A Light for Science

ESRF news

Number 60 March 2012

ESRF upgrade: illuminating science

Phase II ahead: reports from the Users' Meeting

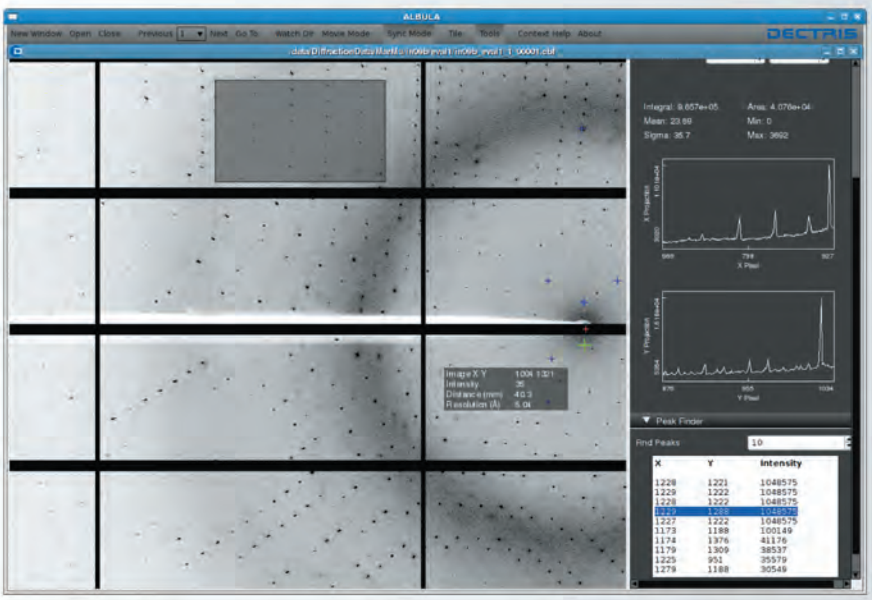
Magnetic enigma: settling a 70-year-old controversy

DECTRIS
Next Generation X-Ray Detectors

PILATUS **Processing Unit**

The PILATUS Processing Unit (PPU) efficiently complements PILATUS detector systems installed at beamlines. It consists of a high-end server, which delivers massive processing power capabilites, and dedicated software packages, which eliminate bottlenecks in many of today's beamline installations.

The software packages include solutions for data synchronization and data visualization. The synchronization software FURKA copies diffraction images from the detector server to a large RAM disk on the processing server. GRIMSEL continuously copies/re-links the images from RAM disk to a large disk array with sufficient capacity for several weeks of regular user operation. The visualization software ALBULA provides real-time display of the collected data. Parallel computing third-party software packages like XDS, Spotfinder, shelxd_mp, etc. can take full advantage of the multi-CPU/multi-core architecture of the PPU.



Real-time data visualization
Very fast data analysis

Highly reliable data transfer
Storage for weeks of user operation

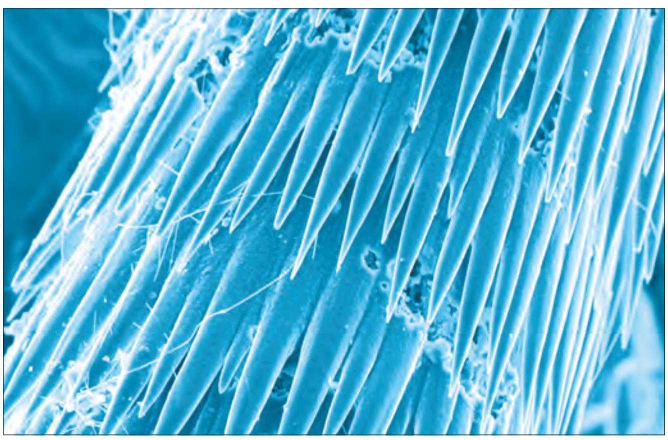
A light for science

C ARGOUD/ESRF

Users' Meeting 2012: science, upgrades and sub-zero temperatures, p8.

C ARGOUD/ESRF

The earth moves: experimental-hall extension takes shape, p14.



B POKROY

Biomineral structure reveals its secret, p19.

On the cover:
Illuminating science at the ESRF.
See "Focus on: upgrade", pp12–16.

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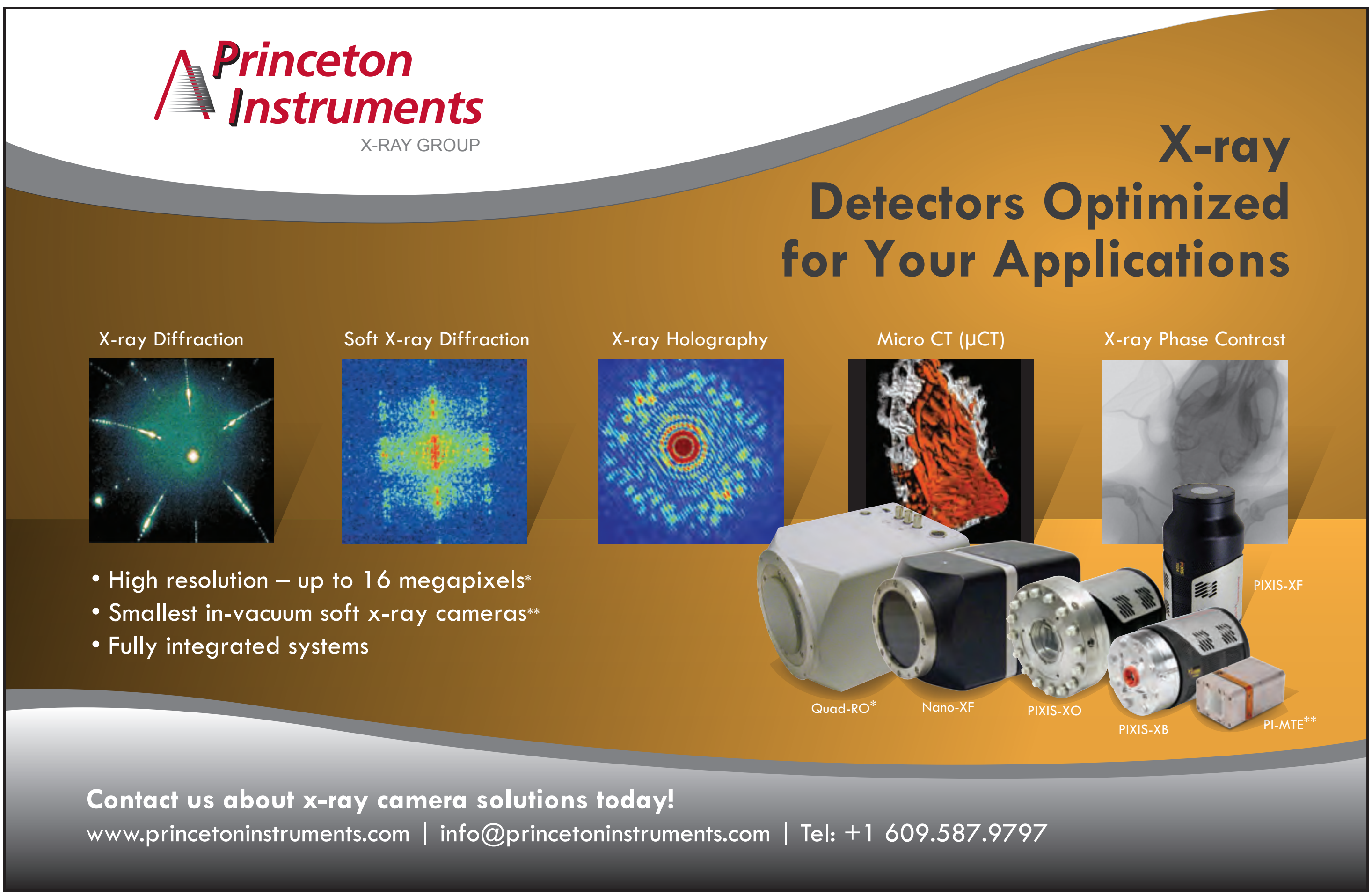
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ESRFnews

Editor
Matthew Chalmers
Tel +44 (0)7857 866 457
E-mail mdkchalmers@gmail.com

Editorial committee
Nick Brookes
Dominique Cornuéjols
Andy Fitch
Claus Habfast
Axel Kaprolat
Joanne McCarthy
Sean McSweeney
Serge Pérez
Harald Reichert
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Publisher
Susan Curtis
Group editor
Joe McEntee
Art director
Andrew Giaquinto
Production
Paul Nash
Technical illustrator
Alison Tovey
Display-advertisement manager
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Mark Trimnell
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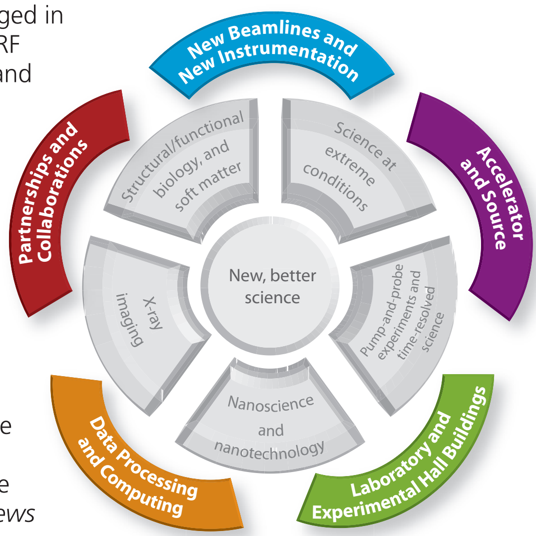
Halfway there

As we approach the halfway mark of Phase I of the ESRF upgrade, it is an appropriate moment to consider what we have achieved so far for our users. We have reached the peak activity of the upgrade, with the long shutdown having started on 5 December 2011 until 5 May 2012. This is the first time since the inauguration of the ESRF that the accelerator complex and storage ring have been shut down for such an extended period of time. All divisions are now extremely busy, using the opportunity to install or modify as many components as possible. The most visible part of the ongoing works is, of course, the construction activity managed by our Technical Infrastructure Division for the new premises that will house the extended experimental floor in the sectors ID27–ID02 and the new lab and office building.

The Accelerator and Source Division is engaged in numerous projects, including works on the RF systems (solid-state amplifiers and cavities) and on many straight sections. The Experiments Division along with the Instrumentation Services & Development and the Technical Infrastructure Divisions, meanwhile, are heavily engaged in beamline upgrade and refurbishment projects. The first new beamlines have become available for user operation, with more to follow after the long shutdown. Many more beamlines and deliverables will continue to become operational until the end of Phase I of the upgrade in early 2015. A more detailed account on ongoing works and the achievements of the first half of the upgrade is given in the articles of this issue of *ESRFnews* dedicated to our upgrade activities.



We are proud to report that the performance of the ESRF for its users has not dropped significantly during this period of heavy works. The machine performs better than ever, with record values for the mean time between failure and availability, and its scientific output is as high as ever – producing about 1800 peer-reviewed publications per year despite the temporary closure of many beamlines for reconstruction activities. This year we will reach the landmark number of 20 000 refereed publications since the ESRF started up. I would like to express my deepest gratitude to all ESRF staff for its outstanding dedication to continued user operation and upgrade activities.

Phase II

At its meeting in Bad Zurzach in 2008, the ESRF Council decided to adopt a staged approach for the ESRF upgrade comprising two phases. With Phase I now well underway, and on schedule, it is time now to prepare for Phase II of the upgrade. In November 2011, Council charged ESRF management with producing a proposal describing Phase II plans and activities within certain temporal and budgetary constraints. A major task this year is therefore to consult users about their scientific and technical needs, a process that began at the 2012 Users' Meeting.

Currently, the Phase II proposal includes improvements to the accelerator complex, the public beamline portfolio of the ESRF, and a dedicated programme to develop advanced optics, detectors and software. A series of workshops will be set up in 2012 to hammer out the details of Phase II upgrade beamline projects, with full involvement of our Science Advisory Committee. The final proposal will be submitted to Council in time for its spring meeting in 2013, with a decision taken hopefully later that year. Getting all of this preparatory work done during 2012 while Phase I of the upgrade is in motion will certainly be a challenge, but it will be a major step towards the completion of an upgrade that will keep the ESRF at the top of its game for the next 20 years.

Harald Reichert, research director, ESRF

Users' corner

All beamlines used the long shutdown from **December 2011** to **May 2012** to put into place improvements in automation, control software, sample environment and positioning. However, some beamlines are undergoing more significant improvements to instrumentation, as detailed below.

Beamlines open starting 5 May until December 2012

Beamline	Status	Upgrades and refurbishments
ID01	Open	
BM01A	Open 6/12	Multi-axis diffractometer upgraded and equipped with latest Agilent Ti CCD detector. Pilatus2M pixel detector installed.
BM01B	Open	
ID02	Open	
BM02	Open	New Kappa diffractometer and longer SAXS camera. Simultaneous GISAXS and GIXRD with dedicated sample environments possible. New XPAD pixel detectors.
ID03	Open	New vertical axis diffractometer for chambers.
BM05	Open for industry use	Large microtomography stage along with a small stage for microtomography installed.
BM08	Open	Upgrade of stepper motors and vacuum control to ESRF standards.
ID08	Open	
ID09A	Open	
ID09B	Open	New high-power nanosecond laser: 4 ns pulses synchronised at 10 Hz, tunable 400–2300 nm, fully user-controlled.
ID10	Open 6/12 refurbished	Transformed into one beamline with two stations, one for coherent scattering (CS) and the other for liquid surfaces and interfaces scattering (LSIS), with independent fully optimised optics and instrumentation (see p16).
ID11	Open	New flexible diffractometer for coupled diffraction and imaging experiments with sub-micron resolution. Diffraction, imaging and fluorescence probes will be permanently mounted to allow fast switching between experimental modes.
ID12	Open	
ID13	Open	
BM14U	Open	
ID14-1	Open	
ID14-4	Open	
ID15A	Open	
ID15B	Open	
ID17	Open	Start of the clinical trials for the SSRT phase 1. New sample stage for CT imaging of large and/or heavy samples, with the detector at 11 m from the sample.
ID18	Open	
ID19	Open/ refurbished	Refurbishment part I: additional optics hutch and new sample stages (see p16).

BM20	Open/ refurbished	X-ray optics completely replaced for seamless energy coverage and rejection of higher-order harmonics from 5 to 35 keV. Improved beam diagnostics for better adjustment and stability.
ID21	Open	
ID22	Open	
ID23-1	Open	
ID23-2	Open	
BM23	Open	
ID24	Open/upgraded	Installation of ID24-L end station (chemistry/catalysis).
BM25A	Open	
BM25B	Open	
ID26	Open	
BM26A	Open	Installation of a white beam collimating mirror. Replacement of a monochromator in 8-9/12.
BM26B	Open	Permanent installation of microfocusing tools.
ID27	Open	
BM28	Open	
ID28	Open	New spot size of 14 x 7 μm^2 (hor x vert) and flux density enhanced more than tenfold.
ID29	Open	New multi-probe motorised support for online spectroscopy measurements.
BM29	Open 6/12 upgraded	Removal from ID14-3 to BM29. New optics hutch and refurbished experimental hutch, including HPLC system (liquid chromatography in situ) to be used in parallel with sample changer robot.
BM30A	Open	New sagital bender installed in monochromator for easier wavelength changes, and robotic systems reorganised for the future automated sample harvesting system.
BM30B	Open	
ID31	Open	
BM32	Open	

Beamlines closed in May 2012 as part of Upgrade Programme (see pp12–13)

Beamline	Name	Status
ID10 A/B/C	Troika I, II and III Beamlines	Closed – rebuilt as ID10
ID14-2	Structural Biology Beamline	Closed – move to ID30A1
ID14-3	Biology Bio-SAXS Beamline	Closed – move to BM29
ID16	Inelastic X-ray Scattering Beamline	Closed – move to ID20

Following the 1 March deadline for proposal submission, the next Beam Time Allocation Panel meetings will take place on 26 and 27 April. Decisions will be communicated to proposers in the first half of June.

Next proposal submission deadline: 1 September for submission of standard proposals, for beam time during the period March to July 2013.

Your science, your future

Cutting-edge research and the scientific potential of 19 revamped beamlines took centre stage at the 2012 ESRF Users' Meeting, alongside plans for the ESRF's longer-term future.

More than 300 scientists braved Siberian temperatures in early February to attend the 22nd ESRF Users' Meeting. So frozen was the ground, in fact, that construction for the ESRF upgrade buildings was suspended for the duration of the meeting. But the impressive progress made so far towards the upgrade was clear to all who attended, with a broad arc of earth ready to take the foundations of two major experimental-hall extensions and a giant crane waiting to lift the buildings' 1000 tonnes of steel frame into place.

The ESRF is due to restart on 3 May, which means 2012 will offer approximately 4000 hours of user operation compared with 5500 hours in previous years. Given that this is the longest period the ESRF source has been closed in 20 years, and that the experimental site has moved by a couple of mm due to the 50 000 tonnes of earth that has been excavated and dumped nearby, the restart of the machine will be critical, explained head of the ESRF's Technical and Infrastructure Division Rudolf Dimper. "Currently we are in the most difficult phase of the upgrade project, with network cuts, vibrations, noise and weather conditions among the challenges we face," he said, remarking that it was a "very strange feeling" to watch part of the ESRF being demolished.

ALL PHOTOS: CHANTAL ARGOUD

Structural biologists meet at the Winter School for Macromolecular Crystallography.

A four-day workshop at this year's meeting brought together users investigating magnetic materials ranging from low dimensional systems to macroscopic samples under extreme conditions.

Jeroen van Bokhoven of the ETH Zurich speaks about catalysis at the plenary meeting.

Upgrade ahead

Alongside scientific deliberations at this year's Users' Meeting, which included seven plenary lectures, 43 parallel-session presentations and multiple talks during three satellite workshops, the upgrade was a key point of discussion. Research director Harald Reichert reiterated the five themes of the upgrade – improvements to the accelerator and source, new and upgraded beamlines, enabling technologies, new buildings and scientific partnerships – and summarised the latest action taking place on the beamlines. Developments are too numerous to mention, suffice it to say that over the next 30 months the ESRF will be completely transformed to offer users unparalleled scientific potential.

Indeed, the rate and scale of changes to the ESRF's structural-biology infrastructure was cause for concern among structural biologists at this year's meeting. "The degree of automation and throughput that will be possible with the upgrade is going to go down well with the community," ESRF user Beatrice Vallone from the University of Rome La Sapienza told *ESRFnews*. "There are a lot of new ways to handle samples – it will be a new age, and we want to make sure that we contribute to the process and that the community is well informed about when certain beamlines are open."

The structural-biology parallel session was standing-room only, and other sessions at the meeting were similarly well attended. Some 90 delegates gathered for a workshop dedicated to hard X-ray photoelectron spectroscopy (HAXPES) and standing waves (see p10), many having come to discuss the future of their field following the recent closure of ESRF's ID32 beamline due to a 6% cut in the ESRF budget. "There is a lot of frustration," H L Meyerheim of the Max Planck Institute for Microstructure Physics in Halle, Germany, told *ESRFnews*. "This is a large community that has been working very successfully for the last few years, and the ESRF provided a unique facility." A workshop on magnetic materials and the 4th Winter School on Soft X-rays in Macromolecular Crystallography also took place in parallel.

Science impact

Few facilities other than a third-generation synchrotron can boast the range of science on display at this year's User's Meeting. In 2012 the ESRF is set to pass the milestone of 20 000 refereed papers since it began in 1994. In trying to catch as many talks as possible during the two-day meeting, *ESRFnews* learned of recent studies into the kinetic chewing mechanism used by cockroaches, hidden sketches behind priceless artworks, the microstructure of mollusc shells, the refractive indices of fish-eye lenses and the proteins that allow a winning sperm to attach itself to an egg – in addition to breakthroughs in catalysis, surface and materials science.

"In total the ESRF is rebuilding 19 beamlines – a major task – with minimal disruption, and the new beamline portfolio will be well balanced in terms of meeting core science themes of users' home nations," Reichert told delegates. "It's time to start planning the next phase, and we start this discussion today.

Phase II of the ESRF upgrade, which represents a potential €60 m additional capital cost that is yet to be secured, would begin in 2015 and was the subject of lively sessions at this year's meeting. The Vercors building extension, which was cancelled due to the ESRF budget cut, is unlikely to be reinstated said directors, but the Chartreuse extension will permit an additional three long beamlines during Phase II plus there is scope for extending other beamlines. The ESRF intends

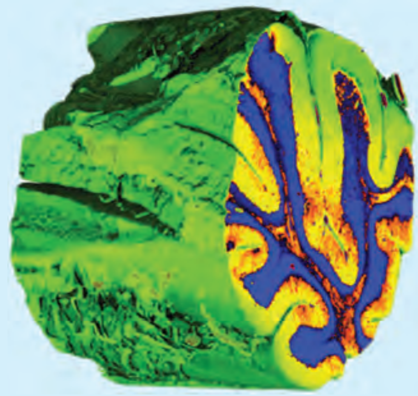
Young Scientist award: taking X-ray imaging into new territory

CHANTAL ARGOUD

The ESRF's **2012 Young Scientist award** goes to physicist Irene Zanette for her pioneering development of X-ray grating interferometry, a technique that increases the image contrast from low-absorbing objects, such as soft tissue. Starting from a situation when there was no X-ray interferometer available to ESRF users, Zanette designed and built a fully operational instrument with world-leading performance at the ID19 beamline during her three-year PhD. The technique is now fully available to users. "I am honoured," the 28-year-old told *ESRFnews*. "This award is a prestigious recognition for my work and for the work of my collaborators. I'm glad that my achievements and the importance of this emerging imaging technique have been recognised by this community."

Moreover, Zanette developed a 2D grating interferometer for directional dark-field and quantitative phase radiography, and also demonstrated low-dose methods for multimodal grating-based tomography. The resulting technique has enormous potential for imaging biological samples, since it can reveal features that traditional absorption contrast imaging cannot. It also has applications in materials science, for instance in imaging tiny density differences in alloys and structures at the nanoscale (e.g. cracks and pores), and in optics characterisation.

Zanette took up a postdoc position at the University of Munich in November, and says that the technique has attracted interest from manufacturers of X-ray machines. But she plans to stay firmly in academia to develop X-ray interferometry further. "Irene is a truly outstanding young scientist," wrote ESRF's head of imaging, José Baruchel, in his letter of nomination. "It is because of her personal achievements that the ESRF-user community today benefits from several new imaging modalities with unique performance in Europe and the world."



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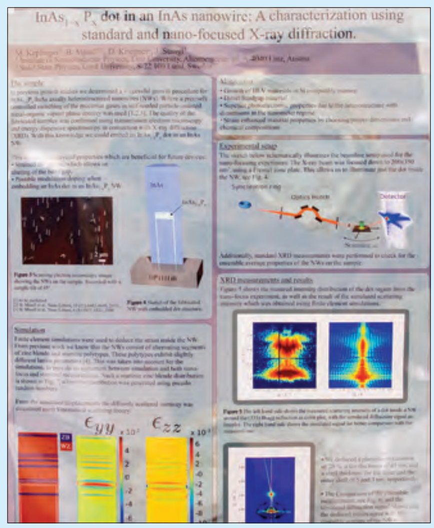
A human cerebellum imaged at the ESRF using X-ray grating interferometric phase tomography, distinguishing white matter (orange) from two types of grey matter (blue and yellow).

The imaging capabilities of X-ray grating interferometry – a striking image of an ant – can be seen on p21 of this issue of *ESRFnews*.

In the picture: the Users' Meeting poster session…



CHANTAL ARGOUD

Left: users gather for the poster session at this year's meeting. Right: a close-up of this year's best poster, won by ESRF user Mario Keplinger from Johannes Kepler University of Linz, Austria, who uses X-ray diffraction to characterise nanowires.

to present the Phase II proposal to users and the ESRF Council in spring next year, with the aim of gaining approval in the autumn. Preparatory works would then take place during 2014 and implementation in 2015.

User communities with Phase II upgrade plans were advised to submit one-page proposals to management. The ESRF's imaging group, for instance, will propose a dedicated facility that exploits the intensity and coherence of the ESRF source to carry out ultrafast phase-contrast imaging, allowing *in vivo* studies of processes such as breathing (chewing, in the case of cockroaches) in addition to the formation of alloys and other materials. In discussing its Phase II plans, the HAXPES and X-ray standing wave community said the field could face a period of several years without a dedicated facility.

"We are aiming to re-establish the budget at the start of 2014 and thus reinstate two beamlines," said director-general Francesco Sette, suggesting that new user communities, particularly those in the Russian Federation, are the best way to recoup the 6% budget deficit. "We welcome the voice of users here at the ESRF, but it should also be heard in users' home nations," he said.

The ESRF is also thinking much further into the future. In December, an international working group will present a long-term scientific plan to Council detailing the study of the next generation of storage-ring sources 10–30 years from now, which may see a horizontal emittance of 10 pm and beams 1000 times more brilliant than those of today. "The financial situation in Europe is not easy but we are working very hard for you, the users," concluded Sette. "We are very grateful that the support is there, and that comes only from the quality of your science."

Matthew Chalmers

Inside matter

A two-day workshop devoted to hard X-ray photoelectron spectroscopy and X-ray standing waves took users deep into the structure of materials.

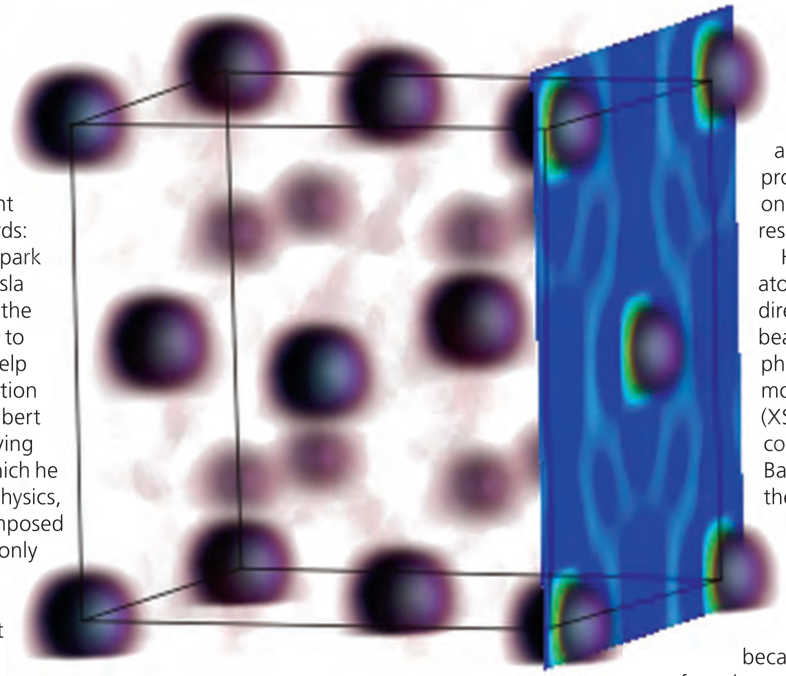
In 1887, physicist Heinrich Hertz discovered something remarkable about the then unknown subatomic world: when an atom absorbs light it emits an electron with a specific energy. His experiment was crude by modern standards: Hertz had observed that the spark of a spark inductor called a Tesla transformer is stronger when the sparking electrode is exposed to light. Yet his findings would help to launch the quantum revolution two decades later. In 1905, Albert Einstein explained the underlying "photoelectric effect", for which he won the 1921 Nobel Prize in Physics, by suggesting that light is composed of discrete quanta (photons): only photons with a frequency above a certain threshold have sufficient energy to eject a single electron.

Decades later, in 1963, Swedish physicist Kai Siegbahn and co-workers realised that the kinetic energy of the photoelectron is characteristic of the electronic and therefore chemical state of the atom, giving birth to a technique called electron spectroscopy for chemical analysis (ESCA). Siegbahn received the Nobel Prize for Physics in 1981 for the work, following in the footsteps of his father who had won the same prize in 1924 "for his discoveries and research in the field of X-ray spectroscopy".

Today, the wealth of chemical and electronic information provided by photoelectron spectroscopy is a highly valuable tool in physics, chemistry and material science. However, until recently traditional photoelectron spectroscopy has been limited to the very outer skin of materials because electrons are strongly absorbed by matter. In order to explore bulk materials the photoelectrons must have enough kinetic energy to punch their way out of a sample, and that demands a brilliant source of hard X-rays, such as the ESRF.

Unique resource

During the past few years, newly developed beamline instrumentation and advances in electron analyser technology have led to a rapid development of hard X-ray photoelectron spectroscopy (HAXPES), a technique that was kick-started during a dedicated workshop at the ESRF in 2003. The high kinetic energy of the photoelectrons reveals chemical/electronic information from material depths that are not accessible by traditional photoelectron spectroscopy. Because of the peculiar properties of X-ray crystal monochromators, whereby the lattice planes of a crystal act as a grating, it is also possible to obtain better energy resolution with higher X-ray energies.



The 3D atomic distribution of manganese in a gallium-manganese-arsenide unit cell, obtained from a direct Fourier transform of X-ray standing wave data.

High impact: HAXPES/XSW has revealed…

- Details about the interplay of structure and electronic properties of highly correlated materials, such as high-temperature superconductors.
- New information about solar cells and fuel cells necessary to improve their performance.
- The structure of highly dilute magnetic atoms in semiconductor alloys, aiding the development of spintronics.
- Buried interfaces that impact new memory and transistor devices for the next generation of micro-electronic chips.
- How graphene binds to surfaces, which is essential for employing graphene in future micro/nano-electronics.

Consequently, HAXPES facilities have become available or are planned at several storage-ring light sources around the world where they promise to make a major impact on basic, applied and industrial research.

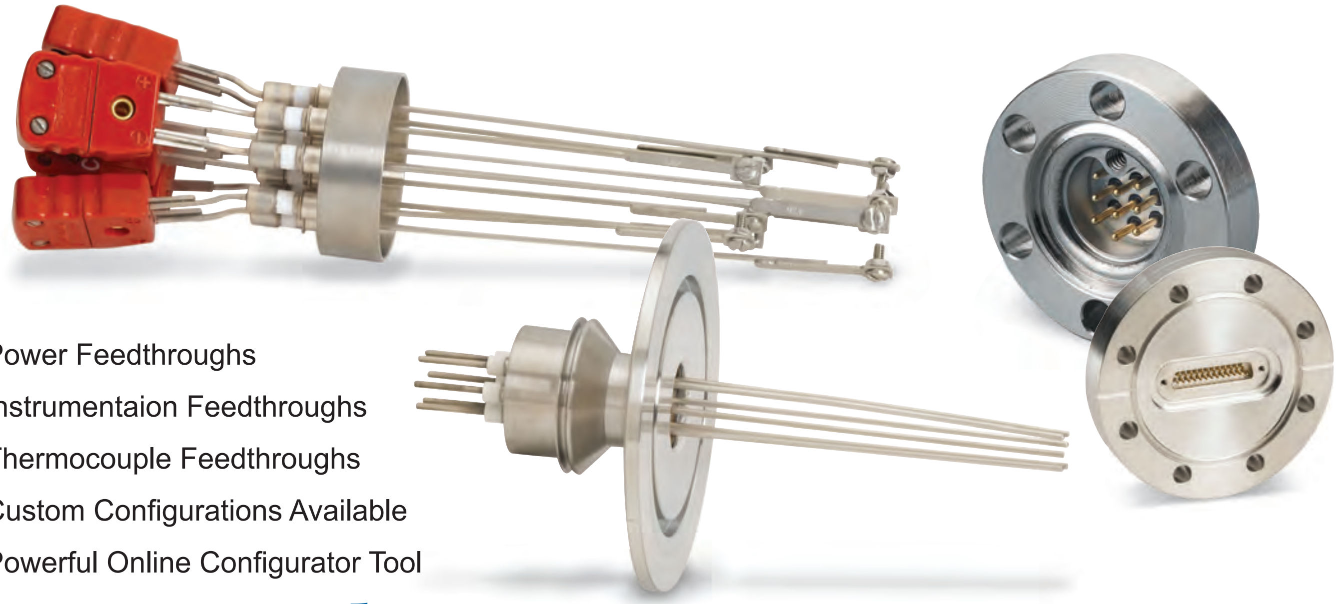
HAXPES cannot reveal the atomic structure of materials directly, but there is a neat way to beat this limitation by exciting the photoelectrons with a periodically modulated X-ray standing wave (XSW). The XSW technique, conceived in the 1960s by Boris Batterman at Bell Laboratories in the US, records the photoelectric scattering excited by an interference field created by the coherent superposition of two travelling waves. As with HAXPES, the XSW technique became useful only with the advent of synchrotron radiation and for the past decade the ESRF has played a major role in developing both techniques. The ESRF's ID32 beamline combined them, allowing users to study the structure of matter at surfaces, interfaces, and in the bulk. Budget cut and logistics associated with the ESRF Upgrade have meant that ID32 was one of two beamlines that were closed at the end of 2011.

Where next?

At the 2012 ESRF Users' Meeting, 87 delegates from 15 countries gathered to discuss the prospects of HAXPES and XSW. Thirty talks and 21 posters left no doubt that both techniques, and in particular their combination, are in a very dynamic state of development, with numerous outstanding results across a range of subjects. Highlights included: new details about the electronic structure of quasicrystals, a class of materials discovered in 1984 for which the 2011 Nobel Prize in Chemistry was awarded; the discovery that organic molecules on a surface remain intact but bend, which is relevant to organic light-emitting diodes; and insights into the corrosion of alloys, which make up all technologically relevant materials.

Attendees debated the needs of their field until well into the night. It was their unanimous opinion that the ESRF cannot lose out on the opportunities that these techniques offer, and their sincere hope that a state-of-the-art HAXPES/XSW beamline will find a new home at a new port very soon.

Jörg Zegenhagen



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Branching out: the ESRF’s

Diffraction imaging for nano-analysis

Where: ID01
What: Long beamline for nano-X-ray diffraction across a wide energy range (2.2–50 keV), offering coherent imaging of individual nanostructures as well as basic surface diffraction and small-angle scattering. Combines X-ray diffraction with atomic-force microscopy to allow investigation of the structure–function relationship at the nanoscale, allowing the properties of device-like structures to be studied in unprecedented detail.
Open for business: late 2014
Scientist in charge, Tobias Schulli, *says*: “As more of our users study applied materials, rather then model systems, this flexibility in terms of energy range and variable beam size is well adapted for samples that are heterogeneous in their chemistry and crystal structure on the nanoscale.”

High-energy beamline for buried interface structures and materials processing

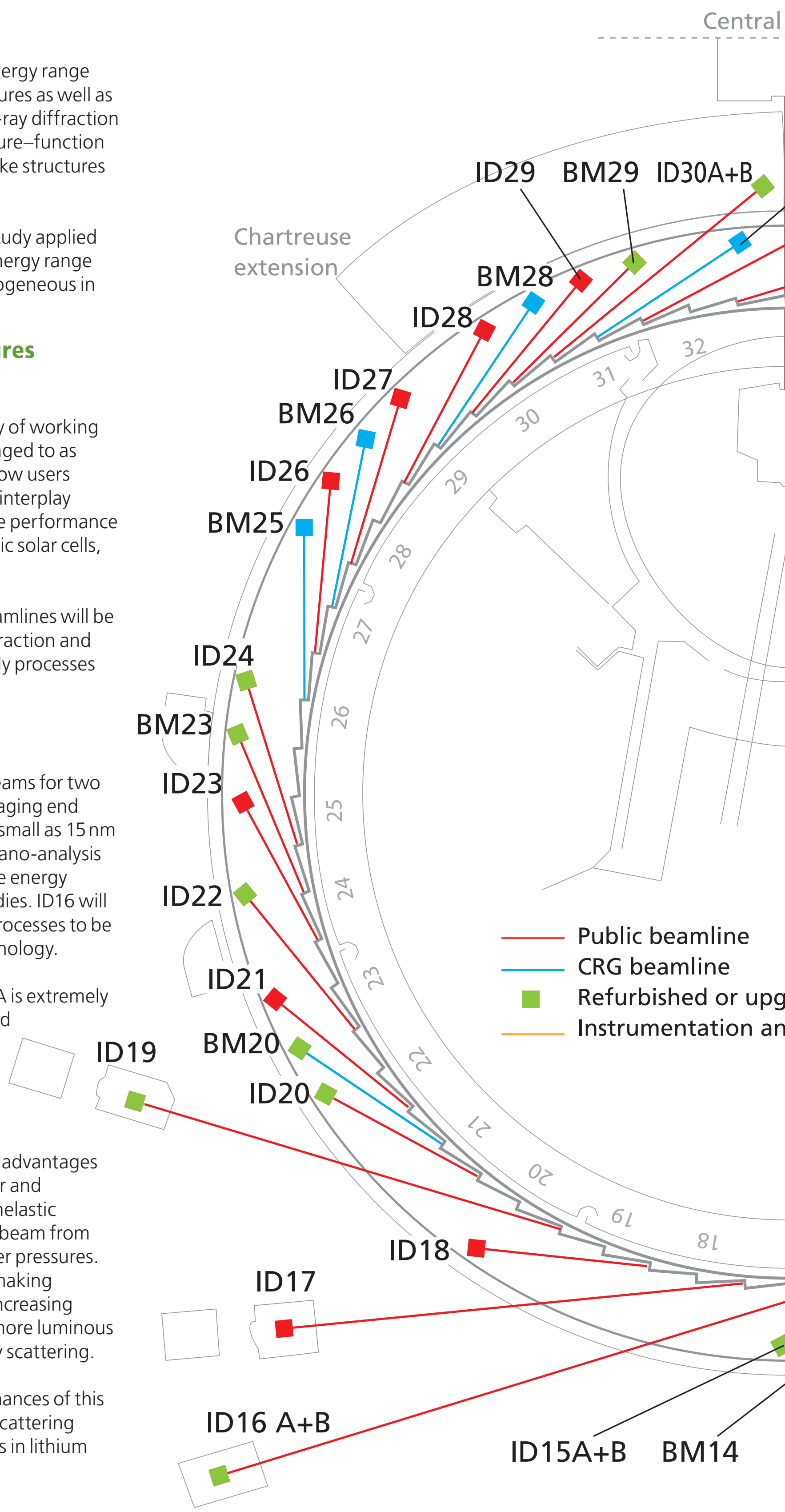
Where: ID31 (previously ID15)
What: Long beamline covering energies 30–150 keV for the study of working devices *in situ*, with new optics allowing the beam size to be changed to as small as 200 nm at the push of a button. Smaller spot sizes will allow users to study less perfect, more realistic, interfaces to understand the interplay between microscopic material properties and macroscopic device performance – in particular concerning advanced materials for fuel cells, organic solar cells, rechargeable batteries and catalytic materials.
Open for business: early 2015
Scientist in charge Veijo Honkimäki *says*: “Technically these beamlines will be the best in the world. The big change is that we can combine diffraction and imaging techniques with auxiliary techniques, and therefore study processes such as chemical reactions *in situ*.”

Nano-imaging and nano-analysis (NINA)

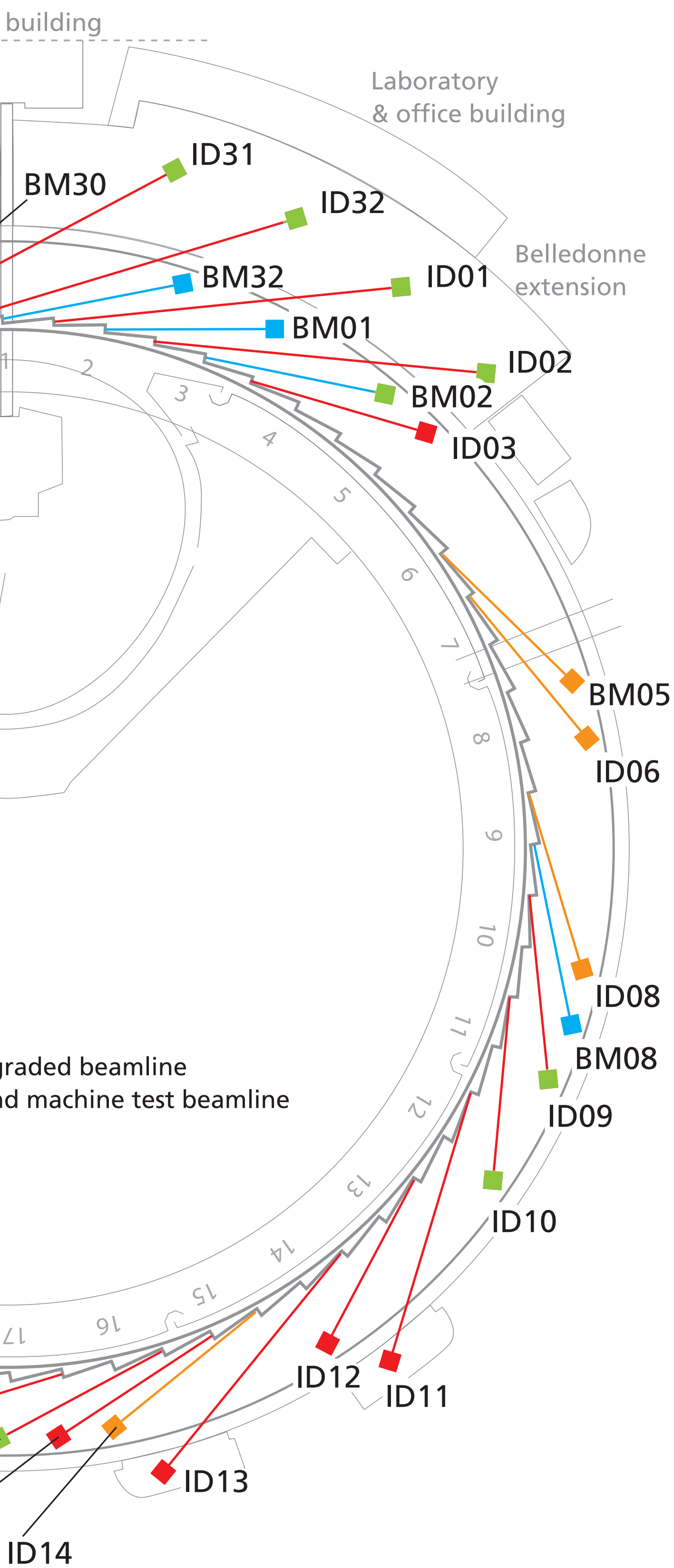
Where: ID16 (previously ID22)
What: Long, high-brilliance beamline providing nano-focused beams for two end stations. Operated in a cryogenic environment, the nano-imaging end station will focus hard X-rays at specific energies to a spot size as small as 15 nm and combine fluorescence analysis and nano-tomography. The nano-analysis end station will provide a monochromatic beam tunable in a large energy range, offering a multianalysis nano-probe for spectroscopic studies. ID16 will focus on biomedical research, for instance allowing subcellular processes to be studied, as well as environmental sciences, energy and nanotechnology.
Open for business: February 2014
Scientist in charge Peter Cloetens *says*: “Application-wise, NINA is extremely important. Many synchrotrons are pushing towards nano-focused beams but NINA will be at the forefront.”

Inelastic hard X-ray scattering for electronic spectroscopy

Where: ID20 (previously ID16)
What: Two end stations offering a spectroscopic tool with all the advantages of a hard X-ray probe – bulk information, high-penetrating power and elemental and spin sensitivity – designed to enhance the ESRF’s inelastic scattering programme. The upgrade will decrease the size of the beam from around 100 microns to 10 microns, allowing experiments at higher pressures. The energy range will also increase from 6–10 KeV to 5–20 KeV, making resonant experiments possible at a larger number of edges and increasing compatibility with more complex sample environments. Finally, more luminous spectrometers will broaden the scientific impact of inelastic X-ray scattering.
Open for business: March 2013
Scientist in charge Giulio Monaco says: “The increased performances of this upgrade beamline will attract a broader group of inelastic X-ray scattering users, in particular those studying low-Z materials for applications in lithium batteries and hydrogen storage.”



s new beamline portfolio



Soft X-rays for magnetic and electronic spectroscopy

Where: ID32 (previously ID08)
What: State-of-the art facility for soft X-ray absorption spectroscopy and very high-energy resolution resonant inelastic X-ray scattering, with sophisticated sample environments and tunable X-ray beam sizes ranging from microns to hundreds of microns. The beamline will provide new facilities for users to study the electronic and magnetic properties of materials, offering magnetic dichroism techniques and soft resonant inelastic X-ray scattering to meet the demands of an expanding user community.
Open for business: August 2014
Scientist in charge Nick Brookes *says*: "Measurements with extremely high-energy resolution of the magnetic, electronic and vibration energy losses will have a tremendous impact in fields like high-temperature superconductivity."

Time-resolved ultra small-angle X-ray scattering (SAXS) and pump-probe experiments

Where: ID02/ID09 (previously ID2/ID09B)
What: Two independent beamlines. Long beamline ID02 will extend SAXS to ultra-small (microradian) angles with sub-millisecond time resolutions, pushing the technique's applicability to systems ranging from colloidal plasmas to highly self-assembled biomimetic systems. ID09 is dedicated to time-resolved diffraction and scattering, with picosecond laser pulses initiating structural changes in the sample that can then be probed with ultrashort X-ray pulses.
Open for business: ID02 April 2014; ID09 operational
Scientist in charge of ID02 Theyencheri Narayanan *says*: "Until now people have mostly studied complex systems comprising passive objects, but the upgrade will provide high resolution and sensitivity allowing the study of active systems such as the physiological activation of a muscle cell."

Massively automated sample selection integrated facility (MASSIF) for macromolecular crystallography

Where: ID30 and BM29 (previously ID14-3)
What: A unique resource based on second-generation automation for macromolecular crystallography experiments, designed to help structural biologists tackle ever more ambitious projects, such as complex membranes. The hub of the project is a sample-evaluation and sorting facility (MASSIF), from which the most suitable crystals for data collection will be distributed to the best suited of seven end stations (MASSIF-1/-2/-3, ID23-1/-2, ID29 or ID30B). Such screening is vital to cope with the problem of inter- and intra-sample variations in modern macromolecular crystallography experiments.
Open for business: BM29A June 2012; ID30A May 2013; ID30B May 2014
Scientist in charge Christoph Mueller-Dieckmann *says*: "The goal is to be able to evaluate 1000 samples/day per end station on MASSIF. This degree of automation will benefit structural biologists and the pharmaceutical industry."

Time resolved and Extreme conditions X-ray Absorption Spectroscopy

Where: ID24/BM23 (previously ID24/BM29)
What: High-brilliance energy dispersive X-ray absorption spectroscopy (EDXAS) allows users to study the local and electronic structure of matter in real time and *in situ*; the behavior of matter under extreme pressures and temperatures, such as those in the Earth's core; or the structure–function relationship in industrially relevant catalysts. Two independent end stations (EDXAS_S "small spot" and EDXAS_L "large spot") on ID24 combined with the general purpose EXAFS station on BM23 will permit X-ray absorption spectroscopy in sample volumes 20 times smaller and time resolutions 1000 times better than before.
Open for business: BM23 open; EDXAS_S May 2012; EDXAS_L Sep 2012
Scientist in charge Sakura Pascarelli *says*: "Scientists can use several other synchrotrons for fast X-ray absorption spectroscopy, but it is the microsecond time resolution for single-shot acquisition coupled to the micrometre-sized spot that makes ID24 unique worldwide."

The ESRF shines on

MIHAIL ULIANIKOV/ISTOCKPHOTO

The ESRF is undergoing a transformation that will ensure it remains the world's leading provider of hard X-ray light.

With a ceremonial strike of a pickaxe on 29 November, ESRF director-general Francesco Sette marked the start of civil construction works for the ESRF upgrade. Meanwhile, a fleet of heavy plant began the task of excavating some 50 000 tonnes of earth to prepare the foundations for the associated upgrade buildings. By the time the lorries have departed in spring 2013, the ESRF will boast two new experimental halls flanking the main building, a new satellite building and some 3400 m^2 of fresh office space.

Eight new beamline projects, comprising 11 beamlines and 15 independently operable stations, will then be unleashed. Alongside refurbishments and improvements to existing ESRF beamlines, plus a brand-new Science Building to be built next year, the upgrade will ensure that the ESRF meets the scientific demands of users for the rest of the decade. The first public beamline upgrade is already complete: ID24, which is devoted to time-resolved and extreme-conditions X-ray absorption spectroscopy, was inaugurated on 28 November.

The idea for a major upgrade to the ESRF dates back to 2003, when management updated to its long-term scientific plan to the ESRF Council. "The ESRF was operating extremely well at the time, so one option was to continue as we were," recalls former ESRF director-general Bill Stirling, who is now scientific coordinator for Grenoble's GIANT partnership. "But from looking at other facilities and labs in the world, we realised that we needed a major upgrade to maintain the ESRF's position as one of the best – if not the best – X-ray sources in the world. The upgrade represents five years of my life and I am extremely impressed by what the ESRF's staff and user community have achieved."

"The ESRF has always served as a model for other synchrotrons, and this is true of its upgrade programme too"

After several years of difficult financial discussions and extensive scientific and technical considerations, which culminated in the publication of the two-volume "Purple Book", in 2008 the ESRF received funding for the first phase of the upgrade pertaining to the period 2009–2015. The total cost of the project was fixed at slightly more than €170 m, 75 m of which was to come from the ESRF's continual reinvestment budget.

A 6% reduction in financial contributions to the ESRF, which came to light in 2010, has delayed construction by six months and forced the cancellation of one new experimental hall extension (the "Vercors" building) and one satellite building at ID20. The timing of the upgrade was nevertheless fortunate, insists former upgrade preparation leader Ed Mitchell. "The council gave us the 'green light' in the autumn of 2008, just before the economic crisis hit," he says. "Had we been just a few months later, it's less sure that the upgrade would have gone ahead."

ESRF upgrade timeline: the future is now…

FUTURE

MAR 2012	Works start on Science Building
MAY 2012	End of long shutdown; laying of concrete for experimental-hall extension; ID24-S starts user operation
JUN 2012	BM29 starts user operation
SEP 2012	ID16 satellite building available; ID24-L starts user operation
JAN 2013	Restaurant and other common-building works begin
MAR 2013	Chartreuse extension and new laboratory & office building available; ID20 starts user operation
MAY 2013	Belledonne extension available; ID30A starts user operation
MID-2013	Refurbishments of ID10 (Feb) and ID19 (May) complete

PAST

DEC 2011	Start of long shutdown for upgrade building civil-engineering works
NOV 2011	Inauguration of ID24/BM23 and BM20 beamlines
AUG 2011	First 6 m straight machine section equipped with 4 undulator carriages
MAY 2011	Inauguration of new data centre
APR 2011	First tower of the new solid-state RF amplifier installed
MAR 2011	Upgraded BM23 starts user operation
APR 2010	New beam-position monitoring system installed
MID-2009	Conceptual design reports for all public ESRF beamlines


C ARGOUD/ESRF

Out with the old: wreckers make way for the extended ESRF experimental hall and new laboratory and office building (below).

Synchrotron science has changed dramatically since the ESRF started up in 1992, as anyone who is fortunate enough to own a copy of the ESRF "Red Book" – which set out the founding goals of the facility in 1987 – will attest to. For instance, the life sciences were expected to take up only a small fraction of proposals without the exploitation of undulator beamlines, yet today macromolecular crystallography (MX) is the largest single user group – with an extensive new MX suite called MASSIF being a major component of the upgrade. Meanwhile, subjects such as palaeontology and cultural heritage have blossomed despite not being on the radar when the ESRF was built. An important advance at the ESRF has been the exploitation of the coherence properties of its X-ray beams, allowing higher-resolution imaging and dynamical studies.

"That's how it should be – it's progress," says research director Harald Reichert. "In planning for Phase II of the upgrade we're not only sticking just to the 'Purple Book' anymore because that was five years ago and science has evolved since then."

Smaller, brighter beams are the theme of the ESRF upgrade, with beams as small as 10 nm allowing users to address the behaviour of matter in volumes comprising just a few thousand atoms. In addition to major improvements to the accelerator and source, most of which are already in place, the upgrade will allow longer beamlines to be operated with vastly improved optics, detectors and data-analysis tools. A new satellite building located 185 m from the storage ring will house a dedicated nano-imaging and nano-analysis facility ("NINA"), but many other beamlines will benefit from more tightly focused, nano-sized beams.

"NINA is a star of the upgrade in terms of industry users," says Mitchell. "It will have killer applications in focusing our X-ray beams down to minute spot sizes, as does the new ID31 project, which will be at very high energies, plus there's the MASSIF facility, which will open the door to phenomenal amounts of sample throughput for protein crystallography."

Serving society

Nanoscience and technology is one of five core areas of applied and fundamental research that the upgrade is designed to address. The others are: pump-probe experiments and time-resolved diffraction (with time resolutions sufficient to "film" the movement of single atoms or even electrons); science at extreme conditions (offering the capacity to study minute quantities of matter under very high pressures, temperatures and magnetic fields); structural and functional biology and soft matter (elucidating, for instance, the basic mechanism of molecular machines and cellular reproduction), and X-ray imaging (with applications ranging from medicine to archaeology).

Such capabilities are intended to support the scientific communities of the ESRF's member and scientific associate countries to better address health, energy, environment and climate change, new materials and nanotechnology. "At the time of the 'Red Book', the ESRF was considered a pure fundamental science machine, but if you look at the users' needs today you will see that applied sciences and innovation constitute a large part of the user community and are very well served by the five science areas that we are targeting," says Reichert.

Every ESRF beamline will undergo at least some form of upgrade, and those with only light improvements will be candidates for Phase II of the upgrade beginning in 2015. The national "CRG" beamlines will not receive additional ESRF funding, but they stand to benefit from improvements to the source, sample environments and larger experimental halls. A major upgrade to the German beamline ROBL (BM20) was inaugurated on 10 November.

"Being the first third-generation synchrotron to be built, the ESRF has always served as a model for other synchrotrons, and this is true of its upgrade programme too," says Brian Stephenson, director general of the Advanced Photon Source in Argonne, US, which has recently completed a conceptual design report for a major upgrade of its own. "We always appreciate the pioneering efforts of the ESRF."

Matthew Chalmers

Upgrading the source

The ESRF upgrade pushes the performance of the storage ring, booster and linac beyond even the most optimistic expectations at the time of their design. Crucial developments during Phase I of the upgrade include:

- Enhanced beam-position diagnostics providing higher beam stability and enabling reduced vertical emittance.
- Increasing the useful length of the straight sections to 6 m (one 7 m section), creating space for more undulator beamlines via "canting".
- A new and more modular RF power source based on semiconductor technology to replace ageing high-power klystrons.
- Improved RF cavities with "higher-order-mode damping" to replace the existing cavities, enabling the beam current to be increased to 300 mA.
- Improved control systems across the source and beamlines.

SEP 2013 Commissioning of Science Building

DEC 2013 Refurbished common building, including restaurant, and new site entrance available

FEB 2014 New ID16 starts user operation; ID31 refurbishment complete

APR 2014 New ID02 starts user operation

MAY 2014 New ID30B starts user operation

JUN 2014 New ID32 starts user operation

DEC 2014 New ID01 starts user operation

EARLY 2015 New ID31 starts user operation; Phase II of upgrade begins

2008 Funding granted for Phase I of the Upgrade

2007 Publication of the ESRF "Purple Book"

2006 Upgrade science case presented to ESRF council

2003 Formal Upgrade discussions begin

1998 40 beamlines in operation

1992 First electron beam in storage ring

1988 Signature between governments of 12 member states

1987 Publication of the ESRF "Red Book"

Time to evolve

Major refurbs to ID19 and ID10 will boost ESRF's imaging, soft-matter and interface science.

ID19: Brand-new optics

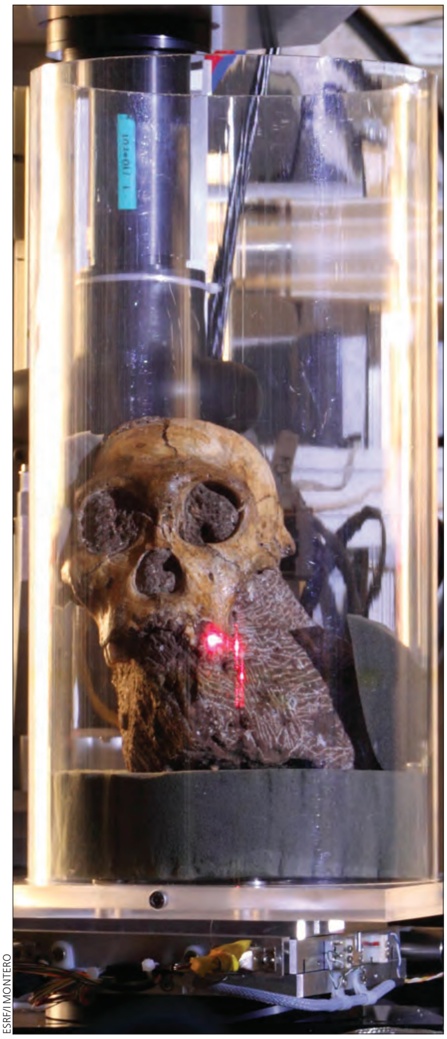
Since 2000, when the ESRF's ID19 beamline carried out the first-ever synchrotron-radiation scan of a fossil, palaeontology research has grown to occupy more than 35% of the ID19 microtomography proposals, with experiments leading regularly to high-impact publications. The recent increase in the beamline's productivity has taken its toll on components, however, and ID19 is now undergoing a major €2 m refurbishment that will maintain the ESRF's position as the world's premier X-ray imaging facility.

The science-driver of the refurbished ID19 remains palaeontology. However, the improvements will directly benefit other research areas, ranging from cultural-heritage studies and materials science to engineering, environmental sciences and biology – with industry taking a growing interest in ID19's imaging capabilities. While smaller beams are the goal of many of the ESRF's revamped beamlines, ID19 is aiming for a bigger, stronger beam that will allow multi-scale imaging at sub-micron resolution of objects that are up to 40 cm across. In particular, the facility will be optimised for high-quality "pink beams" whereby the white beam from the source is filtered to produce a pseudo-monochromatic beam with a large bandwidth and extremely high flux.

"This is a big jump," says scientist-in-charge Paul Tafforeau. "The energy range will increase by a factor of two or three, imaging will be up to 100 times faster than what we can do now, and the maximum propagation distance will be three times longer, so we will be able to do propagation phase-contrast imaging of very large samples at high energy that is unique in the world."

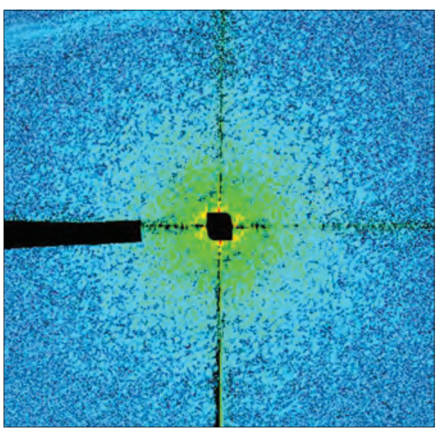
The renewed ID19 is due to be complete by spring 2013. In January work began on an extension to ID19's optics hutch to house new filters and focusing optics, to be followed by the installation of new sample stages and attenuators plus a complete refurbishment of control electronics. During the summer shutdown this year, a new insertion device revolver and a transfocator will be installed while the existing monochromator will be completely refurbished during the 2012 winter shutdown.

The refurbishment project also encompasses ID19's sister beamline ID17, which will be equipped with a new sample stage designed for large-fossil scanning plus a refurbished monochromator for higher-energy operation and eventually a new detector. "The ID19/17 refurbishment will really make a lot of new things possible," says Tafforeau. ● MC



ESRF/I MONTERO

A 1.9 m-year-old large fossil (*Australopithecus sediba*) being scanned at ID19.



Speckle pattern from unstained *Deinococcus Radiodurans* bacteria obtained at ID10C.

ID10: Coherent convergence

The ESRF's ID10A beamline has pioneered the technique of X-ray photon correlation spectroscopy (XPCS). Here, coherent X-rays scattered from a disordered sample produce a grainy diffraction pattern called a "speckle" pattern that allows users to follow the dynamics of condensed-matter systems, such as the mixing and unmixing kinetics in alloys. Located a few metres downstream from ID10A, the ID10C station has recently enabled coherent X-ray diffraction imaging (CXDI) – a technique that provides nanoscale data about samples at higher resolutions than competing imaging techniques.

The ESRF's ID10B branch, meanwhile, specialises in the applications of surface-sensitive techniques for studying the 2D structural organisation and slow kinetics in artificially or self-ordered soft-matter at interfaces, on scales ranging from a few tenths of a nanometre to several micrometres.

Following a significant €2 m refurbishment, the ID10 complex – previously known as the Troika I, II and III beamlines – will restart in June 2012 under the name "soft interfaces and coherent scattering" (SICS). ID10A/C and ID10B will be transformed into one beamline with two end stations working in 50% time-sharing mode. One station (SICS-CS) will be devoted to coherent scattering, namely XPCS and CXDI, while the other (SICS-LSIS) will concern liquid surfaces and interfaces scattering based on X-ray reflectivity and grazing incidence scattering. Each station will benefit from independent optics and instrumentation optimised for each of the techniques, and will be served by two different silicon monochromators, one replacing ID10B's underperforming semi-transparent diamond monochromator.

"The refurbished CS beamline will keep us among the leaders in the field," says CS scientist-in-charge Yuriy Chushkin. Compared with the previous ID10 configuration, the new CS station will operate with a beam intensity twice as large and better coherence preservation, while an extended sample-detector distance will improve the oversampling of speckle patterns as required for CXDI. Meanwhile, the LSIS station, explains scientist-in-charge Oleg Konovalov, has obtained a factor 10 increase in the flux, a larger energy range (8–30 keV), an anomalous scattering option and a faster liquid reflectivity set-up. This will give the ESRF a leading position in studies of buried interfaces, coupling a fine-beam focusing with a small-beam divergence and offering the possibility to probe shorter timescales. ● MC

ANA WRIGHT

Magnetic enigma

The ESRF has settled a 70-year-old controversy surrounding the transition of magnetite, the most primitive magnetic material known, from a conductor to an insulator. Or has it?

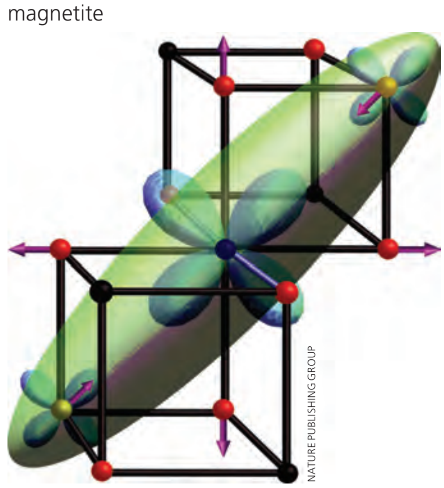
From left: Paul Attfield, Mark Senn and Jonathan Wright with samples of magnetite bought at a market in Brazil. Inset: the electron density in the low-temperature phase of magnetite is approximated by an ellipsoid encompassing three iron sites (blue sphere: Fe^{2+}, yellow spheres: Fe^{3+}).

Two-and-a-half-thousand years ago, humans discovered magnetism. Ancient scholars had stumbled across the seemingly magic property in the dark-coloured mineral lodestone – a permanently magnetic iron ore formed from crystallised magma that paved the way for the first compasses. The magnetic oxide in lodestone is magnetite (Fe_3O_4), yet for the past 70 years magnetite has been the subject of fierce scientific disagreement. "This is the oldest magnetic material known to man," says magnetism expert Michael Coey of Trinity College Dublin in Ireland. "If we don't understand this, then what do we understand?"

The controversy dates back to 1939 when Dutch chemist Evert Verwey discovered that magnetite transforms from a conductor to an insulator at a temperature of 120 K. The "Verwey transition", which has since been observed in other transition-metal oxides, has practical uses such as for identifying magnetite in rock samples and for recognising "magnetotactic" bacteria in sediments. But quite how the mineral becomes an insulator has eluded researchers.

Magnetite is a moderately good conductor at room temperature because its cubic crystal structure contains Fe^{2+} and Fe^{3+} ions on equivalent sites, leaving one electron delocalised and able to hop around. Following ideas developed by physicist Eugene Wigner, Verwey proposed that the change in conductivity at low temperature is due to electrons settling down on alternate sites to form a less symmetric, charge-ordered state. Observing the specific ionic ordering of the low-temperature phase is challenging, however, since fewer than 1% of magnetite's electrons are involved in the transition.

Paul Attfield and Mark Senn of Edinburgh University and Jon Wright of the ESRF have now mapped the complete low-temperature superstructure of magnetite for the first time (*Nature* **481** 173). The team used high-energy X-ray diffraction at the ESRF's ID11 beamline to study the mineral's electron-density distribution as it was cooled to below the Verwey-transition temperature, using an almost perfect single-domain grain of magnetite



NATURE PUBLISHING GROUP

40 micrometers across. "In Europe, this is only possible at the ESRF, thanks to the extremely high energy of its synchrotron X-rays," says Wright.

Based on tens of thousands of X-ray reflections from the crystal, the results show that Verwey's charge-ordered picture is broadly correct, but that the reality is much more complicated. Indeed, to reproduce the low-temperature X-ray data, the team had to superpose no fewer than 168 different patterns of atomic displacements. There was, however, an underlying pattern: the localised electrons appear to be trapped within groups of three iron atoms where they can no longer transport an electrical current, dubbed "trimerons" by the Edinburgh–ESRF team.

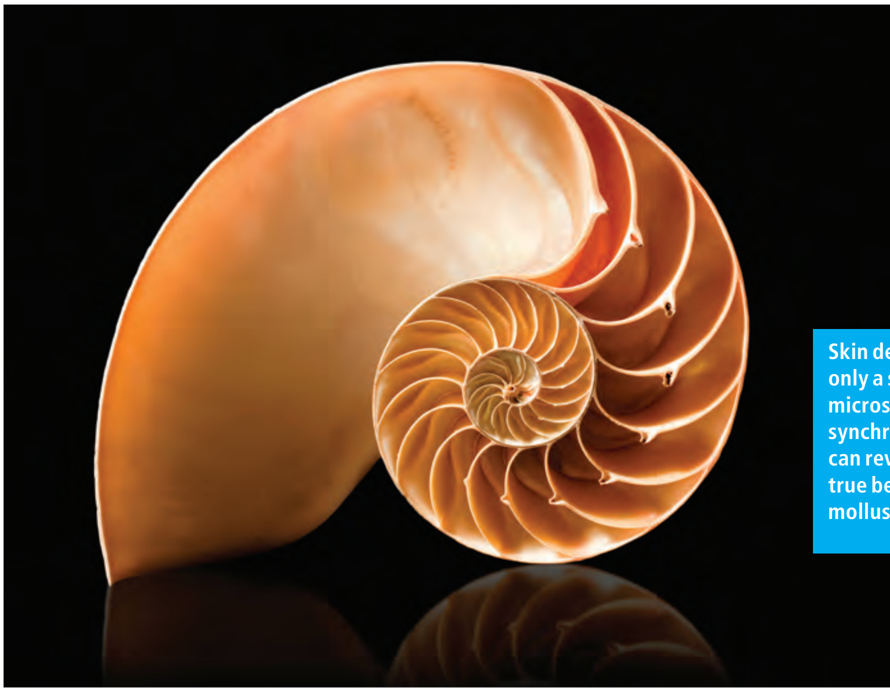
"We have solved a fundamental problem in understanding the original magnetic material," said Attfield, who set his sights on explaining the Verwey transition in 1983 when he came across the problem in a university exam paper. "This vital insight into how magnetite is constructed and how it behaves will help in the development of future electronic and magnetic technologies."

Coey describes the result as a *tour de force*. "At long last the charge order in magnetite below the Verwey transition has been solved," he tells *ESRFnews*.

Yet not everybody is quite so sure that magnetite has given up all of its secrets. Friedrich Walz of the Max-Planck Institute for Intelligent Systems in Stuttgart, who has studied magnetite using "magnetic after effect" techniques, thinks the result should be regarded as a step towards, rather than the final, solution of the "prevailing problems" in magnetite. "The ingenious idea of Attfield *et al.* in observing low-temperature X-ray spectra may, hopefully, contribute to close the impetuous dispute, but it seems to work with micro-crystals rather than with imperfect macro-crystals," he says. "The next question will be to what extent are their results accepted – especially by those groups of X-ray researchers who, despite great efforts, were not able so far to produce comparable spectra below the Verwey temperature."

Matthew Chalmers

Learning from molluscs



SIMON INGATE/ISTOCKPHOTO

Skin deep: only a serious microscope or synchrotron can reveal the beauty of mollusc shells.

Understanding how sea creatures engineer their superior armour inspires advanced materials, ranging from artificial bone to rock-hard semiconductors.

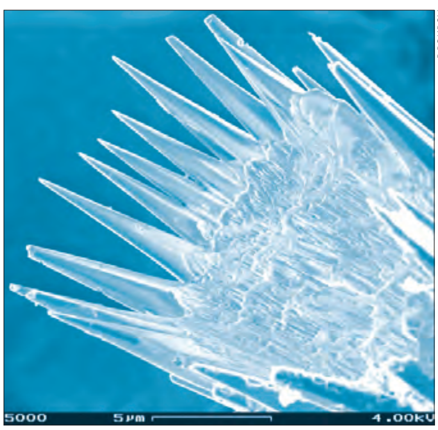
It's hard not to marvel at the beauty of seashells, be it their mathematically intriguing spirals or iridescent mother-of-pearl coatings. But for some people, these surface properties are mere distractions. "I think mollusc shells are much more beautiful when you look at their structure under high magnification," says materials scientist Boaz Pokroy of the Technion Israel Institute of Technology. "It's amazing to see how relatively simple organisms have such a sophisticated way of producing functional materials from such basic ingredients, all at standard temperatures and pressures."

Mollusc shells consist almost entirely of calcium carbonate, the same compound that makes up chalk. Whereas chalk is brittle enough to be broken by a nervous teacher at a blackboard, however, shells are tough enough to protect creatures from the grip of a hungry lobster or other dangers. Mother-of-pearl may look pretty, but the laminated organic–mineral structure responsible for its optical properties is perfect for diffusing cracks. Indeed, molluscs – a diverse class of organisms with tens of thousands of individual species – have survived for over half-a-billion years.

Now, thanks to synchrotrons, researchers are beginning to understand how nature engineers its biomineral armour. "We hope that our model systems, which are simpler than those in nature, will allow us to extract guiding principles that help us to understand biology," says ESRF user Anna Schenk of the University of Leeds in the UK. "But we also want to use those principles to help us to design materials and minerals that are technically more relevant – it's fascinating to find out the processes that govern these beautiful structures that are so hard to replicate in the laboratory."

Biomimetics

The secret to biomineralisation lies in how a tiny amount of organic material, such as a protein, gets incorporated into the crystal structure of a mineral rather than simply acting as glue between crystallites. Experiments carried out at the ESRF during the past five years show that proteins are incorporated into calcium carbonate at the atomic level. Precisely how this happens, giving shells their impressive mechanical properties, is not fully understood. "Another open question is how proteins recognise the crystallographic surfaces of minerals in the first place," explains Pokroy. "A protein is a large molecular soft-matter object that somehow can bind to calcium carbonate or a silicon structure – and moreover, it can bind to a specific crystallographic facet."



B POKROY

The microscopic structure of *Herdmania momus* veteritic spicules, a rare and metastable polymorph of calcium carbonate found in marine filter-feeders commonly called sea squirts. Nanotomography at the ESRF's ID22 beamline is allowing researchers to understand the function of the intricate 3D structures.

Experiments at the ESRF's ID31 beamline have gone some way to answer these fundamental questions, while ID22 has enabled non-destructive, high-resolution imaging of biogenic crystals and structures in 3D. Pokroy and co-workers, who include Emil Zolotoyabko of the Technion and Andy Fitch of the ESRF, have shown for instance that polymers introduce different lattice strains and thus distortions into the mineral crystal. In addition to providing geologists with a technique to differentiate between biological and geological material, such results could help identify what needs to be tuned in technological materials to achieve desired properties.

Calcium phosphate associated to hydrogels, for instance, can be used to make biocompatible bone-replacement materials. But there is also the possibility of transferring this additive-mediated mineral growth to metal oxides or semiconductors to make materials with better mechanical – or perhaps completely new – properties. The self-repairing nature of mollusc shells could even lead to "smart" engineering materials that repair themselves after failure.

"Research is explorative at the moment because we don't understand very well yet what the crucial processes are," says Schenk. "The impact of synchrotrons has been huge because you can study the sub-micron- and nano-structure, and learn about the crystallography of these samples in very small proportions. At ID31 the powder experiments are really well automated so you can measure many samples and look at the results online."
Matthew Chalmers

Machine maestro

The ESRF’s new director of accelerators, **Pantaleo Raimondi**, has plenty of ideas up his sleeve to push the machine performance further.

CARGOUD/ESRF

Pantaleo Raimondi has developed novel ways to focus electron beams into smaller volumes to increase the “luminosity” of particle colliders.

Pantaleo Raimondi took up his new role as director of the ESRF’s Accelerator and Source Division on 1 February, and was just a few days into the job when *ESRFnews* caught up with him. One of the challenges he faced during his first week, he says, was to prise himself away from the machine, having made several revolutions of the tunnel. “I can’t help it – that’s the fun part,” he explains.

Compared with other machines he has worked on, Raimondi says the ESRF source looks very shiny. “All the elements are how they should be, but as an accelerator physicist I already start to think about what might be possible here and there,” he says. “Also, there a lot of new things for me such as insertion devices. The group here is really incredible – in the world everybody basically just copies what they do.”

Raimondi comes to the ESRF from the world of particle physics, having bounced between major electron–positron colliders on both sides of the Atlantic during his 25-year career. For him, however, particle physics and synchrotron science are no different when it comes to accelerators: both provide a service. “A lot of accelerator people don’t like it when I say it, but to me the accelerator is just another piece of ‘detector’,” he explains. “You get gratification through having ideas about equipment and making it better, but the fascinating thing is what these tools bring – the science.”

Previously Raimondi was head of the accelerator division at Italy’s national institute for nuclear and particle-physics research in Frascati (INFN-LNF), where he headed up the “SuperB” project. This €0.5 bn electron–positron collider would study the differences between matter and antimatter by producing copious quantities of particles called B mesons, with plans to turn the facility into a third-generation light source thereafter. Government approval and funding for the 1.2 km-long facility is underway, although Raimondi says that it’s not clear how SuperB will evolve given the strong competition that the project is facing from other “B factories” worldwide.

“Particle physics and synchrotron science are no different when it comes to accelerators”

Best of both worlds

Raimondi trained as a theoretical physicist, whetting his appetite for hardware during his PhD when he worked on the ALEPH detector at CERN’s Large Electron Positron collider (LEP). He made the transition to accelerator physics in 1986 when a position came up at the INFN in Frascati, and then moved to SLAC in the US where he became responsible for focusing the beam of SLAC’s linear collider to sub-micron levels. “After that experience, all my other activities seemed really easy-going,” he recalls. He took his experience back to LEP in the late 1990s before returning to SLAC to work on plans for the International Linear Collider alongside research into compact plasma-based accelerators, returning to Frascati in 2002.

His most significant contributions to accelerator physics concern novel ways to focus particle beams, although Raimondi – who has more than 200 publications to his name – is modest about his achievements. “A good idea might be 10–20% of the final result, but to make it real the credit goes to everyone involved,” he remarks.

His “crab waist” technique, first demonstrated at the INFN’s DAFNE electron–positron storage ring in 2008, uses a simple geometry of sextupole magnets to focus electron beams in much smaller regions. The resulting increase in luminosity, he points out, can increase the performance of future colliders by a factor 100 and extend the physics programme of these facilities by at least a decade. “The low emittance required in this novel scheme matches the requirements for very high-brilliance light sources,” he explains. “It opens up a whole new type of experiment.”

Raimondi says he has a lot of ideas to be added to the long list made by his group to further boost the performance of the ESRF source. “In general the goal is to get smaller and more stable beams, together with the worldwide effort to find new ideas and solutions for synchrotrons, but the ESRF accelerator complex is in excellent shape and the people have an excellent knowledge of it, so my first challenge is to get to the same place as everybody else,” he explains. “I like this attitude of working both on the machine and experiment needs simultaneously, and I see that everybody is keen to push the ESRF’s performance even further.”

Raimondi in brief

Born
Italy, December 1961.

Family
Divorced, two children.

Education
PhD theoretical physics, Bari University 1985.

Work
2007–2011 & 2002–2005: head of Accelerator Division, INFN-LNF
2005–2007: professor, Stanford University/SLAC
1996–2002: physicist, SLAC
1987–1991 & 1993–1994: physicist, ENEA Frascati

Likes
Mountain walking, watersports and running.

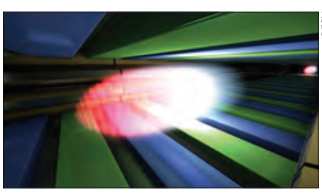
ESRF/I ZANETTE

X-ray antics: This incredibly detailed image of an ant obtained at the ESRF's ID19 beamline is based on a technique called X-ray grating interferometry, which provides high-sensitivity differential phase and dark-field (small angle X-ray scattering) signals. It therefore bears tremendous potential for imaging tiny density differences and structures at the nanoscale that produce low absorption contrast. In the above false-colour image (obtained with an X-ray photon energy of 23 keV and with gratings placed 480 mm apart), green and red correspond to scatter signals in the x and y directions, respectively. 2D X-ray grating interferometry was developed by former ESRF PhD student Irene Zanette (now at the University of Munich) and Timm Weitkamp of the ESRF and SOLEIL, along with colleagues at the Paul Scherrer Institute in Switzerland. (2010 *Phys. Rev. Lett.* **105** 248102).

In the corridors

Record-breaking movie from FLASH

A light source has won an entry in this year's *Guinness Book of World Records* for the fastest "movie" ever shot. Researchers at DESY's free electron laser FLASH in Hamburg demonstrated an interval of 50 fs between two independent images – almost a trillion times faster than the frame rate of a feature film. The team split a coherent X-ray beam into two flashes, one of which was sent on an optical detour of 0.015 mm such that it arrived 50 fs after the first, and then stored both images as superimposed holograms (detectors are not fast enough to be able to read out such quick-fire images). Capturing data on such short timescales allows researchers to track the movements of molecules and nanostructures in real time. However, with a total of just two frames in its record-breaking movie, possibly making it also the world's shortest film, further work is needed before the technique can be used in practice. The feat was carried out in late 2010 (*Nature Photonics* **5** 99).



DESY

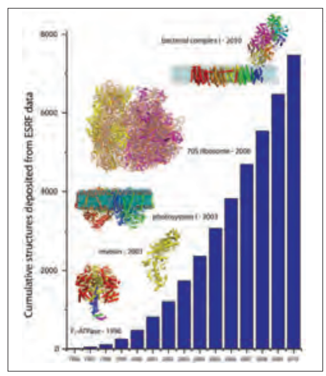
Fastest film ever over in a FLASH.

To tweet or not?

Researchers in the physical sciences have led the way in using computers to analyse data, but they are still conservative when it comes to adopting new web technologies, according to a report by the UK's Research Information Network, the Royal Astronomical Society and the Institute of Physics. Based on surveys of scientists, the report finds that web use varies widely between fields. *Google Scholar*, for instance, is used by 73% of Earth scientists and by 70% of nanoscientists to discover new research findings but by just 13% of particle physicists and 7% of astrophysicists. Meanwhile, whereas all chemists and Earth scientists surveyed say they read online journals, only 38% of particle physicists do so, instead preferring preprint servers such as *arXiv*. Few physical scientists use "Web 2.0" tools such as blogs, *Twitter*, Open Notebook Science, social networks and public wikis to share research data. The report claims that scientists view these services as "distractions" from their communications with key colleagues. A previous survey of researchers in the life sciences also showed that the use of social-networking tools for scientific research is "far more limited" than might be expected.

Structure factory

The ESRF has passed a milestone in its structural biology activities, with the number of protein structures deposited in the Protein Data Bank in a single year (2010) exceeding 1000 for the first time. In Europe, the ESRF now accounts for 47% of total synchrotron structural-biology output. Some 21 540 data sets were collected from 123 309 crystals studied during 2010. The majority of the structures were solved from data collected on the six protein crystallography beamlines run by the ESRF, but significant contributions also came from collaborating research group (CRG) beamlines including BM14, BM16 and BM30A.



ESRF

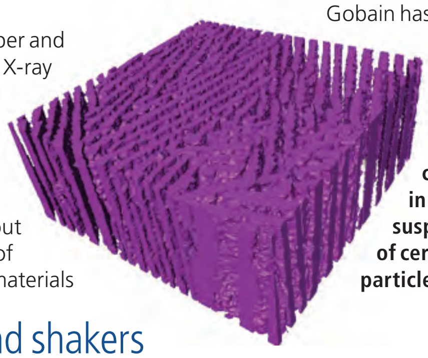
Building the future

Industry giant Saint-Gobain is using the ESRF to develop advanced construction materials.

The traditional way to refresh the air inside a building is to open a window and let fresh outdoor air circulate. But this method tends to clash with the goal of reducing a building's energy consumption. Is there another way to improve the indoor air quality?

Research scientists at Saint-Gobain are using the ESRF to explore innovative construction materials that can remove pollutants from the air in built-up areas. "Indoor air quality is an increasingly important issue in building construction," says chemist Helena Kaper of Saint-Gobain CREE's Laboratory of Synthesis and Functionalisation of Ceramics (LSFC) in Cavaillon, a joint laboratory with the CNRS. "We are studying the effect of different dopants in materials for air purification. The dopants are key to the performance of the materials, but we don't know precisely how."

Last June, Kaper and colleagues used X-ray absorption spectroscopy at the ESRF's BM23 beamline to extract information about the integration of dopants in the materials matrix of a sample, principally by looking at their neighbouring matrix atoms. "We hadn't used the technique before and we quickly realised that our samples were quite complicated, explains Kaper, adding that ESRF beamline staff were vital in guiding the experiment.



Ice crystals in a frozen suspension of ceramic particles.

Strengthening its synchrotron connections further, Saint-Gobain has recently funded an 18-month postdoc position at the ESRF to work with the LSFC. "Having a postdoc based here is a model for industry collaboration that we would like to see more of at the ESRF," says ESRF head of business development Ed Mitchell. Saint-Gobain's recent contact with the ESRF was established in 2009, when the ILL, CEA and ESRF organised an event to showcase their industry capabilities. "It was a chance to meet the people who did XAS on the beamlines," says Julie Russias of the Structure Lab at Saint-Gobain CREE.

Last year, X-ray tomography at BM05 allowed Saint-Gobain researchers to visualise micro-scale defects in monocrystals that contained very small, poorly organised domains. "We have a branch of Saint-Gobain that makes crystals for scintillators, which are used in light detection for security or medical applications," explains Russias. "One of the advantages of working for a large company such as Saint-Gobain is that it can invest in the basic science, and if we can't find any uses for it then we can move on to something else. Applications are long term."

Although most of Saint-Gobain's ESRF research is proprietary, the company has also used public beam time on ID15 and ID19 for imaging. In 2009, for instance, Sylvain Deville and co-workers at the LSFC froze a concentrated suspension of ceramic particles and were able to observe the growth of ice crystals *in situ*, shedding light on natural freezing mechanisms that affect the processing of construction materials (*Nature Materials* **8** 966).

"For us the ESRF is really a need because it's a tool that gives us information on a scale that we cannot get in the lab," says Deville. "We are constantly discovering new X-ray techniques that are useful to us, so there is much more to come."

Matthew Chalmers

Glass act: Saint-Gobain at a glance

Saint-Gobain is one of the largest companies in the world, with almost 200 000 employees in 65 countries and annual sales exceeding €40 bn. From its beginnings as a glass manufacturer in Paris in 1665, the company has expanded into all aspects of construction materials and has 12 research centres. Glass research is still a core activity, carried out at a joint CNRS laboratory in Aubervilliers, Paris. Scientists there have recently used the ESRF's ID15a and ID19 beamlines to study the interplay between the microstructure and the numerous chemical reactions at play during glass melting.

Movers and shakers

Prize-winning thesis

ESRF user Anne Möchel, a physicist at the Peter Grünberg Institute at Julich, has won the German Thermoelectric Society's Young Researchers Award 2011 for her doctoral thesis: "Lattice dynamics in thermoelectric Zintl phases". While researching her thesis, Möchel made extensive use of the ESRF in addition to an impressive number of other major facilities both in Europe and the US.

Skin studies recognised

French fashion house and cosmetics manufacturer Chanel has bestowed its 2011 CE.R.I.E.S. Award, which honours research concerning physiology or biology of healthy skin and/or its reactions to environmental factors, to ESRF user Joke Bouwstra of the Leiden Amsterdam Centre for Drug Research in the Netherlands. Bouwstra, who researches the skin barrier, plans to use the €40 000 award to undertake further research at the ESRF.

Going for gold

ESRF scientist Anatoly Snigirev has been awarded the gold medal of the RAMES State Committee of Science of the Republic of Armenia for his collaboration within the French–Armenian partnership programme over the past 25 years.

Back to school

In October, 30 European science teachers descended on Grenoble to attend a three-day course on the physics and chemistry of life, organised by EIROforum. Participants attended lectures and tutorials delivered by researchers from the EMBL, the ESRF, ILL and the European XFEL, where they learnt how electrons, neutrons and X-rays can be used to enable 3D studies of proteins, macromolecular complexes, viruses and entire cells.

That's 'Sir' Venki to you

Venki Ramakrishnan of the University of Cambridge in the UK, ESRF user and winner of the 2009 Nobel Prize in Chemistry, was knighted in the UK's 2012 New Year Honours list for services to molecular biology. The Queen confers the title of Knight Bachelor, which entitles male recipients to use "Sir" before their names, at a ceremony at Buckingham Palace.

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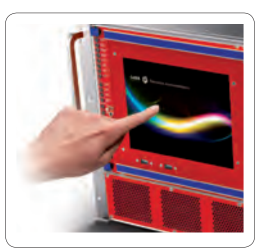

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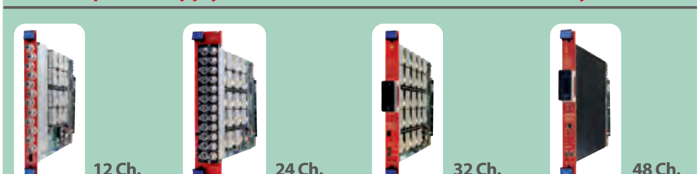

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