N° 45 • JUNE 2007

ESRF Newsletter

Discovering our planet

European Synchrotron Radiation Facility
http://www.esrf.fr/UsersAndScience/Publications/Newsletter

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ESRF Newsletter is produced for the ESRF by IOP Publishing, Dirac House, Temple Back, Bristol BS1 6BE, UK; tel: +44 (0)117 929 7481; e-mail: esrfnewsletter@iop.org; web: iop.org

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ISSN 1011-9310


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Discovering our planet. This issue focuses on earth and environmental sciences. pp5–15.

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Editorial

Montserrat Capellas, editor of the *ESRF Newsletter*.

THERE'S SO MUCH MORE TO KNOW ABOUT EARTH

We hear it in the news, we talk about it with our friends, we feel its effects in our lives. Climate change is everywhere. This serious threat to our future raises an uncomfortable truth: we don't know very much about our planet.

Scientists are still not even sure what the Earth is made of and what happens below our feet. Precisely why earthquakes, volcanic eruptions and other natural phenomena occur is still uncertain. The French author Jules Verne "travelled" to the centre of the Earth in his 1864 book, and what he imagined then doesn't have much to do with what scientists really believe now.

However, all of this is changing because new technologies are now making it easier for researchers to reproduce the conditions found in the Earth's interior, in the laboratory. Using diamond anvil cells coupled with the ESRF's powerful X-rays, scientists can study how materials react to the high temperatures and pressures occurring deep inside our planet. This has allowed them to investigate the different layers of the planet by studying tiny samples of elements that are likely to be in them. Recently, new clues have emerged about the core's composition.

It is not only the deepest parts of our planet that interest researchers. To get a fuller picture, we also need to investigate the "ground-floor" level. The near-surface layers of the Earth contain never-ending archives of what life and climate used to be like in the past. Thorough research has been carried out at the ESRF to decipher the biological archive of corals (p14). X-ray fluorescence has allowed scientists to map the different components of the growth layers of the corals, which provide information about their lifetime. And even though it has already produced fascinating results, the investigation is far from complete.

The different chemical elements around us can also affect our planet and our health. In many cases, harm is caused by human actions that destroy the ecosystems. However, nature holds many surprises. For instance, there are plants that can help to counteract the pollution that we have caused in the soil. Once more, the technique of X-ray mapping of different chemical compounds has provided outstanding results on how heavy metals are immobilized, removed or excreted from plants (p9).

Upgrade programme

We are still far from obtaining a full picture of the planet. Nevertheless, the ESRF has already played an important role in increasing the scientific community's knowledge. This contribution will grow further if the facility's ambitious upgrade programme is realised. This promises many new and exciting research possibilities in environmental sciences, such as *in situ* measurements under extreme conditions to study microbial life in harsh physical (temperature, radiation or pressure) or geochemical (desiccation, salinity, pH) conditions.

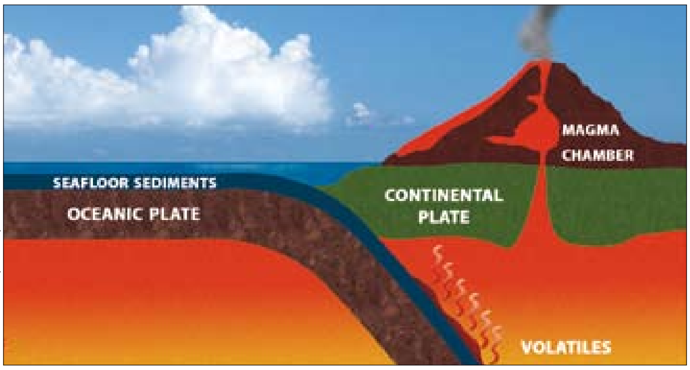
In high-pressure research, the development of a multi-anvil press at the ESRF will also extend our capabilities in this important area. This device will offer the possibility to control temperature and pressure gradients, as well as redox potentials – that is, to do real chemistry in a controlled system. It will also contribute to extending the complementarities between the ESRF's current stress–strain programme through deformation studies under high pressure and temperature conditions. The development of combined ultrasonic wave speed measurements will help us to understand better how seismic waves travel through the Earth's mantle. These studies can also be allied to similar higher-frequency measurements made at X-ray inelastic scattering beamlines, and static diffraction measurement of elastic properties to extract thermodynamic information about Earth-forming materials.

The upgrade programme will allow the ESRF to contribute even more in making our world more familiar to us and less mysterious.

Feature news: earth and environmental sciences

WATER AND ROCKS: AN EXPLOSIVE COCKTAIL IN THE SUBDUCTION ZONE

Robert Simmon, NASA, GSFC



Subduction zone. Schematic of the different parts of this zone.

Researchers from the University of Lyon (France) are looking into the behaviour of rock in subduction zones and its interaction with water, which can cause the rock to fracture. Their results give insight into the trigger for both volcano eruptions and earthquakes.

Most earthquakes and volcanoes occur at plate boundaries. Some of these, where one oceanic plate is driven back to the mantle, beneath another continental or oceanic plate, are known as subduction zones. Ocean plates are born in the middle of the ocean and, to begin with, owing to their high temperatures, they are very reactive with water. As time goes by they cool, becoming thicker and denser. Finally they end up dying in the subduction zone, where they sink, perhaps as far as the core–mantle boundary.

Natural phenomena like earthquakes are caused by the movements of the subducting plate, and volcanoes are formed when ocean plates, forced under the lighter overriding plates, dehydrate as pressure and temperature increase. The fluid released induces partial melting of the mantle wedge by decreasing the melting temperature of rocks; this then rises to the surface.

The reactions taking place in the subduction zone are directly linked to the volcano and earthquake activity. The materials in the subduction zone either take the water back to the surface or send it deeper into the mantle. Scientists from the University of Lyon are studying what happens to the water. Their final aim is to put tight constraints on the recycling of water and elements at the subduction zones, and thereby onto the global cycle of water

More specifically, they've studied samples of the rock serpentinite, which lies in the subduction zone. Serpentinites are made mostly of the mineral serpentine and are formed by the hydration of dry mantle rocks and contain 13 wt% of water. They are abundant in subduction zones, in the subducting slab and particularly just above it. There they create channel that brings back very deep samples to the surface, including blocks of extreme metamorphic rocks – like eclogites and serpentinite – and consequently a lot of water.

It has been suggested that within the subducting slab the rocks' dehydration could trigger a series of earthquakes, the locations of which are parallel to and below the Benioff line. However, this requires that serpentine dehydration is rapid, which goes against current theory. The team has thus measured the speed at which the high-pressure variety of serpentine (antigorite) dehydrates at high pressure on ID27.

Scientists were able to determine the time that water needs to get out of the serpentine. They realised that the expulsion of the water from it is much faster than the relaxation time of the bulk serpentinite rock. "This means that water can probably not escape the rock very easily, and this is likely to induce hydraulic rock fracture and cause earthquakes," says team leader Isabelle Daniel.

This success results from a well planned experiment using X-ray diffraction. It consisted of submitting the serpentine to a pressure and temperature at the limit of the stability field of the material. The team was able to follow the reaction by carrying out time-resolved experiments and monitoring the dehydration process.

Time-resolved experiments in the high-pressure beamline have improved throughout the two years that the scientists have been studying this material. "We started by taking two minutes to get the experiment done and now we have gone down to half a minute. Our next experiment will hopefully register reactions at a couple of seconds or less, so it has improved a lot in a space of two years", explains Daniel. •

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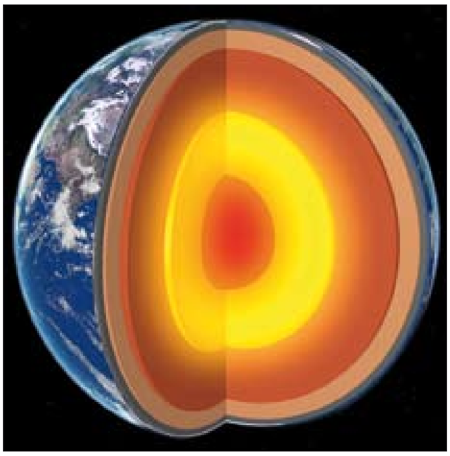
COMPOSITION OF EARTH'S CORE BECOMES CLEARER

It's at 5000 °C and is more than half the diameter of the Earth. It contains iron, together with other elements that have yet to be identified. Researchers from the University of Paris (France) have come up with a hypothesis to unveil the mystery of the contents of the Earth's core, where silicon and oxygen amalgamate with iron.

Thanks to diamond anvil cells and several ESRF beamlines (ID9b, ID16, ID27, ID28), the conditions of the Earth's core can be applied to samples of material that are supposedly found there.

One way of studying the Earth's composition is by looking at seismic wave propagation, but this must be contrasted with mineralogical and geochemical models. These can be defined by calculating the speed of sound waves of materials inside the Earth passing through an elastic medium with synchrotron X-rays.



Cut-out of the Earth. The interior of our planet comprises the crust (light brown), the mantle (dark brown), the outer core (yellow) and the inner core (red).

Light elements are alloyed to the iron in the core. Their presence was shown by Francis Birch in 1952 when he said that the core was too light to be made only of dense iron. He estimated that the outer core contains about 10% of a mixture of lighter elements, although these are expected to be less abundant in the solid inner core. However, their identity is still unknown.

A team from the University of Paris recently proposed that the inner core is made of iron, silicon (2.3%) and traces of oxygen. The outer core contains 2.7% silicon and 5.3% oxygen. Silicon and oxygen can be partly dissolved in iron, so the total amount of light element in the inner core is 2.5%, with 8% in the outer core.

The researchers studied the sound velocities of iron alloyed with lighter elements, such as sulphur, oxygen and silicon. These are the most likely alloys, based on cosmic abundances and the composition of the solar system. The team measured the speed of sound at high pressure using high-resolution inelastic X-ray scattering.

From the data came a striking discovery. A very high concentration of sulphur would need to be in the Earth's core to account for its density and velocity profile. If sulphur was the only element in the inner core, it would have to represent 10% of the inner core. However, from geochemical models, this is impossible and the value should be no more than 1.7%. And the possible combination of other elements also has to be considered. The results showed that there is 2.3% silicon and 1.6% oxygen in the core. This agrees with geochemical models and existing theories.

Nevertheless, theoretical calculations indicated that the main light element in the inner core is silicon (2.3%), with traces of oxygen. The inner core composition influences that of the outer, and this led scientists to conclude that the latter should contain 2.8% silicon. This agrees with studies on the solubility of silicon in molten iron.

What happens to the sulphur? The researchers ruled it out from their model, considering its low condensation and volatilisation temperatures. Nevertheless, they state that there may be about 1% sulphur in the core, but it would have a very small effect on the core's thermoelastic properties.

"This research is far from finished," explains team leader James Badro. "We still have a lot of questions to answer." For example, carbon is also speculated to be an eventual constituent of the core, and similar tests need to be carried out. "More important, from a geochemical point of view we need to address the effect of our candidate light elements on the partitioning of trace elements between the silicate rock and the iron metal. This takes us back to the oldest period of Earth formation and could shed new light on the fundamental question of how it formed and how it evolved in its earliest days," Badro concludes.

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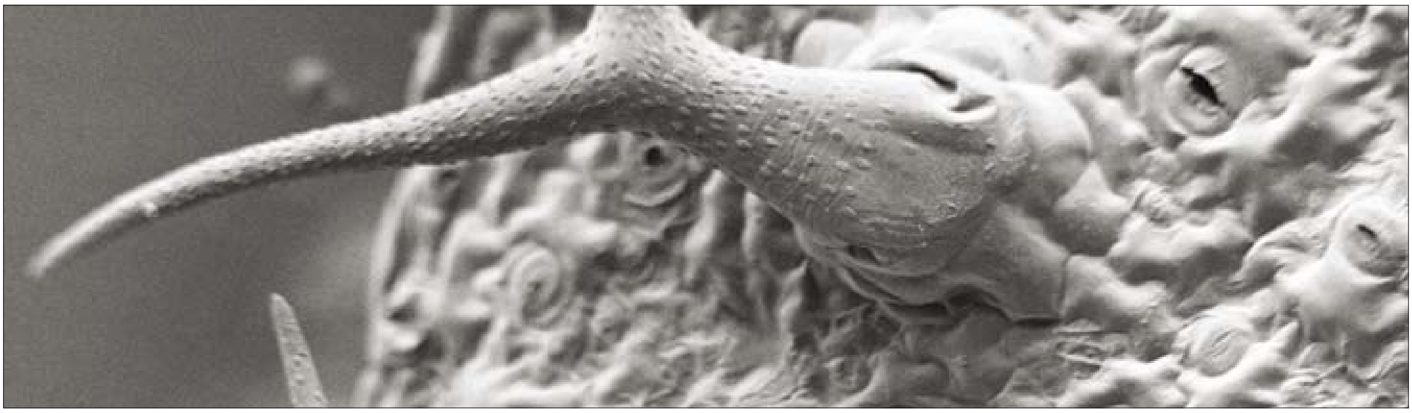
Marie-Pierre Isaure

Toxic trichomes. Scanning electron micrograph of epidermal hairs of *Arabidopsis thaliana*, where some heavy metals are stored.

WHY ARE PLANTS SUCH BIG HEAVY METAL FANS?

Researchers from the Centre National de la Recherche Scientifique (CNRS) and University Joseph Fourier in Grenoble (France) use the ESRF to look at how plants clean soil and water, with a view to harnessing higher plants and bacteria to fight increasing global pollution.

Some 18 years ago the multinational oil company Chevron discovered that the toxic selenium that it was dumping in to San Francisco Bay was converted to harmless compounds after it had circulated in a 35 hectare wetland established between its outfall and the bay. The plants in the wetland were responsible for this transformation, the entire wetland ecosystem acting as a biogeochemical filter. The root system of the plants slowed the water flow and the root activity favoured the retention of selenium in the sediment, and its volatilization as non-toxic gas.

Today, wetlands are planted in many places around the world to phytoremediate soils and purify domestic or industrial wastewaters and landfill leachates. Last year an ecological park was inaugurated in Nanterre (France), where ornamental plants clean the dirty waters of the River Seine, while decorating the landscape.

For many years the use of green technologies to restore the environment has been viewed with scepticism by many companies that preferred more traditional techniques. However, following several successful industrial-scale experiments, sustainable technologies using green plants are taking off in Europe.

These techniques, involving complex and synergistic processes between plants, microbes and mycorrhizal fungi, are poorly understood, and today's technologies largely rely on empirical usage. A molecular-scale understanding of the functioning of biogeochemical systems is critical for formulating effective metal containment and extraction technologies.

The group from the CNRS and the University Joseph Fourier is trying to identify the mechanisms by which toxic metals are immobilized in the rhizosphere, or solubilized and transported to the root, and then detoxified by plants. For example, it has shown that zinc sulfide contained in sediments from waterways contaminated by smelting activities is transformed into sparingly soluble (i.e. non-toxic) zinc phosphate when the sediment is dredged and planted with grass.

Tolerance and hyperaccumulation

Also, in partnership with the Phytorestore company, the group optimized the Jardins Filtrants process used to decontaminate solid matrices and wastewaters by improving the efficiency of the complexation of metals with chemical extractants. This work was conducted on the Collaborating Research Group beamline FAME at the ESRF for the analysis of the bulk samples, and on a dedicated microEXAFS beamline at the Advanced Light Source (US) for microscopic measurements.

In contrast with metal-tolerant plants, which prevent the accumulation of metal into photosynthetic tissues, hyperaccumulating plants translocate excess amounts to harvestable parts, such as the leaves. The intriguing mechanisms of metal tolerance and hyperaccumulation are actively studied worldwide. The team is comparing several species of the Arabidopsis family, including the zinc and cadmium hyperaccumulator *Arabidopsis halleri*, and the non-tolerant and non-accumulator *Arabidopsis thaliana*, which is the model plant in molecular biology. Recently it has studied cadmium accumulation in *A. thaliana* on ESRF 's ID21 beamline. This wasn't an easy experiment because the samples need to be frozen so that the cadmium doesn't change form. "In hydrated samples the signal is low. Thanks to the optimal focusing and detection system of the beamline, we could map the samples at high resolution and determine what types of molecule cadmium are bound to," explains team member Geraldine Sarret. In the leaves, cadmium is mostly stored in the cell walls of the trichomes (epidermal hairs on the leaf) and is bound to polysaccharides. In other cells, cadmium is trapped by sulphur-containing molecules, which have a high affinity for this metal and are produced in response to cadmium exposure. These detoxification mechanisms prevent the metal from interacting with the machinery of the cell.


Science Photo Library

Born to clean. *Arabidopsis thaliana* is key to the research team's investigation.

In some cases, such as in tobacco leaves, cadmium and zinc are excreted through the trichomes in the form of 50–200 μm particles, especially when a supplement of calcium is provided to the plant. So smoking increases human exposure to these metals.

The team determined the composition and structure of this new type of biogenic particle by combining micro-X-ray fluorescence, diffraction and absorption on the ESRF's beamline ID21, and the ALS beamline 10.3.2. Both metals were incorporated into calcite and vaterite grains – two polymorphic forms of calcium carbonate. Thus leaves should be washed carefully to decrease the amount of trace metals in cigarettes.

Scientists also suggest that the bioextraction of the mobile fraction of metals from the soil, and their subsequent bioexcretion as metal-rich carbonate precipitates during the cultivation of tobacco, could progressively diminish their overall bioavailability after several vegetative cycles.

With ever-increasing imaging and spectroscopic resolution and elemental sensitivity at synchrotron facilities, scientists are closer to understanding how metal contaminants are stored in specific subcellular compartments of biological tissues. The exact location of metals may vary with species, but the key molecular reactions for metal detoxification are probably similar in many organisms, since all forms of life, including ancestral bacteria, can resist chemical poisoning to a degree.

"Environmental science is an area where fundamental knowledge and societal applications are directly interlinked, and this research will have obvious benefits to humans," says team member Alain Manceau.

"The combined use of X-ray fluorescence, diffraction and absorption, when applied from the nanometre to the millimetre scale of spatial resolution, offers unique access to the problem and can help to answer a number of environmental questions. It's crucial to use submicrometre probes so as not to miss key details, but these probes can only look at an extremely small portion of the bulk sample. So one needs to remember that lower X-ray resolution (i.e. looking at a larger part of a sample with a broad beam) is always required to assess and quantify how representative observations are made at high resolution," he says. •

MC

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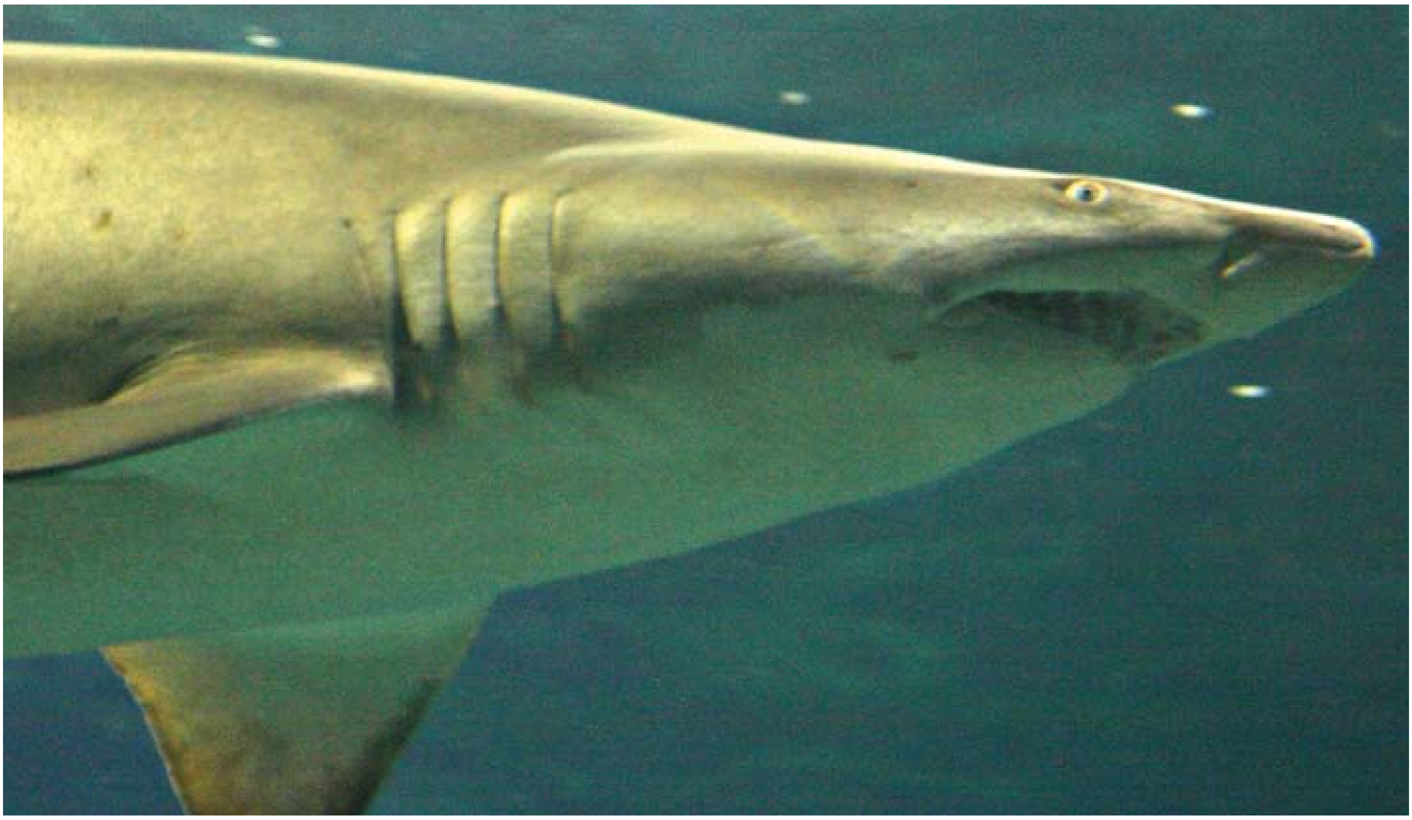
...SEE the Future

HOW RELATIVELY SAFE MERCURY BECOMES TOXIC

Using synchrotron radiation at the ESRF, an international team has found that the less-poisonous form of inorganic mercury in soils binds to sulphur compounds, which are key in its transformation to the toxic form. The research, published in *Environmental Science and Technology*, has been awarded Top Science Contribution.



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Poison on the menu? Sharks have been found to contain high concentrations of methylmercury, which may enter our foodchain.

Minamata, Japan, 1956: a chemical factory releases methylmercury in its industrial wastewater. This highly toxic chemical accumulated in fish in Minamata Bay, resulting in the mercury poisoning of the local population, causing the death of almost 2000 people.

After this catastrophe, mercury was banned as a fungicide in many countries in the late 1960s, but fish are still accumulating mercury well beyond the levels that are currently recommended by health authorities for consumption. In Sweden alone some 40 000 lakes were still blacklisted in the 1980s.

The reason why mercury is one of the most poisonous elements known to us is that it binds very strongly to functional groups of various enzymes and proteins. It then inhibits, or negatively affects, key organic functions, such as the development of the nervous system of infants. However, not all mercury is so toxic.

The less-poisonous inorganic mercury is mainly released into the environment as a result of the combustion of fossil fuels. The majority of it is transported over great distances in the atmosphere and can stay in the air for up to a year. It is then deposited onto soils, sediments and surface waters. In some regions, local excavation of the mineral cinnabar and gold mining are also major sources of the metal.

The transformation of mercury

Inorganic mercury is not as lipophilic ("fat loving") as methylmercury and cannot pass through cell membranes. To some extent it is also excreted by organisms. The transformation of inorganic mercury into methylmercury makes the element available to bio-organisms, thereby making it toxic. Once scientists understand the chemical speciation of mercury, they can limit its bioavailability and think about initiating soil remediation processes.

Scientists from the Swedish University of Agricultural Sciences, the University of Wisconsin and the University of Minnesota (USA) have used the ESRF to determine the form of mercury in natural organic matter at the scale of environmentally relevant concentrations. Research began at Brookhaven National Laboratory (NSLS) and has been continued at the ESRF. "We managed to investigate 100 mg of mercury per kilogram of soil on beamline ID26," says leading scientist Ulf Skyllberg. "These are really low concentrations with respect to work previously done and it represents reality much better. Nevertheless, this concentration is still almost 1000 times as high as in most natural soils."

The team used X-ray absorption spectroscopy, which has only recently been used to characterize the speciation of mercury in soils and sediments. This is a big step forward compared with earlier operationally defined wet chemical methods. The ESRF upgrade programme, which is currently in preparation, will allow scientists to study even lower concentrations.

The team observed that inorganic mercury binds to two reduced organic sulphur groups. This determines to what extent bioavailable forms of mercury are present in soils for the methylating bacteria – the microorganisms transforming inorganic mercury to methylmercury.

The next step is to identify the relative importance of different sulphur-containing molecules in soil-based organic matter in the transformation of mercury. Also, to understand the factors controlling methylmercury formation in the environment, it is extremely important to uncover the influence of iron and inorganic sulphur on the chemical speciation of mercury.

The award in *Environmental Science & Technology* of Top Science Contribution during 2006 has brought the work of Skyllberg's team into the limelight so that it is recognised by the scientific community.

"Hopefully, this will help us to get the funding needed to further explore the fascinating interplay between chemical speciation, methylmercury production and subsequent bioaccumulation in various environmental settings," Skyllberg says.

SIGRID EECKHOUT

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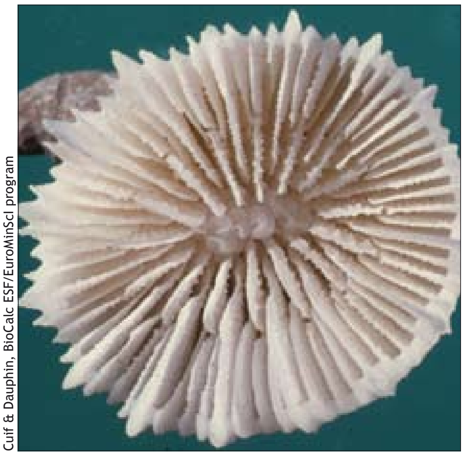
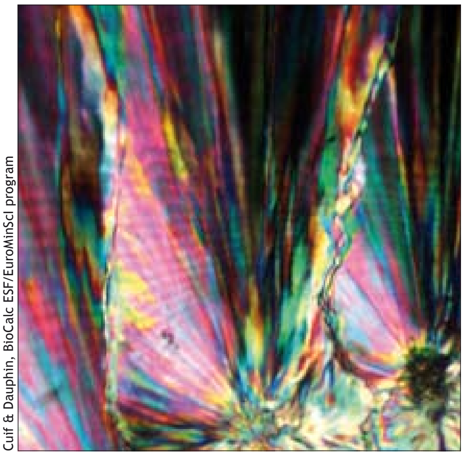
CORALS REVEAL SECRETS ABOUT PAST CLIMATES

In a world that still holds many mysteries, despite technological advances, a better understanding of the past can help. That's where "proxy" data come in. In nature, measurements made of slowly growing biogenic structures, such as tree rings or stony corals, can indirectly reveal information about previous climates. At a time when climate change is a serious concern, the ESRF's X-rays are helping to fill in gaps in our knowledge.

Stony corals are an archive of sea history. They grow in tropical and deep-sea waters, producing huge calcareous structures by the superimposition of continuously repeated crystallization of growth layers just a few microns thick. In any chemical reaction, fractionation of the isotopes for a given element depends on the temperature, as shown by H C Urey in the 1950s. Thus corals act as "recorders" for the temperature variations in seawater through the layered growth of their skeleton.





Skeletons built by stony corals. Corals (left; field view 25 mm) are constructed from calcium carbonate fibres (right; field of view 250 μm), three dimensional arrangements and species-specific compositions that have long been unexplained.

Scientists from the University of Orsay (France) have been studying these beauties of the sea for some years using the X-ray microscopy beamline ID21 of the ESRF. Their most important result so far is the dismantling of a long-held theory that the growth of the corals (and so their crystallization) was a purely chemical process.

The team has shown that, in contrast to the purely calcareous skeletons that should result from a simple chemical precipitation process, organic compounds are a key component of coral skeletons. Thanks to the submicrometric focused X-ray beam associated with the specially built mapping device at ID21 and a highly selective X-ray monochromator, localized microfluorescence has demonstrated that sulphated polysaccharides are distributed in perfect correspondence with the growth layering of the mineral skeletons. This implies that polysaccharides participate in the crystallization process of the coral growth layers. "This completely changed our views about coral crystallization," explain team leaders J P Cuif and Y Dauphin. "The impact of the ID21 spectrometric and imaging system was decisive by establishing the organic-mineral link in each step of the coral growth," they add.

This starts to explain why each coral species records temperature changes with its own sensitivity. This is the enigmatic "vital effect" suggested by Urey in his 1951 paper. "Our aim now is to elaborate the new rules of the species-specific temperature recording, taking into account the fact that in living organisms the crystallization process is biochemically driven. This should lead to replacing the present empirical approach of the proxies by a rational understanding of isotope fractionation in biogenic crystals."

Heating corals

A team from the University of Warsaw and the Institute of Paleobiology (Poland) is doing similar work. The group used ID31 to carry out high-resolution powder diffraction studies of corals. It investigated the structural phase transition from aragonite to calcite in biogenic samples at ambient temperature and after heating them to 500 °C. The team used powder diffraction for its measurements, although the sample was not pulverized but in one piece. By heating the samples the researchers tried to understand how long the biogenic sample would still preserve "biological" signatures. In this case they looked at different lattice parameters in comparison to synthetic or geological ones. "This may have some significance for an astrobiological apporoach, for example if we compare a meteorite that shows similar changes of lattice parameters as Earth biominerals," says team leader Jarek Stolarski.

The main results showed that the crystal structure of biogenic samples is influenced by interaction with organic molecules. The team realised that the strain of the calcite phase obtained by heating coral samples is twice the size of that in natural aragonite samples.

Further studies will focus on how the basic aragonite crystallites are arranged in the coral skeleton. Early results show that they join together like Lego blocks. The key question is how these blocks are merged and what organic components are intercalated between them. •

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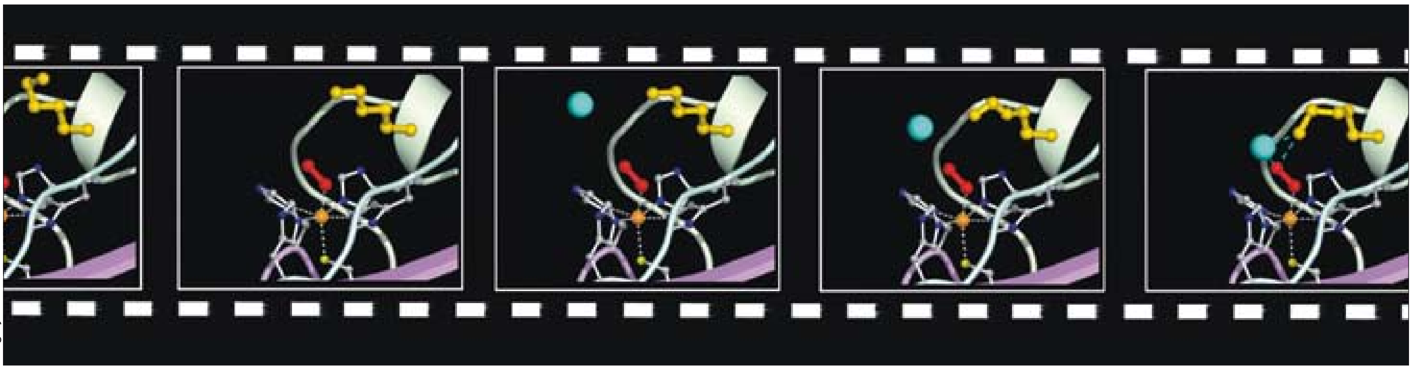
PROXIES PROVE POPULAR

Paleoclimatology and the study of proxies illustrate the remarkable possibilities of X-rays. Teams have carried out experiments on ice from polar lakes or stalagmites. These act as an archive of the weather in mid- and low latitudes. Scientists used micro-X-ray fluorescence to study the role of sulphate aerosols in the altering regional climate.

Owing to the growing use of synchrotron radiation in paleoclimatology, the ESRF held a meeting last October on Environmental Proxies: from Inorganic Precipitation to Biocrystallization. This attracted members of EuroCLIMATE and EuroMinScI , both funded by the European Science Foundation. Either studying natural materials or dealing with crystals resulting from experiments, they both aim for a better understanding of the relationships between the structure of biocrystals, their chemical or isotopic compositions and the properties of their growth environments. More than 60 delegates were visiting a synchrotron facility for the first time.

Feature news



Gergely Katona

Lights, camera, action! The film strip illustrates how the lysine amino acid (the yellow part of the protein) connects with a water molecule (shown in blue) and then imports this into the enzyme to perform the catalytic reaction on the superoxide (shown in red).

FREEZE FRAME: SCIENTISTS FILM PROTEINS AT WORK

It is difficult to find similarities between Grenoble and Hollywood. It is yet more difficult to find common ground between the researchers at the ESRF and the Institut de Biologie Structurale (IBS, France) and world-renowned film makers. However, a team from these Grenoble-based institutes have managed to produce a movie. The protagonist is not a celebrity in this case but a protein, the role of which is to eliminate toxic molecules. The scientists filmed this protein in action by freezing it at several states and they published their results in *Science*.

Most of the research done on proteins is based on investigating them while they are at rest. Studying them in action, meanwhile, has been hampered by a number of technological constraints. However, a French team has overcome these limitations and has made a "movie" of an active enzyme (a protein that catalyses chemical reactions) found in bacteria.

"The achievement of this research is two-fold: on one side there is the technological success of filming an enzyme in action; on the other there are the results that contribute to the knowledge of how this enzyme works," says Dominique Bourgeois, who is corresponding author for the resulting research paper.

The role of the enzyme, superoxide reductase, is to eliminate the superoxide radical, a toxic molecule. To survive, all organisms must fight oxidative stress, which is produced by outflows from the oxygen metabolism.

Links with Alzheimer's?

In humans approximately 2% of the oxygen that is used to breathe is transformed into the superoxide radical instead of into water. This level is increased in people who are affected by neurodegenerative diseases, such as Alzheimer's. A large amount of the molecules worsen the symptoms of these illnesses, so scientists are looking for drugs that will eliminate them.

The enzyme studied by the team acts uniquely in bacteria. Its counterpart in humans is more complex, but the principles are the same. Synthesizing an enzyme like this through biomimetics is an exciting possibility for developing drugs for the treatment of such afflictions.

To produce the film the team used the ESRF-IBS Cryobench laboratory to freeze the protein at three different states while the reaction took place. To ensure that the right intermediate states were "trapped", the researchers used Raman spectroscopy. This provided them with strong evidence that the states were the appropriate ones by showing them the chemical bonds in each stage of the reaction.

Once they had identified the states that they were looking for, they studied the sample with synchrotron X-rays. "We expect this new methodology to be of use to many researchers in the field," says Bourgeois.

Filming certain proteins while reactions occur has been possible at the ESRF for some years. However, experiments were, until now, restricted to proteins that get excited by light and are in very resistant crystals. •

MC

Reference

Katona *et al*. 2007 Raman-assisted crystallography reveals end-on peroxide intermediates in a nonheme iron enzyme *Science* **316** 449—453.

SOME DISEASES SHOW MOLECULAR SIMILARITIES

Alzheimer's, Parkinson's, Creutzfeldt-Jakob and other degenerative diseases are more closely related at the molecular level than was realised, an international team, including ESRF scientists, has reported in *Nature*.

The brains of patients with degenerative diseases contain harmful rope-like structures known as amyloid fibrils, which are protein molecules linked by watertight "molecular zippers".

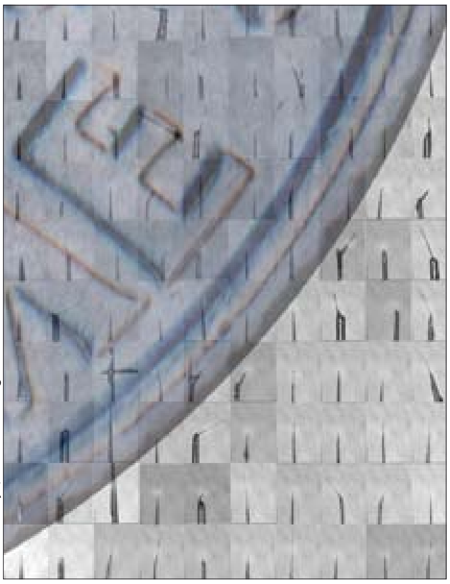
"We have shown that the fibrils have a common atomic-level structure," says David Eisenberg, a UCLA-DOE professor of chemistry and biology and a member of the research team. "All of these diseases are similar at the molecular level; all of them have a dry steric zipper. With each disease, a different protein transforms into amyloid fibrils, but the proteins are very similar at the atomic level."

The UCLA team (US), with scientists from the University of Copenhagen (Denmark) and the ESRF, carried out part of their research at the microfocus beamline at the ESRF, where they used a very small beam of X-rays to study microcrystals. "It has been a great international collaboration," Eisenberg says.

The research, while still preliminary, could help scientists to develop tools for diagnosing these diseases, and potentially for treating them through "structure-based drug design" he adds.

The researchers have reported 11 new three-dimensional structures of fibril-forming segments, including those for both of the main proteins that form amyloid fibrils in Alzheimer's disease.

"It's been a joy to see so many new structures," says team member Michael Sawaya. "We see many similarities, but some details are different. As we study more structures, we expect to determine the common features." He continues: "It is clear from the positions of the atoms where the zipper is. Like pieces in a jigsaw puzzle, they have to fit together just right. We are finding out how they fit together. We don't yet know all of the ways of forming the zippers; we are working to fill in the missing pieces and are hopeful of doing so."



Michael Sawaya, David Eisenberg/UCLA

Montage of 100 microcrystals. These are used to determine the X-ray structures of amyloid fibril cross-beta spines. Each of the small circles shows where the X-ray beam intersects the crystal. The superimposed image of a US dime provides a reference scale.

The research shows that very short segments of proteins are involved in forming amyloid fibrils; Eisenberg and his colleagues know some of the segments. This makes it easier to design tests to detect whether a new drug is effective, says Eisenberg. Several of the disease-related proteins contain more than one amyloid fibril-forming segment.

Eisenberg believes that the zipper is universal in amyloid fibrils and wants to know whether it is possible to pry open the zipper or even prevent its formation. The team can now produce fibrils and has developed a test to determine whether they break up, using a variety of chemical compounds. This strategy could be used to break up the fibrils.

A mystery on which the *Nature* paper sheds light is the cause of different strains of prion (infectious proteins) in which the protein sequence is identical. The team presents a strong hypothesis that the origin of prion strains is encoded in the molecule packing in the fibrils.

In an earlier *Nature* paper (9 June 2005), Eisenberg's team presented the three-dimensional structure of an amyloid-like protein from yeast that revealed the surprising molecular zipper. "In 2005 we were like prospectors who found flakes of gold in a stream," he says. "Now we see the real nuggets. Here we present atomic-level structures for crystals related to fibrils from proteins associated with numerous human diseases." •

MC

Reference

Sawaya *et al*. Atomic structures of amyloid cross-β spines reveal varied steric zippers *Nature Advanced Online* 29 April 2007.

Feature news

PILING UP COLUMNAR LIQUID CRYSTALS MAKES BETTER SOLAR CELLS

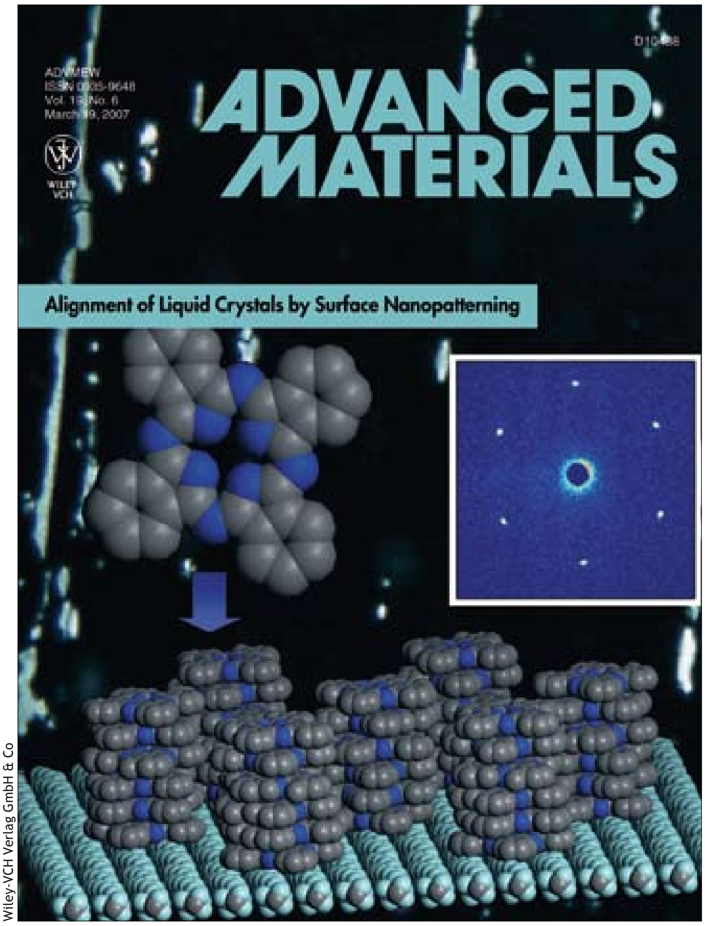
An international team of researchers has found a way to pile up columnar liquid crystals in an open film to make the columns orientate vertically. This represents a step forward in the search for better organic systems to manufacture solar cells on a large scale.

Today, solar cells are built from inorganic silicon, though it's expensive and thus not appropriate for mass-production. With the aim of making solar-cell technology more accessible for everyday life, scientists are studying organic columnar liquid crystals as a substitute for silicon. These would make solar cells more versatile and compatible with flexible layers.

It has been proved in the past that the preferential orientation of these liquid crystals with the columns perpendicular to the surface would make the solar cells more efficient. However, such an alignment depends on the substrate surface energy, the chemical structure of the molecules and the processing conditions, such as temperature and time.

Rubbing PTFE up the right way

With all of these factors taken into account, researchers from the CNRS Institute of Chemistry of Surfaces and Interfaces in Mulhouse (France), the Université Libre de Bruxelles (Belgium), the ESRF and the Chemnitz University of Technology (Germany) fabricated a nanopatterned surface by rubbing polytetrafluoroethylene (PTFE or Teflon). The rubbed layers of PTFE are found to promote the homeotropic alignment of the liquid-crystal columns, meaning that they are perpendicular to the substrate plane. The columns form a single crystal-like monodomain, which implies that the alignment of liquid crystals is uniquely defined by the rubbing direction. Thanks to the ESRF X-rays, the scientists were able to observe the structure and spontaneous alignment in thin films of these materials. They carried out X-ray diffraction measurements on the Collaborating Research Group beamline DUBBLE (Dutch-Belgian beamline).



Wiley-VCH Verlag GmbH & Co

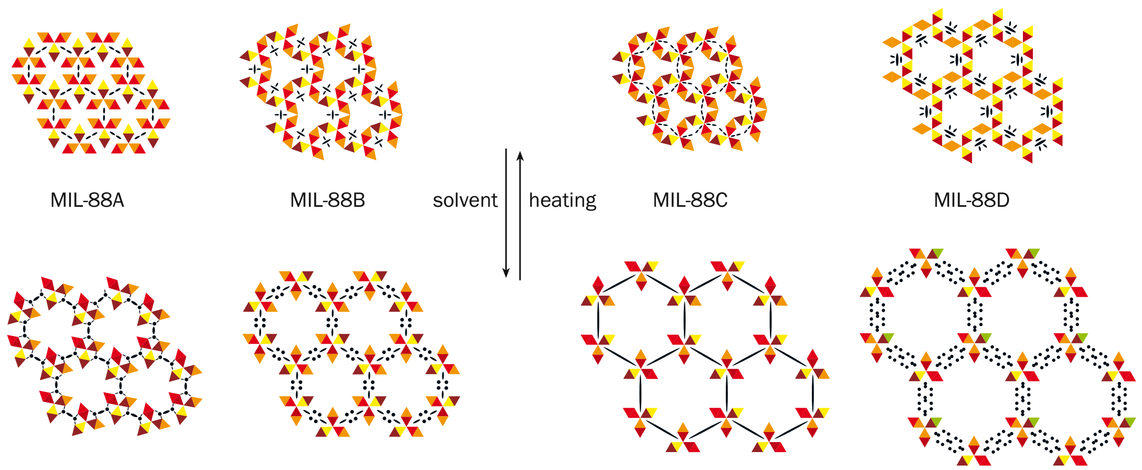
From the cover of *Advanced Materials*. A schematic representation of columns of liquid-crystal phthalocyanine molecules orientated vertically (homeotropically) on a PTFE-rubbed surface. A characteristic six-spot X-ray diffraction pattern confirms the homeotropic alignment of columns exhibiting a single-crystal-like domain. The background shows an optical micrograph obtained in polarized light, which appears black due to the columnar alignment.

Despite the visualisation of columnar liquid crystals, we are still far from using organic solar cells in everyday life. The advantages of this technology, apart from the cost, are the temperature of processing (~150 °C) and a broader choice of substrates than inorganic silicon. The main downside is the cells' lower efficiency in comparison with silicon. "However, the possibility of using the organic cells on flexible or irregular substrates compensates for the low efficiency," explains Dimitri Ivanov, leader of the research. •

MC

Reference

Gearba RI *et al.* 2007 Homeotropic alignment of columnar liquid crystals in open films by means of surface nanopatterning *Advanced Materials* **19** 815–820.



Breathtaking discovery. Structures (along the c axis) of the MIL-88A, B, C, D series in their dry (top) and open (bottom) forms.

SCIENTISTS UNCOVER UNPRECEDENTED 'BREATHING' BEHAVIOUR IN FLEXIBLE NANOPOROUS MATERIALS

Scientists all over the world are participating in the quest for new materials with properties suitable for the environmentally friendly and economically feasible separation, recovery and reuse of vapours and greenhouse gases. One team from France, the UK and the ESRF has recently discovered an unprecedented giant and reversible swelling of nanoporous materials with exceptional properties: huge flexibility and profound selectivity.

Porous hybrid solids are the new materials that could make the world more environmentally friendly. A team from Institut Lavoisier, University of Versailles (France), has developed metal-organic, 3D structures with cages and channels, known as MIL (material Institut Lavoisier). These compounds contain metal ions – in this case chromium and iron – with organic linkers, rendering them highly flexible and thus very malleable. They can open up or close down in response to external factors, such as pressure, temperature, light and the influence of gases and solvents.

The researchers, in collaboration with staff of the Collaborating Research Group Swiss-Norwegian beamline at the ESRF, have for the first time tracked a giant reversible increase in volume of these solids. This ranges from 85% of their size to an unprecedented 230%.

This reversible "breathing" is similar to the action of the human lungs: growing when inhaling; shrinking when exhaling. But lungs only expand by about 40%.

The huge swelling effect has been achieved in a simple way. MIL materials were immersed in solvents and their cavities were filled and thus opened by entering solvent molecules. This made the structures grow, without breaking bonds and thus retaining the crystallinity of the materials. This process was monitored at the ESRF using high-quality synchrotron radiation. The results were combined with computer chemistry simulations.

The swelling process can be reversed by heating the solvated form – the dry form is then recovered. In this form the material exhibited closed pores with almost no accessible porosity.

The same team published a paper last autumn where it showed that, surprisingly, some gas molecules can close (but not open) the pores on absorption. Moreover, the closed hydrated form demonstrates a remarkable selectivity in absorption of polar and non-polar gases.

The next step for the team is to investigate how hydrogen or greenhouse gases can be stored in these kinds of material. This may open a door in the near future to ecological applications such as hydrogen-fuelled cars or the capture of carbon dioxide. ●

MC

References

C Serre *et al.* 2007 Role of solvent–host interactions that lead to a very large swelling of hybrid frameworks *Science* **315** 1828–1831.

P L Llewellyn *et al.* 2006 How hydraton drastically improves adsorption selectivity for CO_2 over CH_4 in the flexible chromium terephthalate MIL-53 *Angewandte Chemie International* **45** 7751–7754.

SHAPING THE FUTURE OF THE ESRF

ESRF UPGRADE MEETING

Presentation of the Upgrade Programme to the scientific community

JOIN THE DISCUSSION IN GRENOBLE

24 OCTOBER 2007

http://www.esrf.eu/events/conferences/UpgradeMeeting


ASSA

The times they are a changin'. An artist's impression of a section of the proposed upgraded Experimental Hall. Longer beamlines could take advantage of the ESRF's fine X-ray source properties and scientific centres could be built around beamline villages.

MOVING FORWARD: NEW SCIENTIFIC OPPORTUNITIES AT THE ESRF AS UPGRADE PROGRAMME GETS GOING

The new upgrade programme that is in preparation at the ESRF will demonstrate what novel science could be done at the facility if the Council gives the green light to the project at the end of this year. If given the go-ahead, the programme could start in 2008. It is predicted that it would take a decade to complete.

After more than 10 years of continuously supplying synchrotron light of outstanding quality to the many thousands of ESRF users, the time has come to envisage a "step function" in the improvement of the accelerator and source facilities, the beamlines and the infrastructure of Europe's most powerful light source. Indeed, since 12 countries decided 20 years ago to create the first third-generation synchrotron radiation facility, the landscape of science and technology for generating and using synchrotron light has evolved significantly.

What were once unprecedented challenges have now become routine; developments in the field of protein crystallography are a good example. New scientific disciplines, such as art, archaeology and palaeontology, have recently discovered the virtues of ultrabright X-ray beams in the non-destructive study of paintings and other precious historical objects. As to methodological evolutions, computed tomography using phase contrast, for example, has developed to a mature state with many crucial applications in materials science and other fields.

WHAT THE PROGRAMME SAYS

The ESRF's current upgrade programme defines an ambitious renewal programme that aims to ensure the facility's leading scientific position over the next 10 to 20 years.

The programme involves the enhancement of its beamlines and the extension of about one-third of the Experimental Hall, so that beamlines can be extended for distances of up to 140 m – and new beamlines built – for nanofocusing applications.

The accelerator complex will also be improved to maintain the very high brilliance and reliability of the ESRF's X-ray source, and in parallel a longer-term design for a new higher-brightness lattice will also be prepared.

Instrumentation being critical to the success of the ESRF, the programme will include significant advances to underpin the beamline and source improvements, which are likely to be used in partnership with synchrotron labs across Europe.

Finally, since science benefits from collaborations among researchers, the programme will promote the development of productive science-driven partnerships with both academia and industry.

Already accustomed to today's state-of-the-art beamline instrumentation, ESRF users want to push the limits of their investigations even further, with better resolution in time, energy, space and angle; higher elemental sensitivity; and the availability of extreme environmental conditions, such as pressure, temperature and magnetic field.

Moreover, results should be obtained within a shorter data-collection time because the available beamtime isn't sufficient to satisfy all users' demands. Even with the new synchrotron facilities coming into operation, a decrease in the number of experiment proposals isn't expected. In addition to the current oversubscription of beamlines by a factor of two, there's a latent demand by potential users who are discouraged by the limited likelihood of being able to obtain beamtime.

New synchrotron sources

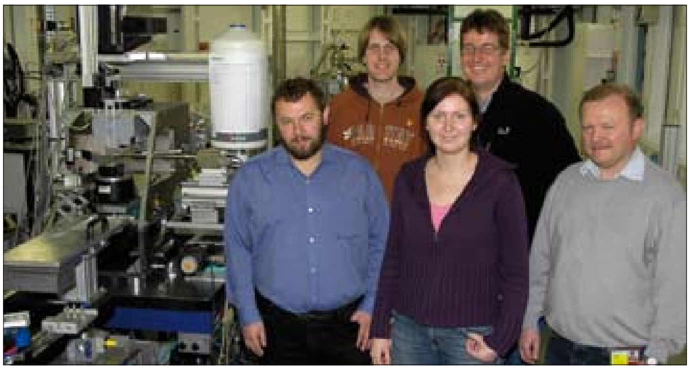
Today the ESRF has to face some serious competition from new national storage ring sources in Europe (BESSYII, ELETTRA, SLS, DIAMOND, SOLEIL, HASYLAB). For the higher-energy X-ray range, only PETRA III will be directly competitive. In addition, fourth-generation sources, such as the X-FEL, have to be considered.

For all of these reasons (new sources, improved techniques and new user communities) the role of the ESRF as the principal European light source needs to be reconsidered. The ESRF's long-term goal is to give the best possible service to European science, including industrial applications, while paying particular attention to countries that do not have the benefit of their own national light sources.

The ESRF can make an important contribution to the development of the European Research Area. This can be done directly through synchrotron radiation science and also by integrating a well structured, organized and harmonized network of accelerator-based light sources. However, we must also retain a global vision of our synchrotron light community that will assure the political influence needed to obtain adequate funding and attract a sufficient young researchers, without whom we would not be able to survive. ●

ANDREAS K FREUND

● For more information, see http://www.esrf.eu/AboutUs/Upgrade. The next issue of the *ESRF Newsletter* will describe the programme in greater detail.



Number 13: lucky for some. The first team on the new ID13. Front, left to right: Manfred Burghammer (ESRF), Silvia Schmitz, Andreas Schwab. Back: Jan Feldkamp, Christian Schroer.

In ID11's hutch. Sitting, left to right: Céline Besnard, Irene Margiolaki (ESRF), Sebastian Basso, Jonathan Wright (ESRF), Marc Schiltz. Standing: Carsten Gundlach (ESRF), Gavin Vaughan (ESRF).

NEW BEAMLINES ALLOW WORK AT THE NANOSCALE

Two experimental stations at the ESRF have been extended, with the aim of enabling research at the nanoscale to be carried out. The first beneficiaries arrived in March and were pleasantly surprised by what they found.

When the users greet you with smiles after several days of experimenting, you can guess that they are going back home with lots of useful data. The fact that these are the first users of the refurbished beamline may also have something to do with their mood. Since March the two ESRF extended beamlines are up and running and users seem happy.

Thanks to the dedication of the technical and scientific staff, the extension of the materials science beamline ID11, led by Gavin Vaughan, and the microfocus beamline ID13, led by Christian Riekel, has already benefited the first users. After six months of construction, the two beamlines have doubled their length. Samples are now located about 100 m from the source and experiments using a sub-100 nm beam have already been performed.

The first team using the extended ID11 is a group from the École Polytechnique Fédérale de Lausanne, Switzerland, led by Marc Schiltz. As part of a long-term project with the ESRF, these researchers were focusing on the analysis of proteins with many crystals. "It is often very difficult to grow a large single crystal for X-ray analysis, so our approach is to find a method to analyse many thousands of submicron crystals," explains Schiltz.

The team has already carried out experiments on ID31, which Schiltz defines as complementary to ID11. The first one has a very high instrumental resolution, while the new ID11 uses an area detector, provides a stronger intensity and still has a good angular resolution because the detector can be set far from the sample.

"We develop refractive X-ray lenses and a set-up to diminish the beam size," explains Christian Schroer, leader of the team from the Technische Universität Dresden in Germany. The aim is eventually to integrate the lenses on the beamlines permanently, as part of a long-term project with the ESRF's ID13 beamline. "For the moment we have reached 80 nm in size, which is not bad at all," says Schroer.

Meteorites and heavy metal

Apart from their quest for nanobeams, the Dresden team carried out fluorescence imaging experiments on two samples: part of a meteorite with Frank Brenker's group from Frankfurt University, Germany, and portions of the plant *Arabidopsis thaliana* in collaboration with Walter Schröder from the Research Center Jülich, Germany. It made element maps of micrometre-sized regions of both, searching for small pieces of presolar material in the former and heavy metal accumulations in the latter.

"This plant accumulates heavy metals in a very heterogeneous way, so we do need a very small and stable beam, such as the one on ID13," explains Schroer.

It's early days for ID11 and ID13, and the feedback from the first teams is crucial. The smiles on their faces prove their satisfaction with their experiments. Schiltz asserts: "The data look very promising." •

MC

Interview

ED MITCHELL: THE SCIENTIST AND THE MANAGER ROLLED INTO ONE

Back in 1995, Ed Mitchell had just finished his PhD. Two job offers popped up immediately: working for one of the world's leading financial management and advisory companies, and a postdoctoral researcher contract at the ESRF. His career would take the path of either management or science – two disciplines that are considered by many to be poles apart. He chose the latter, but his attraction to the former didn't vanish.

Today he continues to work as a scientist at the ESRF, but he also leads the group that, since September last year, has been putting together the facility's ambitious upgrade programme.

Take your pick: management or science?

Both equally. I wouldn't like to give up doing science for a management role, but I also enjoy the latter. A combination of both is a perfect balance in my working life.

At the moment my time is spent 80% on coordination of the upgrade programme and the rest taken up by science. Despite it being only 20% at the moment, I am fortunate to co-supervise three PhD students and this is like an occasional fresh mint against the bureaucracy and paperwork of the programme.

What is the value of the upgrade group?

I believe it's one of the first transversal project groups at the ESRF. We have accelerator and source and experiments division staff working together, in close collaboration with technical services, administration and computing. You learn not only from each other's work but also from everyone's ideas and various different points of view.

What is the point of the upgrade programme?

Some may think that we should not disturb the status quo – that we already have the best. However, there are a lot of light sources coming on stream and we have to maintain our leading position in synchrotron research.

This is therefore a great opportunity to specialize and explore niche markets where the ESRF can really excel, because we have superb in-house knowledge and capabilities, and we're one of the few high-energy sources.

The ESRF is in a unique position to provide leadership over a huge range of areas because we have 15 years of experience. On top of that, we can get together with other synchrotrons to share our experience – and, of course, vice versa.

If we help other synchrotrons to grow, won't they then take away our users?

I hope they do, because this will give us an opportunity. At the moment we do standard work in certain fields – such as protein crystallography – that can be done perfectly well at

Split personality. Ed Mitchell may be one of the ESRF's busiest people, as both scientist and coordinator of the upgrade.

the new synchrotrons. If the users go to their national facilities to do their "standard" experiments then this will open a window for us to focus

"This is a great opportunity to specialise, explore niche markets where the ESRF can excel, because we have superb in-house knowledge and capabilities, and we're one of the few high-energy sources."

on unique and specialized work, even taking on some risky future initiatives that may only be possible to do on a European scale.

What will the upgrade programme consist of?

New, better beamlines, updates to our X-ray source, leaps forward in technology to enable the science… everything. But, in making these developments, we don't want to close down the ESRF for long periods of time, because our users rely on continuous operation and access. There will, though, be one or more shutdowns of some months during the main building works for the extended experimental hall.

What if the users don't come back after the longer shutdowns?

The upgrade programme is not part of the natural evolution of the facility. Instead of increasing the performance progressively, we will go for a big step up, so the improvement will be considerable.

I don't think users will abandon us, but they need to be informed of what changes we are going to undertake so that they can also consider new opportunities for experiments and exciting science.

The Institut Laue-Langevin – the neutron source facility – underwent a long shutdown for a refurbishment programme two years ago and it didn't lose its users.

What are the different stages in the upgrade programme?

The programme will be implemented over the next 10 years. To begin with we had to get the ideas down. This resulted in the *Purple Book*. Everyone at the ESRF was involved: we got great support from the writers who worked hard to prepare material.

In June the book has to be given to the Council members. The Science Advisory Committee that advises the Council has already seen it. In the autumn we will talk to the users to get more feedback on the project. And finally, by the end of the year, I expect to see a concrete response from the Council.

What is your bet on what the verdict will be?

They'll be positive about it. The Council of the ESRF has been going to the member countries explaining what the programme is about and, so far, the feedback has been really good. Besides, the European Commission acknowledged the ESRF upgrade as an important project for European research in the ESFRI roadmap.

We can't be sure, though. We will have to wait until the end of the year. What I am convinced of is that we do have a great programme for innovative science. •

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THE MAN WHO THINKS THAT DEADLINES AND PRESSURE ARE FUN

Ed Mitchell has the look of a businessman. He always carries his mobile phone, a tiny diary filled with appointments and a notebook. He tends to speak quickly, making use of every second at his disposal.

Perhaps it's no surprise, then, that he confesses to being turned on by deadlines, short timescales and pressure. "It's fun," he insists. "Although you can only take it for a year or so, then a holiday is needed."

The beginning of the project that he is currently coordinating, the ESRF upgrade programme, demands strict adherence to deadlines. The production of the *Purple Book* put his and the writers' capacity to cope under pressure to the test, but deadlines are being met with the goodwill and dedication of the ESRF staff.

The pressure, coupled with the fact that this is a brand-new venture, has made this job the ideal position for Mitchell. He finds starting up projects very fulfilling. He built two macromolecular crystallography beamlines with the MX team, and more recently he managed the start-up, with numerous collaborators, of the Partnership for Structural Biology. Once the partnership had become a reality and the staff were settled into their new labs, he was keen to move on to new endeavours… and more deadlines.

Scientific highlights

SOFT CONDENSED MATTER GROUP

Development of optical tweezers for sample fixing in microdiffraction experiments

H Amenitsch,[1] **E Ferrari,**[2] **M Rappolt,**[1] **B Sartori,**[1] **P Laggner,**[1] **V Garbin,**[2] **E Di Fabrizio,**[2] **M Burghammer,**[3] **C Riekel,**[3] **D Cojoc.**[2] 1 IBN, Austrian Academy of Sciences, Austria; 2 CNR-INFM, National Lab TASC, Italy; 3 ESRF, Microfocus Beamline – ID13, France.

Since the demonstration of optical trapping with dual beams and of single-beam gradient force optical traps by Ashkin *et al.* (1986), optical tweezers have pioneered the field of laser-based optical manipulations. The applications range from the manipulation of single atoms, through the investigation of mesoscopic or colloidal systems, to the manipulation of living cells.

To manipulate, characterize and measure the diffraction pattern of individual objects down to single phospholipid liposomes, an optical tweezers set-up combined with an imaging microscope has been developed. This has been commissioned at the ESRF's ID13 microfocus beamline, and the trapping of about 50 multilamellar palmitoyl-oleyl-phosphatidylethanolamine liposome clusters of about 10 μm diameter was demonstrated in a liquid-filled capillary (Amenitsch *et al.* 2007, Cojoc *et al.* 2006, Cojoc *et al.* submitted).

Furthermore, a scanning diffraction experiment with a 1 micrometer monochromatic beam at about 13 keV was performed to demonstrate the fixing capabilities and to confirm the size of the liposome cluster by X-ray diffraction.

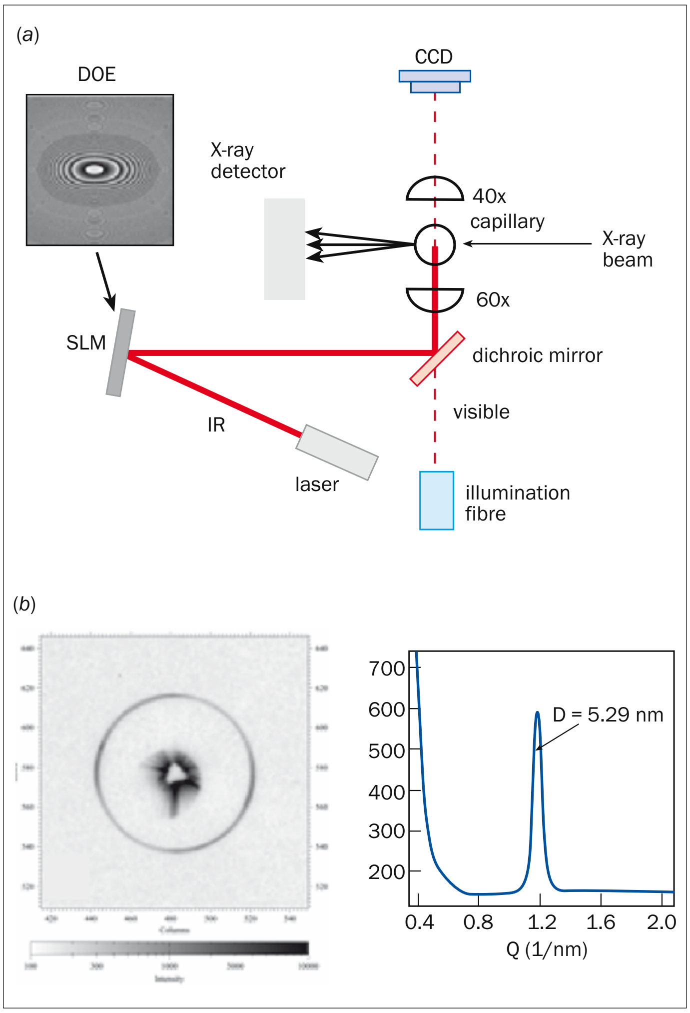

Figure 1. A. Optical set-up for trapping the liposomes in the microbeam. The inlet is a diffractive optical element (DOE) displayed on the spatial light modulator (SLM). B. Diffraction pattern (left) and azimuthally integrated intensity (right) of the trapped liposome cluster.

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D Cojoc *et al.* (submitted).

OPTICS GROUP

Detection of lattice distortions in diamond crystals on the 10^{-8} level

J Härtwig,[1] P Van Vaerenbergh,[1] F Masiello,[1] A Rommeveaux,[1] A Chumakov,[1] G Carbone,[1] S H Connell,[2] M Rebak,[2] D Dube,[2,3] R Setshedi,[2,4] S Ballestrero,[2] R Burns,[5] J O Hansen.[5] 1 ESRF, France; 2 University of the Witwatersrand, South Africa; 3 University of Johannesburg, South Africa; 4 Cape Peninsula University of Technology, South Africa; 5 Element Six Technologies, South Africa.

Figure 1. Comparison of three topographs taken with different set-ups from a highly pure Type IIa, 100-oriented diamond (5×5 mm^2). The lower left part was not polished to the end so it shows several scratches. The rest is nearly defect-free, showing mainly three isolated single dislocations. The left image is a white beam topograph in Laue (transmission) geometry with an estimated detection limit of slightly better than 10^{-6}. The other two are double crystal topographs, with all crystals in Bragg (reflection) geometry. The middle one was taken at 12 keV with the 444-reflection of the silicon monochromator (Darwin width 1.00 arcsec) and the 115-reflection of the diamond sample (Darwin width 1.02 arcsec). The theoretical detection limit is about 4×10^{-8}. The right one was taken at 20 keV, with the 800-reflection of the silicon monochromator (Darwin width 0.31 arcsec) and the 800-reflection of the diamond sample (Darwin width 0.25 arcsec). The theoretical detection limit is about 1.2×10^{-8}.

Bragg diffracting X-ray optical elements that conserve coherence should have a high degree of bulk and surface perfection. Concerning the bulk defect properties, this means that in larger crystal regions no dislocations, microdefects, inclusions or precipitates should be present and the relative lattice parameter changes should be in the order of about 10^{-8}.

There are only a few methods that can measure strain inhomogeneities in near-perfect crystals with the necessary strain sensitivity. Sophisticated double-crystal diffraction topography methods like plane wave topography can be used. At ID19 an instrument exists that allows measurements to be made in various configurations with increasing strain sensitivity. A non-dispersive double crystal (n,-m) set-up is realised by using a bendable silicon monochromator combined with high-order reflections (Altin *et al.* 2002). In this way, rocking curves (the autocorrelation function of sample and monochromator reflectivity curves) with steep flanks can be obtained, resulting in a very high strain sensitivity when working on the steepest part of the flanks.

In a recent experiment we pushed the detection level of about 10^{-7} (a more "classical" case) down to about 10^{-8}. This was done using diamond plates of one of the most recent growth experiments. The sample presented here was not polished to the end on one surface in the left lower part. In this way, surface scratches remained and they are clearly visible in the X-ray topographs. In the remaining part you can recognise the images of three single dislocations (right upper part).

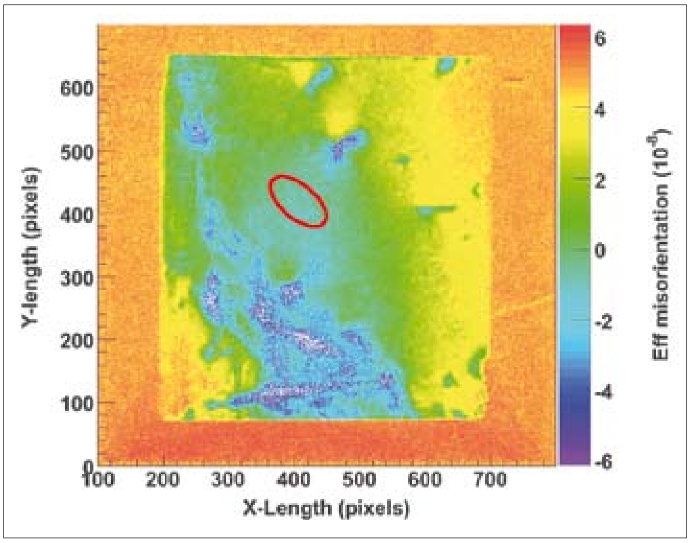

Figure 2. Quantitative strain (effective misorientation) map taken from the right topograph in figure 1, showing regions (e.g. in red ellipse) with local strain close to 3×10^{-8}.

Figure 1 shows the strain sensitivity in three different experimental set-ups. The visibility of the defects and, in particular, the extension of the related long-range strain fields that create the defect images are different. Crystal parts that appear to be homogenous in the first two topographs start to look inhomogeneous due to the very high strain sensitivity in the right topograph, which is recorded with a set-up that has a theoretical detection limit of about 1.2×10^{-8}. An advantage of this double-crystal apparatus is the possibility (in certain conditions) of quantitative strain (effective misorientation) determinations from topographs (Bowen and Tanner 1998; Lerche *et al.* 1991). Figure 2 shows one such result.

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HIGH-RESOLUTION AND RESONANCE SCATTERING GROUP

Hyperfine interaction of α-Fe in an external magnetic field

C Strohm, P van der Linden, R Rüffer, ESRF.

A newly developed in-house high-duty cycle minicoil (repetition rate 6–8 cycles per min) has been operated for more than 20 000 pulses above 20 T without failure.

The magnetic pulse had a shape of a half sinus with 0.55 ms duration. The sample, a 10 µm thick iron foil enriched in ^{57}Fe, was mounted in a non-magnetic flow cryostat (10 K – RT). Data were taken at 120 K. Time-resolved measurements (NFS) at ID18 with fast detectors (APD) and 0.8 ns binning allowed the development of the magnetisation curve in the iron foil during the cycle of the pulsed magnetic field to be followed.

A clear change in the NFS spectra indicates the development of the expected collapse of the hyperfine field with respect to the external magnetic field (the internal field is antiparallel to an external field).

This experiment demonstrates the feasibility of carrying out measurements of NFS under applied pulsed magnetic fields.

TECHNICAL BEAMLINE SUPPORT (SURFACE SCIENCE LABORATORY)

Optomechanical interaction in the X-ray regime

O Dhez,[1] M Rodrigues,[1] A Siria,[2,3] W Schwartz,[2] S LeDenmat,[1] G Torricelli,[4] O Bikondoa,[1] TH Metzger,[1] J Chevrier,[2,5] F Comin.[2] 1 ESRF; 2 Institute Louis Néel CNRS, France; 3 CEA-LETI, France; 4 Leicester University, UK; 5 University Joseph Fourier, France.

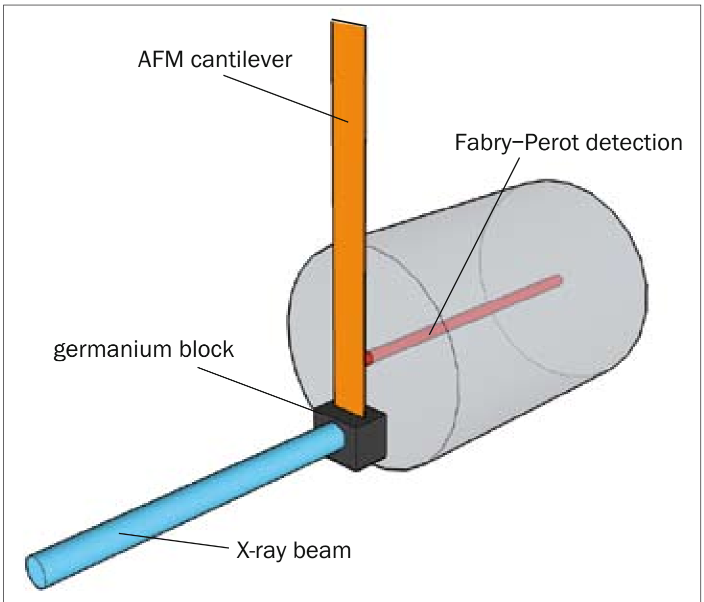


Figure 1. Schematic of the experimental set-up.

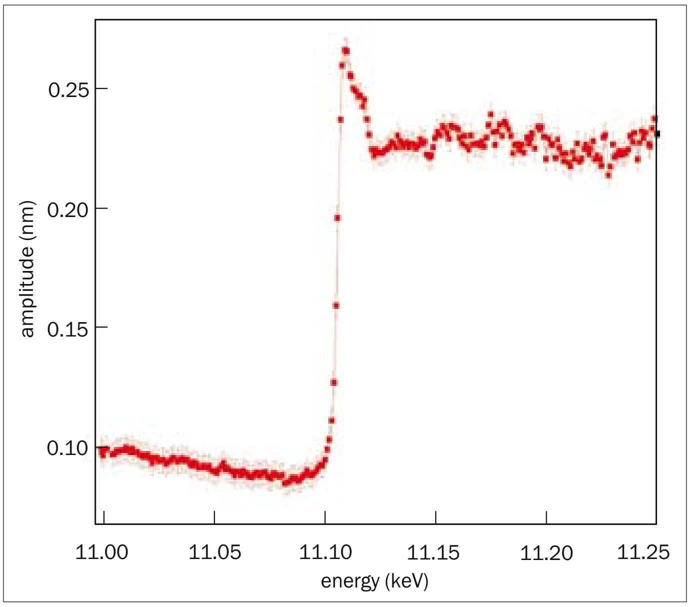


Figure 2. Cantilever oscillation amplitude versus photon energy.

The mechanical interaction between a tiny germanium block glued to the extremity of an AFM cantilever and an X-ray beam has been studied by measuring the displacement of the cantilever via a Fabry—Perot interferometer coupled to its back. The experimental arrangement is shown on figure 1.

The X-ray beam is chopped at the natural frequency of the cantilever-germanium system (2—3 kHz following the type of cantilever) and the Fabry—Perot output is measured via a lock-in amplifier.

The aim of the experiment is to couple the microcantilever to the X-ray beam mechanically through a well identified electronic transition: the germanium K-edge threshold. The energy of the impinging beam is then swept through the 1 s absorption edge at 11100 eV while the amplitude of the cantilever oscillation is recorder by the interpherometer.

As shown in figure 2, the oscillation amplitude reproduces the EXAFS features well. The error bar is of 5 pm (picometres) over a "mechanical edge jump" of about 200 pm. In this first experiment the excitation is due to mechanoelastic coupling to the X-ray beam.

Future experiments should be able to disentangle these effects from those due purely to radiation pressure. ●

MACROMOLECULAR CRYSTALLOGRAPHY GROUP

The structure of Wza reveals a new class of membrane protein

C J Dong,[1] K Beis,[1] B R Clarke,[2] A Brunkan,[2] C Whitfield,[2] J H Naismith.[1] 1 University of St Andrews, UK; 2 University of Guelph, Canada.

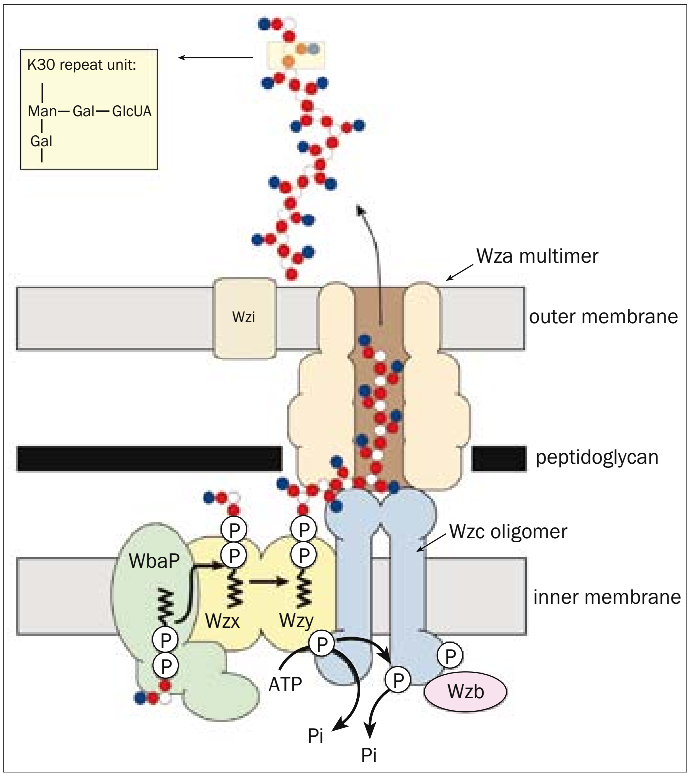


Figure 1. Schematic representation of Wza in the cellular

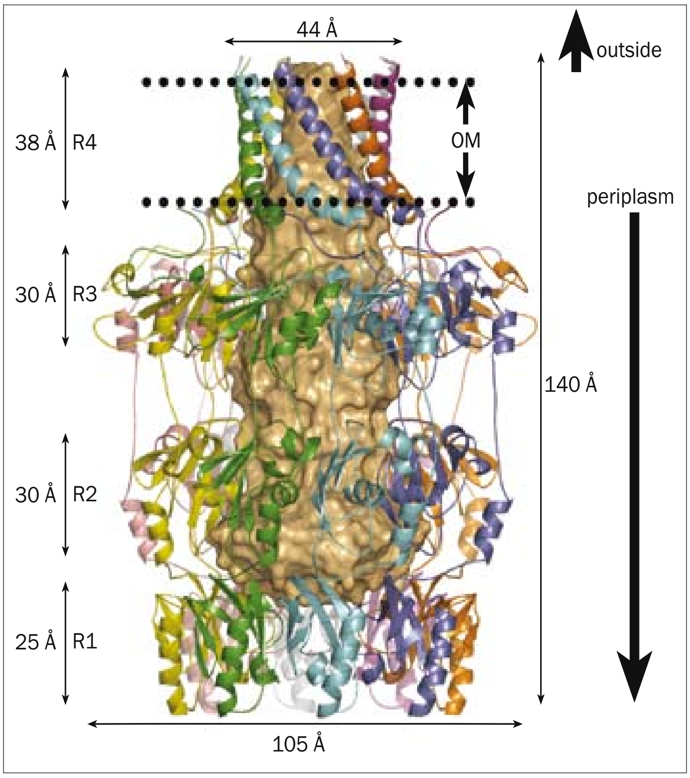


Figure 2. The structure of Wza elucidated from single crystals

Wza, the first membrane lipoprotein that has been shown to traverse the outer membrane, is a carbohydrate exporter that is part of a much larger molecular machine. The crystal structure of Wza, which was finally solved after six years' effort and numerous data collection trips to the ESRF, shows the protein to comprise four domains and that the transmembrane domain folds as a helical barrel.

This is a novel membrane-spanning motif for bacteria and the structure solution raises the possibility that other proteins that have been assigned as lipoproteins may, in fact, also be transmembrane proteins.

Wza's structure rewards the long years and beam time spent on it (Dong *et al*. 2006). The protein has four domains arranged round a central eight-fold rotational axis and its shape is like that of an amphora (figure 1).

Analysis of the amino acid sequence of Wza had failed to identify any transmembrane regions. However, examination of the protein surface reveals that the helical barrel (domain R4, figure 1) is hydrophobic, indicating that this is the membrane-spanning region.

The size of the hole through the helical barrel is consistent with its role in carbohydrate export. The protein is closed in the periplasm by the PES (polysaccharide export sequence) domain, the defining sequence feature of this protein family. The other two domains are gene duplications and share structural similarity to ubiquitin. It is proposed that the protein binds Wzc (figure 2), which opens the PES domain and thus allows carbohydrate export.

Reference

G J Dong, K Beis, B R Clarke, A Bunkan, C Whitfield, J H Naismith 2006 *Nature* **444** 226–230.

Loving nature. James Badro exploring part of the North Californian coast.

"The link between the properties of materials at the atomic scale inside the Earth and phenomena at a scale of thousands of kilometres is fascinating."

JAMES BADRO: A GEOPHYSICIST WITH A PASSION FOR STUDYING THE GROUND BENEATH OUR FEET

James Badro loves volcanoes and mountains, despite living in the centre of Paris. This 35 year-old French-Lebanese geophysicist tries to find out what our planet is made of, how it behaves and what happens 650 km beneath our feet. When he talks about his job, his enthusiasm transmits more than a description of what he does; it's proof of how intensely he enjoys it.

His study on spin transitions and how they can affect the swirling movements in the Earth's mantle, and influence the dynamics of the planet, featured on the cover of *Science* in 2003. In another paper a year later he awoke an interest in the geophysics community. He acknowledges that it is probably his most valuable contribution to the field so far. The work that he carried out on ESRF's ID16 was essential for his discovery.

How did the *Science* paper alter your career?

When I published the paper with my colleagues I had already been working on the subject for many years. Spin transitions in terrestrial materials were theorised in the 1950s and 1960s, but it was impossible to study them in the extreme conditions of pressure relevant to planetary interiors. I started measuring spin transitions in the diamond anvil cell early in my career. Little by little the technique improved, but it was not a very popular field of research. When the *Science* papers appeared I got some calls from scientists who wanted to collaborate with our team. The papers influenced the community a lot and, at the moment, I think there's too much attention to this subject. My close colleague Guillaume Fiquet and I say that we have created a monster.

How has synchrotron light contributed to your research?

Put simply, I have scientific questions and the ESRF has one of the most powerful, if not the best, tools with which to answer them. The synchrotron is useful in two areas: the work on elastic properties and that on electronic properties of the materials inside the Earth.

The main source of information on the deep Earth comes from the propagation of seismic waves. When there is an earthquake, the waves travel through the Earth and we can understand the properties of the material that the waves have gone through. Ultimately, we know to a certain degree of accuracy the elastic properties of the planet from the study of seismic waves. We study the elasticity of various minerals at the synchrotron. Comparing our elasticity data with that of the

SCIENCE IN EUROPE COMPARED WITH THE US

James Badro has been a researcher at the Centre National de la Recherche Scientifique at the University of Paris since 1999 and he is currently a visiting scientist at Lawrence Livermore National Laboratory in the US, so he is very well placed to make a comparison of science on both sides of the Atlantic.

"I don't think science in France, and to a lesser extent in Europe, is doing well in universities, so a lot of our best scientists are leaving, mostly to the US," he says. "We even see French scientists going elsewhere in Europe!"

Badro believes that French science doesn't function well because of the system. "In the US, a researcher has an idea, applies for money and can obtain real means to carry out the research in a very short period of time. In France it takes ages and you have to fight the system," he explains.

"But the real danger is that it is becoming very hard for us to hire the best researchers, to attract the best foreign scientists, because our system is rigid, unadapted to our globalized world, and uncompetitive."

However, he believes that European institutes such as the ESRF and CERN are actually doing very well, and that the proof is that many Americans come over and use these facilities for their research. "They are examples of what research institutes in Europe should be like."

Earth obtained from seismic waves, we can produce mineralogical and compositional models of the Earth.

The other approach is the study of electronic properties. If you look at the materials in deep Earth in their simplest expression, they're boring. Add iron and they become complex, fascinating minerals because of iron's electronic properties. That's why we study electronic spin transitions in iron, because this can have huge effects on chemical equilibria, heat transport, convection and electrical conductivity.

How often do you come to do experiments?

I used to be at the ESRF so often that even some members of staff thought I was permanently working here. I spend a lot of time in the synchrotron and have carried out experiments on ID28, ID16, ID27, ID24, ID09b and ID18F. I miss it from time to time when I am not here, but when I am, after four days sitting on the beamline day and night, I just want to leave. I love it because that's where real science is done, and I hate it because I need two weeks to recover afterwards. At the moment I am coming to the ESRF less than I used to. I spend more hours in my lab at the University of Paris or at Lawrence Livermore in the US, where I'm a visiting scientist.

Is it a job or a passion?

This is the kind of job that you do with passion; otherwise you may as well give up. I find the link between phenomena at the scale of ten thousands of kilometres, like the opening of an ocean or the formation of the Himalayas, and material properties at the atomic level fascinating, with the aim of answering how our planet works.

Where did your passion come from?

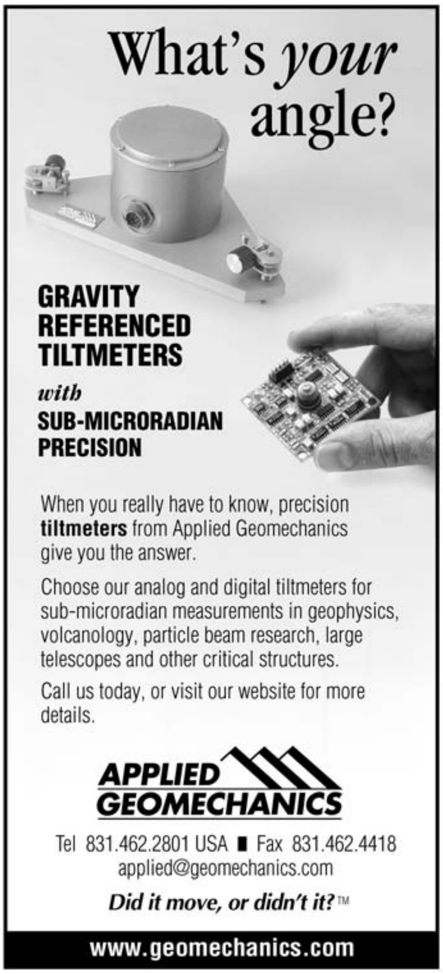
I had a revelation when I was 21. I was studying physics. At university, though, most of the course didn't thrill me, except for thermodynamics. Then I did an optional class called "geoscience for physicists" and that captivated me. It was real physics applied to a real object, keeping you "down to Earth", so to say.

What are your plans for the future?

Regarding my research, the bulk of our "business" is still the elasticity and chemistry of Earth materials. But I am getting more and more involved in petrology and geochemistry, studying the initial stages of formation of the core – basically the first 100 million years of the planet. In these early times, the metallic core was forming and separating from the rocky Earth. My team, in collaboration with Lawrence Livermore, tries to reproduce the conditions that prevailed, to understand how it happened, although we don't use synchrotron radiation as much now.

In terms of where my professional life takes place, I am at a breakpoint in my life. If I stay in France, I have to take my accreditation to become a professor. Otherwise, I might consider answering one of the offers I have from abroad. The options are open, but what I am sure of is that I don't want to give up research. •

MC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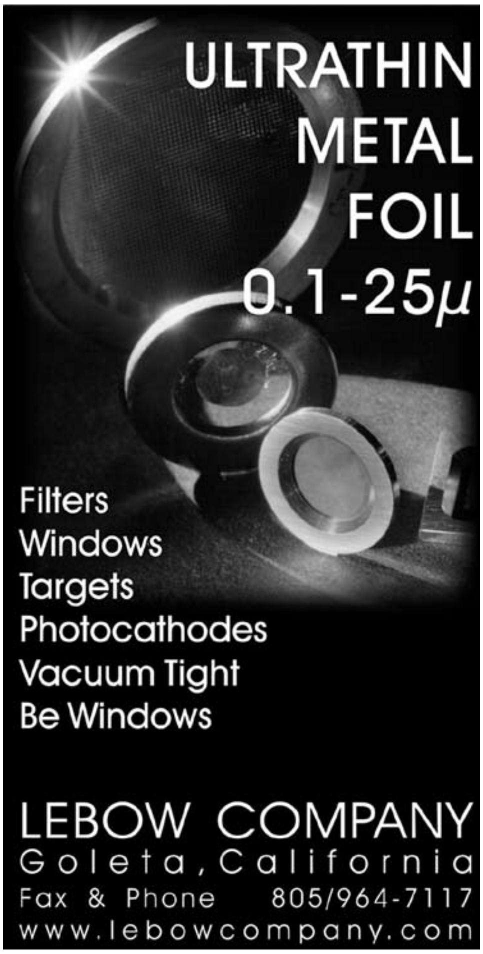
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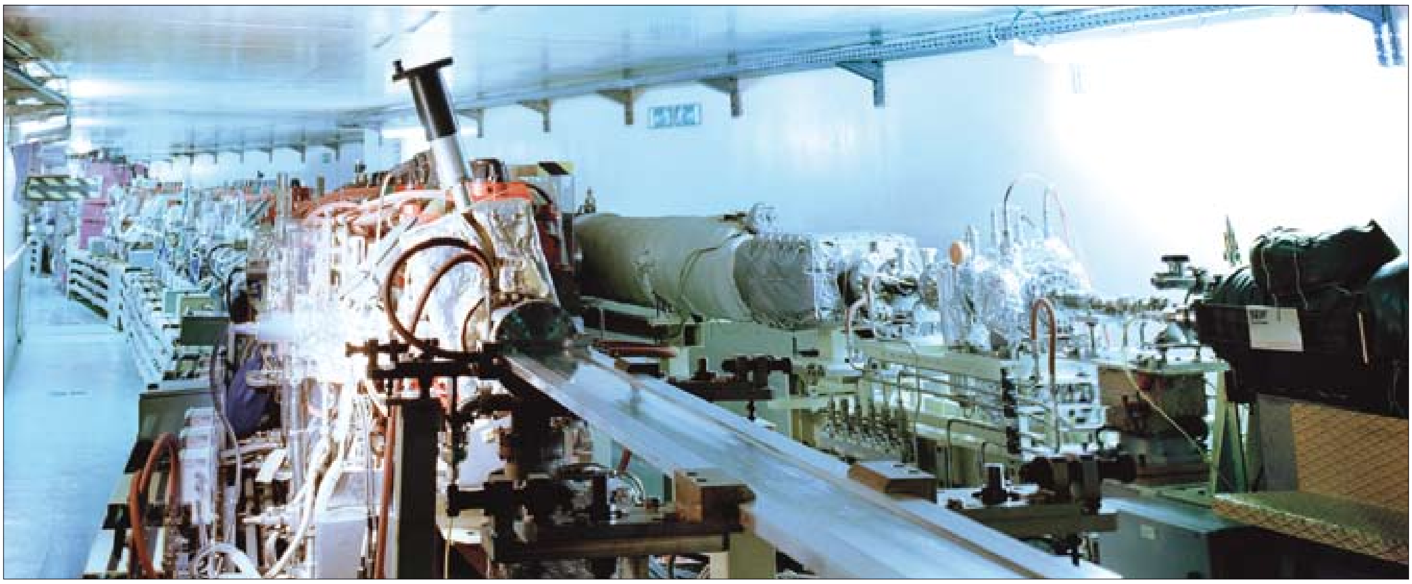
The machine



Peter Ginter

Performing machine. The storage ring, which has been repeatedly modified over the last two decades to increase its capacity.

ESRF STORAGE RING HEADS TOWARDS 300 mA GOAL

The level of current stored is absolutely key to the performance of the ESRF's storage ring. It has been a long, hard climb to get this current up first to 100 mA, then 200 mA, but these milestones were reached and now work is under way to hit the next one – 300 mA.

Both the flux and the brilliance from undulators in a synchrotron light source are proportional to the storage ring current. It is therefore desirable to maximize this current. In most synchrotron sources the limitation on the maximum current originates from the power load on the photon absorbers and beam instabilities induced by the interaction of the beam with the radio frequency (RF) cavities.

At the ESRF the question of the induced beam instabilities has been central and a constant fight for many years. As it takes time and specialized know-how to develop new cavities, few laboratories develop their own cavities and a few well tested designs are reused by many facilities.

The cavities selected in 1988 in the ESRF red book, to equip the storage ring and the booster, consist of assemblies with five coupled cells. Their fundamental resonance at a frequency close to 352.2 MHz is optimized to accelerate the circulating electrons. These cavities were developed at CERN for the Large Electron Positron collider, together with the associated high-power transmitters. The benefits recognized at the time were availability and compactness, and the adaptation to the ESRF required only small modifications.

The drawbacks were known: the limitation of the maximum stored current due to the coupled bunch instabilities (CBI). These result from the interaction of the beam with the electromagnetic fields of the higher-order resonating Modes (HOM) of the RF cavities.

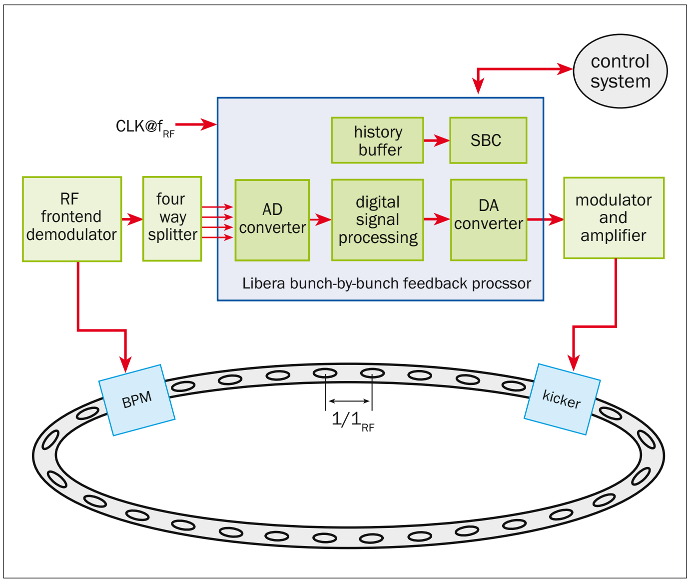
Much work has taken place since the commissioning in 1992 and will continue to overcome these instabilities and achieve stable beam with low emittance and low energy spread at the highest current. We will summarize below the main milestones of the current ramping.

The first milestone

The red book promised a 100 mA current while the lowest CBI thresholds were predicted at around 40 mA. At the time of construction, several methods to avoid CBIs were identified, such as a precise stabilization of the cavity body temperatures, which makes possible the systematic shifting of the resonating frequencies of the most perturbing HOMs away from the natural beam oscillation frequencies.

During commissioning in 1992, another stabilizing effect was established by filling a portion of the ring circumference, leaving a gap without bunches. Both methods were applied and it was found that more than 100 mA could be stored stably in 1/3 filling mode.

An upgrade to the RF system was launched in 1995



What makes 300 mA possible. The fast digital bunch-by-bunch feedback system developed for the damping of coupled bunch beam instabilities. The position of each of the 992 bunches circulating in the storage ring is monitored bunch by bunch and turn by turn in the ring by means of a beam position monitor pick-up. The signal is demodulated at a harmonic of the RF and filtered in real time in a field programmable gate array. The analogue output is amplified and sent to a kicker. The sequencing is such that each bunch is excited by a signal, which results from the digitally filtered position signals recorded for that particular bunch at several previous turns.

with the goal of storing 200 mA with a fully safe and redundant system. This implied complementing the existing four cavities installed in cells 5 and 7 of the ring with a third pair of cavities in cell 25, powered by a new transmitter. Following the commissioning of the new cavities and transmitter in 1997, stable beam could be reliably delivered at a current of 200 mA and in 1/3 filling mode. Several unsuccessful attempts were made to store 200 mA in uniform filling (needed for a lifetime two to three times as long, and a better use of the detectors in the beamlines) until a new stabilization system of the cavity temperatures was developed in 1998.

The challenge was to be able to adjust the temperature of each cavity body between 25 and 60 °C precisely and to stabilize this temperature to ±0.05 °C, while the RF fields typically dissipate 60 kW in the walls of a single cavity. It took many machine dedicated time (MDT) shifts to identify the correct individual temperature settings of all six cavities. Since 1998 the system has operated with very few failures, allowing a reliable delivery of 200 mA of stable beam in uniform filling during user service mode (USM).

A programme to raise the current further was initiated in 2001. A precise tuning of the cavity temperatures allowed storing 250 mA in 1/3 filling mode, but numerous attempts carried out in 2003 and 2004 to operate such a current in uniform filling mode failed. The difficulty was only overcome in December 2006, when 300 mA could be stored in uniform filling, thanks to a newly developed fast digital bunch-by-bunch feedback system (see figure).

Three-fold feedback

Three independent feedback systems have been implemented: one against each of the longitudinal, vertical and horizontal bunch oscillations. The characteristics of the filters have been optimized to maximize the damping of oscillations in the corresponding plane. In fact, it is the longitudinal feedback that damps the HOM-induced longitudinal coupled bunch instabilities to a residual amplitude below the noise level. For the ramping to 300 mA, the vertical feedback was used to damp transverse oscillations due to the interaction with residual ions trapped by the beam. The horizontal feedback will become useful to keep the beam stable while optimizing the magnet optics for a maximum lifetime.

As of April 2007 the bunch-by-bunch feedback is still in the commissioning phase and the current has been raised to 300 mA only a few times for some hours in MDT. The plan is to use it more systematically during MDT at restarts in order to evaluate in more detail its impact on the operation. It should allow the delivery of 300 mA in uniform filling mode in USM starting in mid-2008, once all defective crotch absorbers have been exchanged and sufficient experience with 300 mA has been gained.

The current set of three RF transmitters is capable of providing the required power of 1.5 MW to the electron beam, but without redundancy. The aim is therefore to restore sufficient redundancy through an upgrade of the RF transmitters as part of the proposed ESRF upgrade.

This development is the result of collective work with contributions from many colleagues in the RF, diagnostics, power supply, theory and operation groups of the Accelerator and Source Division, in Computing Services and in Technical Services.

J JACOB, P ELLEAUME

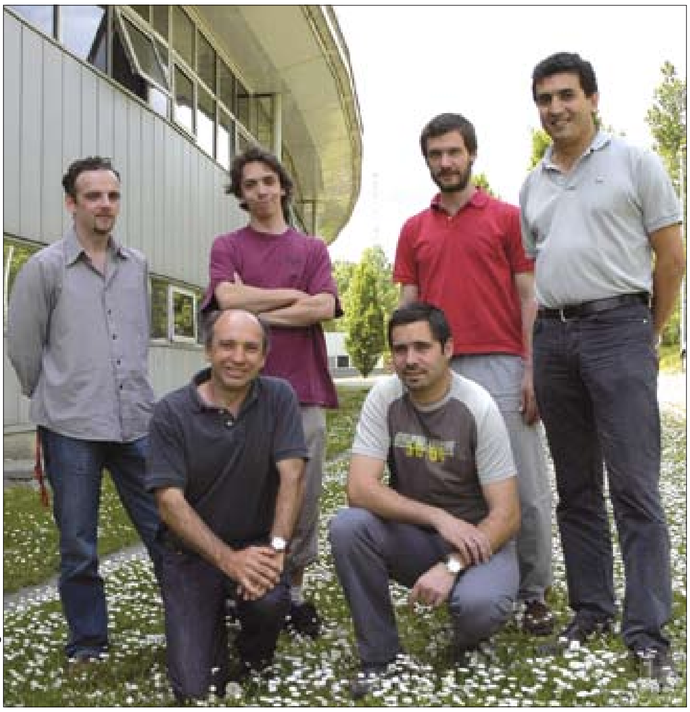
Visiting a beamline

THE NEW HIGH-PRESSURE BEAMLINE: FOLLOWING ITS UPGRADE, ID27 TAKES SAMPLES TO THE LIMITS

It can reach pressures two million times as high as atmospheric pressure and temperatures of up to 5000 °C. This may sound like science fiction, but these are the limits of the high-pressure beamline at the ESRF, ID27.

After the beamline moved from ID30 to ID27 in 2004, it notably increased the possibilities that it offers researchers. Mohamed Mezouar, scientist in charge, reckons that the move has only been for the good: "We have more flux, more stability thanks to a five ton marble piece, and we also have two specialized hutches, so we don't have to spend a lot of time mounting and dismounting set-ups." Each hutch is dedicated to high-pressure equipment, namely the Large Volume Press Edinburgh—Paris and the diamond anvil cell. Despite all of the changes, when the beamline was considered for refurbishment it had not aged at all. "It had been functioning very well for five years, but we felt that we had reached its limits, so we upgraded it. In fact, we could say that this beamline is a precursor of the upgrade programme for research in high pressure," explains Mezouar.

As well as a forerunner, ID27 is also a "classic high-pressure beamline". It provides answers to the most basic questions about the structure of material by using X-ray diffraction. It is the first step that researchers need to take to study materials at high pressure. Only after that can they expand their investigation with other techniques, such as inelastic scattering and absorption.


Chantal Argoud

The ID27 team. Left to right, front row: Stany Bauchau, Jean-Philippe Perrillat. Back row: Wilson Crichton, Guillaume Morard, Gastón Garbarino and Mohamed Mezouar.

Physics, chemistry and earth sciences

The main focus of research on ID27 is the effect of high pressure on disordered systems; investigation into the synthesis of new materials based on light elements like boron, oxygen and nitrogen; and the study of the thermoelastic properties of geomaterials.

The beamline staff are divided in two: Mohamed Mezouar and postdoctoral researcher Gastón Garbarino are in charge of the research involving mainly physics and chemistry, while scientist Wilson Crichton and postdoctoral researcher Jean-Philippe Perillat are more dedicated to earth sciences. The team is completed by junior scientist Guillaume Morard and technician Stany Bauchau. There are currently no PhD students as a result of the optimization of the new beamline.

Earth sciences correspond to 30% of the total activity on the beamline, "so it is a considerable amount", asserts Mezouar. Despite having competing beamlines in synchrotron sources like APS and Brookhaven National Lab (both in the US) or SPring-8 (in Japan), ID27 receives applications from all over the world. Scientists from the Geophysical Laboratory in Washington, US, have carried out experiments on the beamline several times.

Despite its youth, ID27 already shows signs of its success. It gets three times as many proposals for beamtime per round than its capacity allows. Publications also offer a good means of measuring its achievements. Mezouar smiles when he announces that around 350 papers have been produced, thanks to research on ID27 and the former ID30 during the last decade, and this number just keeps increasing. •

MC

Gallery of events

S Claisse

Teaching inspiration. Some 66 stands showed science teaching methods at the fair.

S Claisse

Let's tango. Teaching physics with dance.

SCIENCE TEACHING FLIES HIGH AT SCIENCE ON STAGE

Science on Stage 2, organized by EIROforum and funded by the European Commission, took place in April in Grenoble. The ESRF and the Institut Laue-Langevin (ILL), both members of EIROforum, hosted the event.

The sound of bandoneón music fills the air: it is the sensual tune of a slow tango. Two people dance to the music. They dance as if their spirits were propelling them round the room, enraptured by the music. This romantic vignette is actually full of plain and hard physics. The balance, the signals and the dynamics of the tango go beyond passion – they're pure physics embracing the art of dancing. It's a simple connection, yet unimaginable for most young secondary-school students. This was one of the workshops at Science on Stage 2 and it reflected the spirit of the whole event: the quest by teachers from across Europe for new resources to make science an appealing subject for pupils.

Over the years, some 2000 teachers have taken part in five festivals – three dedicated to physics and the last two to every kind of science. The fair, the stage shows, the workshops and the visits to the scientific institutes hosting the festival provide an ideal forum for teachers to exchange views with each other and with professional scientists. This year, 500 teachers from 28 countries took part. But, with significant involvement of staff and resources, the million-dollar question is: does Science on Stage accomplish its purpose?

David Richardson, a physics teacher from Bristol (UK), says that it does. "The best thing is seeing how other countries present the same principles in a different cultural approach," he says. For him it's not only about being a spectator but also about learning from the other teachers. "I attended Physics on Stage 3 and I got so many ideas from it that I put on a show in the UK from what I had seen, called Physics to Make You Go Wow."

Kites from kebab sticks

On the Spanish stand, Juan Miguel Suay, a physics teacher from Alicante, was building kites made from paper and kebab sticks. The aim was to explain geometry and aerodynamics. He shared Richardson's vision about the benefits of the event: "I am getting lots of ideas for my lessons," he explains. His most attractive experiment was monitoring pressure using simple tools.

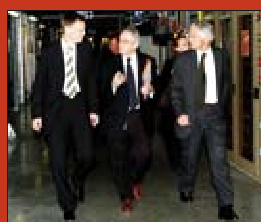
With a variety of imaginative and sometimes "wild" experiments, Science on Stage could make many teachers and children change their minds about science. Suay says: "Pupils – even parents – think science is for freaks. But science is about finding out how the world works and why things are one way and not another."

Having finished the kite he is making, he will let it soar in the wind of Grenoble – in much the same way that his (and the rest of the teachers') ideas have flown free during a week dedicated to finding a better way to teach science across Europe. •

MC

EC COMMISSIONER VISITS ESRF

The European Commissioner for Research, Janez Potočnik, attended Science on Stage 2 and took part in a round table about the future of education in Europe. Despite a very tight schedule, he visited the ESRF, the ILL and the European Molecular Biology Laboratory.



ESRF USERS' MEETING BREAKS NEW RECORDS

There was intense activity last February in the ESRF auditorium and meeting rooms. Three workshops combined with the ESRF Users' Meeting to attract around 350 scientists from 22 countries – the largest number in recent years. This offered the perfect forum to discuss the Upgrade Programme of the facility, as well as new trends in different fields.

Chantal Argoud

Networking. A coffee break during the Users' Meeting.

The main focus of the Users' Meeting 2007 was the upgrade programme, which is designed to keep the ESRF at the top of the scientific and technical scale for at least the next decade.

Carsten Detlefs presented some of the key scientific cases that will be feasible if the upgrade is approved. For example, research at a nanometre scale will make it possible to study cellular structures and create elemental maps at unprecedented resolution, will help the development of even smaller semiconductors or more efficient devices for data recording, and will allow the study of fundamental properties of materials.

Extreme sample environments, such as high pressure and strong magnetic fields, could give experimental access to new fields in the planetary and geosciences. The upgrade also aims to increase the capacity for emerging fields that make heavy use of imaging techniques, such as environmental sciences, clinical applications, palaeontology and cultural history.

THE IMPORTANCE OF BEING A SYNCHROTRON USER

Chantal Argoud

At the Users' Meeting, Pietro Gambardella received the Young Scientist Award from Laszlo Vincze, head of the Users' Organisation (see left). Gambardella is a scientist at the Institut Català de Nanotecnologia in Barcelona (Spain) and user of ID08 and occasionally ID12. The prize acknowledges his work on "the understanding of magnetic properties of low-dimensional systems using polarised X-ray absorption spectroscopy".

"At the ESRF I have found a very stimulating and collaborative environment. Most of our experiments would not have been possible without the extensive preparation and support from the staff at the ESRF," he comments.

To read a full interview with Gambardella, visit the ESRF website at www.esrf.eu/news/timeout.

Upgrade plans

The upgrade team also described the main changes that the ring and beamlines would bring about. A series of new long beamlines to cater for nanofocusing applications are planned, together with an extension of the Experimental Hall, which will include additional lab and office space. Beamlines with two end stations could become independent from each other, which could eventually lead to an increase in the overall number of beamlines.

The Users' Meeting wasn't only about the upgrade. Prof. Peter Müller-Buschbaum, from the T U München, opened the meeting. He focused on the study of local structures with micro- and nanobeams, showing results of measurements carried out at ID13.

Another record broken this year was the number of posters exhibited in a specially set-up marquee. A total of 102 posters filled the space with outstanding science cases. The prize for the best was awarded to Anne Martel, a PhD student on ID13. Her poster presented a microfluidic chip for the study of fibroin aggregation using the techniques of micro-SAXS/WAXS at the ESRF. ●

MC

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NEG coatings are deposited onto the surface of a vacuum chamber to provide effective conductance-free pumping action for gases. Being a barrier for gases, a NEG film drastically reduces thermal out-gassing and allows, thanks to its pumping ability, the achievement of very low pressure.

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