates quantum systems with neural networks. The method was developed by Vincenzo Savona and his PhD student Alexandra Nagy at EPFL – and independently by scientists at the Université Paris Diderot, the Heriot-Watt University in Edinburgh, and the Flatiron Institute in New York. The total body of work is being published across three papers in Physical Review Letters.

## *Predicting the properties of a quantum system is enormously complex*

"We basically combined advances in neural networks and machine-learning with quantum Monte Carlo tools," says Vincenzo Savona, referring to a large toolkit of computational methods that physicists use to study complex quantum systems. The scientists trained a neural network to represent simultaneously the many quantum states in which a quantum system can be cast by the influence of its environment.

The neural-network approach allowed the physicists to predict the properties of quantum systems of considerable size and arbitrary geometry. "This is a novel computational approach that addresses the problem of open quantum systems with versatility and a lot of potential for scaling up," says Vincenzo Savona. The method is set to become a tool of choice for the study of complex quantum systems, and, looking a bit more into the future, for assessing the effects of noise on quantum hardware.

**REFERENCE**
T. Nagy, V. Savona, **Variational quantum Monte Carlo with neural network ansatz for open quantum systems**, *Phys Rev Lett* **122**, 250501 (2019).
DOI: 10.1103/PhysRevLett.122.250501



# GRAVITATIONAL LENSES: A RULER TO MEASURE ASTRONOMICAL DISTANCES

**One of the most challenging tasks in astrophysics consists in measuring cosmological distances, behind which hides the Hubble parameter, $H_0$, describing at what rate the Universe expands today, about 13.7 billion years after Big-Bang. The natural phenomenon of gravitational lensing, *i.e.* how mass deviates light, allows us to measure $H_0$ independently of any other method.**

$H_0$ is one of the six key parameters describing the geometry and expansion history of our Universe. There are two broad classes of methods to measure it. First, using the imprint of acoustic waves in the Cosmic Microwave Background (CMB), when the Universe was still young. The quantity actually measured is H(z) where z is the redshift of the CMB, *i.e.* z=1100. By using a cosmological model, one can extrapolate H(z=1100) to H(z=0), which is the Hubble constant now, aka $H_0$. Because $H_0$ is extrapolated from z=1100 to z=0, one speaks of "inverse distance ladder". This gives $H_0$ = 67.4 ± 0.5 $km.s^{-1}.Mpc^{-1}$ [1].

The second class of methods involves measurements at low redshift. The most popular one uses objects at increasing distances, each "bin" of distances being used to calibrate the next one, and the most distant bin is measured using bright supernovae explosions. This is called the distance ladder because of the many steps required to reach larger and larger distances. The latest supernovae results give $H_0$ = 73.5 ± 1.4 $km.s^{-1}.Mpc^{-1}$ [2].

Of course, the two classes of methods should give the same answer as they all measure the same Universe! But they disagree, meaning either that one or both measurements are wrong, or that the model used to extrapolate H(z=1100) to H(z=0) from CMB is questionable. Before blaming cosmological models, obtaining more independent $H_0$ measurements is of uttermost importance.

Gravitationally lensed quasars belong to the second class of distance indicators, but do not require the construction of a distance ladder! The principle is simple: when a distant quasar (bright core of a galaxy) is seen aligned with a foreground massive galaxy (the lens), we see multiple images of it. Because the alignment is not perfect and because the lens galaxy is not symmetrical about its center, the optical paths to each quasar image do not have the same length. In addition, photons propagating from the quasar pass next to the potential well of the foreground lens galaxy. As a result, any signal emitted by the quasar is seen delayed in each lensed image, the origin of the delay being both geometrical and gravitational. This delay depends on the distance scale of the Universe, *i.e.* $H_0$, and on a model for the potential well of the lens. Measuring the delay from luminous variations of the quasar images, and constraining the lens model from sharp images obtained with the Hubble Space Telescope leads to a measurement of $H_0$ through the geometrical part of the delay.

The H0LiCOW international collaboration, co-founded by Frédéric Courbin, specialises in such measurements and finds $H_0$ = 73.3 ± 1.8 $km.s^{-1}.Mpc^{-1}$ [3], adding to the tension in $H_0$ values from Planck, as opposed to low redshift measurements. There are unfortunately (too) many explanations so far to explain this tension, but astrophysicists are at work to narrow down the measurement error bars and rule out theories.


**REFERENCES**

[1] Planck team, **Planck 2018 results. VI. Cosmological parameters**, *arXiv* 1807.06209, 2018

[2] A.G. Riess, S. Casertano, W. Yuan, L.M. Macri, D. Scolnic, **Large Magellanic Cloud Cepheid Standards Provide a 1% Foundation for the Determination of the Hubble Constant and Stronger Evidence for Physics beyond ΛCDM**, *ApJ* **876**, 85 (2019). DOI: 10.3847/1538-4357/ab1422

[3] K. Wong *et al*, **H0LiCOW XIII. A 2.4% measurement of H0 from lensed quasars: 5.3σ tension between early and late-Universe probes**, *arXiv* 1907.04869, 2019 (in press in *MNRAS*)

# Apprentices training

**Education and training is one of EPFL's missions, and this includes the training of apprentices in professions related to its activities. Within the Institute of Physics, several services and laboratories host apprentices under the supervision of local trainers.**

Apprenticeship is a curriculum that lasts three or four years depending on the profession, and that alternates theoretical instruction and practical training of a profession. The theoretical instruction is given by the Lausanne vocational school. For one to two days a week, each apprentice studies the general and specific professional subjects. Practical training and professional skills related to the profession are taught in training companies or organisations, such as EPFL.

In each laboratory or shared service of the institute, a person is responsible for the training of the hired apprentice. Each apprentice is a true valuable collaborator, and is perfectly integrated into the life of IPHYS services and laboratories. Presently, several apprentices are being trained at IPHYS.

One computer apprentice is trained within the IT team. He participates in the development and maintenance of the institute's machines and network. He also learns the commissioning of operating systems and software, performs various tests related to network and server communication, and becomes familiar with enterprise computing.

The mechanical workshop is training three polymechanical apprentices on its two locations (BSP and PH buildings). The polymechanics manufacture parts in various materials and learn to use all machining and assembly techniques. They participate in the design of 3D parts, and are familiar with the programming of digital machines to produce them. Apprentices also get the opportunity to use laser cutting machines to make complex-shaped parts, a specialty of the BSP workshop.

Four apprentices in physics are trained at the IPHYS clean rooms, the Crystal Growth Facility, and the High Energy Physics Laboratory. Physics laboratory technicians collaborate with other scientific or technical specialists to set up experiments or analyse physics laboratory equipment. They are in addition involved in making samples of various materials and their characterization through testing and analysis. The physics workers also study mechanics and electronics. Integrated into a laboratory team, they take care of logistics and maintenance of equipment.

At the end of the apprenticeship, and after passing a theoretical and practical exam, each apprentice receives a federal capacity certificate (CFC) that validates the training. After graduating, each apprentice can enter professional life, or join a specialised high school (HES) to obtain a higher degree. There are even former apprentices returning to EPFL to complete a master's degree and a thesis. We thank all IPHYS trainers for their dedication and involvement, and wish success to all apprentices in training.



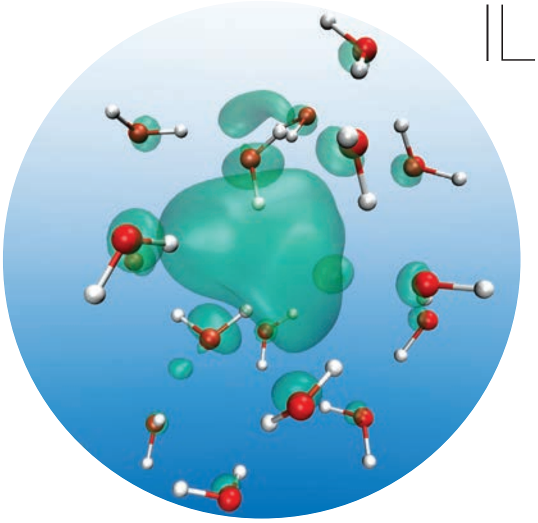
# Innovative copper coils

**The mechanical workshop has manufactured copper coils by wire erosion and computer numerical control (CNC) machining for a new type of electromagnets for the Laboratory for Quantum Gases (LQG) of Jean-Philippe Brantut.**

Quantum gases experiments, where a dilute vapor is cooled down to 1 nK, require controlled magnetic fields that are usually produced by coils made of wound wire, which offer little flexibility. The LQG combines quantum gas experiments with optical interferometry, making space occupation constraints even tighter. To meet this challenge, the group, together with the mechanical workshop, has developed a new design, where the coil is realised using a bulk copper plate in which a thin spiral is cut. This allows to make electromagnets of almost arbitrary geometries.

Using its state-of-the art wire erosion and CNC milling machines, the mechanical workshop team succeeded in cutting a continuous, ~6 meters long spiral in single-block, 200 mm-thick copper disks. The most delicate aspect has been to ensure the mechanical stability of the spiral throughout the process. This challenging geometry required 72 hours of continuous machining and 20 km of 0.25 mm-thick brass wire for the cut.

This new method of electromagnet development is now becoming the standard for coils in the LQG. The interest has sparked beyond EPFL, leading to a scientific publication (*Roux et al*, SciPost Physic 2019) and a participation to the tech transfer initiative of the NCCR Quantum Science and Information Technology.



# ILLUMINATING THE "WET" ELECTRON

**Scientists at IPHYS have made the first in-depth study of the so-called "wet" electron – a phenomenon that occurs when an excess electron is added to liquid water.**

One of the strangest-sounding puzzles of chemistry is that of the "wet electron". When an excess electron is added into liquid water, some molecules re-organise themselves to form a cavity around it. When this happens, the electron is referred to as "hydrated". Even though the hydrated electron is well studied, we know little about how it is actually formed. Recent experiments have suggested that the excess electron goes through two changes before it finally becomes hydrated: the "quasi-free" electron stage, where the excess electron is fully de-localised in the water, and the "wet" electron stage, which is still a mystery.

It is not just a fundamental question; the hydrated electron is involved in reduction reactions in aqueous chemistry or even in mutagenic lesions in the DNA of cells. This means that understanding the response of liquid water to an excess charge is important for a number of applications.

Now, scientists at the Institute of Physics have performed advanced computer simulations to clarify the mechanism leading to the formation of the hydrated electron and to deliver a well-rounded picture of the wet electron's properties. The research was led by Alfredo Pasquarello and carried out in the context of his Master's course "Computer Simulation of Physical Systems".

"We found that, before the formation of the hydrated electron, the excess electron repeatedly switches between the quasi-free electron and wet electron precursor states," says Michele Pizzochero, the first author of the study. The study also revealed that the wet electron occurs when the excess electron partially breaks the hydrogen-bond network of liquid water. All this happens before the entire system (water plus excess electron) reaches thermodynamic equilibrium.

*The hydrated electron is still a mystery*

The work is the first to determine the atomic structure and the energy level of the wet electron. "Overall, our findings shed new light on the elusive wet electron, and offer an appealing theoretical picture to the interpretation of experimental observations," says Michele Pizzochero.

**REFERENCE**
M. Pizzochero, F. Ambrosio, A. Pasquarello, **Picture of the Wet Electron: A Localized Transient State in Liquid Water**, *Chem Sci* **10**, 7442 (2019).
DOI: 10.1039/c8sc05101a

# Cécile Hébert awarded the Teacher Prize of the Physics Section

**The Teaching Prize 2019 was awarded to Professor Cécile Hébert. This award, presented by the Physics Section, honours every year a teacher who has particularly excelled in this important mission.**

Cécile Hébert is the head of the Electron Spectrometry and Microscopy Laboratory. She constantly challenges herself and is not afraid to test out new teaching tools and methods, an approach that helped her win the 2019 prize for best physics teacher.

Cécile Hébert has the non-trivial task to convey the basic concepts of general physics every year to around 200 first-year students from outside the physics section. "I try to get them used to taking a problem, breaking it down, modelling it, using their knowledge of math and challenging the result." Feedback from a high-school teacher has helped Hébert pinpoint her students' difficulties and adapt the exercises. She also keeps her class' attention through experiments drawn from everyday life, like feeling the force of inertia when the metro breaks.

To encourage her students to engage, Hébert also uses SpeakUp, an app that allows students to ask questions anonymously and vote for the questions they think are most relevant. "And then, in class, I answer the questions that get the most votes," she says. Since the spring semester, she has also created her own Jupyter Notebooks, which are programmable exercise books that model experiments and show students the equations behind them.

AWARDS

# Craie d'Or 2019 awarded to Donna Testerman

**The 3rd year Bachelor students in Physics have awarded the Craie d'Or of the best Bachelor Teacher to Donna Testerman for her course on advanced linear algebra.**

It has now become a tradition. Towards the end of the spring semester, following the Practical Work III poster presentations, 3rd year physics students present the Craie d'Or to the Best Teacher of their bachelor curriculum.

In 2019, the ceremony took place on May 3rd and Gaëlle Wavre, delegate of the 3rd year students, revealed the winner. She started by thanking all the teachers, without whom the students would not be where they are now, very close to getting their bachelor degree. She then presented the Craie d'Or to Donna Testerman for her course on Advanced Linear Algebra (1st year), mentioning that the perfect structure and clarity of her lectures were particularly appreciated by the students, not to mention the small chocolates distributed before the exams.

Donna Testerman confessed that teaching math to the physics students has been a great love story. When she started teaching this course, she discovered that these students loved math and loved applying math. Since she has stopped teaching this course (after 2017), she is really missing physics students. Obviously, students are missing her too.

AWARDS

# Arnaud Magrez awarded the Polysphère d'Or 2019

**During the Graduation Ceremony, the AGEPoly has presented the Polysphère d'Or to Arnaud Magrez, teacher in the Physics Section.**

On the occasion of the Graduation Ceremony, the students honour the best teacher of each faculty with a polysphère. The teacher who obtains the highest mark in the vote among all the faculties receives the Polysphère d'Or.

In 2019, the Polysphère d'Or has been awarded to Arnaud Magrez who is responsible for the physics lab work for 3rd year bachelor students in physics, together with Iva Tkalcec Vâju and Daniel Oberli. In this course, students conduct experiments in the form of projects every Friday for four weeks.

"I love my lab work course," says Arnaud Magrez, "because I spend one day a week with the students. They are in groups of two or three, which allows me to easily exchange with them, to help them develop experimental skills, to test their fundamental knowledge as well. Over time, it creates a kind of complicity. Many have a sincere gratitude, then I have the impression of having accomplished my mission. For the anecdote, the section did not ask me to give this course. I asked the section to have this course, which takes a lot of time during and outside the semester but gives me a lot of fun."

Obviously, his students share this fun, while describing him as demanding, strict, but pedagogue. For Arnaud Magrez, "it is an exceptional honour to receive an award from the students. They are the *raison d'être* of a school. I am very proud."

OUTREACH

# Open Days

**On the occasion of the fiftieth anniversary of the federalisation of EPFL, the School opened its doors to the public on September 14th and 15th. The physics laboratories showed the multiple facets of their research with a rich program of activities spread over three locations.**

In the CE area and neighbouring buildings, visitors could explore the secrets of matter, from elementary particles to innovative materials and living matter. They could for instance dive into the quantum world, visualise atoms with high resolution microscopy, learn about the structure of crystals, or visit a nuclear reactor. The Physics Show demonstrated to a packed auditorium the different facets of energy through an entertaining series of spectacular experiments.

At the Swiss Plasma Center, visitors could see how physicists produce small stars in a tokamak, with the aim of mastering fusion, a new source of energy, inexhaustible, safe and respectful of the environment. They found out which challenges remain to achieve fusion on Earth and what is the path towards the commercialization of fusion energy.

Finally, at the SwissTech Center, visitors could embark on a journey into space offered by the Laboratory of Astrophysics and the other space researchers of EPFL, taking visitors literally among the stars with virtual reality. Needless to say, visitors could not see all the many activities proposed all over campus. Overall the Open Days were a great success with over 40,000 visitors throughout the weekend.

AWARDS

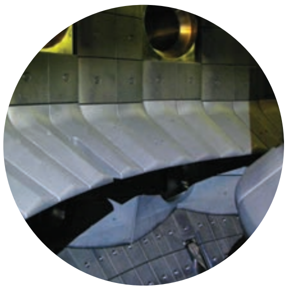
# Rogério Jorge gets the Physics Doctoral Thesis Award

**Rogério Jorge got the award for his thesis entitled "A moment-based model for plasma dynamics at arbitrary collisionality" supervised by Prof. Paolo Ricci at the Swiss Plasma Center and Prof. Nuno Loureiro at MIT and the University of Lisbon.**

Rogério Jorge worked on one of the most important issues faced by the fusion community, namely the understanding of the plasma turbulent dynamics in the tokamak edge, where the plasma temperature decreases from values as high as ten times the temperature in the core of the Sun to the room temperature of the wall. He provided a seminal contribution to the development of a model that will allow the numerical simulation of this challenging region. Rogério Jorge distinguished himself as a teacher and was also a very active representative of the Physics PhD students, one of the main organisers of the first EPFL Physics Days, and heavily involved in the discussion of the organization of the teaching assistantship.

The Doctoral School has also recognised the following doctorates with a special distinction: Mikhail Ivanov, Rogério Jorge, and Michael Schenk.

INSTRUMENTATION



# Diaphragm installed in TCV tokamak

**A diaphragm made of carbon baffles was installed in the TCV tokamak to improve its performance.**

In a fusion reactor, the fuel of heavy hydrogen isotopes must be heated to very high temperatures (100M°C) to be in the plasma state. The plasma is kept away from the walls by magnetic fields. However, a fraction of the plasma particles manages to escape the magnetic cage and impact, typically, the bottom of the vessel. One of the remaining challenges in fusion research is to reduce the number and temperature of these particles to prevent excessive erosion.

A promising method is to increase the density of the neutral gas in the lower part of the machine to remove energy and momentum from the escaping particles before they hit the floor. This gas unfortunately tends to penetrate into the hot plasma, degrading the performance.

The physicists and engineers of the Swiss Plasma Center imagined installing a diaphragm in the machine that separates the lower region from the hot plasma. Under the leadership of Holger Reimerdes, carbon baffles were designed, manufactured, equipped with measuring instruments and installed inside the machine, forming this diaphragm to isolate the two regions from one another.

The first experiments show that it is indeed possible to increase the neutral pressure in the lower region without disturbing the hot plasma in the upper region. The increased neutral pressure is furthermore seen to reduce the particle impact on the bottom of the vessel as intended.

# Two professors retire

**Professors Elyahou (Eli) Kapon and Leonid Rivkin retired after a rich and successful carrier. We warmly thank them for their services to science, teaching and academic administration at EPFL and beyond.**

A graduate from the University of Tel Aviv, Eli Kapon also obtained his PhD from this university in 1982. After a postdoc at Caltech, he joined Bellcore in 1983 where he worked on optoelectronics of III-V semiconductors and on semiconductor nanostructures, more particularly quantum wires, first as a member of the technical team, then as head of department. In 1993, he was appointed as full professor at EPFL. As an expert on microelectronics and optoelectronics, he directed EPFL's first laboratory devoted to nanostructures – with a focus on semiconductors and photonics. The activities of his laboratory ranged from the design and manufacturing to the characterization of physical properties and the study of the industrial development of innovative devices in the field of quantum and photonic nanostructures. Eli Kapon was also very active in teaching general physics as well as more specialised topics in different sections at EPFL. He has been a member of numerous international committees, acted as a consultant to the European Space Agency and served on a European Research Council (ERC) committee. In addition, he has registered 17 patents and founded a company.

Leonid Rivkin studied physics in Novosibirsk and at Harvard University. After obtaining his PhD at Caltech in 1985, he worked on several projects in accelerator physics at the Linear Accelerator Center in Stanford (SLAC), then at CERN's Large Electron-Positron Collider. He joined the Paul Scherrer Institute (PSI) in 1989, where he worked among others on the Swiss Synchrotron Light Source (SLS) project as part of the project management. In 2002, he became head of the accelerator operation and development division at PSI. He was appointed full professor in accelerator science at EPFL in 2006 and was at the same time put in charge of the Large Research Facilities at PSI, where he was made Deputy Director in 2017. He is regarded as one of the leading international scientists in the field of particle accelerators and has made a significant contribution to many of the world's most important accelerators. More recently, Leonid Rivkin set up the Swiss Collaboration on Accelerator Research and Technology (CHART). Leonid Rivkin has been a member of many international scientific committees, including the Scientific Policy Committee of CERN, of which he is presently the chair. His research and teaching activities have helped to foster EPFL's relationships with PSI and CERN. He attracted more than 40 CERN doctoral students in accelerator physics and supervised their thesis work defended at EPFL. Many students from various disciplines followed his master course on particle accelerators, which is unique in Switzerland.



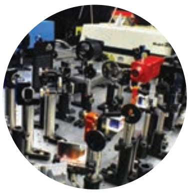
# SWISSto12 raises 18.1 million

**SWISSto12, an EPFL spin-off that supplies telecommunications components to the satellite and aerospace industries, has completed of a fund-raising round of 18.1 million CH.**

The company plans to use the money, secured from Swisscanto Invest, Swisscom Ventures and CNB, to scale up the production and marketing of its components, some of which went into orbit several months ago.

Data-transfer needs are growing non-stop, requiring ever more satellite bandwidth, and thus increasingly high wave frequencies. Yet the higher the frequency the more difficult it is to control, and this is where the quality and shape of antennas play a crucial role. SWISSto12 uses a patented process to manufacture metal-plated 3D-printed components. The firm's antennas are ten times lighter than their all-metal equivalents – a significant difference in an industry where every gram saved translates into lower cost.

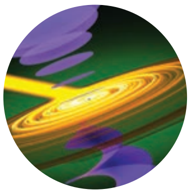
"We have already attracted the attention of major names in the satellite and aerospace industries," says CEO Emile de Rijk, whose PhD thesis at the Laboratory of Jean-Philippe Ansermet led to the spin-off. "Our partners include Airbus Defense and Space, Thales Alenia Space, Cobham Advanced Electronic Solutions and the European Space Agency." SWISSto12's technology could also change the way miniature satellites and constellations, two fast-growing market segments, and the antennas fitted to airplane fuselages are designed and manufactured.



## Seeing individual quanta of vibrational energy at ambient conditions

Phycists in the group of Christophe Galland have for the first time successfully observed a single quantum of vibrational energy, a so-called phonon, at ambient conditions. To generate the phonon, the scientists shot ultrafast laser pulses onto a diamond crystal to excite its atomic lattice into vibration. They triggered a collective vibration involving more than 100 billion atoms that exchanged energy with single photons from the laser light. The work opens up new possibilities for the study of quantum phenomena and ultrafast quantum technologies at room temperature.

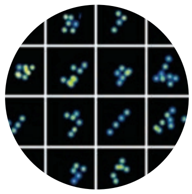
S. Tarrago Velez *et al*, **Preparation and decay of a single quantum of vibration at ambient conditions**, *Phys Rev X* **9**, 041007 (2019).
DOI: 10.1103/PhysRevX.9.041007



## Twisting whirlpools of electrons

Using a novel approach, physicists from the lab of Fabrizio Carbone have been able to create ultrafast electron vortex beams, with significant implications for fundamental physics, quantum computing, future data-storage, and even certain medical treatments. The scientists fired circularly polarised, ultrashort laser pulses on electrons passing through a nano-hole fabricated onto a metallic film, and demonstrated that, during the interaction of the electrons with the field, the wave function of the electrons took on a chiral modulation.

G. M. Vanacore *et al*, **Ultrafast generation and control of an electron vortex beam via chiral plasmonic near fields**, *Nat Materials* **18**, 573 (2019).
DOI: 10.1038/s41563-019-0336-1



## An open platform for large field-of-view super-resolution imaging

The lab of Suliana Manley has developed a waveguide-based approach for points accumulation in nanoscale topography (PAINT) microscopy, waveguide-PAINT. Using waveguides enables increased throughput and data quality for PAINT, by generating a highly uniform ~100 × 2000 $\mu m^2$ area evanescent field for total internal reflection fluorescence (TIRF) illumination. The capabilities of the open platform was demonstrated by using DNA-PAINT to image multiple whole cells or hundreds of origami structures in a single field of view.

A. Archetti *et al*, **Waveguide-PAINT offers an open platform for large field-of-view super-resolution imaging**, *Nat Comm* **10**, 1267 (2019).
DOI: 10.1038/s41467-019-09247-1

## International Physicists' Tournament

The 2019 edition of the International Physicists' Tournament took place at EPFL, following the first place of the EPFL team at the 2018 edition. A 10-member student organizing committee, led by Evgenii Glushkov and chaired by Prof. Jean-Philippe Ansermet, had put together an intense week of competition, site visits, and social events. A record number of 19 teams from 16 different countries took part in the competition. The EPFL team reached the semi-finals, securing a 5$^{th}$ place. The Ecole Polytechnique of Paris won the competition.

## SNSF awards a PRIMA and three Ambizione grants

The Swiss National Science Foundation (SNSF) has awarded Ambizione grants to three young researchers to perform their own projects within the Institute of Physics: Mayeul Chipaux (hosted by Nicolas Grandjean), Tom de Geus (hosted by Matthieu Wyart) and Nils Johan Engelsen (hosted by Tobias Kippenberg).

The SNSF has also awarded a PRIMA grant to Jennifer Schober, a researcher with the Laboratory of Astrophysics.

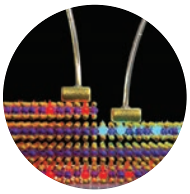
## Edoardo Baldini receives the SPS IBM Prize and the APS Carl E. Anderson Award

Edoardo Baldini, a former PhD student in the labs of Majed Chergui and Fabrizio Carbone, has won two distinctions for his PhD thesis entitled *"Nonequilibrium Dynamics of Collective Excitations in Strongly Interacting and Correlated Quantum Systems."* One is the IBM Prize of the Swiss Physical Society and the other is the Carl E. Anderson Division of Laser Science Dissertation Award from the American Physical Society. Edoardo Baldini is presently postdoctoral fellow at MIT.

## Making and controlling crystals of light

Dissipative solitons are stable solutions of driven nonlinear systems. Of particular interest are soliton solutions of integrated photonic microresonators, both for applications in telecommunication and metrology, as well as model systems to study fundamental dynamics. Researchers in Tobias Kippenberg's lab have demonstrated that dissipative solitons can form perfect crystal states in rings. Moreover, they unveiled that their formation and annihilation can be controlled precisely and deterministically. This is in stark contrast to the established paradigm in dissipative soliton formation, i.e. that multiple solitons form stochastically.

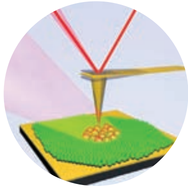
M. Karpov *et al*, **Dynamics of soliton crystals in optical microresonators**, *Nat Phys* **15**, 1071 (2019). DOI: 10.1038/s41567-019-0635-0



## A new 2D magnet draws future devices closer

The groups of Andras Kis (IEL) and Oleg Yazyev (IPHYS) have discovered a new type of 2D magnetic material, platinum diselenide ($PtSe_2$), which can be integrated into spintronic devices. The magnetism of $PtSe_2$ is caused by defects on its surface, which are irregularities in the arrangement of atoms. Its magnetism, even within the same layer, can be further manipulated by strategically placing defects across its surface – a process known as "defect engineering" that can be accomplished by irradiating the material's surface with electron or proton beams.

A. Avsar *et al*, **Defect induced, layer-modulated magnetism in ultrathin metallic $PtSe_2$**, *Nat Nanotech* **14**, 674 (2019). DOI: 10.1038/s41565-019-0467-1



## Gap-plasmon-enhanced high-spatial-resolution imaging

Scientists at the Laboratory of Physics of Living Matter have developed a gap-plasmon-enhanced imaging approach based on visible photothermal-induced resonance able to provide chemical identification with high sensitivity and a few nm spatial resolution. Visible radiation is absorbed by the studied molecules and induces thermal expansion, which is observed with an Atomic Force Microscope cantilever.

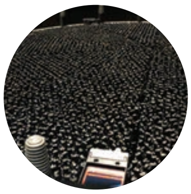
J. Zhou *et al*, **Gap-Plasmon-Enhanced High-Spatial-Resolution Imaging by Photothermal-Induced Resonance in the Visible Range**, *Nano Lett* **19**, 8278 (2019). DOI: 10.1021/acs.nanolett.9b03844

## Klaus Kern celebrates the 100$^{th}$ thesis of his laboratory

The 100$^{th}$ PhD student of Prof. Klaus Kern at EPFL successfully defended his thesis. This important milestone, a first at EPFL, highlights not only the huge research activity led in his laboratory, but also his qualities in attracting talented scientists to our school.

## EPFL becomes a Collaborating Centre of the IAEA

EPFL was officially designated as a Collaborating Centre of the International Atomic Energy Agency (IAEA), the world's central inter-governmental forum for scientific and technical co-operation in the nuclear field. It works for the safe, secure, and peaceful uses of nuclear science and technology, contributing to international peace and security and the United Nations' Sustainable Development Goals. The IAEA endorses the EPFL for spearheading the creation of an international network of industries and research institutions, led by the Laboratory for Reactor Physics and System Behavior, that will develop an advanced, open-source simulation platform for the analysis of nuclear reactors.



## 5,000 "eyes" will track the expansion of the Universe

The Dark Energy Spectroscopic Instrument (DESI) is a US-led international project, with significant contributions from EPFL's astrophysicists. DESI, now installed and tested on the Mayall telescope at Kitt Peak National Observatory, will spend the next four years obtaining optical spectra from ~$10^7$ galaxies and quasars, constructing a 3D map spanning the nearby universe up to 11 billion light-years. DESI will use 5,000 fibre-optic "eyes" able to automatically point at preselected sets of galaxies, gather their light, and map their distance from Earth. From this 3D map astrophysicists will precisely derive the expansion of the Universe as well as important constraints on the cosmological model.

# PHYSICS IN FIGURES

## TECH TRANSFER 2014-2019

**25**
patent applications

**13**
patents pending

**12**
patents granted

**8**
start-up companies created

## IPHYS EXTERNAL FUNDING

**43%**
external funding in total budget

**13**
ERC grants

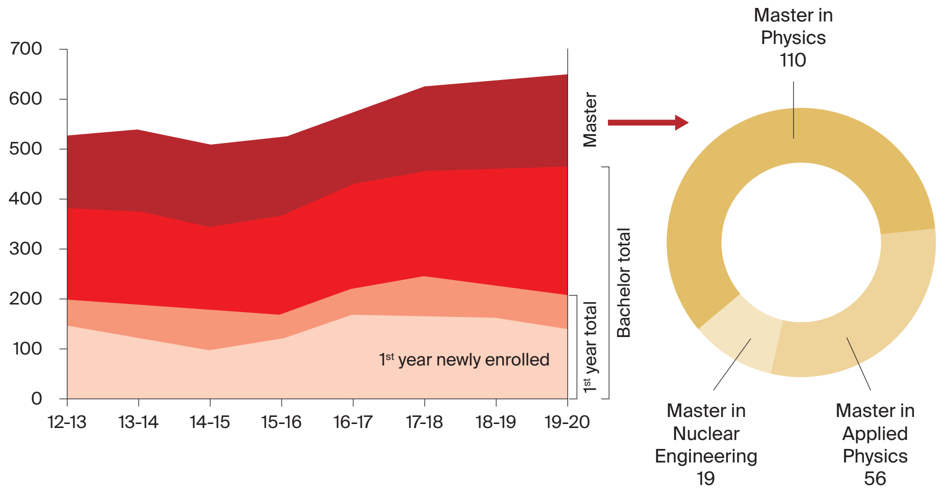
**2**
SNSF professorships

**9**
Ambizione grants

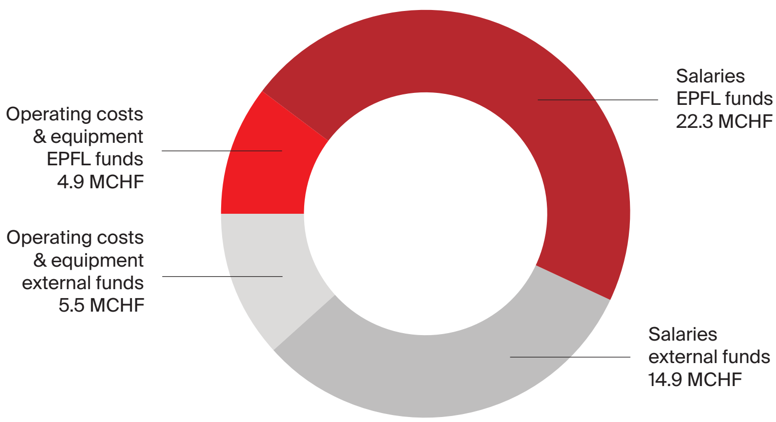
## TEACHING (year 2019)

| | |
|---|---|
| 92 | bachelor degrees delivered |
| 74 | master degrees delivered |
| 38 | PhD degrees delivered by EDPY |
| 10 | PhD degrees delivered to IPHYS graduate students by other programs |
| 651 | physics students |
| 3861 | students in other sections following physics courses from SPH teachers |
| 3800 | experiments demonstrated |

## NUMBER OF STUDENTS IN PHYSICS




## FULL-YEAR IPHYS EXPENDITURE

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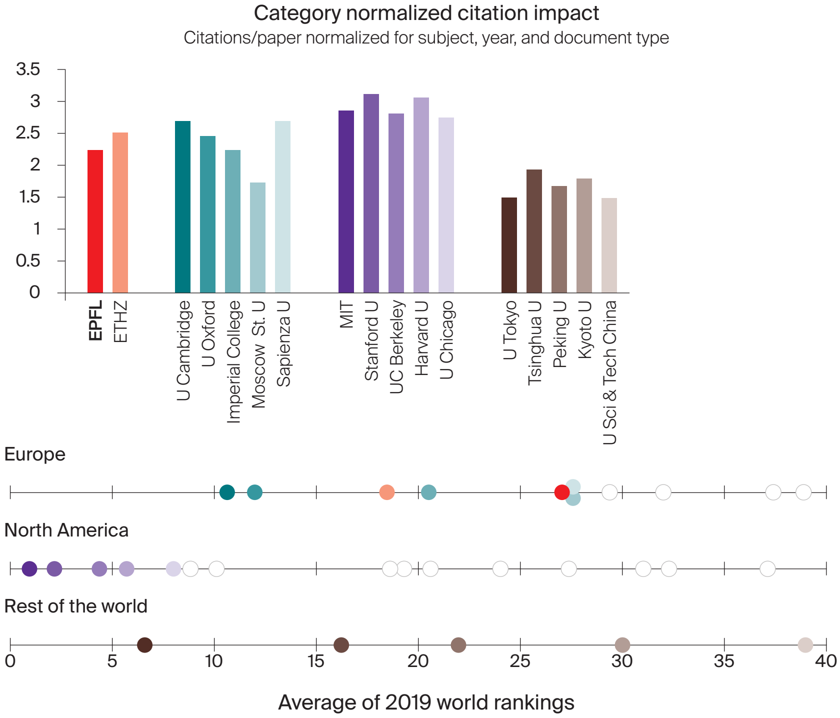
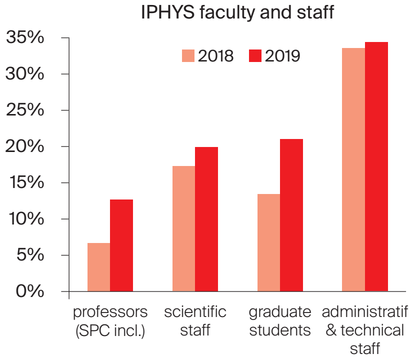
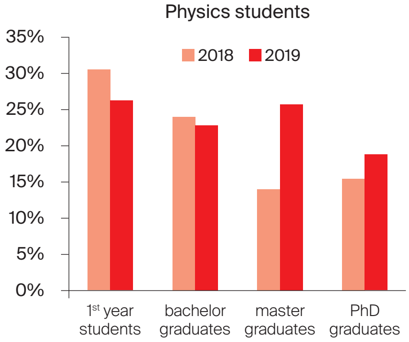
## PUBLICATIONS 2014-2018 (InCites 22/02/2020)




## PROPORTION OF WOMEN




## IPHYS FACULTY AND STAFF (in fte)

| | |
|---|---|
| 29.2 | professors (chairs), plus 3 in SPC |
| 144 | scientific staff and lecturers |
| 148 | graduate students |
| 23 | administrative staff |
| 40 | technical staff |

## WORLD / EUROPE RANKINGS 2012-2019

38th / 16th

63rd / 23rd

ACADEMIC RANKING OF WORLD UNIVERSITIES

30th / 6th

47th / 9th

NANYANG TECHNOLOGICAL UNIVERSITY

9th / 3rd

12th / 5th

QS WORLD UNIVERSITY RANKINGS

Not available 29th / 9th

U.S.News & WORLD REPORT

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Creating an electron vortex wave-packet from an electron plane wave
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DNA origami resolved by PAINT at the nanometric scale
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The EPFL team preparing for the International Physicists' Tournament
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Ultrathin $PtSe_2$ device
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Shai Mangel (100$^{th}$ PhD student, left), Klaus Kern
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Andreas Pautz after signing the cooperation agreement with the IAEA
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DESI's focal plate with its 5,000 robot "eyes"
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