ALBA

10 YEARS | ILLUMINATING THE UNKNOWN

# Activity Report 2020

ALBA Synchrotron
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# FOREWORD

The year 2020 will remain in the history and in our memories forever connected to the coronavirus pandemic. We are proud to be one of the instruments that the scientific community has used to fight the pandemic. Several experiments have been and are being carried out by public and industrial users devoted to understand the dynamics of the interaction of the virus with our bodies and to develop solutions.

Our research infrastructure, as many other analytical facilities around the world, after facing the lockdown for ensuring the security of staff and users, started organizing the operation within all necessary restrictions to offer quick access to those researchers working in the solutions against the pandemic.

At ALBA the full lockdown lasted one month, the partial operation with few beamlines another month, and the operation with all beamlines recovering the original calendar was on place on mid-May. Combining working at the facility with teleworking has been on-going during the whole period.

And we are proud to have completed during 2020 almost 100% of the originally scheduled experiments, thanks to a fast reaction replacing user presence at the facility with evolved remote control, mail-in services, and specially thanks to the fabulous involvement of beamline scientists and support staff to cover the unavoidable absences. Lessons learnt are used to develop in the future more sustainable and effective services, also in collaboration with other facilities, mainly but not only, the LEAPS ones.

The construction of five beamlines has made progress, in spite of inevitable delays. Among the milestones to be reported are the first photons through the front-end down to the first mirror of the LOREA beamline.

The year 2020, while celebrating one decade from the official inauguration, will be remarked in ALBA history for another important reason: it sets the start-up for planning the upgrade project ALBA II, the transformation of ALBA towards a 4$^{th}$ generation light source, including the set-up of a multilateral collaboration with several institutes for fostering the birth of a science, technology and innovation hub nearby the facility.

I want to personally thank all the ALBA staff, who have shown that the challenges can become opportunities when addressed with constructive and solidary spirit.
Enjoy the reading

**Caterina Biscari**
Director

# 10 years at the forefront of Spanish science


On the 22nd of March 2010, the ALBA Synchrotron was inaugurated to become an important pillar of the Spanish and European research landscape. The facility provides extended research capabilities to academic and industrial users thanks to the excellence in the operation of state-of-the art instrumentation, and to the scientific and technological initiatives originating at the facility.

The facility with eight operational beamlines, five more under construction and one devoted to accelerator's diagnosis, covers photon energies from infrared to hard X-rays, giving answers in very diverse scientific areas (health, energy production and storage, environment, communications technologies or our cultural heritage, among others).

**2,030** research institutions

**More than 5,000** users

**More than 2,000** scientific publications

**50** private national and international companies

**More than 1,500** experiments

# A bright new future

The Governing Council meeting of the ALBA Synchrotron, held on 16 December 2020, approved the start of the ALBA II preliminary design in 2021 to define the necessary parameters and funds.

The ALBA II project foresees transforming the ALBA Synchrotron from 3rd to 4th generation, through the partial replacement of the accelerator, the construction of new beamlines and the upgrade of some components of the existing beamlines.

Photon brilliance (photons per unit time, per unit area, per unit solid angle and per unit spectral bandwidth) and the coherent fraction of the photon flux will be increased by orders of magnitude, providing the ground for unmatched analytics tools and developing new approaches for a sustainable, clean and smart economy and a more efficient health system. ALBA II will have a total capacity of 21 beamlines, of which 13 receiving photons from IDs and up to 8 from fixed field dipolar systems, which will substitute the present dipolar sources (DSs).

**"ALBA II will be a key answer for growing research demands caused by the ecological and economical challenges of the 21st century and the aftermath of the COVID-19 crisis"**

The present plan foresees that the design and construction of ALBA II will take place between 2021 and 2028, maintaining the current operation of the ALBA Synchrotron. Between 2029 and 2030, there will be a technical shutdown to install and commission the new components, with research activity restarting in 2031. It will be a cost-effective process since it will keep the existing infrastructure and most of the accelerator and experimental beamlines.

A proposal for developing ASTIP, the ALBA Science, Technology and Innovation Park, is being elaborated. ASTIP aims to be, a scientific hub that will expand research capabilities in complex materials and biological systems. ASTIP will include three new centers: the Complex Materials and Technologies Center (COMTEC), the Advanced Multiscale Bio Imaging Center (AMBIC) and the innovation hub (SYNDUSTRY). Altogether, it will blend a unique combination of characterization and imaging tools, big data, material growth and device fabrication facilities.

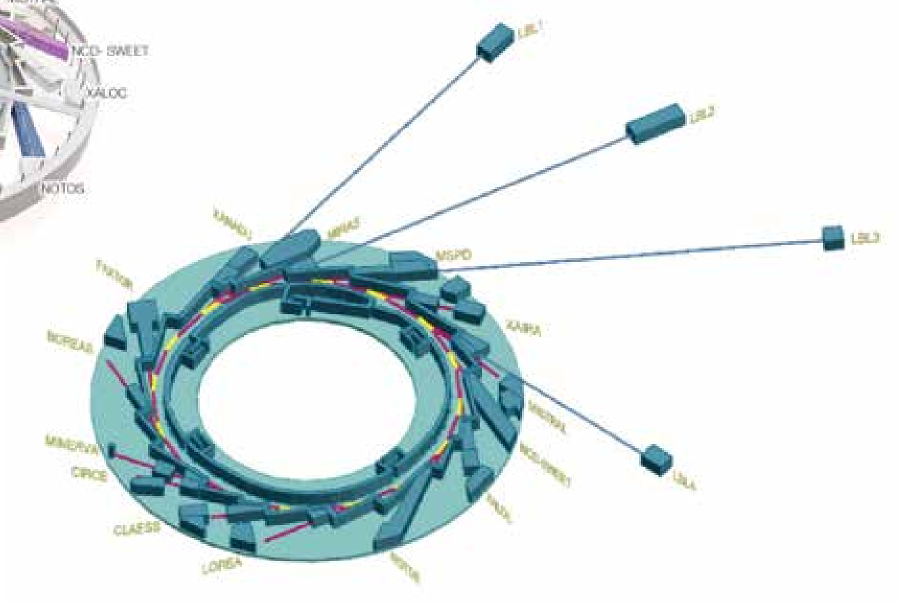



**Figure 1.** At the top, schematic representation of ALBA Synchrotron and its beamlines (infographics by Fundamentium). At the right, ALBA layout with the proposed layout of long beamlines.

# Beamlines under construction

**Figure 2.** Panoramic view of LOREA beamline during installation of components in 2020.

In 2020 ALBA has continued making significant progress in the construction and design of new beamlines. LOREA and NOTOS are opening to users in 2021.

**LOREA. Angled-resolved photoemission spectroscopy for advanced materials**

In 2020, the installation of the whole beamline was executed and the first part of the beamline, inside the optical hutch, was completed. Synchrotron light from the front-end reached the first mirror of the beamline (M1). The features of the undulator were tested and investigated with the use of DiagOn, upstream M1. The remaining parts to be completed, the monochromator, M3, and the K-B, suffered some delay due to pandemic constraints. The control system for the main parts of the beamline was deployed and successfully tested.

**NOTOS. X-ray absorption & powder diffraction**

The installation of the front-end was completed and, after the commissioning of X-rays in September, it is now operating. The main infrastructure of the hutches was installed and the cabling campaign for the optical hutch was finished. The maintenance process of the components for the optical hutch coming from the Spanish ESRF CRG Spline, was concluded and their installation started. The Double Crystal Monochromator was delivered and its Site Acceptance Test started. The contract for a Silicon Drift Detector for XAS measurements was awarded. In parallel to the installation, the design of the end-stations and reactive gas system made progress.

**FAXTOR. Fast X-ray tomography & radioscopy**

The contracts for the photon source and the front-end were assigned and the technical design started. The photon source consists in a 5 poles wiggler with a 2.5 T peak field. The photon source and the front-end are expected to be delivered in spring 2022 and summer 2022, respectively. The documentation for the call for tenders of the optical and the experimental hutches is ready to be published. Particular attention has been put in the design of the conceptual layout of the double multilayer monochromator, FAXTOR's main optical element, in order to optimize its stability.

**MINERVA. Support beamline for the development of the ATHENA mission (Advanced Telescope for High Energy Astrophysics)**

The design of the optical layout was defined and the specifications of most of the beamline elements were characterized. The contract for the front-end has been signed to be installed during the winter shutdown of 2021/2022. A call for tenders for the construction of the optical hutch was published at the end of the year.

**XAIRA. Microfocus beamline for macromolecular crystallography**

In 2020 the photon source, a 2.3m-long in-vacuum undulator, and the front-end of the beamline were successfully installed. The Personal Safety System was verified. The optics is under manufacturing and the conceptual design of the end-station, including a Helium chamber to reduce background, is completed.

**Figure 3.** Optical hutch (blue), experimental hutch (pink) and control hutch (white) of XAIRA beamline.

# Working together for better research facilities

The League of European Accelerator-based Photon Sources (LEAPS) is a strategic consortium initiated in 2017 by the directors of the synchrotron radiation and free electron laser user facilities in Europe. 16 organisations representing 19 light sources facilities across Europe are part of the consortium, chaired by Caterina Biscari, director of ALBA.

In 2020, LEAPS responded immediately against the COVID-19 pandemic, coordinating common actions like enabling raping access mode for COVID-19 related research or favoring remote access for users. The direct result of all the experience and knowledge shared about digitalization and automatization is the project **Digital LEAPS**, that will help facilities to become more resilient towards new crisis within the scope of the European Green Deal and Missions of Horizon Europe. The LEAPS statement and subsequent **taskforce of inclusion, diversity equity and anti-discrimination** show how facilities coordinate and promote best practices for social improvements.

Coordination among research facilities went beyond light sources and, in 2020, driven by a LEAPS initiative, the Analytical Research Infrastructures of Europe (ARIE) was created. ARIE represents more than 100 European research infrastructures and provide service to tens of thousands of users. They include advanced electron microscopies, magnetic field laboratories, proton, laser, light sources, neutron and ion research facilities. In 2020, ARIE presented their plan to tackle Horizon Europe Missions, the ARIE enhanced its cross-border, multidisciplinary collaboration to offer Europe a strong and valid weapon against the present COVID-19 challenge and other potential viral and microbial threats. See:https://leaps-initiative.eu/wp-content/uploads/2020/09/ARIE-MISSIONS-PosPaper-FINAL-RELEASE_09.2020.pdf

LEAPS League of European Accelerator-based Photon Sources

# GOVERNING BODIES

**ALBA is funded in equal parts by the Spanish and Catalan Governments. The composition of the governing bodies in 2020 was:**

## GOVERNING COUNCIL

**Chair:** Pedro Duque Duque, Minister of Science and Innovation (MICINN, Spanish gov.)
**Vice Chair:** Mª Àngels Chacón i Feixas (May 2018-September 2020), Ramon Tremosa (since September 2020), Minister of Business and Knowledge (Catalan gov, GENCAT)
**Members:**
• Rafael Rodrigo Montero, Secretary-General for Sciency Policy Coordination, MICINN
• José Ignacio Doncel Morales, Deputy Director for Singular Scientific and Technical Infrastructures, MICINN
• Carmen Castresana Fernández, Director-General of Research Planning
• Francesc Xavier Grau i Vidal, Secretary for Universities and Research, GENCAT
• Joan Gómez i Pallarès, Director-General for Research, GENCAT
• Margarita Arboix Arzo (January-October 2020), Javier Lafuente Sancho (since December 2020), Rector of the Universitat Autònoma de Barcelona (UAB)
**Secretary:** Luisa María Rodríguez Garrido, State Lawyer, MICINN
**Vice-Secretary:** Berta Bernad Sorjús, Lawyer of the Catalan Government, GENCAT
**Guest:** Caterina Biscari, Director of ALBA

## EXECUTIVE COMMISSION

**Chair:** Francesc Xavier Grau i Vidal, Secretary for Universities and Research, GENCAT
**Members:**
• Rafael Rodrigo Montero, Secretary-General for Science Policy Coordination, MICINN
• José Ignacio Doncel Morales, Deputy Director for Singular Scientific and Technical Infrastructures, MICINN
• Joan Gómez i Pallarès, Director-General for Research, GENCAT
**Secretary:** Berta Bernad Sorjús, Lawyer of the Catalan Government, GENCAT
**Vice-Secretary:** Luisa María Rodríguez Garrido, State Lawyer, MICINN
**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:** 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)
• Michael Wulff, ID09 Beamline Manager at the ESRF (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)

# FACING A PANDEMIC

Montse Pont, Coordination Office

The COVID-19 pandemic has dramatically affected the entire world, wiping out more than three and a half million lives and causing a huge economic crisis both in terms of human toll and economic loss. The pandemic completely changed the way ALBA was operating. But the challenging situation led us to react very quickly and find new ways of giving an excellent service to our user community.

The ALBA Synchrotron was among the research facilities that endorsed the manifesto for EU COVID-19 research (https://www.albasynchrotron.es/en/covid-19-information/ec_rtd_cv-manifesto.pdf).

On 11 March, the ALBA Emergency Committee was created including representatives from the management, the different divisions and the works council, and held its first meeting of the many that followed.

During the total lockdown - enforced in Spain from mid March to mid April - the operation was stopped and only a minimum crew relate to security, goods reception and general maintenance remained at ALBA. All official users until the end of June were cancelled and they were offered a mail-in service as soon as the beamtime was available again.

At the beginning of April, an operational model was devised to restart operations at ALBA while ensuring maximum safety for the staff. This model was based on two plans. One, called OP(perational) mode, took care of the operation of the accelerator and the operating beamlines, and was adapted from the already scheduled operations calendar. The second, called DEV(elopement) took care of activities like maintenance, installations and repairs.

The operating plan started with only our macromolecular crystallography (MX) beamline, and all beamlines were slowly restarted allowing only one person at the beamline, with the rest

**Figure 4.** Theodosios Famprikis (Ph.D. graduate from Université de Picardie Jules Verne, Amiens, France since November 10, 2020) in the experimental hutch of the MSPD beamline at the ALBA Synchrotron.

**Figure 5.** Images of some of the ALBA staff members working from home during the lockdown.

working between mail-in and remote access. Two months after closing ALBA down, we went back to running the facility in very similar conditions to the original operations calendar and, one month later, we were back on the original schedule. After the summer, and as the pandemic restrictions were lifted, the users were allowed to come back to ALBA. As a result, almost 100% of the original number of the experiments planned for 2020 have been performed, which is a great success in the world of synchrotron radiation.

**Almost 100% of the experiments originally planned for 2020 were eventually performed**

ALBA introduced a quick access COVID-19 call, which by the end of 2020 has hosted up to 8 experiments from both academic and industrial communities. The turnaround time between proposal and available beam time is as low as one week.

The DEV plan initially contemplated very few people onsite doing mostly individual jobs and ensuring essential operations and the running of the conventional infrastructures. After four weeks, ALBA allowed small groups of people working together and also the return of external contractors. Some projects in construction have suffered unavoidable delays due to the reduced integrated working time at the facility and at the supplying companies, which were not able to deliver key components on time. In July, operations were resumed as scheduled, including maintenance, installations and repairs.

One key to adapting to the times of pandemic has been to ensure good teleworking conditions for all ALBA employees, as well as to equip the beamlines with additional IT capabilities to ensure seamless connectivity between users and the ALBA staff present at the beamlines. The main upgrades have been the increase of licenses for Remote PC users and the bandwidth of the Remote Desktop Proxy connections from 25 Mbps to 200 Mbps. Also worth noting is the installation of 21 additional NX NoMachine clients to support sample mail-in operation at the beamlines. These enhanced teleworking options, complemented by Zoom, have allowed connectivity for all ALBA staff (approx. 200 people) and up to 10 beamlines.

# HEALTH & SAFETY

**Victor Garrido, head of the Health & Safety Office**

The usual service activities from the Radiation Protection Service (RPS) and the Conventional Preventive Services have been maintained throughout the year and our presence has been guaranteed whenever necessary, even during the COVID lockdown in March. Besides regular activities, the singular conditions caused by the pandemic led us to elaborate a contingency plan against COVID-19 during the first quarter of the year, and its implementation has resulted to date in a very low impact of the pandemic at the ALBA community.

The approved and published contingency plan includes three different scenarios - containment, mitigation and escalation - and we have adopted different strategies according to the scenario in which we were at each time. Aligned with the scenarios, we defined working "MODE" protocols for new and existing beamlines to ensure light source availability (as explained in the previous section). The main objective was to determine the levels of presence and types of work required and to switch from one working mode to another according to the circumstances. The mode of operation was first based on task planning and then we proceeded to define the level of occupancy. All this was discussed in the special Emergency Committee created ad hoc to deal with this pandemic situation and allowed us to react promptly, resolutely and consensually to these unforeseen events. Common measures such as use of PPE, social distancing, hygienic habits or organizational measures such as time regulations, reduction of mandatory presence, promotion of teleworking when possible or cancelling business trips and outreach visits… all of those actions were discussed in this Emergency Committee. FAQs and Safety Guidelines were issued to keep everyone up to date with current measures and also to be used as material for training during the year. Apart from describing the new working conditions under COVID-19, we also created the role of "supervisor on site" to ensure compliance with the new rules within our premises. Issues collaterals to the pandemic have also come up such as the definition of working time flexibility and reduction of working hours in case of school closure and vulnerable people affection, or a mail-in procedure to limit user access when necessary. Finally, a planned step as the transition from external to internal prevention service was postponed to 2021.

The Health & Safety team started 2020 with the leave of one of its members and the opening of a recruitment process that was necessarily suspended due to the COVID-19 situation. Interviews were finally resumed in July and a new member joined us in September. All radiation measurements performed ensure that the levels of radiation outside the shielding enclosures are below public level as usual and, on the other hand, the performed electromagnetic field risk assessments allowed us to complete the work on radiation risk control initiated last year. The LOREA beamline opened its front-end for the first time on 26 July 2020 and after the first radiation measurements, the classification of the area surrounding LOREA's Optics Hutch was downgraded to watched area, and will remain like that until the end of the commissioning phase. The functionality of XAIRA's personal safety system (PSS) was also verified during the summer shutdown, together with the rest of the PSS works. And MINERVA shielding calculations were performed and finished before summer. A great effort was made to the BEATS European project, which aims at building a tomography beamline at SESAME. The Annual Meeting of the project was hosted and organized by ALBA at the end of February. The new SESAME Safety Engineer, Dr. Iyad Zahran, did a training stage at ALBA.

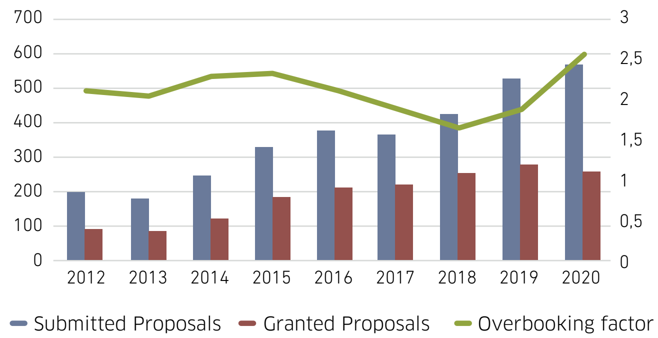
Another example of activities outside the management of the pandemic was the RADON study, which started in 2017 and continued in 2019, were received in September and confirm that all spaces at ALBA are well below the exposure limit established by law, with one exception corresponding to a small service room outside the main building for which further studies and engineering solutions will be developed during 2021. Finally the Health & Safety Office wants the express its gratitude to the whole ALBA's team for their support and commitment. Thanks and keep safe!

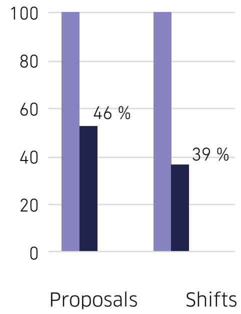
# KEY FIGURES IN 2020

## Serving our user community

**4,776 operation hours**
(20% reduction due to pandemic constraints)
**3,736 hours for beamlines**
(20% reduction due to pandemic constraints)
**52.1 hours** Mean Time Between Failures
**0.9 hours** Mean Time to Repair

**98.2%** beam availability

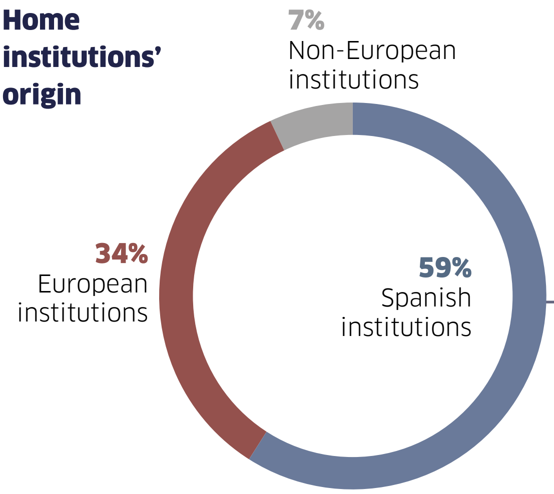



**573** Submitted Proposals
**263** Granted Proposals

**6,758** Requested Shifts
**2,613** Awarded Shifts

### Home institutions' origin

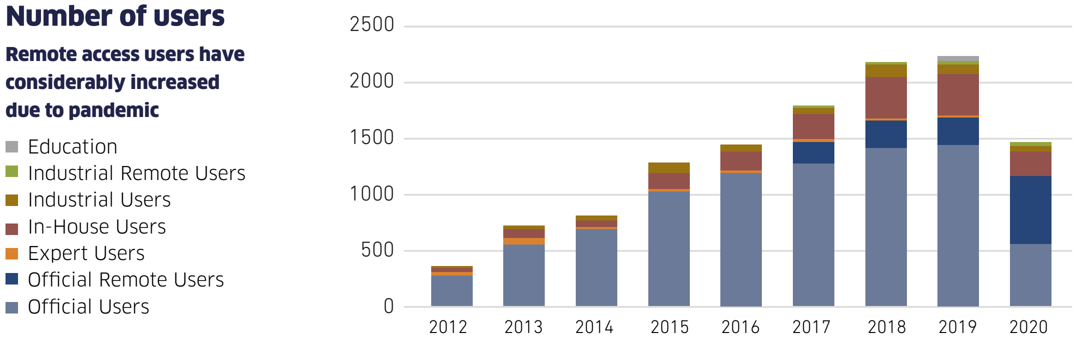



**34%** Catalonia
**23%** Madrid
**15%** C. Valenciana
**12%** Basque Country
**7%** ALBA
**3%** Andalusia
**3%** Aragón
**3%** Others*

*Sum of Asturias, Cantabria, Castilla-La Mancha, Castilla y León and Navarra

### Number of users

**Remote access users have considerably increased due to pandemic**



## Research area

Environmental sciences **2%**

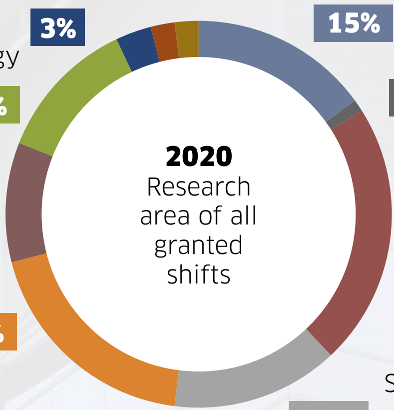
**2%** Cultural heritage

Materials sciences for information technology **3%**

**15%** Biology/Life sciences (not PX)

Chemistry, surface science, catalysis **12%**

**1%** Geo-Sciences




**10%** Protein crystallography (PX)

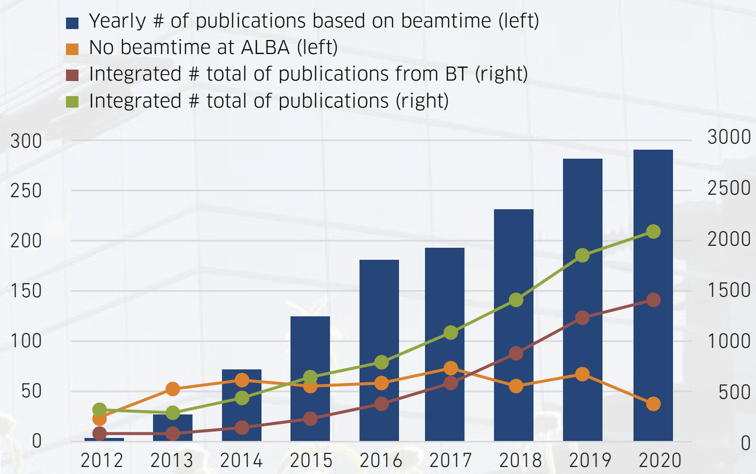
**22%** Solid-state physics/materials science (structure, phase transitions, nanomaterials)

Materials sciences for energy technology **19%**

**14%** Solid-state physics (electronic properties, magnetism, basic quantum materials)


**32%**
Granted experiments declared by the main proposer as relevant for industry

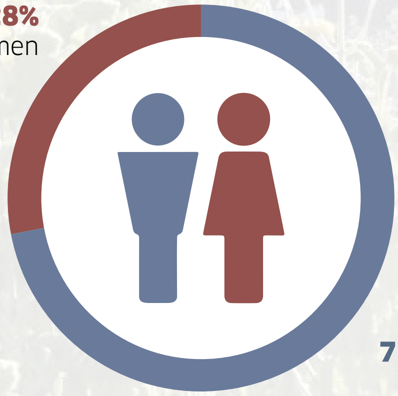
## Publications




**211** Staff Members

**23%** Non-Spanish nationalities

**28%** Women



**72%** Men

# 2020 AT ALBA

## JANUARY

**ALBA towards the re-industrialization of the local area**

Representatives of the “Pact for the Re-industrialization of Vallès Occidental” participated in a meeting held at ALBA.

## FEBRUARY

**Óscar Matilla, new head of the Computing division.**

He arrived at ALBA in 2006, at the very beginning of the project. He has been the head of the Electronics section for the last ten years and has strongly contributed to the concept, realization and operation of the Control and Electronics systems at ALBA.

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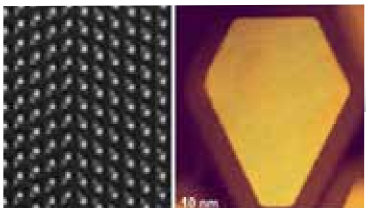
## MARCH

**Ten years at the service of science and society**

On 22 March 2010 the ALBA Synchrotron was inaugurated, starting a new era by assisting researchers from a wide range of fields and generating knowledge, development and well-being for society.



## APRIL

**ALBA will host a microscopy platform**

A joint action of nine research institutions and the support of European Regional Development Funds will enable the installation of two new major experimental facilities, one dedicated to materials science and another to molecular biology.

## MAY

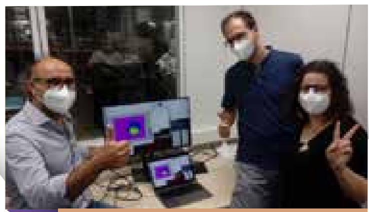
**Contributing to overcoming COVID-19**

ALBA and other synchrotron facilities worldwide opened specific calls for rapid access to dedicated beamtime for prioritizing the research on the SARS-CoV-2 virus, its therapy and vaccine. Besides, the IT Systems Section also started a virtual server to process data for an international project, which was bringing researchers together to accelerate the open science effort to develop new life-saving therapies. X-ray science facilities around the world, with an aim to further coordinate and strengthen their support of scientific research and solutions to the COVID-19 pandemic, assembled for a remote access video SR20 Summit and adopted a dedicated Action Plan.

**JUNE**

### ALBA resumes all on-site activities

At the end of June, ALBA resumed all on-site activities and the whole staff combined teleworking with presence at the facility, as did Spanish public administrations, once the first wave of the pandemic was over.



**JULY**

### First photons from the LOREA beamline

The commissioning time on 24 and 25 July was used to open LOREA to its first synchrotron light. LOREA is the 9th ALBA beamline, devoted to angle-resolved photoemission spectroscopy (ARPES).

**SEPTEMBER**

### Results of the innovation impact of ALBA

A pilot exercise was performed within the framework of the RIPATHS project, co-financed by the European Union's Horizon 2020 research and innovation programme. Results represented a novel route for ALBA impact identification resulting in more than 350 patents directly or indirectly citing ALBA publications.

**OCTOBER**

### Caterina Biscari stays on as chair of LEAPS in 2021

The LEAPS General Assembly decided by unanimity to have the director of ALBA again in 2021 as Chair of the League of European Accelerator-based Photon Sources (LEAPS).

**NOVEMBER**

### Catalan Minister of Business and Knowledge visited ALBA

Ramon Tremosa visited the facility and met the directors of several research centers of the area, where he announced the intention of the Catalan Government to create a public-private investment fund to promote the transfer of knowledge from Catalan research.

**DECEMBER**

### Green light to start working on the ALBA upgrade

The Governing Council approved the start of the ALBA II preliminary design in 2021, wich will transform the facility from 3rd to 4th generation, through the partial replacement of the accelerator, the construction of new beamlines and the upgrade of components of the existing beamlines.

# Life sciences and soft condensed matter

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

The year 2020 will be remembered as very challenging. The pandemic outbreak stroke ALBA from early March and has since challenged our operation, research, technical development, management, outreach and, especially, our personal resilience. The response of all ALBA staff, and in particular that of the Life Sciences section, has been commendable. Always following the safety rules, the beamlines were given permission and were able to cater the experiments related to COVID in spite of the dire conditions. Several academic and industrial experiments were carried out at the XALOC and NCD-SWEET beamlines during lockdowns. As early as June all beamlines were able to resume experiments even though the severe mobility and occupancy restrictions complicated beamline operation. As seen in the Facts & Figures section, beamtime availability was not hampered as much as one could expect from the critical situation. In brief, 72% of the awarded beamtime at the beamlines of the section could be finally delivered, plus 8 COVID experiments. In fact, by the time of writing this report, some results have already been published to shed light on the COVID-19 uncertainties (see https://doi.org/10.1073/pnas.2021847118 and https://doi.org/10.1038/s41467-021-21165-9).

Beamline scientists, engineers, technicians, floor coordinators, offices administration and in general all services staff were able to rise from adversity and work under pressure. Although many activities inevitably slowed down, they never stopped and even unforeseen services such as remote operation of non-MX beamlines were developed. Scientists offered to perform complex sample preparations and experiments and data analysis, exceeding their duties as local contacts, when necessity arose.

Science at ALBA has therefore been developing in the chinks left by the emergency. The Life Sciences beamlines and laboratories have been studying a large variety of samples during 2020, from protein crystals to tissues, requiring very different preparation methods.

Developments at the operating beamlines did not stop either. The infrared beamline MIRAS brought into operation a 4.2 K bolometer detector for far-Infrared region. The full-field transmission soft X-ray microscopy beamline MISTRAL continued the development of a Cryo-SIM instrument for correlative microscopy in cryo conditions and improved its tomographic data collection rate. NCD-SWEET is now able to carry out simultaneous SAXS/WAXS or GiSAXS/GiWAXS experiments. The macromolecular crystallography beamline XALOC has upgraded the control and data analysis system, which plays a critical role in this highly automated technique. Beamlines under construction within the section have also seen significant progress. The microfocus macromolecular crystallography beamline XAIRA has the photon source, a 2.3m-long in-vacuum undulator, and the front-end already installed, while the optics are expected in the near future. The photon source and the safety hutches of FAXTOR, the new hard X-ray tomography and radioscopy beamline, are next in the line.

The beamlines of the section are well supported by close-by biological laboratories, which have been expanded to a total area of 230 $m^2$. A new, fully equipped mammalian cell culture lab with biosafety level 2 capabilities has been put into operation. An automatic dispenser for protein crystallization compatible with LCP techniques is also available for academic and industrial usage upon demand.

Last but not least, the first CryoEM microscope to be installed at ALBA has been procured thanks to a consortium of several institutes in the Barcelona area. The 200-kV microscope is to be operative by the end of 2021 and will be equipped with a field emission gun, an automated sample exchanger and a state-of-the-art direct electron detector. This configuration has a great potential for single particle analysis.

# Development of a new enzyme for the recycling of PET plastic waste

**French researchers jointly published an article that made the cover of the scientific journal Nature: engineered PET-depolymerase to break down and recycle plastic bottles. The development of this novel enzyme places this technology at the forefront of efforts to better protect our oceans and planet against plastic pollution. Some of the experiments were carried out at the XALOC beamline in the ALBA Synchrotron.**

Researchers from the Toulouse Biotechnology Institute (TBI) - an INSA Toulouse/INRAE/CNRS Joint Research Unit - and Carbios - a French green chemistry company that is a pioneer in bioplastics engineering – describe in this article the development of a new enzyme that can biologically depolymerise plastic waste made of poly(ethylene terephthalate) (PET) and facilitate its recycling into new bottles. PET is one of the most common thermoplastic polymers on the market and is used to manufacture bottles, food packaging and polyester textiles. The development of this novel enzyme places this technology at the forefront of efforts to initiate a true transition towards the circular economy and thus better protect our oceans and planet against plastic pollution.

They were able to resolve the crystal structure of the proteins studied using synchrotron light for X-ray data collection. More specifically, they collected diffraction data for the Leaf-branch cutinase S165A variant at the XALOC beamline in the ALBA Synchrotron.

Following several years of research by both academics and industry, Carbios and TBI have been able to enhance the depolymerisation of PET waste: the enzyme they have engineered can break down 90% of PET over just 10 hours. By combining molecular design and engineering, the French scientists have in parallel been able to improve the thermostability and activity of this PET hydrolase which can very efficiently break down PET into terephthalic acid and mono ethylene glycol, achieving a productivity of 16.7 g/L/h terephthalic acid from a suspension of 200 g/kg post-consumer PET waste. In collaboration with the Critt Bio-Industries from INSA Toulouse, Carbios succeeded in purifying the monomers to further manufacture new bottles, thus demonstrating the circular nature of the process.

This constitutes major progress, as the yield has been multiplied 100-fold compared to previously published processes. It is a world first that opens the way to deploy a circular economy technology that is applicable to all PET waste and offers a breakthrough solution to dealing with the current environmental and industrial problems posed by the massive use of plastic materials.

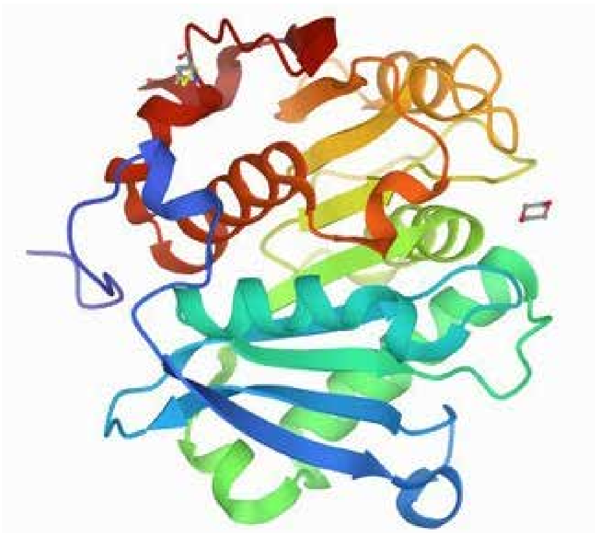


**Figure 6.** High-resolution crystal structure of hydrolase Leaf-branch cutinase S165A variant. / "https://www.rcsb.org/structure/6THS"Protein Data Bank

**REFERENCE:** Tournier, V., Topham, C.M., Gilles, A. et al. An engineered PET depolymerase to break down and recycle plastic bottles. Nature 580, 216–219 (2020). https://doi.org/10.1038/s41586-020-2149-4
**LINK TO THE ORIGINAL NEWS:**
https://www.inrae.fr/en/news/development-new-enzyme-recycling-pet-plastic-waste-new-bottles

# Chemistry and Materials Science

**François Fauth, Head of the Chemistry and Materials Science Section (Experiments Division)**

The Chemistry and Materials Science section (CHEMAT) covers operational aspects of the hard X-ray beamlines MSPD and CLAESS, dedicated to Powder Diffraction and Absorption Spectroscopy, the Soft X-ray beamline CIRCE-NAPP, dedicated to Photoemission Spectroscopies, as well as the Chemistry and High Pressure laboratories which are to be used by all staff and users that request it.

From an operational point of view, MSPD & CLAESS maintained a record-high number of academic proposals (96 and 102 respectively) of which 49 and 38 were granted beamtime, respectively. In the case of CIRCE beamline, 79 proposals were submitted, of which 26 were performed. These numbers particularly highlight the severe oversubscription of hard X-rays spectroscopy (CLAESS) and of Ambient Pressure XPS techniques, which are known to be intensively used in heterogeneous catalysis studies and in battery / electrochemical studies. The latter field, together with high-pressure techniques, remains the highest requestor on MSPD. The pressure of demand of hard X-ray spectrocopy will likely be reduced when the NOTOS beamline starts operating in 2021, as it covers both hard X-ray absorption and powder diffraction techniques.

The scientific highlight of the section of course extensively covers the two ALBA strategic research lines: Catalysis and environmental sciences and Materials for energy-related applications, but also societal challenge with a strong program on cultural heritage through microdiffraction techniques.

The 2020 user operation was first marked by the COVID-induced lockdown, and then by preventive constraints. Many experiments were performed in mail-in service mode but 6 experiments had to be cancelled on MSPD, 2 in CIRCE, whereas none on CLAESS. The cancelled experiments dealt with *in-situ* data collection on Operando batteries, for which cells have to be freshly prepared in the Ar glove box of the ALBA chemistry lab. All experiments requests for proprietary research were however granted beamtime when technically feasible.

In 2020, 63 and 43 and 24 publications in peer-reviewed journals resulted from MSPD, CLAESS and CIRCE beamtime respectively. Whereas the number remained constant for MSPD, it almost doubled for CLAESS, and we can confidently expect to maintain a one experiment - one publication ratio from now on. CIRCE is also close to that landmark.

Regarding instrumentation, on MSPD, a new mirror and cooling system has been ordered and the Call for Tender for a new position-sensitive detector has been issued and the contract signed. Both components will be integrated in 2021. On CLAESS, a proper infrastructure for hazardous gas experiments at high pressure (max 20bar) has been built and its safety approved by an external company. In the CIRCE-NAPP, a parking chamber was built and the control of the monochromator from the photoelectrons energy analyzer acquisition software was implemented.

2021 will see operation start on NOTOS, which spans both techniques used on MSPD and CLAESS, and we aim at acquiring an efficient and fruitful complementarity between beamlines and staff.

# Unveiling the synergistic effect of NCM cathode materials in lithium-ion batteries

**An international research group developed a universal and facile synthetic strategy to synthesize a $LiNi_xCo_yMn_{1-x-y}O_2$ (NCM) material for lithium-ion batteries. The study provided new insights into the synergistic effect of core and shell during electrochemical cycling. These findings offer a new perspective for rational design of layered nickel-based cathode materials with high energy and long cycling life with particular two-phase electrochemical characteristics.**

$LiNi_xCo_yMn_{1-x-y}O_2$ (NCM) intercalation compounds with core-shell architecture have been found to be promising cathode candidates for next-generation lithium-ion battery applications. The NCM cathodes functional properties are dependent on the transition metal relative ratios, making a challenge to control the real structure of core-shell NCM cathode materials and to understand the synergistic effect of core and shell during the electrochemical cycling. An international research group featuring researchers from the State Key Laboratory of Electronic Thin Films and Integrated Devices (University of Electronic Science and Technology of China); the Institute for Applied Materials (Karlsruhe Institute of Technology, Germany ); the Technische Universität München (Germany) and the ALBA Synchrotron developed a universal and easy synthetic strategy to synthesize an NCM material for the lithium-ion batteries, which are composed of an inner Ni-rich core and an Mn-rich shell. The material combines high capacity of the Ni-rich phase and high stability of the Mn-rich phase thus providing improved electrochemical properties compared to any of these phases taken separately.

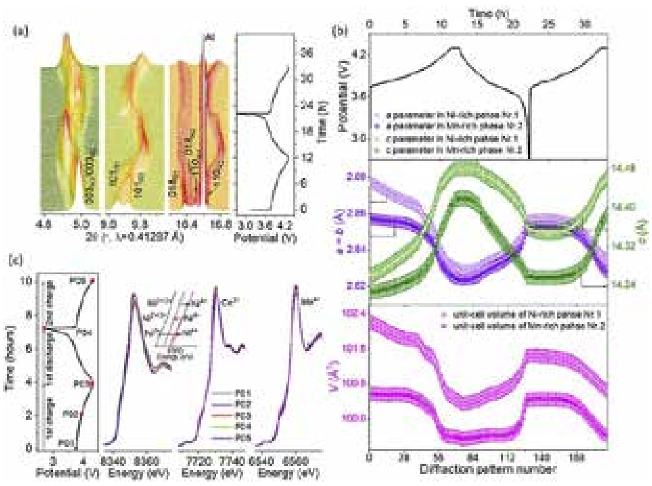


Figure 7. Data obtained at MSPD and CLAESS beamlines in the ALBA Synchrotron. (De)Lithiation mechanism of core-shell NCM cathode materials during cycling. (a) SRD reflection evolution of the core-shell NCM electrode during the first charge-discharge and the second charge process. (b) variation of lattice parameter as a function of de-lithiation and lithiation process, lattice parameters of each SRD pattern reveal a good structural stability for the Mn-rich phase Nr.2. (c) in situ XANES spectra at Ni, Co, and Mn K-edges of the core-shell NCM cathode during cycling.

This study provides new insights into the synergistic effect of the two layered phases in the core-shell morphology on the electrochemical performance of NCM cathode materials. These findings also offer a new perspective for rational design of layered Ni-based cathode materials with high energy and long cycling life with particular two phase electrochemical characteristics.

The core-shell material was synthesized by sequential co-precipitation of the transition metal hydroxides followed by reaction of the obtained precursor with lithium carbonate. The crystal structure of the pristine material was determined by simultaneous refinement of the synchrotron X-ray powder diffraction data- taken at the MSPD beamline in the ALBA Synchrotron - and neutron powder diffraction data - SPODI beamline at Neutron Research Source Heinz Maier (Leibnitz, Germany). The mechanism of the charge/discharge processes was analyzed using *in-situ* synchrotron powder diffraction – also at the MSPD beamline in ALBA - and *in-situ* X-ray absorption spectroscopy – at the CLAESS beamline in ALBA.

**REFERENCE:** Weibo Hua, Björn Schwarz, Raheleh Azmi, Marcus Müller, Mariyam Susana Dewi Darma, Michael Knapp, Anatoliy Senyshyn, Michael Heere, Alkesandr Missyul, Laura Simonelli, Joachim R. Binder SylvioIndris, Helmut Ehrenberg. Lithium-ion (de)intercalation mechanism in core-shell layered $Li(Ni,Co,Mn)O_2$ cathode materials. Nano Energy (2020). DOI: https://doi.org/10.1016/j.nanoen.2020.105231

# Electronic and Magnetic Structure of Matter

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

This section encompasses the soft X-ray beamlines BOREAS, CIRCE, the associated Materials Science Laboratory, and now also the LOREA beamline for angle-resolved photoemission spectroscopy.

A major milestone in 2020 was the successful start of the commissioning of the LOREA beamline optics, which received its first beam in July 2020. The commissioning will progress along 2021 in parallel to the completion of the installation, with the start of user operation expected in the second half of the year.

Yearly performance was again high in a year in which remarkable efforts were done by the staff to minimize the impact of COVID-19 and related lockdown, repair interventions and a quick and intense move onto remote experiments (mostly BOREAS). In the case of the CIRCE beamline, 79 proposals were submitted, of which 26 were performed with 290 user shifts delivered; for BOREAS, 84 proposals were submitted, of which 36 were performed with 319 user shifts delivered. Oversubscription remains high, at a rate of of 2.2 and 2.3 requested/delivered proposals, respectively. Proprietary access was also present at BOREAS and CIRCE.

The 2020 scientific productivity continues a yearly growth path, and achieved numbers above previous years records: 28 peer-reviewed articles, 9 of which with IFP > 7 and an average impact factor of 7.1 based on experiments at BOREAS; 24 publications, 12 of which with IPF > 7 and an average impact factor of 7.2, based on experiments at CIRCE. To this one we may add 3 additional publications from magnetism activities at the MISTRAL beamline, with a high average impact factor (11.2). Published results were key to advances in information technology relating to novel magnetic materials (see highlights in the next pages). Furthermore, there has been remarkable development of synchrotron radiation “key enabling techniques” of relevance for information technology, like the implementation of PEEM-shadow technique, optimization for magnetic resonant scattering from chiral domain walls or world-class 3D magnetic tomography at MISTRAL. This evidences the high quality of the science performed by our user groups and the cutting-edge capabilities offered by the ALBA beamlines portfolio in the context of electronic and magnetic properties of materials.

Regarding scientific collaboration activities and visitors, a new national MINECO research subproject on 3D magnetic imaging of topological magnetic states was awarded to MISTRAL staff in a program coordinated by the University of Oviedo, while a FlagEra research subproject on Graphene/Ferromagnetic chiral heterostructures was awarded to BOREAS team in a program coordinated by IMDEA nanoscience.

# Enabling novel magnetic material advances in information technology

Digital information is steadily increasing year after year. To satisfy this huge demand, the search for new magnetic materials attracts worldwide interest as they have a crucial impact on energy, transport and information storage/conversion application. In 2020, several experiments have been performed at ALBA to find new solutions that will expand the progress of information technology devices and techniques.

A new highly-anisotropic Rh-based Heusler compound was reported as an ideal candidate for high-density magnetic recording media through fast heat-assisted writing technology. $Rh_2CoSb$ is a new hard magnet with potential for thin film magnetic recording. A magnetocrystalline anisotropy of 3.6 $MJm^{-3}$ is combined with a saturation magnetization of µ0Ms = 0.52 T at 2 K (2.2 $MJm^{-3}$ and 0.44 T at room-temperature). The magnetic hardness parameter κ of 3.7 at room temperature is the highest observed for any rare-earth-free hard magnet. The work is the result of an international collaboration led by teams from the Max Planck Institute (Germany) including experiments at the Trinity College Dublin (Ireland), the ALBA Synchrotron (Spain), the Dresden High Magnetic Field Laboratory (Germany), IFW and TU Dresden (Germany). The BOREAS beamline helped to characterize this new material probing the origin of its giant magneto-crystalline anisotropy.

***Reference: https://doi.org/10.1002/adma.202004331***

Researchers at the Autonomous University of Barcelona (UAB), the Institute of Materials Science of Barcelona (ICMAB-CSIC) and the ALBA Synchrotron, in collaboration with the University of Barcelona (UB) and the Catalan Institute of Nanotecnology (ICN2), developed a new technique to locally modify the properties of a metamagnetic material. The method consists in applying local pressure to the surface of the material using nanometric needles, and allows a much more easy and local modification than current methods. The research opens the door to a more accurate and precise control of magnetic materials and allows to improve the architecture and capacity of magnetic digital memories. In order to resolve the magnetic changes around an individual indentation on the nanoscale, the work used the Photoemission Electron Microscopy combined with X-ray magnetic circular dichroism at the CIRCE-PEEM beamline.

***Reference: https://doi.org/10.1039/D0MH00601G***

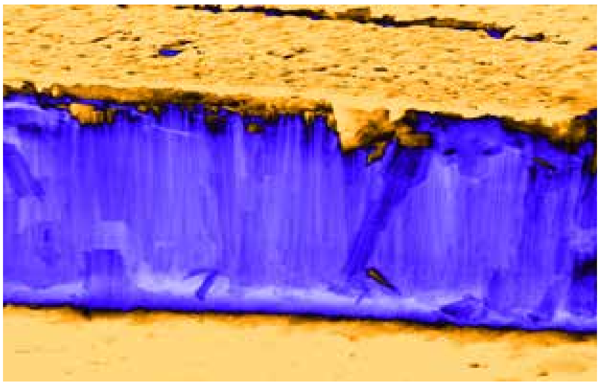


**Figure 8**. New flexible and antiferromagnetic material / ICMAB-CSIC. https://doi.org/10.1021/acsami.0c00704

Antiferromagnetic materials offer a more robust alternative for storing information than ferromagnetic materials (the most widely used today to encode information, for example, on magnetic cards). Researchers from the ICMAB-CSIC obtained a flexible tape of an antiferromagnetic material able to store information in a more robust and secure way than the ubiquitous ferromagnetic materials. This innovation may have application where flexibility and data storage robustness are required, such as credit or identification cards. Some of the experiments were performed at the CIRCE beamline where researchers studied the ferromagnetic domain distribution at high temperature (T = 150 ºC) collected by X-Ray Magnetic Circular Dichroism in combination with Photoemission Electron Microscopy (XMCD-PEEM).

***Reference: https://doi.org/10.1021/acsami.0c00704***

Scientists made a breakthrough in the development of a new generation of electronics that will require less power and generate less heat by exploiting the complex quantum properties of electrons, the spin state of electrons. Spin capacitors had been so far proposed theoretically and experimental realizations were either requiring very low temperature or exhibiting very small holding times for the storage "spin charge". However, devices incorporating a hybrid MnOx/C60 interface, a particular metal oxide-fullerene heterojunction, exhibited spin polarized charge trapping of electrons with large holding times at room temperature. The discovery is the result of a research collaboration led by the University of Leeds together with the ALBA Synchrotron, the Paul Scherrer Institute (Switzerland), the Science and Technologies Facilities Council and the University of St Andrews, both in the UK.

***Reference: https://doi.org/10.1126/sciadv.aax1085***

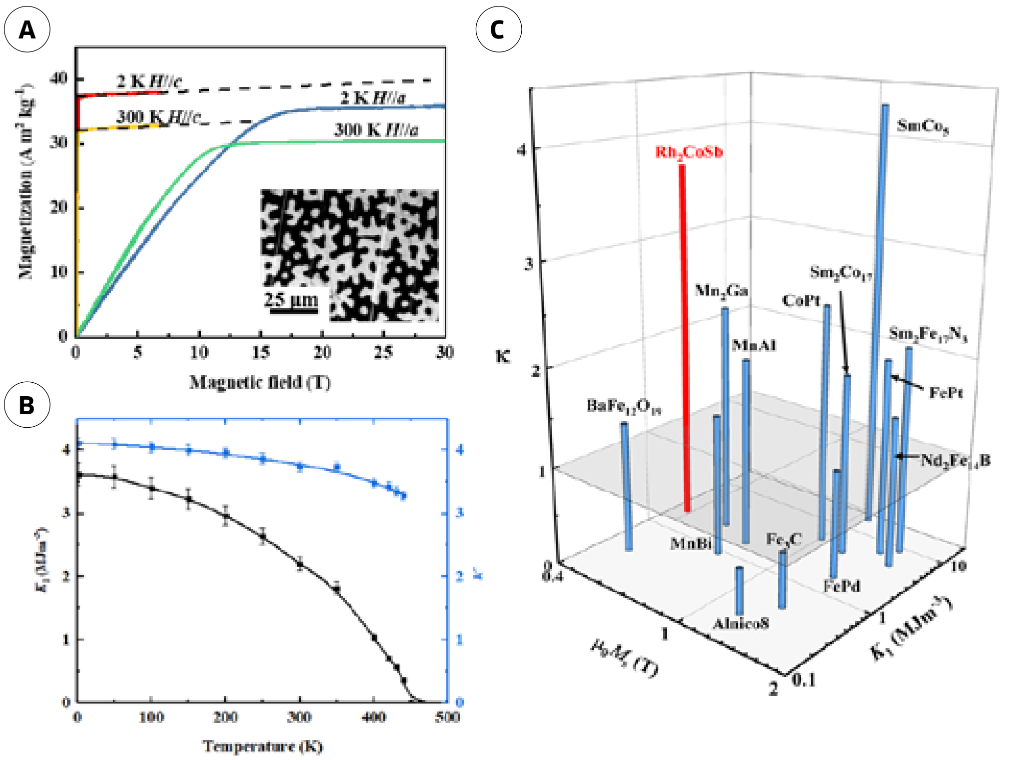
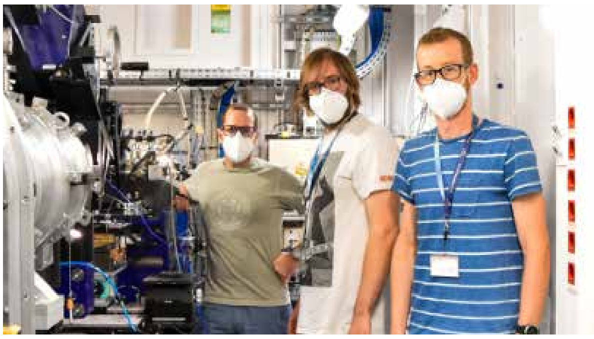



**Figure 9.** Magnetic hardness of various well-known magnetic compounds used in magnetic storage and as permanent magnets, including the new Heusler rare-earth-free compound discovered in this work. https://doi.org/10.1002/adma.202004331

# SUMMARY OF SELECTED HIGHLIGHTS

## LIFE SCIENCES AND SOFT CONDENSED MATTER



### BL11 - NCD-SWEET

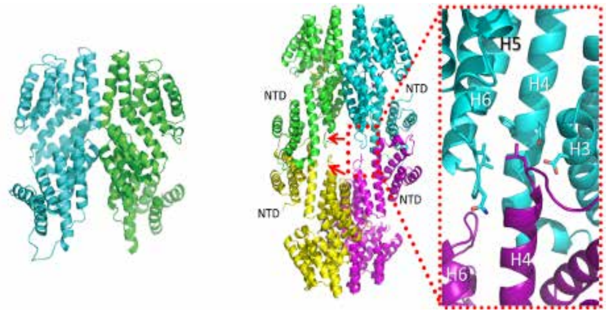
#### CSIC RESEARCHERS STUDY POTENTIAL DRUGS AGAINST COVID-19 AT ALBA

A research team from the Centre of Biological Investigations Margarita Salas (CIB-CSIC) used synchrotron light to study the possible effect of an antitumoral drug of clinical use over the viral cycle of the SARS-CoV-2 coronavirus. The drug might interrupt viral transport inside the cell, blocking its replication.

### BL13-XALOC & BL11-NCD-SWEET

#### RESEARCHERS FROM ALBA UNRAVEL A STRUCTURAL MECHANISM INVOLVED IN BACTERIAL CONJUGATION

A study led by scientists from ALBA reported an in-depth structural analysis of bacterial proteins involved in conjugation, Rap and Rco, at various levels of atomic detail. They demonstrated that Rap tetramerization is induced by peptide binding, through a novel “foot-2-foot” interaction, not previously seen in other proteins of the Rap family. Tetramerization hampers Rap-Rco interaction, releasing Rco, which is a repressor protein, and thereby blocking conjugation, the transfer of genetic material between bacteria.




“Inactivation of the dimeric RappLS20 anti-repressor of the conjugation operon is mediated by peptide-induced tetramerization” DOI:10.1093/nar/gkaa540


### BL01-MIRAS

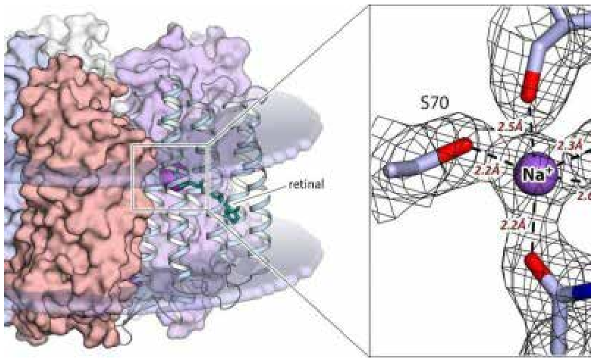
#### IRTA AND THE ALBA SYNCHROTRON COLLABORATE IN THE STUDY OF A NEW BIOMATERIAL FOR DECONTAMINATION OF HEAVY METALS

They analyzed the biochemical properties of this biomaterial, and its possible use to absorb and immobilize heavy metals from contaminated water. This is the first time that IRTA (Institute of Agrifood Research and Technology) and the ALBA Synchrotron establish a scientific collaboration.

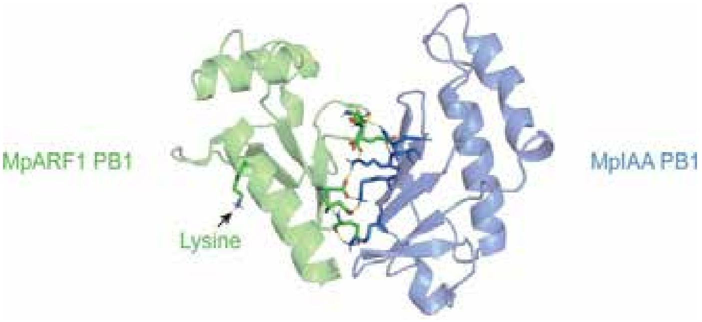
### BL13-XALOC

#### BIOPHYSICISTS REVEAL HOW OPTOGENETIC TOOL WORKS

An international research team obtained for the first time the structure of the light-sensitive sodium-pumping KR2 protein in its active state. The discovery provides a description of the mechanism behind the light-driven sodium ion transfer across the cell membrane. Understanding how KR2 works is crucial for optimizing the functional characteristics of that protein and using it as the basis for new optogenetic tools.




“Molecular mechanism of light-driven sodium pumping” DOI: 10.1038/s41467-020-16032-y




"Design principles of a minimal auxin response system"
DOI: 10.1038/s41477-020-0662-y

## BL13-XALOC

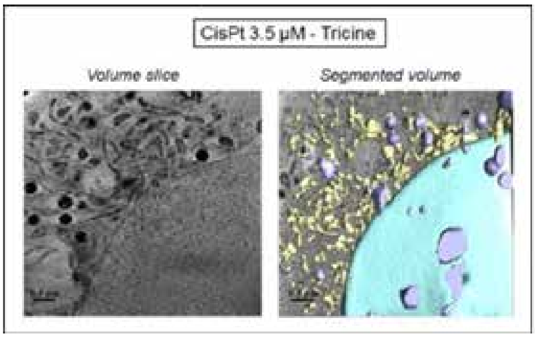
### PLANT BIOLOGISTS DISCOVER SIMPLE PRINCIPLE OF PLANT RESPONSES TO AUXIN HORMONE

Researchers from the Netherlands, Japan and Spain found a simple mechanism for controlling plant growth. Implementation of these findings can help growers to design new crops with for example resistance against disease, drought or flood.

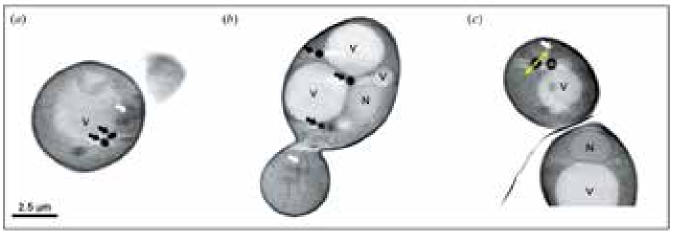
## BL09-MISTRAL & BL11-NCD-SWEET

### TRICINE AS A POTENTIAL ENHANCER FOR CISPLATIN-BASED SKIN CANCER TREATMENT

A study led by researchers at the Institute of Investigation and Innovation Parc Taulí, in close collaboration with ALBA, demonstrated that the use of tricine as an adjuvant for cisplatin chemotherapy enhances drug effectiveness against cutaneous squamous cell carcinoma.




"Multiparametric Analysis of the Effectiveness of Cisplatin on Cutaneous Squamous Carcinoma Cells Using Two Different Types of Adjuvants" DOI: 10.1371/journal.pone.0230022
"A comparative study of the effectiveness of cisplatin and 5-fluorouracil on cutaneous squamous human carcinoma cell line: Potential chemotherapy alternative to surgery" DOI: 10.1111/dth.12373



"Synchrotron multimodal imaging in a whole cell reveals lipid droplet core organization" DOI: https://doi.org/10.1107/S1600577520003847

## BL09-MISTRAL

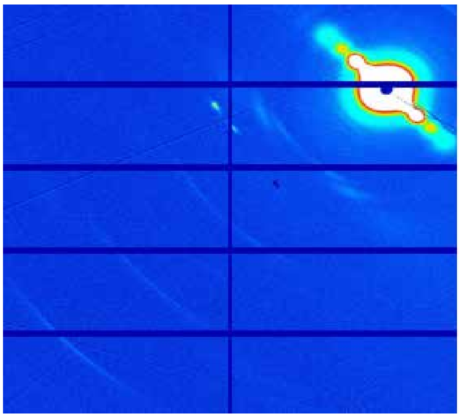
### NEW NON-INVASIVE CELL IMAGING METHOD REVEALS LIPID DROPLET STRUCTURE

A research team led by the French National Research Institute for Agriculture, Food and Environment (INRAE) developed a new multimodal imaging method that combines different microscopy techniques used at the ALBA Synchrotron and the French SOLEIL synchrotron. This method was used to gather complementary information about the composition and structure of lipid droplets in yeast cells. One of its advantages is that it does not employ any chemical markers or fixing agents, which can potentially damage cells.

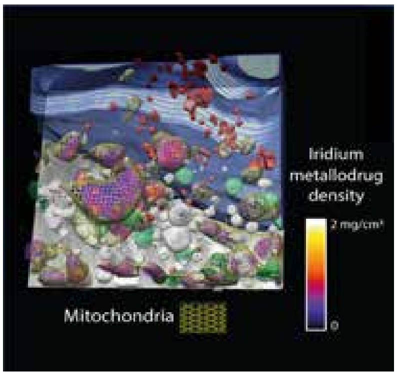
## BL11-NCD-SWEET

### UNDERSTANDING HOW THE TAXANES ANTITUMORAL DRUGS MODULATE CELL MICROTUBULES

Researchers from the Centre of Biological Investigations (CIB-CSCIC), in collaboration with the University of Utrech and the Institute of Materia Medica, found that addition of paclitaxel (a type of antitumoral drug) to microtubules alters their structure. This compound modulates the material properties of microtubules by converting destabilized growing microtubule ends into regions resistant to depolymerisation, eventually leading to cell death.



"Taxanes convert regions of perturbed microtubule growth into rescue sites" DOI: 10.1038/s41563-019-0546-6




## BL09-MISTRAL

### IMAGING HOW ANTICANCER COMPOUNDS MOVE INSIDE THE CELLS

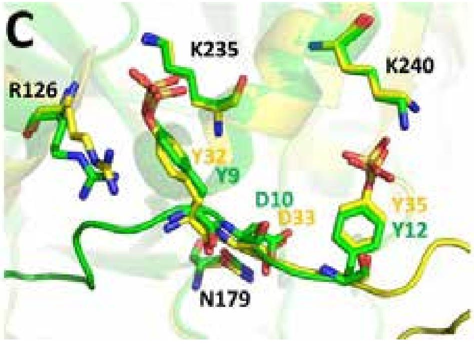
Iridium-based metallodrugs are emerging as novel tools to destroy cancer cells by disrupting their intracellular redox balance. Scientists at ALBA, IMDEA Nanociencia, ESRF and CNB-CSIC correlated on the same cell, for the first time, two 3D X-ray imaging techniques to image the anticancer agent at work in the cryopreserved intracellular nano-space.

“Unambiguous Intracellular Localization and Quantification of a Potent Iridium Anticancer Compound by Correlative 3D Cryo X-Ray Imaging” DOI: 10.1002/anie.201911510

## BL13-XALOC

### THE AFRICAN FLY OF DEATH MIGHT ALSO HELP SAVING LIVES

For the first time, an international team of scientists recreated in the lab the molecule that allows the tsetse fly to feed on blood. It’s a powerful yet small anticoagulant with a unique and strong binding to thrombin, the key enzyme of the coagulation pathway. X-ray diffraction measurements at ALBA and ESRF were instrumental to understanding the structure and the mechanism of action of this molecule, which suggests it is also a promising platform for designing improved anticoagulant drugs.

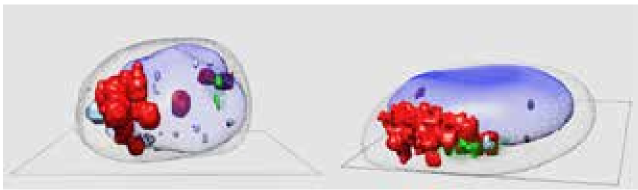



“Sulfotyrosine-Mediated Recognition of Human Thrombin by a Tsetse Fly Anticoagulant Mimics Physiological Substrates” DOI: 10.1016/j.chembiol.2020.10.002

## BL09-MISTRAL

### THE ROLE OF CCT PROTEIN IN THE CONTROL OF THE IMMUNE SYNAPSE FORMATION HAS BEEN IDENTIFIED

A study from the National Centre of Cardiovascular Investigations (CNIC), the Institute of Sanitary Investigation of the University Hospital La Princesa (IIS Princesa) and the National Centre for Biotechnology (CNB-CSIC) showed how the CCT protein, a cytosolic chaperonin, behaves in the reorganization of the cellular skeleton involved in the immune synapse. This interaction process between lymphocytes and antigen-presenting cells is necessary for the activation of lymphocytes and determines the immune response intensity.

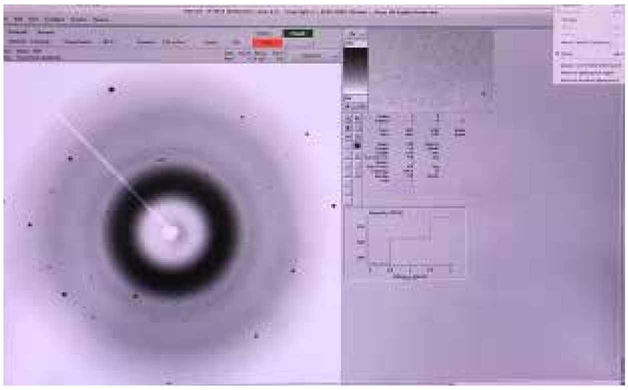


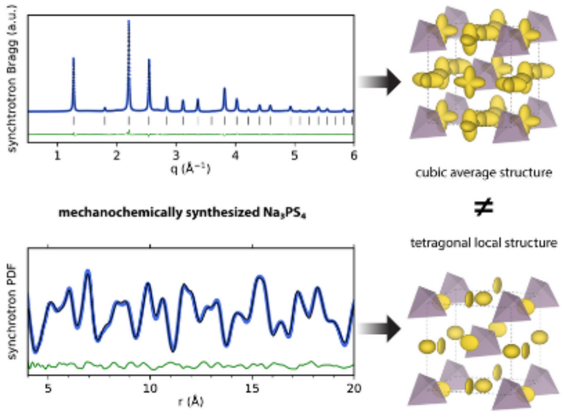
“The chaperonin CCT controls T cell receptor-driven 3D configuration of centrioles” DOI: 10.1126/sciadv.abb7242

## BL04-MSPD

### ITALIAN CERAMICS IN DEPTH UNDER ALBA'S LIGHT

Pottery glazes and decorations from Montelupo dating from the 14th to the 19th century were analyzed through a series of X-ray micro-diffraction measurements with synchrotron light. Researchers from the Catalan Institute of Classical Archaeology and the Autonomous University of Barcelona carried out the experiments, which will provide useful information to reconstruct the technological processes used to manufacture the ceramics.






"Under Pressure: Mechanochemical Effects on Structure and Ion Conduction in the Sodium-Ion Solid Electrolyte $Na_3PS_4$"
DOI: 10.1021/jacs.0c06668

## BL04-MSPD

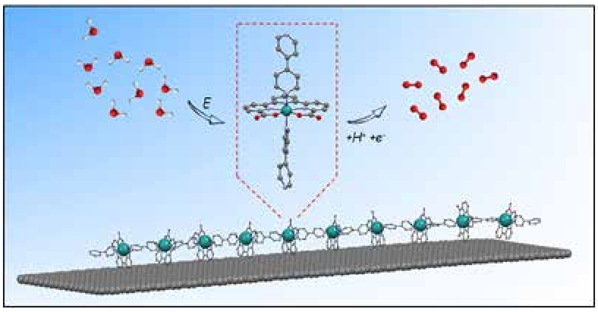
### THE EFFECTS OF PRESSURE ON THE ION TRANSPORT OF THE SODIUM-ION SOLID ELECTROLYTE $Na_3PS_4$

An international research team described the effects of pressure on the structure and ionic conductivity of the $Na_3PS_4$ solid electrolyte. Researchers used several techniques and carried out unique variable-pressure impedance spectroscopy experiments to investigate the response of ionic conduction to applied pressure. The results of this study are of high interest in the field of solid-state batteries as a next-generation technology for large-scale electrochemical energy storage to enable electric vehicles and renewable electricity production.

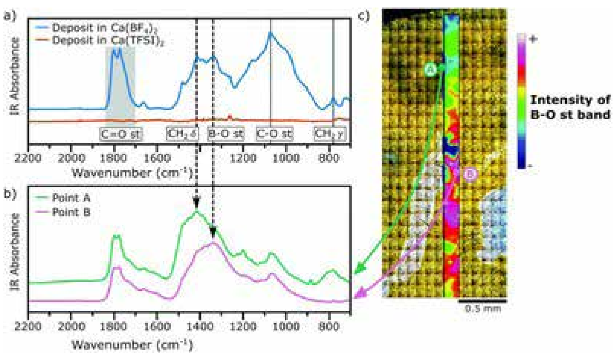
## BL11-NCD-SWEET

### OLIGOMERIC MATERIALS TO ENHANCE WATER SPLITTING

A new oligomeric, hybrid molecular material behaves as a rugged and powerful molecular electro-anode for the water oxidation reaction achieving unprecedented current densities in the whole range of pH, but especially at neutral pH. The catalyst is adsorbed to the graphitic surface via a novel aromatic C-H-π interaction – an anchoring strategy that has never been described for molecular catalysts until now and that can be extended to other catalytic reactions. The study was developed by the Institute of Chemical Research of Catalonia.



"Water oxidation electrocatalysis using ruthenium coordination oligomers adsorbed on multiwalled carbon nanotubes"
DOI: 10.1038/s41557-020-0548-7

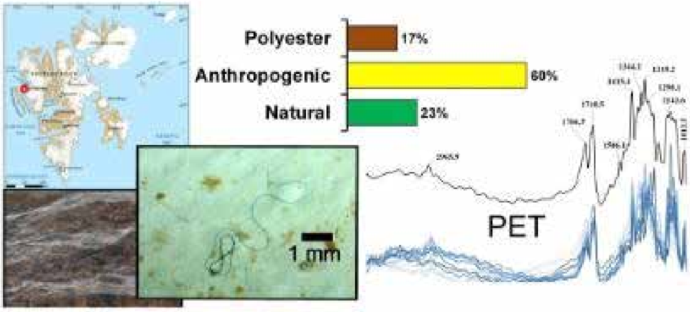



"Understanding the nature of the passivation layer enabling reversible calcium plating" DOI: 10.1039/D0EE02347G

## BL01-MIRAS

### BORATE-BASED PASSIVATION LAYERS ENABLE REVERSIBLE CALCIUM BATTERIES

This study combined experimental and theoretical approaches to study the passivation layers formed on calcium metal electrodes and their influence on the reversible operation of calcium-based batteries. The work is led by researchers from the Institute of Materials Science of Barcelona (ICMAB-CSIC), who have performed experiments at the MIRAS beamline at ALBA in a collaboration through an in-house research program.




## BL01-MIRAS

### MICROPLASTICS DETECTED FOR THE FIRST TIME IN A FRESHWATER LAKE IN THE ARCTIC

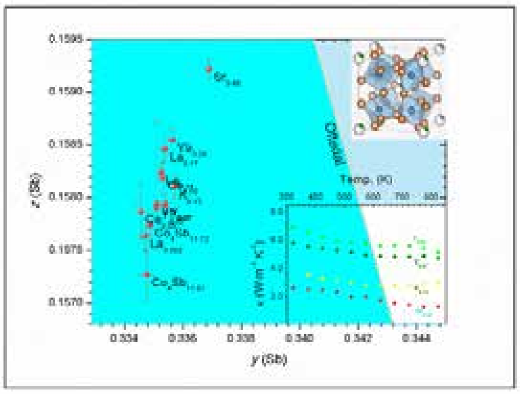
Researchers from Autonomous University of Madrid (UAM), the University of Alcalá (UAH), the Spanish Institute of Oceanography (IEO) and ALBA demonstrated for the first time the presence of microplastics in a freshwater lake in the Arctic.

“Fibers spreading worldwide: Microplastics and other anthropogenic litter in an Arctic freshwater lake”
DOI: 10.1016/j.scitotenv.2020.137904

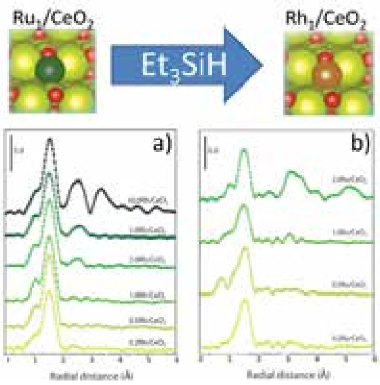
## BL04-MSPD

### IN SEARCH OF SKUTTERUDITES-BASED COMPOUNDS AS IMPROVED THERMOELECTRIC MATERIALS WITH SYNCHROTRON LIGHT

A research led by the Institute of Materials Science of Madrid (CSIC) allowed to understand a great deal of physical properties in relation to the thermoelectric performance of different prepared skutterudites, promising thermoelectric materials which can convert heat to electricity and vice versa. The synchrotron data was essential to investigate the structural details of the new skutterudite-type compounds.




“Unveiling the Correlation between the Crystalline Structure of M-Filled $CoSb_3$ (M = Y, K, Sr) Skutterudites and Their Thermoelectric Transport Properties”
DOI: 10.1002/adfm.202001651




“One-Pot Cooperation of Single-Atom Rh and Ru Solid Catalysts for a Selective Tandem Olefin Isomerization-Hydrosilylation Process” DOI: 10.1002/anie.201915255

## BL22-CLAESS

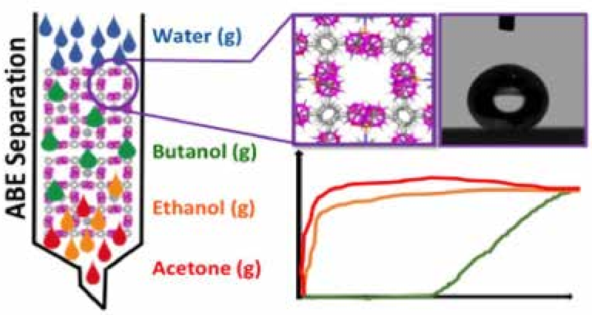
### OPTIMIZING THE PRODUCTION OF ORGANOSILANES WITH SINGLE-ATOM CATALYSIS

An international research team from Germany and Spain showed that the combination of ruthenium and rhodium single-atom catalysts stabilized at the surface of cerium dioxide creates a synergetic effect enabling a highly selective olefin isomerization-hydrosilylation tandem reaction. The process is highly relevant from an industrial point of view considering that complex mixtures of olefins are used as starting materials for plastics, alongside straightforward catalyst recycling and reuse.

## BL13-XALOC & BL11-NCD-SWEET

### TOWARDS GREEN ENERGIES: NEW MATERIALS FOR BIOBUTANOL SEPARATION

Researchers from the Institute of Materials Science of Barcelona (ICMAB-CSIC) discovered a metallic organic framework (MOF) that allows the separation of butanol from acetone-butanol-ethanol mixtures that are extracted from the fermentation process of biomass feedstock, as part of the standard industrial process to produce biofuels. This new compound, mCB-MOF-1, shows promising results compared to other methodologies or other MOF materials.

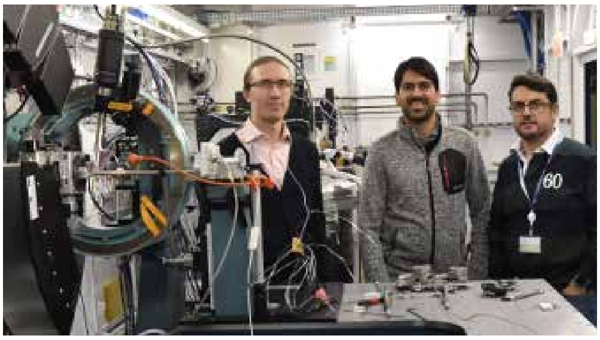



“A Highly Water Stable meta-carborane based Copper-Metal-Organic Framework for Efficient High-Temperature Butanol Separation” DOI: 10.1021/jacs.0c01008

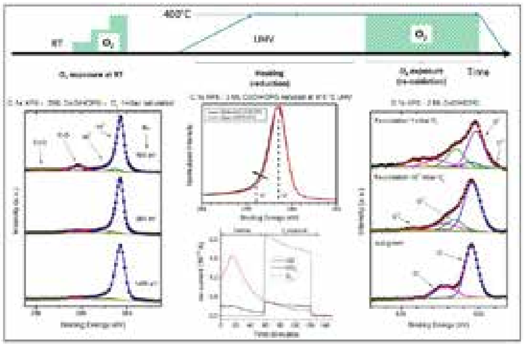
## BL04-MSPD

### UNDERSTANDING THE FREEZING/MELTING TRANSITION OF WATER IN NANO-CAVITIES, A PATH TOWARDS SOLIDIFIED NATURAL GAS

Samples of water-saturated activated carbon are confirmed to be efficient host materials for the formation of solidified natural gas. Researchers from the University of Alicante achieved a 100% water-to-methane hydrate conversion, which represents the most efficient storage of solidified natural gas to date. Measurements at ALBA allowed the study of the ice and hydrate formation and, for the first time, determined the structure ice takes when confined water freezes.



“Freezing/melting of water in the confined nanospace of carbon materials: Effect of an external stimulus”
DOI: 10.1016/j.carbon.2019.10.081



“In-situ study of the carbon gasification reaction of highly oriented pyrolytic graphite promoted by cobalt oxides and the novel nanostructures appeared after reaction”
DOI: 10.1016/j.carbon.2019.11.030

## BL24-CIRCE-NAPP

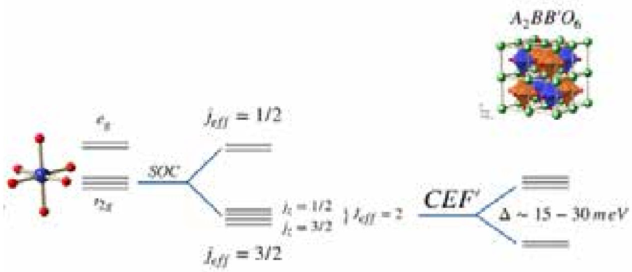
### NANOPATTERNING OF HIGHLY ORIENTED PYROLYTIC GRAPHITE (HOPG) AT LOWER TEMPERATURES

An international research team demonstrated the oxidation effect of HOPG at room temperature by the deposition of an ultra-thin layer of cobalt monoxide (CoO). The formation of carbon defects reveals a weakening of the C-C sigma bonds, facilitating the carbon gasification reaction catalyzed by CoO at lower temperatures than using typical metallic nanoparticles. This fact opens the door to a more comprehensible and efficient graphite and graphene nanopatterning for multiple applications.

## BL04-MSPD

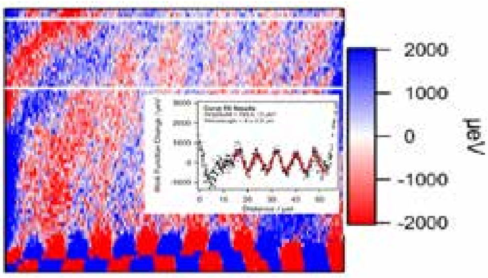
### SYNCHROTRON LIGHT TO DETERMINE STRUCTURAL TRANSITION IN DOUBLE PEROVSKITES

A study from McMaster University, Institut Laue Langevin, Oak Ridge Laboratory, University of Toronto and ALBA has shown that double perovskite materials based on osmium, display octupolar order at low temperatures. This provides the first comprehensive framework for understanding how such an octupolar phase might be stabilized and identified in d-electron double perovskite materials.




“Octupolar versus Néel Order in Cubic 5d2 Double Perovskites”
DOI: 10.1103/PhysRevLett.124.087206

# ELECTRONIC AND MAGNETIC STRUCTURE OF MATTER




“On the Promotion of Catalytic Reactions by Surface Acoustic Waves” DOI: 10.1002/anie.202005883

## BL24-CIRCE-PEEM

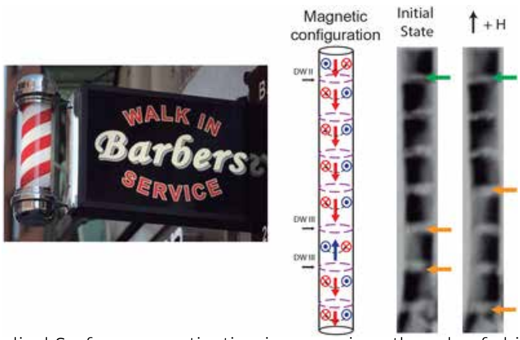
### HOW SURFACE ACOUSTIC WAVES CAN ENHANCE CATALYTIC ACTIVITY

An international team of researchers studied the mechanism by which surface acoustic waves (SAW) enhance catalytic activity. They were able for the first time to measure the effect of SAW on the electronic structure of a Pt model catalyst and achieved a remarkable precision with a new experimental setup at the CIRCE beamline.

## BL24-CIRCE-PEEM & BL09-MISTRAL

### "NANO-BARBER POLES": HELICAL SURFACE MAGNETIZATION IN NANOWIRES

A study fruit of a collaboration between Spanish research institutions showed that cylindrical nanowires have at the center a magnetization aligned with the axis of the wire and at the surface a magnetization that describes helical lines like the barber poles'. The helicity provides chirality to the magnetic configuration, and they found that two adjacent magnetic domains having opposite chirality are more difficult to move that two adjacent domains with the same chirality. This result evidences the role of the chirality in the dynamics of domain walls might be used as a practical variable for magnetic data storage.

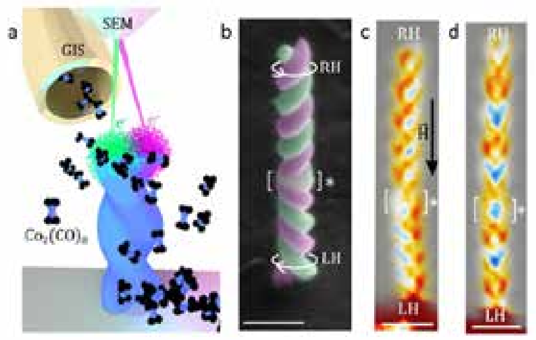



"Helical Surface magnetization in nanowires: the role of chirality"
DOI: 10.1039/D0NR05424K

## BL09-MISTRAL

### ARTIFICIAL DOUBLE-HELIX FOR GEOMETRICAL CONTROL OF MAGNETIC CHIRALITY

The imprinting of complex 3D chirality at the nanoscale was demonstrated. The results prove it is possible to control magnetic configuration with geometrical morphologies displaying 3D chirality and open a new avenue on applied nanomagnetism. The research was the result of a multiple collaboration of scientists from the Cambridge, Glasgow and Zaragoza Universities, the ALBA Synchrotron and the Lawrence Berkeley Laboratory.

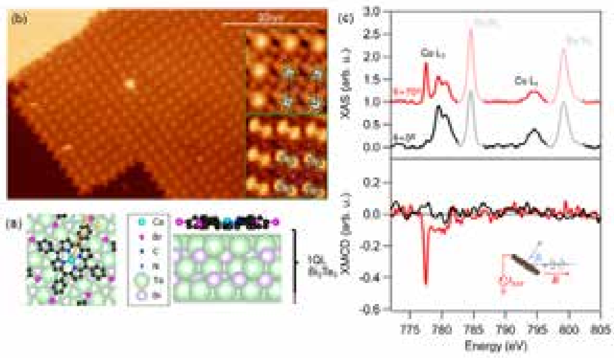



"Artificial double-helix for geometrical control of magnetic chirality" DOI: 10.1021/acsnano.0c00720

## BL29-BOREAS

### MOLECULES WITH A SPIN ON A TOPOLOGICAL INSULATOR SURFACE: A HYBRID APPROACH TO MAGNETIC TOPOLOGICAL STATES OF MATTER

The properties of topological insulators are mostly dominated by their peculiar topological surface electronic states. Interfacing them with magnetic materials and harnessing their interactions can give rise to interesting quantum and topological phenomena that have inspired novel spintronic applications. Led by researchers from the ICN2, an international team with collaborators from CFM-San Sebastian, ETH Zurich, ISM-Trieste and the ALBA Synchrotron, demonstrated that it is possible to balance electronic and magnetic interactions between single magnetic ions and topological surface states by coordinating the ions with different organic ligands, leading to possible new routes to manipulate the electron spin at the interface with a topological insulator.

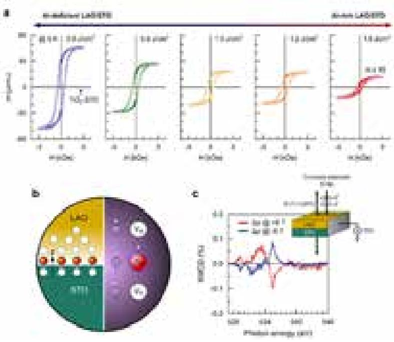



"Molecular Approach for Engineering Interfacial Interactions in Magnetic/Topological Insulator Heterostructures"
DOI: 10.1021/acsnano.0c02498

## BL29-BOREAS

### UNEXPECTED PHYSICS IN COMPLEX OXIDE INTERFACES: EMERGENCE OF MAGNETIC ORDERING TUNED BY DEFECTS

An international team of researchers discovered that the B-site cation stoichiometry is crucial for the creation and control of the magnetism at the interface between $ABO_3$-perovskite oxides. The findings present a new perspective for the understanding of interfacial magnetism, with potential applications in spin-based energy such as low-energy consumption electronics.

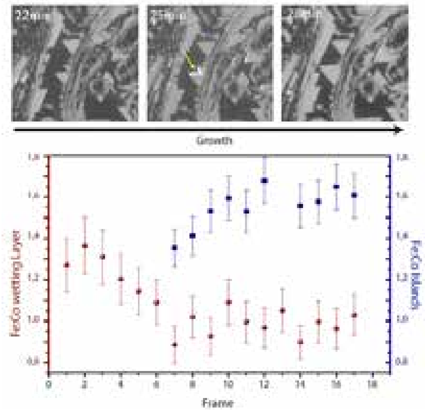


"The emergence of magnetic ordering at complex oxide interfaces tuned by defects" DOI: 10.1038/s41467-020-17377-0

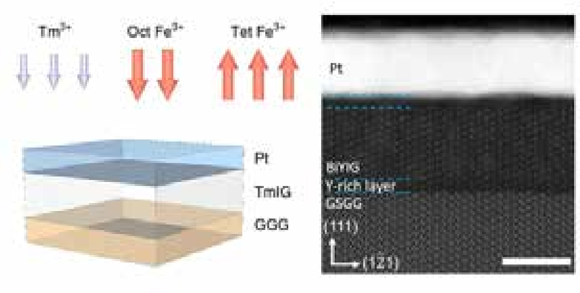
## BL24-CIRCE-PEEM

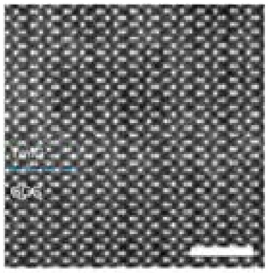
### FOLLOWING OXIDE THIN FILM GROWTH IN REAL SPACE AND TIME

Researchers from the Complutense University of Madrid, the Institute of Ceramics and Glass (ICV-CSIC), the Institute of Physical Chemistry Rocasolano and ALBA studied the dynamic changes in the distribution of cobalt and iron atoms during the growth of mixed cobalt-iron oxides on a metallic substrate. This is the first time that growth at such high temperatures (1.000 ºC) has been followed in real space and real time with synchrotron radiation, providing valuable chemical information.




“A real-time XAS PEEM study of the growth of cobalt iron oxide on Ru(0001)” DOI: 10.1063/1.5140886



“Interfacial Dzyaloshinskii-Moriya Interaction Arising from Rare-Earth Orbital Magnetism in Insulating Magnetic Oxides” DOI: 10.1038/s41467-020-14924-7

## BL29-BOREAS

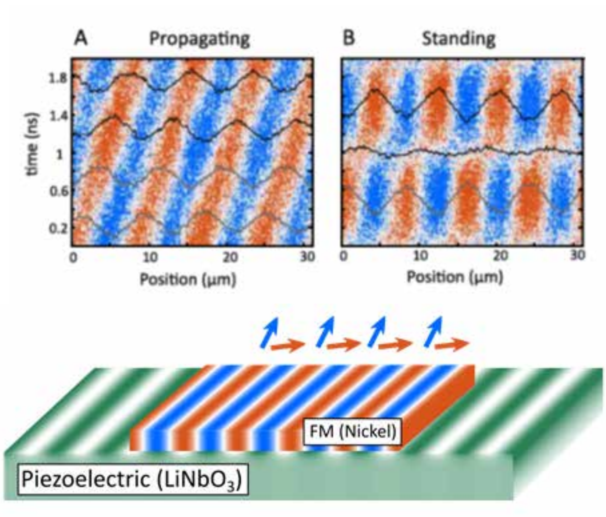
### ENGINEERING INTRINSIC INTERFACIAL DZYALOSHINSKII-MORIYA INTERACTION FROM RARE-EARTH ORBITAL MAGNETISM IN INSULATING MAGNETIC OXIDES

A chiral exchange interaction denominated Dzyaloshinskii-Moriya interaction (DMI) is responsible for exotic chiral and topological magnetic states such as spin spirals and skyrmions. A study led by researchers from the Department of Materials Science and Engineering of the Massachusetts Institute of Technology (US) revealed that, in perpendicularly magnetized iron garnets, rare-earth orbital magnetism gives rise to an intrinsic spin-orbit coupling generating interfacial DMI at mirror symmetry-breaking interfaces.

## BL24-CIRCE-PEEM

### ACOUSTIC SPIN WAVES: TOWARDS A NEW PARADIGM OF ON-CHIP COMMUNICATION

For the first time researchers directly observed sound-driven spin waves (magnetoacoustic waves) and revealed their nature. The results show that these magnetization waves can travel longer distances (up to centimeters) and have larger amplitudes than the commonly known spin waves. The study was carried out by researchers from the University of Barcelona (UB), the Institute of Materials Science of Barcelona (ICMAB-CSIC), and the ALBA Synchrotron, in collaboration with the Paul-Drude-Institut in Berlin.




Generation and imaging of magnetoacoustic waves over millimeter distances” DOI: 10.1103/PhysRevLett.124.137202

# INDUSTRY

**Marta Ávila, Bárbara Machado, Alejandro Sánchez and Núria Valls**
**Industrial Liaison Office, industrialoffice@cells.es**

The Industrial Liaison Office (ILO) of the ALBA Synchrotron acts as a single contact point for those companies and institutions willing to use the fast, confidential and full service advantages of the industrial access. The year 2020, for obvious reasons, has represented a challenge and almost all the industrial experiments have been performed by mail-in or by remote connection, given the mobility restrictions. Thanks to the efforts performed by the ALBA scientists in the implementation of these measurements, the industrial beamtime has remained at a high level, specially taking into account that the total beamtime delivered in 2020 was approximately 20% lower than the initially expected value. Most of the beamlines hosted industrial experiments and 7 new companies discovered the usefulness of the synchrotron techniques at ALBA, hence increasing our portfolio of industrial users to a total of 56 companies and institutions. Around 50% of the industrial experiments were related to pharmaceutical applications, while the rest concerned chemical, nanotechnological, batteries, textile and cosmetic applications. Additionally, several other services related to the supporting laboratories and divisions at ALBA were provided, such as metrology of mirrors, sophisticate electronic equipment, technical support, trainings and consultancy services to other synchrotrons, facilities and companies.

One of the main objectives of the ILO is to engage with national and international companies to use the characterization and analytical services available at ALBA. To that end, the ILO participates in fairs and related industrial workshops and organizes visits and meetings at our facility to increase awareness of the synchrotron techniques amongst the industrial community, which are often less experienced on this type of technologies. Most of these activities had usually been carried out face to face, however the ILO adapted very quickly to the new circumstances by moving outreach activities online. Thus the regular annual industrial workshop of May was transformed into a webinar on Cosmetics remotely organized together with the deep-tech cluster Secpho. Active outreach activities were carried out by participating in online B2B meetings focused on water sustainability, food and food processing and on manufacture of batteries and batteries for electrical vehicles. Finally, a webinar was organized to foster the industry's access to ALBA by using the support of the H2020 CALIPSOplus project through the tailor-made for SMEs trans-national access (TamaTA). This project allows SMEs to use the analytical tools of the main European synchrotrons for free. Several companies showed interest in the project after the webinar, and just a few weeks later some of these SMEs had already benefited from the TamaTA funds. Additionally, a publication was also issued in the Journal of Pure and Applied Optics entitled "The ALBA Synchrotron: An invaluable tool for science and innovation".

Another mission of the ILO is to reinforce the technology transfer of the knowledge generated at ALBA. For this purpose, the ILO produced a brochure about our technologies' offers addressed to the industry as a supplier and presented it at the Foro Transfiere fair held in Málaga in February, and produced another brochure showing the opportunities of ALBA's invitations to tender at the initiative of the INEUSTAR association, which disseminated it among its industrial partners and on the web. The portfolio of industrial services and activities provided by ALBA were presented to the Center for Industrial and Technology Development (CDTI), a Spanish institution in close contact with the industrial ecosystem. Additionally, an innovative development relating to a high-frequency, high-voltage feedthrough was registered as a patent. Furthermore, a study performed by the CSIL (Centre for Industrial

Studies), under the H2020 RI-PATHS (www.ri-paths.eu) project, correlated patent databases with publications from ALBA academic scientific users and ALBA's own and found that more than 350 patents cited directly or indirectly those publications, which is another indicator of the innovation impact arising from ALBA (www.albasynchrotron.es/en/industry/csil-alba_report_final.pdf).

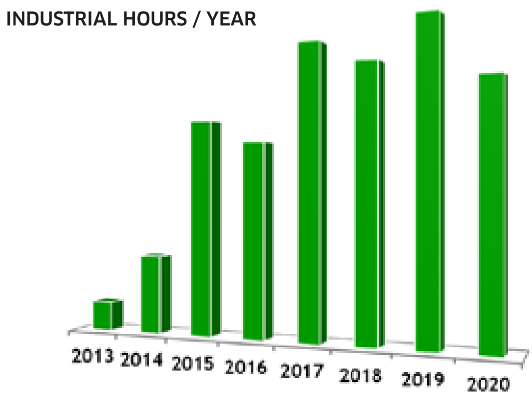



**Figure 10.** Industrial beamtime hours per year in arbitrary units.


**Figure 11.** Webinar to foster the industry's access to ALBA (TamaTA) with the support of the H2020 CALIPSOplus project.

# Helix BioStructures performs first post-lockdown COVID-19 measurements at ALBA

During the COVID-19 pandemic, it has been of paramount importance to continue the work at research facilities such as ALBA, especially given the demand for services that could shed light on the possible structure of proteins involved in COVID-19. The facilities at ALBA were aware of the inherent responsibility to serve the societal needs and its commitment to research and innovation to stay open and available despite the ongoing pandemic. Synchrotron beamlines are widely used to overcome structural biology challenges within healthcare, and COVID-19 was certainly no exception. The ALBA staff crafted a careful re-opening in order to ensure continued safety in the hope that COVID-related studies would be utilizing ALBA resources. While establishing new safety precautions and operating the facility with essential personnel was challenging,  it simply reflected the commitment to scientific discovery at ALBA.

Helix BioStructures, a contract research organization based in the US, was the first user with COVID-19 related samples measured at ALBA on 22 April using the XALOC beamline. Helix Biostructures is an early drug discovery services company offering specialized services to pharmaceutical companies around the world thanks to a talented team of scientists. One of their main services is X-ray crystallography, which can be a valuable tool for drug design and development. Collecting data at ALBA was its CEO and cofounder Josh Carter. The samples he was examining were part of an attempt to further elucidate the atomic structure of protein targets involved in COVID-19. The aim of the project was to determine the most effective means of blocking or inhibiting critical paths that lead to SARS-CoV-2 infection and illness. By obtaining structural insight into atomic interactions between specific viral protein(s) and new potential therapeutics, it stands to expedite the drug design process and bring possible drugs to market in a shorter period of time. The importance of these projects strenghtens the case for ALBA facilities to remain open and available to researchers and scientists to contend with new and emerging infectious diseases.

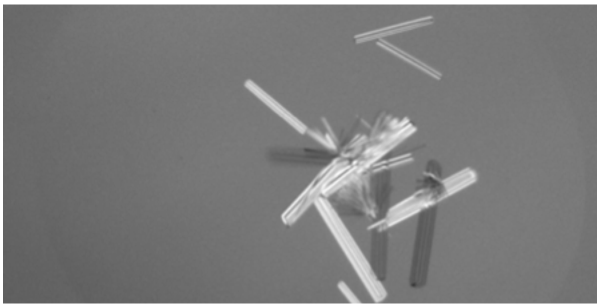


**Figure 12.** Crystallographic samples from Helix Biostructures.


**Figure 13.** Experimental hutch of XALOC beamline.

Helix Biostructures was able to send samples internationally despite the uncertainty and unexpected issues concerning new government rules and restrictions to limit the spread of COVID-19. Work undertaken by ALBA staff to provide beamtime for such sensitive samples all the while navigating non-standard conditions earned the praise and appreciation of those early users following reopening. “I want to express my sincere appreciation to you and your staff that given your efforts to keep the facility open and allow this data collection to happen is remarkable. I truly appreciate it and will do what I can to advertise ALBA as a premier synchrotron facility” said Josh Carter CEO of Helix Biostructures, praising the work that the ALBA staff was able to provide under the extraordinary circumstances.

CLARITY. INTEGRITY. PROFESSIONALISM.
HELIX BIOSTRUCTURES

# ACCELERATORS

Francis Pérez, Head of the Accelerators Division

2020 was the year of COVID, but nonetheless a year of progress for the Accelerators' team. Progresses were mainly related to the installation of equipment for the new beamlines, but also to improvements to the day-to-day operation, and new developments for the future.

Starting with the new beamlines, and after the successful commissioning of the elliptical undulator for the LOREA beamline during the previous year, the opening of the front-end and delivery of the first photons to start the beamline commissioning was achieved at the end of July.

The installation of the front-end for the NOTOS beamline was followed by its conditioning during September, having it ready to start the commissioning of the beamline, which is expected to be completed by February 2021.

As for the XAIRA beamline, the installation of the front-end was performed in August, the successful Site Acceptance Test of the in-vacuum undulator was performed in the ALBA magnetic lab during autumn, and it was installed in the storage ring in late December, as shown in the picture.

In addition, several contracts for the MINERVA and FAXTOR beamlines have been placed: the front-ends for both beamlines and, in particular, the contract for a novel in-vacuum (2.5T, 5-pole, 5mm gap) wiggler, which is a challenging device that will provide high flux with a beam size optimized for the FAXTOR experiments.

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

One development worth to mention is the implementation and commissioning of the so-called Trim Coils correction in the bending magnets, which is now operational for user operation and is

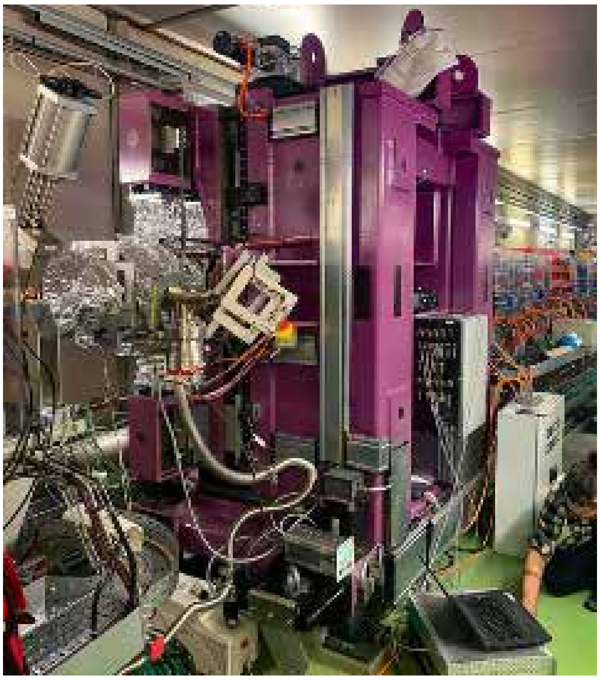


**Figure 14.** XAIRA's in-vacuum undulator installed in the Storage Ring.

able to locally correct quadrupolar errors at the source points, reducing the beta beating error, which is a measure of the asymmetry of the accelerator, resulting in a more reliable and stable beam source size at the emission points for the beamlines. Details of the system are given in the technical note that follows.

Also, in order to improve our diagnostics of the electron beam, two new systems have been installed in the accelerators. An Integrating Current Transformer (ICT) has been installed in order to have a redundant measurement of the beam current. It is a novel device, installed for the first time in a storage ring, which has been implemented at ALBA in close collaboration with the company that has developed it. And a new synchrotron radiation pin-hole diagnostics system has been installed in order to have a second and more precise measurement of the transversal beam size. Both systems are expected to become fully operational during 2021.

In terms of development for the future, the upgrade of ALBA to a 4th generation light source,

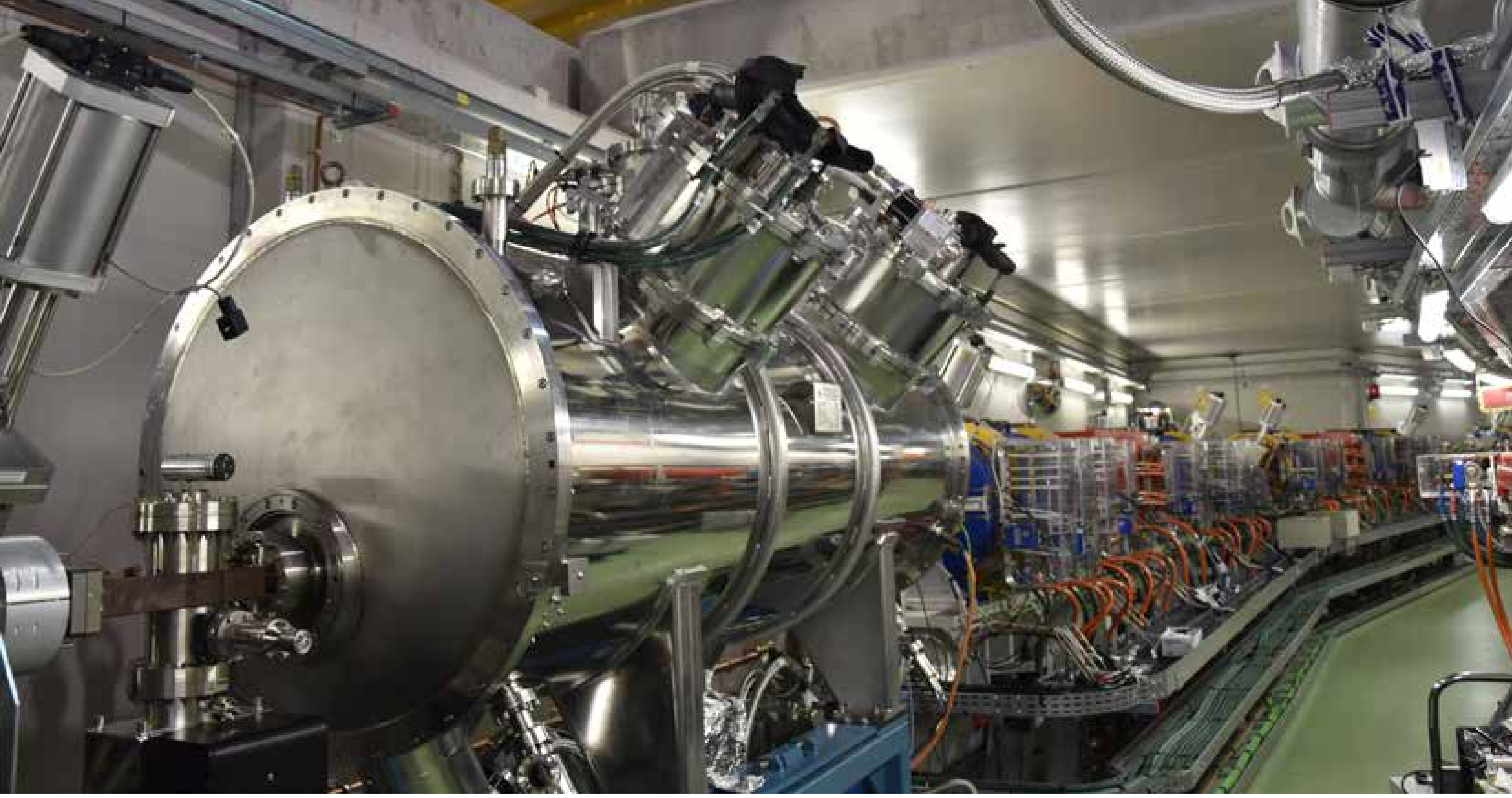


**Figure 15.** ALBA Storage Ring, showing at the forefront the superconducting wiggler.

ALBA II, has started. The beam dynamics group has already designed several possible alternatives for the upgrade, in all cases improving the emittance by a factor of around 30, and the brilliance of the photon beam from the undulators up to 80 times. Continuous progress is being made with the aim of having a first conceptual proposal for the storage ring upgrade by mid 2021.

Also for the future of ALBA and ALBA II, we are developing a 3rd harmonic RF system which shall improve the beam lifetime of the storage ring by a factor of around three. During this year, the prototype of the RF cavity is being constructed, a tender for the solid state power amplifier at 1.5GHz has been launched, and the development of the digital LLRF system has started.

In addition, we have been actively involved in several international collaborations in accelerators R&D, including several H2020 projects, such as the Compact Light Source XLS collaboration, and the ARIES collaboration for the development of new accelerator technologies. We have also participated in research activities related to the FCC, the Future Circular Collider project from CERN, with the study of High Temperature Superconductors for the vacuum beam screen, and the development of the Speckle technique for beam size measurements. We are also involved in the project BEATS, which is a European contribution of a hard X-ray imaging beamline for the Middle East Synchrotron SESAME, located in Jordan. And a contract was signed with the Canadian Light Source to implement the ALBA Low Level RF (LLRF) digital system in their accelerators, starting with the LLRF of the booster, which will be commissioned by the end of 2021.

All this was achieved in the strange situation in which the COVID-19 pandemic put all of us. The collaborations mentioned earlier have been conducted without travelling, only by using teleconferencing tools to hold the meetings and even sharing experimental results remotely. Installations have been done with the minimum people required on site, sometimes with remote support from the experts working at home. And operation, which due to the March lockdown has been reduced by 20% of the expected operational hours, has been performed with extra safety procedures to ensure the health of the staff who had to operate from the control room. The commitment of the operators and floor coordinators, of the rest of the accelerator division, and of the support division personnel has, despite the difficulties, resulted in an excellent operation of the accelerators, delivering an outstanding 98,2% of the time committed to the users of the ALBA facility.

# Upgrade of the ALBA Storage Ring optics correction with the dipole trim coils

Gabriele Benedetti, Beam Physics Section

In 2020 the dipole trim coils were equipped with 32 power supplies that have allowed individual correction of the gradient errors and a more reliable correction of the electron beam size to the optimum values for the beamlines.

Any small gradient field error in the magnets of a storage ring produces a distortion of the accelerator beam optics, i.e. of the electron beam size along the ring with respect to the design values, and it can affect the performances of the accelerator (electron beam lifetime, flux and brilliance of the synchrotron radiation…). In a real accelerator, sources of magnetic errors are unavoidable and arise mainly from unknown mechanical errors, due to the machining of the iron poles and to the assembly of the magnets, and from miscalibrations of the power supplies.

The ALBA ring comprises 112 quadrupoles, with individual power supplies, and 32 combined gradient dipoles powered in series but equipped with trim coils that allow for small individual adjustments. We know, from magnetic measurements, carried out in our laboratory before the installation, that our magnets have random gradient errors within 0.3% of their design value [1]. This translates to a maximum beam size, distortion of 10% with respect to the design value (Fig. 16), which must be corrected in order to recover the design beam sizes, especially at the photon source points of the experiment beamlines.

The beam-based technique to detect and correct the errors in the 144 magnets of the ALBA storage ring relies on the analysis of the measured orbit response matrix and it is performed with the code LOCO [2]. The orbit response matrix returns the orbit variation at the 120 beam position monitors, when the beam is given a kick by each one of the 88 steering magnets distributed all along the ring (Fig. 17). There are hence two measured matrices,

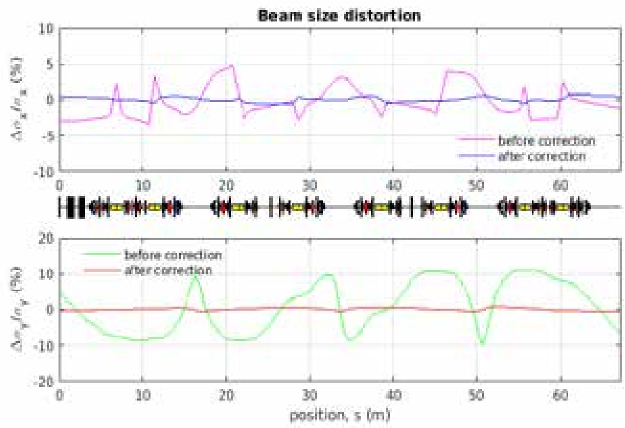



**Figure 16.** The relative distortion of the horizontal (top) and vertical (bottom) electron beam sizes in the ALBA storage ring is reduced from up to 10% to less than 1% after the gradient correction with the quadrupoles and the dipole trim coils. In the middle, a diagram of the magnetic lattice is drawn.

one for the horizontal and one for the vertical orbit changes, with 120 x 88 = 10560 elements, where each element has information concerning all the 144 real magnet gradients of the storage ring. LOCO fits the measured response matrix by adjusting the gradients of the lattice model in order to reproduce the measurement. The gradient variations found by the analysis are the focusing errors of the magnets. Therefore, the trick to recover the design optics consists in compensating

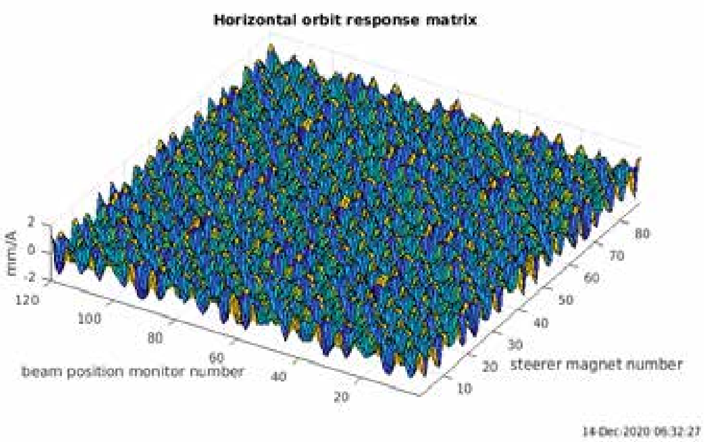



**Figure 17.** ALBA orbit response matrix of 120 x 88 = 10560 elements to be analysed with the LOCO code to find the magnetic gradient errors.

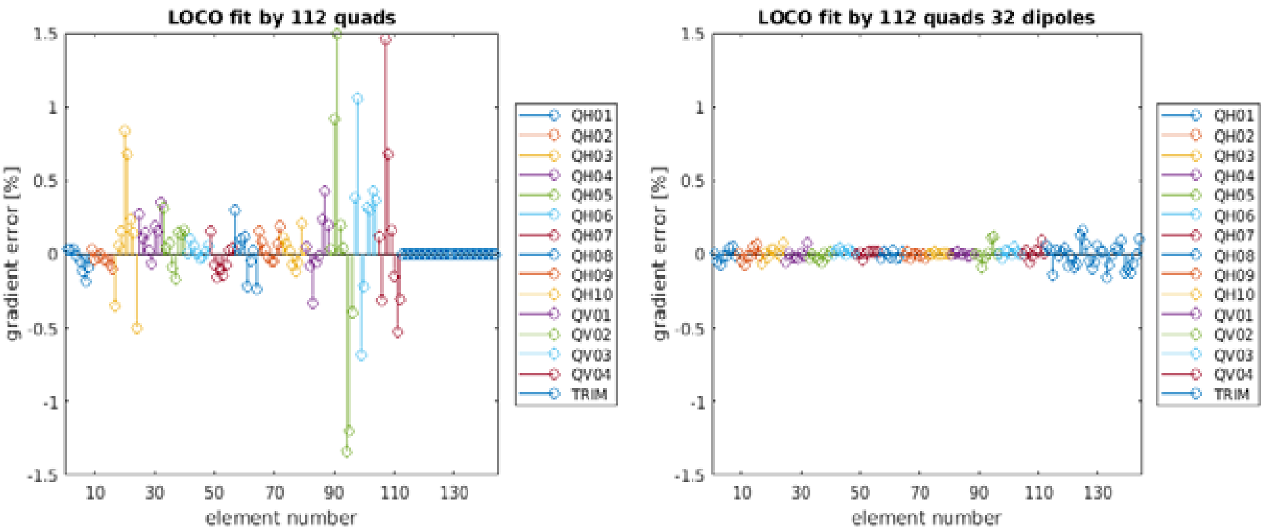



**Figure 18.** The effective gradient errors found in the 112 quadrupoles by LOCO (left), when the dipole trim coils were not available, were up to 6 times higher, 1.5%, than the realistic gradient errors, within 0.25%, found and corrected in 2020 adding the 32 individual dipole trim coils (right).

the current set-points of each magnet with the values found by LOCO [3, 4].

Before 2020, local correction of the 32 combined dipole errors was not possible because the trim coils were not equipped with power supplies, and we could only use the 112 quadrupoles to correct on average the optics distortion given by all the magnets. As a consequence, the set-points changes applied to the quadrupoles were up to 6 times (Fig. 18-left) higher than the real local errors and the reliability of the model optics was affected by this overuse of the quadrupole correction. In 2020, the dipole trim coils were equipped with 32 power supplies and eventually it was possible to apply local correction of all the magnetic gradient errors with much smaller and realistic values in each magnet.

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# ENGINEERING

Joan Casas, Head of the Engineering Division

The Engineering Division comprises a team of 34 multidisciplinary engineers and technicians who give support to the other divisions in ALBA, and maintain and upgrade the general infrastructures and services of the facility.

One of our two sections is devoted to civil engineering projects (construction and technical services and supplies such as electric power supply, compressed air, technical gases and 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 the accelerator, as well as support to operation in vacuum, survey & alignment and cryogenics. Moreover, it provides beamline engineers to the Experiments Division. During the operational phase, these engineers support the beamline with plenty of projects for little upgrades. During 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.

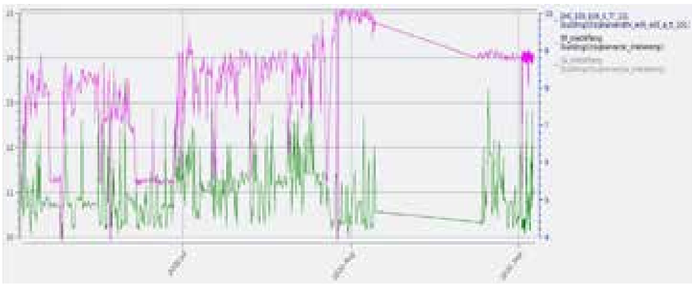
Finally, the workshop and logistics group is an essential element in all manufacturing and installation operations, including most of the technical installations upgrades hereafter pointed out.

## FACILITY UPGRADES

Some of the facility upgrades planned and designed during 2019 have progressed to the implementation phase at different levels. The conditioning of a specific area to host the new Microscopy Center has led to a call for tenders that will allow the start of works during the first quarter of 2021. The civil engineering works for the expansion of the electronics laboratory have been also completed, as well as some other minor upgrades (related to offices and meeting rooms). This has been achieved despite the singular conditions during most of the year in which the pandemic situation has led to a prioritization of teleworking, and has raised serious difficulties for on-site work.

These difficulties have also been overcome to complete a couple of upgrades on technical installations that are very relevant for the normal operation of the facility. On one side, we have completed the upgrade of the de-ionized water cooling system through the replacement of the 3-way mixing valve in the common return. This upgrade was done during the summer shutdown and was commissioned to be operative already upon restart of operations in September. Results achieved with this upgrade have been stunning, which is relevant not only because the thermal stability problem is solved, but also because it constitutes an experimental validation of the hydraulic model built for this system during years. This modelisation was the fundamental tool used to diagnose the root cause of the problems and led to the implemented solution.

On the other side, the challenging upgrade of the compressed air system has also been a success. This project has been organized in two



The plot depicts the excellent evolution of the regulated temperature around 24ºC, during the first hours of operation of the new 3-way mixing valve. Notice the contrast with the poor regulation before the upgrade (SR_InletW/Temp). Source: Accelerators division.

**Figure 19.** De-ionized water temperature vs. time.

phases. In 2020, the first phase consisting in the replacement of the dryers was completed. The old passive dryers will remain installed as a system redundant with the new active dryers, which include a pre-cooling stage. This upgrade will dramatically reduce the loss of pressure coming from the compressors,  making the whole system much more efficient. The new dryers went into operation after the summer shutdown and have been working flawlessly since then. Losses have been dramatically reduced up to the point that one of the two existing compressors remains now stopped as a hot redundancy element. Besides the direct benefit of the upgrade, the new dryers have been located in a different area in the service gallery, clearing enough precious space in the technical building for the further installation of a third compressor during 2021.

Other important upgrades have been done on Phase I beamlines: in MSPD (new Mythen detectors integration), NCD (sample heater upgrade and design of a new sample heater), XALOC (sample jet), CLAESS (electrochemical cell interface), CIRCE (NAPP sample parking design) and BOREAS (portable high-temperature magnet, cleaving chamber and glove box).

## PROJECTS FOR THE NEW BEAMLINES

During 2020, a lot of activity was deployed on the new beamlines under construction. In LOREA the components inside the optical hutch were installed and commissioned (M1, fluorescent screen monitor and a collimator), and the in-house developed monochromator installation progressed up to the completion of the mechanical assembly, as well as M3 and the Kirkpatrick-Baez mirror mechanics. In addition to this, we also started the assembly and installation of the supports and stages for the end-station.

In NOTOS, the development of the XAS station moved from the design to the manufacturing phase, and the design of the end-station metrology table started. Moreover, the control hutch was installed, as well as all the technical services such us compressed air and cooling. Finally, the maintenance (reconditioning) of all the instrumentation from ESRF was completed. Some of the complementary instruments have been already installed like the whitebeam attenuator and M1 mirror and its downstream slits and fluorescence screen monitors.

In XAIRA, both design and manufacture made significant progress in relation to the end-station, the backbone and cryogenics (the horizontal prefocusing mirror, the monochromator and the Kirkpatrick-Baez mirror mechanics and optics went into production). The call for tender for the acquisition of the required cryocooler was launched, the contract was awarded and the manufacture started. The front-end and the insertion device (in-vacuum undulator) were also installed in 2020. Besides, we received a prototype of the bearing omega stage for the diffractometer, to be used for testing purposes. The final in-house designs of the fluorescence screen monitors were completed.

As for FAXTOR, there was a lot of activity towards the definition and generation of specifications for the backbone, especially for the double multilayer monochromator. We also continued the procurement process of the front-end and the multi-pole wiggler insertion device.

Finally, in 2020 we started the construction of a new beamline for the European Space Agency. The new beamline will be used in a key manufacturing step of the assembly of mirror modules for the orbital X-ray telescope ATHENA. Our beamline, named MINERVA (the name given to Athena by the Romans) will allow the individual positioning of the mirror modules to build up a large optical element, by using X-rays generated at our accelerator at the actual operating energy of the final instrument. The schedule for the development and construction of this beamline is very tight, and already in 2020, we completed all the works for the Preliminary Design Review (not only the formal meeting with the European Space Agency but also the internal Preliminary Design Review for the main components such as the monochromator, the sample chamber, the detector tower and the feedback system). During 2020, we also tendered and awarded the contract for the front-end, and launched an invitation to tender for the radio-protection optical hutch.

# The European Space Agency (ESA) beamline at ALBA

Carles Colldelram, Head of the Transversal Section (Engineering Division)

An important achievement of 2020 was the start of a new beamline at ALBA, MINERVA, funded by the European Space Agency (ESA) and the Spanish Ministry of Science and Innovation. This new beamline will be used for the characterization of the main mirror components of the space X-ray telescope ATHENA mission (Advanced Telescope for High Energy Astrophysics) to be launched by the ESA in the early 2030s to detect high-energy X-rays from black holes or galaxy clusters. This telescope will include instrumentation to perform spatially-resolved X-ray spectroscopy and deep wide-field spectral imaging in the photon energy range from 0.2 keV to 12 keV with a performance greatly exceeding that offered by current X-ray observatories. The telescope includes an innovative Silicon Pore Optics Technology configured as a modified Wolter-Schwartzschield optics geometry with 12 m of focal length with an effective area of 1.4 $m^2$ at 1keV. This lens is composed of 15 concentric rings and filed by about 600 sub-systems called mirror modules (MMs). Individual MM, in turn, is also organized in a set of four stacks of 37 highly polished silicon wafer reflecting plates. The alignment of the 4 stacks constituting a singular MM is crucial to achieve the expected angular resolution of Athena. For that reason, a dedicated X-ray metrology facility is required for their assembly and characterization.

A suitable metrology source for the MM characterization are synchrotron light sources. Currently there is already a working beamline, XPBF 2.0 (BESSY II in Berlin). Characterization of one MM requires usually one day and Athena contains about 700 of them. For that reason, to boost the assembly process, ALBA has started the construction of MINERVA, a dedicated test beamline that will provide the necessary equipment to assemble and characterize each MM before being mounted on the telescope. MINERVA will be interoperable with XPBF 2.0 and will follow its design as close as possible. However, its construction is also an opportunity to explore new and different approaches to characterize the MMs.

Characterization of the mirrors requires a 1 keV X-ray beam source with a collimation better than 1 arcsecond rms. In order to cope with this, a bending magnet will be the light source at ALBA which will deliver 1013ph/s/0.1%BW at the selected working photon energy. The energy selection will be performed by a multilayer coated toroidal mirror. It deflects the beam horizontally inboard by 14 degrees, at the same time that it collimates the beam both vertically and horizontally resulting in a residual divergence of the beam of 3.3x1.9 $\mu rad^2$ rms.

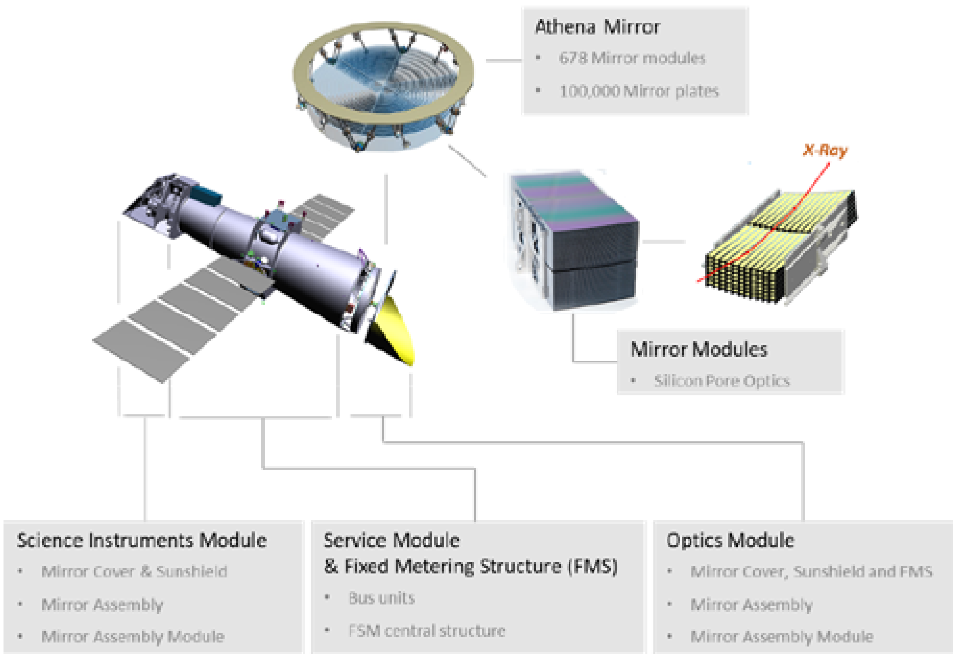



**Figure 20.** Athena telescope mirror optics concept.

The beamline optics design follows the telescope optics lay-out. The X-ray beam is reflected by the MM pointing at a 2D array detector placed 12m away from the mirror, where the focalization parameters are characterized. The mirror modules are mounted on a sample station where the collimated X-ray beam is deflected towards the detector tower to be characterized.

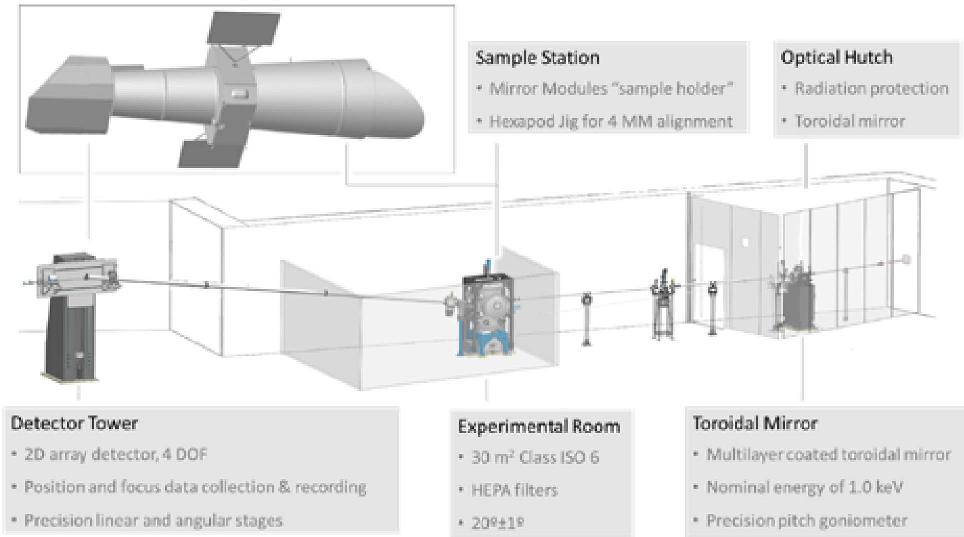



**Figure 21.** BL25 MINERVA optical lay-out.

The mirror modules must be assembled at a controlled temperature (20ºC±1ºC) in a clean environment. A clean room enclosure will be constructed, which will have an HVAC system equipped with EPA particle filters in order to reach ISO class 6 clean conditions. The total space is planned to be enough to allocate work areas for MM assembly and set up, for instance close to the sample vessel.

The monochromator will be based on a high-precision mechanics goniometer concept already proven at the MIRAS beamline. This mechanism performs the angular X-ray beam incidence pitch positioning with sub-microradian angular resolution and high stiffness reaching up to 192 Hz for the first resonance mode. The system is designed in a way that the mirror holder and surrounding elements are mounted on a single column. The stages perform the movement of the column decoupled from the chamber by means of a big bellow. The column acts as a standalone insert that is the base for all the mirror optics (the mirror itself, the mirror holder, the cooling pipes and the cooling and electrical feedthroughs).

The alignment of the four mirror modules (MM) is carried out using a Jig provided with three small hexapods. The three hexapods are responsible for the relative positioning of three out of four MMs, with respect to the fourth one, which remains as a reference. A large hexapod will then move the complete jig to align it with the beam, and a horizontal linear stage (ball spindle and ball linear guides motioned by a stepper motor) will move this large hexapod to perform faster and more precise scans (in the existing XPBF beamline in Berlin, the scans are carried out by the large hexapod, whose motion ranges make it non-standard). All these elements, the three small hexapods, the large hexapod and the linear stage will operate in vacuum.

The above described assembly (the jig, the three small hexapods, the large hexapod and the linear stage) is mounted on an in-vacuum base plate whose movement is driven from outside the chamber by a vertical stage. The vacuum chamber is fully decoupled of the sample positioning stages by means of welded bellows with robust columns holding the in-vacuum base plate. This air positioning vertical stage is also different from the original design, which was a rough pre-positioning stage made originally by means of lifting jacks, to a precision vertical table based on the ALBA skin concept design solution; concept that has been used in many other applications at ALBA.

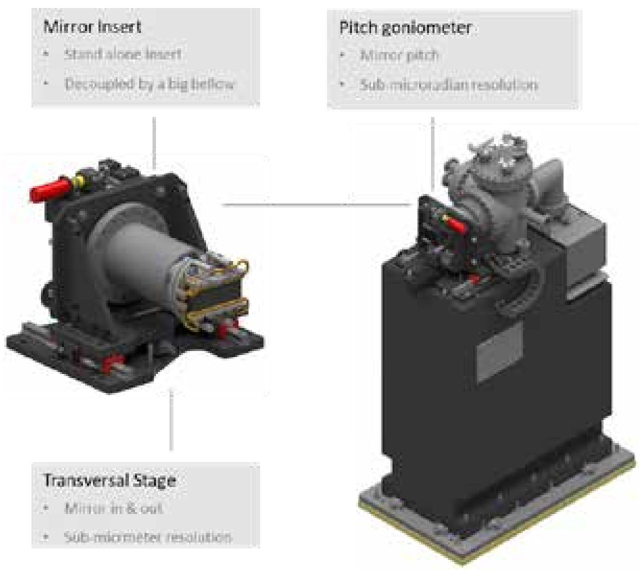



**Figure 22.** Toroidal multilayer mirror.

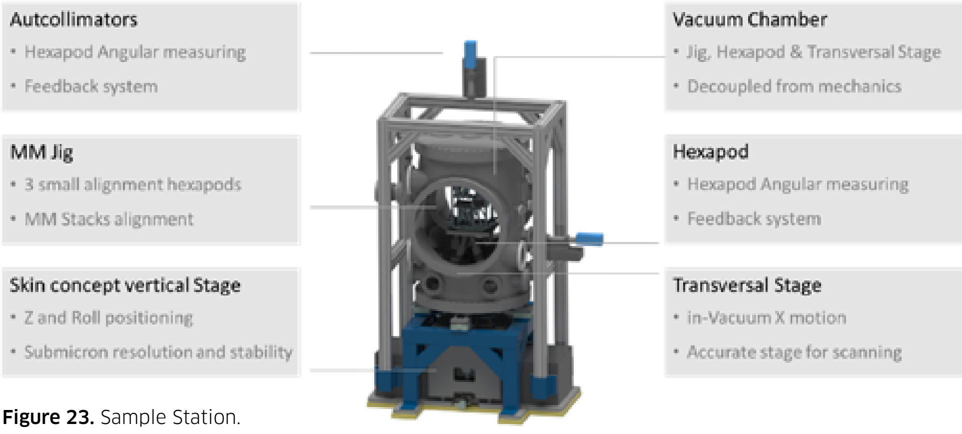



**Figure 23.** Sample Station.

This solution includes two vertical precision stages mounted at each side of the granite, for better mechanical and thermal stability. They include ball spindles and ball linear guides that accurately move a thick plate with a flexure shape on its top. With this configuration, synchronized motion allows vertical movement and a differential movement will perform a precision roll by allowing a small deformation on these flexures. This results in a very compact stage where two movements need the space of a single one around the granite, thus increasing stiffness. This stage configuration will also allow the vertical scanning with submicron linear resolution and high stability that has been proven in previous applications.

A metallic frame around the chamber includes two autocollimators that measure the 3 orientation angles of the main hexapod inside the vacuum chamber, providing the actual orientation for a control feedback loop. In addition, a laser tracker, placed so as to have sample and detector visibility, will also measure the absolute position of the hexapod top base plate, allowing accurate alignment between the sample and the detector at the tower.

The MM deflected beam is sent to the detector which is mounted on a 4-axis positioning system. The combination of these four axis allows to follow the beam, far from the sample, on a spherical shape to perfectly follow the beam excursions on both angles but also the focal length. The mechanics of all the stages are based on precision ball spindles and ball linear guides. The vertical guides are heavy sizes to withstand all the stages mass and vacuum forces, considering its long range, and at the same time stiff enough to prevent amplification of vibrations. In the current design, the positioning stages have been compacted and configured only onto the inboard side on a big granite column (another difference from the XPBF beamline, where a structure made of aluminium is being used).

The granite is an outstanding reference plane, mainly for the vertical long stage, for mechanical and thermal stability. It simplifies the mechanics, as the stages sequence is arranged in a way that compacts all the mechanics on the side, on the granite, improving stability and robustness despite its cantilever shape. And it is giving much better visibility for the laser tracker beam path.

At this point, the preliminary design review has been successfully overcome. The design is in the detailed phase, and the long lead components and subsystems have been already awarded or are being tendered. The facility is expected to be ready for user operation by 2022 and will be operated during about 10 years.

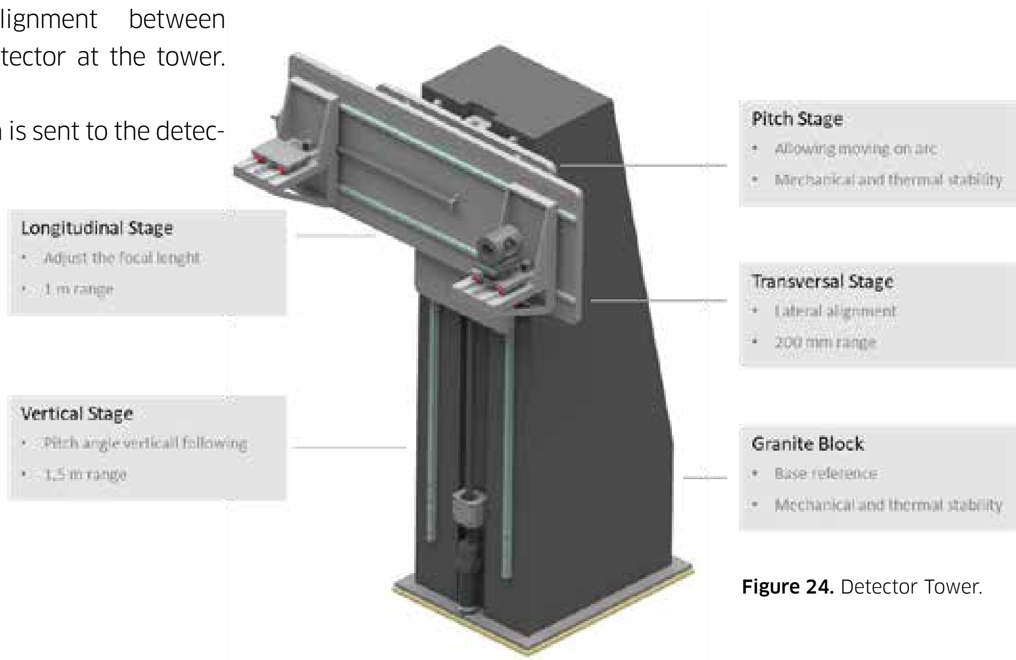



**Figure 24.** Detector Tower.

# COMPUTING

Óscar Matilla, Head of the Computing Division

2020 has inevitably been a tough year. The outbreak of the COVID-19 pandemic led to a plot twist that completely took a turn for the worst. The Computing Division had to demonstrate its capacity to respond to this new situation. But, in V. Green's words, adaptability is intrinsically not to wait for the storm to pass but, to the extent possible, try to "dance in the rain". This year, the Computing Division has demonstrated the greatest responsiveness. First, when the pandemic lockdown began, the required resources were allocated to allow ALBA staff to work remotely. All systems were set up and all ALBA personnel were trained to operate them, with amazing results. Secondly, we tailored our team's work to this new scenario to continue advancing on all of our yearly commitments. Now, if we look back at the progress made in 2020, we can be proud of what has been achieved. Inevitably, the confinement and the working constraints at ALBA have had an impact. However, although the deadlines could not be met, great strides were made in most of them.

For example, we continued advancing the construction of the new beamlines. In LOREA and NOTOS, a big part of the whole control and electronic infrastructure was installed during last year. A major effort was made by the engineers and technicians to get the scientific equipment, the IT infrastructure, the control system and the equipment protection system in place and ready for the first day of commissioning with beam. In XAIRA, the Personnel Safety System was installed and integrated into a new SCADA. And in FAXTOR and XAIRA, the first tests to define the infrastructure required to manage high-throughput detectors started. In the case of MINERVA, the Preliminary Design Report was approved, which is the starting shot for an accelerated race to complete the beamline in two years.

But, in addition to the new installations, the continuous improvement of our infrastructure in operation never ends. In the accelerators, apart from the new front-end installation, the archiving system was upgraded for better usability. As for the power converters, the in-house design of the last power stage of the booster bending power supply was completed, commissioned and the reliability tests have started. Regarding the beamlines, in NCD-SWEET, the ICAT data catalog is now operational and ingesting real experimental data. This is the first step towards the creation of a Data Analysis as a Service platform for NCD-SWEET in 2021. In BOREAS, the new Radial Distribution Chamber was installed and integrated in the Control System. Along with previous activities, we kept the multiple developments of our backstage tools in sight. For example, the final version release of the CableDB 2.0 database allows now to better monitor the lifecycle of our equipment; and also worth noting is the new Learning Management System that is already available for the staff.

But we also need to pave new paths forward. In 2020, we began extending the use of our in-house applications to mobile devices. And, for instance, a Kubernetes cluster has been set up which will serve as a basis for many future developments. On the other hand, we must soak up new technologies such as cloud computing. This year, the Computing Division has been selected by the EU to participate in the Open Clouds for Research Environments (OCRE) funded project, which has the objective to demonstrate the effectiveness of Cloud services usage in research. Looking back, 2020 was definitely a tough year. We had no choice but to adapt to the new circumstances. Now we are again heartened by what 2021 has in store for us.

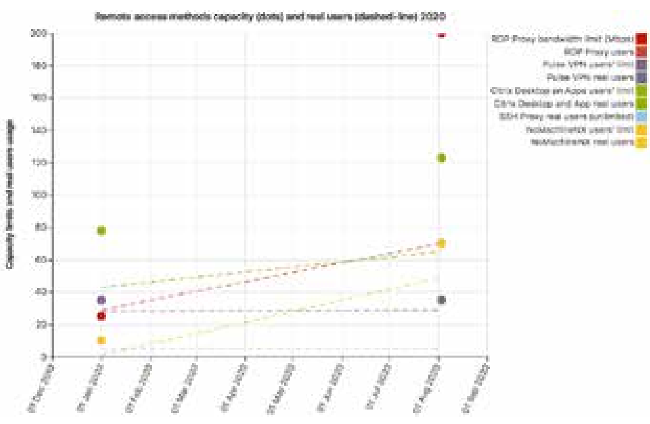



**Figure 25.** Remote access capabilities increase during 2020.

# High-throughput detectors data management; inherently born to run

G. Cuní, J. Andreu, P. Carnicer, T. Coutinho, M. Fisz, T. Pérez, J. Salabert
Controls Section and IT Systems Section, Computing Division

The data acquisition system and the IT infrastructure allow scientists to collect the data from their experiments for subsequent processing and analysis. Each of these three stages needs to be designed to perform according to the requirements and has a direct impact on the quality and success of the scientific investigation. The appearance of faster detectors with highly increased resolution (i.e. larger throughput) for synchrotron applications forces us to review the current solutions to be capable of handling, processing, and storing larger amounts of data.

However, in many situations, these stages are intimately related and cannot be addressed as separate challenges. For some experiments, having real-time feedback about the quality of the data being acquired is critical. This requires processing it and providing specific key performance indicators to monitor the experiment. This information is crucial to rapidly enhance the experimental setup or to stop scanning if the acquired data is already sufficient. In other cases, the technical challenge is to efficiently process the acquired data and to adopt specific solutions taking into consideration the computational cost of each process: from the transfer of large amounts of data between various storage and processing devices, to the selection of the most suitable technologies available to deal with intensive calculations.

An example of using high-throughput detectors is an experiment which involves generating images at incredible high frame rates. For instance, the new FAXTOR beamline is expected to produce 45 GB/s during the peak. To put this into perspective, that means generating the same amount of data as 45 HD movies per second. Retrieving it from the detector system is already a daunting task. Getting the data out of the detector is the first step, but the whole chain of processes must be as fast as the data acquisition. The whole IT infrastructure and the processing pipeline must be designed to cope with the data stream in order to store it and make it available for processing. In some situations, this data processing chain has to be configured to automatically discard no-data images, verify the quality of the data, or start some automatic preprocessing such as partial reconstructions. In other cases, real-time feedback is required, which becomes much more complex as the volume of data increases due to automation or increased flux, resolution, or frame rates. Lastly, given the amount of data generated, data reduction and compression become imperative for the sustainability of the IT infrastructure. This implies that certain data compression formats are adopted and therefore, the programs that are in the acquisition pipeline should be compatible with these formats.

The ultimate throughput speed will be determined by the slowest step in the chain. Thus, in some cases, it is the processing step that needs to be optimized by, for instance, parallelization and/or specific GPU cluster technologies. A detailed joint design for software and IT infrastructure is required.

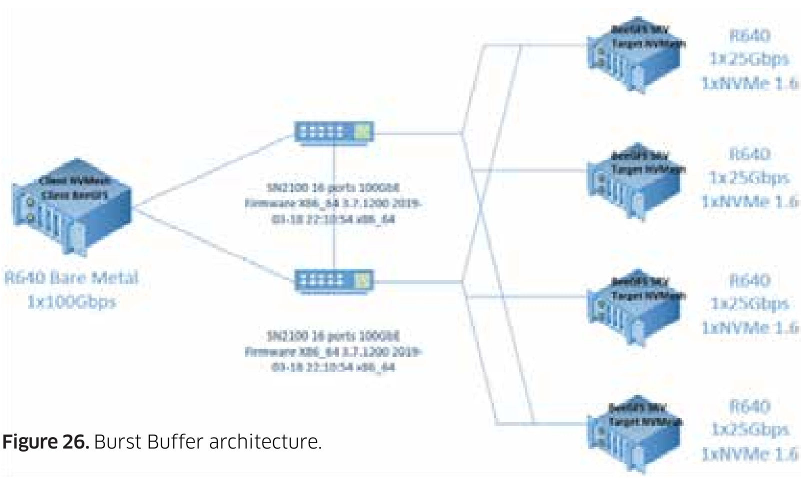
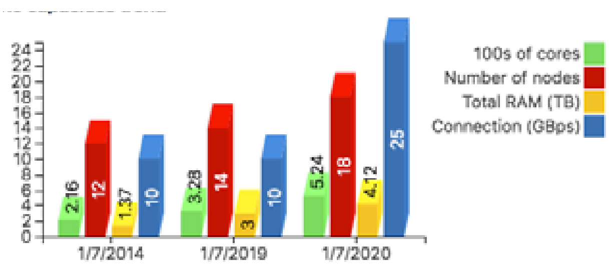



**Figure 26.** Burst Buffer architecture.

During 2020, ALBA continued to develop the XAIRA and FAXTOR beamlines. Both are highly demanding in terms of data throughput, network speed, performance and storage, and need of processing capabilities. Designing all the necessary infrastructure for this high-throughput systems when the hardware parts have not yet been acquired is a challenge. The first step consisted in simulating the detectors by installing a computer with enough memory to “load” the data to be released. With the help of real data sets, we began the design of the necessary IT infrastructure and software processes. Working with real processing software will be key for accurately determining the number of CPU cores, memory and bandwidth needed to process the data. See Figure 27: ALBA HPC historic evolution. On the other hand, it will allow the evaluation of the various data transfer and storage technologies needed in the computer infrastructure. A new system called Burst Buffer file storage based on NVMe-SSD disks and with a limited capacity of 3TB but a very high read/write performance was installed and benchmarked (see figure 26). This system is based on Excellero NVMesh and BeeGFS parallel filesystem. The use of RoCEv2 & RDDA (Remote Direct Drive Access) protocols and the high-speed (100GbE) and low-latency network allows high-speed access without servers with very powerful CPUs.

**ALBA HPC historic capacities trend**




| Total | Number of nodes | Number of cores | Total RAM (TB) | Connection (GBps) |
|---|---|---|---|---|
| 2014 | 12 | 216 | 1.37 | 10 |
| 2019 | 14 | 328 | 3 | 10 |
| 2020 | 18 | 524 | 4.12 | 25 |

**Figure 27.** ALBA HPC historic evolution.

The estimated performance required by XAIRA from a single client is 1.3GB/s read/write, while the Burst Buffer achieves this performance even when just using 1 client thread. See Figure 28 below for BeeGFS performance.

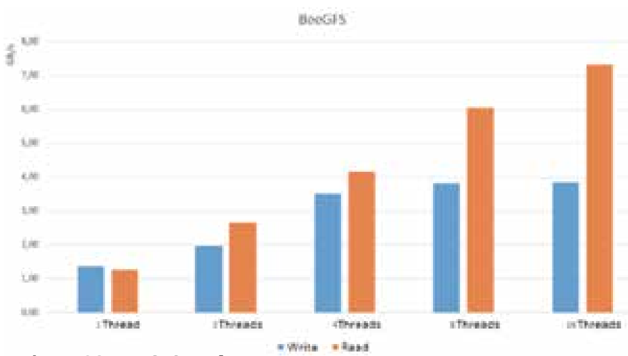



**Figure 28.** BeeGFS performance.

Both the online analysis and the post-processing for XAIRA and FAXTOR will also require upgrading the Hight-Performance Computing cluster, after the right server capacities are confirmed with simulations to be performed using external rented servers.

In early 2021, a setup will be installed in the Data Acquisition Lab with several direct high-speed 100GbE links to our CPD, hosting the HPC cluster and the Burst Buffer. It will allow us to evaluate the whole data path: from the “detector” at the beamline, to the processing infrastructure at the Data Center, back to the visualization software and the rest of the data processing at the beamline. It will be possible to reproduce exactly what the users of the beamline will experience in the future. However, this is not a marked path; a close interaction with the beamline scientists will be necessary to ensure that the final result meets the needs of the beamlines that are being built.

# PROJECTS & COLLABORATIONS

ALBA was granted European Regional Development Funds (ERDF) through the Spanish and Catalan administrations for long-term projects. Besides, in 2020 ALBA participated in different international and national collaborations with other facilities and research centres.

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

**818.608,51 €** 2020 Competitive Calls
**361,402 €** 2020 Agreements

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

**Spain Multi-Regional Operational Program 2014-2020**

| 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 - 2022 |
| 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 - 2023 |

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

| 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 to different beamlines and subsystems of ALBA | 1,246,180.00 € | 623,090.00 € | 2015 - 2023 |

## EUROPEAN PROJECTS IN WHICH ALBA PARTICIPATES

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

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

Project for developing a model describing the socioeconomic impact of research infrastructures (RIs) and their related financial investments. The project ended in 2020 and included a pilot exercise, which identified ALBA's impact through direct and indirect patents citation.

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 world-class 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.

Doctoral training programme in Functional Advanced Materials.

The iNEXT-Discovery project aims to facilitate the access to advanced technological instrumentation for the development of new drugs, advanced vaccines, novel biomaterials, engineered enzymes for food production, efficient biofuels, and other benefits. ALBA participates with its MISTRAL beamline for cryo soft X-ray imaging of cells, which includes tomography and spectroscopy.

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

# EDUCATION & OUTREACH

**ALBA has continued on sharing its knowledge about synchrotron-based research and technology as well as giving support to the education of university and vocational training students.**

## VIRTUAL MEETINGS AND CONFERENCES

In 2020, most of the meetings organised by ALBA moved to virtual environments. While some of the scientific conferences were postponed to 2021, like the 12th Workshop on Accelerator Operations (WAO), others were held in virtual formats. That was the case of the 3rd LEAPS Plenary Meeting that took place on 24-25 November 2020, gathering more than 170 participants from all Europe. In 2020, the collaboration with Portugal intensified by hosting a joint meeting on 17 December with 100 attendees from the Portuguese community of synchrotron users. Also worth highlighting are the special meetings with all staff during the most severe months of the pandemic, enabling a fluent and efficient communication.

Top, snapshot of Zoom application with some of the participants at the FCT-ALBA joint meeting. Down, some of the participants at the 3rd Plenary LEAPS Meeting.

## A STRONG COMMITMENT TOWARDS EDUCATION

Since 2014, ALBA has been regularly receiving students who perform different types of internships and gain knowledge and skills in a wide variety of scientific and technological areas: from engineering to accelerators' technologies, synchrotron light applications, computing and controls, health & safety, administration and finances or communications and marketing.

In 2020, ALBA hosted 31 students. 14 were university undergraduates and 11 vocational training students. They did stays of 4-10 months at the facility to learn a job while they were studying (adapted to teleworking as soon as the lockdown was enforced due to pandemic). Besides, 6 PhD students developed their thesis under the supervision of ALBA members. As done in the past, members of the ALBA staff are also involved in teaching activities, like for example the degree in Physics at the Autonomous University of Barcelona (UAB) and two master studies at the Polytechnic University of Catalonia (UPC).

## COMMUNICATING IN PANDEMIC TIMES

The COVID-19 pandemic had a huge impact on communications and outreach activities, forcing us to cancel all face-to-face activities and events and increase internal communications to ensure that clear instructions and advice were provided to all staff members.

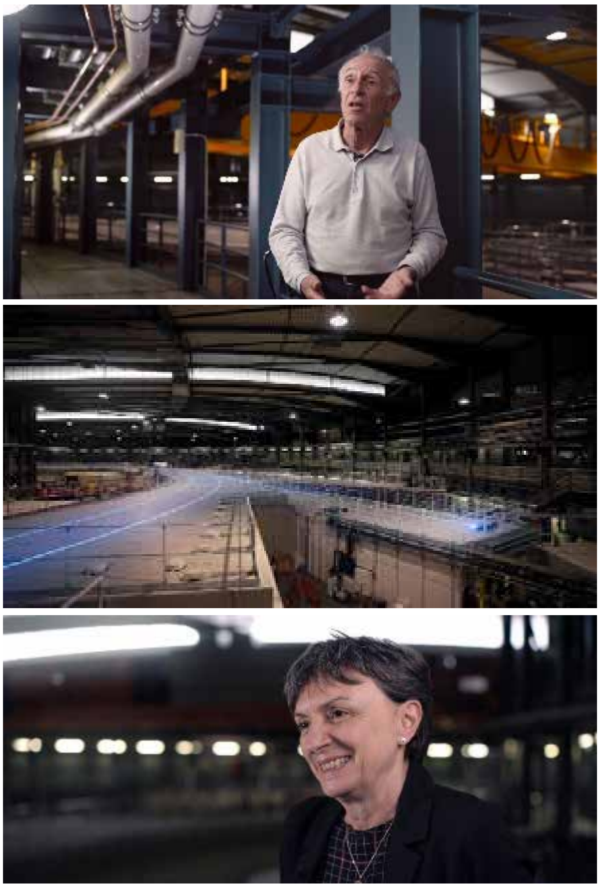
The educational project *Misión ALBA* held its second edition, with the participation of 178 schools and more than 7,500 students from all over Spain. ALBA was able to adapt the materials to enable the participants to follow the project from home, as all the school classes were cancelled from March to

June 2020. The project ended with a live chat with almost 600 students actively taking part.

As mentioned before, research activity was kept at high levels (being able to perform 95% of scheduled experiments). Therefore, a record number of highlights were developed during the year to communicate the results of experiments carried out at the facility. Even though mainstream media were exclusively focusing on pandemic issues, ALBA's media impact was slightly superior to the amount obtained in 2019 (500,000€).

In 2020, a new website (link: https://jobs.albasynchrotron.es) was prepared to foster attracting new talent to the ALBA Synchrotron. Available job positions are shown, together with different professional profiles and the main benefits of working in a facility like ours.

2020 was earmarked for celebrating the first 10 years of successful operation of the facility. Several communications materials were developed to highlight the anniversary, among them a series of videos, infographics and a leaflet.



Snapshots from the video series and logotype adaption for 2020.

**31 students**

**465 media impacts**

**516,500 € media value**

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