N°22

LE RAYON DE SOLEIL

THE SYNCHROTRON MAGAZINE

2012, 10 years with SOLEIL

SOLEIL SYNCHROTRON

CONTENTS

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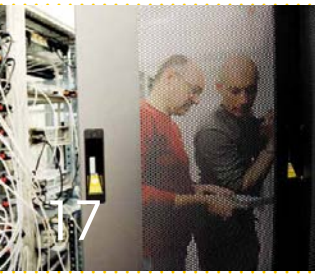

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Editorial

Jean Daillant
Director General

On November 6, 2002, SOLEIL was granted permission from the Saint-Aubin local authority to build a synchrotron on the Orme des Merisiers site.

In the last ten years, the SOLEIL teams have succeeded in designing, constructing and deploying one of the best synchrotrons in the world. We have made some ambitious decisions during our quest to achieve scientific excellence and to share our know-how, and their relevance is evident today: SOLEIL's sources and accelerators are given as examples. Over 4000 different users both in France and across the world have already chosen SOLEIL. An abundance of results was obtained that we could never have imagined ten years ago. We have developed large-scale regional, national and international partnerships. We have also become a scientific and technical culture center, open to the general public. We are grateful for all the support that we have received along the way from our shareholders at the CNRS (French National Center for Scientific Research) and the CEA (French Atomic Energy and Alternative Energies Commission), as well as our territorial partners, the Ile de France and Centre regional authorities, and the Essonne departmental authority. This support has allowed us to concentrate our efforts on our end goal, that is, providing scientific communities with top experimental and analytic tools, and guiding each individual discipline so that they may benefit fully from these assets.

The next 10 years will prove just as exciting. The first beamlines are now mature and, through new developments, have started to show a wider potential than originally envisaged, and the new beamlines will provide us with possibilities that were not even imaginable ten years ago. The challenge now is to maximize their impact for all our different scientific communities and industrial partners.

ON THE PROGRAMME

SOLEIL beamlines

THE EXPERIMENTAL PROGRAM AT SOLEIL INCLUDES THE PROVISION OF 29 BEAMLINES. Most recently included in this program are the long ANATOMIX beamline (formerly known as "Nanotomography"), which will provide further opportunities for nanoscale imaging, especially in the biomedical and advanced materials fields, PUMA, part of the IPANEMA* platform, which will be dedicated to the study of ancient materials and ROCK, which focuses on issues related to energy. ROCK and ANATOMIX are being developed in part through Equipex programs.
At the end of 2012, 21 of the 29 lines are open to users and 3 others (PROXIMA2, PSICHE and SIRIUS) will be available in 2013.

*Institut Photonique d'Analyse Non-destructive Européen des Matériaux Anciens, (European Photonic Institute for the Non-Destructive Testing of Ancient Materials), the first platform in Europe dedicated to the study of ancient materials.

ACCESS

Receiving outside users

THE SOLEIL BEAMLINES ARE AVAILABLE TO OUTSIDE USERS around 230 days per year, representing an annual total of about 690 eight-hour sessions per beamline, up to 10% of these targeted at industrial projects. These users from state research laboratories, companies, hospitals, museums... have 3 modes of access. A "classic" half-yearly (February and September) call for projects evaluated by six International and independent SOLEIL Scientific Committees, providing free access to SOLEIL beam time, with an obligation to publish the results.
There is also "à la carte" access, without prior selection, where services are paid for and the results can remain confidential. Finally there is "tailored" access for collaborative research projects between SOLEIL groups and public and/or private outside research groups.

2002

6th November: SOLEIL obtains a building permit from the Mairie of Saint Aubin

2006

18th December: SOLEIL officially opened by the French President, Jacques Chirac

2008

January: SOLEIL opens its doors to outside users

IN BRIEF

A REMINDER

In 2012, there are about 400 people working on site every day at SOLEIL, welcoming 3000 users conducting their research on the beamlines.
They will come across 5000 visitors curious to discover the synchrotron. All with an annual operating budget of 60 million euros.

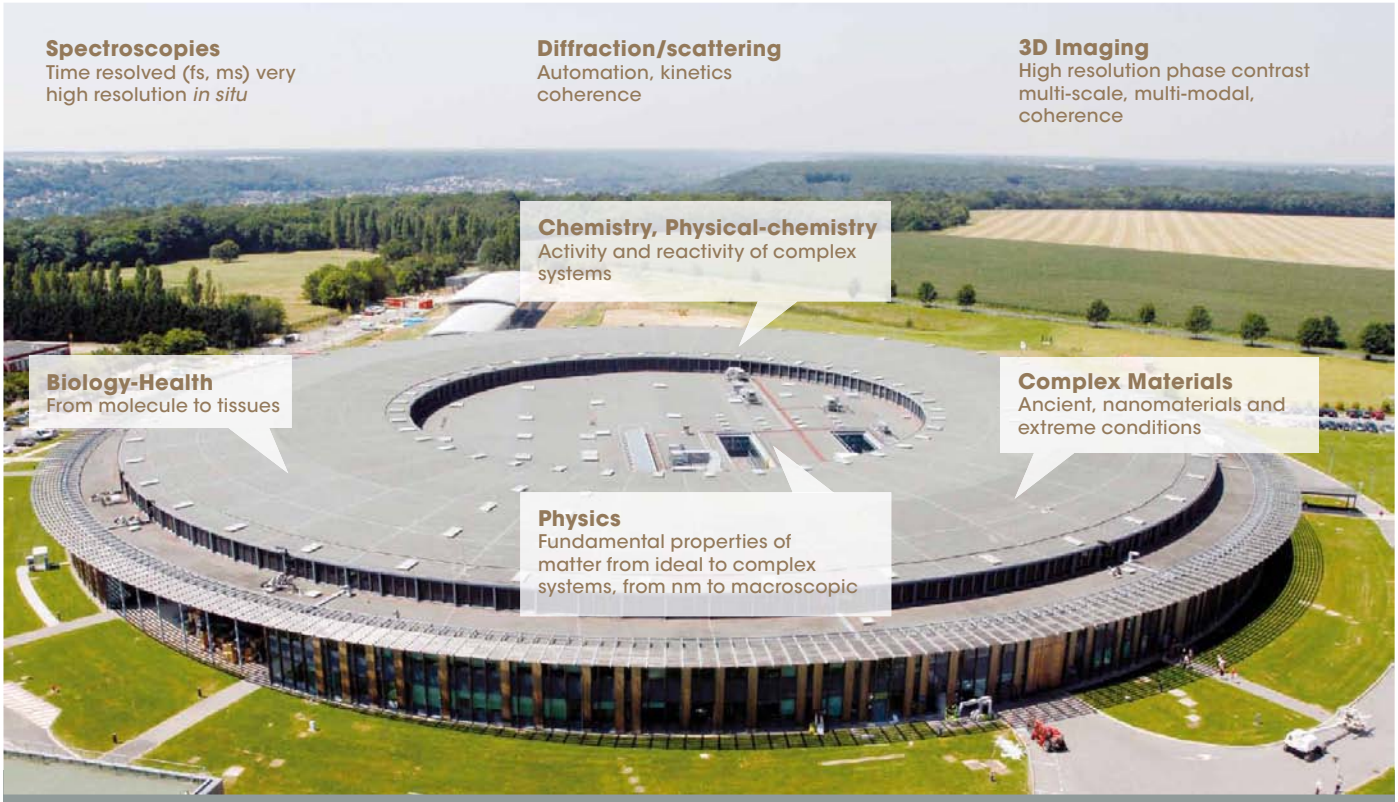
SOLEIL WEBTV

In 2010, SOLEIL created a platform on Dailymotion, a French video-sharing website. Fifty videos are now available, generating more than 41,000 viewings. New programs are being developed, including augmented reality. SOLEIL accounts were opened on Twitter, Facebook and LinkedIn in 2012. Since then, the number of weekly visits to the SOLEIL website via social networks has been multiplied by 10.

ORIENTATION

SOLEIL's strategic plans

SOLEIL is focusing its efforts and performances on four strategic areas: chemistry and physical chemistry, biology and health, complex materials and ancient materials, and finally physics.



The specificities of the 26 SOLEIL beamlines operating in 2013, with three new beamlines in the pipeline for 2015, and the expertise of the scientists who run them, reflect its strategic goals. Chemistry and physical chemistry concentrate on the study of the properties of complex model systems. Biology and health covers the study of isolated molecules right up to cells and tissues. The complex materials and ancient materials field spans the study of their structures on the nanometer scale to their properties under extreme conditions, while physics leans towards the fundamental properties of matter, aiming to make the link between isolated systems and those placed in a complex environment.

Chemistry

Regarding chemistry and physical chemistry, the specificity of synchrotron radiation is to provide a wide spectral range of X-rays perfectly adapted to the identification, quantification and speciation of the chemical elements involved, regardless of the structural and molecular organization of the sample in which they are present: liquid, gel or solid. Relying on technological developments in terms of focusing the X-ray beam, selecting its wavelength and its detection length, it is now possible to map characteristics with micrometer resolution under native conditions,

as well as time-resolved studies of structural transitions in the millisecond range. Specifically, these may concern, for example, the characterization of nucleation and growth phenomena, the study of catalysts during reactions, and studies on the organization, structure and reactivity of soft interfaces and self-assemblies.

Biology and Health

In the broad field encompassing biology and health, the whole spectrum of radiation provided by SOLEIL, from infrared to hard X-rays, is used for multi-modal and multi-scale analysis of live material. Beamlines have been designed specially to allow the study of isolated macromolecules on the atomic scale up to two- and three-dimensional quantitative imaging of cells and tissues at spatial resolutions of a few tens of nanometers. The methods available include X-ray diffraction and scattering, IR and VUV spectromicroscopy, X-ray absorption and fluorescence, and the use of coherent X-ray tomographic imaging under non-destructive and very high resolution conditions. Offering methods unique to synchrotron radiation and leading-edge instrumentation with the latest available technologies, the eight beamlines involved provide morphological and functional information resulting from an integrative approach to biology and its applications in pharmacology and biomedicine.

Physics

In fundamental physics, the emphasis is on very high spectral or angular resolution, thereby providing users with unprecedented characterization tools for both spectroscopy and diffraction based structural analysis. The spectral range available goes from the far IR (even in the THz, i.e. a few cm-1) to hard X-rays. Analyzers and spectrometers available are at the forefront of current technology with complex sample environments that make it possible to establish a continuum between a perfectly characterized isolated system and the same system placed under «real» conditions (high pressure, matrices, nanoparticles, aerosols, etc.). This also goes for studies at reduced lateral scales (using microscopes or nanobeams), which allow or will allow linking the properties of matter at the local level and the properties of samples on a macroscopic scale (so-called mesoscopic approach). A special effort has been made at SOLEIL to promote time-resolved studies by means of pump-probe experiments coupling laser and synchrotron radiation on the scale of a few ps or fs.

Paul Morin (on the left) and Jean-Pierre Samama, scientific directors of SOLEIL.

Materials

Finally, in the materials field, the aim is to characterize advanced materials to better control their functionalization or behavior in extreme situations (stress and strain, pressure, temperature, radioactivity etc.) To this end, a special effort has been made to enrich the range of observation conditions, often by combining several experimental techniques requiring the use of several beamlines for the same project. Regarding heritage material, an original approach is being developed with the construction of the IPANEMA platform next to the synchrotron to receive and optimize long-term projects.

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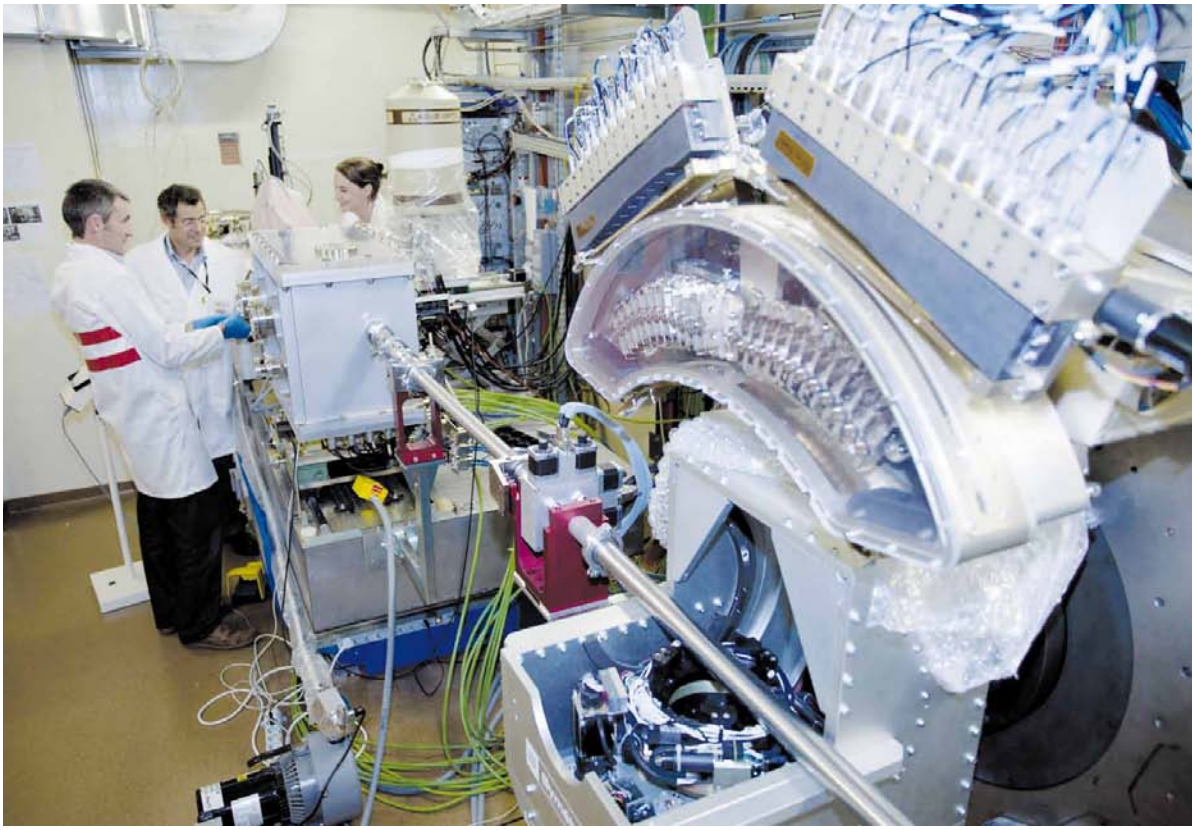
RESEARCH AND DEVELOPMENT

Customized optimization of SOLEIL beamlines

SOLEIL has 29 beamlines planned for 2015, of which 26 are already operating today. To be able to conduct the research needed by those who designed and run these beamlines, as well as the scientific communities who ask to use them, all groups at SOLEIL are mobilized. They are adapting or developing equipment to maintain at the highest international level the scientific results obtained at SOLEIL. The work is "customized" to overcome problems specific to each beamline.



In the experimental hutch of the MARS beamline, with its diffractometer on the foreground.

First came the building

The machine part - accelerators and storage ring - and SOLEIL beamlines were built on a concrete slab 80 cm thick, placed on 600 concrete piles driven down to a depth of 15 meters. These are therefore balanced "on stilts" on a separate structure from the rest of the building to minimize the impact on the electron beam trajectory of vibrations produced around the site (vehicles on neighboring roads, for example), and prevent settling due to the presence of expanding clay in the soil.

These already restrictive provisions, which meet stringent stability specifications, are far from sufficient for Nanoscopium. This 155-meter-long beamline (see Rayon de SOLEIL 21, p9) requires constraints that are 30 times greater, especially with regard to rotational deformities of the structure.

Imagine wanting to pierce an apple with an arrow placed in front of the Eiffel Tower, aiming from... Athens. This is equivalent to what is expected, in terms of accuracy, from the X-ray beam the wall of the storage ring and hitting a sample placed in the Nanoscopium experimental hutch. Effects related to wind or temperature – likely to cause deformities much greater than the stability criteria imposed - are parameters normally taken into account in architecture. But when you have to consider vibrations on such a precise scale, this becomes much more unusual.

The originality of the project lies more in the approach than in the means used. Since 2008, plans show, to the nearest millimeter, at what points beamline stability must be maximized. Then, performance is achieved by the geometry and

Installation of a mirror in the optics hutch of the DEIMOS beamline.

thickness of different independent concrete slabs, tailored to each of these "strategic" points, upon which the beamline will rest. Faced with such a challenge, we had to take risks and get started, because there were no precedents to rely on. Mission accomplished: tests at the end of October showed that the Nanoscopium hutches are stable to the said specifications.

A la carte insertion devices

At SOLEIL, 21 beamlines operate with insertion devices, sometimes with two different undulators. However, no two are completely identical, and some of them have been entirely designed at SOLEIL to meet the exact requirements of researchers (see insert). But this willingness to customize does not prevent having an overview: among the components of undulators, some are present in several different types, like building blocks. A «duplication» strategy is illustrated by the fact that the modulator wiggler used to create the ultra-short electron bunches for the slicing experiments carried out on the CRYSTAL and TEMPO beamlines, is also used as the light source for the PUMA beamline (see Rayon de SOLEIL No. 20, p11): a two-in-one wiggler, if you like.

More conventionally, but always with machine optimization in mind, canted undulators have permitted two beamlines to be installed on a single straight section of the ring, for the two parts of the PROXIMA2 beamline and the Nanoscopium / ANATOMIX beamlines. And, in general, the whole optical setting of the ring has been designed to satisfy the users of the beamlines in terms of the size of the electron beam source points, by guaranteeing excellent machine performance (notably the life of the beam).

Another very popular feature: after maintenance periods, just a weekend of beam is sufficient to reach the vacuum necessary for conducting experiments, so users are not penalized. This advantage is due to having chosen to cover the walls of the vacuum chambers with NEG1 deposits over 60% of the ring. This makes the conditioning of the ring much shorter when starting-up the machine, saving about half the time.

Cutting edge optics

With beamlines aiming to perform at the limits of current technology, innovation is required. On Nanoscopium, having reliable optics means that, on the active zone, which is one hundred millimeters in length and one mm in width, the acceptable pitch deviation on the mirror surface is below 1 nm. Polishing a mirror to such precision "in one go" is not feasible and local adjustments must therefore be carried out during a second phase, in order to meet the stringent surface specifications required. To these alterations must be linked a nanometrology step in order to verify that the required specifications have indeed been met. However, measuring instruments on this scale do not exist!

This is why, since 2010, the Optics Group at SOLEIL has developed in collaboration with two local companies, EOTECH and MB Optics, an interference microscope that will control these ultra-high precision mirrors but also other optical elements at SOLEIL. Because of its resolution, this instrument has a reduced field of view. To measure an optical surface this is moved step by step under the instrument. A large number of data sets are thus collected. They must be connected after subtracting the internal reference of the interferometer to obtain the topography of the optical surface, known as stitching interferometry. One difficulty is that the reference is not absolutely known. The solution under development is based on the fact that the same point on the surface is measured several times, each measurement involving a different point of the reference. Thanks to the resolution and stability of the instrument and to the redundancy of the measurements, the test surface and the reference are both reconstructed.

The microscope and stitching algorithms, in which synchrotrons and optics manufacturers have expressed an interest, are currently

- **Nanoscopium :** the first cryogenic in-vacuum undulator (77K) with PrFeB-based magnets.
- **DEIMOS :** in-vacuum undulator resulting from the original combination of two existing concepts - coupling permanent magnets and electromagnets/copper-plated coils - to switch the polarization direction (right/left helicoidal) of the X-ray beam with a frequency of 5 Hz.
- **SIRIUS :** ultra-short period Apple II undulator giving high energy X-rays with linear polarization.

Discussion within the "Conception-Engineering" group.

undergoing validation on test surfaces. As the software has been developed to run in a modular fashion it will be possible, for example to substitute parts with existing SOLEIL software; yet again, as for sources, there is a desire to make the most of our existing material.
SOLEIL beamlines will benefit from another development of the Optics Group, alternate multilayer gratings (AML). Under specific beam incidence conditions, the alternate multilayers have both the advantages of a multilayer grating and a crystal as they allow it to choose the order of diffraction of the incident beam (its energy must be above 1000 eV for this), and they have "multilayer behavior" by greatly increasing its reflectivity.
The preparation of these rather complex gratings is the result of a collaboration between the Horiba Jobin-Yvon company, SOLEIL and the Optics Institute. Jobin-Yvon provides the "network substrate" (based on Si) etched according to the target period and depth requested. Then, at SOLEIL, the etching is characterized by AFM. As these parameters are known, diffraction efficiency is optimized by computer simulation, to define the optimal multilayer. Then multilayer deposits (Mo_2CB_4C, MoB_4C or CrB_4C) are created at the Optics Institute, with calculated thicknesses. A final check is made on the metrology beamline at the wavelength used. The DEIMOS AML will soon be mounted on the beamline, and then SIRIUS and HERMES will follow.

Positioning the sample

Positioning of the sample in the photon beam also has to meet very high demands. Whether it is varying the angle of incidence of X-rays for nanoARPES measurements on ANTARES (see Rayon de SOLEIL 21, p4), moving the sample in the X-ray beam on HERMES to reconstruct 2D chemical images using STXM microscopy, or rotating this sample to obtain 3D images on the tomography beamline ANATOMIX, in all cases the resolutions are of the order of several tens of nm. On these scales the mechanics are never perfect. The periodic defects of guiding using ball-bearings or rollers are avoided by replacing these movements with flexural deformation systems, which allow precise displacements on a nanometer scale. Areas to analyze can reach up to several millimeters, so the positioning devices use a «two-stage» mechanism; the first, fully designed by the SOLEIL Design and Engineering Group can move over the sample where each zone is then finely scanned by the second commercially available stage (total stroke of 50 microns for ANTARES). Thus, a mosaic of areas is analyzed consecutively.

As for the buildings, discussed above, sensitivity to vibration and heat need to be taken into account. To minimize the effect of temperature variation, the materials chosen have low coefficients of thermal expansion, piezoelectric motors are used and therefore do not warm up at all when stopped, and assembling tricks, using the direction in which expansion takes place, neutralize the effects. These effects are even more critical in the case of instruments under vacuum (HERMES), because of lower heat dissipation.

The temporal dimension also needs to be taken into account: on Nanoscopium, the relative positions of the optical elements (mirrors, slits) producing a secondary X-ray source must be micron stable for 8 hours to obtain a stable nano-beam on the sample that is 70 meters away. To measure this, a kind of electronic "water level" is installed stretching from the beam monitors in the ring to the granite stand where the sample will be placed, more than 150 meters away. This Hydrostatic Leveling System (HLS) has been optimized by SOLEIL's Alignment and Metrology Group, based on a commercially available instrument.
Then, during analysis of the sample, all nano-movements must be monitored and controlled. Again, there are two measurement levels: for a resolution of a few tens of nanometers, commercial optical encoders suffice. For greater precision, specific interferometers are being developed at SOLEIL. That of ANTARES is in operation, while that of HERMES is being defined. Information (analysis of interference fringes created between a reference light beam and a measurement beam) is used to correct mechanical defects that distort movement.

Detecting the signal

Third generation sources such as SOLEIL allow for experiments requiring space- and time-resolved measurements, while maintaining wide information dynamics. To have detectors that match the performance of its machine, SOLEIL collaborated with the Marseilles Center for Particle Physics (CPPM) and the ESRF beamline, CRG-D2AM, to develop a new generation of so- called hybrid pixel 2D detectors (see Rayon de SOLEIL No. 21,

p20). Adapted to the characteristics of the hard X-ray beamlines, these consist of a sensor the rear face of which is pixellated, each pixel being coupled to an electronic counter etched on a dedicated circuit. Similarly to CCD cameras, these "XPAD3" detectors measure the number of photons emitted by the sample and their positions, but they also offer several extra advantages. An energy threshold can be set beyond which these photons are detected, which reduces noise and accurately identifies the emitted photons, especially during experiments using a polychromatic incident beam (Laue diffraction). Another advantage: the sensor can be in standard Si or CdTe, more sensitive to high-energy X-rays (>15 keV).
Methodological developments have also been made in terms of the XPAD3 operating system in order to significantly improve its measuring abilities: it is possible to accumulate recordings of photons detected over hundreds or even thousands of repeat cycles of the same experiment with a duration of the order of one second. By synchronizing the XPAD and the experimental cycle, data are stored in memory registers corresponding to N phases of the cycle, and ultimately the XPAD provides, not Nx1000 images, but N, which greatly simplifies data treatment.
Finally, in a synchrotron such as SOLEIL, photon pulse durations are used to study dynamic phenomena on the scale of picoseconds (10^{-12} s), and thanks to the new slicing technique (see Rayon de SOLEIL No. 20, p11) even femtosecond pulses (10^{-15} s) have been reached. For this, a sample is excited with a laser and then probed with synchrotron radiation at different time intervals after excitation. These "pump-probe" measurements are repeated at the laser frequency – i.e. up to 10 kHz - to obtain sufficient amounts of data. For this type of experiment, the electron bunches circulate in the ring at a frequency of 847 kHz. There are, therefore, almost 85 times more "probe" "than pump", so it is necessary to select the photon pulses immediately following laser excitation. Until now, the solution had been to use a mechanical chopper to stop the "surplus" electron bunches, an expensive solution difficult to set up and regulate, and limited to a frequency of 1 kHz. Using XPAD 3.2, the selection is now made at the detection level: only the photons emitted after the pulse probe of interest are counted. For this, an electronic signal synchronized with the radio-frequency system of the storage ring successively inhibits and disinhibits all the pixels of the counter, during the passage of electron bunches. An electronic "chopper" that has already proved itself on the CRISTAL beamline.

... and acquisitions "on the fly"

Faced with changes in the means of taking measurements, and how to optimize beam time, the challenge is to obtain the maximum of data in the shortest time - while having the possibility, before launching an experiment, of validating the experimental conditions to ensure the collection of relevant data is possible. Hence, the need to have real-time feedback on the current acquisition. This is the goal of fly-scan, the principle of which is to measure several experimental dimensions in parallel, e.g. the position of the detector, the intensity of the photon beam and experimental information (fluorescence, absorption, or diffraction measurements with the XPAD, for example), and not step by step, but on the fly. One dimension is thus measured continuously and all the others are associated with it, the idea being to add as many extra dimensions as desired.
This unprecedented "made in SOLEIL" system of simultaneous multi-technique data acquisition is based in part on the existence of a clock common to all measurement systems (distributing an electronic signal, the role of which is to synchronize acquisitions). It also requires an ad hoc software infrastructure developed around the NeXus format (see Rayon de SOLEIL 20, p20), which allows for data homogenization. When the synchronizing signal triggers one of the actors of the system, it generates a data series stored in an individual elementary file specific to the device activated. And, all individual files relating to the experiment are merged into a single file as output. It thus becomes possible to correlate completely independent systems, all information having been brought to the same time base.
SOLEIL fly-scan was initially developed for Nanoscopium and will eventually be offered to other beamlines.
Setting up this acquisition system also involves a whole management structure - storage, processing and availability to users – the generation of a huge data stream involving, notably, SOLEIL's data storage infrastructure.
A huge challenge that SOLEIL's Computer and Electronics Division is now trying to meet.

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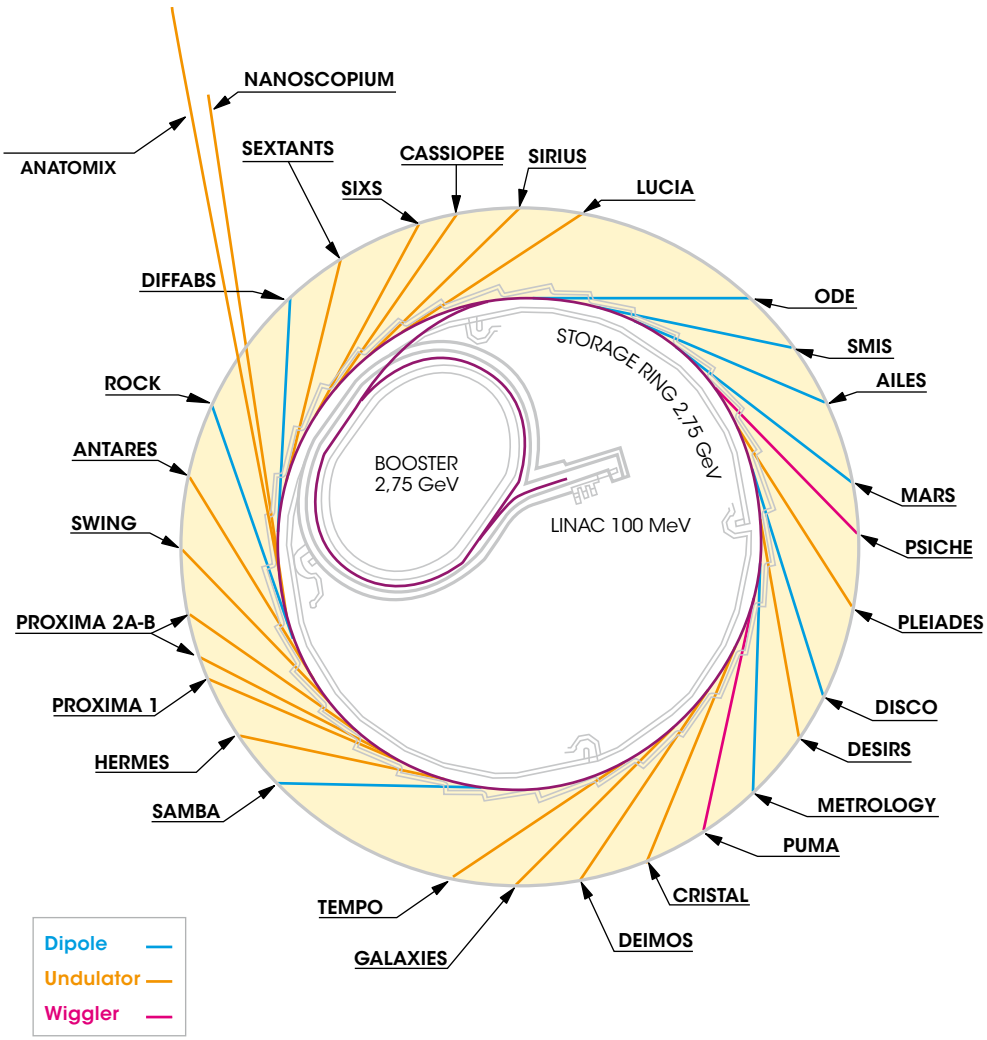
1- NEG (non evaporative getter): titanium zyrconium and vanadium alloy deposited in a layer ~ 1 micron thick.

In the "Detectors" laboratory.

PANORAMA

The SOLEIL beamlines

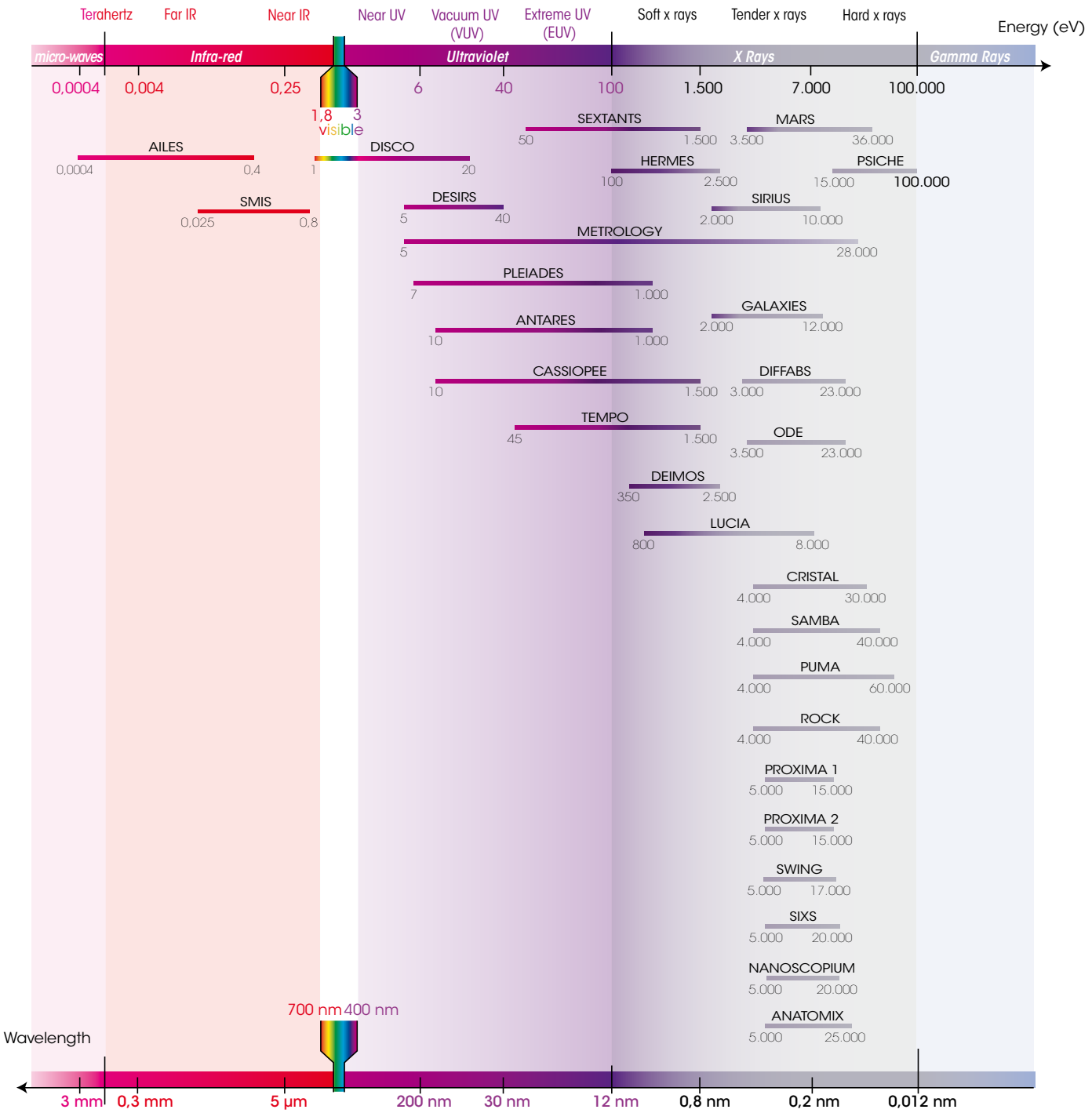
At SOLEIL, the beamlines provide access to one of the broadest energy ranges of all existing synchrotrons.



- LUCIA: XAS, X microscopy, X fluo
- ODE: XAS (dispersive), XMCD
- SMIS: IR microscopy, IR spectroscopy
- AILES: IR &THz spectroscopy
- MARS: XAS, X fluo, XRD, SAXS – on radioactive samples
- PSICHE : XRD, tomography (absorption) - high P&T
- PLEIADES: XPS, VUV-soft x-ray absorption
- DISCO : UV-visible microscopy, UV spectroscopy, UV fluo, UV dichroism
- DESIRS: UV-VUV absorption, VUV dichroism
- METROLOGIE: scattering, XRD
- PUMA: XAS, XRD, X microscopy, tomography, X fluo
- CRISTAL: XRD – condensed matter
- DEIMOS: XMCD
- GALAXIES: inelastic x-ray scattering, hard XPS
- TEMPO: XAS, time-resolved XPS, XMCD / XMLD
- SAMBA: XAS, Raman, UV-visible absorption
- HERMES: soft x-ray microscopy, XPS
- PROXIMA1: XRD - biocristallography
- PROXIMA2: XRD – biocristallography
- SWING: SAXS
- ANTARES: XAS, microscopy, angle-resolved XPS, nm scale
- ROCK: XAS
- DIFFABS: XRD, XAS, X fluo
- ANATOMIX: tomography (phase contrast), X microscopy, nm scale
- NANOSCOPIUM : XAS, X fluo, X microscopy, nm scale
- SEXTANTS: XAS, XRD, resonant x-ray scattering
- SIXS: SAXS & XRD – surfaces & interfaces
- CASSIOPEE: XAS, angle, energy, spin-resolved XPS
- SIRIUS: grazing incidence XRD & SAXS, X fluo

Fluo : fluorescence spectroscopy
IR: infrared
P&T : pressure and temperature
SAXS: small angle x-ray scattering
THz: terahertz
UV, VUV: ultraviolets, vacuum UV (high energy UV)
XAS: x-ray absorption spectroscopy
XMCD/XMLD : x-ray magnetic circular/linear dichroism
XPS: x-ray photoelectron spectroscopy
XRD: x-ray diffraction

10 years


Terahertz
Far IR
Near IR
Near UV
Vacuum UV (VUV)
Extreme UV (EUV)
Soft x rays
Tender x rays
Hard x rays
Energy (eV)
micro-waves
Infra-red
Ultraviolet
X Rays
Gamma Rays
0,0004
0,004
0,25
1,8
3
visible
6
40
100
1.500
7.000
100.000
SEXTANTS
50
1.500
MARS
3.500
36.000
AILES
0,0004
0,4
DISCO
1
20
HERMES
100
2.500
PSICHE
15.000
100.000
SMIS
0,025
0,8
DESIRS
5
40
SIRIUS
2.000
10.000
METROLOGY
5
28.000
PLEIADES
7
1.000
GALAXIES
2.000
12.000
ANTARES
10
1.000
CASSIOPEE
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1.500
DIFFABS
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8.000
CRISTAL
4.000
30.000
SAMBA
4.000
40.000
PUMA
4.000
60.000
ROCK
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40.000
PROXIMA 1
5.000
15.000
PROXIMA 2
5.000
15.000
SWING
5.000
17.000
SIXS
5.000
20.000
NANOSCOPIUM
5.000
20.000
ANATOMIX
5.000
25.000
700 nm
400 nm
Wavelength
3 mm
0,3 mm
5 µm
200 nm
30 nm
12 nm
0,8 nm
0,2 nm
0,012 nm

RETROSPECTIVE

Building assets

December 2001.
The land is subject to preventive archaeological excavations (Inrap) before a building permit application is made.

March 2003.
A board shows what's being built beyond the fence...

March 2004.
The walls of the LINAC and the booster.

July 2004.
Framework of the roof of the synchrotron building under construction.

November 2004.
Setting up the first elements of the LINAC. This is operational for the first time in July 2005, followed by the booster in October 2005.

March 2006,
the DESIRS optical hutch in the experimental hall, still almost empty.

March 2006.
The ring is ready. The first electrons will circulate in May 2006.

May 2006.
View down into the DIFFABS optical hutch. In September 2006, DIFFABS is the first SOLEIL beamline to produce photons.

June 2003.
After terracing of the land, the foundations of LINAC, the booster and the ring can be seen.

December 2003.
The ends of some of the 600 piles are visible that support the concrete slab on which SOLEIL's accelerators are built.

October 2005.
The tunnel of the storage ring gradually fills up.

March 2006.

July 2012.
The building extension to house the Nanoscopium and ANATOMIX beamlines is visible at the top right of the photograph.

September 2012.
Synchrotron building extension for Nanoscopium and ANATOMIX.

SPOTLIGHT ON

SOLEIL accelerators
specificities and innovative aspects

In the booster tunnel.

Ten years after the starting of its construction and after five years of operation, SOLEIL delivers photons to 27 beamlines with five possible filling patterns, all in Top-up injection mode. Their characteristics and performances are summarized in Table 1. The transverse feedback (bunch by bunch digital feedback system) is essential at SOLEIL in order to keep a high intensity beam stable together with transverse dimensions close to the theoritical ones. The systems that have been developed are highly efficient in multibunch, hybrid, 8 bunch and single bunch modes. The targets of 500 mA stored in 416 bunches, 100 mA in 8 bunches and 20 mA in a single bunch, have been achieved with good performances in terms of beam position stability, beam size stability, injection efficiency and beam lifetime.

The availability of the photon beam during user operation and the mean time between failures (MTBF) are improving year after year as shown in Figure 1, and have reached in 2011 record values of 98.4% and 56 h respectively.

Unprecedented approaches have been successfully applied in the design of accelerators and have showed, after several years of operation, good performances:
- High ratio (45%) of insertion device (ID) straight section length over a total 354 m circumference.
- Intensive use of Non Evaporable Getter (NEG) coating vessels in all the Al chambers (56% of the circumference).
- Development of a dedicated "HOM free" Superconducting RF cavity.
- Development of 180 kW 352 MHz solid state amplifiers.
- Innovative Insertion Devices.
- Extremely tight requirements for beam position stability and transparent Top-up operation.
- New type of beam position moni-

Table 1: the different operation filling patterns proposed at SOLEIL.

MODE OF OPERATION	USER OPERATION	ULTIMATE PERFORMANCE ACHIEVED
Multibunch	430 mA	500 mA
Hybrid	425 mA + 5 mA	425 mA + 10 mA
8 bunch	88 mA	100 mA
1 bunch	12 mA	20 mA
Low α (Hybrid): bunch length and bunch current	4,7 ps RMS and 65 µA per bunch	2.5 ps RMS and 10 µA per bunch

tor (BPM) digital electronics: LIBERA modules.

SOLEIL has been designed as a low emittance synchrotron light source with a modified Chasman-Green optics accommodating a total length of 162 m for straight sections, over a circumference of 354 m. The optics of the Storage Ring is continuously optimized to restore the nominal performances inherently affected by increasing number of IDs used during operation. In 2011, an additional quadrupole triplet and a 4-magnet chicane have been installed in one long straight section allowing the installation of two canted 5.5 mm gap in-vacuum undulators providing two independent beamlines (Nanoscopium and ANATOMIX) from a single straight section. This new optics is routinely and successfully used in operation since January 2012. A short bunch length operation based on "Low Alpha" mode has been developed and is available as a routine user operation. More recently, a coupling correction has been implemented in order to maintain the ratio between the vertical and horizontal emittances at a fixed 1% value for any IDs configuration.

The position stability of the photon beams delivered to the beamlines is one of the criteria of quality expected by the synchrotron radiation users. Suited solutions have been sought to minimize the effects of each type of instability since the design of the facility. In addition, two active orbit feedbacks (Slow Orbit FeedBack and Fast Orbit FeedBack) are operating together thanks to a sophisticated protocol. The long term position stability (8h) at all the source points, is within 1 µm RMS in both planes and the low frequency noise sources have been identified and minimized, which allowed reducing the 0.01 Hz to 500 Hz noise below 200 nm RMS at the IDs locations. Special care has been given to the new 160 m long beamline Nanoscopium. Meetings called "Relation de Conjugaison" take place regularly since January 2012 between Machine people and Beamline scientists in order to improve further the stability criteria.

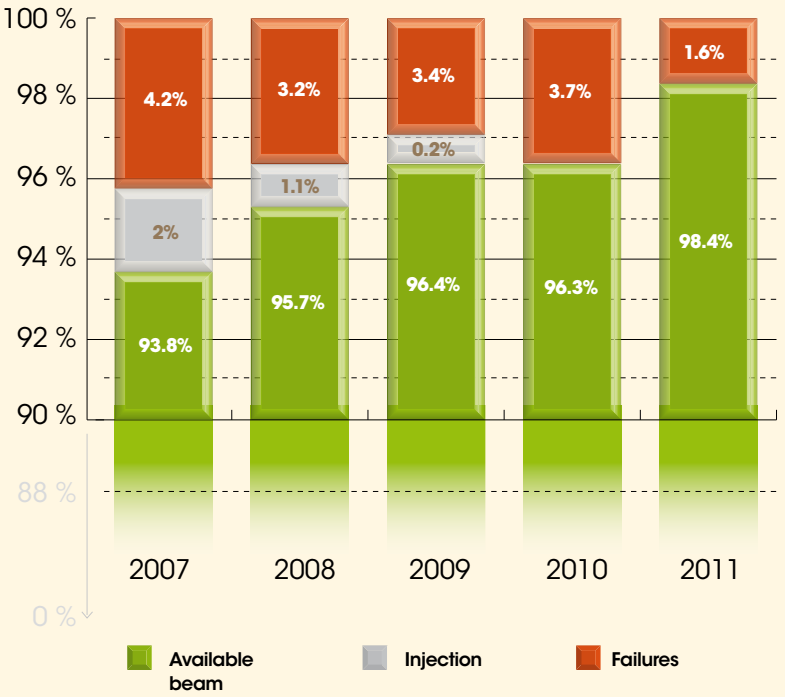


Figure 1: Photon beams availability in user operation.

SOLEIL Storage Ring was designed to operate in Top-up injection mode since the design phase. All equipment involved in the injection system have been specified to generate as small as possible perturbations on the stored beam. This concerns many aspects of the design and realization of the injection pulsed magnets, their vacuum chambers, their pulsed power supplies and timing electronics. All the pulsed power supplies, designed at SOLEIL, are based on solid-state switches even for high voltage ones, and demonstrate an outstanding reliability with a contribution close to zero to storage ring beam time loss. Extensive work has been done on systematic measurements, analysis of each phenomena, tuning or modification of each device until we reached good and acceptable

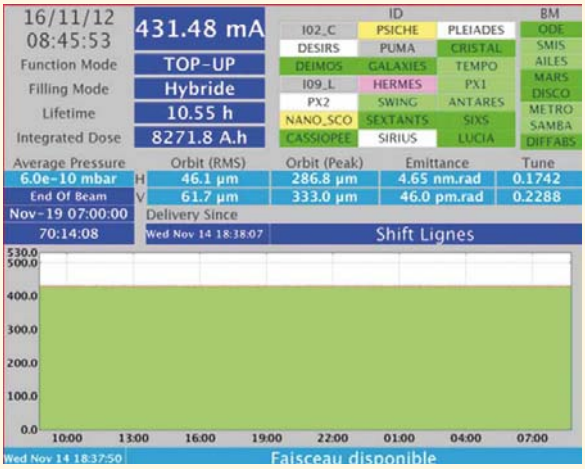
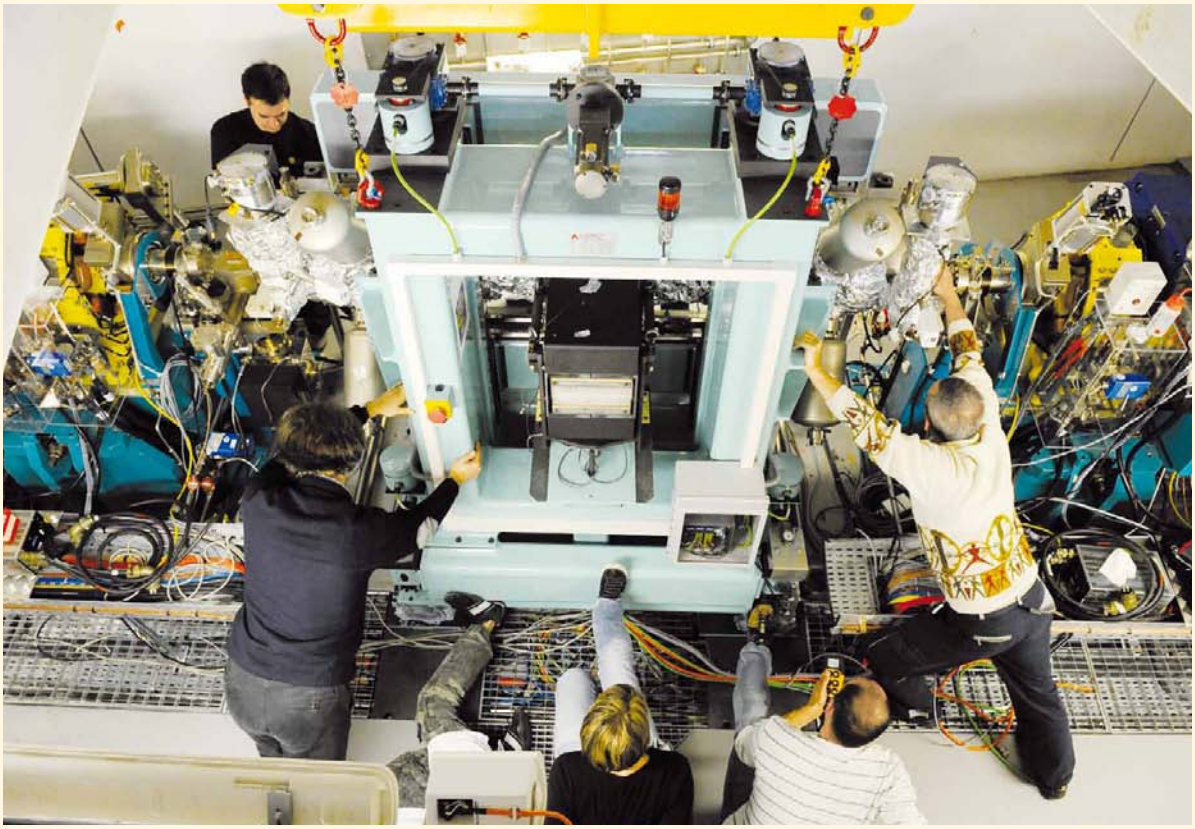


Figure 2: Parameters of the electron beam in the storage ring during user operation (Top-up mode, hybrid filling).



Installation of an undulator in the storage ring tunnel.

results for the users: the residual bump at storage ring injection has been reduced to < 100 µm RMS in horizontal and to < 40µm RMS in vertical. Efforts are still devoted to further improve these results and particularly in the vertical plane where a pulsed dipolar corrector is installed and is planned to be tested soon.

As mentioned above, the SOLEIL Storage Ring presents a very high fraction of its circumference dedicated to accommodate IDs. Presently 26 IDs from various types are installed in the Storage Ring, several of them being unique. The UV-VUV region is covered with electromagnetic devices (HU640 + three HU256), offering tunable polarizations. An electromagnet/permanent magnet undulator (EMPHU) using copper sheets coils for fast switching of the helicity is under commissioning. Thirteen APPLE-II type undulators, with period ranging from 80 down to 36 mm, provide photons in the 0.1-10 keV region, some of them featuring tapering or quasi-periodicity. Five U20 (and one U24) in-vacuum undulators cover typically the 3-30 keV range whereas an in-vacuum wiggler (WSV50), with compensation of the magnetic forces via adequate springs, covers the 10-50 keV spectral domain. An R&D cryogenic in-vacuum undulator (U18) made of $Pr_2Fe_{14}B$ magnets has been built and successfully tested on the machine. Other projects in construction or in design phase are going on and will be presented in a future communication.

The RadioFrequency system of the Storage Ring is based on superconducting cavities which make the damping of the parasitic high order modes (HOM) easier, and therefore helps improving the beam stability. The SOLEIL cryomodule relies on a "home-made" design, based on a pair of 352 MHz "HOM free" cavities inside a single cryomodule. For their RF power sources, it was thought that, although quite innovative and challenging for the required power range (total of about 600 kW), the solid state technology could offer significant advantages as compared to the vacuum tubes. Moreover, the absence of commercially available vacuum tubes at 352 MHz in the desired power range and the acquired expertise on Solid State Amplifier (SSA) prototypes at LURE, led us to choose powering each of the four Storage Ring cavities with one 180 kW SSA and the Booster cavity with one of 35 kW. These SSA proved to be very reliable as well as easy and flexible in operation, featuring an outstanding operational availability and MTBF (> 1 year).

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FOCUS ON

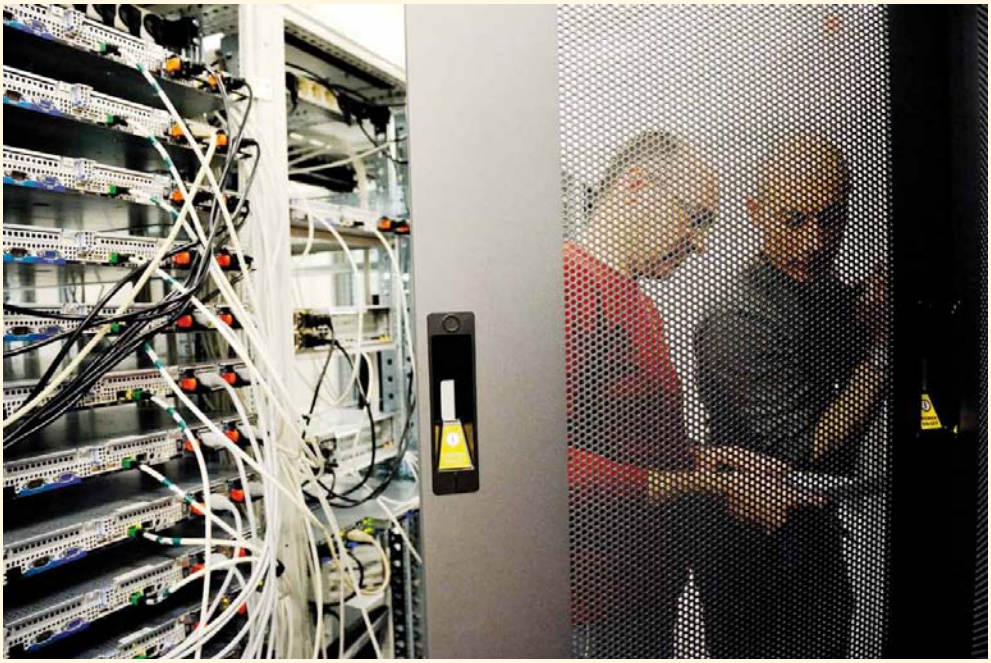
Computing and controls at SOLEIL

A little over 10 years ago, nothing had yet been set up in terms of computer networks or control systems. The Computing Division was faced with a tight schedule and limited resources. A look back at the choices made and their consequences today.

From the start, the creed of (then limited!) computing and controls groups was to "standardize what can be standardized" to optimize the installation and maintenance requirements, and reduce costs; "in modern, open and adaptable structures" in order later to be able to easily integrate new needs and new technologies. Although it is not always easy for a prospective user of a system to look beyond solutions either already practiced or standardized, a look back on the past 10 years shows that this approach made it possible to provide the systems needed in a reasonable time.

Very quickly the first computer systems were installed in temporary buildings that housed the fledgling Synchrotron SOLEIL company (see Rayon de SOLEIL #7). This was to support the daily activities of each member of the project in issuing the first orders and the first pay slips.

In parallel, studies were initiated on how best to control the machine and beamlines, and experimental data acquisition: first assessments of needs, evaluating existing technology and systems in other facilities or under development. In the end we chose TANGO1 software as the basis of all control and acquisition systems (see Rayon de SOLEIL #11 & 12).



State of affairs in 2012

The three computer networks at SOLEIL- the site network (Intranet, visitors), the network dedicated to control the machine, and the one dedicated to experiments (subdivi-

At the heart of the synchrotron building, one of the secure air-conditioned computer rooms housing the servers managed by the Computing Division.

TANGO

Originally developed by the ESRF and then through international cooperation, TANGO software has now been adopted by nine large installations, installed in many laboratories and proposed by industrial companies in response to calls for tenders on large projects.

It is a distributed object-oriented control system based on software entities called "devices" representing equipments. TANGO includes generic configuration, testing and storage tools, and is interfaced with tools such as Matlab, LabView, Igor, or Python.

In addition, SOLEIL has linked TANGO with GlobalSCREEN software from ORDINAL, to build supervisory GUIs that can go as far as integrating data preprocessing applications, as well as Passerelle, a graphical sequencing tool from ISENCIA.

http://www.tango-controls.org/

Interaction between the Accelerators & Sources and Computing Divisions: test, in laboratory, of a control system for the electron beam.

ded by beamline) – add up to over 6,000 connection points. These rely on a 2x10Gb/s redundant core architecture, providing high availability, and distributing the associated services to each network. Over 800 workstations (desktop and laptop ones) are deployed and maintained. The intranet also supports IP telephony traffic used since 2005. More recently, Wi-Fi infrastructure has been gradually developed and now covers all buildings.

SOLEIL has over 25 data acquisition and control systems, bringing together 2,500 computer and electronic subsystems: servers and X-ray terminals, CompactPCI electronics for fast acquisition and control needs; programmable logic controllers to automate industrial control; motorization and specific electronic developments. This has led to the deployment of more than 30,000 TANGO devices. This is the first installation to have used TANGO on such a large scale.

Another aspect is the means of calculating and storing experimental data3 available to SOLEIL scientists and beamline users: cluster calculations of 11.9 Tflops (1T = 10^{12}), 1 petabyte (10^{15} bytes) of primary storage on mirrored disks between the two computer rooms, LTO libraries to ensure secondary storage (and archiving on request).

Meanwhile, the initial management computer system has been upgraded to manage all SOLEIL's personnel and material resources, but also all the services related to beamline user and project administration: from submitting proposals up to final reports.

A story that doesn't stop there

It is now necessary to maintain these systems at the best operational level. Thus, over the years, virtualization techniques have been introduced to optimize the number of servers and intense reliability campaigns divided by 2 the calls to computing support when the number of beamlines in service continued to grow etc...

The current challenge is the explosion in the volume of experimental data, because of the simultaneous introduction of 2D detectors and the FlyScan acquisition system (see article p6): the expected daily volume will exceed one Terabyte of data on each beamline involved, with high speed bursts, so the technical means currently in place will need to be adapted.

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Experimental data

The experimental data are stored on dedicated infrastructure, distributed between local beamline storage and primary and secondary central storage: Active Circle software manages the security and archiving of data on it. The data are kept for at least 100 days after the end of an experiment. A dedicated application, SOLEIL Data Retrieval, provides remote access to directories associated with an experimental project and the download of data files, when the volumes concerned are compatible with a transfer over the network.

Experimental data are stored on this infrastructure, preferentially in NeXus standard (see Rayon de SOLEIL #20). Based on the HDF5 Format, chosen by the European collaboration PaNData to harmonize data formats, NeXus allows the creation of self-supporting files including the metadata necessary for exploiting raw data. More than two million NeXus files have already been produced at SOLEIL. However, all the existing analysis applications do not yet use this format: developed in partnership with the Australian ANSTO neutron source and recently DESY and ANKA, an interface called CDMA or Common Data Model Access will allow the file format and data organization of these files to be hidden in order to share data and applications between research institutes. This unified data access layer is implemented in data reduction applications already operational on some beamlines.

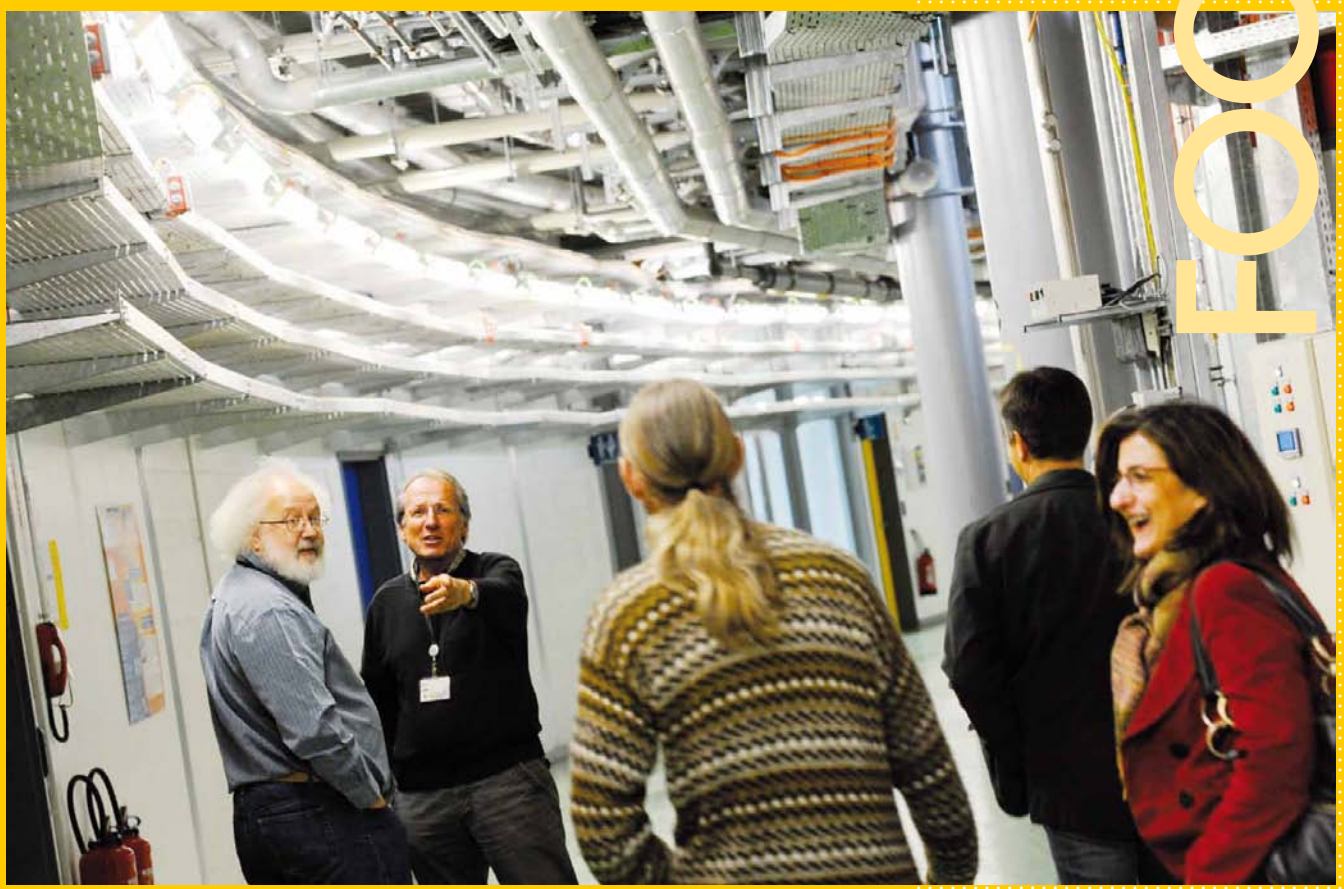
http://sunset.synchrotron-soleil.fr/sun/

Motion systems

SOLEIL has over 1,500 motors currently operating, mainly on the beamlines to drive monochromators, mirrors, etc. Today, 84% of them are controlled by a standardized SOLEIL solution: a commercial controller integrated in a ControlBox chassis linked to a power unit- DriverBox for stepper motors (VacuumBox for those under vacuum) and ServoBox for actuators.

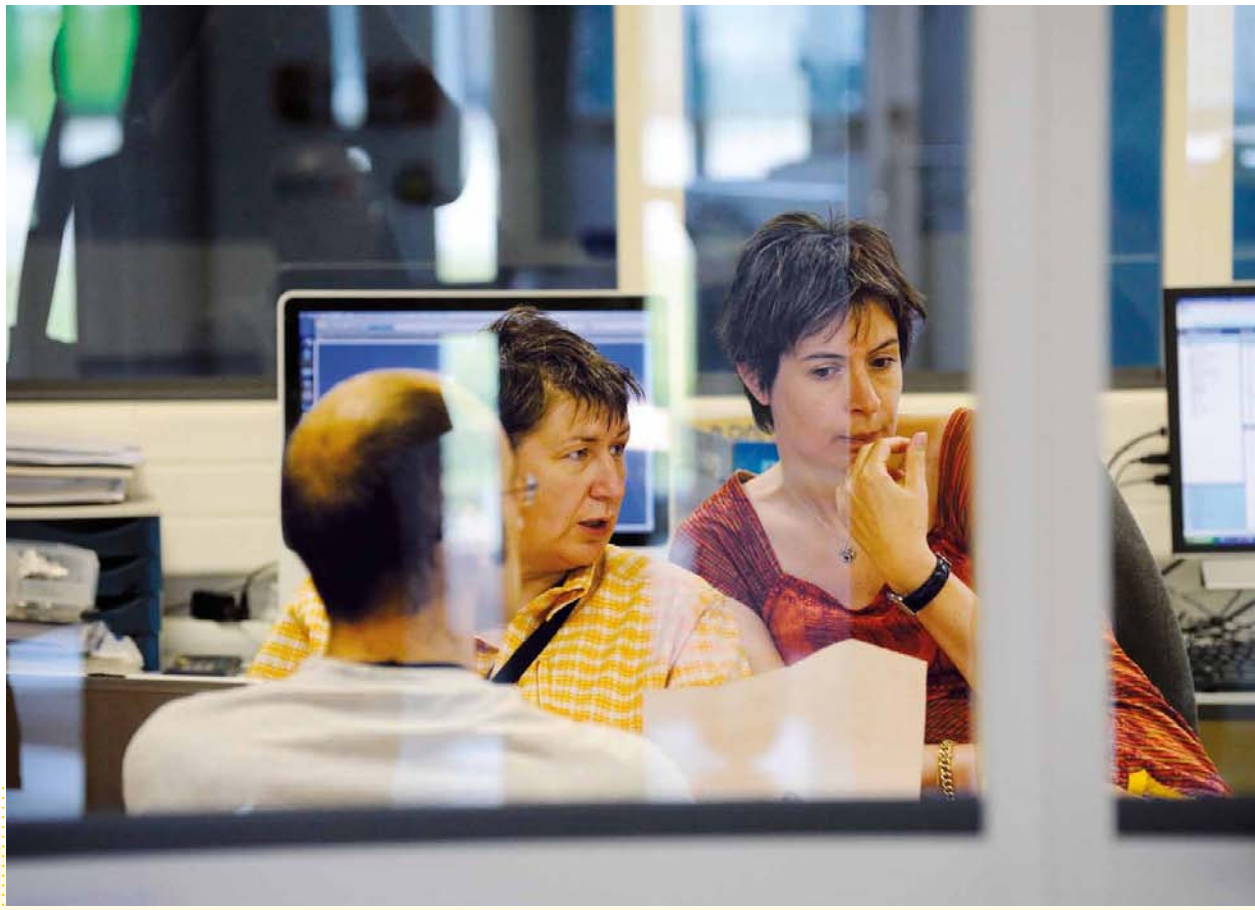
In partnership with the future Swedish synchrotron MAX IV, SOLEIL has launched a project, called REVOLUTION, to renew the current controller selected in 2004 in order to extend the performance and capabilities of the standard solution: complex trajectories, nanopositioning, etc.

Research interdisciplinarity and results



Assessment of the four years since the light source and beamlines at SOLEIL have been operating now justifies all the choices made over the past ten years.

Research
interdisciplinarity and results



Permanent interactions between the beamlines teams.

Beam stability, instrument quality and the expertise of the personnel who operate the facilities means that, in 2012, more than 3,000 users can now be accommodated annually on the beamlines, to achieve, under the best conditions, nearly 2000 projects and, since its opening to users in 2008, recorded nearly 500 publications in journals of high and very high impact factor (more than 2/3 of all the publications). Designed originally as specific beamlines in terms of method of analysis and scientific user communities, it is now clear that the borders between disciplines are fast disappearing and their interfaces are becoming more numerous. This wealth of science and innovation, which builds on the strengths of each discipline (chemistry, physics and biology, to name but three) continues to require the unique means of analysis and characterization of the SOLEIL beamlines, but in a new form: a single project now often requests several beamlines, able to analyze the same sample in a sequence of studies and applying defined methods. And that ideally includes the preparation of this sample on site at SOLEIL. This new approach to the use of SOLEIL can be illustrated by several examples.

Catalysis

Optimizing catalysis means mastering the reproducibility of the composition, preparation and structure of the catalyst material, in situ analysis of how it changes with use, and following the catalytic process itself under specific conditions of temperature and pressure. To do so, X-ray scattering to monitor the process of material nucleation and growth, X-ray absorption and fluorescence coupled to mass spectro-

SWING

Crystallization of quantum dots within a 3D biomimetic template

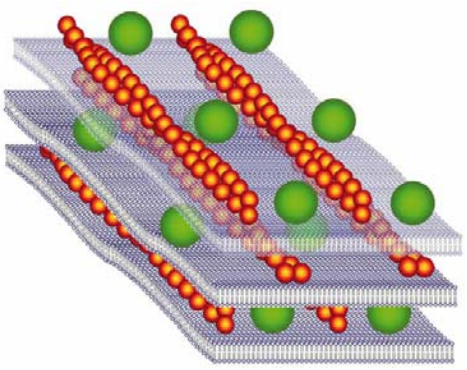


Figure 1 : schematic view of the structure. Strong electrostatic interactions between anionic microfilaments (red) and cationic lipids results in large undulations of the lipid bilayers (blue). Quantum Dots (green) are embedded between actin filaments as well as lipid membranes.

Generating new physical properties using the crystallization of nanoparticles is highly challenging. The design of such new materials with unexpected physical properties is thus the major motivation in the investigation of new strategies for controlling the crystallization of nanoparticles. In this context, biological molecules and molecular self-assemblies are promising templates to organize the spontaneous formation of structures of well-defined shapes and monodisperse characteristic sizes. Here is the report on the ability of a self-assembled three-dimensional crystal template of helical actin protein filaments and lipids bilayers to generate a hierarchical self-assembly of quantum dots (QDs; Figure 1). With this goal, functionalized quantum dots are incorporated during the dynamical self-assembly of this actin/lipid template through electrostatic interaction.
This slow mixing results in the formation of crystalline fibers. This process ensures the high quality of the crystal.
A very well-defined 3D crystal of QDs is then formed; its parameters (26.5 x 18.9 x 35.5 nm^3) are imposed by the membrane thickness, the diameter, and the pitch of the actin self-assembly. The inclusion of extraneous objects providing additional well-defined length scales is necessary to create 3D order, which is lost without actin.
The fluorescence properties of the 3D crystals of quantum dots demonstrate a direct effect of the nanostructuration of the quantum dots within the crystal.
Such a formation of 3D arrays of nanoparticles opens new route toward optical materials that are easily prepared by using self-assembling of vesicles, proteins, and hydrophilic nanoparticles in aqueous environment. This strategy could be extended to any kind of hydrophilic nanoparticles with various morphologies. Furthermore, the range of characteristic lengths can be extended by using other biological materials.

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Reference :
E. Henry et al. Nano Letters 11(12) (2011), 5443-5448

metry, photoemission and also tomography, are all complementary and necessary to answer the many complex questions aimed at optimizing, in terms of efficiency and cost, high value-added processes.

Life Sciences

Life sciences and health care, for which "Integrative Biology" and developments in regenerative and restorative medicine are major challenges to society, find at SOLEIL all methods of qualitative and quantitative analysis possible with third generation synchrotron radiation sources: X microscopy X, SAXS, IR & UV spectromicroscopies, biocristallography... Using these techniques, enriched by 3D imaging available soon on the Nanoscopium and ANATOMIX beamlines, SOLEIL addresses the need for multi-modal, multi-scale studies and characterization of Life, from the three-dimensional structure of macromolecules and their complexes to hierarchical tissue structures, via the cell and tissue distributions of chemical elements and therapeutic agents.

Material Sciences

The study of materials, often at the interface between physics and chemistry, is traditionally well established in synchrotron facilities, insofar as the characterization techniques (diffraction, scattering, absorption, fluorescence) are widely developed. SOLEIL largely meets this demand by providing many beamlines covering these techniques. Specific developments have led to more precise answers, often in collaboration with external support, for example by the increasing number of studies of materials under stress or in complex environments, or under extreme

To be continued on page 22...

PROXIMA 1

The 3D structure of surface proteins of the chikungunya virus has been elucidated

The chikungunya virus, spread by mosquitoes, causes infections the symptoms of which (severe joint pain), are similar to those of the dengue virus.

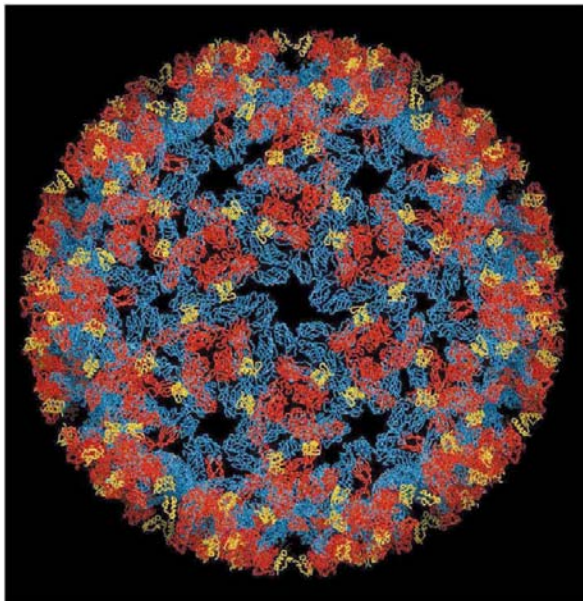

Figure 1: Surface of a particle of the chikungunya virus consisting of 240 E3/E2/E1 protein complexes (in blue/red/yellow, respectively)

The Pasteur Institute laboratory has been able to describe the atomic scale organization of proteins that form the outer layer of the virus and the structural changes related to the mechanisms of both invasion and production of new viruses.
Two protein complexes have been identified: p62/E1 and E3/E2/E1, the second from maturation of the first. The virus attaches itself first to the membrane of the target cell by means of E2. This membrane then surrounds the virus to enclose it in vesicles that transport it to successive cell compartments, endosomes, directing it towards the lysosome, responsible for dismantling it.
However, the pH of endosomes gradually becomes acidic, which activates E1. This protein will ensure the fusion of the viral and endosomal membranes, allowing the virus to release its RNA into the cell. And it is the cell machinery that will allow the virus to multiply after replication of the viral RNA.
Meanwhile, P62, insensitive to acidic pH, associates with E1 and allows the complex to migrate to the cell membrane. During this migration, p62 undergoes a maturation process, leading to the creation of E2 and E3.
The E3/E2/E1 complexes, thus formed, assemble to form new viral particles that bud from the surface of the infected cell and invade new cells.
Understanding these mechanisms shows that the stabilization of the E3/E2/E1 complex would prevent the virus from invading the cell.
The study also identified areas on E2 that recognize neutralizing antibodies, paving the way for new approaches to vaccines.
These studies make use of the low-resolution structure of protein complexes, obtained by cryo-electron microscopy, as well as the structure of the protein complex in its mature form, elucidated on the PROXIMA 1 beamline, in collaboration with the company Global Phasing Ltd (Cambridge).

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Reference :
Voss, J. E. et al. Nature 468 (7324) (2010) 709–712

... Continued from page 21

conditions of temperature and/or pressure, magnetic or electric fields. The use of coherent beams is developing to characterize, for example, the stress field at the interface, as well as high resolution and sensitivity tomography for 3D analysis. Special care is given towards ancient materials studies which require indeed a very specific sample preparation. Finally, time-dependent studies benefit from different modes of operation of the ring (1 bunch, 8 bunch, hybrid mode, low alpha) and there has been a particular growth in the development of femto-slicing to generate femtosecond pulses (see Rayon de SOLEIL 20, p11).

Knowledge of the fundamental properties of matter is a key issue in order to develop complex materials in the future or understand their behavior (control) on a large-scale or under external excitation. This often requires the development of complex experiments where a maximum of parameters are measured simultaneously. The decision by SOLEIL to develop «customized» beamlines (see page 6), where the technical choices on the source, optics, right up to detectors were pushed to the limit, has led to some original results, recognized in high-level publications.

PLEIADES

Imaging molecular potentials of 'hidden' states

A knowledge of electron-density distributions and potential energy surfaces of molecules is a key for predicting the physical properties and chemical reactivity of molecules.
The measurement of the energy of electrons, ejected by molecules as a result of their exposure to radiation, is one of the most commonly used methods to study different molecular states. Using traditional methods however, many electronic states cannot be accessed or they appear strongly overlapped with other states, which makes their isolation and characterization impossible.

The PLEIADES group, in collaboration with theoreticians from Japan and Sweden, has found a way to "pull-out" molecular states from the regions of overlap and reconstruct their potentials, otherwise inaccessible by other methods. Using resonant photoemission (RPE) spectroscopy, the molecular states of interest are reached not directly, as in traditional photo-electron spectroscopic methods, but indirectly via an intermediate state. This neutral, highly excited state is produced by absorption of a soft x-ray photon of a well-defined energy. Several femtoseconds after this absorption, the highly excited species thus produced relax by emitting a valence electron. However, in the intermediate state the molecule vibrates and has sufficient time to change its bond length. The probed part of the final state potential is different, therefore, from that probed by direct photo-electron spectroscopic methods, which can access only the so-called vertical transitions. In such transitions, the geometry is the same as in the ground state and no change of bond length takes place. By tuning the photon energy of the excitation radiation however, different vibrational levels of the intermediate state can be reached, which allows the width of the probed region in the final states to be controlled.
This technique is very demanding and requires high-brightness radiation sources owing to the dramatic decrease of the signal when tuning the excitation energy to higher vibrational levels of the intermediate state. Until now, such experiments can only be carried out on PLEIADES, but it will soon be possible to perform similar studies at the PETRA III synchrotron at DESY in Germany, and at MAX IV at Max-Lab in Sweden

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Reference : Miron, C. et al. Nature Physics 8(2)(2012) 135-138

Figure 1: RPE spectra (dots) of nitrogen molecule recorded for a series ν = 0 – 6 of vibrational sub-states of the N1s→ π* core-excited state. Total and partial calculated cross sections are shown as continuous lines.

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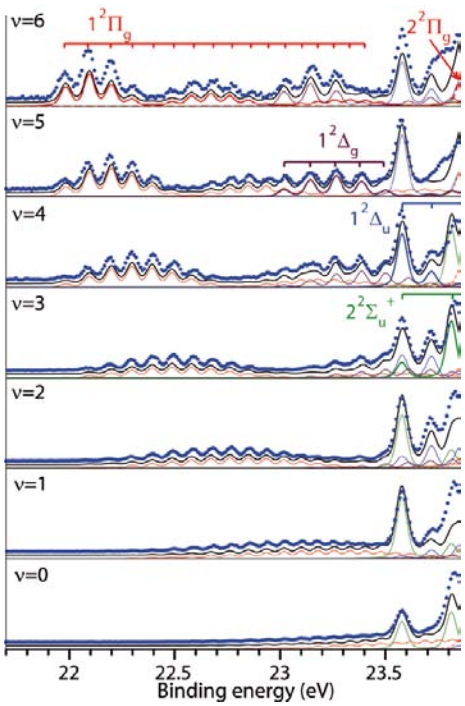

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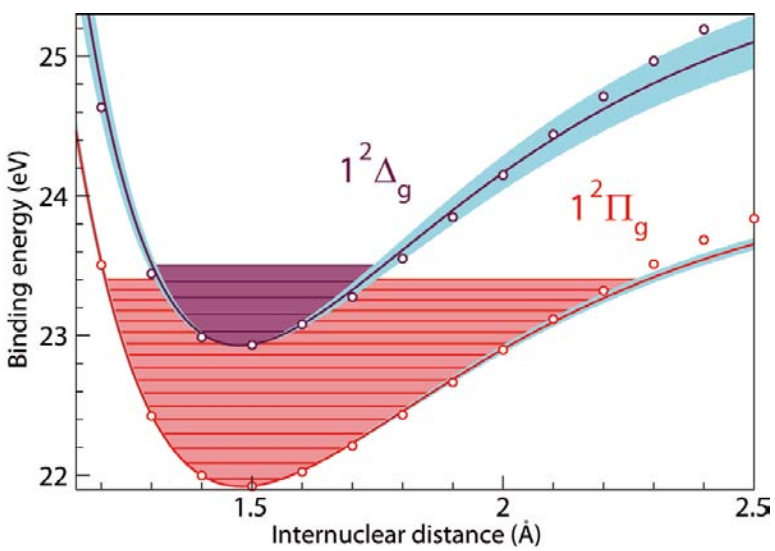

Figure 2: Comparison between the reconstructed molecular potentials based on ultrahigh resolution RPE data and ab initio calculated potentials (open circles). The error bars are shown as blue colored areas.

CRISTAL

Single bulk dislocations revealed by coherent x-rays in silicon

Dislocations are linear defects of crystals. They are involved in most of the physical properties of the crystals: mechanical properties of materials, electronic properties of semiconductors… Techniques like Scanning Tunneling Microscopy or Transmission Electron Microscopy provide atomic resolution images of dislocations, but the studied samples must not exceed few tens of nanometers in thickness; and the study of bulk dislocations remains a challenge. On the CRISTAL beamline, a combination of coherent x-ray diffraction and x-ray topography allowed to detect and get structural information about dislocations embedded a few micrometers beneath the sample surface. A Si(110) sample containing a few dislocations loops of about 100 mm in diameter was chosen as the model material to be studied. During a coherent x-ray diffraction experiment on a crystal, the intense beams reflected by the atomic planes of the crystal, known as Bragg reflections, are studied. If the sample is perfectly ordered throughout its illuminated volume, these reflections are single peaks. On the other hand, if the sample contains such defects as dislocations, the Bragg peaks split into two or more sub-peaks. In this study, the scientists first selected an isolated bulk dislocation by x topography. Then, they mapped it with a coherent beam of a few microns. Direct analysis of the intensity gives an image of the dislocation loop. Moreover, they observed a splitting of the Bragg reflection because of the dislocation, but the diffraction images provide further information about the core of the dislocation: a streak appears on the diffraction pattern meaning that the dislocation lines of the loop are dissociated into two parallel partial dislocation lines separated by a stacking fault, another classic defect in this material. Improvements in X-ray sources and optics will soon broaden the possible applications of this technique that also allows considering studies of phase defects in the bulk under various conditions such as magnetic or electrical field, high pressure, low temperatures...

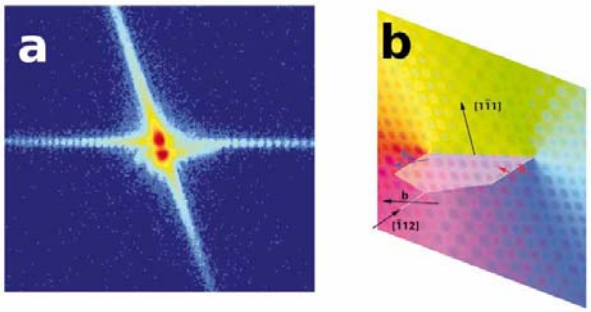

Figure 1 : (a) Coherent x-ray diffraction pattern measured at the 220 reflection when a dislocation line is illuminated. The Bragg reflection is split because of the phase shift introduced by the dislocation. A streak also appears due to the fact that the dislocation is dissociated into two parallel partial dislocations separated by a stacking fault. (b) Schematic representation of a dissociated dislocation corresponding to the diffraction pattern shown in (a) and of the associated Burgers vectors, which gives the direction and amplitude of the atomic shift due to the dislocation.

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Reference : Jacques, V.L.R. et al. Physical Review Letters 106 (2011), 065502

SAMBA

An unprecedented structure of Re oxyde evidenced by *operando* XAS and Raman

Because of its high selectivity and the conciseness of the number of reactions required, the catalytic conversion of alcohols is an elegant way of yielding valuable products from biomass. Among possible reactions, the direct conversion of methanol (CH_3OH) to methylal ($CH_2(OCH_3)_2$) has drawn an increasing attention, both owing to its green chemistry implications and its relevancy as model reaction to probe bifunctional active sites. Practically, the gaseous methanol is contacted with the outmost surface of a divided catalyst where the reaction takes place. The present study is devoted to silica-supported oxorhenate catalysts, ReO_x/SiO_2. When prepared using the conventional impregnation technique, the material was less active and less selective than bulk ReO_3 or ReO_x/TiO_2.
The activity of supported oxorhenate catalysts were previously demonstrated as being highly correlated to the nature of support while the structure of the active phase was consistent with isolated ReO_4 moieties in tetrahedral coordination in all reported cases.
In order to solve the paradox, the scientists had previously proposed that differential hydration of the rhenium phase –possibly driven by the support- could influence the catalytic performance of the supported ReO_x materials rather than the support itself. The present work presents results obtained from a catalyst prepared using a one pot sol-gel based procedure.
At 240°C, the catalyst was 4 times more efficient than conventional Re/SiO_2 catalysts operating at the same temperature. Raman spectroscopy and rhenium L_{III} edge XAS gave insights on this peculiar activity. To this end, the spectra collection was performed simultaneously to the catalytic reaction using a dedicated spectroscopic cell making it possible to flow the reactants and control the temperature of the catalyst.
With Raman, two unusual stretching ν(ReO) modes are detected at 944 and 992 cm^{-1}, reflecting an original structure. Their intensity is visibly decreased under reacting

CASSIOPEE

Towards oxide-based multi-functional transistors

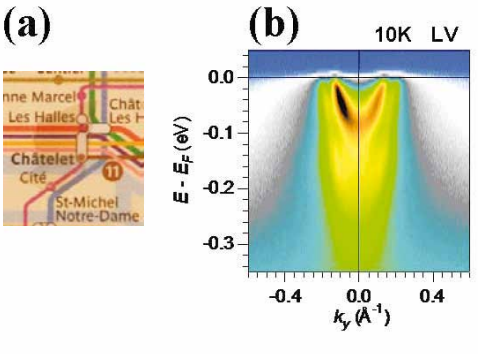

Figure 1 : (a) Photo of one of the insulating $SrTiO_3$ samples studied (with Paris metro map on the background). (b) Corresponding energy-momentum (E, k) density of electrons at 10K. The two free-electron parabolas are quantized energy levels due to the 2D confinement.

In the last 50 years, personal electronic devices have reshaped the ways we live, communicate and work. This revolution was made possible by the engineering of metal-oxide-semiconductor field effect transistors (MOSFETs), the two-dimensional electron gases (2DEGs) at the core of components for today's electronic devices. But the techniques used to create these integrated circuits will reach their 10 nm limit soon. In order to meet the growing demand of performances and miniaturization, alternatives are being explored. $SrTiO_3$, one of these alternatives, has been the subject of intense research. The interfaces between $SrTiO_3$ and other insulator oxides show two-dimensional metallic behaviour (even though the two constituents are insulators) and present interesting properties such as superconductivity, magneto-resistance, thermoelectricity... Furthermore, $SrTiO_3$ is non-toxic and its components are widely available in nature. However, the fabrication of these interfaces is difficult and costly to produce.

But an unexpected discovery has opened a new avenue for the generation and understanding of these 2DEGs. Originally studying the bulk electronic structure of $SrTiO_3$ for several dopings, an international team evidenced the presence of a highly metallic 2DEG, even in the case of bulk-insulating samples. By breaking a piece of $SrTiO_3$ under vacuum, the scientific team, led by researchers at Université Paris-Sud and CNRS, discovered that the bare surface of $SrTiO_3$ spontaneously develops this metallic 2DEG. The results were revealed by high-resolution angle-resolved photoemission measurements (Fig. 1b) carried out on CASSIOPEE beamline and in SRC (USA). Their results clearly evidence some bands crossing the Fermi energy E_F, i. e. being metallic. The metallic layer, two nanometers thick, is obtained through a simple and inexpensive process, potentially reproducible for other transition-metal oxides.

Such a discovery is a leap forward for the nascent field of oxide-based electronics. In the future, it could allow combining the intrinsic properties of a transition-metal oxide matrix with those of a 2DEG at its surface. For instance, one could imagine the realization of non-volatile memories by coupling a ferro-electric oxide with a 2D metal at its surface, or fabricating transparent circuits on the surface of photovoltaic cells or touch screens.

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Reference : A. F. Santander-Syro et al. Nature 469 (2011), 189-193

conditions, suggesting that those frequencies feature a structural moiety which is implied in the reaction mechanism. To get to a better depiction of the new structures evidenced by Raman, operando XANES and EXAFS spectra were recorded on the SAMBA beamline using the Quick-EXAFS oscillating monochromator (cf Rayon de SOLEIL 18, p24).

The results are consistent with the existence of an unprecedented structure in which the ReO_4 tetrahedron interacts with water Re atoms by water molecules, as can be found in the bis-aquo adduct $Re_2O_7.2H_2O$.

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Reference :
A. Yoboué et al. Chemical Communications 47(14) (2011) 4285–4287

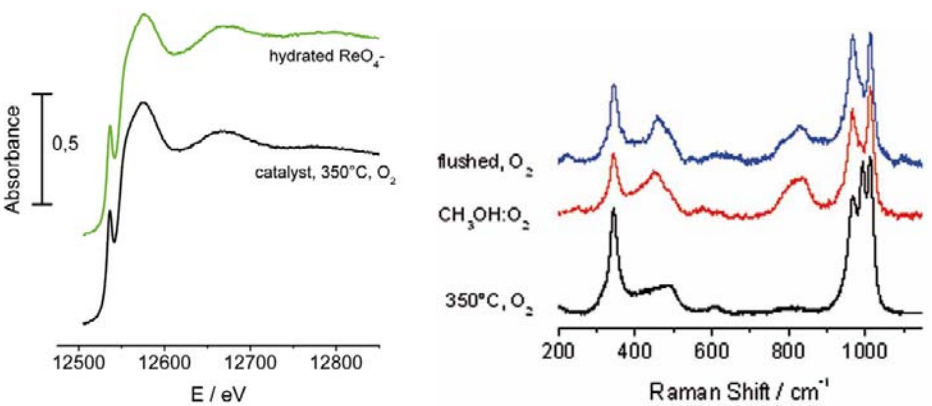

Figure 1: Left: compared XANES spectra recorded at the L_1 Re edge of ReO_x/SiO_2 (O_2, 350°C) catalyst and aqueous ReO_4-. Right: Operando Raman spectra of the ReO_x/SiO_2 catalyst dehydrated at 350°C under O_2 (black), operating methanol oxidation at 240°C (red line) and subsequently flushed in helium and oxygen (blue line).

EXPERT PORTRAIT

HÉLÈNE ROZELOT, HEAD OF PLANNING AND QUALITY ASSURANCE

Hélène Rozelot

What is your role at SOLEIL?

Initially, my job title was "Head of planning of SOLEIL project implementation, and its follow-up." This was in late 2001 when SOLEIL's construction had not yet started, so there were still major challenges ahead in relation to planning! Then from 2007, when SOLEIL became operational, another component, Head of Quality Assurance, was added to these responsibilities still in vigor.

To be in charge of planning, what does that involve?

Talking with people "on the ground", with those responsible for the development of an equipment or a given project to assess the duration and sequence of tasks necessary to achieve this, and mobilize all forces needed to complete these tasks within the specified deadlines. To achieve this, three forms of constraint must be taken into account:
Time constraints of course: making sure the different schedules are compatible with one another by paralleling all tasks to be performed, then identifying the risks of delays, which in turn jeopardize the meeting of deadlines set at the start (through work overload on some teams, for example). In fact I need to know who will be involved, but also ensure that they will be available, especially as the same group often works on several projects. This is becoming increasingly true at SOLEIL as the construction of new beamlines for example, is being carried out concurrently with usual operations, maintenance work and availability of beamlines to outside users; so there are a growing number of tasks to accomplish with existing staffing levels.
Then there are the financial constraints: we need to balance the financial commitments related to projects with set billing targets (e.g. the EquipEx project).
And finally technological constraints: at SOLEIL leading-edge equipment designed after R & D studies has by definition never been manufactured before. We therefore do not know exactly how long it will take to make it. This means, more than ever, being in regular contact with the teams involved, to be able to specify more accurately how long the work will take.

So you have an overall vision on how projects are progressing

That is the aim! With all the information that the various Heads of department and project managers provide me with, I can often spot the glitches that threaten the smooth running of these projects. Detected early enough, it is usually possible to anticipate - outsource a task, for example - and thus avoid bottlenecks. Such decisions are taken in response to regular reports (every two months) that I present to top management. I make these syntheses of the progress of projects in collaboration with Pascale Prigent, who coordinates the installation of equipment on the beamlines, and Philippe Eymard, responsible for buildings and infrastructure.

And the "quality assurance" part, what does that consist of?

It is in two parts. I must ensure that a set of provisions are in place that will minimize risks at the organizational level. In other words, make sure that things are "streamlined" in terms of operational procedures and mechanisms. At SOLEIL these are matrix operations: projects involve groups from different divisions, include a wide variety of tasks, with staff sometimes working in parallel on several projects. To avoid suffocation and stress it is important to develop working methods that run as smoothly as possible. In my opinion, making people who are engaged in a transverse project more involved by organizing them into "project groups", thus valorizing all actors in the project and allowing them to have an overview, is, for example, one approach. Effective informal practices already in place would benefit from being formalized. Why reinvent each time something that has been proven?!
One could say that these actions are part of a "quality assurance" process.
On the other hand I am also responsible for the establishment of a process that can be described as "product assurance": provisions to ensure the reliability of equipment and that it meets requirements. A tool such as CMMS, which physically lists all the SOLEIL equipment, its identity, configuration etc., can store a history of the life of equipment and draw up operational statistics, i.e. records their reliability. It is then up to us to find ways (see check list...) to quickly become operational again after failures or to implement preventive maintenance.

How would you describe your job?

My job is extremely rich and varied in terms of interactions, relationships and tasks to accomplish. This is time-consuming, and I am in contact with almost all staff at SOLEIL! Yet, in the end, I often work alone, for example to produce all the syntheses, which is sometimes difficult. And I can have the unenviable role of being the harbinger of bad news when I have to announce that a project will be completed later than expected... But when I see that more and more of my colleagues are sensitive to aspects of planning and quality assurance, and they understand its purpose and interest, I think that we are getting somewhere!

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Industrial Partnerships and Business Development at SOLEIL: contributing to strengthening the competitiveness of companies

Positioning

As one of its mission statements, SOLEIL aims to position itself as a key source of R&D and technological innovation for the business world.

The two main tasks of the Industrial Partnerships and Business Development Group (GRIVAL), a support group for all SOLEIL divisions, are:

• Administration of access by companies (from industry and services to industry), to the equipment, skills and services offered by SOLEIL.

• The business development from the knowledge generated at SOLEIL by its in-house scientific research, technological development and innovation: R&D partnerships with companies, acquisition and management of intellectual property rights, transfer of know-how or technology to industrial enterprises and creation of innovative start-ups.

Results of the first four years of operation at SOLEIL (2008-2011)

The regular promotion and prospecting actions towards the business world correspond on average to one company visiting SOLEIL per week, an active presence at a trade show or a business convention each month and monthly participation in research-industry networking clusters: these actions generate each year more than 600 exchanges of information with companies.

This business activity led, by the end of 2011, to an average of 25 industrial projects per year, evenly distributed between services billed to industry and projects selected by program committees, representing approximately 5% of all projects carried out by external users of SOLEIL.

Concerning the business development from its knowledge, the main results at the end of 2011 are as follows: fifteen industrial partnerships for the use of beamlines or for R&D projects, 4 know-how transfers to French SMEs, 5 international patents in co-ownership with companies or public research organizations, 3 SOLEAU envelopes (limited intellectual property rights) filed and a project of start-up based on environmental analysis services.

Forecasts for 2012... and beyond...

In 2012, SOLEIL recorded an increasing industrial demand for synchrotron use, characterized by a tripling of billed services. In addition to regular users, the portfolio increased with new industrial users from France, Europe and the rest of the world.

Regarding the business development from its knowledge, SOLEIL has produced in 2012 a sixth invention co-developed with a partner, a new know-how transfer to an industrial partner, a multi-partner project to create a research and services platform in the cosmetics industry and a project of technological spin-off.

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SOLEIL offers companies:

• Analysis services for complex materials and living matter on the synchrotron beamlines

• Technical services (magnetic measurements, ultra-high vacuum cleaning, optical metrology, manufacture of micro-systems with deep lithography...)

• Bilateral or multilateral scientific or technological research partnerships

• Know-how transfers for the industrialization, manufacturing and sale of technological products developed by SOLEIL.

ICESS12

THE INTERNATIONAL CONFERENCE ON ELECTRON SPECTROSCOPY AND STRUCTURE (ICESS12), organized by SOLEIL, took place between 16th and 21st September 2012 à St Malo, with nearly 300 participants. Traditionally (first organized in 1971 at Asilomar, USA), this conference brings together surface physics and dilute matter scientists using electron spectroscopy to understand the fundamental processes in radiation/matter interactions and the fundamental properties of matter.
The plenary lectures really illustrated the dynamism of this field, highlighting the tremendous opportunities opened up by the new coherent sources, but also how complementary are the more conventional synchrotron sources which are pushing the spectral resolution to its limits. The inaugural conferences, dedicated to theory, made it possible to carefully analyze the potential and current limitations of theoretical tools in the field. In parallel sessions, fundamental processes in atomic and molecular physics were addressed (localization, quantum recoil effects, ultrafast dynamics, etc.), in surface physics (electron correlation, topological insulators, graphene), but also looking at the interface of the domains (reactivity, catalysis, physical chemistry, nanoparticles, liquids), which became the occasion for very fruitful exchanges between the scientific communities.
Advances in instrumentation, particularly with the development of analyzers adapted to new sources, means that we can now reach ultrafast (attosecond) phenomena, a time characteristic of electron movements. Meanwhile, sophisticated sample environments give access to the coupling of spectral and spatial information, as well as to the observation of matter under new conditions (high pressure, liquid, etc.).
The conference concluded with a tour of SOLEIL, which was a resounding success (about 100 participants).
We would like to thank those responsible for the remarkable practical organization of the conference, unanimously appreciated by the participants.

SOLEIL Users' Meeting 2013

THE 8TH SOLEIL USERS' MEETING WILL TAKE PLACE ON JANUARY 23RD AND 24TH, 2013 AT SOLEIL AND THE "ECOLE POLYTECHNIQUE" (PALAISEAU).
The meeting provides an invaluable forum for the synchrotron radiation user community, presenting an important opportunity both to obtain the latest information on beamlines performance at SOLEIL and to hear about the latest results obtained at SOLEIL.
The meeting will take the form of three plenary lectures concerning the following topics: Cultural heritage, Material science and Diluted matter.
Round table discussions will be organized on the first day to give the opportunity for interactions between users and beamlines managers.
The parallel sessions will consist in original scientific presentations, selected from submitted abstracts for oral presentation.
During the poster session, the best student poster will be awarded a prize.
A social programme will be held at SOLEIL on the afternoon of January 23rd in conjunction with the commercial exhibitions and visits of SOLEIL.

A satellite Workshop, SYnchrotron Radiation for Electrochemical Energy Storage – SYREES 2013, will be held on January 21st and 22nd, 2013.

www.synchrotron-soleil.fr/Workshops/2013/SUM2013

SRI 2012 (Synchrotron Radiation Instrumentation)

FROM JULY 9TH – 13TH THE CITÉ INTERNATIONALE CONGRESS CENTER IN LYON hosted representatives of synchrotrons around the world for this International conference week on instrumentation for synchrotron radiation sources and beamlines.
SOLEIL and ESRF were jointly responsible for the scientific program, which included about 140 lectures and 650 posters.
With over 1,000 participants from around the world, this 2012 edition of SRI broke all attendance records since the first one held in the early 80s.
This event brought together users, researchers and engineers, as well as industrial suppliers of synchrotron radiation centers. As in earlier conferences, a significant number (about 80) of young researchers benefited from grants from the Region Rhône-Alpes, allowing them to be accommodated free of charge in a student residence. More than 70 businesses, mostly high-tech suppliers to synchrotrons around the world, held stands in the exhibition area.
You can get an idea of how this week

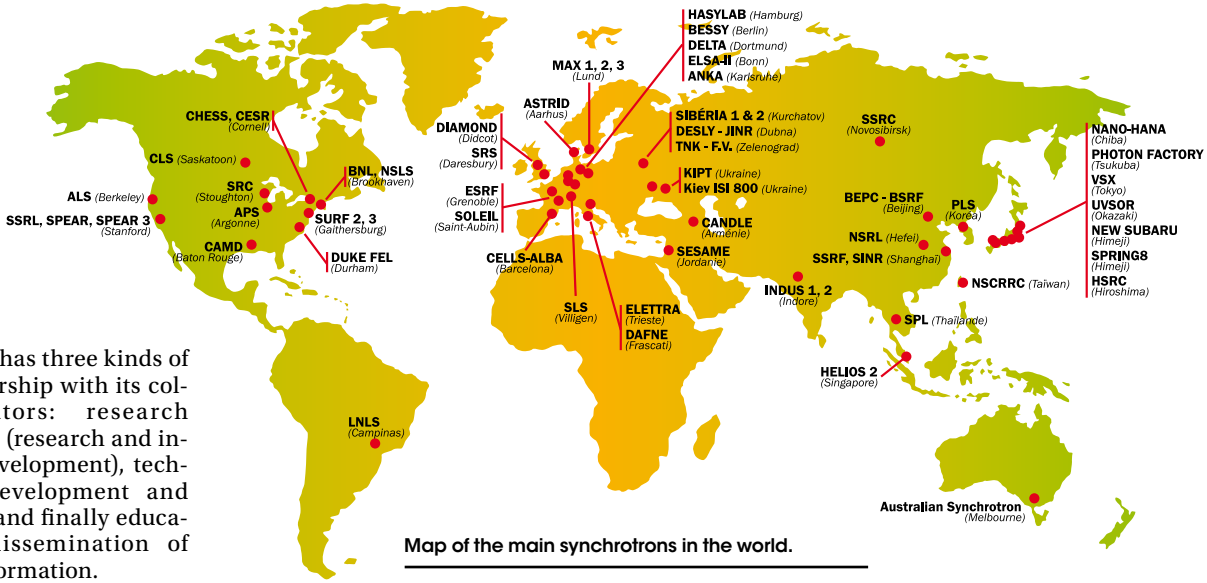
devoted to science, technology and innovation panned out by logging on to **www.sri2012.org**

The next SRI conference will take place in New York in 2015 and, as is the tradition, the local SOLEIL- ESRF 2012 organizing committee will accompany our American colleagues to ensure that the 12th SRI enjoys the same success.

KEY FIGURES
4 DAYS OF CONGRESS
1009 PARTICIPANTS
679 POSTERS
72 EXHIBITION STANDS

SOLEIL's partnerships: design, build and implement together

Research is definitely a collective venture and SOLEIL is constantly interacting with its environment: its communities of users, its European and international counterparts, as well as institutional, industrial, economic and educational bodies who request its services. SOLEIL is forging partnerships with many players.



Map of the main synchrotrons in the world.

SOLEIL has three kinds of partnership with its collaborators: research partnerships (research and instrument development), technological development and innovation, and finally education and dissemination of scientific information.

Sharing expertise, fostering innovation

As a sign of the times, SOLEIL's partnerships are also subject to increasingly rigorous and detailed contracts. There have been more than 70 since early 2011 (an increase of approximately 20% per year), totaling nearly 200 since the creation of SOLEIL and it continues to accelerate! Since that date, for example, SOLEIL is a partner in several new projects, including 4 EQUIPEX (including NANOIMAGES-X, where it is coordinator), 4 LABEX (NanoSaclay, PALM, P2IO and PATRIMA), 5 ANR (including 1 as coordinator), 5 European projects (BioSTRUCT-X, CALIPSO, M3D, oPAC and LANIR), one Erasmus Mundus (SERPChem), a dozen actions with the 'Fondation de Coopération Scientifique du Plateau de Saclay' and over thirty bilateral agreements with companies, research and/or educational organizations and associations.

Most of these projects generate income. Partnerships created in previous years brought in about 800k€ income in the 2011 budget. However it should not be forgotten that:

- Partnerships are considered in principle as joint research actions at shared cost, often 50/50 – with SOLEIL contributing in kind or with its own funds to the activities,
- Collaborations subject to calls for proposals are not perennial, e.g. the CECILIA2 consortium was not extended by the European Commission in 2011 and it took a year before European transnational access was refunded again (CALIPSO).

Enter, or not, in a logic of calls for projects

Many of our partnerships are partly funded by third parties (ANR, LABEX, European Commission, ESF, regions, etc.) on the basis of calls for projects (44/year for ANR alone!). Given the preparatory work required before the submission of a project to these calls, it is necessary for SOLEIL to weigh up the pros and cons in terms of scientific strategy, positioning within the project partners, management constraints and also image. The few euros gleaned in a project can turn out be expensive to manage during the 4 or 5 years of the contract. Conversely, becoming attached to a project at the last moment can be very beneficial not only in terms of resources but also new relationships!

At SOLEIL, the right approach is based on our researchers' initiatives, their ability to imagine the future, in a word, their "feeling" for a project. It is up to us to find, with them, the most suitable framework for the development of their research, teaching and technology transfer projects.

This does not prevent us from thinking about more sustainable partnership models such as thematic platforms for research and services, such as the IPANEMA platform for ancient materials that SOLEIL devised in 2004 to meet the needs expressed by the scientific communities. Partly funded through the CPER 2007-2013 with the Ile de France region and the state, this is being built on the SOLEIL site and is now owned by a consortium of partners that will make it grow and evolve.

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Science and society, an everyday commitment

Tools for working and discovery for all.

SOLEIL is an interdisciplinary place and it wanted to meet the expectations of its shareholders and partners by becoming a center for the exchange and dissemination of scientific and technical information for all. SOLEIL has thus been open to the public every day since the project started in 2002 and develops scientific activities for schools and colleges as well as the general public. This activity is driven in partnership with the most committed players in the field: educational boards (especially that of Versailles and Orléans Tours), schools, associations, local authorities and media libraries... To demystify, de-compartmentalize, participate in the transmission of knowledge, this is another side to the daily work of SOLEIL groups who offer the opportunity to everyone to discover and take in the latest scientific thinking at their own pace.

Researchers and scientific mediators, united in purpose

At SOLEIL, high school or college classes, students, local residents and the general public are always present on site and now form part of everyday life of the research groups. The role of those who lead the research at SOLEIL is essential in transmitting knowledge and creating the dialogue around the research that SOLEIL has developed. Thus, the specifications for public understanding of science at SOLEIL aim to create a dynamic where the knowledge acquired or experienced and experimental practices become enriched. The researcher is not the custodian of absolute knowledge, but the resource provider: he or she gives life to the content by including it in practice and enabling a link to be made, for example, between what is learned in the classroom and what happens in a research center. In this connection, a partnership established for the past 10 years with the Education Board of Versailles has been totally indispensable. Non-formal education such as this complements the work of teachers, who endorse this collaboration. For SOLEIL, respect for all forms of knowledge and all procedures, academic or self-taught, guide their everyday relationship. Its 10 years experience of science literacy contradicts the common misconception of public mistrust towards science and scientists.

SOLEIL, a research center open to the public every day.

To be continued on page 32...

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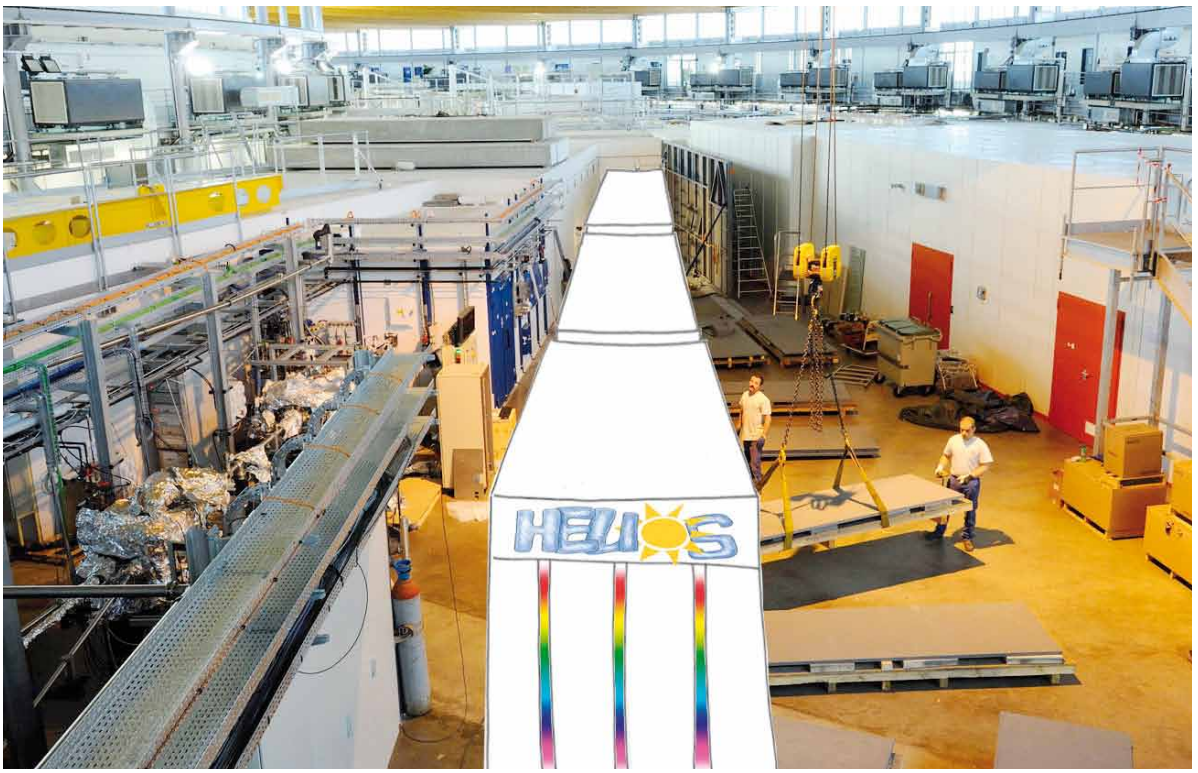
HELIOS, a beamline project solely for training and mediation purposes.



SOLEIL Pursuit, a crazy idea for a full-scale treasure hunt in the synchrotron, initially started with the support of the Ile-de-France; this annual program is becoming a permanent feature.

Science together, another approach to science

A science bus, science theatre, educational events in the underground and in the market place, teaching kits, experimental workshops and customized lectures... to support this approach, the SOLEIL toolbox grows each year at the request of the public. All product support, all activities organized by SOLEIL or in which it participates, result from requests on the ground. Already tens of thousands of people have met us on site, at special events or at more conventional venues (science festivals throughout the Ile-de-France, trade forums in Essonne and elsewhere, Science Roundabout in the city, science days, etc.).
Every time there is a single watchword, "listening", to questions from the audience, to their doubts and expectations. At SOLEIL everyone is aware of this. As always, some were harder to convince, but all those who experienced a real dialogue with the public returned enthusiastic and are now the most ardent spokespersons for this action. Enthusiasm shared, as shown by our visitors, especially with teachers who return, year after year, with new classes and suggest improvements and new topics.
Today, in order to render more familiar topics and techniques that we develop, the public must be allowed to venture further, at home, at school, at exhibitions, etc. For SOLEIL, the whole purpose of its actions is ultimately to share scientific knowledge.

↘ KEY FACTS
OVER 30,000 VISITORS
10 EDUCATIONAL MODULES ON DIFFERENT TOPICS (TEACHER/STUDENT KITS - VIDEOS AND OTHER ASSOCIATED MULTIMEDIA), 8 EXHIBITIONS ON FREE LOAN (SYNCHROTRON, LIGHT/MATTER, CHEMISTRY, ENERGY ETC.) AND 5 COORDINATED EXPERIMENTAL WORKSHOPS.

→ **www.synchrotron-soleil.fr**

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