KEY TOPIC

NEW MATERIALS FOR THE FUTURE

5232

The magazine of the Paul Scherrer Institute

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BACKGROUND

What the future is made of

Humans have always done more than simply use the materials they find in nature: they constantly shape, process and change them. The first requirement for this is knowledge of their properties and structure. Researchers at PSI create this knowledge.

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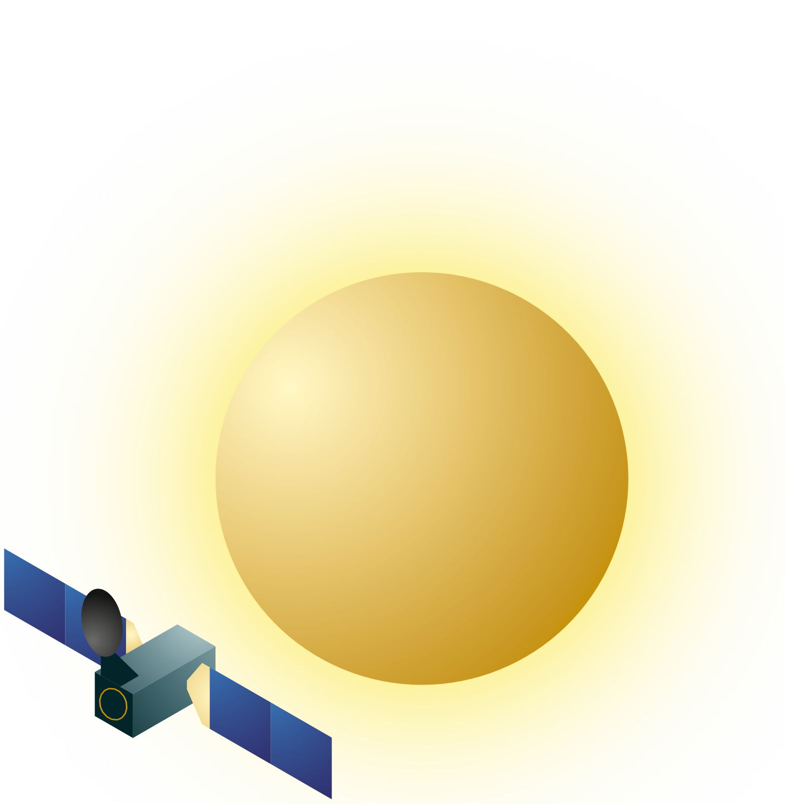

INFOGRAPHIC

Deep insights and hard tests

The globally unique ensemble of research facilities on the campus of the Paul Scherrer Institute PSI offers researchers and industry the possibility to gain knowledge, which they use to develop and test new materials for products or their manufacture.

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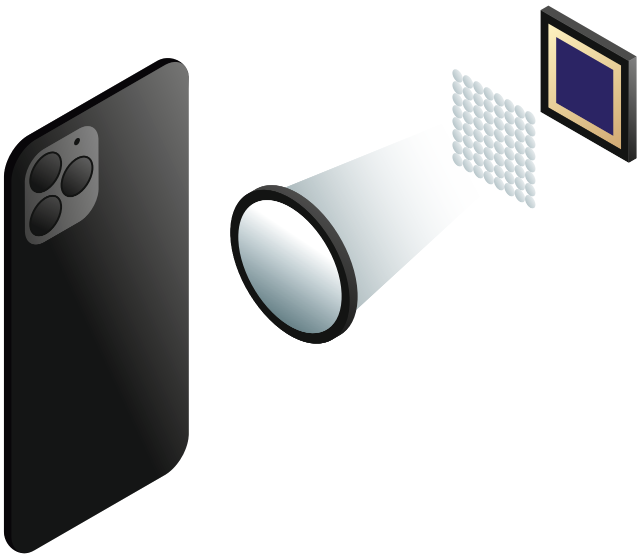

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A feel for the finest structures

In our digital age, progress goes hand in hand with miniaturisation. To make everything ever smaller, materials need to be manufactured and processed using advanced techniques. In the PSI Laboratory for Nano and Quantum Technologies, researchers are developing innovative techniques for micro- and nanofabrication.

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Christian Rüegg, PSI Director

Making life better through materials research

It is so self-evident and so inextricably bound up with our everyday life that it rarely attracts our attention: we are constantly surrounded by a multitude of materials, and we deal with them almost unconsciously. We seldom reflect on the fact that these materials had to be produced, and that some are the result of centuries or millennia of continuous development efforts – for example, in many metal objects or ceramics. Since the Stone Age, the drive to discover, shape and improve materials has been one of humanity's core characteristics, one that makes our species truly special. Not least, materials serve to classify entire epochs such as the Stone Age, Bronze Age and Iron Age.

Many challenges we are facing today will only be mastered if we manage to improve materials and adapt them to new needs. Materials science plays a central role here: it includes numerous sub-disciplines, and its boundaries with other scientific disciplines often cannot be sharply drawn – for example, when it comes to the development of methods for making new materials. Conversely, the same applies when we need to develop new materials before we can realise certain processes or applications.

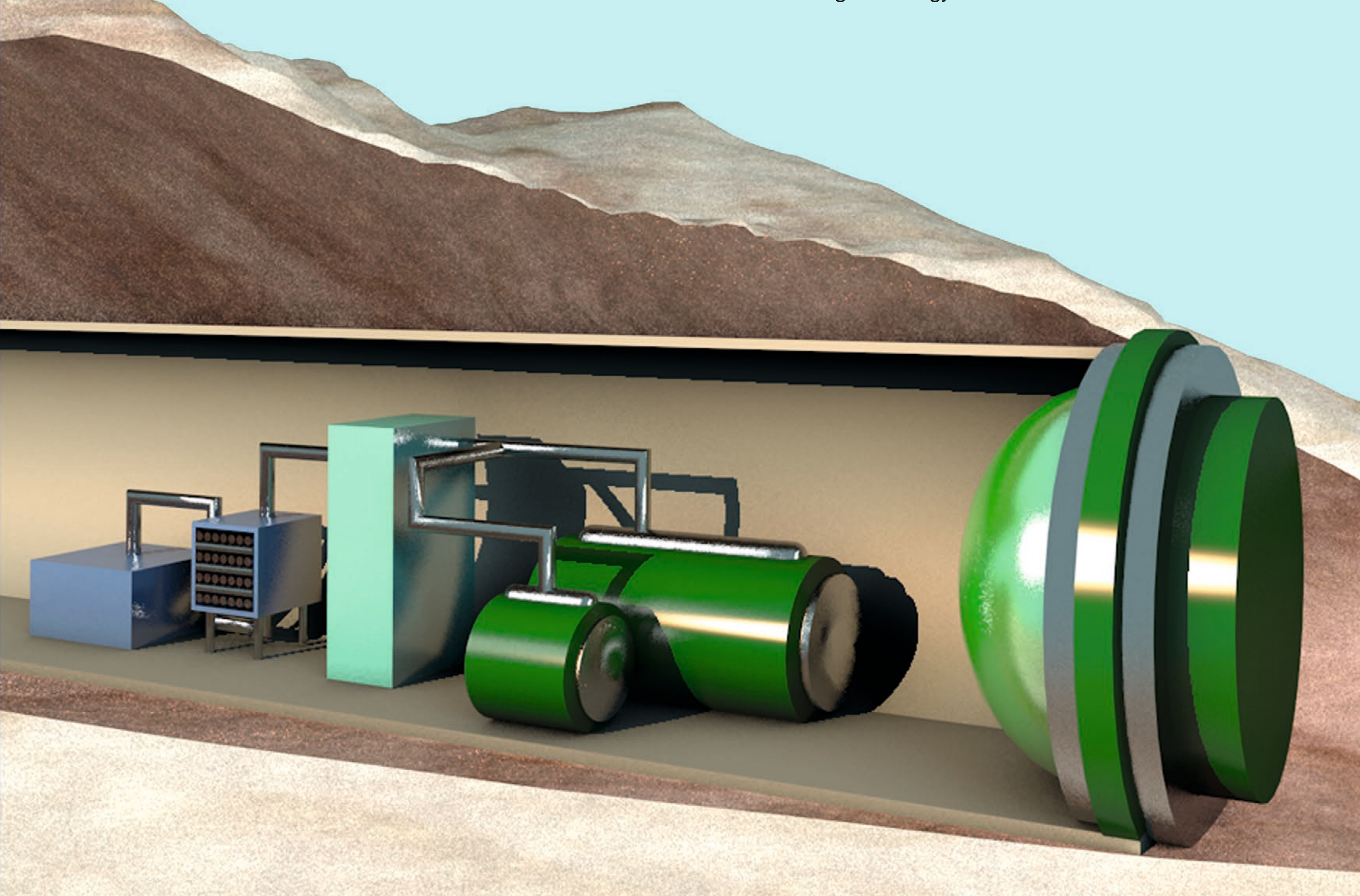
In any case, many researchers at PSI are working in the materials sciences as well as collaborating in the field with institutions of the ETH Domain, notably the Swiss Federal Laboratories for Materials Science and Technology Empa. For this they use PSI's globally unique ensemble of large research facilities, including the one whose hall I am standing in, the Swiss Light Source SLS. With SLS, as with the other large research facilities, we are looking deep inside matter – down to the atomic level – to understand its innermost processes. That provides the foundation for developing new materials: sometimes for seemingly trivial everyday objects, sometimes for the medicines, energy supplies or computers of the future. In all cases, we expect our materials research to contribute to improving people's lives through technology.

Pop and fizz

There’s hardly another sound so closely tied to special occasions as the popping of champagne or prosecco corks. Besides the familiar pop that occurs when the bottles are opened, though, another physical phenomenon can be observed. A fine veil of mist wafts from the neck of the bottle. It consists of either small water ice crystals or dry ice. This vapour arises because of a process technically known as adiabatic state change: a system changes its state without exchanging energy with its surroundings. In the case of sparkling wine, gas trapped between the liquid and the cork suddenly expands when the bottle is opened. Behind this, among other things, is thermal energy stored in the gas. The result: a tremendous cooling of the gas. Depending on the initial temperature, either tiny water droplets freeze to form ice, or carbon dioxide freezes to form dry ice. The mist appears white to grey in the former case, bluish in the latter. No matter which, one thing always remains the same: Cheers!

Storing energy with pressure

PSI researchers have taken part in a pilot project to investigate whether energy can be stored effectively using compressed air. Using an electric compressor, they forced air into an underground cavern. In doing so, a phenomenon occurs that can also be observed when inflating a bicycle tyre: the air heats up during compression. Without interference, this heat would dissipate into the surrounding earth or rock. But if the compressed air is released through a turbine, new electrical energy can be generated. The disadvantage: the gas cools down as it expands and freezing moisture can even disable the turbine. The researchers therefore seized on a trick and stored the heat generated during compression in a well-insulated reservoir. When releasing the air through a turbine, they returned the conserved thermal energy to the gas. This increased the efficiency of the method from 45 to 55 percent without heat storage to almost 75 percent with heat storage – ultimately recovering significantly more energy. This method, known as advanced adiabatic compressed air energy storage, could prove to be a building block for the targeted energy transition.



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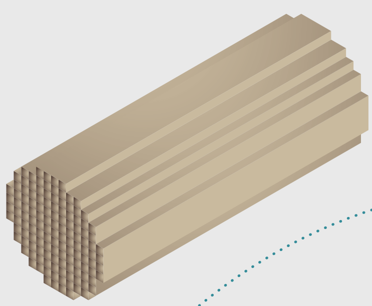
KEY TOPIC

New materials for the future

Whether quantum computers, microelectronics, modern medicine or resource-saving production methods for bulk commodities: materials science provides the basis for mastering current and future challenges.



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Deep insights and hard tests

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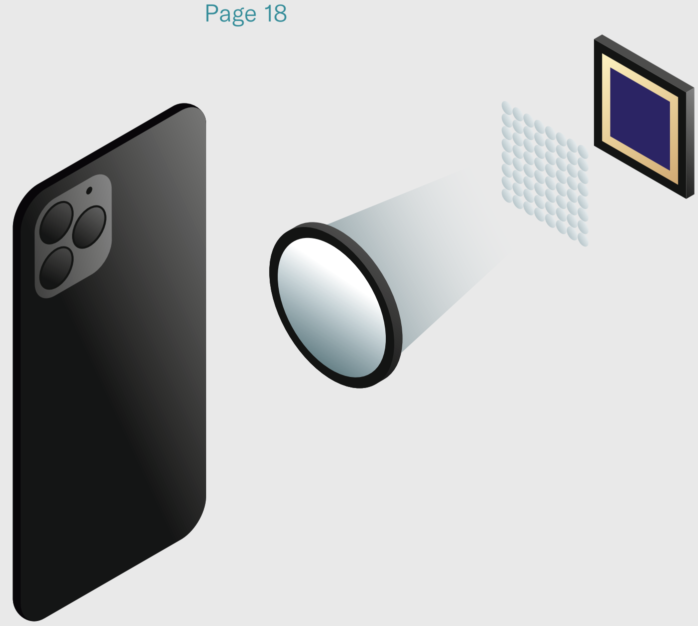
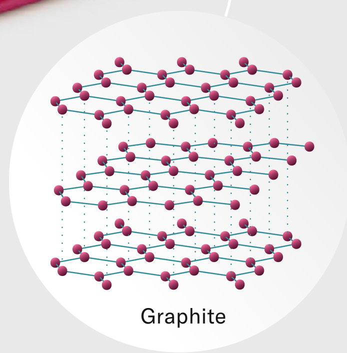


What the future is made of

Humans have always done more than simply use the materials found in nature: they constantly shape, process and change them. To do so requires knowledge of their properties and structure. Researchers at PSI create this knowledge, which can then be used to develop new materials: for example, for higher-performance energy storage, better electronics, more sustainable packaging and more efficient manufacturing processes.

Text: Barbara Vonarburg



The same and yet different

Frithjof Nolting, head of the Laboratory for Condensed Matter at PSI and adjunct professor at the University of Basel, knows how much materials can differ from each other depending on how their atoms are arranged. One example: graphite and diamond. Both consist of carbon alone, but have completely different properties. Graphite is suitable for pencil leads, cut diamond for hard gems.

Frithjof Nolting is standing in front of one of the measurement stations of the Swiss Light Source SLS, which uses intense X-ray light to visualise the internal structures of materials. “The structure of a material determines, to a large extent, its properties,” the physicist says, illustrating the point with a convincing example: diamond and graphite. The two materials are made of the same element – pure carbon – but the carbon atoms are arranged differently in each. In graphite, the carbon lies in stacked layers that are not bound to each other. In contrast, the carbon atoms in diamond are cross-linked three-dimensionally. That’s what makes diamond so hard and graphite so soft. Nolting heads the Laboratory for Condensed Matter in PSI’s Photon Science Division (PSD). At the SLS, his lab, together with others in the division, operates different beamlines and uses these measurement stations for materials research. “Here at the Tomcat beamline, for example, we investigate metal foams,” Nolting explains. “A new class of materials with many interesting properties.”

Metal foams are already being used today, for example as damping material in the front hood of ICE trains operated by Deutsche Bahn, and also as side supports in cars or components in the aerospace industry. Metal foams are very porous and therefore light, yet still stiff and strong. They absorb impacts, vibrations or noise, and provide very good thermal insulation. “The foams’ density and firmness, as well as their thermal conductivity, are strongly dependent on how their microstructure has formed,” Nolting says. For the production of the foam, a metal alloy with an additive is usually used. Two things happen when this mixture is heated: the metal melts, and a gas, formed at the same time, expands. In this way, the material is foamed up like a sponge.

Watching how the microstructure develops

PSI researchers from the X-ray Tomography group in the PSD, together with colleagues from Germany, have followed this process at the Tomcat beamline. For this they used a block of metal a few millimetres in size and positioned it for X-ray imaging on a rotating table capable of turning at up to 500 revolutions per second. While the rotating metal sample was slowly being heated, a high-speed camera took pictures that were later combined into 3D images, as in medical computer tomography. “With 1,000 tomograms per second, we even set a world record for this examination method,” says PSI physicist Christian Schlepütz.

The 3D images, with a resolution of just a few micrometres, revealed that many small bubbles initially form in the metal alloy, some of which fuse together within a thousandth of a second. Since the bubbles’ size and their cross-linking determine the mechanical properties of the metal foam, such studies can be used to improve processes for manufacturing this promising material to suit different applications.

An important trend in research, according to physicist Nolting, is that materials are more and more often being examined under variable conditions or during operation: “in situ” or “operando” measurements, as the experts say.

Higher-performance batteries

“We carry out a lot of operando characterisations,” says chemist Sigita Trabesinger. “In the process, we look at the cell of a battery and measure structural changes as it charges and discharges.” She heads the Battery Electrodes and Cells group at PSI. Today lithium-ion batteries are found in smartphones, laptops, cordless drills, e-bikes and electric cars. Yet because their energy density is limited, these power storage devices need frequent recharging. “The next step, which will significantly improve the energy density of batteries, is the use of metallic lithium instead of the graphite that is common today,” says Trabesinger (see graphic page 13). “That’s like the holy grail in the search for alternative materials.” But first, numerous obstacles have to be overcome in the construction of suitable batteries.

Researchers were already experimenting with lithium-metal batteries in the 1970s. Back then it became clear that, after a few charging cycles, the metal in the battery cell was forming dendrite structures that could produce a short circuit – a source of danger. “We are now trying to find a way so that no dendrites can grow,” says Trabesinger. One of the ways they are pursuing this is to test different electrolyte solutions. Depending on the composition of the solvent, more or less lithium is deposited in the battery cell. “Back then it was like working with your eyes shut, in contrast to the methods available to us today,” the chemist says.

On a computer screen, she enthusiastically shows images taken at the ICON beamline with the neutron microscope of the large research facility SINQ at PSI. The images show how, during the charging cycles of the battery, the lithium metal in the electrolyte solution in the cell is deposited and disappears again, or remains as so-called “dead” lithium. “We want to understand how to reduce this dead lithium as much as possible, since it can no longer be used and also poses a safety risk, because dendrites can form from it,” Trabesinger says.

In industry, there is major interest in this research. “We currently have two industrial projects that are being funded by Innosuisse, and we are negotiating additional projects and other types of collaboration with several companies,” says Trabesinger. In another project, her group is looking for a new material that can be used to increase the energy density of sodium-ion batteries. Sodium is more readily available than lithium – it can be obtained from sea salt, for example. But sodium batteries still have a lower performance than those made with lithium.

Sustainable alternatives to plastic

The quest to find substitutes for rare, expensive or environmentally harmful materials is an important current topic in materials science, Frithjof Nolting stresses. Researchers are working to find materials that are energy-efficient in their production and use and that can be reused. Marianne Liebi, head of the PSI group Structure and Mechanics of Advanced Materials and assistant professor at ETH Lausanne (EPFL), is involved in a project for developing a new

Improving energy storage

PSI chemist Sigita Trabesinger investigates, among other things, how batteries can be optimised for energy storage – for example, by preventing the formation of so-called dendrites between the electrodes. These can even cause dangerous short circuits.

packaging material as an alternative to plastic. The raw material is a type of cellulose that is chemically modified so that it can be shaped by increasing the temperature, to produce a thermoplastic product. The project is funded by the Swedish government and 15 industrial partners, including Tetra Pak.

"At PSI we investigate the structure of material samples with X-ray methods," the materials scientist says, showing a small test sheet made of the new material. Depending on how the thermoplastic cellulose is heated, poured and cooled, different structures are created. These in turn are closely linked to the mechanical properties. For example, the new material must not be too brittle. Structural analyses made with the help of X-ray light at the cSAXS beamline, for example, show whether or not the specifications can be met.

The problem with the milk lid

In an earlier project, Liebi and her team studied milk cartons made from conventional plastic. "We all know how frustrating it is when you tear off the tab on the closure but the lid won't open," she says. To improve this opening, the manufacturing company Tetra Pak ran simulations in preparation for building new production machines. These calculations, however, assumed material properties that did not correspond to reality. "We looked at the nanostructure of the milk lids and were able to provide additional, important information that the company could feed into its simulations, thus improving them," the researcher explains.

Liebi says she is often asked if it is worth putting so much research into something so mundane. "But if you think about how many milk cartons are used worldwide every day, a small improvement, such as a little less plastic for production, can have a big effect." Many objects in our everyday life are full of fascinating physics and highly developed materials, Frithjof Nolting acknowledges. Aside from the development of new materials, the combination of materials research and digitalisation is also becoming increasingly important, for example in advanced manufacturing. "This is another area where we are providing important insights," Nolting says as he leads the way to another SLS beamline where 3D printing of metals is being investigated – "an unbelievably exciting area," according to Nolting. This process can be used to produce very complex components, for example for turbines and compressors or surgical instruments. Numerous companies, including Oerlikon and ABB as well as the Swiss watch industry, are interested in PSI's research in this area.

Miniature printer in the X-ray beam

With a small printer specifically developed for the purpose, the manufacturing process can be examined with X-ray light on site – in situ – at this beamline, called MicroXAS, as well as at the Materials Science and Tomcat beamline. The method used is called laser powder bed fusion. The metal is applied to a build platform as a fine powder. A high-power laser, which is focused down to a tenth of a millimetre, moves over the powder, melts it and brings it into the desired shape, which then hardens. The next thin layer of powder follows, which the laser then melts. The component grows layer by layer in this way. "In these experiments, we look at what happens to the crystal structure of the metal at the atomic level," says PSI physicist Steven van Petegem, co-developer of the miniaturised printer.

A detector records the X-ray signal. It is a proprietary development of the PSI detector group with a very high-speed action. This is necessary, because the laser is moving across the powder bed at a speed of up to one metre per second. In addition, the material is heated by the laser to 2,000 to 3,000 degrees Celsius, after which it cools down to room temperature at lightning speed, with a cooling rate of up to ten million degrees per second. So the wealth of information must be gathered quickly. The experiments show that this very complex process can lead to the formation of undesirable effects such as pores and cracks, or it can result in unexpected phase transformations leading to unpredictable material properties.

"Only precise knowledge of the microstructural development during this manufacturing process makes it possible to undertake the necessary adjustments to avoid these defects," says van Petegem: "But with the 3D printer, we can also generate certain microstructures that can't be made with conventional processes." If you print specific areas with the laser more rapidly or more slowly, the material becomes locally harder or less brittle. In this way, novel components can be fabricated that behave optimally in the application. "At the moment we are in the process of understanding what happens in these 3D printing processes," says van Petegem. This is aided not only by the investigations at SLS, but also by measurements carried out at the Swiss Spallation Neutron Source SINQ.

Component under load testing

"The advantage of neutrons is that we can use them to penetrate deeper into the material than with X-rays," says Markus Strobl, head of the Applied Materials group at PSI. "At SINQ, we can look through centimetre-thick metal parts that are used, for example, in mechanical engineering, and see what's happening inside." With the help of neutrons, the researchers are investigating how samples produced using 3D printing behave under load testing. "We are the only research institute where components can not only be stretched or pressed in one direction in the neutron beam, but can also be subjected to complex load conditions in two directions," Strobl explains.

The measurements show how the crystal structure and thus the mechanical properties of the material change under the load. While one crystal lattice tends to give way, another is rather firm but fractures if the load is too great. "Particularly with 3D printing, you can vary such properties within a component and thus adapt it precisely to the requirements of its subsequent application, providing you understand the characteristic material properties well enough," according to Strobl. Advanced manufacturing is among the strategic research areas selected by the ETH Board as being especially important to society. Within this framework it promotes and to a significant extent finances relevant research efforts at PSI.

"Our strengths in materials research are the large research facilities and the imaging, scattering, and spectroscopy we can carry out with them," says Nolting. This allows researchers to visualise structures and defects in materials using many different techniques, and to gain fundamental insights regarding properties of the materials. "But we also can produce samples and characterise materials with additional techniques," the physicist says. In addition, there are excellent teams at PSI with expertise in fields such as detector development, automation, the construction of complex instruments and the analysis of large amounts of data. "At PSI we have a vast pool of knowledge in both scientific and technical areas that is needed to address challenges in materials science today." ◆

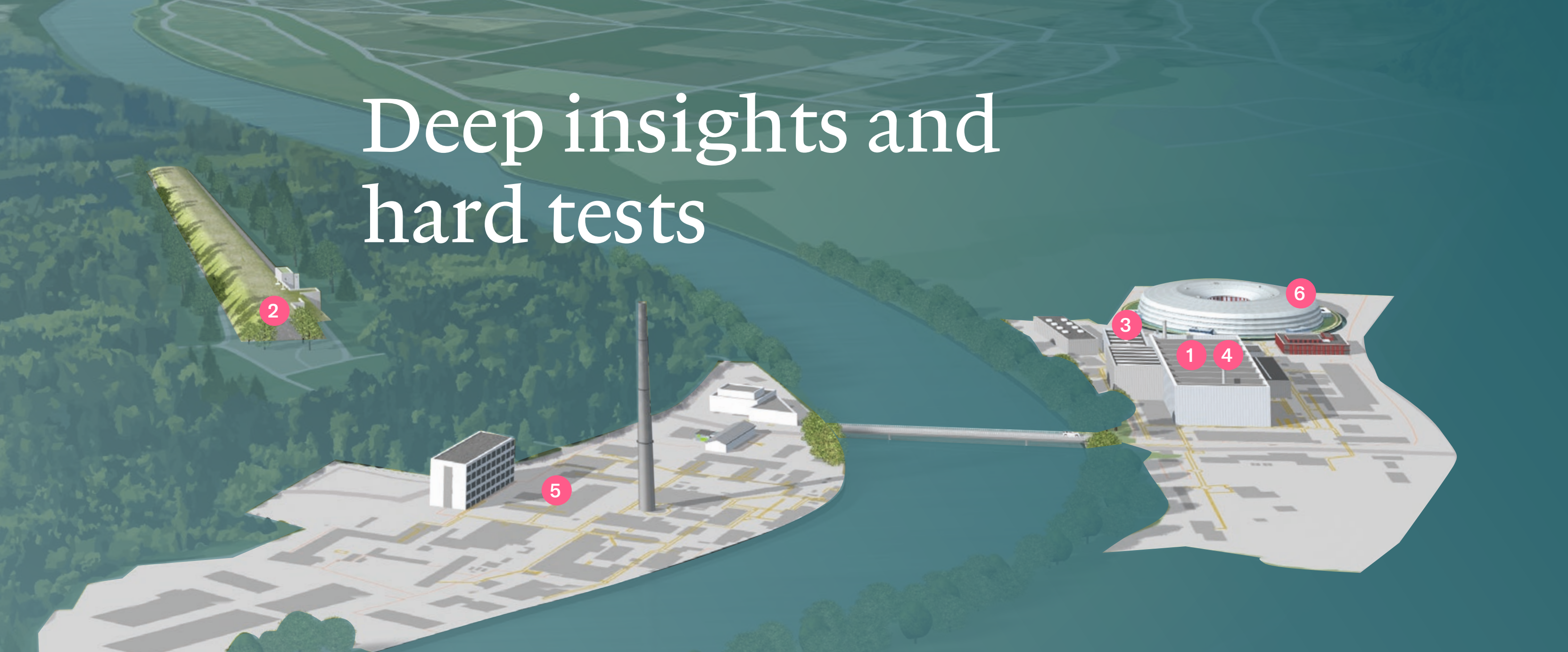
Knowledge makes life better

Marianne Liebi, head of the Structure and Mechanics of Advanced Materials group at PSI and tenure-track assistant professor at EPFL, studies, among other things, how the materials in everyday products can be improved. Through better understanding of the nanostructure of milk container lids, she was able to optimise their production.

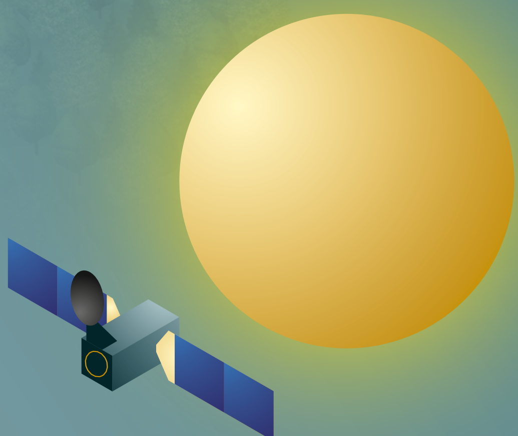
“A small improvement, such as a little bit less plastic for production, can have a big effect.”

PSI researcher Marianne Liebi

Deep insights and hard tests



The globally unique ensemble of research facilities on the campus of the PSI offers researchers and industry the possibility to gain knowledge, which they use to develop and test new materials for products or their manufacture.



1

The Swiss research infrastructure for particle physics CHRISP

Particle accelerators are central components of PSI and provide the particles used for fundamental physical experiments. Using particle beams made up of pions, muons, neutrons, protons and electrons, PSI researchers investigate how our universe is structured. At CHRISP, they determine fundamental natural constants with extreme precision and search for discrepancies in the current Standard Model of particle physics. They also develop and test detectors for experiments at PSI, for the European research centre CERN in Geneva, and for space missions. For example, PSI researchers developed components for the space probe Solar Orbiter (see figure), which will add to our knowledge of our sun, and for the Jupiter mission JUICE, which will explore the system of the gas planet.

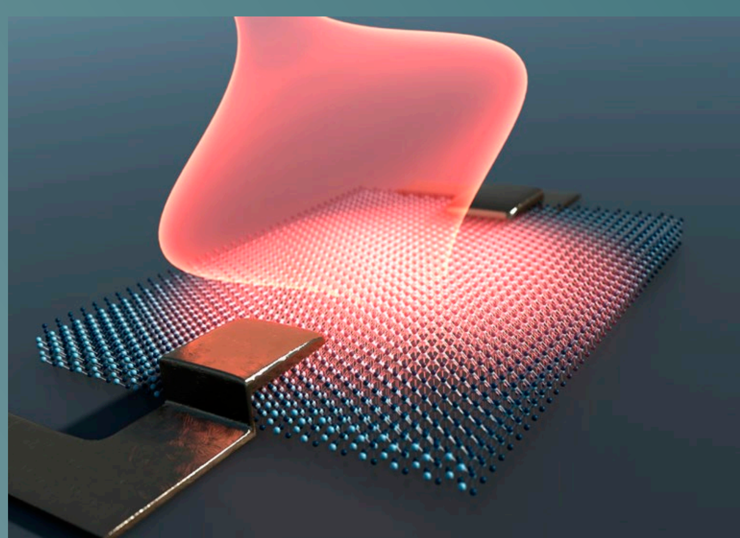
Further information: https://psi.ch/en/node/43472

2

The X-ray free-electron laser SwissFEL

At SwissFEL, accelerated electrons generate intense flashes of laser-quality X-ray light. This allows extremely fast processes in materials to be filmed as if with a high-speed camera, step by step on an atomic or molecular basis. One international team was able to show how light can fundamentally alter the properties of solids and how these effects could be used for future applications. A quasi-two-dimensional crystal between contacts was excited by a laser pulse (see figure). The physical properties of the crystal were shown to change dramatically on ultra-short time scales in the femtosecond range. The findings make it possible to better understand which forces cause electrons to form superconductors – materials that conduct electricity without heat loss and can serve as fantastic magnets.

Further information: https://psi.ch/en/node/18788

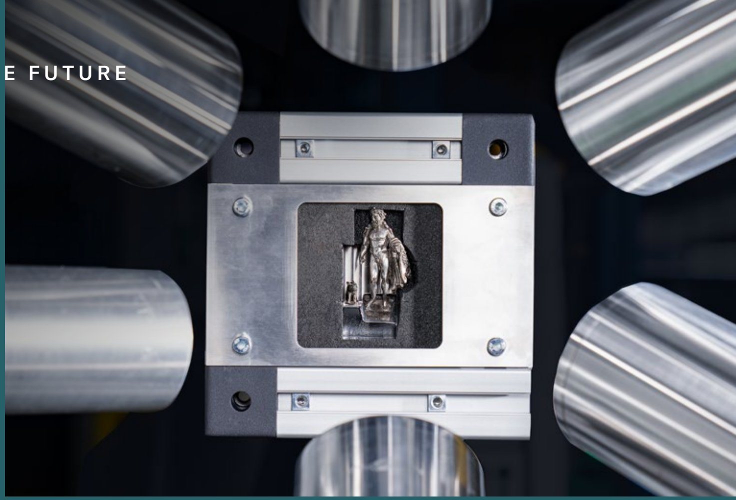


3

The neutron source SINQ

The neutrons of SINQ not only make it possible to investigate the magnetic and superconducting properties of materials for new electronic components and storage media, but also can be used to look inside archaeological artefacts. Metals are nearly transparent to neutrons, while parts that contain hydrogen show up particularly clearly. Among other things, researchers have been able to reveal the secret of an optimal violin varnish, which simultaneously provides ideal protection and excellent sound properties.

Further information: https://psi.ch/en/node/28454

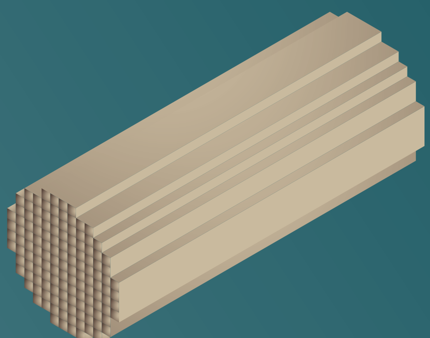


4

The muon source SμS

When the beam of fast protons from the accelerator is directed onto two carbon rings, muons form. These electrically charged elementary particles can be used for the local determination of magnetic fields inside materials or for non-destructive analysis to identify the chemical elements that make up a sample. PSI offers globally unique experimental possibilities with slow muons, which can be used to measure magnetic fields in arrangements of thin layers of materials. With one especially precise measurement method, researchers were able, among other things, to analyse the exact composition of a silver alloy from which an ancient statuette of Hercules (see photo) was cast.

Further information: https://psi.ch/en/node/28451

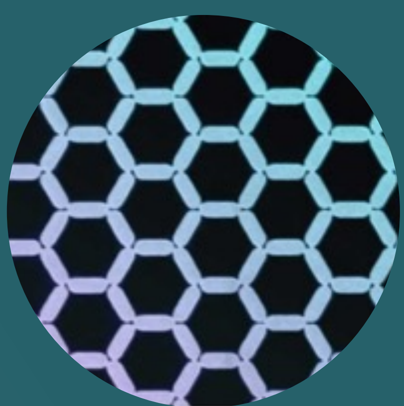


5

The Energy System Integration Platform ESI

PSI uses the ESI Platform to bring together its diverse expertise in energy research and to conduct tests. Equal attention is given to identifying what is feasible right now and to embedding research results in the development of scenarios for possible future energy systems. This should help to implement the Swiss government's Energy Strategy 2050. Among other things, it calls for the reduction of energy consumption, the expansion of new renewable energy sources such as solar, wind and biomass, and better use of existing resources. To that end, PSI researchers are for example developing new processes and materials. They have developed a new catalytic converter for cleaning the exhaust from natural gas engines (see figure). In contrast to previous catalytic converters, it is also very active at low temperatures and remains so for a long time. Thus the combustion of natural gas can be made cleaner and more climate-friendly.

Further information: https://psi.ch/en/node/18743



6

The Swiss Light Source SLS

In the circular SLS building, electrons move at almost the speed of light and emit X-ray beams that are especially intense and highly concentrated. With its help, researchers have been able, for example, to observe for the first time how tiny magnets in a special arrangement align themselves solely due to temperature changes. This insight into the processes within so-called artificial kagome spin ice (see figure) could play an important role in the development of novel high-performance computers. With the project SLS 2.0, the facility is being upgraded to enable even better research in the future.

Further information: https://psi.ch/en/node/28439

A feel for the finest structures

In our digital age, progress goes hand in hand with miniaturisation. To make everything ever smaller, materials need to be manufactured and processed using advanced techniques. In the PSI Laboratory for Nano and Quantum Technologies, researchers are developing innovative techniques for micro- and nanofabrication. These can be used, for example, to improve the production of microlenses for smartphones or to fabricate components for quantum computers.

Text: Barbara Vonarburg

For decades, a process called lithography has been used to manufacture microchips. In ancient Greek, “lithos” means stone and “graphein” to write. In microelectronics technology, the stone is a silicon wafer coated with photoresist. The pattern of the chip’s conductor tracks is written on it with light so that part of the coating can be removed, exposing the silicon for the subsequent process step. Over the years, this lithography process has been continually developed so that it can be used to produce tiny structures for a wide variety of applications. “Here in our clean room we have tools we can use to write very small structures only a few tens of nanometres, or millionths of a millimetre, in size,” says Kirsten Moselund. She heads the Laboratory for Nano and Quantum Technologies, which operates the clean room at PSI, and is professor of electrical and microtechnology at the École Polytechnique Fédérale de Lausanne (EPFL).

While the industry uses ultraviolet light to produce microchips, exposing the entire pattern of the so-called mask all at once, PSI researchers use an electron beam for the tiniest structures. “This achieves a much higher resolution,” Moselund explains. “Because electron beam lithography only writes with a single beam, it is much slower than UV lithography. For that reason it is not used today for mass chip production, but it is often used to produce the masks, as well as in research.” The result is the same, namely a structured resist layer that protects only part of the underlying material from etching. Thus nanostructures can be transferred not only to silicon, for example, but also to glass, metal, sapphire and even diamond. Fine diamond lattices made in this way in the PSI clean room are used to diffract and focus X-rays at the Swiss Light Source SLS.

Advanced lithography not only enables the nanostructuring of materials, but also literally opens up a new dimension. “The conventional lithography used to manufacture microchips is black-and-white – you are essentially writing a two-dimensional pattern,” Moselund explains. “It’s particularly exciting that lithography can now be used to create 3D structures as well.” The method is called grey-scale lithography and while it can be done with an electron beam, using a laser is much faster.

Ubiquitous modern micro-optics

In grey-scale lithography, the laser irradiates the photoresist with light of different intensities and thus generates different exposure or grey-scale levels that form a three-dimensional relief. “With this technique you can, for example, directly write a lens that then consists of the photoresist, a plastic,” explains the laboratory head. “But you can also etch away the relief to get a round structure like the lens in the underlying material.” An important application area for grey-scale lithography is modern micro-optics, which is ubiquitous today. There are several microlenses in every smartphone or tablet. In medicine, micro-optical systems are used in minimally invasive surgery. In augmented reality glasses, tiny projection optics guide the information into the eye. In car headlights, microlens arrays improve the quality and control of the light beam.

The direct production of such microlenses with grey-scale lithography alone would be too complex and expensive, however. For mass production, this process can be combined with a second one: nanoembossing lithography. Helmut Schift, head of the Advanced Nanomanufacturing group at PSI, is one of the pioneers of this method. He explains: “If you want to produce large quantities, you need a replication technique – like in the kitchen when you bake cookies. You can’t cut out every single one: you need stamping and embossing techniques.” With the help of grey-scale lithography, a precise stamp can be produced to mould the 3D structures into the desired material.

Kirsten Moselund, head of the Laboratory for Nano and Quantum Technologies at PSI and professor at EPFL, is looking into ways to enhance the performance of microlens arrays.

Like cooking waffles

Schift again compares the process to kitchen technology. “The procedure is similar to that used to make waffles.” The material to be embossed is heated, the stamp is pressed in, the relief is transferred and is preserved when the material is cooled again. In this way, a large number of precise copies can be made from an original. But the technology has its pitfalls. “In the kitchen, you need to have enough control over the batter so that it fills the grid plate and bakes evenly within a certain amount of time,” the scientist explains. “Then you have to open the waffle iron again and be able to remove the waffle without it sticking. A layer of Teflon and a little oil generally takes care of that.”

Smooth surfaces

Schift’s team succeeded in developing especially thin non-stick layers for nano-embossing lithography, as well as in overcoming a serious disadvantage of grey-scale lithography: the original structures and the resulting lenses have a rough surface, which can lead to unwanted scattering and glare effects. “We found a method of smoothing out this roughness afterwards without touching the surface,” says Schift. To do this, the researchers irradiate the surface with UV radiation and later selectively melt it. “It’s similar to preparing crème brûlée by caramelising the sugar on top of the crème with a gas torch,” Schift says.

The bottom line for the researcher: “We don’t make the smartphone cameras better directly, but we develop new technologies with one extra trick and show our colleagues in the industry how to better understand and extend certain processes. This is possible because we approach the problems more openly and always ask ourselves why something works or doesn’t work; that is our materials research.” Among the companies that have benefited from the PSI researchers’ findings is Ams-Osram in Rüschlikon, which specialises in smartphone cameras. However, microlenses are not only used in mobile phones, but also increasingly in the automotive industry. SUSS MicroOptics in Neuchâtel received an order from the car manufacturer BMW to produce projection optics for its luxury models. They create a carpet of light at the push of a button on the car key, to make it easier to get into the car in the dark. For efficient series production of the lenses, the Swiss company had to use more efficient embossing lithography in place of its previous complicated production process.

This process is not only suitable for the production of microlenses, however, because if you emboss certain structures on a material, you can change its adhesiveness and other mechanical

Microlens arrays have diverse applications in technology and research. With their help, beam paths for lighting can be optimised, for example in smartphone cameras (see figure).

properties. “We can emboss almost any material,” says Schift, mentioning by way of example cellulose and a collaboration with the University of Basel. The Basel researchers are developing biocompatible electrodes that could one day be used as medical implants in the brain or spinal cord, using a cellulose-based material. This must be flexible, able to absorb water and be adaptable to tissues of the human body. To give the material the desired properties, the PSI team embossed a fine pattern on the surface of the cellulose.

High-tech and handcraft

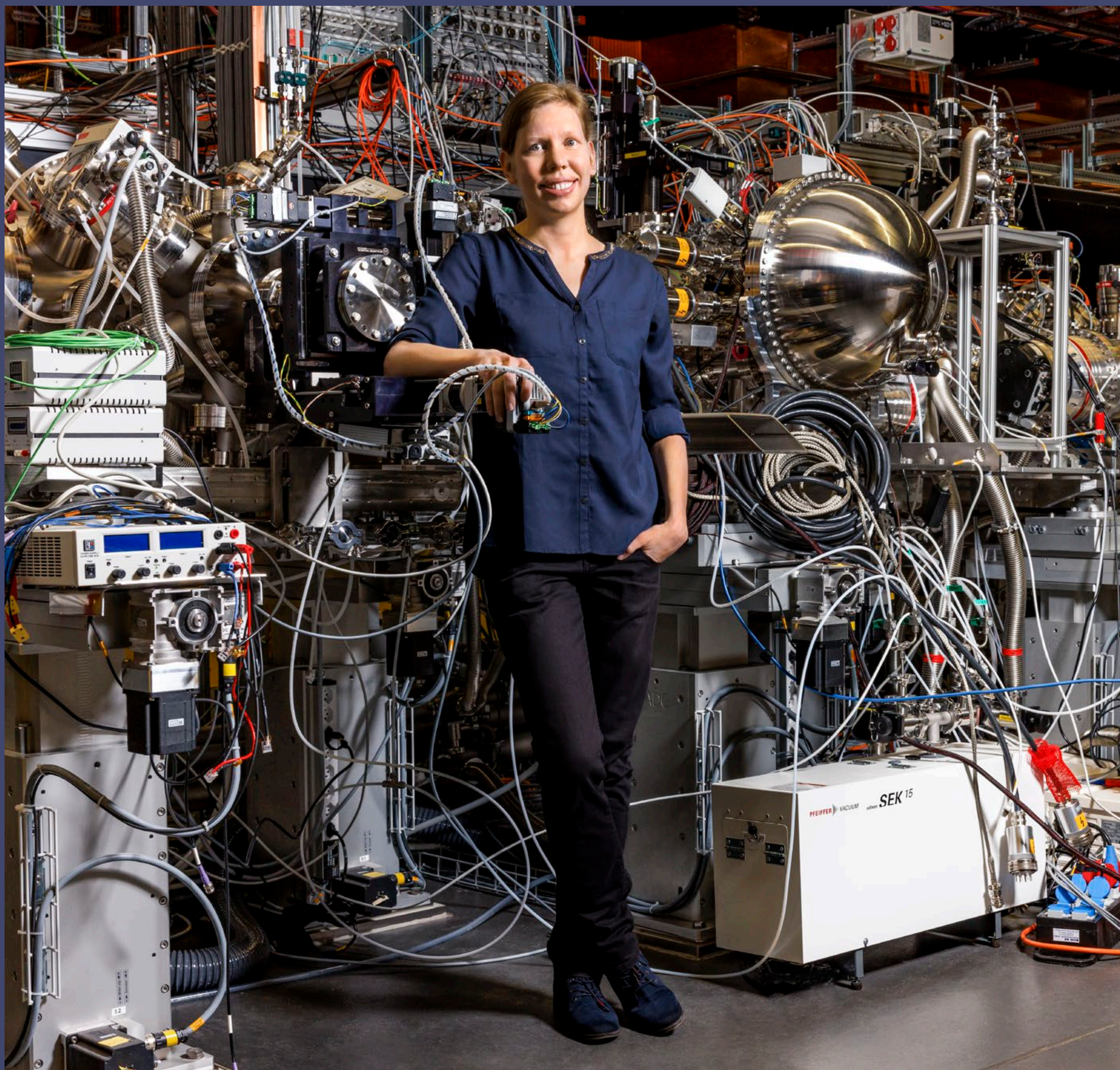
“Here we’re looking at new materials, components and manufacturing processes, such as grey-scale lithography, and trying to understand how the physics behind it works,” says Kirsten Moselund, as she watches a colleague in a protective suit working on a microchip in the clean room, keeping a close eye on a stopwatch. She, too, draws a comparison to cooking: “We’re always developing something new, maybe using a little more or less of a certain material and having an intuition about when it is just enough. A lot of it is handwork and requires a great deal of finesse.” You need to have a feel for it even though you can’t touch the structures.

This also applies to the production of building blocks for novel quantum computers that are being developed in the Quantum Computing Hub. Founded last year by PSI and ETH Zurich, this centre is affiliated with the Laboratory for Nano and Quantum Technologies and is also headed by Moselund. “We have two quantum groups pursuing concepts with so-called superconducting qubits, and both are working in our clean room.” Qubits are the basis of every quantum computer. In contrast to conventional binary bits, qubits can assume several states at the same time. In the future they are expected to make it possible to solve mathematical problems that till now have been out of reach even for supercomputers. There are several possibilities for the practical realisation of qubits. One of them is superconductivity, in which electric current is conducted with practically no resistance and thus without loss. Such qubits are constructed as so-called Josephson junctions.

Playing with different materials

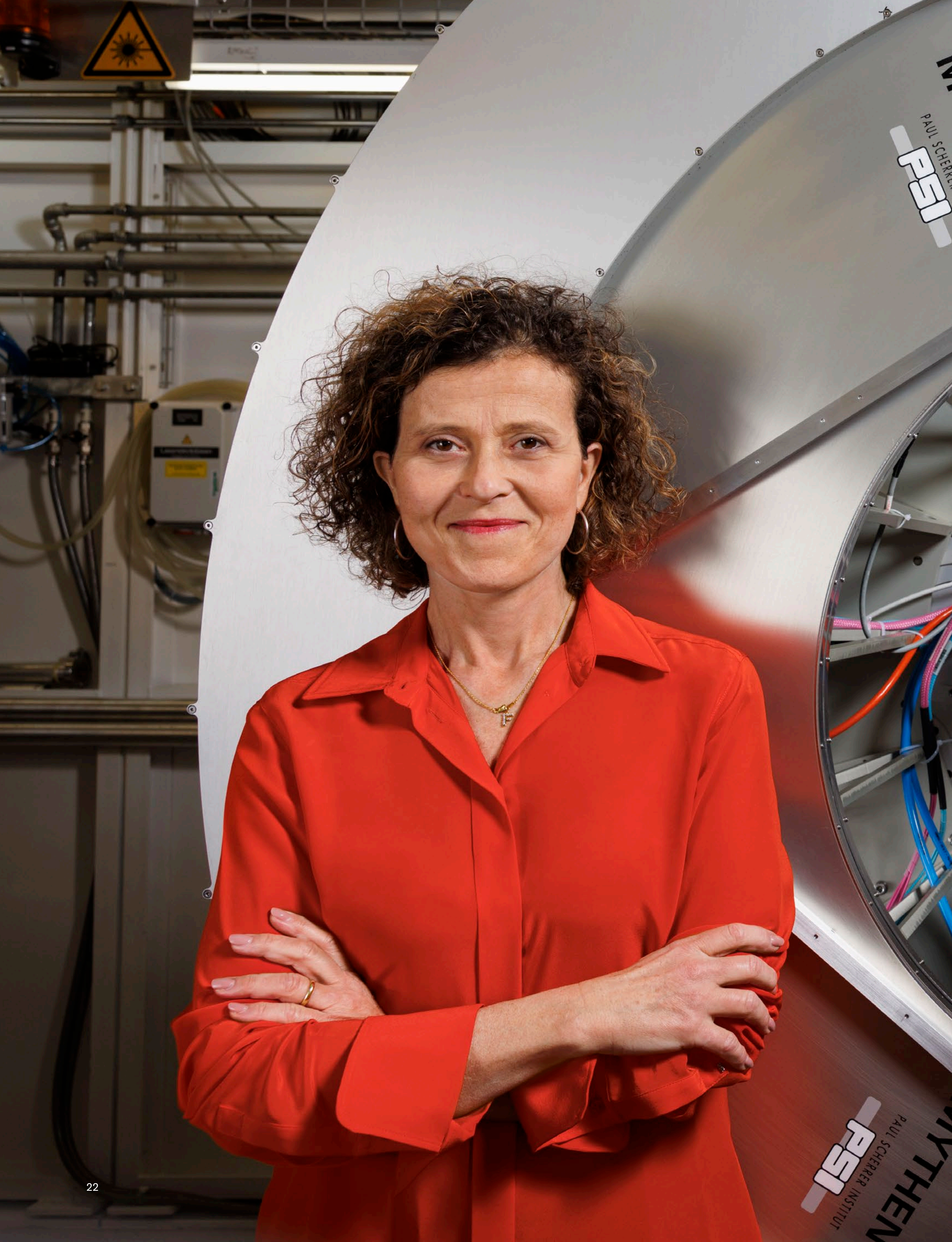
A Josephson junction consists of two thin, superconducting metal layers sandwiching an even thinner, non-conducting oxide layer. “You can use various materials for this,” explains Moselund. Today the most commonly used metal is aluminium. But for this to become superconducting, it has to be cooled to a very low temperature of minus 273.16 degrees Celsius, that is, to almost absolute zero. With other metals such as niobium or tantalum, superconductivity sets in at slightly higher temperatures. “It might be worth investigating different materials and playing with them,” the researcher says. The structure of the oxide layer, which consists for example of aluminium or magnesium oxide, also plays an important role. Defects in this layer can significantly interfere with the function of the superconducting qubits.

The lab head is looking forward to the new, much larger clean room that is currently being built in the Park Innovaare innovation campus next to PSI. There, state-of-the-art equipment will aid in the production of Josephson junctions and enable an expansion of research in this field. “With the new instruments, we will be better able to control the production processes,” the researcher explains. Also, the existing cooperation with industry will be strengthened. PSI, with its experts, has the opportunity to establish new technologies. “That makes it exciting for us and the companies to work together, even if the research results can’t be applied straight away,” says Moselund. “But it is important that we think about what we will need in the future and conduct our research with foresight.” ◆



Nanoparticles in a new light

Physicist Kirsten Schnorr is group leader at the PSI large research facility SwissFEL, the Swiss X-ray free-electron laser, where her team designed, set up and commissioned the Maloja experiment station. Today she is investigating chemical and physical interaction processes between X-rays and nanoparticles – of heavy elements in particular – in a project supported by the Swiss National Science Foundation with funding of 1.3 million Swiss francs. Gold and other heavy elements absorb X-rays very efficiently, and a deeper understanding of such processes could lead to more effective radiation treatments for cancer.


PSI
PAUL SCHERRER INSTITUT

Fabia Gozzo, CEO of Excelsus Structural Solutions, in front of the experiment station for powder diffraction at the Swiss Light Source SLS. The PSI spin-off uses this unique facility to analyse the crystal structure of complex molecules and thus makes an important contribution to drug development.

IN SWITZERLAND

Safe medicines thanks to X-ray light

For more than ten years, the PSI spin-off Excelsus Structural Solutions has been helping companies in the pharmaceutical and chemical industries to precisely analyse drugs. With the help of the Swiss Light Source SLS at PSI, the researchers look deep inside the crystal structure of the drugs.

Text: Benjamin A. Senn

Imagine a piece of ice that doesn't melt even at room temperature. In Kurt Vonnegut's 1963 science fiction novel *Cat's Cradle*, the protagonist discovers just such a strange substance. It has the same chemical composition as water ice but remains completely unaffected by temperatures above zero. The special crystalline arrangement of its atoms ensures this paradoxical behaviour, which this uncanny substance can also transfer to ordinary water. As soon as the so-called ice-nine comes into contact with it, the water freezes immediately and also turns into ice-nine – a fictional doomsday scenario, since contact with the oceans would turn the blue planet into a ball of ice.

Even if this story is fictitious, ice-nine, like much in science fiction literature, is based on a genuine scientific phenomenon known as polymorphism. This term refers to the property that the crystalline arrangement of a substance's building blocks can occur in different three-dimensional forms. Changes in state variables such as pressure and temperature can alter the arrangement of the atoms and convert different polymorphic forms into one another. Although all these forms have the exact same composition, they can have different physical properties. Like water, ice-nine consists of two hydrogen atoms and one oxygen atom, but its crystalline arrangement prevents it from melting at room temperature.

Polymorphism can be devastating in pharmaceuticals, because different forms can, for example, have different dissolving behaviour: one form might be absorbed poorly or not at all by the body, in which case the effect would be absent. As with ice-nine, an undesirable form can also spread and contaminate an entire production run of a drug. To prevent such scenarios, Fabia Gozzo, founder and CEO of Excelsus Structural Solutions, has been offering her services with her team of six since 2012, analysing the crystal structure of the relevant products.

From Villigen to Brussels and back

The Excelsus headquarters are located on the west side of PSI: a small, cosy office with six workstations, a white oval conference table in the middle and a red refrigerator in the background. The atmosphere is friendly and familiar. "This is where we plan and analyse the experiments we carry out for our customers at SLS," Fabia Gozzo proudly explains. Since 2016, Excelsus has been part of Park Innovaare, the innovation hub in Villigen, whose new campus will be ready for occupancy by the end of 2023. Excelsus and other innovative companies and startups will then work in the immediate vicinity of PSI's large research facilities, which they can use for their developments.

Villigen is also where the history of Excelsus began. Fabia Gozzo came to PSI in 1998 – at that time SLS was still a construction site. When it came to setting up the experiment station for powder diffraction, Fabia Gozzo took on this task on short notice – today this facility is one of the best in the world. During this time, she was already toying with the idea of starting her own business and offering her experience to the pharmaceutical industry. When she quit her job at PSI after 12 years and moved to Brussels with her family, this idea took shape and finally led to the founding of Excelsus in 2012.

"Initially I worked alone from Brussels. The budget was small, and I drove to and from PSI by car for measurement orders," Gozzo recalls. But as the customer base grew, so did her team. Mathilde Reinle-Schmitt started as a postdoc at Excelsus and now works as assistant director. "A year after Mathilde, Mickaël Morin joined the team, who was also appointed assistant director in 2022. Pam Whitfield followed in 2017 as leading scientist – she is currently based in England. Ines Collings, who is presently on maternity leave, and Fanny Costa joined in 2021 – all talented and experienced researchers who support Excelsus with their know-how."

Today Excelsus works mainly for pharmaceutical companies. "Most of the time, we receive different samples of a drug in powder form," explains Mathilde Reinle-Schmitt. These samples come, for example, from different production conditions, or they were stored differently – all factors that can potentially alter the crystal structure and thus the effectiveness of a drug. "Our job is to use SLS to find out whether unwanted polymorphic forms are present in the samples."

The power of synchrotron X-ray diffraction

"In the chemical and pharmaceutical industries, the crystal structure of materials is analysed mostly using conventional equipment such as laboratory powder diffractometers," explains Fabia Gozzo. In principle, these devices consist of an X-ray source and a detector. The X-rays are scattered by the crystal lattice as they enter the sample and are recorded by the detector as they exit. The interaction of the radiation with the sample provides information about the crystal symmetry and the spatial position of the individual atoms.

"Laboratory equipment like this is well suited for routine tests," says Fabia Gozzo. "But small amounts of polymorphic forms in a mixture can not be distinguished." That is why Fabia Gozzo and her team rely on SLS and the synchrotron radiation generated here – a special type of X-ray radiation. "The synchrotron radiation from SLS is around 500,000 times more intense than the X-ray light from the best laboratory

The Excelsus team: Fanny Costa, Mathilde Reinle-Schmitt and Mickaël Morin (from left to right) in front of the Park Innovaare deliveryLAB. The new innovation hub in Villigen will be ready for occupancy by the end of 2023.

equipment. Together with a high angular resolution, this enables the detection of even the smallest impurities."

In addition, the detector used for the measurements has a detection time of just a few microseconds – this means that the experiments can be carried out extremely quickly, which reduces the radiation exposure and protects the fragile molecules from being damaged by the examination. Fabia Gozzo remembers: "Originally, the PSI physicist Bernd Schmidt and his team conceived the Myth detector at SLS as a device for time-resolved measurements – like making a film in the microsecond range." At the time, Gozzo was working as a scientist at PSI and had the idea of using this detector for radiation-sensitive samples. "Together with the PSI detector group, we carried out a series of complex calibrations – finally we managed it: a fast acquisition time with fantastic data quality!"

A mix of industry and research

As a service provider, Excelsus buys the beam time needed for its clients directly from PSI and cooperates with the researchers at the SLS beamlines. "Thanks to our close collaboration with PSI, we are very flexible and can guarantee our customers fast and uncomplicated access to SLS with its unique analysis methods," Gozzo explains.

The service portfolio ranges from the detection of polymorphic forms to support during drug development and production, as well as providing scientific expertise in legal cases dealing with patent issues or drug counterfeiting. The team has to constantly adapt to the latest research. This includes regular exchange at scientific conferences as well as conducting their own research and publishing new results. "We have one foot in industry and the other in research." The CEO smiles: "And this healthy mix is what makes our challenging work so much fun." ◆

Latest PSI research news

100 bar hydraulic pressures are possible using the special test equipment.

6 brake pistons press the brake pads onto the brake disc.

0.1 mm is the clearance achieved through optimisation.

1 Further optimising car brakes

PSI researchers and staff from the technology transfer centre ANAXAM, together with industry partner Audi Sport, have literally brought light into the darkness: they used neutrons to examine a brake caliper in action and demonstrated potential for optimisation. During their experiments they observed precisely how the brake pistons press the brake pads onto the brake disc, as well as how the braking process ends. The experiments were carried out on the Neutra beamline at SINQ, the Swiss spallation neutron source. PSI researchers used a detector that registered the neutrons behind the test setup and ultimately provided a two-dimensional image of the inside of the brake caliper. After subsequent optimisation of the brake pistons by the industrial partner, three pistons on the inside of the brake caliper showed improved behaviour under the neutron beam – specifically better clearance – so that when the brake was released, contact between the brake pad and brake disc was reliably interrupted.

Further information:
https://psi.ch/en/node/55166

2 Switching medicines on and off with light

Using the X-ray free-electron laser SwissFEL and the Swiss Light Source SLS, PSI researchers have produced a film that could give a crucial boost to the development of a new type of drug. The field they are advancing is called photopharmacology. This discipline develops agents that can be selectively activated or deactivated with light. For their investigation, the researchers used the active ingredient combretastatin A-4 – CA4 for short – which is currently being tested in clinical studies as an anti-cancer agent. It binds to the protein tubulin, from which microtubules are assembled. These form the basic framework of the body's cells and also drive the process of cell division. CA4 destabilises the microtubules and thus can inhibit the uncontrolled division of cancer cells, thereby slowing tumour growth. After chemical modification, the agent essentially becomes light-sensitive, so that it can be switched on and off. The large research facilities of PSI enable researchers to observe this process with particular precision. The ability to film photoactive substances in action opens up the possibility to gain many other important insights within medical research.

Further information:
https://psi.ch/en/node/55436

3 Powering aircraft sustainably

PSI and the Swiss startup Metafuels are developing a new process for obtaining sustainable aviation fuel, or SAF for short. Together they are now devising the construction and operation of an initial pilot plant on the PSI campus to validate the technology and use it on a commercial scale in the near future. The aim is to develop and market an efficient process for producing inexpensive synthetic kerosene from renewable resources. Water, renewable electricity and carbon dioxide from sustainable sources will be used to produce a high-quality aviation fuel that can be used already to power today's aircraft types – either as an additive to fossil kerosene or potentially even as the main fuel. In collaboration with the Metafuels team, PSI researchers have developed a catalytic process that not only avoids using fossil-based precursor materials but also, in comparison to SAF processes in use to date, achieves a higher level of selectivity – in other words, the ratio of yield and conversion – as well as a more efficient use of energy from renewable sources. This technology should help realise the net-zero goal in aviation as well as other sectors.

Further information:
https://psi.ch/en/node/55853

4 Night smog mystery is solved

In a large joint project including researchers from PSI, scientists have clarified why smog occurs in the Indian capital New Delhi at night, contrary to all the rules of atmospheric chemistry. The team found that the levels of particulate matter are triggered by fumes produced when wood is burned. For around 400 million people in India's Ganges River lowlands, burning wood is a common practice in cooking and heating. Since no restrictions apply, people sometimes burn plastic and other waste as well as wood. Such fires produce a gas mixture with countless chemical compounds. These molecules cannot be seen in the air with the naked eye, even in high concentrations. As night falls in New Delhi, however, the temperature drops so rapidly that some of the gas molecules condense and within a few hours agglomerate into particles up to 200 nanometres in size. These can be perceived as a grey haze.

Further information:
https://psi.ch/en/node/56398

Favourite recipes from around the world

People from 64 nations work at PSI. Of course, they all bring their own culinary preferences with them. In this gallery we can only present five researchers with their favourite dishes – and we found it hard to choose. Nevertheless, with one click you can set off right away on a delicious gourmet trip around the world.

Text: Christian Heid

Mexican

Manuel Guizar Sicairos heads the Computational X-ray Imaging group working in the large research facility Swiss Light Source SLS at PSI and as an EPFL professor. His group focuses on the development of novel imaging methods and advanced reconstruction techniques. His favourite dish? *Aguachile de camarón*. It is a flavourful, refreshing and zesty Mexican appetiser where the prawns are "cooked" by lime juice – a method widespread in Latin America.

Recipe: https://psi.ch/en/node/57186#mexikanisch

Brazilian

Camila Bacellar is a beamline scientist and group leader of the Alvra experiment station at the large research facility SwissFEL, the Swiss X-ray free-electron laser. Among other things, she supports guest scientists in carrying out their experiments. She loves to eat *pão de queijo*: these little cheese balls are widely enjoyed throughout Brazil as a snack or even for breakfast. Ideally, fermented cassava pulp, *polvilho azedo*, is used to prepare it.

Recipe: https://psi.ch/en/node/57186#brasilianisch

Japanese

Takashi Ishikawa heads the Cellular Structure Imaging group. Using electron cryo-tomography and -microscopy, researchers here create and analyse images of biological macromolecules and organelles. He made our mouths water with *tori no karaage*, fried chicken. Depending on your preference, the pieces of meat are marinated in soy sauce, sake, ginger or garlic. Many different variations of this dish are served at the Karaage Matsuri Festival in the Japanese city of Oita.

Recipe: https://psi.ch/en/node/57186#japanisch

Hungarian

Fanni Juranyi is an instrument scientist at the large research facility SINQ, the Swiss Spallation Neutron Source. She studies diffusional and vibrational motions in complex materials, and how they are related to their properties. One of her favourite dishes is called *lángos*, a flatbread, which is very popular in Hungary. Traditionally, it is simply brushed with a garlic paste (pressed garlic, water and oil) and salted. Besides the traditional lángos, there are many variations. For example, you can also enjoy it with sour cream and grated cheese.

Recipe: https://psi.ch/en/node/57186#ungarisch

Indian

Kannan Ramachandran is a scientist in the Energy Economics Group which belongs to the Energy and Environment Research Division as well as to the Nuclear Energy and Safety Research Division. His research concentrates on the development and application of energy-economic models for policy making on energy and climate change mitigation. He presents us with *idli*, a classic South Indian dish, as his favourite. Particularly for breakfast, *idli* is served on a banana leaf. The dough, made from black lentils and rice, is fermented before being formed into small flat, round cakes and steamed. It is accompanied by sambar sauces based on lentils and tamarind, as well as coconut chutney, whose taste can be either sweet and sour, or hot and spicy.

Recipe: https://psi.ch/en/node/57186#indisch

Swiss precision and Greek temperament

Iakovos Barmpadimos calculates climate risks for the reinsurance company SCOR. The atmospheric physicist learned an important part of the necessary skills during his doctoral research at PSI. “It was the ideal preparation for my present job.”

Text: Jan Berndorff

The clouds hang low over Lake Zurich on this January day. At Bürkliplatz, around the corner from the Zurich office of the French reinsurance company SCOR, things are getting busy. Diagonally to the left, the opera house dominates the lake shore. On the distant shore to the south, the sun flashes through the dense cloud cover. It would be hard to imagine better conditions to set the scene for a talk with atmospheric physicist Iakovos Barmpadimos. It quickly becomes clear that insurance expert Barmpadimos, who works mainly with numbers in his job, has other talents too – for example, when it comes to demonstrating steadfast persistence with an umbrella on the storm-whipped shore of Lake Zurich. Versatility is important to him. This served him well during his doctoral training at PSI and ETH Zurich. That’s when he acquired the self-confidence needed to give a public talk: “I used to be rather shy and nervous on such occasions. But in the four years I spent as a doctoral candidate at ETH Zurich and doing research at PSI, I was able to give a lot of lectures,” he recalls. He also refined his ability to work with particular precision, which he needs for his current job. This involves calculating realistic insurance premiums on the basis of data on past climate damage, as well as future projections. Defending his doctoral thesis proved to be a very good learning experience.

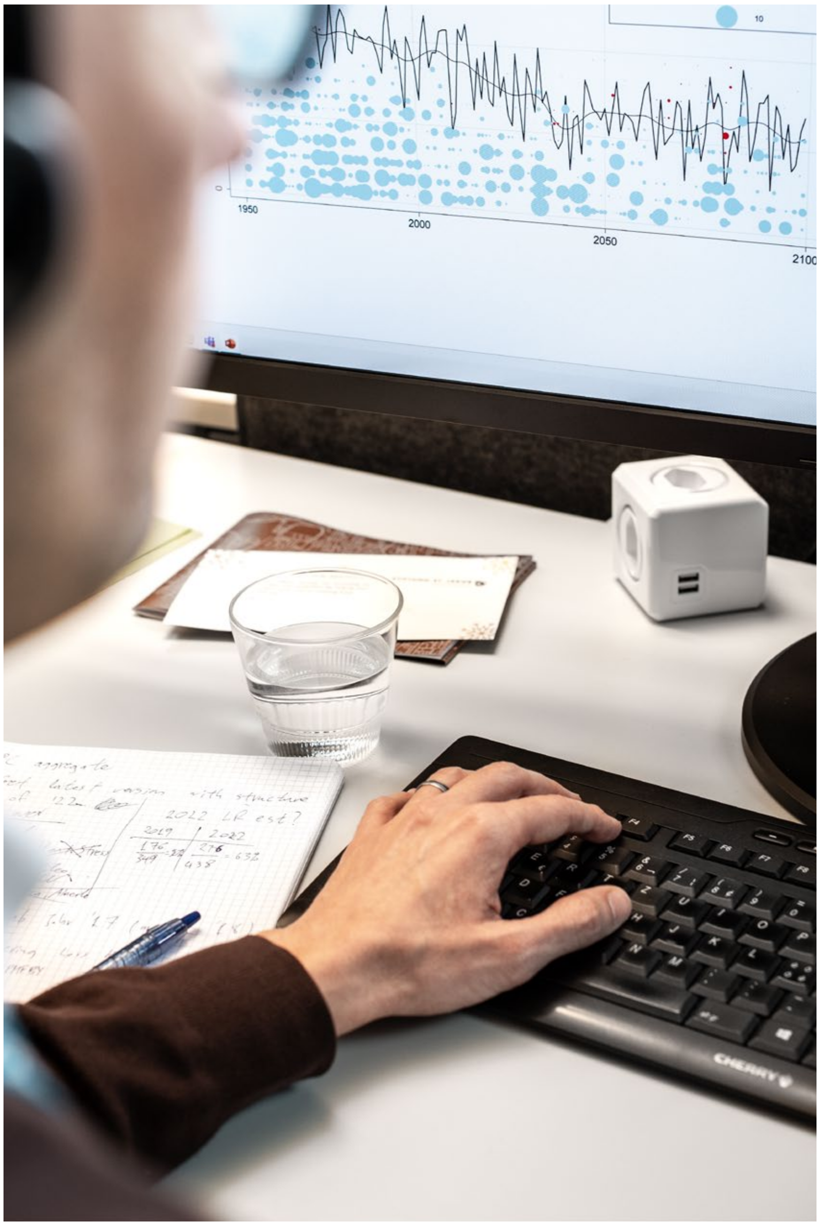
Analysing disasters

We go back to his workplace in the new glass building his employer and roughly 250 co-workers moved into two and a half years ago. Open-plan offices, dark wall-to-wall carpeting, lots of potted plants, a dignified, quiet ambience. On Barmpadimos’s desk stand two large monitors with graphic displays. On the right is a map of France on which areas in the Massif Central region are coloured dark blue. The monitor on the left shows a time diagram on which many blue patches of different sizes can be seen under a wildly meandering transverse line. “Both graphs are the result of our work regarding a cold snap in France in April 2021,” Barmpadimos explains. After it had been unseasonably warm there at the end of March – up to 25 degrees Celsius – and many plants were already blooming, the temperatures in important growing regions such as Burgundy and Beaujolais fell locally to a record-breaking minus eight degrees on the night of April 7. “For the wine and fruit growers, it was a total disaster. They lost nearly their entire harvest for that year.”

Naturally, many were insured against frost damage. However, the event prompted SCOR to recalculate the premiums for the reinsurance policies used by agricultural insurers to protect themselves against major losses. The premiums need to be constantly adjusted to changes in circumstances. And in Barmpadimos’s area of activity – climate-related loss events – there is accordingly a lot to do as a consequence of climate change.

So it was a matter of compiling weather data and loss events for this region over the past few years, making projections for the future using current climate models and calculating appropriate premiums on this basis. The problem of cold spells in spring is not that they are mounting up. On the contrary, they occur even less frequently as a result of the general warming trend. But the plants are blooming and budding earlier and earlier – sometimes by several weeks. “As a result, it is becoming more common, despite frost events being less frequent overall, for plants to freeze,” Barmpadimos says. The chart on his left monitor shows this. “And naturally, we have to take this into account.”


CANADA



“People forget and suppress it very quickly – until the next major disaster.”

Iakovos Barmpadimos, atmospheric physicist

He is certainly also thinking of the fate of the farmers who are affected, and the fact that it doesn't get any easier for them when insurance premiums rise with increasing weather extremes. But he has to tune that out at work. "In principle, we ultimately have the same interest," he says, "to avoid loss as much as possible." That's why at some point it no longer makes sense to live and cultivate crops in regions where the risk of natural disasters continues to rise. That's something the people who are affected and the responsible authorities would have to take into account. "For events that don't happen that frequently, such as cold snaps or floods, it's often difficult to convince people. They forget and suppress it very quickly – until the next major disaster."

Worldwide calculations

Each year Barmpadimos carries out around fifty such premium calculations – worldwide. He also works for clients – insurance companies – in India, Pakistan, Germany, Turkey and the USA, mainly in the agricultural sector. He and other SCOR employees often travel to their locations to discuss project results and negotiate final premiums.

He originally studied physics in his home town of Athens. He specialised in atmospheric physics and meteorology. He thought it might be easier, however, to find a job in the field in other European countries. He completed his master's degree in applied meteorology at the University of Reading in the UK. In 2007 he made the move to Switzerland to pursue a PhD at ETH Zurich. He carried out his research work at PSI, focusing on aerosols under different environmental conditions in the Gas-phase and Aerosol Chemistry group, headed by André Prévôt, with atmospheric chemist Urs Baltensperger as his doctoral advisor. "Iakovos was very good at programming and was able to quickly familiarise himself with new topics," Prévôt recalls. "His open and genial Mediterranean manner certainly enriched our research group and laboratory."

When Barmpadimos first moved to Switzerland, he didn't yet know a word of German – let alone Swiss-German. "I still don't speak that," the 42-year-old says. "But my colleagues at PSI gave me a very warm welcome and helped me wherever they could – including matters outside of work, such as dealing with authorities and moving. The atmosphere was like family."

They didn't just work together, but also went on trips in the mountains and played sports – among other things, Barmpadimos was a member of the PSI basketball team and took part in a number of tournaments between research institutions, for example in Berlin. In general, he is very interested in sports. As an ardent fan of his home football club AEK Athens, he meets regularly with around twenty other supporters living in Zurich and also goes to the stadium with them when AEK plays in the European Cup nearby. "That's where my Greek temperament comes into play," he grins.

He even learned to ski during his time at PSI. "As a Greek, that was completely foreign to me before. My colleagues taught me, with the patience of a saint. So today I can also go skiing with my two children – I have married a Swiss woman and started a family. That, of course, is part of life here in the Alps."

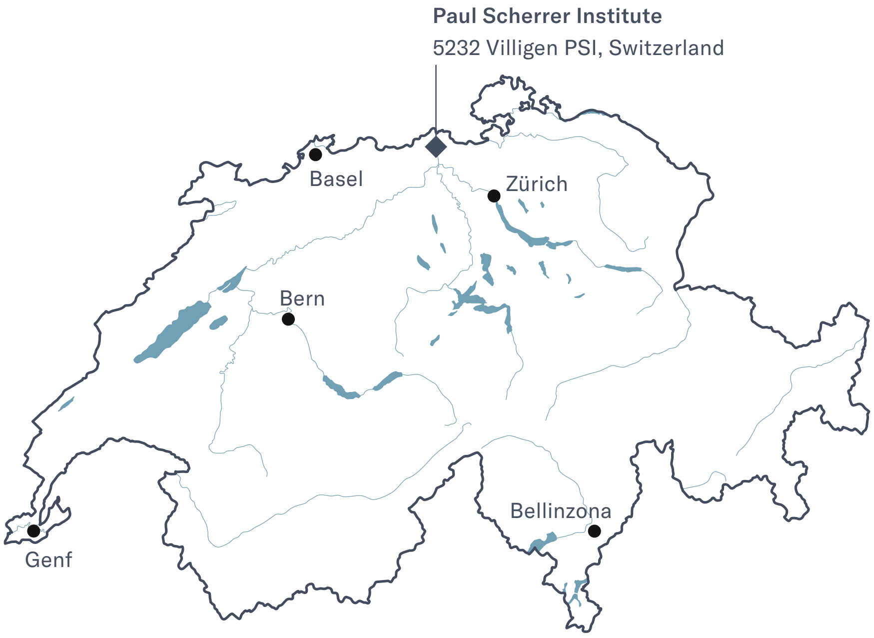
Even today, more than ten years after leaving, he still has sporadic contact with PSI. In the beginning he even had a hand in some research publications. "But I don't do that any more, and I'm focusing on my work here." Nevertheless, there are professional contacts as well as the personal ones – such as when ETH Zurich invites actuaries like him, as experts with practical experience, to a seminar for staff and students.

Putting down roots in Switzerland

Along with support from the team at PSI, language courses and his family have also contributed to getting settled in Switzerland. Barmapadimos can no longer imagine returning to Greece: "I feel absolutely at home in Switzerland, and I've put down roots here. I like my work and handling data very much, likewise the punctuality and precision of the Swiss – and not only for professional reasons."

But as a father, isn't he concerned that climate change is coming to Switzerland too? "Naturally," he says. "We will have to adapt. And by that I don't just mean it's no fun to ski on artificial snow in the middle of a brown landscape. There will be more storms, heavy rainfall, droughts and other weather extremes. But it doesn't help at all to stick your head in the sand. We need to try everything we can to avoid the worst." ◆

From our base in Aargau we conduct research for Switzerland as part of a global collaboration.



5

large research facilities that are unique in Switzerland

800

scientific articles a year based on the experiments performed at PSI's large research facilities

5,000

scientists from across the globe perform experiments at our large research facilities every year

5232 is Switzerland's prime address for experiments on large research facilities. The Paul Scherrer Institute PSI even has its own postcode, a distinction that seems justified for an institute that extends over 342,000 square metres, has its own bridge across the River Aare, and has around 2,200 employees – more people than in most of the surrounding villages.

PSI is situated on both banks of the River Aare in the canton of Aargau, in the municipal areas of Villigen and Würenlingen. Its main areas of research are in the natural sciences and engineering. Funded by the federal government, it belongs to the domain of the Swiss Federal Institute of Technology (ETH Domain), which also includes ETH Zurich, ETH Lausanne (EPFL), and the research institutes Eawag (Swiss Federal Institute of Aquatic Science and Technology), Empa (Swiss Federal Laboratories for Materials Science and Technology) and WSL (Swiss Federal Institute for Forest, Snow, and Landscape Research). We conduct basic and applied research and thus work on sustainable solutions for central questions from society, science and business.

Complex large research facilities

Switzerland's federal government has given PSI the mandate to develop, build, and operate large, complex research facilities. These are the only such facilities within Switzerland, and some are the only ones in the world.

Running experiments at our large research facilities enables many scientists from the most diverse disciplines to gain fundamental insights for their work. The construction and operation of these kinds of facilities involve so much time, effort, and cost that comparable measurement equipment is not available to academic and industrial research groups at their own institutions. That is why we keep our facilities open to all researchers worldwide.

To obtain a time slot to use the experimental stations, however, both Swiss and foreign scientists first have to apply to PSI. Selection committees comprising experts from all over the world assess the scientific quality of these applications and recommend to PSI which candidates should be given measurement time. Even though there are around 40 measuring stations where experiments can be carried out at the same time, there is never enough capacity for all of the proposals submitted – around one-half to two thirds have to be rejected.

Around 1,900 experiments are performed every year at PSI's large research facilities. Time slots are free of charge for all researchers working in academia. In a special process, users from private industry can buy time to carry out proprietary research and use the PSI facilities for their own applied research. For this, PSI offers special research and development services.

PSI operates five large research facilities in total where the internal processes of materials, biomolecules, and technical devices can be explored. Here scientists use different beams to "illuminate" the samples they want to investigate in their experiments. The beams available for this range from particles (neutrons or muons) to intense X-ray light from a synchrotron or X-ray laser source. The different types of beams allow a wide variety of material properties to be studied at PSI. The high complexity and cost of the facilities is due to the massive size of the accelerators needed to generate the different beams.

Four main areas of research

However, PSI not only acts as a service provider for researchers, but also carries out an ambitious research programme of its own. The findings produced by PSI scientists help us to understand the world better, and also lay the foundation for developing new types of equipment and medical treatments.

At the same time, our own research is an important prerequisite for the success of our user service programme for the large research facilities. Only researchers personally involved in current scientific developments in the fields external researchers are working in can support them in their investigations and further refine the facilities to ensure they continue to meet the needs of cutting-edge research in the future.

Our own research is concentrated on four focus areas. In the area of Future Technologies, we investigate the diverse properties of materials. With the knowledge this yields, we create the foundations for new applications – whether in medicine, information technology, energy production and storage, or new industrial production methods.

The goal of our work in the focus area Energy and Climate is developing new technologies for a sustainable and safe energy supply, as well as for a clean environment. Also in this area, we are investigating interconnections within Earth's climate system.

In the focus area Health Innovation, researchers are looking for the causes of diseases as well as for potential therapeutic methods. In addition, we operate the only facility in Switzerland using protons for the treatment of specific cancer diseases. This special technique makes it possible to destroy tumours in a targeted way while leaving the surrounding health tissue largely undamaged.

In the area Fundamentals of Nature, researchers are seeking answers to fundamental questions about the basic structures of matter and the functional principles of nature. They investigate the structure and properties of elementary particles – the smallest building blocks of matter – or clarify fundamental processes in living organisms. The knowledge gained in this way opens up new approaches to solutions in science, medicine and technology.

The brains behind the machines

The work at PSI's large research facilities is challenging. Our researchers, engineers, and professionals are highly specialised experts. It is important for us to foster this expertise. So we want our employees to pass on their knowledge to the next generation, who will then put it to use in a variety of professional positions, not just at PSI. Around a quarter of our staff are therefore apprentices, doctoral students, or postdocs.

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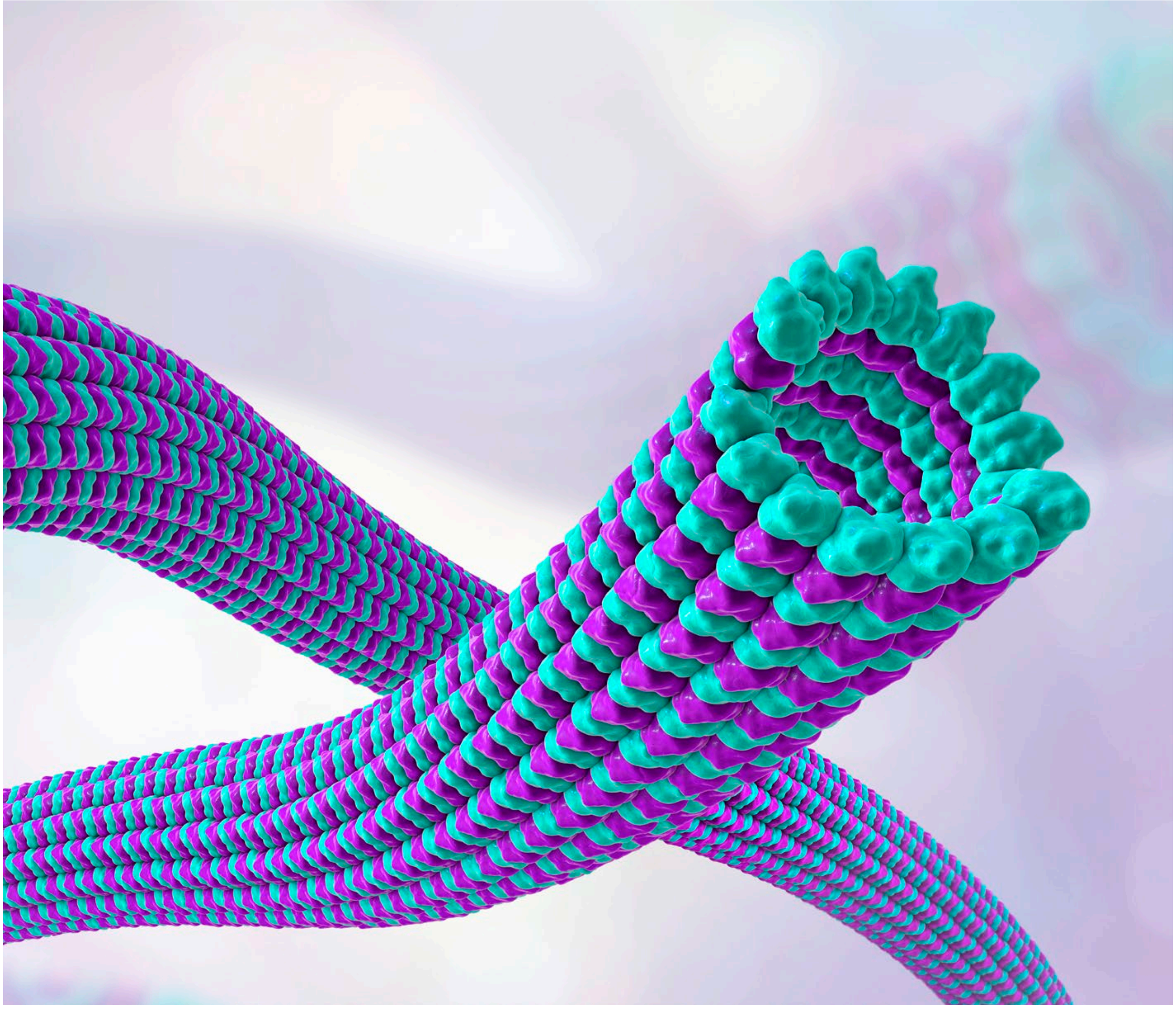
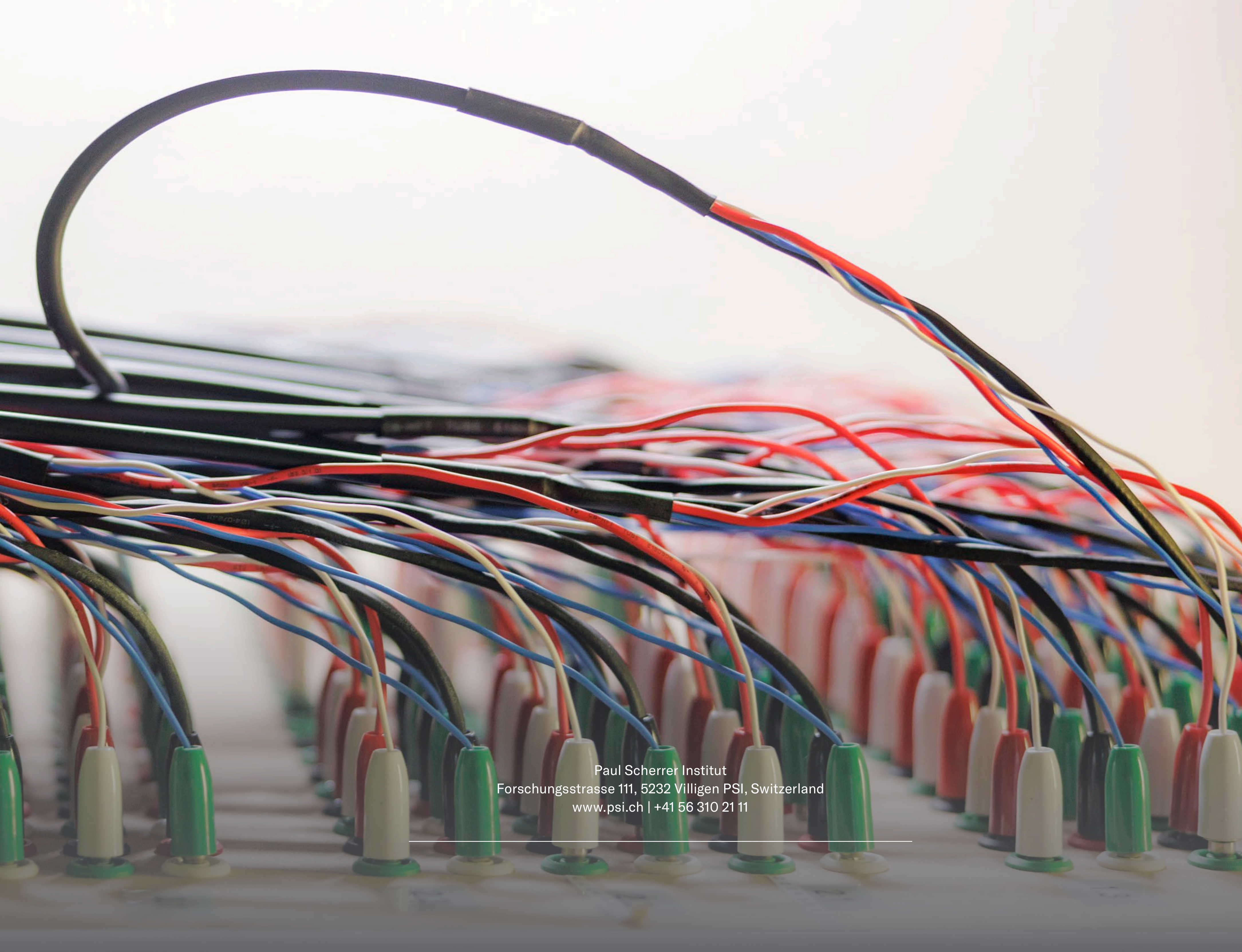


Coming up in the next issue

The cytoskeleton is one of the most promising topics in current biological research. Contrary to what its name might suggest, it is not just an internal framework. It also plays an important role in fundamental life processes, including cell division and the mobility of a cell's internal functional units, the organelles. Disruptions to these processes can, for example, cause neurodegenerative diseases. On the other hand, agents that specifically attack the cytoskeleton offer approaches for therapies, against cancer for example. PSI researchers are working at the top level of global research to better understand processes involving the cytoskeleton and thus to create new possibilities for medicine.



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