Activity Report 2019

ALBA

© ALBA Synchrotron. All rights reserved.
ALBA Synchrotron
Carrer de la Llum 2-26
08290 Cerdanyola del Vallès (Barcelona)
Spain
Tel. +34 93 592 4300

Editors: Salvador Ferrer and Sarah Moreira

Graphic design: Lucas Wainer

Printing: Artgraf

This document has been printed on recycled paper (Cyclus Print and Cocoon papers from Antalis).

FOREWORD

Unveiling the mechanism of one of the main reasons of antibiotic resistance, the bacterial division; observing, for the first time after its prediction, an antiferromagnetic topological insulator with great potential applications in spintronics; developing a new method to stabilize perovskite thin films in search of cheap and efficient solar cells, are examples of the more than 250 papers published during 2019 in relation to ALBA beamtime experiments.

All ALBA key indicators are steadily ramping up, the volume and impact factor of its scientific production being the best evidence of the facility's performance and of the excellence and dedication of its staff and knowledgeable users.

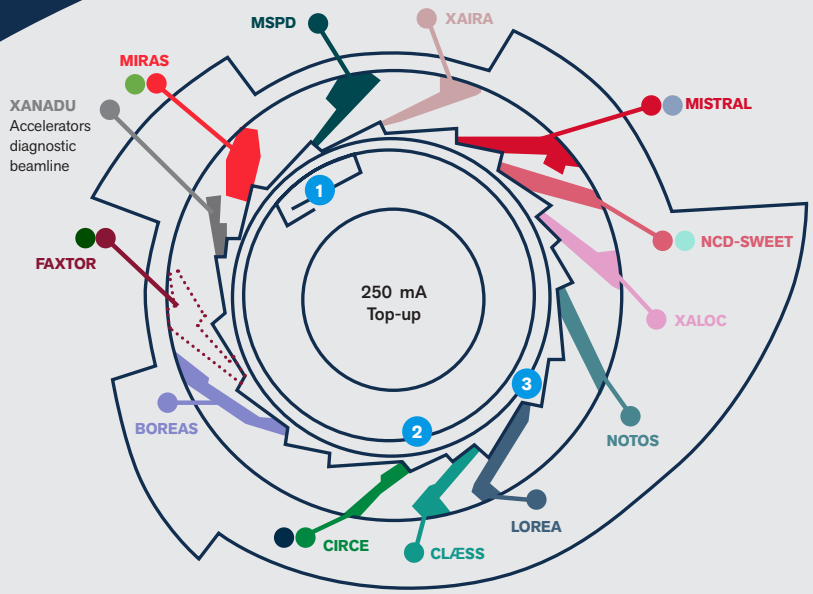
Construction of the next beamlines is ongoing and the commissioning of two of them is starting in a few months. An agreement with several institutions from the Barcelona area has been signed for the creation of an advanced microscope center co-owned by different actors, whereby ALBA will be hosting in the near future a cryo-EM for life science and a TEM for materials science, perfect complements to the instrumental capacity of the synchrotron.

Active participation in the European panorama of light sources, now channeled through LEAPS, is a constant source of betterment in all scientific and technological areas, opening opportunities to academic and industrial communities that go beyond the reach of single national facilities. Regarding international cooperation, a step forward has been taken with the signature of a collaboration agreement between the Portuguese Fundação para a Ciência e a Tecnologia (FCT) and ALBA, which was signed under the auspices of the science ministers of both countries.

At the end of the year, we were greeting the Vice-Director Gastón García who, after 14 years at ALBA, has gone back to Madrid to become the Director of the Centre for Micro Analysis of Materials at the Autonomous University of Madrid. Gastón has been an essential person in ALBA, from the first up to the last day with us. His wide scientific and technical knowledge, his managerial skills, his extreme generosity, and his unceasing availability for helping and solving problems, will be highly missed by the whole ALBA team. We wish him all the best for his new and interesting professional development, looking forward to strengthening the collaboration between our two facilities.

We maintain our commitment to serve the society by helping to find solutions to many of the challenges our world is facing. We are confident that our national and regional funding agencies will continue supporting us with renewed effort, within the application of their proclaimed policies of R&D promotion.

Caterina Biscari
Director



1 LINAC
Electrons are accelerated to 100 MeV

2 BOOSTER
Electrons reach 3 GeV

3 STORAGE RING
268 m circumference
Electrons deliver synchrotron light to the beamlines

ELECTRONIC AND MAGNETIC STRUCTURE OF MATTER

- **CIRCE-PEEM**
  Photoemission microscopy (PEEM) for nanoscience and magnetism
- **BOREAS**
  Circular magnetic dichroism & resonant magnetic diffraction
- **MISTRAL**
  Spatially resolved spectroscopy and magnetic domain imaging.
- **LOREA*** (under construction)
  Angled-resolved photoemission spectroscopy for advanced materials

LIFE SCIENCES AND SOFT CONDENSED MATTER

- **NCD-SWEET**
  Small & high-angle X-ray scattering/diffraction
- **XALOC**
  X-ray diffraction for macromolecular crystallography
- **XAIRA*** (under construction)
  X-ray microdiffraction for macromolecular crystallography
- **FAXTOR*** (under design)
  Fast X-ray tomography & radioscopy
- **MIRAS**
  Infrared microspectroscopy
- **MISTRAL**
  X-ray cryo-tomography and microspectroscopy

CHEMISTRY AND MATERIALS SCIENCE

- **MSPD**
  High-resolution & high-pressure powder diffraction
- **NOTOS*** (under construction)
  X-ray absorption & powder diffraction
- **FAXTOR*** (under design)
  Fast X-ray tomography & radioscopy
- **CLÆSS**
  X-ray absorption & emission spectroscopy for catalysis and environmental science
- **NCD-SWEET**
  Small & high-angle X-ray scattering/diffraction
- **MIRAS**
  Infrared microspectroscopy
- **CIRCE-NAPP**
  Near-ambient-pressure photoemission (NAPP) for surface chemistry and catalysis

ALBA AT THE SERVICE OF SPANISH RESEARCH

The ALBA Synchrotron is the largest scientific infrastructure in Spain, providing cutting-edge synchrotron-based techniques to more than 2,000 researchers every year. Based on a complex of electron accelerators, ALBA produces extremely bright beams to analyse and understand the properties of matter with photon energies ranging from infrared to hard X-rays. ALBA provides solutions to current societal challenges, spanning from health to energy production and storage, from environmental problems to advances in communication technologies, and from understanding our cultural heritage to preserving it.

NEW BEAMLINES ARE BEING INSTALLED

At the end of 2019 there are four beamlines under different stages of construction. LOREA and NOTOS have entered the installation phase, XAIRA is in an advanced design stage, while FAXTOR is still in an early stage of design.

LOREA is the most advanced among the four beamline projects. Almost all its optomechanical components have been delivered, tested, and are installed at their final position. The monochromator, which is an in-house design, has been pre-assembled in order to test its performance. The final assembly will be finished in summer 2020. Also, parts of the end station, like the electron analyzer, have been delivered, while the rest of its components are being manufactured or tested at factory. The beamline will be ready to start

commissioning in autumn 2020, and the goal is to have expert users before the end of the year.

The components of NOTOS coming from Spline (ESRF) have been serviced and are ready for installation. Meanwhile, the contract for the rest of the components has advanced as expected. The design of the double crystal monchromator is finished, and the new and repolished mirrors will be delivered in 2020. The installation of the front end and of the beamline infrastructure has started. The commissioning of the beamline is expected to start in September 2020.

The project for XAIRA has progressed in different aspects. The procurement of the optomechanical components of the beamline, including the monochromator and the refocusing of optics, is very advanced, and the supply contracts will be signed early in 2020. Besides, the conceptual design review of the end station has been completed, allowing to start a more detailed design. Meanwhile, other parts of the beamline are also progressing; the front end, radiation hutches and part of the infrastructure have been delivered, while the photon source is being manufactured.

Finally, the project for FAXTOR was also started during 2019. The beamline concept has been defined, and the optical design of the beamline is almost complete. The technical specifications of the photon source and of the front end have been prepared in order to publish the corresponding call for tenders early in 2020.

GOVERNING BODIES

ALBA is funded in equal parts by the Spanish and Catalan Governments. The composition of the governing bodies in 2019 is:

GOVERNING COUNCIL

Chair: Mª Àngels Chacón i Feixas, Minister of Business and Knowledge (GENCAT Catalan gov.)
Vice-Chair: Pedro Duque Duque, Minister of Science, Innovation and Universities (MINCIU, Spanish gov.)
Members

- Rafael Rodrigo Montero, Secretary-General for Sciency Policy Coordination, MINCIU
- José Ignacio Doncel Morales, Deputy Director for Singular Scientific and Technical Infrastructures, MINCIU
- Rosa Menéndez López, President of the Spanish National Research Council (CSIC)
- Francesc Xavier Grau i Vidal, Secretary for Universities and Research, GENCAT
- Joan Gómez i Pallarès, Director-General for Research, GENCAT
- Margarita Arboix Arzo, Rector of the Universitat Autònoma de Barcelona (UAB)

Secretary: Berta Bernad Sorjús, Lawyer of the Catalan Government, GENCAT
Vice-Secretary: Severo Bueno de Sitjar de Togores, State Lawyer, MINCIU
Guest: Caterina Biscari, Director of ALBA

EXECUTIVE COMMISSION

Chair: Rafael Rodrigo Montero, Secretary-General for Science Policy Coordination, MINCIU
Members:

- Francesc Xavier Grau i Vidal, Secretary for Universities and Research, GENCAT
- José Ignacio Doncel Morales, Deputy Director for Singular Scientific and Technical Infrastructures, MINCIU
- Joan Gómez i Pallarès, Director-General for Research, GENCAT

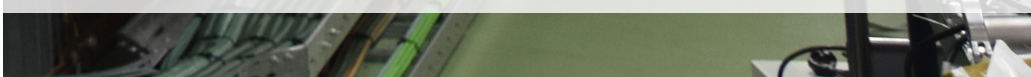
Secretary: Severo Bueno de Sitjar de Togores, State Lawyer, MINCIU
Vice-Secretary: Berta Bernad Sorjús, Lawyer of the Catalan Government, GENCAT
Guest: Caterina Biscari, Director of ALBA

SCIENTIFIC ADVISORY COMMITTEE

Board of internationally renowned experts in the field of synchrotron radiation, who participate in the strategic scientific direction of the ALBA Synchrotron with the aim of ensuring the quality and relevance of the research performed and developed at ALBA.

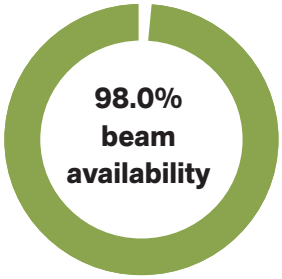
Chair: Ian Robinson, Professor of the London Centre for Nanotechnology & X-Ray Scattering Group Leader at Brookhaven National Laboratory in New York (USA). Beatriz Roldan, Director and Head of the Department of Interface Science at the Fritz Haber Institute (Germany).
Members:

- Gwyndaf Evans, Principal Beamline Scientist for VMXm at Diamond Light Source (UK)
- Reinhard Brinkmann, Lead Scientist at the DESY Accelerator Division (Germany)
- Valerie Briois, ROCK Beamline Manager at Soleil Synchrotron (France)
- Tiberio Ezquerra Sanz, Head of Soft and Polymeric Matter Group at Instituto de Estructura de la Materia-CSIC (Spain)
- Amina Taleb-Ibrahimi, Director for Matter Sciences at Soleil Synchrotron (France)
- Pedro Fernandes-Tavares, Project Leader for the Storage Rings at Max-IV Laboratory (Sweden)
- Marco Stampanoni, Paul Scherrer Institut & Swiss Federal Institute of Technology (Switzerland)
- Carlo Carbone, Research Director at Consiglio Nazionale delle Ricerche, Istituto di Struttura della Materia (Italy)
- Oliver Seeck, Leader of the PETRA III experiments group at DESY (Germany)



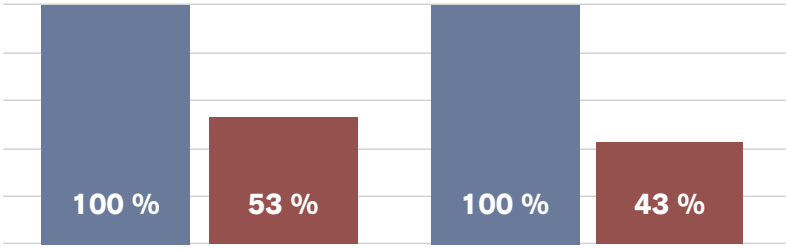
KEY FIGURES IN 2019[1]

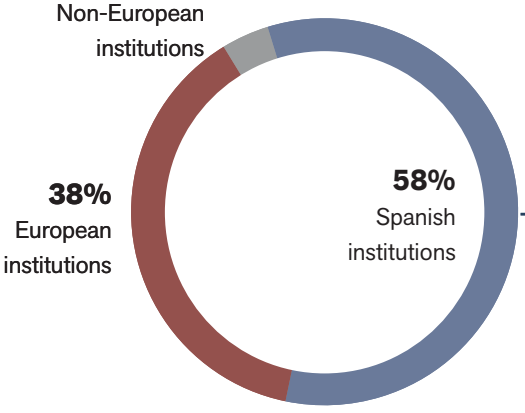
Serving our user community

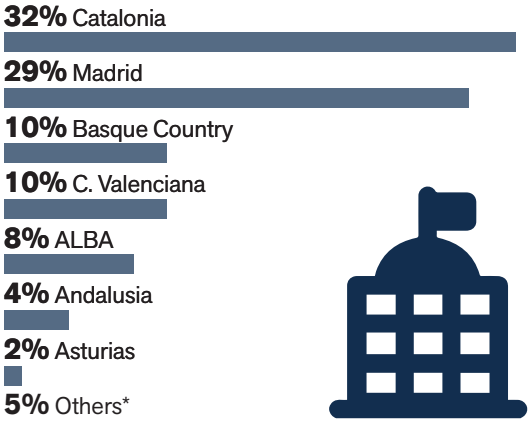


5,888 operation hours
4,680 hours for beamlines
90 hours Mean Time Between Failures
1,8 hours Mean Time To Repair

535 Submitted Proposals
281 Granted Proposals
6,447 Requested Shifts
2,770 Awarded Shifts

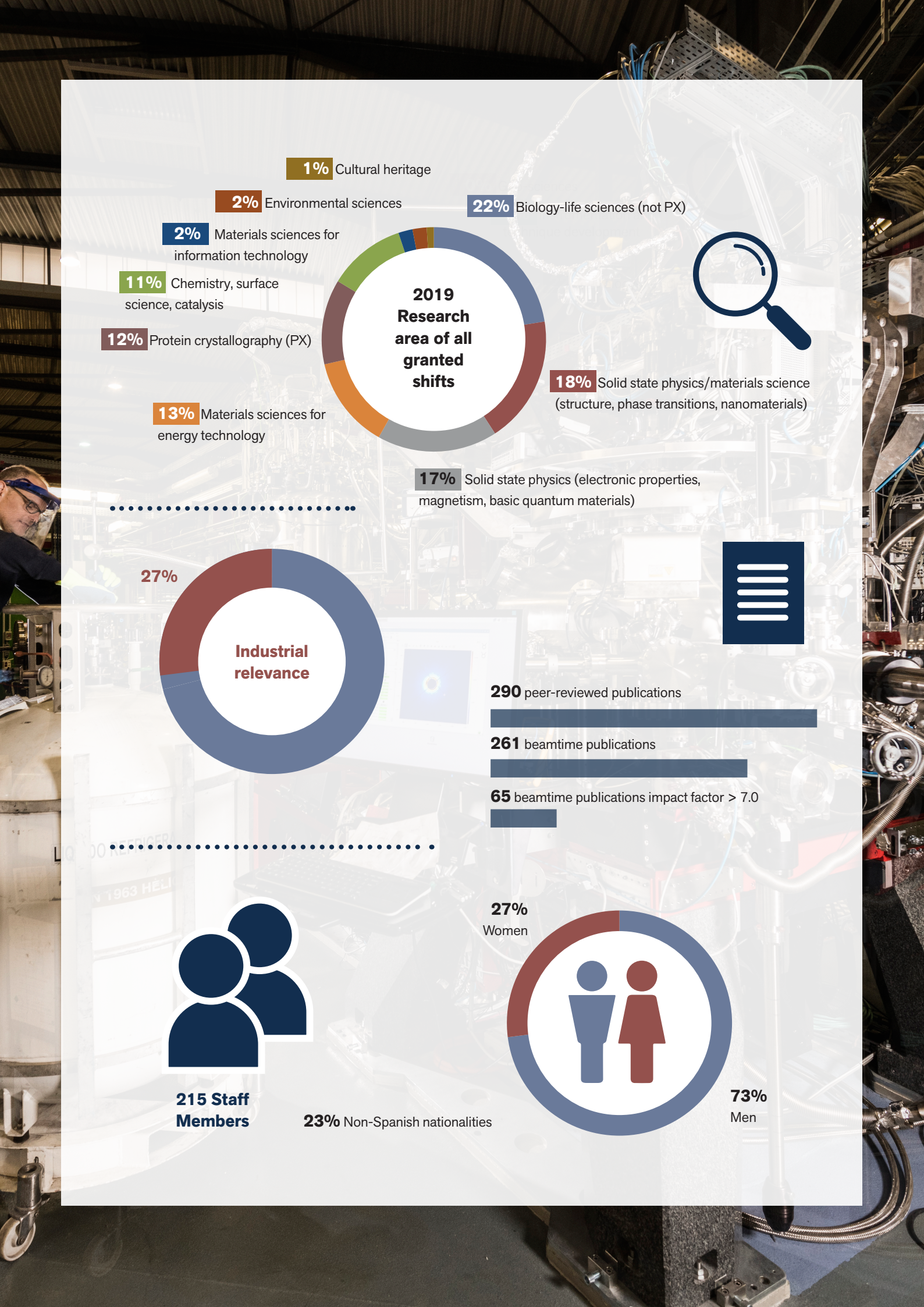






*Sum of Aragon, Castilla-La Mancha, Galicia and Castilla y León

1. Percentages are rounded up to units


1% Cultural heritage
2% Environmental sciences
22% Biology-life sciences (not PX)
2% Materials sciences for information technology
11% Chemistry, surface science, catalysis
12% Protein crystallography (PX)
2019 Research area of all granted shifts
18% Solid state physics/materials science (structure, phase transitions, nanomaterials)
13% Materials sciences for energy technology
17% Solid state physics (electronic properties, magnetism, basic quantum materials)
27%
Industrial relevance
290 peer-reviewed publications
261 beamtime publications
65 beamtime publications impact factor > 7.0
215 Staff Members
23% Non-Spanish nationalities
27% Women
73% Men

JANUARY

Launching of the BEATS project for a tomography beamline at Sesame

The European grant is worth 6 million euros and will span a four-year period from beginning 2019 to end 2022. Nine partner institutes, including ALBA, join forces for the project.

FEBRUARY

Boosting the scientific collaboration with Portugal

Science ministers from Portugal and Spain visited ALBA, motivated by a collaboration agreement that promotes the Portuguese scientific community using the ALBA Synchrotron and a training program for Portuguese postdoctoral researchers at ALBA.

MARCH

Klaus Attenkofer appointed new scientific director of ALBA

From 4th March, Klaus Attenkofer is in charge of the Experiments division. He highlights "his enthusiasm in being part of the ALBA team, a facility with huge growing possibilities and outstanding research capabilities".

APRIL

Promoting the construction of a Mexican synchrotron facility

Caterina Biscari, director of the ALBA Synchrotron, took part in the first interdisciplinary council for building a synchrotron in the Mexican state of Hidalgo.

MAY

Discussing synchrotron light applications for the polymer industry

The Industrial Office organised a workshop addressed to companies in the polymer industry. The participants learned about the applications of the synchrotron techniques to improve the properties of these materials.

JUNE

ALBA received an award from the Engineers of Girona

The Manel Xifra awards ceremony was jointly organised by the Association of Industrial Engineers of Girona and the company Comexi Group. The ALBA Synchrotron was awarded in the category of applied research or technological centres.

JUNE

More than 2,400 people visit ALBA

The ALBA Open Day 2019 welcomed 2,425 visitors who were able to know first-hand how the facility works and its main scientific applications.

2019 IN ALBA

AUGUST

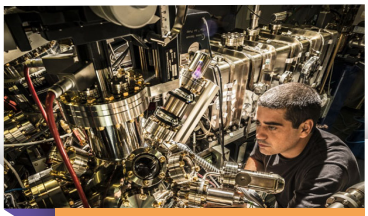
Installation of a new dipole chamber for LOREA

The new dipole chamber for LOREA was installed during the summer shutdown. The replacing of the old dipole chamber with the new one was necessary to allow the complete exploitation of the LOREA insertion device in the whole energy range and with all polarisations.

SEPTEMBER

New investments from the Catalan Government

The President of the Generalitat de Catalunya, Mr. Quim Torra, visited the ALBA Synchrotron and announced an investment aimed at opening a new microscopy centre that will host two high-performance electron microscopes at ALBA.



OCTOBER

The International Day of Light: a winning picture from ALBA

Photographer Sergio Ruiz won the Technology and Science Prize of the #IDL2019 Photo Contest with a picture at the CIRCE beamline of the ALBA Synchrotron.

OCTOBER

The Spanish synchrotron user community gathers at ALBA

The IX AUSE (Spanish Synchrotron User Association) Congress and IV ALBA Users Meeting were held at ALBA. 150 delegates discussed scientific results obtained with synchrotron light and the present and future challenges of these facilities.

NOVEMBER

Hiring young talent

Five young people joined ALBA's staff thanks to the grants of the programme "Empleo Joven". During two years, they will give support to the areas of communication, experiments, accelerators and computing.

DECEMBER

Caterina Biscari, new chair of LEAPS

At the League of European Accelerator-based Photon Sources (LEAPS) plenary meeting, Helmut Dosch handed over the symbolic LEAPS baton to Caterina Biscari, director of ALBA, who will take over as chair of LEAPS in January 2020.

LIFE SCIENCES AND SOFT CONDENSED MATTER

Judith Juanhuix, Head of the Life Sciences and Soft Condensed Matter section (Experiments Division).

The Life Sciences and Soft Condensed Matter section is progressing steadily in increasing the number and variety of the beamlines and in gathering an ever larger variety of samples at resolutions that span several orders of magnitude. The samples used at the beamlines of this section range from single-type proteins in an ordered repeat forming microcrystals whose structures are solved at a near-atomic resolution using hard X-rays, up to whole tissues probed with infrared photons at a micrometric scale.

Four beamlines in the section are operating at full momentum to boost such different studies. In the hard X-ray range, this section includes the operating macromolecular crystallography beamline XALOC and the non-crystalline scattering/diffraction beamline NCD-SWEET. XALOC is a consolidated beamline routinely producing an excellent photon beam for all single-crystal oscillation methods. The reliability of the beamline and the success of the remote access have led to introducing several BAG groups per day and boosting the industrial activities. XALOC is also successfully performing *in-situ* experiments and exploring its capabilities in jet-based serial crystallography. NCD-SWEET has seen its submissions double due to the great results of the upgrade of the beamline done in previous years, and is now giving service to a wide range of experiments and sample environments, which benefit from the microfocus option it is routinely providing. In particular, the GISAXS experiments have experienced a large increase in number and output scientific quality, as seen in the highlights.

This section also comprises a full-field transmission microscopy beamline in the soft X-ray range, MISTRAL, one of the few beamlines of this kind in the world. In the bio field, MISTRAL is able to image whole vitrified cells in 3D at a resolution of a few tens of nanometers using the water window region, in which the carbon-rich structures have high absorption contrast. The beamline has an epifluorescence visible-light microscope online which allows correlative microscopy. MISTRAL is also carrying out spectroscopic 2D and 3D imaging at several interesting X-ray absorption edges such as Ca, O or Fe. Finally, the infrared beamline MIRAS, dedicated to spectroscopic and imaging studies, allows investigating a large variety of samples like tissues, single cells and many organic and inorganic samples in transmission, reflection and grazing incidence geometries at a spatial resolution of a few microns.

These beamlines are fully serviced by nearby biological laboratories, which include specialized mammal cell and biosafety level 2 labs, open to beamline users and to in-house research. An automatic dispenser for protein crystallization compatible with LCP techniques is available for academic and industrial usage upon demand.

The portfolio of beamlines in the section is being completed with the construction of two new beamlines. The microfocus macromolecular crystallography beamline XAIRA is under construction and is expected to see the first experiments by the end of 2021. The new hard X-ray tomography and radiography beamline FAXTOR has seen great progress with the design of the optics and the procurement of the photon source, and will see the light of day in 2023.

The scientific strategy of the section is being geared towards tackling relevant scientific challenges from a multi-scale perspective by using several beamlines and external national and international collaborators.

Unveiling the mechanism of bacterial division

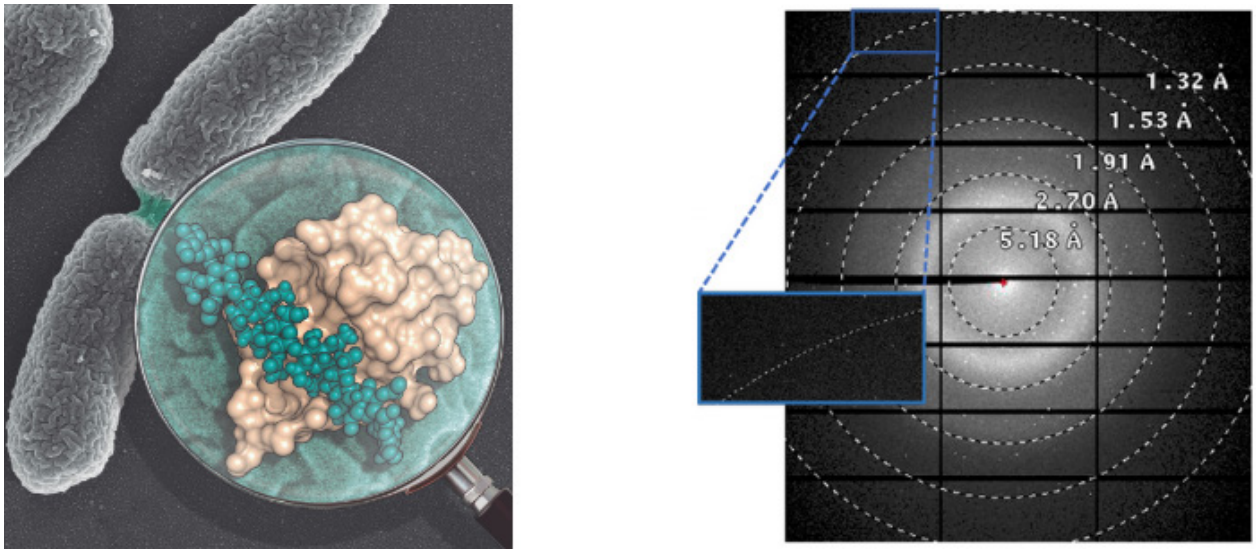
The high division rate of bacteria is one of their main weapons for antibiotic resistance. This work opens the door to the development of drugs that can block this precise mechanism.

The high division rate of bacteria, that is, the successful way in which they reproduce, is one of their best weapons against antibiotics. A team from the Rocasolano Institute of Physical Chemistry (IQFR-CSIC) in Madrid, Spain, the University of Notre Dame in the United States and the National Centre for Biotechnology (CNB-CSIC) in Madrid, Spain, has revealed the structure of a key machinery in the process of bacterial division. The conclusions, published in the journal *Nature Communications*, open the door to the design of a future drug capable of blocking this precise machinery, without which bacteria become sensitive to the antibiotic effect.

A wide group of various proteins that assemble in an ordered and dynamic way orchestrates bacterial cell division, thus forming a precise machinery that guarantees the proper development of reproduction. Virtually all bacterial species have specialized domains that recognize the bacterial wall (composed of peptidoglycan) at the time of division and allow the correct location in space and time of these proteins during the generation of the two daughter cells from the mother cell.

The scientists have used the X-ray crystallography technique, in the XALOC beamline at ALBA, to obtain the structure of these specialized domains. More specifically, they have studied the SPOR (*Sporulation-related repeat*) domain of the RlpA protein of ***Pseudomonas aeruginosa***, a multiresistant bacteria against which there are few antibiotics available and which is considered a "critical priority pathogen" by the World Health Organization.

This work unveils, for the first time, why all SPOR domains recognize the same type of wall to facilitate the division. The results provide information at the atomic level on how the SPOR domains get connected to the bacterial cell wall and, thus, open the door to the development of molecules that can specifically block these domains, which would make bacteria sensitive to antibiotics.



On the left, the SPOR domain (beige) connected to the cell wall (green spheres). In the background, a microscopy image of Pseudomonas aeruginosa *dividing in two. /IQFR-CSIC. On the right, diffraction image of SPOR-RlpA crystal collected in XALOC beamline.*

REFERENCE:
Martín Alcorlo, David A. Dik, Stefania De Benedetti, Kiran V. Mahasenan, Mijoon Lee, Teresa Domínguez-Gil, Dusan Hesek, Elena Lastochkin, Daniel López, Bill Boggess, Shahriar Mobashery and Juan A. Hermoso. Structural basis of denuded glycan recognition by SPOR domains in bacterial cell division. Nature Communications. DOI: 10.1038/s41467-019-13354-4

ELECTRONIC AND MAGNETIC STRUCTURE OF MATTER

Manuel Valvidares, Head of the Electronic and Magnetic Structure of Matter section (Experiments Division).

The Electronic and Magnetic Structure of Matter section of the ALBA Experiments Division encompasses the soft X-ray beamlines BOREAS, CIRCE, and the associated Materials Science Laboratory. To this respect, a very exciting development is the ongoing installation of the LOREA beamline on its fast-moving final phase, which is expected to take its first beam in 2020 and will be incorporated to the section.

CIRCE and BOREAS beamlines performed at a very high level in 2019, excelling on the number of user proposals received and experiments completed, industrial access and publications. CIRCE statistics include 26 performed user experiments (336 8-hour shifts), which, taking into account the 76 proposals requested (1,169 8h-shifts), yields an oversubscription rate of proposals (shifts) of 2.9 (3.5); additionally, there were another 3.5 shifts for proprietary access. In the case of BOREAS, the stats are 38 user experiments performed (381 shifts) versus 79 proposals requested (1,073 shifts), yielding an oversubscription rate of 2 (2.8), and 16 8h-shifts for proprietary access. It is worth noting that many of these experiments are sophisticated surface science experiments with *in-situ* preparation (BOREAS, CIRCE-PEEM branch) or *in-situ/in-operando* conditions (CIRCE-NAPP branch).

The 2019 scientific productivity deserves a special mention, as both beamlines have achieved numbers well above previous records: 23 peer-reviewed articles, 6 of which with IFP > 7 and another 2 close to 7, based on experiments at CIRCE; 24 publications, 5 of which with IPF > 7 and another 1 close to 7, with average impact factors above 6, based on experiments at BOREAS. This performance, once again, evidences the high quality of the science performed by our user groups and the cutting-edge capabilities offered by the beamlines in this section. All along 2019, user experiments were key to enable relevant advances of the state of the art and of our current understanding of topological insulator materials (see the section special highlight) and topological magnetic states such as skyrmions, Bloch-point magnetic domain walls or transverse-vortex magnetic domain walls (see the section additional highlights).

Novel capabilities were implemented at the section's beamlines in 2019: a fully in-house designed PEEM cryogenic sample stage was tested and is under a final optimization phase, which represented a significant engineering challenge and required close collaboration between engineering project scientists and PEEM scientists, and an energy-resolving silicon drift detector was installed at BOREAS for partial fluorescence yield approaches, for which considerable control work was done to implement fast on-the-fly spectra acquisition.

Regarding scientific collaboration activities and visitors, scientific staff from the section is leading or taking part in three new national research projects awarded in 2019, and we had several visitors and new staff. At the PEEM end station, we had 3-month PhD stays by Carmen González Orellana (CFM/DIPC, San Sebastián, MINECO) and Shaimaa Ahmed (Egypt, SESAME), and the incorporation of Muhammad Waqas Khaliq as PhD candidate (MSCA COFUND program); at BOREAS we had a 2-month stay by Aritz Lafuente (undergraduate), and again in 2019 Dr. Stefano Agrestini (senior postdoctoral visitor) via the collaboration with the Max-Planck Institute of Chemichal Physics of Solids.

Advances in the field of topological electronic and magnetic states of matter

All along 2019, user experiments at the ALBA beamlines of the Electronic and Magnetic Structure of Matter section were key to enable relevant advances of the state of the art and of our current understanding of topological insulator materials (this special highlight) and topological magnetic states such as skyrmions, Bloch-point magnetic domain walls or transverse-vortex magnetic domain walls (see additional section highlights).

The topological electronic and magnetic states of matter are presently among the most fascinating, complex and fundamental physical phenomena in Materials Science. The signatures of electronic topological order include the occurrence of metallic boundaries on an otherwise insulating material, the display of special fingerprints in the electronic band structure (such as Dirac cones formed by the gapless metallic surface states crossing the insulating bulk gap) or the emergence of exotic particles with fractional charge and statistics. The early theoretical propositions and experimental discoveries of topological insulator materials date from the period 2005-2009, and derived from the physics of the Quantum Hall Effect, which is considered indeed the first example of a topologically non-trivial state of matter. Electronic topological phenomena are now included in a wider class of so-called Quantum Materials. (see for example Moore J, The birth of topological insulators. Nature 464, 194–198 (2010), Nagaosa, N., Tokura, Y. Topological properties and dynamics of magnetic skyrmions. Nature Nanotech 8, 899–911 (2013))

- Prediction and observation of an antiferromagnetic topological insulator.

Otrokov et al., Nature 576, 416–422 (2019). BOREAS

Unlike their non-magnetic counterparts, magnetic topological insulators may exhibit a number of exotic phenomena that have potential applications in spintronics, such as the quantum anomalous Hall effect and chiral Majorana fermions. So far, magnetic topological insulators have only been created by means of doping nonmagnetic topological insulators with 3*d* transition-metal elements, yielding strongly inhomogeneous magnetic and electronic properties and restricting the observation of important effects to very low temperatures. An intrinsic magnetic topological insulator —a stoichiometric well-ordered magnetic compound— could be an ideal solution to these problems. M.M. Otrokov et al. report the first realization of an antiferromagnetic topological insulator in the layered van der Waals compound $MnBi_2Te_4$.

- Topological electronic structure and intrinsic magnetization in $MnBi_4Te_7$: a Bi_2Te_3 derivative with a periodic Mn sublattice.

Vidal et al., Phys. Rev. X, 9 041065 (2019). BOREAS

R.C. Vidal and co-workers report on the first observation of a material with intrinsic net magnetization and topological band inversion that coexist at temperatures below ca. 5 K. This compound, $MnBi_4Te_7$, is a close structural "cousin" of $MnBi_2Te_4$ that is built by alternating layers of $MnBi_2Te_4$ and Bi_2Te_3. Further separation of the magnetic layers in the unit cell promotes competing magnetic states as a function of temperature, which were observed by a variety of experimental techniques on single crystals. $MnBi_4Te_7$ first shows an antiferromagnetic state at 13 K, similar to $MnBi_2Te_4$, and then a metamagnetic transition below 5 K to a state with a ferromagnetic-like hysteresis.

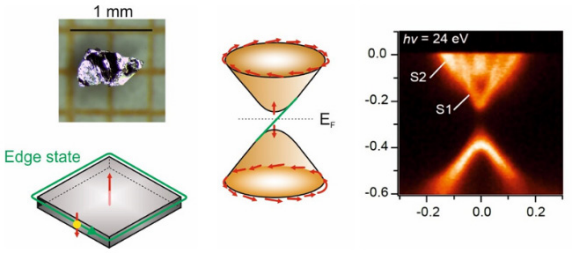


Figure 1. From left to right, an optical-microscope image of a $MnBi_2Te_4$ crystal and a sketch of the expected topological band situation of $MnBi_2Te_4$ in the momentum space: a single two-dimensional Dirac cone which is gapped due to the out-of-plane magnetic order (red) and 1D edge states induced by the non-trivial topology of the magnetic gap (green). Experimental evidence for the presence of a gapped Dirac state on the $MnBi_2Te_4$ (0001) surface is delivered by Angle-Resolved Photoelectron Spectroscopy of the surface electronic structure showing the Dirac state S2 and another surface state S1.

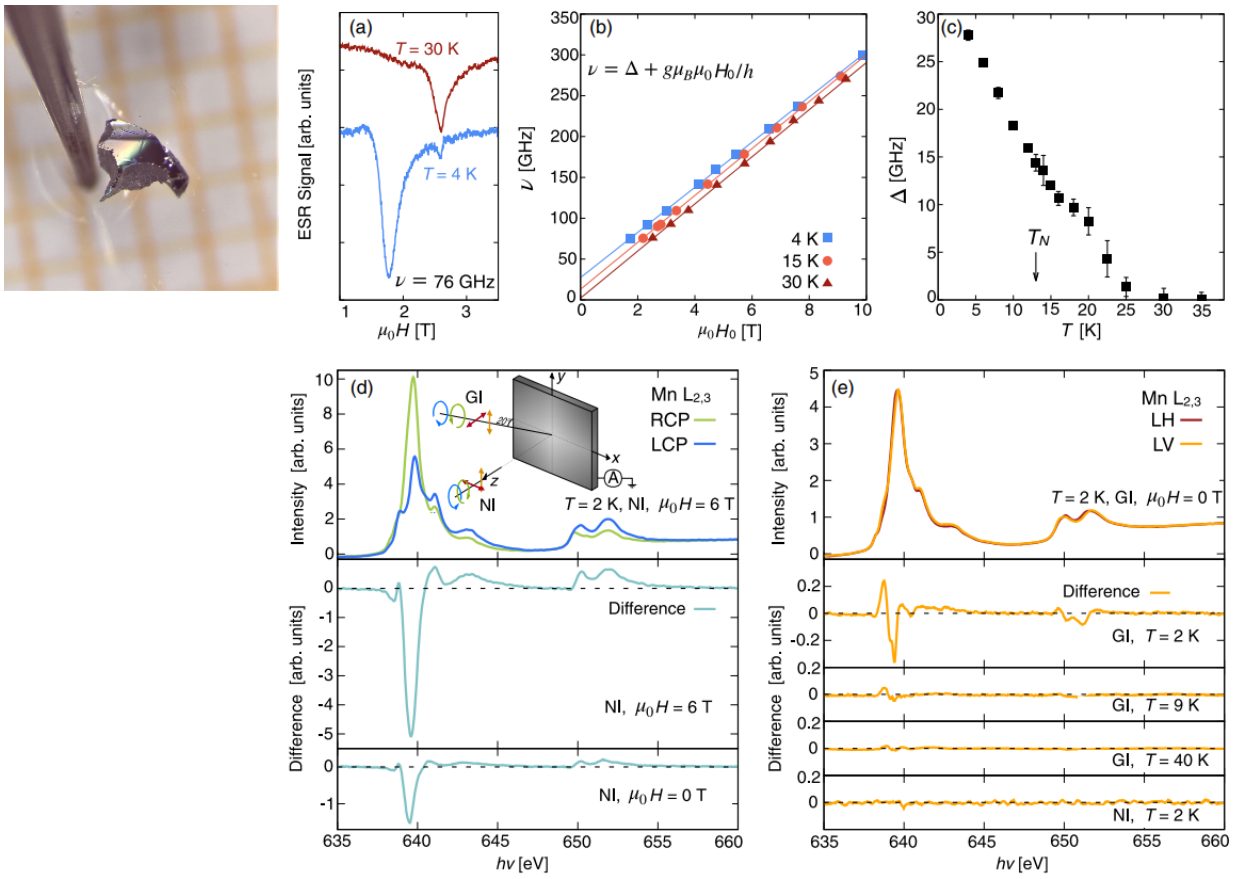


Figure 2. (Left) Microscope photograph of a $MnBi_4Te_7$ single crystal. (Right) Spectroscopy of the magnetic properties in $MnBi_4Te_7$. (a) Typical ESR spectra measured at T = 4 K, 30 K. (b) Frequency dependence of the resonance field of the ESR signal measured at T= 4, 15, 30 K. (c) Anisotropy gap Δ vs temperature extracted from ESR data. (d) XMCD and (e) XMLD at the Mn $L_{2;3}$ absorption edge with circularly polarized (RCP, LCP) and linearly polarized (LV, LH) light, respectively. XMCD signals under an external field of 6 T along the beam direction and for remnant condition at T = 2 K. (e) XMLD data at zero external field for different temperatures.

See also other works in 2019 related to topological insulator materials:
-Cr_2Te_3 Thin Films for Integration in Magnetic Topological Insulator Heterostructures
Burn et al., Scientific Reports vol. 9 Article #: 10793 (2019). BOREAS beamline.
-Surface states and Rashba-type spin polarization in antiferromagnetic $MnBi_2Te_4$ (0001), Vidal et al., Phys. Rev. B (rapid comm) 100, 121104(R) (2019). BOREAS beamline.
-Chemical Aspects of the Antiferromagnetic Topological Insulator $MnBi_2Te_4$
Zeugner et al., J. of Chemistry of Materials, (online) April 2nd, 2019. BOREAS beamline.

Chemistry and Materials Science

François Fauth, Head of the Chemistry and Materials Science Section (Experiments Division).
Carlos Escudero, Beamline Scientist at CIRCE-NAPP (Experiments Division).

Within the ALBA Experiments Division structure, the Chemistry and Materials Science section covers operational aspects of both the hard X-ray beamlines MSPD and CLÆSS, dedicated to Powder Diffraction and Absorption Spectroscopy, as well as the Chemistry and High Pressure laboratories, which are to be used by staff and external users. The scientific program of the Near Ambient Pressure Photoemission (NAPP) station of the soft X-ray CIRCE beamline essentially covers catalysis and related scientific fields, hence interacting with similar topics in MSPD and CLÆSS, which is why in 2019 it was decided to formally include these scientific activities in the section.

From an operational point of view, MSPD, CLÆSS and CIRCE-NAPP registered a record number of academic proposals (93, 86 and 38 respectively) of which 52, 35 and 13 were granted beamtime, respectively. These numbers highlight the severe oversubscription on either soft- (NAPP) and hard-X-ray (CLÆSS) spectroscopy techniques, which are known to be intensively used in heterogeneous catalysis studies but are also starting to be frequently used in battery/electrochemical studies as well. The latter field, together with high-pressure techniques, remains the highest requestor on MSPD. As represented in the selected highlight of the section, microdiffraction techniques at high energy as performed on MSPD tend to be highly valued in archeological studies. On top of that, all the available in-house beamtime is systematically used by beamline staff for own and/or collaborative research. Moreover, all experiments requests for proprietary research were granted beamtime when technically feasible.

The Superconducting Wiggler of MSPD was dismounted and refurbished in early 2019 so as to allow the machine to operate at 250mA. At the same time, during a vacuum intervention on the first mirror, a water leak in one of the two cooling circuits was detected. Both events delayed the start of operations by two weeks but did not significantly alter the operation. On CLÆSS, in order to ensure the protection of equipment, the window supports of all the ionization chambers were redesigned to facilitate their substitution, and a protocol for preventive replacement was introduced. On CIRCE-NAPP, a new assembly of the analyzer entrance cone was implemented and a new cart was built to assemble/disassemble the manipulator from the analysis chamber in a controlled manner, thus avoiding using the crane.

MSPD staff remained unchanged in 2019. CLÆSS welcomed two new postdocs whose scientific interest points towards hetero/homogenous catalysis and photo catalysis, hence well in line with the beamline scientific direction. On CIRCE–NAPP, a new postdoc joined the team in the middle of the year with a scientific focus on metal chalcogenides for photocatalytic water splitting.

In 2019, 56, 26 and 8 publications in peer-reviewed journals were based on research using MSPD, CLÆSS and CIRCE-NAPP beamtime respectively. These numbers, when compared to the number of experiments performed on each beamline, demonstrate the high level of performance of the scientific activity as a whole.

New method to get stable perovskite-based material for more efficient solar cells

An international team of scientists have developed a new method to stabilize black perovskite thin films introducing strains into them using the glass substrate on which they sit.

The demand for green solar-generated electricity is growing and the search for new materials for developing cheap and efficient solar cells is under way.

Perovskite-based devices have recently entered the commercial solar cell market. However, their success and destiny will hinge on improving their long-term stability. This is because some of the promising perovskite materials, like cesium lead triiodide ($CsPbI_3$), struggle to stay black and remain functional under real-world conditions. Instead of being black, $CsPbI_3$ is inclined to form a yellow non-perovskite crystal structure. Therefore, scientists around the world are striving to solve this problem – how to form a stable black $CsPbI_3$ thin film for ambient device operation?

A team of scientists from KU Leuven in Belgium has recently discovered a fundamentally new solution to this problem, and has revealed that the planar architecture of perovskite solar cells can in fact help stabilize black $CsPbI_3$ thin films. They have shown that forming a strong junction between the perovskite and the glass substrate on which it sits, large crystal strains are introduced, shifting its thermodynamic preference toward the desired black form. In particular, the experiments have been performed both at the ALBA Synchrotron (NCD-SWEET beamline) and the European Synchrotron Radiation Facility on $CsPbI_3$ device-ready thin films which were annealed at 330 ºC and then rapidly cooled to room temperature. The heating step is central because the perovskite material binds to the substrate and then is restricted upon cooling (a process called substrate clamping). In this way, the substrate helps to maintain the desired black form structure of the $CsPbI_3$.

The synchrotron light technique used is called GIWAXS (grazing-incidence wide-angle X-ray scattering), where incident X-rays are scattered from the flat perovskite film under a grazing angle, projecting ring-shaped diffraction signals onto the detector, which can rapidly record data. Thanks to this cutting-edge technique, scientists can deeply analyze the structure of these materials and understand the strain-induced changes engineered into the films.

The results confirm substrate clamping and strain is a key enabler in the design of stable perovskite-based optoelectronic devices. The proposed mechanism is fundamentally new and different to other stabilization methods, which typically involve altered chemistry and material morphology, helping to widen the design options on offer to engineers looking to make stable perovskite-based solar cells.

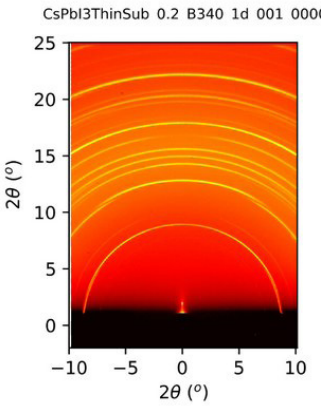
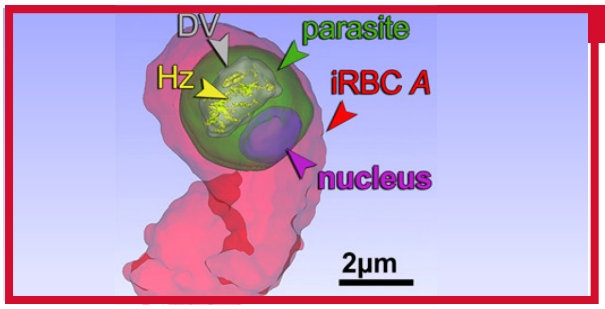


Figure 3. Diffraction pattern from GIWAXS technique at the NCD-SWEET beamline.

REFERENCE:
Thermal Unequilibrium of Strained Black $CsPbI_3$ Thin Films. Science (2019) DOI: 10.1126/science.aax3878

SUMMARY OF SELECTED HIGHLIGHTS

LIFE SCIENCES AND SOFT CONDENSED MATTER



"Mode of action of quinoline antimalarial drugs in red blood cells infected by *Plasmodium falciparum* revealed in vivo". DOI: 1910123116.

BL09-MISTRAL

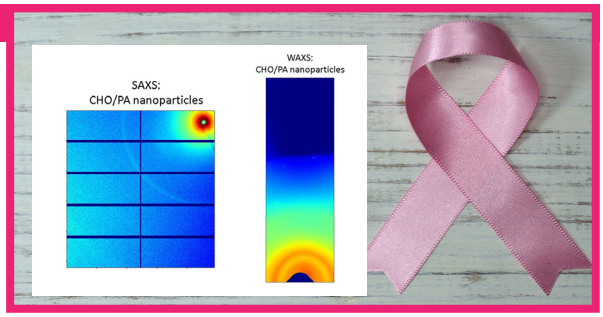
THE MECHANISM OF THE MOST COMMONLY USED ANTIMALARIAL DRUGS UNVEILED IN NEAR-NATIVE CONDITIONS

For centuries, quinoline has been an effective compound in antimalarial drugs, although no one knew its mode of action in vivo. A team led by the Weizmann Institute has discovered its mechanism in infected red blood cells in near-native conditions by using synchrotron light techniques at the ALBA, ESRF and BESSY synchrotrons.

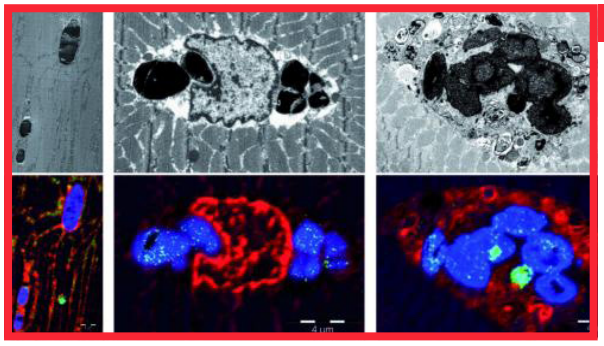
BL11-NCD-SWEET

NEW BIOCOMPATIBLE NANOPARTICLES FOR BREAST CANCER THERAPY

A research team has studied the efficacy of new poly(cyclohexene phthalate) (CHO/PA) polymeric nanoparticles for the sustained delivery of a drug used in breast cancer therapy. The results demonstrate that the polymer maintains its properties when forming the nanoparticles. Moreover, the research has proved that CHO/PA is a biodegradable, non-toxic and blood-compatible polymer.



"Poly(Cyclohexene Phthalate) Nanoparticles for Controlled Dasatinib Delivery in Breast Cancer Therapy". DOI: 10.3390/nano9091208.



"Myoglobinopathy is an adult-onset autosomal dominant myopathy with characteristic sarcoplasmic inclusions". DOI: 10.1038/s41467-019-09111-2.

BL01-MIRAS

ALBA COLLABORATES IN THE DISCOVERY OF A NEW MUSCULAR DISEASE: MYOGLOBINOPATHY

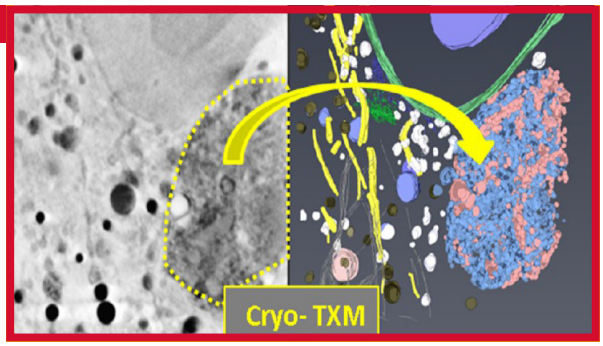
An international collaboration led by IDIBELL identifies the first disease caused by a mutation in myoglobin. Scientists were able to demonstrate the presence of oxidized lipids in the damaged muscle cells.

This discovery has allowed to determine the diagnosis of certain patients after many years of uncertainty and will now allow researchers to focus on finding a cure for this disease.

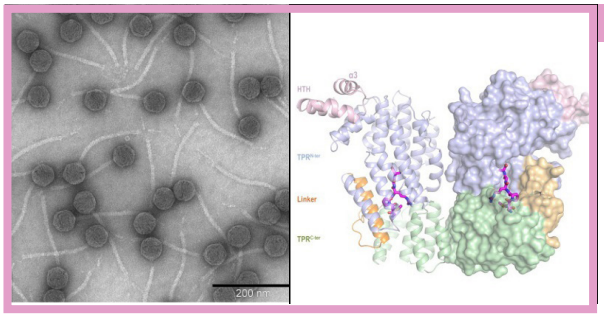
BL09-MISTRAL & BL01-MIRAS

NEW INSIGHTS ABOUT AMYOTROPHIC LATERAL SCLEROSIS (ALS)

Synergetic combination of different imaging and spectroscopic synchrotron techniques performed at ALBA and APS (USA) has discovered new aspects about astrocyte cells of this neurodegenerative disease. Results show significant differences between ALS and control astrocytes, including structural, chemical and macromolecular anomalies. The final goal of the study is to better understand the disease and to contribute to the development of biomarkers and future therapeutic strategies.



"Multimodal Synchrotron Radiation Microscopy of Intact Astrocytes from the hSOD1 G93A Rat Model of Amyotrophic Lateral Sclerosis". DOI: 10.1021/acs.analchem.8b04273.



"Deciphering the Molecular Mechanism Underpinning Phage Arbitrium Communication Systems". DOI: 10.1016/j.molcel.2019.01.025.

BL13-XALOC

DECIPHERING THE MOLECULAR BASIS OF A NOVEL BACTERIOPHAGES' COMMUNICATION MECHANISM

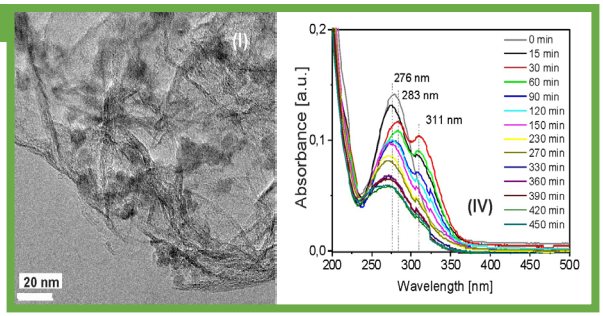
Researchers from the Biomedicine Institute of Valencia (IBV-CSIC), in collaboration with the University of Glasgow, have revealed the molecular mechanism that regulates decision-making processes in the life cycle of certain bacteriophages. These results represent one step forward to unveil the communication systems among bacteriophages and their hosts.

CHEMISTRY AND MATERIALS SCIENCE

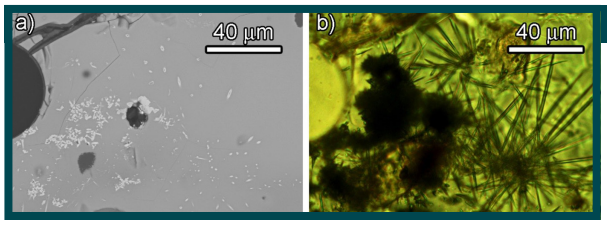
BL01-MIRAS

UREA SUBSTITUTES NOBLE METAL CATALYSTS FOR THE PHOTODEGRADATION OF ORGANIC POLLUTANTS

A new laser-based technique developed by the Institute of Materials Science of Barcelona (ICMAB-CSIC) uses urea, a common substance in the chemical industry and a low-cost alternative to noble metal co-catalyst, to enable a more efficient, one-step production of hybrid graphene-based organic-inorganic composite layers for environmental remediation through photodegradation of antibiotic contaminants from wastewater. The composition and chemical bonds of the urea-enriched thin layers were studied in detail.



"Laser-induced synthesis and photocatalytic properties of hybrid organic-inorganic composite layers". DOI: 10.1007/s10853-018-3144-0.



"Synchrotron tts-µXRD identification of secondary phases in ancient ceramics". DOI: 10.1186/s40494-018-0240-z.
"Breaking Preconceptions: Thin Section Petrography For Ceramic Glaze Microstructures". DOI: 10.3390/min9020113.

BL04-MSPD

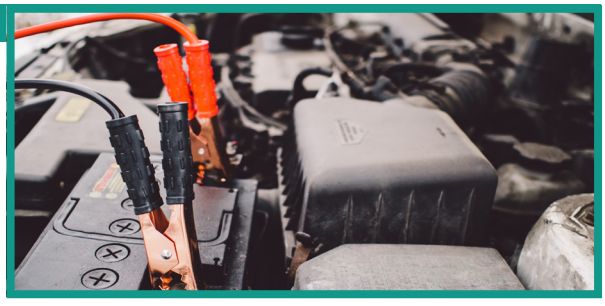
THIN SECTIONS, STILL USEFUL FOR FUTURE RESEARCH

Two articles in the field of archeology have been published, which refute the common perception of thin sections as an old-fashioned laboratory preparation and they have shown how this sample format conceived in the 19th century is still valid and can be adapted to the research and the new tools of the 21st century, such as synchrotron facilities.

BL22-CLÆSS & BL09-MISTRAL

THE ROLE OF MANGANESE IN PROVIDING HIGHER POWER CAPACITY IN LITHIUM AND MANGANESE-RICH CATHODE MATERIALS

Synchrotron light from the CLÆSS and MISTRAL beamlines of ALBA has unveiled the central role of manganese in the limited cycle life of lithium-ion batteries. These are the first published data obtained with the CLEAR emission spectrometer.



"Role of Manganese in Lithium- and Manganese-Rich Layered Oxides Cathodes". DOI: 10.1021/acs.jpclett.9b01174.

BL04-MSPD

FIRST IDENTIFICATION OF A BROWN AERINITE, THE WELL KNOWN BLUE PIGMENT OF THE CATALAN ROMANESQUE ART

Researchers from the ICMAB-CSIC and ALBA have identified brown aerinite for the first time. This work constitutes an example of the utility of the through-the-substrate microdiffraction (tts-μXRD) technique when complex rocks need to be characterized. This technique allows the simultaneous visualization of a thin section of the mineral under polarized light and the measurement of diffraction patterns at the target region previously identified.

"First identification and compositional study of brown aerenite directly on polished thin sections by synchrotron through-the-substrate microdiffraction". DOI: 10.1127/ejm/2019/0031-289.

"Regioselective generation and reactivity control of subnanometric platinum clusters in zeolites for high-temperature catalysis". DOI: 10.1038/s41563-019-0412-6. Image by PressReleaseFinder

BL22-CLÆSS

NEW ZEOLITE CATALYST WITH INDUSTRIAL APPLICATIONS

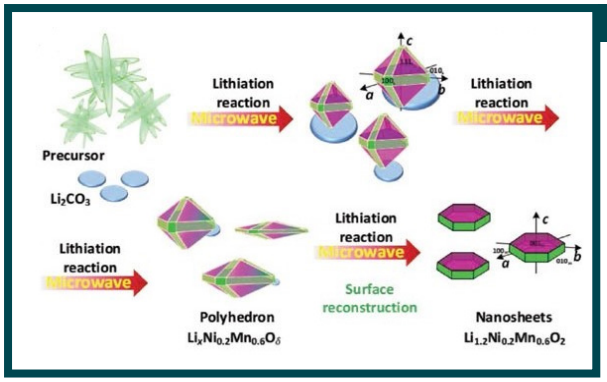
The Institute of Chemical Technology has developed a new zeolite catalyst that remains stable at high temperature, with potential industrial applications such as the production of propylene, one of the chemical compounds most widely used worldwide. X-ray absorption experiments were carried out to characterize the zeolite's materials.

BL24-CIRCE-NAPP

A STEP CLOSER TO SMART CATALYSTS FOR FUEL GENERATION

Researchers at the Federal University of Rio Grande do Sul in Brazil in collaboration with the ALBA Synchrotron have performed the first detailed measurement of the strong metal-support interaction (SMSI) effect in Cu-Ni nanoparticles supported on cerium oxide. A better understanding of this effect is essential for developing smart catalysts that are more selective, stable and sustainable.

"Understanding the Strong Metal–Support Interaction (SMSI) Effect in CuxNi1–x/CeO2 (0 < x < 1) Nanoparticles for Enhanced Catalysis". DOI: 10.1021/acsanm.9b00569. Image designed by jcomp / Freepik.



"Lithium/Oxygen Incorporation and Microstructural Evolution during Synthesis of Li-Rich Layered Li[Li0.2Ni0.2Mn0.6]O2 Oxides". DOI: 10.1002/aenm.201803094.

BL04-MSPD

IMPROVING THE SYNTHESIS OF ALTERNATIVE CATHODE MATERIALS FOR THE NEXT GENERATION OF LITHIUM-ION BATTERIES

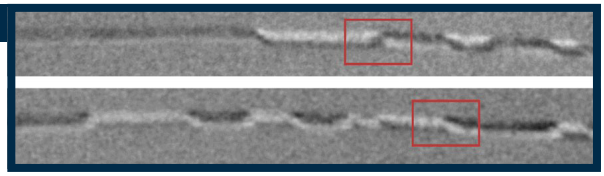
An international group of researchers has unveiled the transformation processes that take place during synthesis of lithium-rich layered oxides that are used as cathode materials in lithium-ion batteries. These low-cost materials showed very high capacity and speed, becoming promising candidates for the development of electric vehicles and energy storage systems. Using synchrotron light, researchers were able to determine structural and chemical changes during the synthesis of these materials.

ELECTRONIC AND MAGNETIC STRUCTURE OF MATTER

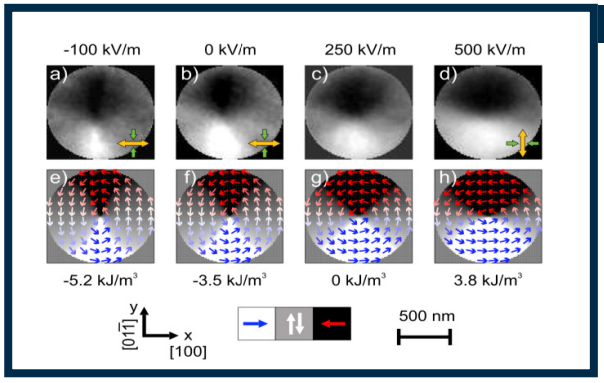
BL24-CIRCE-PEEM

FAST MAGNETIC DOMAIN WALLS, OUT OF THE SHADOW

The fast and reliable motion of magnetic domain walls still remains a major challenge for the development of race track memories. Due to their 3D nature, cylindrical magnetic nanowires host two types of magnetic domain walls with discrete topologies, including the so-called Bloch-point wall, which does not exist in 2D flat nanostrips such as those produced by conventional clean-room technology. Researchers have shown that these unique Bloch-point walls can be driven by injected currents at very high speeds while remaining stable. These results are the first to highlight the important role that the current-induced magnetic (OErsted) field plays in the speed and stability of domain walls in cylindrical nanowires. Part of the experiments used the shadow XMCD PEEM technique.



"Fast domain walls governed by OErtsed fields in cylindrical magnetic nanowires". DOI: 10.1103/PhysRevLett.123.217201.
See also: "Bloch-point-mediated topological transformations of magnetic domain walls in cylindrical nanowires". DOI: 10.1103/PhysRevB.99.024433.



"Piezo-electrical control of gyration dynamics of magnetic vortices". DOI: 10.1063/1.5110169.

See also: "Chiral asymmetry detected in a 2D array of permalloy square nanomagnets using circularly polarized X-ray resonant magnetic scattering". DOI: 10.1088/1361-6528/ab46d7.

BL24-CIRCE-PEEM

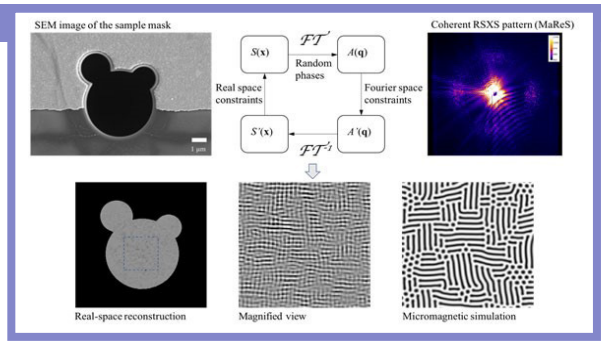
PIEZO-ELECTRICAL CONTROL OF GYRATION DYNAMICS OF MAGNETIC VORTICES

Using time-resolved X-ray magnetic microscopy researchers experimentally demonstrate that strain, acting via the magneto-elastic anisotropy on magnetostrictive microstructures, not only modifies the static magnetic configurations of the microstructures but also allows control of the vortex core gyration dynamics. This is achieved by electric fields in a synthetic heterostructure consisting of a piezo-element coupled with the magnetostrictive microstructures, where the magnetic anisotropy can be controlled by strain. Therefore, the results demonstrate the possibility of using electric-field-induced strain as a low-power approach to tune the dynamical response of magnetic vortices.

BL29-BOREAS

COHERENT SCATTERING IMAGING OF SKYRMIONS UNDER HIGH APPLIED MAGNETIC FIELDS AND LOW TEMPERATURES

Profiting from the coherence of synchrotron light, scientists have performed both reciprocal and real-space observations by lensless soft X-ray imaging of magnetic skyrmion lattice deformation in a chiral magnet $Co_8Zn_8Mn_4$. The holography with extended reference by autocorrelation linear differential operation (Heraldo) technique was used with the circularly polarized soft X-rays, while coherent diffraction imaging was performed with a linearly polarized beam at cryogenic temperatures down to 20K under high applied magnetic fields up to 2 Tesla.



"Element-specific soft X-ray spectroscopy, scattering and imaging studies of skyrmion-hosting compound $Co_8Zn_8Mn_4$". DOI: 10.1103/PhysRevB.99.144408.
See also: "Current-Driven Skyrmion Motion and Drive-Dependent Skyrmion Hall Effect in an Ultrathin Film". DOI: 10.1103/PhysRevApplied.12.044007.

INDUSTRY

Marta Ávila, Alejandro Sánchez, Núria Valls
ALBA Industrial Liaison Office, industrialoffice@cells.es

Thanks to the efforts of the whole ALBA team, the 2019 industry usage has been outstanding and, in addition to providing proprietary access to ALBA beamtime, the Industrial Liaision Office of ALBA has been actively involved in industry and outreach activities such as the organization and participation in industry-oriented workshops, publications on sector-specific journals and B2B and meetings with companies.

Beamtime, labtime, patents and much more

Industrial beamtime in 2019 has reached its maximum so far, and is at a similar level as that of the most important European synchrotrons. The majority of the beamlines were hosting industrial users and we had 6 new companies widen our portfolio to a total of 49 companies and institutions, 25 of which are taking advantage of the ALBA techniques repeatedly. In particular, this year has seen a significant increase of the presence of pharmaceutical companies in XALOC, the beamline devoted to macromolecular crystallography, and beamtime has experienced a high rise in 2019 thanks to word of mouth from previous customers. Other industrial users were coming from the chemical, nanotechnology, energy and cosmetic sectors, which shows the wide diversity of ALBA clients. The results of an anonymous survey amongst our customers depicted a high degree of satisfaction in all the steps of the interaction with ALBA (pre-measurements, measurements and post-measurements).

TamaTA, a work package from the European project CALIPSOplus coordinated by ALBA, continued offering new opportunities for SMEs to access light sources with two new calls during 2019. This project aims at helping to break the barrier between companies and large facilities such as synchrotrons by financing access to such facilities.

Regarding labtime, the Optics and Metrology Laboratory from ALBA has been performing numerous metrological measurements for leading mirror manufacturers. In 2019 a new industrial PhD student started his thesis at ALBA, and a patent named “Device for the correction of mirror curvature” has been filed.

The industry of cosmetics: a key sector

In 2019 we observed a significant interest from the cosmetic industry. After a meeting with a delegation from the Spanish Society of Cosmetic Chemists held at the ALBA Synchrotron premises, several companies from the cosmetic sector showed interest in meeting us to explore potential industrial experiments. Moreover, some industrial experiments have already been performed using TamaTA access to test a skin regeneration cream using artificial skin as a model; such experiments may open the door to new possibilities for cosmetic and skin drug companies. Additionally, a presentation was also done at the International Hair Congress on the 26th of September leading to a publication in the Beauty Cluster blog entitled “Studying hair with synchrotron light”. The usual annual industrial workshop for 2020 will be dedicated to cosmetics.

INDUSTRIAL BEAMTIME

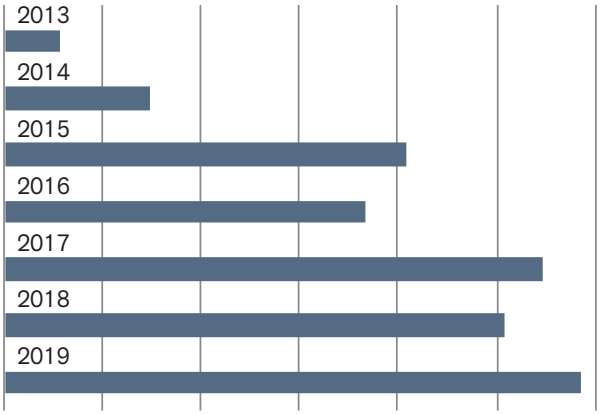


Figure 4. Industrial beamtime per year since the beginning of ILO activities.

Figure 5. Attendees during the Innovation applied to Innovation – I2 workshop on Transfer of Technology.

Workshops and publications

One of the commitments of the Industrial Liaison Office is to show in an accurate but understandable way the benefits of the techniques available at ALBA to the industrial community, either on publications in industrial magazines or by organizing workshops at our premises. On 2019, our yearly industrial workshop was dedicated to the polymer industry (31 May), organized in collaboration with FedeQuim (Catalan business federation of the chemical sector) and having nearly 60 attendees. A new ALBA industrial publication entitled "The role of the ALBA Synchrotron in relation to challenges in the car industry" was published in the journal light! #04: The car of the future, edited by the photonics cluster Secpho.

For the first time, a workshop devoted to industry as a supplier was carried out at ALBA. Almost 80 attendees from nearly 50 companies had the opportunity to interact in the Innovation applied to Innovation – I2 workshop on Transfer of Technology organised on 24-25 October by the ICN2, the ICMAB and the ALBA Synchrotron with the financial support from Transpyrenean Node for Scientific Instrumentation (TNSI) project funded by the INTERREG POCTEFA program. On 29 November, a Hub B30 Innovation brunch was also held at ALBA dedicated to Biopharma production (40 attendees).

Figure 6. Most relevant outreach activities carried out by the Industrial Liaison Office during 2019.

NEW METHODOLOGY FOR PRODUCING BETTER CONCRETES DEVELOPED BY BASF, UPC AND ALBA SYNCHROTRON

One of the largest chemical companies, BASF, joined efforts with scientists from the Polytechnic University of Catalonia and the ALBA Synchrotron to determine how clays and superplasticizers interact in cement pastes. The results paved the way for improving the design of new superplasticizers more resilient to the clays that usually accompany the sands used in concretes as aggregates.

When the cement paste has less water, the density increases and thus the cement paste possesses higher compressive and flexural strength, lower permeability and higher resistance to weathering; at the same time, the volume change from drying and wetting is reduced and that lowers shrinkage cracking tendencies. Therefore, the properties of concretes improve when the amount of water is reduced. However, when the content of water is small, the mortars and concretes become more viscous, reducing its workability and increasing potential placement issues.

Polycarboxylate (PCE) superplasticizers have the ability to fluidize concrete, allowing the reduction of the water content of the paste and resulting in a substantial enhancement in workability. However, polycarboxylate superplasticizers interact with the clays present in sands used for the production of mortars and concretes and diminish their capacity to make concrete and cements fluid.

The interaction between polycarboxylate superplasticizers and clays has been investigated in fresh paste at the NCD-SWEET beamline of the ALBA Synchrotron by researchers from BASF Chemical Company, UPC and ALBA Synchrotron. This research has served to develop an *in-situ* methodology that properly characterizes the interaction between polycarboxylate and clays. Previous methodology used centrifugation and gentle heating of the pastes and this research has shown that it led to artifacts due to this sample preparation. Synchrotron radiation allows measuring the cement pastes without any sample preparation.

The methodologies previously used for the characterization of the interaction PCE-clay did not consider the alterations induced by the centrifugation and drying processes in the PCE admixture, thus the true interaction was not correctly measured. Therefore, it was necessary to measure the interaction in the fresh samples, avoiding the drying process. This is exemplified in Figure 7.

Synchrotron light in this experiment was key, as it allowed measuring the intercalation of superplasticizers in clays in the fresh paste. This way the study is not biased by the sample preparation step.

This new methodology will allow the development of better PCE superplasticizers (more resilient to ubiquitous clays) in the years to come. It should also help sustainability as washing sand is a common practice that consumes precious fresh water.

This investigation did not only provide novel results but is also an example of collaborative efforts between industry and academy and originated a publication in the second-highest impact factor journal of construction and building technology.

Publication: "Influence of experimental procedure on d-spacing measurement by XRD of montmorillonite clay pastes containing PCE-based superplasticizer". Pere Borralleras, Ignacio Segura, Miguel A.G. Aranda, Antonio Aguado. Cement and Concrete Research, 116 (2019) 266–272.

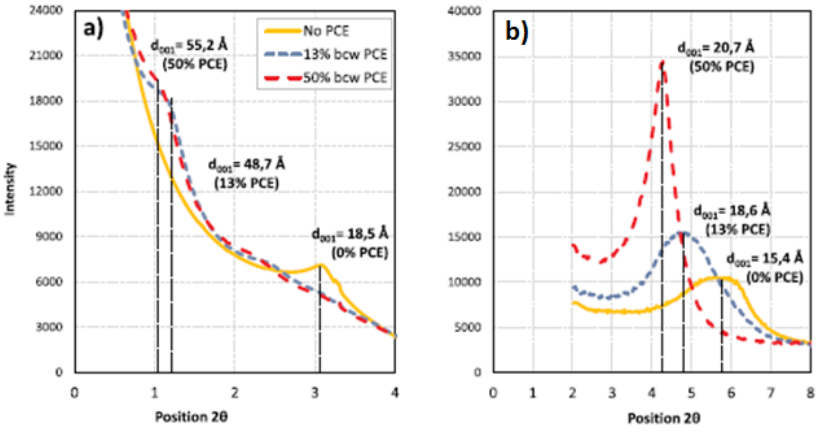


Figure 7: X-ray powder diffraction pattern for clay with increasing PCE content: a) fresh paste measured using synchrotron light, b) dried paste collected with Cu Kα diffractometer.

ACCELERATORS

Francis Pérez, Head of the Accelerators Division

The year 2019 has been a year of accomplishments for the Accelerator's team. The main one has been the achievement, in a reliable and stable operation, of the design nominal current in the storage ring, i.e. 250 mA in a top-up multi-bunch mode operation with a lifetime larger than 20 hours.

This achievement was possible after the repair and upgrade of the Superconducting Wiggler (SCW), which provides synchrotron radiation to the MSPD beamline. In January 2019, the SCW was extracted from the tunnel, placed in the Experimental Hall, and a team from the Budker Institute of Nuclear Physics (Novosibirsk, Russia), who originally manufactured the device, spent two weeks repairing and performing the required upgrades to cope with the overheating experienced the previous year. The pictures below show the SCW during the works.

The increase of current was done in two steps. In March we increased it from 150 to 200 mA, and followed the behavior during several months. Since it was faultless, the final goal of 250 mA in routine operation was established in September 2019. Before that, a stress test at 300 mA was also successfully performed.

Another achievement, which was needed to ensure the proper operation at 250 mA, was the successful isolation of an electromagnetic noise which was affecting the reliability of the radiofrequency (RF) systems. The installation of high frequency filters together with optical fibers connecting the high voltage power supplies to the RF amplifiers, eliminated a noise crosstalk between RF plants which was causing spurious beam losses.

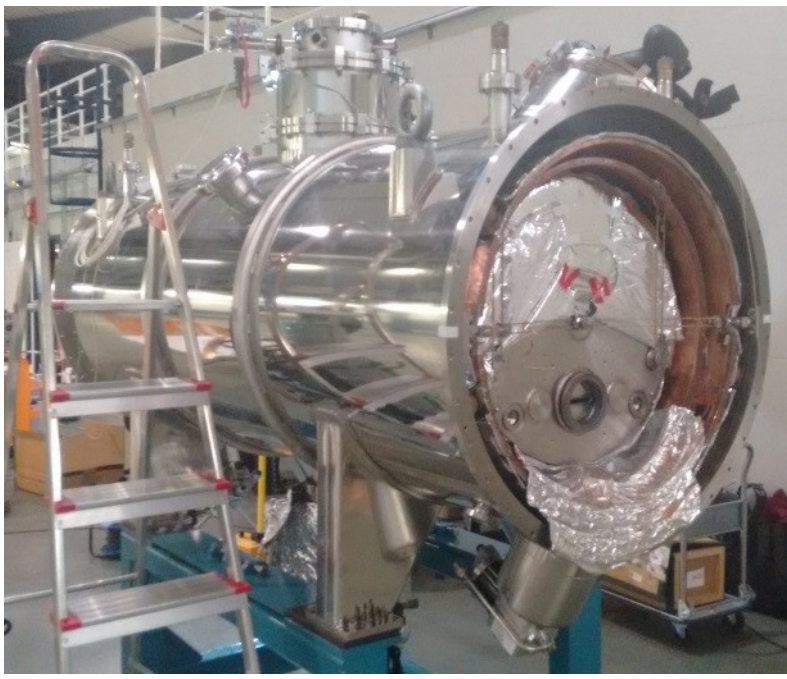
Furthermore, the full commissioning of the in-vacuum insertion device for the LOREA beamline, together with its respective front end, was performed successfully. Now, they are ready to provide synchrotron light for the commissioning of the beamline.

And, to finish with the accomplishments, the H2020 European project EuroCirCol for the design of the vacuum chamber of the Future Circular Collider (FCC), promoted by CERN, was finished, and the full FCC Design Report was presented, with contribution from ALBA staff: https://home.cern/news/press-release/accelerators/international-collaboration-publishes-concept-design-post-lhc

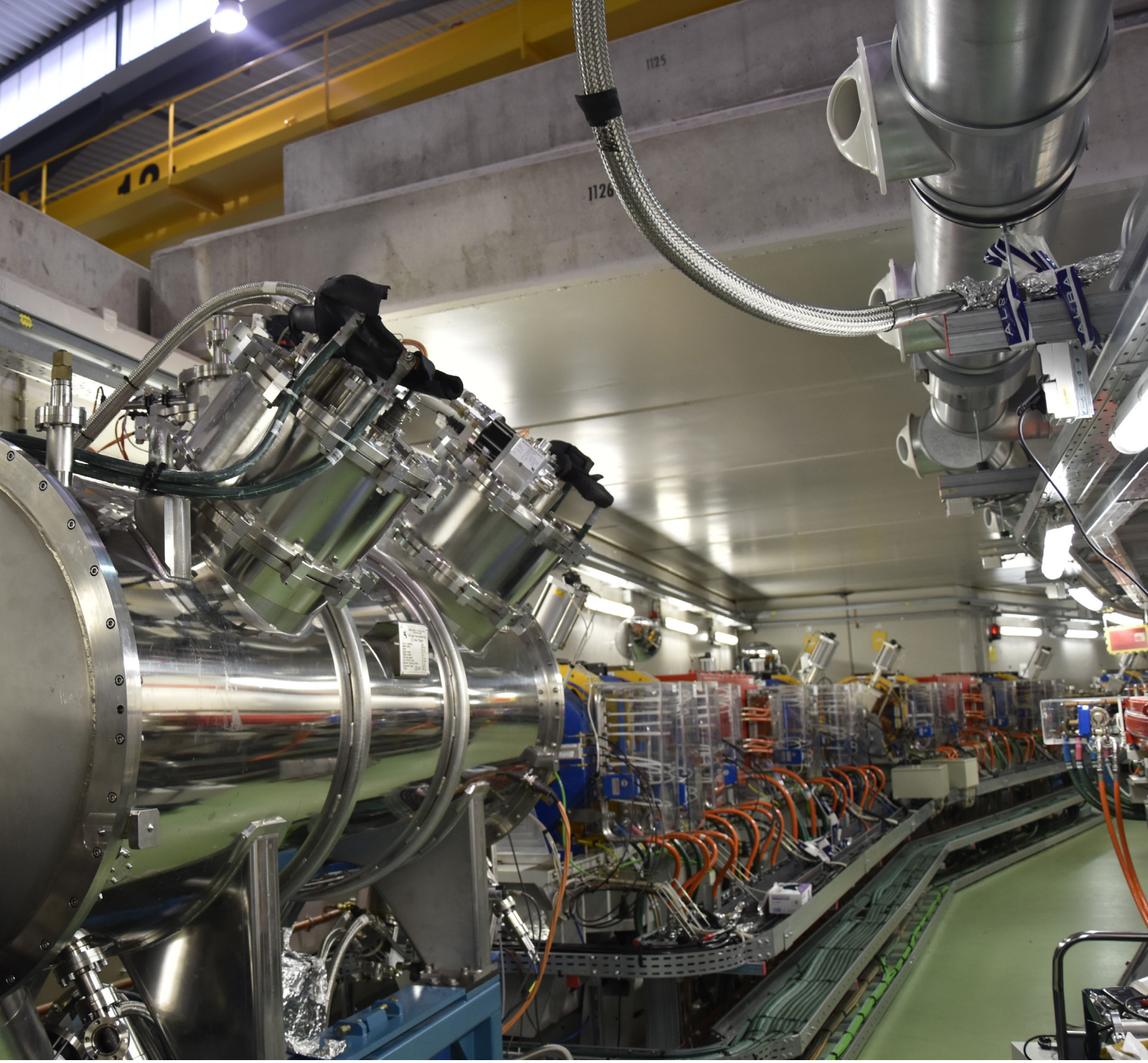
On the other hand, there has been no stop to the continuous day-to-day work of maintaining, operating and improving the complex of the three ALBA accelerators: the Linac, the Booster and the Storage Ring.

Among the improvements carried out during this year, it is worth mentioning the optimization of the electron beam transfer efficiency in the Linac by applying simplex algorithms, which automatically maximize the electron charge at the end of the Linac, with the result of improving the transfer efficiency from 60% to up to 94% in single-bunch operation. This method will also be applied to the injection into the Booster.

Another development that has been finalized in 2019 is the implementation of the so-called Trim Coils correctors in the bending magnets, which will allow to locally correct the quadrupolar errors at the source points and, in this



MSPD Superconducting Wiggler in the Experimental Hall, opened for repair and upgrade.



way, reduce the beta beating error, which is a measure of the asymmetry of the accelerator. This will result in a more reliable and stable beam source size at the emission points for the beamlines.

In addition, we have been actively involved in several international collaborations in accelerator R&D, including several H2020 projects, as the mentioned EuroCirCol collaboration, the Compact Light Source XLS collaboration and the ARIES collaboration for the development of new accelerator technologies. We have also continued participating in research activities related to the FCC, with the study of High Temperature Superconductors for the vacuum beam screen and the development of the Speckle technique for beam size measurements (see following article). Also, we are involved in the project BEATS, which is an European contribution of a Hard XR imaging beamline for the Middle East Synchrotron SESAME, located in Jordan.

Finally, we have organized several meetings and workshops. A meeting of the EuroCirCol European collaboration, (https://indico.cern.ch/event/804470/timetable/), the 6th Workshop of Diagnostics Experts of European Light Sources (DEELS), (https://indico.cern.ch/event/789811/) and the 27th European Synchrotron Light Source (ESLS) Workshop, (https://indico.cells.es/event/224/).

Measuring the electron beam size from a speckle image

Ubaldo Iriso, Head of the Beam Physics Section

The famous double-slit experiment by Young in the 19th century evidenced the interferences generated by a point light source passing through two small apertures. When the light source is small, as depicted in Fig. 8.a, the interferences have the maximum contrast. However, if the dimensions of the light source increase, then the superposition of the interferences arising from the bottom (black) and edge (red) rays (which are shifted in position), originate a transmitted intensity with less contrast as shown in Fig. 8.b. Measuring the contrast of the interferences provides a method to determine the dimensions of a light source, which can be either a star in the sky or an electron beam [1, 2].

If instead of apertures as in Fig. 8, there are small obstacles that scatter a light beam, one also observes interferences, as shown in Fig. 9.a, which corresponds to the simulation of a light beam after being scattered by a spherical obstacle. In this case, the interferences arise from the superposition of rays scattered by different parts of the surface of the obstacle. The plot in Fig. 9.b shows the interference generated by several obstacles of the same size and Fig. 9.c depicts the result of the interferences generated by many (thousands of) obstacles. The pattern in Fig. 9.c is usually known as speckle pattern.

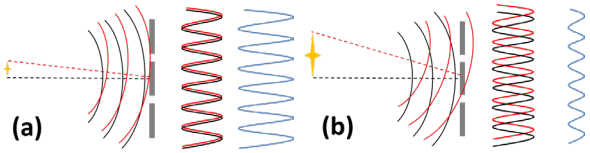


Fig. 8. Schematic of the interferometer with a small (a) and big (b) source of light. The intensity distribution from a smaller object (a) has more pronounced maxima and minima (higher contrast) than that from a bigger star (b).

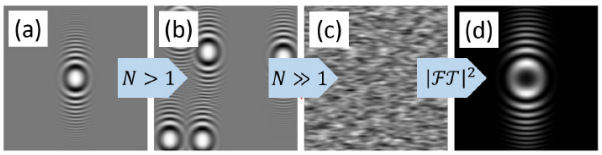


Fig. 9. (a) Simulation of an interferogram produced by one single particle, (b) by many particles, and (c) by millions of particles. (d) Image of the 2-dimensional Fourier analysis of (c).

Figure 9.d illustrates the result of analyzing the speckle pattern in Fig. 9.c using mathematical methods based on Fourier transforms. This provides the spatial period of the fringes and their contrast, which allow to determine the dimensions of the light source, if its distance to the obstacles and their dimensions are known. This is the basic principle of a new method used at NCD-SWEET to determine the dimensions of the electron beam, and it is the fruit of a collaboration between ALBA, CERN and the University of Milano.

At the NCD-SWEET beamline, a monochromatic beam of 12 keV impinged a solution containing Si particles of 500 nm in diameter (the obstacles). As the source of the X-rays is completely dominated by the electron beam source size, i.e. by the dimensions of the electron bunches in the storage ring, by measuring the speckle pattern in Fig. 10.a, and by performing the corresponding Fourier analysis (Figs. 10.b and 10.c), one deduces the dimension of the electron beam. The obtained rms electron beam sizes in the horizontal and vertical directions are respectively 125 +/- 5 μm and 8 +/- 1 μm, which agree with the expected values and were published in the last IBIC19 conference [3].

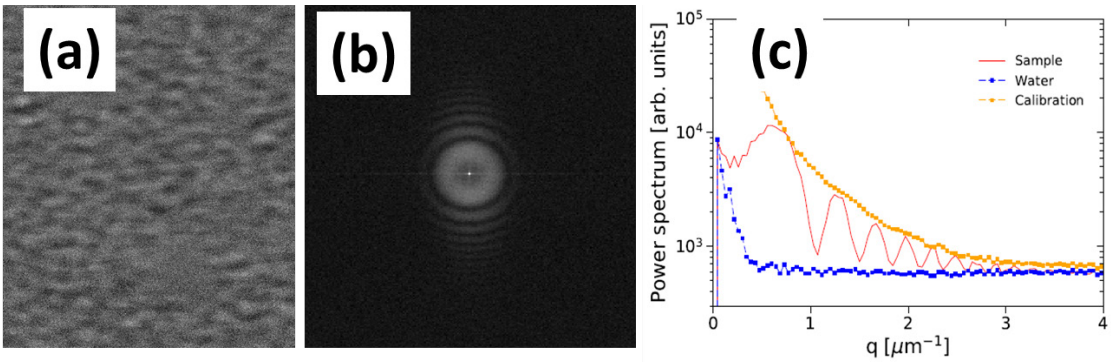


Fig. 10. (a) Speckle image at NCD-SWEET beamline, and (b) Two-dimensional Fourier Transform of the speckle image in (a). Plot (c) shows the projection in the vertical direction of (b) exhibiting the spatial location of the fringes and their contrast.

REFERENCES:
1. Hetch-Optics , Addison Wesley Publishing, 1987
2. L. Torino and U. Iriso, *Transverse beam profile reconstruction using synchrotron radiation interferometry*. Phys. Rev. Accel. Beams 19, 122801, 2016.
3. M. Siano , B. Paroli, M. A. C. Potenza (Univ. of Milano, Italy), U. Iriso, C. S. Kamma-Lorger, A. A. Nosych (ALBA-CELLS, Spain), S. Mazzoni, G. Trad (CERN, Switzerland). *Electron beam size measurements using Heterodyne Near Field Speckles at ALBA*, Proceedings of IBIC19, Malmo (Sweden), 2019.

ENGINEERING

Joan Casas, Head of the Engineering Division

The **Engineering Division** comprises a team of 38 multidisciplinary engineers and technicians who give support to the other divisions in ALBA and maintain/upgrade the general infrastructures and services of the facility.

One of our two sections is devoted to **civil engineering projects** (construction and technical services/supplies like electric power, compressed air, technical gases, de-ionized water) **and maintenance** of facility-related assets and processes (electrical maintenance and mechanical maintenance including HVAC, compressed air and dynamic UPS, among others).

The other section offers transversal engineering services to the beamlines and to the accelerator, as well as support to operations in **vacuum**, **survey & alignment** and **cryogenics** (including the recovery and re-liquefaction of 10,000 l of liquid helium during 2019). In addition, it provides **beamline engineers** to the Experiments Division. On an operational phase, these engineers are supporting the beamline with plenty of projects for small or medium upgrades. On a new beamline design phase, they play a key role not only as developers of specific synchrotron instrumentation but also giving technical management support to the beamline scientist. Finally, the **workshop and logistics** group has been a key component in all manufacturing and installation operations, including the radiological protection elements developed in-house.

FACILITY UPGRADES

During 2019, intense preparatory work has been carried out to upgrade the facility in the near future. The design of the conditioning of a large area next to the experimental hall to house up to three large microscopes for the future **Microscopy Center** has been completed. We also carried out the design of the **electronics laboratory expansion** and the **new storage** for the Controls & Computing division on the recently built 2nd floor above the logistics area.

In addition, two important projects were started in order to improve the accelerators' operation: a **3-way mixing valve** has been designed and ordered from a specialized company. This custom-made gigantic valve will upgrade the deionized water cooling circuit (common return) to recover the required thermal stability for the accelerators' systems. Another important project has been the upgrade of the **compressed air system**. In this case, and in order to cope with the growing demand linked to the natural growth of the facility (more current in the storage ring, more beamlines in operation...) we sacrificed redundancy in the compressed air system in favour of capacity. Now we will improve the system (new active dryers) and we will recover the redundancy for an even better accelerator availability. Finally, during 2019 we carried out a specific project to improve ambient operating conditions of our **dynamic UPS** systems, which were prone to failure during extremely warm summer months.

Other important upgrades on phase I beamlines have been carried out in **MIRAS** (stretching holder, bolometer support) **MSPD** (works on M1 cooling), **MISTRAL** (M4 motorization), **NCD** (OH fluorescent screen monitor holder, microfocus of beryllium lenses, sample heater), **XALOC** (upgrade of the diffractometer), **CLÆSS** (pinhole, new window for the ion chamber, in-vacuum camera system design, expansion of the control hutch increasing surface about 40%), **CIRCE** (NAPP manipulation tooling, magnetization stage, chamber for the atomic layer deposition, high-frequency sample stage, NAPP sample parking design) and **BOREAS** (sample chamber suitcase interface, sample transfer ALI system, beam reference monitor, radial distribution chamber and design of the portable high temperature magnet).

PROJECTS FOR THE NEW BEAMLINES

The engineering division is a key actor in the advancement of the construction of new beamlines.

For **LOREA**, the control hutch has been built, and the technical installations for the technical supplies (gases, de-ionized cooling water and compressed air, among others) have been completed. Concerning instrumentation, the back-bone has been delivered, and some key components have been installed (collimator, photon shutter, gas cell, beam reference monitor, filters, I-zero). Support has been given to the end-station integration, and we started to assemble the in-house developed monochromator.

At **NOTOS**, a large double housing made of lead has been installed for radiological protection. It comprises the optical and experimental hutches. We also completed the installation of the front end, the bremsstrahlung mask and the maintenance of instrumentation components received from ESRF's BM25-Spline. Some other elements have progressed in the design/procurement phase (XAS table, tender for the monochromator).

At **XAIRA,** also both the optical hutch (made of lead) and the experimental hutch (made of steel) have been installed. The latter has been, for the very first time, designed and manufactured internally. Strong involvement in the design of the end station, the backbone and cryogenics has been basic in the closing of the beamline PID (proportional-integral-derivative controller).

Finally, **FAXTOR** received our support for the first steps of the conceptual design and project definition, up to the generation of specifications for the backbone and the layout of the front end, both to be tendered in the near future.

The ALBA Monochromator

Carles Colldelram, Head of the Transversal Section

The soft X-ray beamlines require monochromators having several gratings and mirrors positioned with high mechanical accuracy. Our three operating beamlines CIRCE, BOREAS and MISTRAL have commercial monochromators. The experience cumulated at the Engineering Division over the years allowed to face the challenge of designing and building a UHV monochromator at ALBA, including new design concepts, which will operate at the LOREA beamline devoted to angle-resolved photoemission.

The large energy range of LOREA (10-100 eV) requires a device with 3 mirrors and four gratings with variable line spacing to reduce optical aberrations. The mirrors are located along the beam path and have vertical and incidence angle degrees of freedom whereas the four gratings are placed transversally and the operating one is selected with a linear guide transversal to the beam direction. The mirrors and operating grating are water cooled to cope with the power of the beam. Figure 11 shows the main elements of the device.

The most important part of the monochromator, the grating system, has been carefully designed to be insensitive to external disturbances such as vibrations from the cooling water and at the same time to have very high mechanical performances. The angle of incidence of the X-rays (pitch) is set by a strong sine arm, pivoting on preloaded hybrid angular contact bearings centered on the grating surface, actuated by a linear stage (in air) with a roller spindle that transmits the motion to the vacuum through a double bellow. The measured angular resolution is below 0.1 μrad over an angular range of 11º, which is excellent. The translation of the gratings (see figures 11 and 12) is done by a specifically designed vacuum-compatible linear stage. The gratings are fixed to four columns attached to a granite base, which is the reference also for the mirrors.

The most innovative part of the monochromator is the cooling system of the gratings for evacuating the power load density from the absorbed X-rays of 1 W/mm^2 . It has no vacuum guards or double piping, which are well-known sources of failures. The heat load is removed through copper straps in contact with a temperature controller device connected to fixed water lines. With this, the movement of the grating is unaffected and the transient temperature drifts due to the opening of the beamline front end or a change of grating are minimized. Laboratory tests have demonstrated thermal stabilities of 0.1^{o}C and transient stabilization times of a few minutes. In addition, the operating temperature can be kept fixed for different power loads (for example while changing X-ray polarization) thanks to the temperature controller. Figure 12 shows an overall view of the system.

The movements of the three mirrors (pitch and two translations) are based on preloaded linear and circular ball guides and spindles, including flexures for the circular movement actuation mounted on three independent granites fixed to the monochromator granite base. This compact solution reaches a resolution better than 0.5 μrad over a range of about ±1.5º with a repeatability better than 2 μrad. These mechanics are all in air and the movements are transmitted to the mirror holder, which is supported by a massive column, through a bellow. The cooling system of the mirrors (power load ~ 40 W/mm^2) has a rigid continuous pipe with no welding that is independent of the positions of the mirrors. Cooling pads with InGa interfaces or In foils will be utilized and will be mounted and inspected to be strain-free in the optics laboratory.

At the moment of writing these lines the monochromator is in the Experimental Hall of ALBA being assembled to be ready for operation by summer 2020.

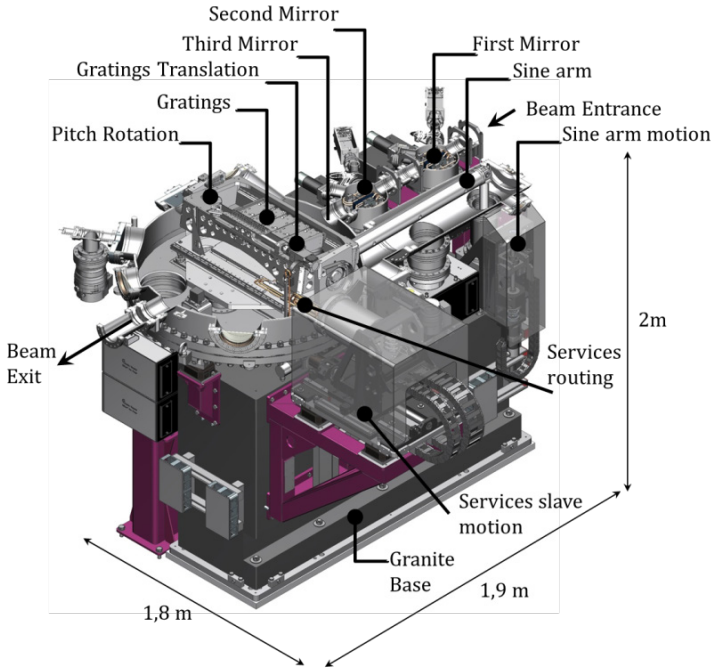


Figure 11. Overall view of the different parts of the ALBA monochromator. The overall dimensions are approximately 2 (Length) x 2 (Width) x 2 (Height) meters.

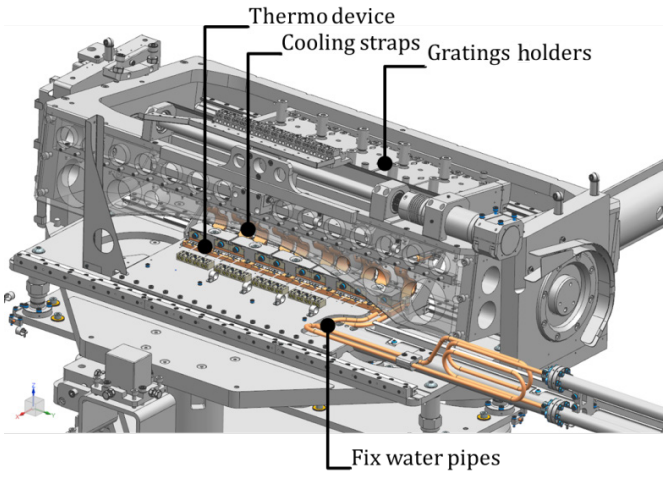


Figure 12. Overall view of the mechanics of the gratings and of the cooling system. The heat load from the X-ray beam is evacuated through cooling stripes connected to rigid cooling pipes. A temperature controller device stabilizes the temperature.

COMPUTING

Óscar Matilla, Head of the Computing & Controls Division

William Gibson, the famous science fiction writer, once said: "The future is already here - it's just not very evenly distributed". Everybody that works in the computing field in a synchrotron light source surely will agree with this vision today: the objectives are defined, most of the required technologies exist, but the work to make the execution of the projects "evenly distributed" appears to be an epic task: the unprecedentedly huge data storage and processing needs of the new detectors, the future envisaged European Open Science Cloud (EOSC) that shall centralize the scientific knowledge, the opportunities in data analytics maybe fostered by new machine learning algorithms… All this jargon is present even in the mass media today. But, in contrast, the reality is that the engineers facing those objectives are like a mountaineer putting on his boots, early in the morning, while gazing the summit of the mountain. In the Computing Division we are boldly looking forward to this future: this year a lot of efforts have been invested to define all the links of the chain and advance to an integral view of data management at ALBA. The challenges are multiple: from the data acquisition of the new detectors that will increase the required bandwidth by an order of magnitude, the need of *in-situ* pre-processing of the experiments, the definition of standardized data catalogues that shall enable automated data analysis pipelines, and finally the use of these defined pipelines to implement Data Analysis as a Service (DaaS) platforms potentially used by a huge number of scientists. Most of these tasks will imply a further specialization of the groups in the Computing Division that has already started during this year.

But this view of the spotlighted stage hides what is in practice our main activity: what happens behind the scenes. We, the Computing Division, in fact spent the majority of our time in 2019 providing support to keep the daily operation from stopping. That included all the groups of ALBA with variable percentages [Figure 13]. Only the quantity of tasks managed in our different Service Desks, more than 9,100, shows the entanglement that a synchrotron operation involves. But in parallel to this daily operation, the computing infrastructure also requires long-term project developments. For example, this year the file storage system used by the beamlines was replaced by a new one-petabyte system. Or the High Performance Computing cluster (HPC), whose capacity was significantly increased. But these tasks executed in the background are not just limited to new hardware installations. This year a new version of our asset management tool, the Inventory Pool, enabled the creation of a Critical Stock where the electronics hardware stock has been catalogued. This is a first stone, and not a small one. The building will be completed next year when an upgrade of our central hardware configuration management repository, the CableDB 2.0, will allow us to automate the life cycle phases of all the hardware installed in our facility. But there are other examples of these backstage works, such as the effort done in two of our flagships, Sardana and Taurus, to make them compatible with Python 3 or the upgrade of different beamlines to the TANGO 9 control system.

In parallel, the construction of the four new beamlines has required full-time involvement. LOREA, NOTOS and XAIRA definitively closed their conceptual stage long time ago and electronics and controls engineers have been working intensively with the scientists to fulfil their tight installation schedules. FAXTOR will follow the path in 2020. Consequently, the time invested in the new beamlines construction has increased this year by 280% with respect to 2018. The exercise of prioritization among the different projects has been arduous. Its final outcome has been that the accelerators and the beamlines currently in operation have had to assume a decrease in the time that Computing could invest in their activities by 20% with respect to last year. (Figure 14).

After an intense 2019 we can look back at our footsteps to discover that, after the hard work, we have climbed to a considerable height. We are immersed in the construction of the new beamlines, upgrading our infrastructures, committed to numerous technical challenges and all this without taking our eyes off the daily operation. As we have enjoyed the ride, we like to know that a similar journey awaits us in 2020.

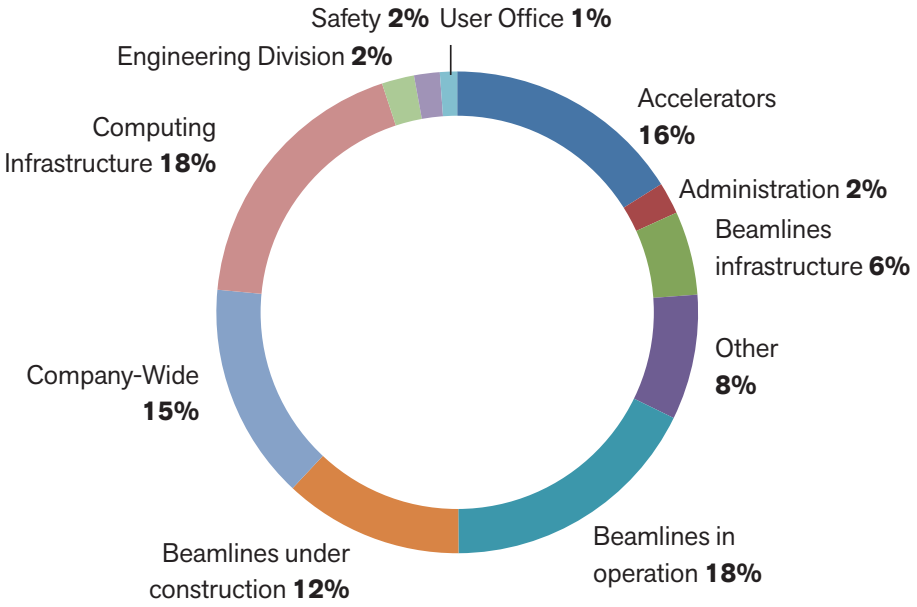


Figure 13. Distribution of the time invested by Computing among different clients.

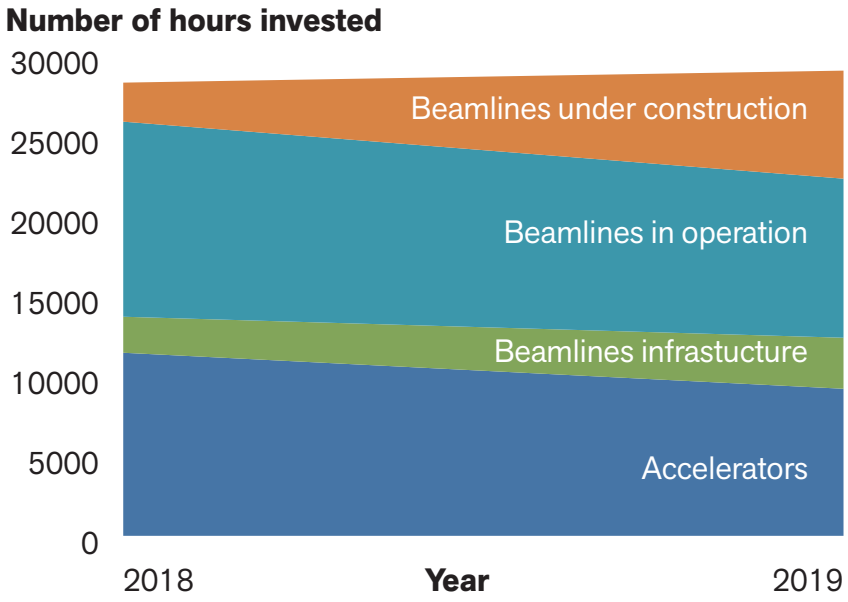


Figure 14. Impact of the construction of new beamlines.

IT infrastructures. Upgrading behind the scenes

ALBA IT Systems team

During an opera performance, when the soprano is singing with her prodigious voice and the spectators are delighted in front of her virtuosity, nobody is thinking about the numerous things needed to make that magic moment possible: the acoustic is perfect, the music heartily follows, the spotlights are perfectly synchronized, the curtains and other mechanisms are properly operated, the temperature of the room is adequate, the seats are comfortable, the theatre is clean, the tickets have been sold online without major problems, the access to the theatre has been agile, everybody could find their sit without problem, the bathrooms are ready in case somebody needs them… The list is endless. This picture is analogous to a scientist performing his experiment at the ALBA Synchrotron. His analysis and interactions to execute his experiments are based on uncountable subsystems he or she, whether or not consciously, blindly relies on. One of the main ones is the Information Technology (IT) infrastructure on which all computing activity is built. We, the IT Systems team, work behind the scenes.

Maintenance activities: upgrading IT infrastructures

All computing activities in the beamlines, accelerators and offices are supported by IT infrastructures. In particular, the outcome of all the experiments is based on each of these infrastructures and requires high capacity, high performance and high availability. In this regard, IT equipment can provide a high level of operational uptime and keep systems running without interruption for long periods by using redundant hardware and software components.

These IT infrastructures cover, among many other of ALBA's needs:

- The **storage of data files at high speeds and with high capacities**, which is generically called **Storage.**
- The **high-performance data connectivity network** between the internal network equipment (or intranet) and also to the Internet.
- The **high-performance data processing,** with data analysis and simulation software, which run simultaneously on aggregations of servers, also known as **High Performance Computing clusters.**

In 2019 some very relevant IT infrastructure upgrades were executed. As previously mentioned, it is crucial that the lead opera singers do not have to interrupt their performances. Everything should be executed without affecting the operation.

- The **migration and replacement of the high-performance data "Storage" server** acquired in 2010 with 256 terabytes with 2 dedicated and independent servers: Office Storage with 260 terabytes and a high-performance Beamline Storage of 1 petabyte of capacity. All original files, shares and access permissions were seamlessly migrated during 2019, after several months of testing and planification. The beamlines were already operating with the new Beamline Storage server after the summer shutdown.

- The 2014 original **High Performance Computing (HPC) cluster** had 10 original nodes, which, aggregated, reached 216 cores and 1.4 terabytes of memory. They started to be **progressively replaced during 2019** by 18 new servers reaching 524 cores, 4.2 terabytes of memory and network ports now capable of speeds of 25 gigabits per second. The cluster includes 2 high-end graphical processors with more than 100 floating point operations per second each and also 2 nodes dedicated to XALOC beamline online analysis express jobs. Part of this infrastructure will also provide remote data analysis workstations for MISTRAL but also data acquisition for XAIRA beamline and remote workstations pilots in 2020.

- **The plan for the purchase and replacement of network switches**, which has been spread during 3 years, from 2018 to 2020. The switches will be used for the new beamlines installations, but also mostly for the replacement of more than 100 original network switches acquired in 2007 for our offices and beamlines network and which are now reaching the end of their life.

- The **Internet connection bandwith** of ALBA through the scientific network Géant-Rediris was increased in November 2019 from 500 megabits per second to 2 gigabits per second symmetrical for uploads and downloads. Additionally a direct connection to the Géant-Rediris dark fibre backbone network is projected for 2020. This new link should soon allow ALBA to lease connection bandwidths of up to 100 gigabits per second, if needed.

▪ The previous data connectivity enhancement was required in order to start using the **latest IT services provided through the Internet** (cloud services), and more specifically our cloud-based backup and archive pilot project, which started in 2019. This pilot project aims to validate the cloud-based IT services as an option for the replacement of our backup and archive tape library acquired in 2010, which will reach its manufacturer end of life in 2020.

New technological challenges

In addition to the daily assurance of the operation, which consumes much of the IT Systems staff's time, **new technological challenges are envisaged in the horizon.**

The scientific activity of the new projected beamlines will generate **unprecedented data volumes and speeds.**

For instance, the **IT Infrastructure required by Phase III beamlines such as XAIRA and FAXTOR** is foreseen to require network speeds of over 25 gigabits per second and also the installation of additional storage and archive servers to cope with the required capacities and file write speeds. XAIRA is foreseen to generate more than 1 petabyte of raw data per year and will also require the use of peak speed storage technologies such as distributed filesystems or shared solid state NVMe disks to be able to cache datasets acquired at the same speed as they are generated by the detectors. They will require write speeds higher than 1.3 gigabytes per second. These datasets will have to be simultaneously made available to the High Performance Computer cluster of servers and workstations to be able to perform online analysis.

Neverending story

Each of these IT Infrastructure equipment and system upgrades is also an **opportunity to increase and adapt their capacities and performances to the always growing needs** and requirements of a center like ALBA. Thus, these upgrades require **careful review, agreement and planning of the future beamline experiment requirements**.

During 2019 we have successfully completed a major upgrade of our IT infrastructures. But there is a exist a non-subtle difference in this analogy we have used: operas are performed in theatres that were designed 500 years ago and cope perfectly well with current performances. That's not the case in IT: in our case our theatre is continuously being redesigned, demolished and rebuilt in an endless loop. But now… let the play continue!

HEALTH & SAFETY

During 2019, the Safety Office has developed its routine service activity without interruption, guaranteeing conventional safety standards and levels of radiation outside the shielding enclosures that allow public access to the area.

In particular, conventional safety activities have been based on developing the tools described in the ALBA's prevention plan available at ALBA's intranet (https://confluence.cells.es/display/HSI/DATA+ROOM+SAFETY+OFFICE) and presented to all ALBA staff in an annual training course. During this period we have issued rules on electromagnetic fields and have given training on how to deal with Legionella and cryogenics. The electrical risk safety rule has been approved during 2019, as was announced. Regarding emergencies, communication has been improved by including a screen displaying messages in the experimental hall.

On the other hand, the Radiation Protection Service (SPR) has worked in parallel on usual routine service activity and new radiation protection projects. Improvements and updates of radiation protection working procedures have been implemented to continuously optimize the level of safety against ionising radiation. Besides, SPR continued a collaboration project with the UAB University to develop neutron measurements at the ALBA Synchrotron. A specific dosimetry campaign has been put in place with UAB passive neutron dosimeters. Moreover, measurements with a UAB Bonner sphere detector in the accelerators' injection areas have been done and completed with Monte Carlo simulations to obtain the neutron spectrum in different areas and calculate the proper calibration factor of the dosimeters. This work has been presented in national and international conferences and has been awarded as best oral contribution in the SEFM/SEPR19 conference. Finally, during the summer shutdown, the SPR has performed the functional verification of the 10th beamline NOTOS Personal Safety System (PSS) and its final implementation in the ALBA PSS, successfully completing one of the main radiation protection elements of the beamline together with the shielding hutch installation.

Internationally, the Safety Office has actively participated in the OPEN SESAME project, through staff trainings and safety assessment of radiation protection, before the closing of the project at the end of 2019. In parallel, the SPR has continued contributing to the BEATS project for the construction of a new tomography beamline at SESAME.

PROJECTS & COLLABORATIONS

ALBA was granted European Regional Development Funds (ERDF) through the Spanish and Catalan administrations for long-term projects. Besides, in 2019 ALBA has participated in different international and national collaborations with other facilities and research centres.

14,472,339.00 € ERDF Funds (2018-2023)

840,353 € 2019 Competitive Call

361,402 € 2019 Agreements

PROJECTS CO-FUNDED BY THE EUROPEAN REGIONAL DEVELOPMENT FUND (ERDF)

Spain Multi-Regional Operational Program 2014-2020

Fondo Europeo de Desarrollo Regional "Una manera de hacer Europa" UNIÓN EUROPEA

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

Project	Budget	Funds	Dates
Update of the data management infrastructure	1,915,466.00 €	957,733.00 €	2015 - 2021
Design and construction of the phase-III beamline XAIRA	6,900,000.00 €	3,450,000.00 €	2015 - 2023
Improvement of phase-I infrastructures (NCD beamline and Booster)	445,000.00 €	222,500.00 €	2015 - 2019
Design and construction of the phase-III beamline NOTOS	3,294,370.00 €	1.647,185.00 €	2015 - 2021
1.5 GHz radiofrequency (RF) systems prototype for ALBA - 3HCprot	390,000.00 €	195,000.00 €	2015 - 2020

ERDF Catalonia 2014-2020 for the Strengthening of the Large Scientific and Technological Infrastructures with the participation of the Catalan Government

UNIÓ EUROPEA
Fons Europeu de Desenvolupament Regional

Generalitat de Catalunya
Departament d'Economia i Coneixement
Secretaria d'Universitats i Recerca

Project	Budget	Funds	Dates
Improvements in the reliability of the radiofrequency (RF) transmitters used by the ALBA accelerator rings	2,055,112.00 €	1,027,556.00 €	2015 - 2019
Transversal electronics equipment and cabling systems for new and operational beamlines	1,466,000.00 €	733,000.00 €	2015 - 2023
Transversal standard vacuum technology and equipment for new and operational beamlines	1,861,000.00 €	930,500.00 €	2015 - 2023
Construction of phase-II beamline LOREA	4,267,000.00 €	2,133,500.00 €	2015 - 2022
Construction of the phase-III beamline FAXTOR	5,104,550.00 €	2,552,275.00 €	2015 - 2023
Implementing upgrades at different beamlines and subsystems of ALBA	1,246,180.00 €	623,090.00 €	2015 - 2023

EUROPEAN PROJECTS IN WHICH ALBA PARTICIPATES

Compact

Project for designing a hard X-ray FEL facility beyond today's state of the art, using the latest concepts for bright electron photoinjectors, very high-gradient X-band structures at 12 GHz, and innovative compact short-period undulators.

OPEN SESAME

Knowledge transfer to the scientific community emerging around SESAME, the synchrotron facility of the Middle East. The project includes training activities (courses, schools, etc.) and staff exchanges.

Project for designing, building and starting a beamline for X-ray tomography at SESAME synchrotron light source in Jordan.

Doctoral training programme in Functional Advanced Materials.

New insights into the mechanisms underlying the amplification of radiation effects of nanoparticles, both in conventional and in charged particle therapy.

Project for putting together SMEs and research centres in the border regions of Spain and France to promote cooperation in R&D&I and technology transfer.

Conceptual design study for a post-LHC research infrastructure based on an energy-frontier 100 TeV circular hadron collider. ALBA's role is to contribute to the management of accelerator developments, organisation of international events and vacuum design.

EU-funded ExPaNDS project to enable photon and neutron research infrastructures at national levels by making the majority of their data 'open', following FAIR principles, and harmonising their data catalogues and data analysis services through the European Open Science Cloud (EOSC).

With the goal of removing barriers for access to worldclass accelerator-based light sources in Europe and in the Middle East. More than 82,500 hours of transnational access are provided to these research infrastructures and specific programmes are in place to teach new users how to successfully use synchrotrons and FELs.

Integrating Activity project that aims to develop European particle accelerator infrastructures, improving the performance, availability, and sustainability of particle accelerators, transferring the benefits and applications of accelerator technology to both science and society, and enlarging and integrating the European accelerator community.

Project for developing a model describing the socioeconomic impact of research infrastructures (RIs) and their related financial investments.

EDUCATION & OUTREACH

One of ALBA's strongest commitments is knowledge transfer and public engagement to ensure that synchrotron light applications and the operation of the facility is accessible and interesting for everybody.

Left, group picture of the participants at the Hercules European School. Right, the Maxwell auditorium during one of the sessions of the IX AUSE Congress and IV ALBA Users Meeting.

SHARING THE KNOWLEDGE

ALBA hosts every year several seminars and workshops to exchange the latest news from a wide variety of research fields. In 2019 ALBA organised 36 events in the facility. 20 external speakers from research centres around the world shared the latest developments in accelerator technology and synchrotron light applications. A total of 14 workshops have been organised by ALBA: some of them within the framework of European projects (EuroCircol, RI-PATHS or POCTEFA). From 1st to 7th April the ALBA Synchrotron hosted the Hercules European School, where 20 young researchers from all over the world learned about synchrotron science from ALBA staff members who, in a very practical way, showed them how to use cutting-edge synchrotron radiation techniques. The course is coordinated by the Université Grenoble Alpes since 1991. The IX AUSE Congress and IV ALBA Users Meeting were held from 8th to 11th October. Around 150 delegates exchanged information and ideas about the scientific results obtained with synchrotron light as well as the present and future challenges of these facilities.

A PLACE FOR STUDENTS

ALBA has its own students programme that offers different types of internships to gain knowledge and skills in a wide variety of scientific and technological areas: from engineering to accelerator technologies, synchrotron light applications, computing and controls, health & safety, administration and finances or communications and marketing.

In 2019, ALBA hosted 32 students. 8 were undergraduates and 13 were vocational training students. They did stays of 4-10 months at the facility to learn a job while they were studying. Besides, 11 PhD students develop their thesis under the supervision of ALBA members. The 3rd ALBA Early-stage Researchers Day was held on the 7th of October 2019, where they presented the status of their projects. Anna Mandziak, who is finishing her thesis at the CIRCE beamline (PEEM endstation) was awarded the best project. Finally, members of the ALBA staff also participated in university teaching activities of the degree in Physics at the UAB and some masters from the UPC.

On the left, vocational training students of the 2019-2020 academic year. On the right, PhD students at the 3rd Early-stage Researchers Day.

SCIENCE AND SOCIETY

In 2019, the ALBA Synchrotron continued to pursue its commitment to convey to the general public the results of the experiments performed at the facility and to encourage the younger generations to choose science as a career.

The educational project Mission ALBA was launched for the first time during the 2018-2019 academic year, with the participation of 253 teachers from 176 schools from all over Spain. During five months, more than 8,000 primary school students performed the experiments proposed by ALBA in their classrooms and discovered the secrets of matter, force, energy and light. The project will be repeated again in the coming years and will be enlarged with new contents and experiments.

Many of the highlights created along the year have appeared in mainstream media and social media, obtaining a media impact equivalent to more than 450,000 € advertising rates. Again, the facility welcomed more than 7,500 visitors that came organised in guided tours (35% school groups) or during the ALBA Open Day, held on the 28th of June 2019, where the event hosted a record number of visitors (2,425) and more than 100 volunteers from the ALBA staff.

Primary school students performing the experiments of Mission ALBA.

7,636 visitors
2,649 high school visitors

32 students

43 events organised
15 workshops

476 media impacts

450,000 € media value

Generalitat de Catalunya
Departament d'Empresa i Coneixement

EUROPEAN UNION
European Regional Development Fund

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

ALBA Synchrotron - www.albasynchrotron.es
Carrer de la Llum 2-26, 08290 Cerdanyola del Vallès (Barcelona) Spain / Tel. +34 93 592 4300