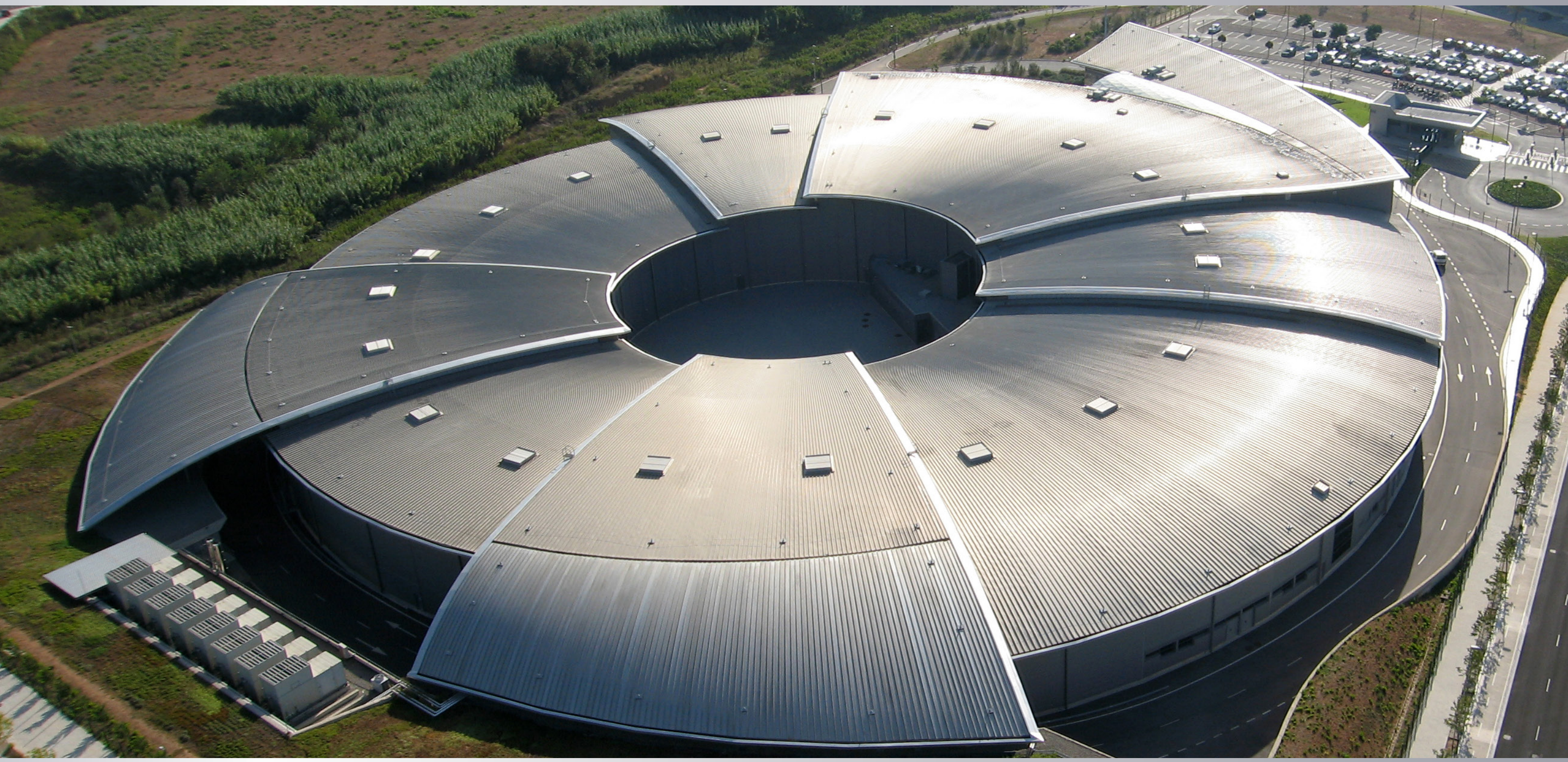


ALBA

RESEARCH INFRASTRUCTURE REPORT

OCTOBER 2017

Generalitat de Catalunya
Departament d'Empresa
i Coneixement

GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMÍA, INDUSTRIA Y COMPETITIVIDAD

a1 INTRODUCTION

Synchrotron radiation is an invaluable instrument for analysis in extended areas of scientific applications ranging from life science to the most innovative materials. This has provoked the development of several facilities in the entire world dedicated to the production and use of this precious tool. Almost all technologically advanced countries have their own synchrotron radiation source. Spain joined the community in the first decade of this century by building the ALBA Synchrotron which constitutes a leap in the national experimental research.

ALBA [1] is a 3rd Generation Synchrotron Radiation (SR) facility located in Cerdanyola del Vallès, Barcelona, Spain, under the responsibility of the Consortium for the Construction, Equipment and Exploitation of a Synchrotron Light Source (CELLS). The CELLS is owned and financed in equal parts by the Spanish and the Catalan Administrations. At present the Rector Council chairperson is the MINECO Secretary of State for Research and the corresponding Ministry of Generalitat de Catalunya, yearly alternating.

ALBA has been identified as a “Singular Technological and Scientific Infrastructure” (ICTS) within the Spanish program of scientific infrastructures. It is networked with other Synchrotron Light Sources and related research centers from and outside Europe through common European projects and bilateral collaboration agreements.

After more than 10 years of preliminary studies, the agreement to establish the Consortium was signed in 2003. The detailed design stage took place from 2003 to 2006. The construction and the commissioning were completed in the following five years, with user’s operation starting in May 2012.

ALBA serves a community of more than 4000 users and has contributed to the increase of the Spanish user community by one order of magnitude from the moment of the project approval, attracting as well competitive international users. Since its approval it has given birth to an industrial user community, has developed an efficient outreach program towards the society, has established a student training program, has contributed to foster high technology companies and has created a network of international links and fruitful collaborations with national research facilities.

On ALBA history, plans and realizations, the economic situation of Spain in the last decade has had a prominent role. The birth of the facility profited from the boom of the economy at the beginning of the century, and the construction, with a budget covering the infrastructure, the accelerator and seven first beamlines, was fully supported from its very beginning. So was the operation, in spite of the austerity which came after 2008, obliging the administrations to reduce and prioritize investments in the national scientific system.

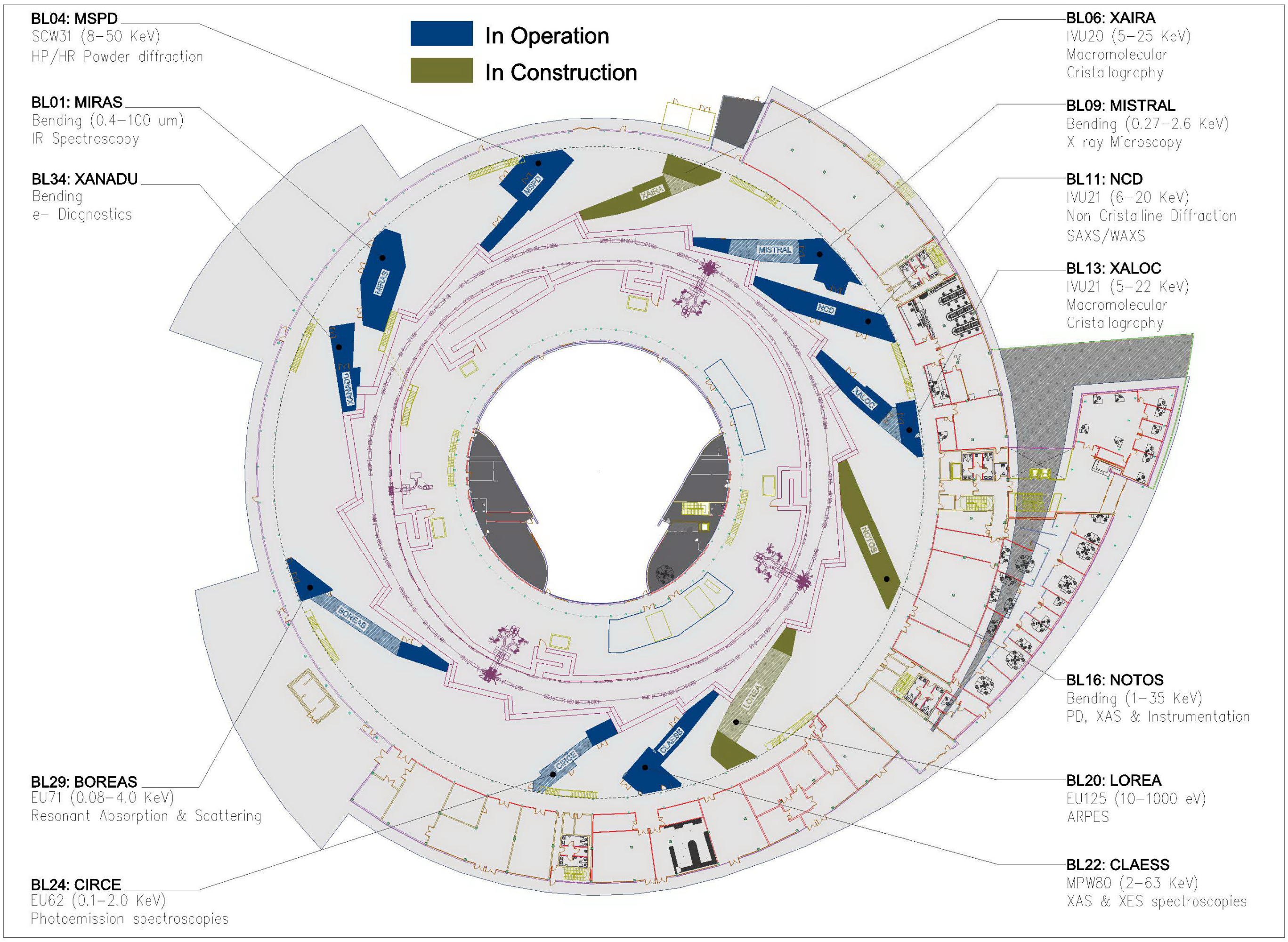


Figure 1 – ALBA Layout including beamlines and accelerators.

In order to give an idea of the results obtained in ALBA, we have chosen to highlight those type of experiments for which ALBA is highly competitive or even somewhat unique. They are what we could call ***ALBA specialties***.

BOREAS: XMCD AT HIGH ENERGIES

Modern computers, magnetic memories, sensors and a large number of devices utilize magnetism as a basic principle of their operation. Research on nanomagnetism has been boosted in the last two decades due to the large number of possible practical applications and to the appearance of sophisticated tools to control and characterize magnetic entities. Since its discovery more than 30 years ago, XMCD (X-ray Magnetic Circular Dichroism) became a key tool for magnetic studies on thin layers and nanostructures. Precise dichroic measurements require stable and reproducible intensities of the two X-ray helicities, of the optics and sample environment. More recently X-ray linear dichroism has also emerged as a suitable tool for investigating the electronic structure of surfaces and interfaces.

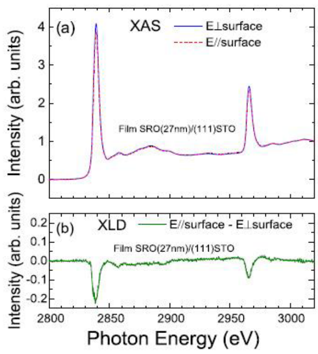


Figure 2 - a) X ray absorption spectra at the Ru L_3 and L_2 absorption energies from a 27 nm ferromagnetic film of $SrRuO_3$ grown on $SrTiO_3$. The photon beam was linearly polarized with the polarization either parallel (red curve) or perpendicular (blue) to the film surface. b) Linear dichroism spectrum obtained subtracting the two spectra in (a).

Thanks to the quality of the optics of BOREAS and particularly of a shallow angle blazed grating in the monochromator, it is possible to have monochromatic photon flux up to 4000 eV with enough intensity to acquire excellent spectra. This feature is not, or hardly is, available at other similar beamlines. An example (see Figure 2 and [2]) is the data from the $SrRuO_3$ perovskite acquired at the Ru L absorption energies at 2.9 keV. Here the dichroism arises from the different absorptions of linearly polarized beams with polarization parallel and perpendicular to the surface of the sample. The dichroic spectrum in Figure 2b displays an excellent S/N ratio. To the best of our knowledge nowhere else spectra of such a quality at this energy can be obtained.

CIRCE-PEEM: time and spatial resolution

Another example of how scientific research on nanomagnetism is linked to practical applications is provided by results from the CIRCE beamline photoemission microscope. The possibility of fast manipulation of magnetic entities as magnetic domains in a ferromagnet with electrical stimuli as voltage pulses is one of the active areas of research in nanomagnetism with direct application in magnetic memories and reading heads.

In an experiment carried out by in-house developments and external collaborations [3], a propagating surface acoustic strain wave on a piezoelectric crystal covered by ferromagnetic Ni particles of 2 μm lateral dimensions layer has been imaged (see Figure 3). Temporal resolution of 80 ps and lateral resolutions of about 40 nm allowed investigating the dynamic effects of the propagating strain waves on the magnetic structure of magnetic particles. This was achieved using the 499.654 MHz clock from the synchrotron timing system. The magnetism was probed by XMCD and the strain by low energy electrons emitted from the sample in a stroboscopic mode. The result shows that strain can be a useful tool for manipulating magnetism at high speeds.

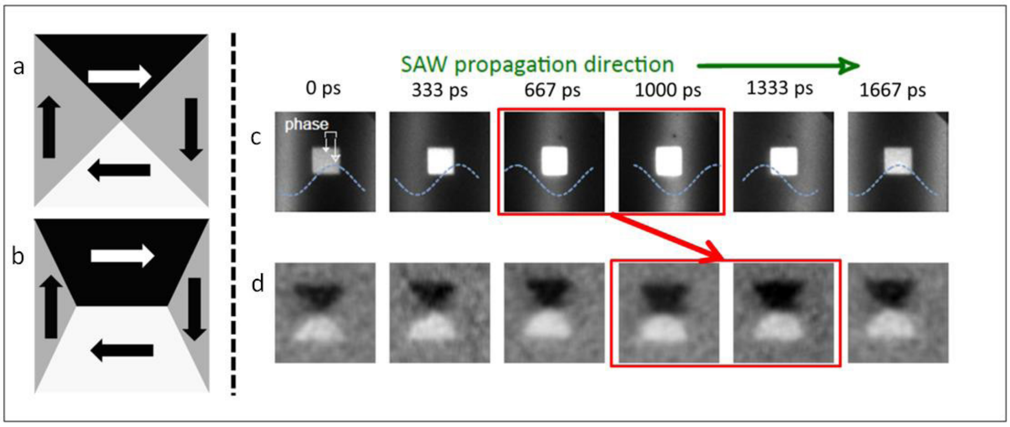


Figure 3 - a: Sketch of magnetic domains in a Nickel square without net anisotropy, forming a flux closure state (arrows indicating magnetic directions, gray color indicating contrast in XMCD-PEEM). b: Domain configuration if an additional uniaxial magnetic anisotropy is induced by strain, favoring the horizontal direction (black and white domains). c: Series of direct images taken with different respective positions of the strain wave and the Ni square. The strain wave appears as a vertical diffuse grey band on the images and moves to the right. The green arrow indicates time evolution. d: Magnetic domains on the Ni square. When the strain wave coincides with the squares (panel c: 667 and 1000 ps) the magnetic domains resemble those in panel. However, the maximum deformation of the domains occurs after the wave has crossed the squares (images within the red frame). This time lag is approximately 300 ps.

MISTRAL: cell imaging

High resolution three dimensional imaging of biological cells is one of the key tools in cell biology, allowing visualizations of their inner morphology in different circumstances. The Cryo soft X-ray microscope, MISTRAL beamline, allows imaging cells with high resolution 3D maps (around 50 nm). The unique feature of X-ray microscopy compared with TEM is that thanks to the much larger penetration of X-rays when compared to electrons, intact cells can be imaged since they do not need to be sliced as in TEM. This has important advantages in cases where slicing is prone to alter the morphology or distribution of particles in the cells.

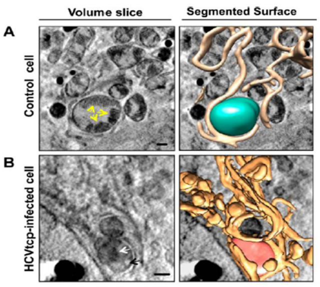


Figure 4 - Comparative analysis of the endoplasmic reticulum (ER)-mitochondria topological relationship of vitrified control (A) and abnormal mitochondria (AbMito) HCVtcp-infected (B). Left side: volume slices, right: segmented surface representation. Scale bars: 0.5 μm. Color code:

Mitochondria Normal ER Modified ER AbMito

The microscope operates with X rays in transmission mode acquiring full field images in ~1 second. The tomography results from a series of images at different angles with respect to the photon beam. MISTRAL has demonstrated its capabilities identifying, as example, the effects of hepatitis at cellular level [4], namely, marked alterations of the mitochondrial morphology correlated with alterations of the endoplasmic reticulum (see Figure 4).

Using the good monochromaticity of the photon beam, it is also possible to perform spectroscopic imaging (i.e. acquiring images at different photon energies) which allows identifying chemical states of absorbing elements. At present, MISTRAL is the most performing beamline in this specialty in the world.

In addition to these “specialties”, ALBA has ***several instruments*** that are not common in many synchrotron sources.

At *CIRCE* the second endstation is a Near Ambient Pressure Photoemission (NAPP) apparatus which allows acquiring photoemission spectra at pressures as high as 20mbar, well above the UHV (Ultra High Vacuum) pressures of conventional instruments. The equipment has a large field of applications in the area of Surface Science, Surface Chemistry and Catalysis. In Europe there are only few active ones and the CIRCE NAPP is oversubscribed with a demand much larger than its capacity.

At *CLÆSS*, an X-ray spectrometer, CLEAR, has been developed in-house and it allows analyzing the energy of the fluorescence emission from a sample excited by absorbed X-rays. The combination of incoming photon energy and emitted energy allows acquiring detailed electronic information on the excited electronic states of the sample under study and also, by selecting the appropriate energies, to acquire absorption spectra with enhanced energy resolution compared to those measured with conventional integrated methods. Its use will allow advanced spectrometer studies of catalytic reactions.

At *BOREAS*, particularly at the *MARES* end-station, a soft X ray reflectometer combined with a cryostat and a 2T superconducting magnet that can rotate with the sample, allows performing unique resonant scattering experiments by measuring reflected intensities while applying a magnetic field along a specific surface direction and changing the temperature from 4 to 400K.

Finally, it is worth mentioning that the rest of the instruments, even though less unique, are also highly performing.

a2 ACCELERATOR COMPLEX

ALBA is the only Spanish Research Infrastructure (RI) whose team has designed, built and is operating a full accelerator system.

The accelerator system of ALBA is composed by the injector (a Linac plus a Booster) and by the Storage Ring (SR). Its schematic lay-out can be found in Figure 1. The 3 GHz Linac delivers electron beams of 110 MeV to the Booster, where electrons are accelerated to 3 GeV, to be then injected into the SR. The nominal e- beam intensity in the SR is 250 mA. The main machine parameters are summarized in the Table 1.

Storage Ring			
Beam Energy	3 GeV	Natural H Emittance	4.6 nm*rad
Circumference	268.8 m	Bunch Length	15.8 ps rms
Number of cells	16	Energy Spread	1.05×10^{-3}
Number of straight sections (length)	4 (8.0m) 12 (4.2 m) 8 (3.1 m)	Energy Loss per Turn	1.1 MeV
H/V Beam sizes (mid-point) BM	49.2/22.8 μm rms	RF frequency	500 MHz
H/V Beam sizes (mid-point) ID	130.0/5.5 μm rms		

Table 1 – Accelerator main parameters.

The ***top-up mode of operation*** started in September 2014. Its implementation has requirements of instrumentation and safety which have been all satisfactorily accomplished. In agreement with the experimental team, injections to refill are scheduled every 20 minutes, although the system provides the functionality and the flexibility to inject at arbitrary time intervals or at beam current thresholds. The re-injection process is performed while users simultaneously work in the beamlines. Several subprojects of optimization have been carried out, related to Linac, Booster, SR, injection, power supplies, operation procedures, radiofrequency, beam stability and insertion devices, routinely ensuring a reliable injection procedure.

A complete set of software applications including low level access to the hardware and human machine interfaces was also produced. There are some experimental techniques that are sensitive to the small perturbation of the beam during injection in the top-up mode. In order that the data acquisition at the beamlines can be continued during injection, a gate signal is provided so that they can either stop acquisition or disregard the measurement data during the injection process.

Two kinds of mechanism have being developed for ensuring photon flux stability and reliability in order to counteract possible beam oscillations due to high electron density, the ***Fast Orbit Feedback*** (FOFB) and the ***Bunch by Bunch*** (BbB) transverse feedback systems.

The FOFB objective has been achieved with vertical beam orbit stability in the range of 100 nm below 100 Hz bandwidth. The system, already tested in 2014, has been set into operation with users since May 2015. The BbB has also been successfully installed and is able to damp the instabilities oscillations up to 250 MHz. The vertical BbB system was set into operation with users in September 2015, the horizontal one in October 2016. The electron cleaning has been successfully tested with the use of the BbB transverse feedback system, in a special mode, where single bunches can be excited into a betatron resonance and electrons of a single bucket being kicked out of the SR.

The synchrotron runs experiments typically 24/6 (24 hours a day, 6 days a week), with one day per week for the accelerator maintenance interventions, eventual issues and beamline setup.

Table 2, which complements Figure 5, summarizes the full history of the operation period, with the number of total operating hours, time offered to official users, availability, Mean Time Between Failures and Mean Time To Repair. The operation started in May 2012, suffering from early usual problems and only 76.7% of the foreseen 2387 hours for users could be delivered during that year. During 2013 there was a long shutdown due to a problem in the infrastructure cooling system which was solved after three months. Part of this shutdown was recovered during the second half of the year thanks to a general effort of all scientific and technical teams, so obtaining a yearly availability of 83.8%. It is worth highlighting here the excellent results since 2014 from the point of view of the facility reliability, which is similar or even better than sister facilities, in spite of the lower staff number.

	2012	2013	2014	2015	2016
Operation (h)	3280	4464	5250	5730	5744
Beamtime for users (h)	2387	3540	3888	4320	4368
Availability (%)	76.7	83.8	96.8	97.3	97.6
Mean Time Between Failures (h)	21	25	34	51	58
Mean Time To Repair (h)	1.0	0.8	1.1	1.4	1.4

Table 2 – Operation summary.

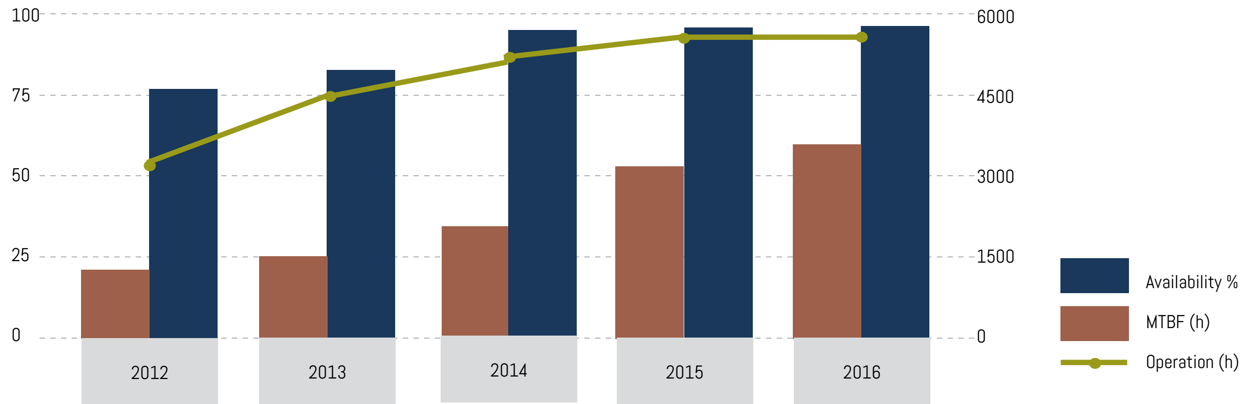


Figure 5- Operation summary. Availability (in %) and MTBF (in h) are on the left vertical axis. Operation hours per year on the right one

a3 EXPERIMENTAL BEAMLINES

The outstanding facilities of a synchrotron light source are the experimental beamlines providing light to users through specialized techniques.

ALBA design was optimized with a large number of available ports and long straight sections when normalized to the total circumference, in order to host several beamlines. Seven beamports were filled with day-one instruments, plus an eighth which hosts a diagnostic beamline. Since 2014 the construction of a new beamline has been started each year. This rate could have been higher if economy were more favorable. It is a rhythm which is essential to maintain and possibly to increase in the future.

ALBA is open to users coming from public research institutions and universities with competitive access mode based on scientific excellence and to industrial users who have direct access. The different access modes will be detailed in paragraph d. of the self-assessment document.

a3i Beamlines in operation [6]

The definition of the beamlines has passed through processes, defined as Phases: call for proposals open to the scientific community, selection and assessment by the Scientific Advisory Committee (SAC), and approval by Governing Bodies. The seven Phase I approved projects were built together with the infrastructures and are operating since 2012. Thereafter the development of new beamlines was put on hold due to economic restrictions. From 2012 to 2014 the operation was consolidated, not only technically and scientifically, but also administratively, and in 2014 the expansion in terms of new beamlines started but with a rate slower than foreseen in the previous strategic plans.

The reduced Phase II consisted of two projects, at present one in operation and the other one in construction. A Phase III process was launched in 2014, and six projects were approved by 2015. The construction of two of them has started in 2016 and 2017. In all these phases the contribution of the ALBA staff has been of major importance as it represents nowadays the Spanish group with the best knowledge of scientific needs and possibilities in synchrotron radiation science.

Uniqueness of certain instruments, summed to the availability of usual synchrotron radiation techniques at the forefront of technology, has fructified and during these first years of operation. More than 700 experiments have been carried out in the different beamlines with more than 4000 users visiting our facility during this period.

The distribution of beamlines is shown in Figure 1. As already mentioned, eight beamlines are operating in the infrastructure, four of them with double end stations. A short description of each of them follows and can be complemented with the information at the ALBA webpage [6], while Table 3 shows their main parameters. Most significant recent developments for each of the beamline are highlighted.

Port	Beamline	Phas.	Op. Start	Source / Endstation	Energy / λ	Experimental techniques	Key scientific fields
1	MIRAS	II	2016	BM	IR: 10-100 µm	Spectroscopy, imaging	Biosciences, Material science, Cultural heritage
4	MSPD	I	2012	SC Wiggler/ HRPD	8 and 50 keV	High resolution powder diffraction	Material science
		I	2012	SC Wiggler/ HRPD	8 and 50 keV	Microdiffraction & High pressure diffraction	Material science, Cultural heritage
9	MISTRAL	I	2012	BM	270 - 1200 eV	Cryo nano-tomography	Biosciences, Nanomagnetism
11	NCD	I	2012	IV undulator	6.5 - 13 keV	SAXS & WAXS	Biosciences, Materials science
13	XALOC	I	2012	IV undulator	5 - 22 keV	Macromolecular crystallography	Biosciences
22	CLAESS	I	2012	Multipole wiggler/ XAS	24 - 63.2 keV	Absorption spectroscopy	Materials science, Catalysis
		I	2016	Multipole wiggler/ XES	64 - 12.5 keV	Emission spectroscopy	Environmental sciences, Electronic structures
24	CIRCE	I	2012	APPLE undulator/ PEEM	100 - 2000 keV	Photoemission electron microscopy	Nanomagnetism, Surface science, Materials science
		I	2014	APPLE undulator/ NAPP	100 - 2000 keV	Near ambient pressure photoemission	Catalysis, Surface science, Materials science
29	BOREAS	I	2012	APPLE undulator/ HECTOR	80 - 4000 keV	Absorption Spectroscopies, XMCD, ...	Nanomagnetism, Surface science
		I	2015	APPLE undulator/ MARES	80 - 4000 keV	Scattering, imaging	Nanomagnetism, Surface science

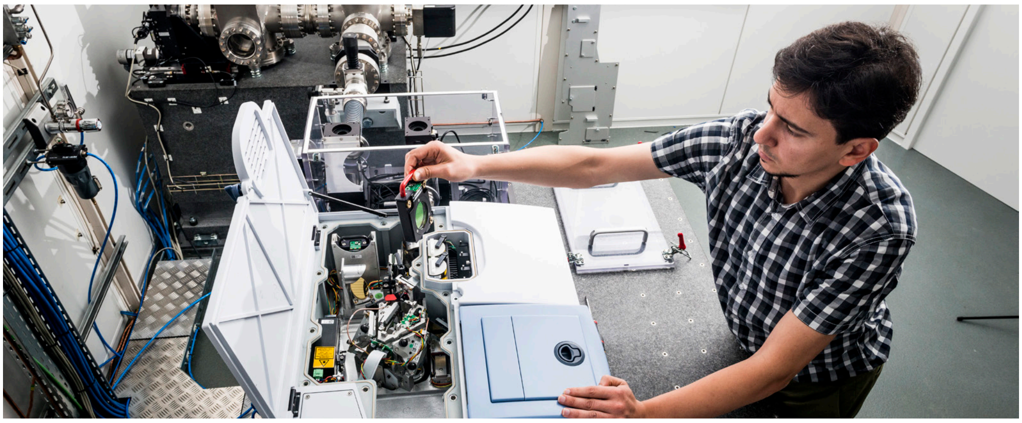
Table 3 – Operating Beamline main characteristics

BL01 - MIRAS: Infrared Spectroscopy & Microscopy Beamline

An important achievement of the last period has been the successful completion of the first Phase II beamline, MIRAS, well within budget and schedule. Its design started in 2014 and the full user operation in October 2016. The project was conducted with a large share of in-house designs with some external advice, highlighting SOLEIL help. The experience of running in parallel the facility operation and a construction project is challenging but it has been useful to optimize the procedures which are now being applied with the more demanding task of several beamlines in construction. PRINCE2 method has been successfully applied to organize the assignments to the different teams.

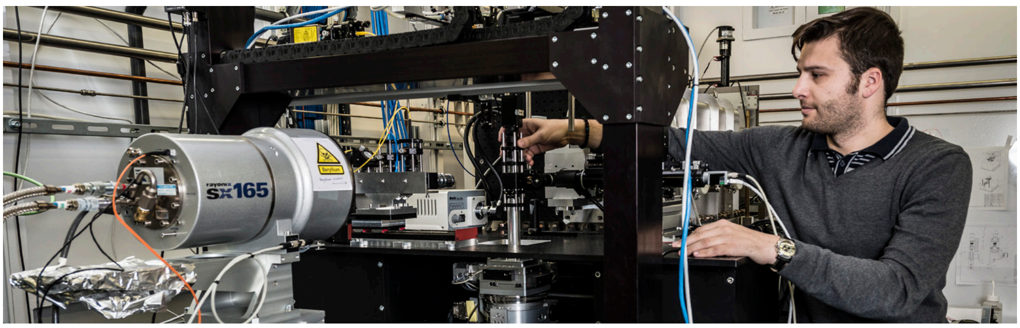
MIRAS is devoted to Fourier Transform Infrared (FTIR) spectroscopy and microscopy. FTIR is a very potential tool to identify the vibrational signatures and therefore the chemical composition of materials.

The beamline provides users with a modern synchrotron-based infrared spectrometer and microscope capability covering a wavelength range from about 1 μm to ~100 μm with a spectral region optimized initially for investigation between 2.5-14 μm.
Transmission, Reflection, Attenuated total reflection (ATR) and Grazing incidence are the most important geometries for sample analysis, and are all available at the beamline.
MIRAS main dedication is on life science (specially for cell studies) and in material science (for studying plastics, blends, fillers, paints, rubbers, coatings, resins, and adhesives, polymer interfaces, etc.). Studies on cultural heritage are also a key application. Industries were interested to use the beamline already at the very beginning of its operation, specifically for conducting research on antioxidants for iron used in construction concrete structures and on distribution of lipids in hair.



BL04 - MSPD: Materials Science and Powder Diffraction Beamline

BL04 (MSPD) beamline is dedicated to Material Science and Powder Diffraction (MSPD), specifically to high-resolution powder diffraction. An experimental end-station is equipped with a large heavy duty three circle diffractometer, with two detectors. It allows to efficiently collect high-resolution data by means of 13 analyser crystals and also to collect data very rapidly (for the study of chemical kinetics, phase transitions, etc.) with a micro strip detector system (Mythen II) for time resolved experiments (down to a few ms timescale).
This beamline is also equipped with a second experimental end-station dedicated to diffraction under high pressure with diamond anvil cell and a charge-coupled device (CCD) detector. Crystalline structure of matter under extreme pressure (up to ~50 GPa) can be analysed.
The photon energy range is 8000-50000 eV. A variable beam spot size at the sample is available, its minimum value being 100 (horizontal) × 100 (vertical) μm^2 (high-resolution powder diffraction station) and 10 (H) × 10 (V) μm^2 (high-pressure end-station).
The light source is a Super Conducting wiggler, with a peak field of 2.1 T. The main components of the beamline optics are the following: mirrors (collimating mirror and multilayer Kirkpatrick-Baez mirror pair for horizontal and vertical focusing); monochromator (a silicon(111) double crystal monochromator).
The main components of the high-resolution end-station are: a high-resolution powder diffractometer; a multicrystal analyser with point counting detectors; and a MythenII 1D pixel array detector. For the high resolution detector system a large pattern with good statistics can be collected in less than two hours. On the other hand, for fast diffraction studies, the Mythen detector allows for collecting a full medium resolution pattern in 10 minutes. In the high pressure end-station the corresponding key elements are: a diamond-anvil cells; and a CCD detector, Rayonix SX165.



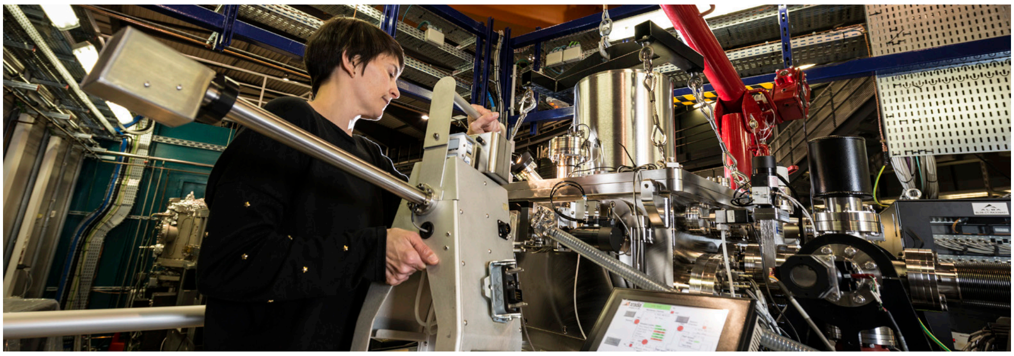
BL09 - MISTRAL: X-Ray Microscopy Beamline

BL09 (MISTRAL) beamline is devoted to transmission X-ray microscopy (TXM). This beamline is optimized to work with soft X-rays in the ‘water window’ energy region. There are only two other instruments of this type operating in the world. Cryo-tomographies of biological material of very high spatial resolution can be obtained. The beamline has a grating monochromator for spectroscopic imaging.

The photon energy range of the beamline optics is 270-2600 eV. The current photon energy range of the TXM is 270-1000 eV, wherein an upgrade for including higher energies is possible (see section 3.1 below). The field of view can be changed from 9x9 μm^2 to 16x16 μm^2. The spatial resolution is close to 20 nm for 2D imaging and 60 nm for 3D reconstructions.

The light source is a bending magnet. The main components of the beamline optics are four mirrors and two gratings for beam conditioning and a variable included angle plane grating monochromator.

The main components of the end-station are: a full-field transmission cryogenic station with tomography capabilities; a charge coupled device (CCD) detector (PIXIS) and a visible light fluorescence microscope which has been recently installed in the beamline.



BL11 - NCD: Non-Crystalline Diffraction Beamline

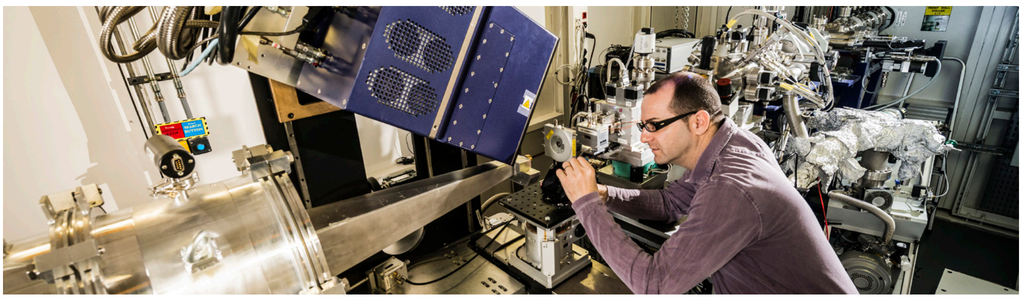
BL11 (NCD) beamline is dedicated to small-angle X-ray scattering (SAXS) and wide-angle X-ray scattering (WAXS) and both measurements can be simultaneously carried out. It is equipped with advanced optics and detectors covering various scientific areas in the field of biomaterials, and hard and soft condensed matter. It allows characterizing a very large range of samples including biological systems, such as fibre systems, membrane systems or cellular organelles, samples in solution and samples of polymers and nanotechnology systems including nanoparticles on substrates. The longest resolvable length is close to 900 Angstrom.

The photon energy range is 6500-13000 eV. The beam spot size can be varied, the minimum value being 70 (H) × 30 (V) μm^2 with the current setup.

The light source is an in-vacuum undulator. The main components of the beamline optics are: mirrors (collimating mirror, focusing mirror); monochromator (Silicon(111) double crystal monochromator); microfocus stage (based on beryllium compound refractive lenses).

The main components of the end-station are: variable position motorized sample table; WAXS 2D detector (Rayonix-LX); SAXS 2D detector (ADSC).

A major upgrade of the NCD Beamline has started during 2016 to be operative in November 2017. The main improvements are the installation of a new 2D detector for the SAXS technique, an intervention in the monochromator to improve stability, and two new tables, for the sample and for the Wide Angle X-Ray Scattering detector. All these actions allow start-of-the-art SAXS/WAXS and undertaking grazing-incident type studies in the near future.



BL13 - XALOC: Macromolecular Crystallography Beamline

BL13 (XALOC) beamline is devoted to Macromolecular Crystallography (MX), based on MAD (multi-wavelength anomalous diffraction) for structure determination. The diffractometer and the optics of the beamline allow the adaptation of the size and divergence of the beam to the crystal within a certain range. The experimental end-station is equipped with a robot for samples whose changer arm, of 6 axes, may also be used to filter a great number of samples of crystallization plates. It has a state-of-the-art PILATUS detector of 6 megapixels.

The photon energy range is 5000-22000 eV. A variable beam spot size at the sample is possible, the minimum value being 50 (H) × 6 (V) μm^2.

The light source is an in-vacuum undulator. The main components of the beamline optics are: mirrors (Kirkpatrick-Baez mirror pair for horizontal and vertical focusing); monochromator (silicon(111) channel-cut monochromator). The main components of the end-station are: kappa-diffractometer, 2D detector (DECTRIS Pilatus-6M).

BL22 - CLÆSS: Core Level Absorption & Emission Spectroscopies Beamline

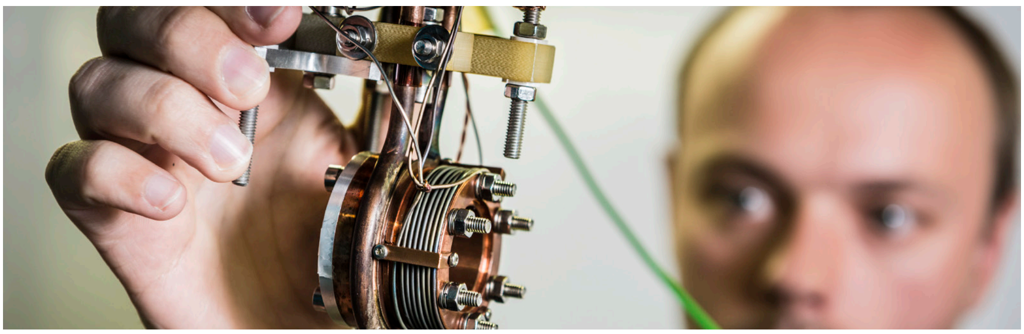
BL22 (CLAESS) is an advanced hard X-ray absorption beamline equipped with a fast monochromator for recording EXAFS spectra (extended X-Ray absorption fine structure) in 1-3 minutes. The beamline has two chemical reactors and an automated system for the management of gases in order to perform measurements of XANES/EXAFS during chemical reactions under conditions close to those relevant to industrial catalysis. In the future EXAFS scans are expected to be done in approximately 100 ms in the intermediate energy range (7-9 keV). It will have an original X-ray spectrometer, in-house design, to perform high energy resolution fluorescence spectral analysis and inelastic X-ray scattering experiments.

The photon energy range is 5000-45000 eV. The beam spot size at the sample is 300 (H) × 150 (V) μm^2.

The light source is a multipole wiggler. The main components of the beamline optics are: mirrors (collimating mirror, focusing mirror); monochromator (silicon(111) and silicon(311) double crystal monochromator).

The main components of the end-station with its current setup are: gas catalysis cells; beam intensity detectors (ionization chambers); fluorescence detectors (silicon-drift and CdTe).

The X-ray emission spectrometer of the CLÆSS beamline, CLEAR, is now operational. This spectrometer in CLÆSS is presently working with the bent Si(111) crystal analyzer setup. The system is being upgraded by implementing also Si(220) crystal analyzer setup which will allow enlarging the accessible energy range.



BL24 - CIRCE: Photoemission Spectroscopy and Microscopy Beamline

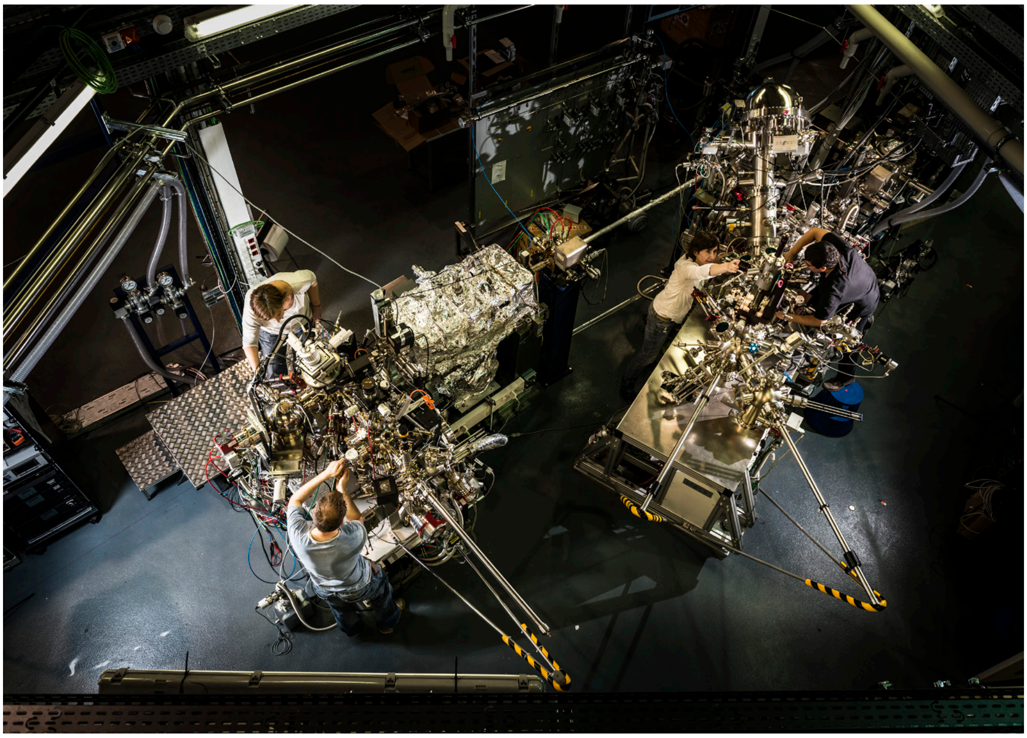
BL24 (CIRCE) is a photoemission spectroscopy and microscopy beamline whose light source is an APPLE-2 helical undulator providing variable-polarization soft X-rays. It has two advanced experimental end-stations for the characterization of surfaces, thin films and nanostructures. The first end-station is a Photoemission Electron Microscope (PEEM), also equipped with an electron gun for Low-Energy Electron Microscopy (LEEM) and an electron energy analyzer. This instrument permits a variety of chemical, morphological and magnetic imaging techniques fully adapted to the field of nanotechnology.

The second end-station is for Near Ambient Pressure Photoemission (NAPP). The main novelty of this instrument is that photoelectron spectroscopy can be performed on samples under pressures of up to 20 mbar. There are only a few instruments of this kind in the world and they are starting to produce major contributions to the characterization of samples in areas such as catalytic processes, environmental sciences and surface science, where gas/solid or gas/liquid interactions play an important role. Both experimental stations have facilities for in situ sample preparation (metal evaporators, gas exposure, heating, cooling, etc.).

The photon energy range is 100-2000 eV. The beam spot size at the PEEM sample position is variable, with a minimum of 30 (H) × 4 (V) μm^2, and at the NAPP sample position 100 (H) × 20 (V) μm^2.

The main components of the beamline optics are: mirrors (one vertically collimating mirror, five further mirrors to deflect the beam into two different branches and focus at the sample positions); monochromator (variable included angle plane grating monochromator with three different gratings).

Several sample environment instrumentation utilities have been implemented in CIRCE during the last period. For example, the setup to excite samples in the PEEM end station has been possible due to the implementation of an independent synchronization system (timing) based on events, precise, accurate and reliable, which are applied to the accelerators and are available also to the beamlines for making pump and probe experiments. The NAPP end station is being upgraded with a beam chopper and electrochemical cell for electrochemistry experiments with lock-in detection. A micro-jet generator for the study of liquids is also being commissioned.



BL29 - BOREAS: Resonant Absorption and Scattering Beamline

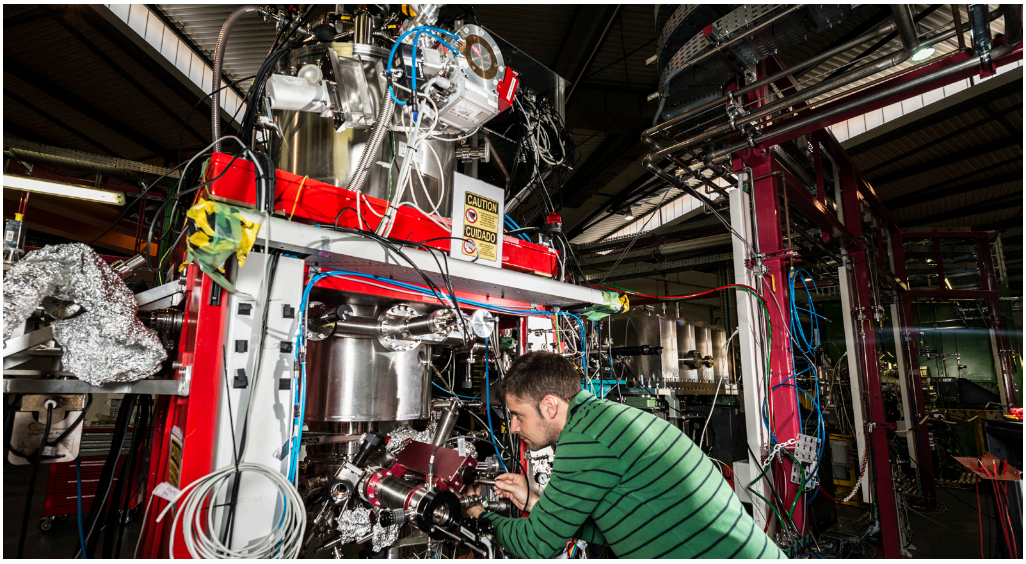
BL29 (BOREAS) is a soft X-ray beamline with a helical undulator to produce variable-polarization light. The first experimental end-station is dedicated to X-ray magnetic circular dichroism (XMCD) and X-ray magnetic linear dichroism (XMLD) techniques, for studies of advanced magnetic materials under magnetic fields of up to 6T along the beam axis and up to 2T in the plane perpendicular to the beam.

The second experimental end-station is dedicated to soft X-ray magnetic scattering (SXRS). This instrument is based on an ultra-high vacuum reflectometer including a newly-developed revolving magnet (based on high-temperature superconducting coils of copper compounds) for the research of magnetic anisotropies on magnetic surfaces, thin films, nanostructures and bulk single crystals.

The photon energy range is 80-4000 eV. Variable beam spot size at the sample is available, with a minimum value of 100 (H) × 20 (V) μm^2.

The light source is an APPLE-2 undulator. The main components of the beamline optics are six mirrors and three gratings for beam conditioning; monochromator (fixed included angle plane grating monochromator).

The second BOREAS end station, MARES, is fully operational. It combines many large subcomponents on a large UHV chamber, among which an in-vacuum 2 Tesla HTS magnet that was a pioneer development; a custom and newly developed UHV CCD camera; a 6-axis 20K cryomanipulator; a UHV double rotary feedthrough for sample and detector arms; a multidetector in-house engineered diode-channeltron electron multiplier arm.



BL00 -XANADU: Diagnostic Beamline

The experimental beamlines are complemented with a Diagnostics Beamline (XANADU) which selects the visible part of the synchrotron radiation produced by a bending magnet to perform diagnostics studies of the electron beam, namely, measure the bunch length using a streak camera, transverse beam size using interferometry techniques, and bunch population by means of photon counting techniques. The beamline is equipped with advanced photon instrumentation that allows these measurements. The Streak and the Fast Gated Camera allows bunch-to-bunch characterization with its 2-ns gating systems, and different electro-optical systems like photomultipliers or avalanche photodiodes have been tested to improve the internal ALBA diagnostics systems.

Furthermore, the beamline offers a wide variety of research studies, which already have been used in collaboration with other labs (like CERN) as a test bench for developments in future machines like LHC or CLIC.

Recent developments benefiting different beamlines

The remote access to beamline control systems and experimental data has become a critical success factor, in particular in disciplines such as protein crystallography where remote access has been already implemented. ALBA provides tools and services for the users to access their experimental data from the public Internet using the credentials of each proposal without file transfer size restrictions. It is currently used at XALOC and will be implemented at MSPD.

A liquid helium cryostat is in shared use by two beamlines: MSPD and CLÆSS. Several sample-related equipment are now available at MSPD for operando characterization of energy-related materials, for example battery analyses.

Currently, most of the experiments in four beamlines (MSPD, CLÆSS, CIRCE and BOREAS) benefit from continuous scans. The control system –Sardana– was generalized and rewritten to natively include continuous scans so any physical channel or value available in the control system can be added to the configuration of the scan, making easier the sharing of efforts and the migration of features from one to other beamlines and across different institutes as well.

The ALBA data center was provisioned with a number of servers for meeting the requirements of application hosting, virtualization and visualization in several beam lines. High Performance Computing (HPC) was setup to speed up a few high demanding data analysis and calculations. The HPC cluster is running applications such as arcimboldo, for crystallographic ab-initio protein solution below atomic resolution, wien2k for electronic calculation of solids, etc.

The new in-house developed Electrometer (**Em#**) is ready to be deployed in the beamlines. It takes advantage of the experience acquired with the previous version of the current amplifier improving the ground architecture to achieve ultra-low current measurement capabilities and enabling current acquisitions under voltage biased conditions up to 1kV. The Em# includes a new ADC with higher resolution and sampling rates and the whole digital processing architecture has been redesigned to have a more versatile instrument capable to implement real-time signal processing, feedback systems, etc. It will be an added value for the Beamlines fully integrated into the control system and continuous scans.

The PRINCE2 method has been successfully applied to organize the assignments to the different teams in order to run in parallel the facility operation and the construction project of beamlines, as already mentioned when presenting MIRAS.

a3ii Beamlines in construction

In the process of shaping the facility development, after a deep analysis of the ALBA capacities, of the progress of the fields and discussions with the SAC and the user community, it has been considered that improving capacities on photemission, microbeam macromolecular crystallograpy and industry-instrumentation had higher priority rather than in nanoimaging and coherence based methods, as announced in the previous strategic plan.

Today there are three beamlines in construction, all of them taking advantage of the European Funds for Development for the period 2014-2020, which cover 50% of investment and staff costs during the construction period. They are briefly described in the following. The other four beamlines approved in Phase III can be found in [6].

LOREA [7], a beamline for angular-resolved photoemission spectroscopy (ARPES) for complex materials, the second Phase II beamline of ALBA, mainly to be dedicated to understanding the electronic structure of graphene-based material, topological insulators and other advanced materials. The project was approved in 2015. During the period 2015-16 the beamline design was completed in two successive stages: optics conceptual design and end station conceptual design. The beamline source (a helical undulator) and the corresponding front end, along with the first optics elements and infrastructure were tendered in this same period, the target being to complete all the tenders within 2017, proceed partly in parallel with installation and commissioning starting in Summer 2017. The target is to enter user operation in 2019.

XAIRA [8], the first phase III beamline, devoted to macromolecular crystallography with a micrometer-sized X-ray beam, was approved during 2016. The project initiation document, key for defining the main ingredients of the project and establishing the scope, quality, cost and schedule boundary conditions, was presented for approval at the very end of 2016 (and approved shortly afterwards). The plan is to build this ambitious beamline along the period 2017-20, with the target of welcoming the first users by the end of 2020.

NOTOS is the second of the six Phase III projects [9]. It original mission, as stated in 2014, was mainly the development of scientific instrumentation and innovation, with a robust program of technology transfer to Spanish companies. This mission is now strengthened by the strategic technological roadmap shared with European Photon Sources through the LEAPS (League of European Accelerator-based Photon Sources) [10] Partnership. In addition the scientific case for this beamline has been extended due to the decision of MINECO of merging the present branch A of the Spanish CRG BM25 at ESRF with the original NOTOS incorporating a considerable part of elements from BM25-A to the initial design. The NOTOS beam line will therefore serve as well users in EXAFS and powder diffraction, devoting to these techniques a substantial part of the total beamtime available. If everything evolves as planned, this beamline is expected to be open to users within the first half of 2020.

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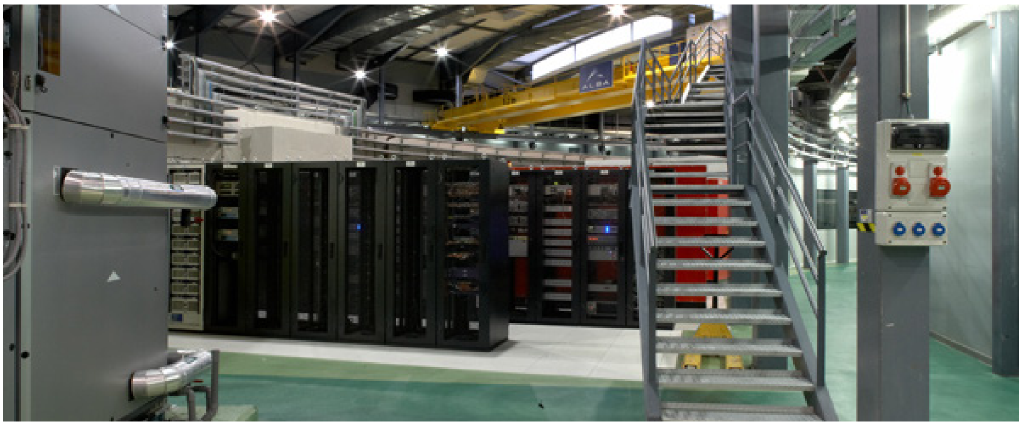
BL06-XAIRA is co-funded by the European Regional Development Fund (ERDF) within the Framework of the Smart Growth Operative Programme 2014-2020.

a4 CONTROL SYSTEM

The control system [11] refers to the assembly of hardware, and software devoted to the acquisition of signals and data, as well as the transmission of commands and set points. The system supervises, regulates and operates the different subsystems of the particle accelerators, beamlines and experimental stations with their large variety of instruments, mechanisms and detectors to observe how light interacts with matter in the samples. The control system integrates automatic regulation, open and closed loops and operator interfaces incorporating a large number of tools including alarm handlers, historical databases and complex sequences.

The ALBA control system is cost-effective and has proven to be reliable and maintainable during operation. The Computing & Control engineers balanced risks and costs, standardized hardware, procedures and software, keeping an open mind to exceptions when appropriate. The control system and the computing infrastructure work 24/7, and are high performance, robust, resilient and reliable; the computing team ensures the support and maintenance of the software tools, the Information Technology (IT) infrastructure and the electronics' equipment and instrumentation.



On the software side, Python, adopted in 2005, is the most used programming language for both server and client applications. This choice paid back in the last years, as Python is today the fastest growing programming language in scientific institutions, for data analysis, graphical interface sequences, and for data acquisition as well.

Commercial SCADAS (Supervisory Control and Data Acquisition software) have adapted well to the industrial environments and are now at the core of industrial processes largely integrated with other applications. Scientific installations still have particular requirements not covered by commercial off-the-shelf software, so collaborations with other institutes are important in order to share the costs of software development. TANGO, started at the ESRF, is a good example of a successful collaboration, where a growing number of laboratories around the world share efforts to write common software tools.

ALBA initiated a project named SARDANA already in the early days of the project; later it became an international collaboration with DESY in Germany, MAXIV in Sweden and Solaris in Poland as the main co-participants, and with a large number of other institutes and companies using the software (published free open source, with an LGPL license on gitgub). SARDANA uses TANGO as middleware to fulfill the requirements of the experiments in a beamline and has also initiated a framework for building graphical user interfaces called TAURUS. SARDANA provides a macro environment to edit and run sequences and macros, together with a hardware repository, which configures and controls the motors, detectors, counters, timers and synchronization elements participating in the data acquisition.

In 2013, the collaboration was pushed to the next stage, formalizing a model for the community to drive the progress. SARDANA and TAURUS Enhancement Proposals (SEPs and TEPs) are created from the needs of the different laboratories, discussed on public channels and given priority and implemented according to the overlap of the needs and to resource availability. As an example, the SEP6, which implements continuous scans in beamlines as the standard data acquisition method, has been completed in 2016 and made public to the community, moving a step forward the standard data acquisition scans. The experimental data and associated metadata are permanently stored in the data center with 10 Gbps direct links from the experimental stations capable to handle data rates up to 600 MB/s from a single Beamline. The current storage has a net capacity of 256 TB with more than 750 TB uncompressed on tapes for backups and archive.

The data to store continuously increase duplicating the total amount produced every two years. The reason is because more efficient detectors, automation, synchronization and data acquisition systems and on the other hand more complex preprocessing and data analysis algorithms are requiring the use of data storage. The total figure will outrun 100 TB/year in 2017.

The experimental data produced by each experiment is stored on spinning disks for a period of time close to two years, depending on the availability of disk space, and later is only kept archived on tapes.

Access to raw data and the associated metadata obtained from a public access experiment is restricted to the experimental team for 3 years. After this embargo period, the data can be made publicly available. These data are remotely accessible by the research group. Some Beamlines offer as well a remote access service for carrying out experiments from their home institutes.

Proprietary access experiments are carried out keeping the proposal, raw data and results confidential.

a5 ENGINEERING CAPABILITIES

ALBA provides and maintains the technical support related to the construction and operation of the facility, in the areas of mechanical engineering, finite element analysis and calculation, project management, civil engineering and maintenance of assets and processes. The corresponding division operates on the fields of instrumentation design, project office, prototyping, workshops and laboratories exploitation, design office, logistics and transport, infrastructure design, construction, maintenance security and access control. Being organized on a matrix scheme, it has the possibility to reallocate the resources according to the needs of the projects, and increase and decrease in size in function of the phase of the project.

Cutting edge engineering methodologies and techniques are applied on high demanding components. Vibrational analysis, thermo-mechanical coupled simulations, and ultrahigh vacuum Montecarlo simulations are combined to produce the most suitable design according to the specifications.

a6 SERVICES

Particle accelerators in general and Synchrotron Light Sources in particular need expertise in many technologies. The knowledge obtained in the construction and operation of ALBA is offered to other institutions and industries, through the exploitation of services and specialized laboratories originally developed for the infrastructure needs. Some of these technologies are developed in ancillary laboratories but the knowledge is much broader. Let us mention the expertise in cooling systems, electrical and thermal power supplies, etc.

Up to twelve different external groups have accessed our structures to use these specialized labs, providing first of all valuable interchange of experiences, and secondly economic means for upgrading the structures and/or hire dedicated personnel. Figure 6 shows how the usage has strongly increased in the last two years.

In what follows the laboratories which are configured as standard services to external users are described in some detail (the so-called *ancillary laboratories*). Those services, included in the corresponding database catalog are: optics and metrology laboratory, magnetic measurements laboratory and radiofrequency laboratory. On the other hand ALBA has available other capabilities, which are used to complement the standard services (like user laboratories complementary to beamtime access) or to conduct eventual ad-hoc collaborations with other institutions. They are all listed and briefly discussed subsequently.

Information on the different services and their access mode can be found in [12].

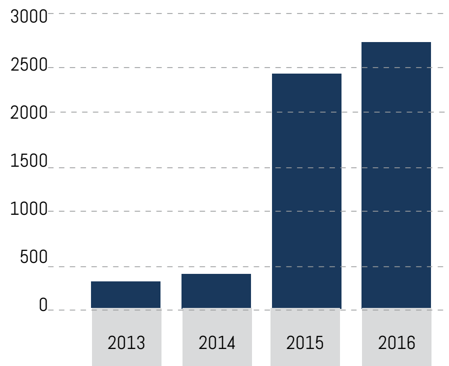


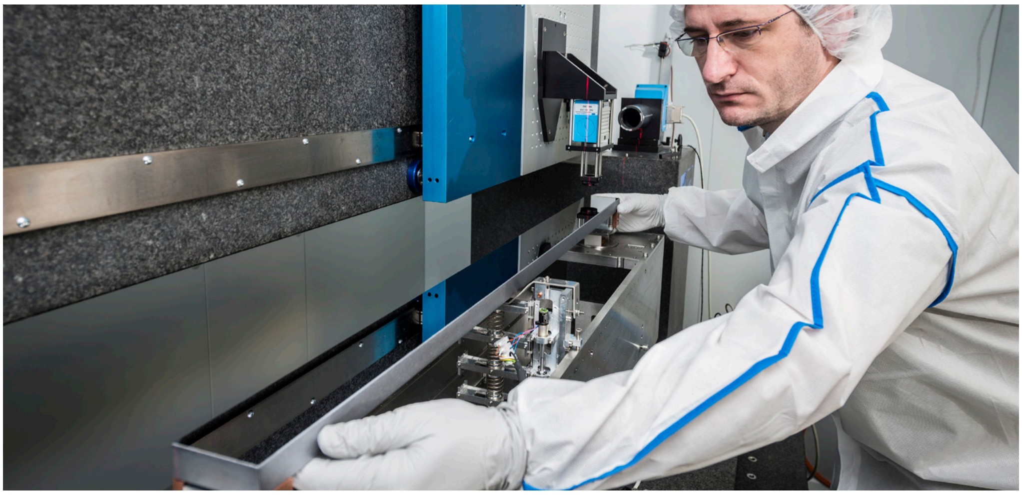
Figure 6 –Hours per year of external usage of specialized laboratories.

Optics and Metrology Laboratory

This laboratory is offered as a standard service and is therefore included in the database catalog. Its main instrument is the NOM (Nanometer Optical Measurement) profilometer. After its use to characterize the mirrors of Phase I beamlines, it has been focused to develop the Nanobender [13] project and to improve metrology techniques. Besides the prototype, this project has originated several publications and two patents, one of them licensed to the engineering company SENER.

The accuracy of the profilometer has been improved in order to obtain a measure of the systematic errors of the instrument, together with an error-free measurement of the surface under test. Such techniques have been implemented to several sets of measurements and a continuous scan has been implemented to allow taking advantage of these techniques in workable time. ALBA profilometer is today as good as the best profilometers in the world, in terms of noise, sensitivity, stability or systematic errors.

The laboratory has quite unique systematic error suppression methods and very accurate optimization models for mirror benders and has started to measure systems for other institutions such as the SwissFEL.



Magnetic Measurements Laboratory

As in the previous case the Magnetic Measurements Laboratory is included in the database catalog as a standard service. It is available to perform accurate magnetic measurements (100 ppm) of high magnetic fields (up to 2 T) in 3D volumes, with a high degree of spatial accuracy. Such measurements can be carried out for up to 2 m long structures as dipoles, quadrupoles and sextupoles, as well as combined function magnets, insertion devices and long magnetic arrays. It is equipped with a Hall probe bench, a flipping coil bench, and a rotating coil bench for magnetic multipole measurement. Helmholtz coils and a fixed stretched wire bench are used to characterize single and assembled blocks of permanent magnets.

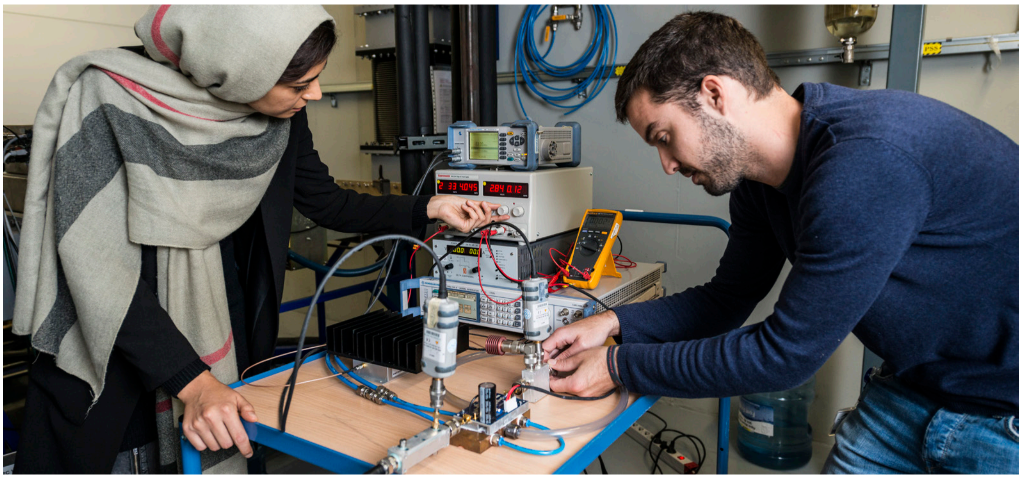
The laboratory is also equipped with special non-magnetic mechanical tools used to manipulate magnets. It can also model and optimize magnetic designs using 3D simulation tools as Radia or Opera. It is used, whenever necessary, to characterize magnetic instruments to be installed at new ALBA beamlines. During the period 2013-2016, the MagLab has been used in order to develop collaborations with other institutes (CERN, SESAME, CIEMAT, ThomX-LAL) and to give service to industrial partners. In particular all SESAME dipoles were measured therein, as well as all ThomX-LAL magnets.

Radiofrequency Laboratory

The Radiofrequency Laboratory (RF), also included in the service catalog, is devoted to tests and calibration of radiofrequency components and complete subsystems: Low Level RF, waveguide component tests, amplifier acceptance tests, high power cavity conditioning and checking complete systems operation performance. It is equipped with a complete 80 kW - 500 MHz RF system, including a radiation protection bunker certified by the Consejo de Seguridad Nuclear (CSN).

The infrastructure includes: High Voltage Power supply (36kW-4A), IOT RF amplifier (80kW), waveguide equipment, low level electronics, personal safety system, water cooling, compressed air and the complementary instruments. The laboratory can also model and optimize RF designs using the 3D simulation tool Microwave Studio. In addition, with its modular design, it allows the test of other RF systems with different frequencies and power levels.

New IOTs are all extensively checked in this laboratory. On top of that, during the period 2013-2016, the laboratory has been used in order to develop collaborations with other institutes (CERN, CIEMAT) and to give service to industrial partners.



a6ii Laboratories open to users

A series of other laboratories or facilities are also open to users as a complementary tool to the access to beamtime at the beamlines, or are available for ad-hoc collaborations with external institutions. They complete the technological offer of the infrastructure, but are not considered a standard service.

Chemistry Laboratory

The laboratory has an Ar gas filled glove box intensively used by the battery users' community and used for preparation of air sensitive samples and an alumina tube for the already present tubular furnace. It is also used for effective chemistry activity (not only storage of hazardous and/or flammable products). A set of Good Practice policy rules guarantees the lab safety.

High Pressure Laboratory

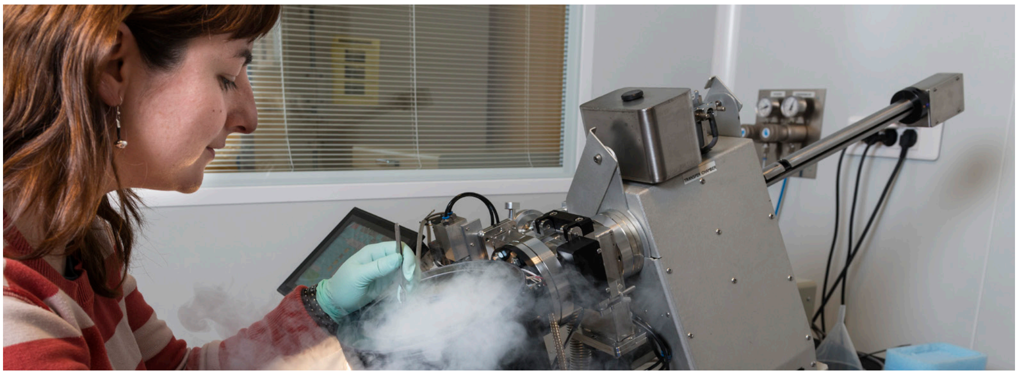
It includes diamond anvil cells; two automatic systems and a manual one for generating the pressure up to 50-60 GPa; vacuum vessel able to anneal samples up to 1000K by resistive heating technique; two microscopes with proper equipment for loading samples in the cells. Equipment for cryogenic loading of Ar and N^2; a semi-automatic Almax-EasyLab spark eroder for drilling the gasket holes; two computer controlled laser spectrometer systems for pressure determination by means of ruby fluorescence method.

Material Science and Microscopy Laboratory

The following tools are available: a UHV-based Scanning Tunneling Microscopy (STM) surface science setup including sample preparation and analysis chambers as well as standard sample preparation tools to be used for thin film preparation by Atomic Layer Deposition (ALD) and plasma-enhanced chemical vapour deposition (PE-CVD) and subsequent characterization; a UHV surface science system for the plasma-enhanced PE-CVD of graphene and carbon nanostructures; a UHV surface science system for test operations regarding the in situ low-pressure RF plasma cleaning of beamline optical components; a wire bonder for the electrical connections on PEEM samples; and an electron beam deposition system for thin film deposition (via a collaboration with ICMAB).

Biology Laboratory

The biology lab has all the necessary equipment to allow for the inhouse production and preparation of biological samples. This has resulted in the analysis of proteins produced, purified and crystallized at ALBA at the NCD and XALOC beamlines. In addition, samples for MISTRAL and MIRAS are routinely prepared in the lab.



a6iii Laboratories for internal use and collaborations

Helium liquefaction plant

A helium recovery network and liquefaction plant have been implemented in a 80m^2 hutch with all the required infrastructure, including a 78m^2 slab to mitigate vibrations from the compressors to the experimental hall. The aim is to recover about 500 l/week of liquid helium once evaporated in the cooling processes. This will be carried out with efficiency greater than 80%.

By means of a collaboration agreement it could eventually liquefy helium for external collaborating institutions in case they have a proper recovery system.

Vacuum and Cryogenics Laboratory

The Vacuum and Cryogenics Laboratory is deployed in a class 100.000 clean room equipped with pumping, measurement and bake-out equipment as well as laminar flow cabinets. The lab provides support to operation and maintenance of the existing vacuum system elements and is the assembly integration and test area for these elements.

The Cryogenics station inside the vacuum laboratory is basically a Helium Cryostat aimed at testing Cryogenic elements and calibrating probes and detectors for the experimental set-ups. It is prepared to include a Raman spectrometer in the future.

Survey & Alignment Laboratory

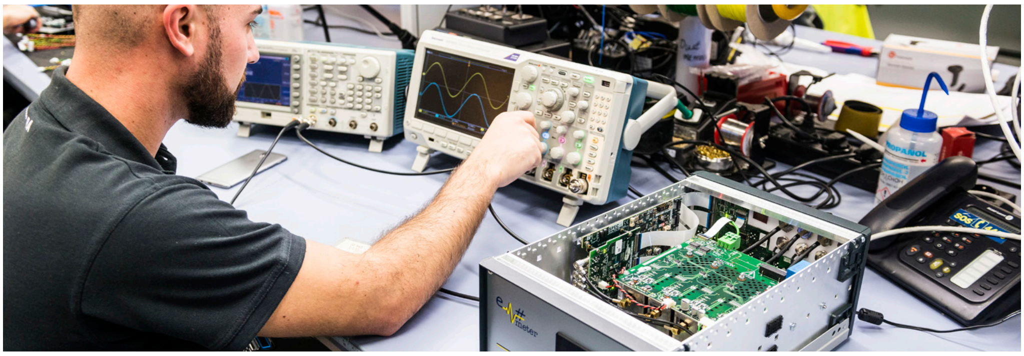
This laboratory provides survey and alignment services, fiducialization, positioning and metrology, with resolutions of 10μm (position) and accuracy in the order of 15 μm and 0.05 mrad (angle), based on a FARO laser tracker. This instrumentation is used to maintain a dense network of reference points which provide the criteria for deciding total or partial realignment campaigns whenever convenient. It is also equipped with an extensometer HBM MGC to provide extensiometry (stress and deformations) test and analysis service.

The lab also provides a full vibration test capability by means of a vibration measurement device with accelerometers and a seismograph.

Electronics Laboratory

It provides services and development projects to maintain instrumentation and infrastructures of control systems and data acquisition. Services include: characterization of instruments, maintenance of electronic connectors and cables, loan of equipment or technical support in general. Includes a small workshop area where a limited number of equipment assemblies can be performed and Printed Circuit Boards (PCB) up to a certain level of complexity can be produced and mounted.

The Instrument /Detector pool located in the lab manages more than 300 pieces of equipment available on loan for the whole installation. Recently a critical stock store has been setup, which will speed up the time-to-repair of hardware in both accelerators and beamlines.



Mechanical Workshop

A 380 m^2 workshop is available with capabilities for prototyping and production of devices up to 1 m length, as well as production of mini-series, with capacities for transport and manipulation operations. The workshop is equipped for assembly, adjustment and alignment of complex mechanical systems, with tools for mechanical metrology, including a clean area of 6 m^2 and a specific welding box with specialized capabilities.

A proximity workshop in the experimental building gives immediate support in mechanical matters to BLs, to produce or modify pieces on a short-term basis.

a7 HEALTH AND SAFETY

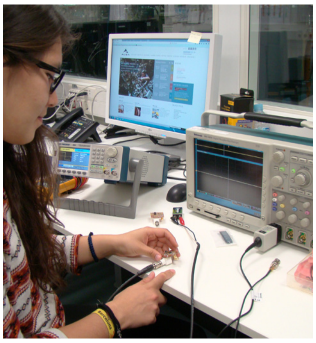
Safety of staff, users, visits and equipment is a priority for ALBA.

Radiological protection policies were fully established at the beginning of the commissioning period 2010-12 and put in practice since the CSN start up notification in 2012. Since then, those policies have been applied in a systematic way with just a few changes. The most relevant one was the classification of the ALBA experimental hall as public area, as originally planned and approved after extended experimental evidence that the shielding system behaved as designed, also in Top Up operation mode.

On the other hand, the conventional safety system has been in gradual evolution during the full period. ALBA has an external prevention service, which was reinforced with a new contract, with extended scope, from 2015 onwards. This external service complements and collaborates with an internal Health and Safety office. One of the remarkable implementations of the last few years is a well-established system for risk evaluation and follow-up of experimental user visits, based on the assignment of safety flags (green/yellow/red), depending on the level of risk detected upon proposal evaluation and implying different actions when the experiment is actually performed.

In addition to the structures defined above there exists a Health and Safety committee, as established by the Spanish legislation, which gives advice on safety aspects and channels the information and participation of workers in this respect.

a8 TRAINING PROGRAM



The ALBA training program has been established on firm grounds during the period 2013-16, reaching a reasonable level of maturity. It comprises the following main subprograms:

- ***PhD training program***, based on collaboration with external institutions and universities, under ALBA personnel supervision. It hosts at the end of 2016 seven Early-Stage Researchers (ESR), with a significant number of additional collaborations in the pipeline. It includes also a PhD industrial program in collaboration with companies.

- ***University undergraduate*** student program, which is organized on the basis of yearly public calls for ca. 6 month long part-time internships. In the last call, launched in September 2016, a total of 18 students were selected to conduct their internships along 2017.

- ***Professional training*** student program (FP), in collaboration with the Education department of the Generalitat, which selects proper education centers for the different training profiles available at ALBA. Internships are part-time, 10 month long, following the so-called "dual" methodology, which has been adopted by Generalitat as a strategic approach and combines lecturing with hands-on training at companies as an integral part of the student's education. A total of 11 FP students are at ALBA for the 2016-17 term.

a9 COMMUNICATION AND OUTREACH

The period 2013-16 saw a strong transition in terms of communication and outreach, moving from a part-time, best-effort basis scheme, to having one person full-time devoted to the subject in a professional way. A very active program has been established. For the general public once a year it includes an Open Day event, which in 2016 reached more than 2000 visitors. All year around there is a group visit program, particularly focused on students and professionals, which welcomes ca. 5000 visitors per year.

The Communication and Outreach Office is responsible of the publication of a yearly activity report and periodic newsletters, reporting on the main achievements of ALBA [14] and issuing frequent web news specific relevant events, including press releases for the most relevant cases.

Other specific ad-hoc outreach activities, includes courses for training of high-school teachers, involvement in global events such as the International Year of Light 2015, European Researcher's Night, collaborating in exhibitions at Science museums, to cite but a few.

In 2014, a new ALBA public website has been released including a new corporate image. The Transparency Portal is active since 2016.

Synchrotron Light Sources are large research infrastructures, based on initial conspicuous investment and continuous support during the operation period. They are usually unique at national level in countries of the size and research capabilities of Spain. As today ALBA is the only Spanish photon source based on accelerators, and we therefore conduct our relational analysis only at international level.

Synchrotron light sources have evolved since the '60 in terms of generations, being the brilliance increase the parameter which defines the passage between successive generations. The brilliance is directly related to the intensity of the stored electron beam and to its emittance. The third generation, based on low emittance storage rings and presence of sophisticated insertion devices where the photon beam production can be tuned in terms of energy range and polarization, appeared in the '90s. Most of the present synchrotron radiation facilities belong to this generation. ALBA represents the youngest 3rd generation facility in Europe. Figure 7 shows the present map of the worldwide synchrotrons dedicated to photon production.

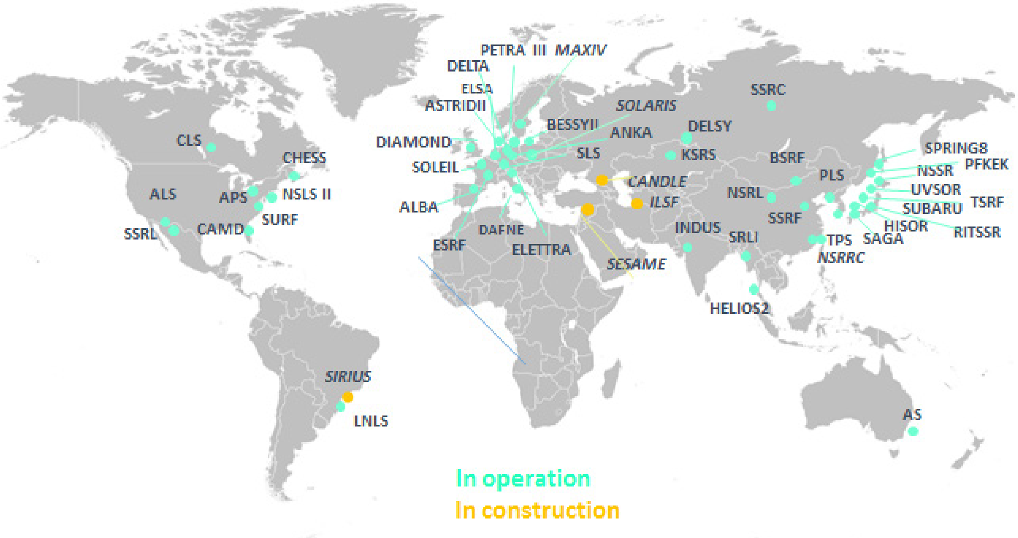


Figure 7 – Map of worldwide synchrotron light source.

Synchrotrons light sources can be classified according to the beam energy: low (E < 2 GeV), medium (E 2-3.5 GeV), and high (E > 6 GeV) energy ones, corresponding in average to soft, soft to medium and hard X-ray ranges, respectively. The natural photon energy range is enlarged thanks to the use of different IDs.

It is worth comparing ALBA with the newest medium-energy synchrotrons, those whose operation has started after the year 2000, as listed in Table 4 with their main characteristics.

First of all let's compare the ***design***. The 3rd generation corresponds to emittances above 1 nmrad. Increasing the circumference allows decreasing the emittance with the associated increase of cost. Figure 8 shows the emittance normalized to the parameter Energy^2/ Circumference for the facilities of Table 4. ALBA has an optimized design with respect to older facilities, also considering the large number of available straight sections.

The 4th generation, based on MultiBend Achromat technology [15], aims at emittances of few hundreds of pm.rad, and the two first facilities in operation will be MAX IV [16] and SIRIUS [17]. Sources which are in operation since one or two decades are considering upgrading the accelerators for implementing the same technology, following the example of ESRF, whose upgrade ESRF_EBS [18] will be completed in 2020.

Secondly let's compare the ***beamline capacity*** and its exploitation. Most of the facilities are taking full advantage of the potential in terms of beamlines, especially those with whom we more naturally compare, like SOLEIL, DIAMOND and SLS. ALBA has up to 29 beamports. We consider that the original plans of filling up all the ports are not any more valid, since the slowness in beamline construction due to economic restrictions has changed the strategy. We aim at a maximum of about 20 beamlines, and then critically review the existing ones for possible upgrades, also in view of a source upgrade that should be prepared for a decade from now.

NAME	LOCATION	Operational	Gener	E(GeV)	C (m)	ε (nm rad)	BL in oper	BL in constr	Upgrade plan
SLS	Villingen, CH	2001	3rd	24	288	5	17	0	YES
CLS	Saskatoon, CA	2004	3rd	2.9	171	18	16	0	YES
SOLEIL	Paris, FR	2006	3rd	2.75	354	3.1	29	0	YES
DIAMOND	Chilton, GB	2007	3rd	3	560	2.7	33	0	YES
AS	Melbourne, AU	2007	3rd	3	216	8.6	9	0	-
SSRF	Shanghai, CN	2009	3rd	3.5	432	4.8	15	21	-
ALBA	Barcelona, ES	2012	3rd	3	269	4.6	8	3	YES
PLS II	Pohang, KR	2012	3rd	3	282	12	32	0	-
NSLS II	Brookhaven, US	2015	3rd	3	792	1	17	3	-
TPS	Hsinchu, TW	2016	3rd	3	518	1.6	7	14	-
SESAME	Amman, JO	2017	3rd	2.5	133	27	2	2	-
MAX-IV	Lund, SE	2017	4th	3	528	0.3	8	3	YES
SIRIUS	Campinas, BR	2019	4th	3	518	0.25	13	0	-

Table 4 – Medium energy Synchrotron Light Sources starting operation after 2000

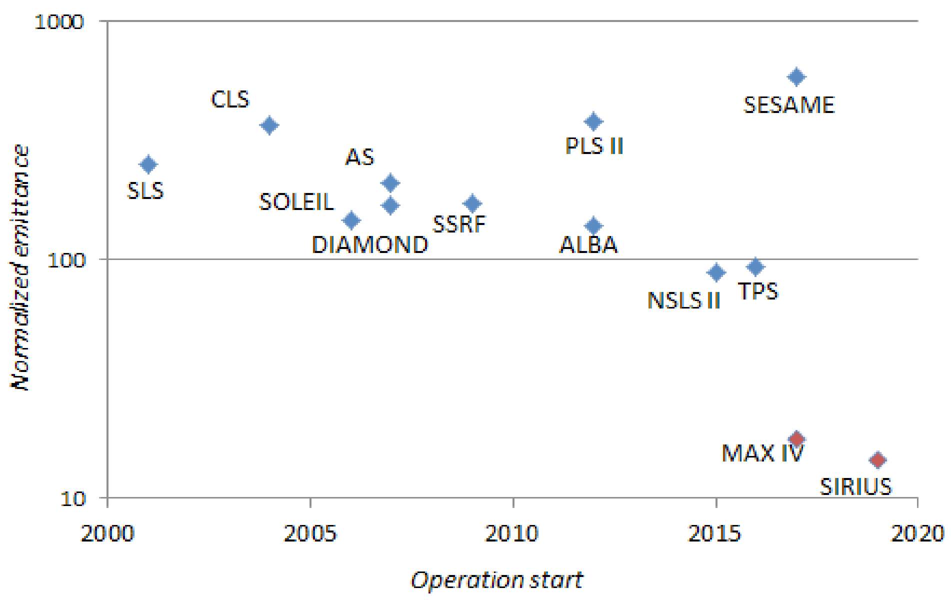


Figure 8 – Emittance normalized with circumference and square of energy plotted versus year of operation start of light sources included in Table 4. Blue dots correspond to 3rd generation light sources, red to 4th ones.

We compare now the ***operation performances***, which were already shown in Figure 5. Comparing our numbers with three of the most performant European facilities we see that we have reached a competitive level of performance (see Figure 9), and design, realization and operation of the whole infrastructure are to be commended. On top of that the merit goes to the staff: if we normalized the indicators with the operation budget and total staff, two of the factors which most influence the capability of a facility for keeping high operation standards, we should be even prouder.

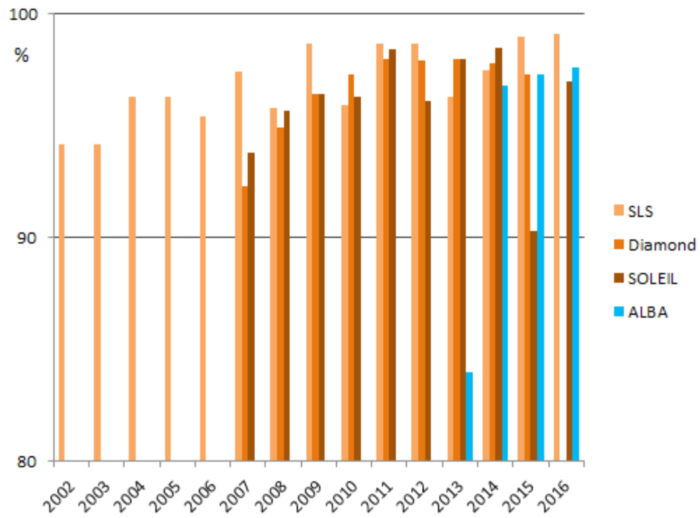


Figure 9 – Historical availability of different 3rd generation European facilities.

For comparing the ***scientific specialization***, let us quote what was written in the introduction about specialties. Even if the total number of beamlines is not comparable with other more mature synchrotrons, we have special instruments which are making our facility one of the few and in some cases unique for some applications, like the cryo microscope MISTRAL or the MARES end-station of BOREAS for resonant scattering. On top of that the full range of beamlines covers a large part of the needs of the Spanish community. It is mandatory to complete with other beamlines the fields not yet reached, as the hard X-ray tomography or the surface diffraction.

We will not repeat here what appears in other paragraphs of the document, about scientific results and number of publications, but we just mention that we are fully competitive with other similar facilities.

ALBA is fully integrated in the international net of research infrastructures. Inside the synchrotron light community it has, even from the very first dates of the operation, participated to the European Commission projects of transnational access, in CALIPSO and BIOSTRUCT.

The international percentage of our users doubled in few years from the original 18% up to almost 40%, maintained at high levels even when the EU projects of transnational access were not any more active, what happened at the end of 2015 and the beginning of 2016 for CALIPSO and BIOSTRUCT respectively.

ALBA is a unique infrastructure, a cutting-edge experimental tool unique in Spain because of its contents and its performance, open to the entire R&D&I system of the country, scientifically and technologically advanced, essential to carry out research and technological developments, so that its non-existence would represent a limitation or loss of opportunities for the country, considered as national S&T heritage because of its quality, and whose construction and conservation is strategic and must have the highest priority. Similar facilities are operating in all innovative and R&D advanced countries of the world of sizes similar or even smaller than Spain. In addition to this flagship character for the Spanish S&T, ALBA reinforces the Spanish participation to the ESRF. Main activities are described in the annual reports [19] [20] [21] [22].

Collaboration with sister facilities, especially from Europe, is an important asset of the usual activity of ALBA staff for maintaining expertise at the state of the art in synchrotron science and technology. In the database an exhaustive catalog of formal collaborations and collaborative projects is given, and we highlight here the most significant.

ALBA has fostered the participation of Spain as observer member of *SESAME* [23], the international synchrotron recently inaugurated in Jordan under the auspices of UNESCO. There is an active collaboration through the participation in the European Commission projects CESSAMag and OPEN SESAME.

ALBA has a prominent role as work package leaders in the projects *Calipso*+ [24] for Trans National Access of academic and industrial users.

ALBA has established several international collaborations in the fields of controls systems and electronics, as *Tango, Sardana, Taurus* and scientific *SCADAS* (Supervisory Control and Data Acquisition Software). Plus other mutual agreement basis, for developing special systems, as for example the electrometer #Em, a project which became an international collaboration when MAX IV joined it in 2015 and other institutes, such as the ESRF, Soleil and SLAC, have expressed an interest in it.

At the Spanish level the collaborations with CLPU [25], CIEMAT [26] and CSN [27] can be highlighted: design and development of the compressor chamber for the TW laser and the compressor and experimental chambers for the 1 PW laser for CLPU; collaboration in the development of a superconducting (SC) cyclotron for medical applications with CIEMAT: the SC magnet is being measured with ALBA magnetic measurement equipment and the cavity has been tested and conditioned at high RF power in the ALBA RF Lab; research collaboration with CSN focused on radiation damage of biological specimens. Collaborations are as well held with other institutions, such as CMAM-UAM. Some of these collaborations proceed via formal agreements, whereas others are based on access to ALBA services or direct technical collaborations of mutual interest without formalization.

ALBA personnel participate regularly in committees of highly representative scientific institutions like CERN, SESAME, MAXLab, European XFEL, PSI and ESRF, Canadian Light Source, Australian Light Source, DIAMOND, HZB, EuPRAXIA, among others. Examples of the collaboration with CERN are the participation at EuroCircol for the design of the Future Circular Collider.

In order to foster internationalization and an ample use of the facility, ALBA has regulated the participation of external countries and entities mainly through the Partnership Beam Line and Association Agreements.

An Association Agreement has been established in 2016 with the Iranian Light Source, ILSF [31]. ILSF is the 4th generation light source project to be built in Qazvin, 140 km North-West from Teheran, presently in the design stage. Enriching collaborations between ALBA and ILSF have been going on already since 2010. The Iranian user community is young and is preparing to take full benefit from the future national synchrotron. A special program of training and access to ALBA beamlines is therefore an important part of the Agreement. Mutual benefit for technological developments and industrial qualification is a consequence of the collaboration.

Results of the intense international collaboration are the assignments for organization of conferences. Only in 2016 ALBA has successfully organized two large conferences, MEDSI2016 and IBIC2016 [28], several other international meetings and workshops. In 2017 the biannual conference ICALEPCS 2017 [29] and the international biannual LLRF workshop [30] will be organized.

ALBA participates to the *LEAPS* initiative [10]: the European X-ray synchrotron and FEL facilities have decided to establish a strategic partnership – the League of European Accelerator-based Photon Sources (LEAPS) – whose primary goal is to actively and constructively promote and ensure the quality and impact of fundamental, applied and industrial research carried out at their facilities. LEAPS is intended to:

- Encourage and facilitate discussions and exchanges among its members on issues relevant to shaping the technology of and future science at accelerator-based light sources in a worldwide perspective. Promote a collective strategy across European facilities, including development of specializations at individual facilities.
- Engage with stakeholders and organizations such as the European Commission and National funding agencies in all matters relevant to the development and long term sustainability of Synchrotron and FEL facilities with the objective of informing and shaping future policies and funding opportunities.
- Engage with the current and potential user communities to discuss their respective needs and anticipate and meet future challenges.
- Strengthen interactions with industry, to exploit more fully the potential of Synchrotron and FEL facilities for industrial research and to develop and exploit enabling technology.
- Cooperate with other Research Infrastructures engaged in the analysis and innovative use of materials and bio-structures, such as laser-, electron-, and neutron-based facilities.
- Develop and periodically update a landscape document outlining the impact of European synchrotron and FEL facilities and needs for developments in order to meet the scientific and societal challenges of the future.
- Develop and periodically update roadmaps and action plans for key technologies.

ALBA location at few kilometers from Barcelona provides an exceptional environment from the point of view of communication, since it is easily accessible from all over the world. Furthermore it is in the Barcelona university cluster which includes several advanced research institutes and facilities what foster collaborations on a daily basis. Being at the center of the Mediterranean it is also a natural destination of those north-African countries, with expectations on forthcoming scientific and technological progress.

ALBA is an environmental friendly infrastructure. The building was constructed with the support of the POLICITY program of the European Union and the usual energy supply arrives from a natural gas cogeneration energy plant which provides both thermal and electrical energy. The building and the garden designs were done with the purpose of preserving the wildlife diversity of the surroundings of the Collserola natural park.

ALBA is an instrument for providing synchrotron light to solve societal challenges, from health to energy production and storage, from environmental defies to communication advances, from understanding to preserving our cultural heritage, in full consistency with H2020 programs.

The first five years of operation have resulted in hundreds of experiments carried out at the beamlines, thanks to stable and reliable operation based on sound design and realization at the service of the scientific community.

ALBA has contributed also to a huge development of the Spanish synchrotron light user community; to the attraction of competitive national and international users and funding; to the cutting edge in-house scientific research and technology development program; and to the development of an industrial synchrotron radiation user community.

Innovation and technological transfer mainly towards national industries are one of the priorities of the facility.

On top of this let's highlight the capacity of ALBA towards improvements of the society, by means of its efficient outreach and student training programs, its fruitful collaborations with other national research facilities and strengthening its international links with foreign institutions.

As mentioned ALBA is engaged in the realization of what has been named Phase II and III beamlines, consisting of enlarging the beamline portfolio for attending the Spanish community needs, as mentioned above in this document.

ALBA is also a European facility, in collaboration and constructive competition with the other European photon sources.

It is engaged in collaborations beyond Europe to create bridges between different cultures, using scientific language, and the already active examples are the Iranian association and the commitment in helping the SESAME project.

c INVESTMENT

A large research infrastructure like ALBA needs an initial investment covering the construction period, and a long-term funding plan covering operation, maintenance and evolution of the facility.

The initial ALBA budget, 201 M€, covered the construction of the infrastructure and of the first seven beamlines, and the staff expenses during the 2003/2009 period. In 2008 a long-term funding plan was defined for the period 2010-2022, for the completion of the installation and for the operation and maintenance, but not for the evolution in terms of new beamlines. The plan has been rigorously respected by both administrations, allowing not only the construction but the setting of a fully competitive user facility.

The lack of new investments funds, which has hampered the evolution of the instrumentation, has been by a small amount compensated with remnants, savings, participation to competitive projects, industrial and laboratory income. These funds have been essential for starting the construction of Phase II, co-funding ERDF funds and covering the deficit during the period 2013/2016. Detailed figures have been introduced in the corresponding section of the ICTS database, and more will be described in the paragraph j. (Funding).

An economic impact and impact analysis of the investment in CELLS was done in 2003 by a team of prestigious team of economists headed by Prof. García-Montalvo [32], similar to the ones realized for the Canadian and Australian light sources. At that time the hypothesis was an initial investment of 163 M€ covering the infrastructure and only five beamlines. The analysis, under certain plausible hypothesis at that moment (discount rate 4%; inflation 2.5%) gave as result an internal rate of return of 9.4%.

The same analysis was repeated at the end of the construction period in 2010 based on real costs. They assumed an operation for 25 years, an inflation rate of 2.5%, a discount rate of 4% and an operation of 230 days/year with a period of 5 years for the saturation. The results of the financial analysis were a benefit/cost of 1.18 and an internal rate of return of 6.4% (between 5.3% and 7.2%). The results of the economic analysis, including correction on the taxes, externalities, saving of time, etc., were a benefit/cost of 1.35 and an internal rate of return of 7.9%, showing a reasonable agreement with the previous study.

During 2017 a H2020 project, RI Pathways, has been granted to a joint community led by the University of Milan, for carrying out cost/benefit analysis for different RIs. ALBA is one of the beneficiaries, together with DESY and the Hadrontherapy facility CNAO in Italy. The analysis will be done with a different methodology and it will be useful to state the economic impact of the infrastructure in its operation period.

ALBA is an open access facility. The strength of a user facility is given by its user community, and its excellence is proved when scientific results account for it. Synchrotron Light Facilities as ALBA are mainly used by academic researchers who publish their results, while a small percentage of users come from industries which keep results for their private use (Proprietary Research).

In 2004 the Spanish user community created a user's association, AUSE, which accounted for about 200 participants. At present the Spanish community has evolved in a much larger group, as shown in Figure 10, almost a factor of 10 with respect to the dimension when ALBA project was approved, and a factor 2.5 from the operation beginning. Notice in the figure not only the increase of Spanish users, but also the internationalization of the facility. Figure 11 shows the time-evolution of the number of institutions with registered users at ALBA, where it can be seen that already in 2014 the number of registered international institutions surpassed the national one.

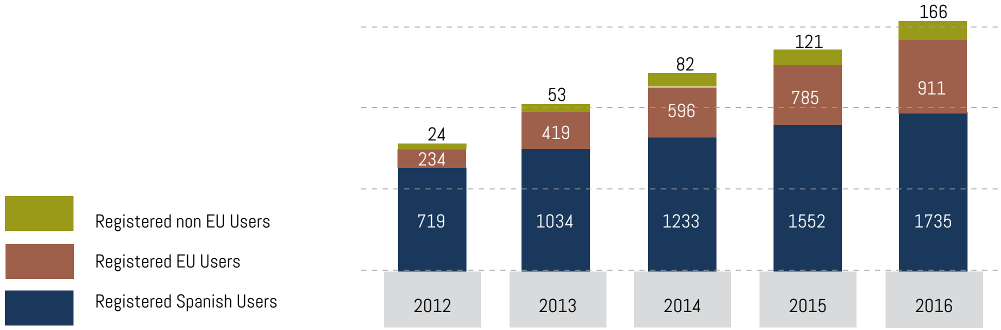


Figure 10 - Evolution of registered users.

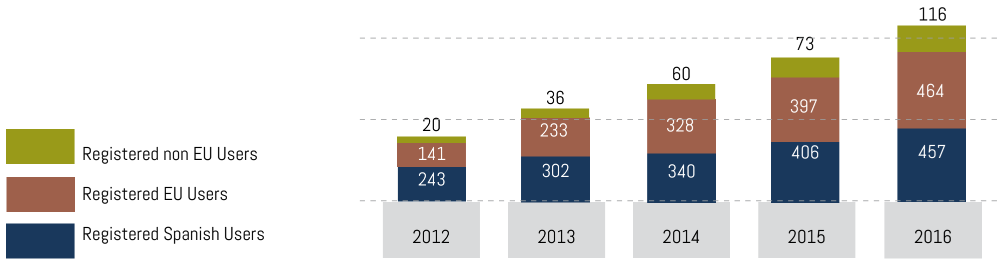


Figure 11 - Evolution of registered institutions.

The ALBA User Office has gradually established and improved the system for hosting the full user workflow, from submission of scientific proposals to welcoming users for effective realization of experiments at ALBA. The activities of the Office are well established, with a stable and reliable, in-house developed, software platform (exported also to other ICTS, namely the "Centro Nacional de Investigación sobre la Evolución Humana"). During 2016, as a reference, ALBA welcomed ca. 1350 user visits.

The access is through the User Office Portal [33]. Inside LEAPS ALBA intends to support and promote standardization of access procedures compliant with the European Charter for Access to Research Infrastructures; greater coherence in the developments of data-policy, -handling, -storage, -analysis, -access and the promotion of Open Science.

d1 ACADEMIC USERS

The research visits have gradually increased during the first years of operation (see Figure 12). First friendly users came in 2011, while commissioning beamlines and they were numerous during 2012 and 2013. May 2012 was the official operation start-up.

Beamlines entered in operation progressively during that year, alternating commissioning periods with user service. The increase in hours dedicated to users together with availability improvement (see Table 2) has resulted in more than 1100 official users during 2016. This number, when normalized with the number of beamlines, is fully competitive with the other synchrotrons in countries with a much longer tradition and more established communities, proving the strength of the Spanish community and the quality of the facility operation. From now on we will see the number of total users significantly changing only when new beamlines come into operation. A sustained in-house activity completes the panorama of the academic research in ALBA, and it is the backbone of the continuous improvement of beamline capabilities. Let's recall what is shown in Table 2 about the number of hours delivered to users during this period, which have increased almost linearly from 3540 in 2013 to 4368 in 2016. These numbers must be multiplied by 7, corresponding to the different beamlines. Around 65% of this time is dedicated to users through the user calls, 10-13% to in-house research, 10% for commissioning and developments; the rest is a buffer for industrial usage and other special needs.

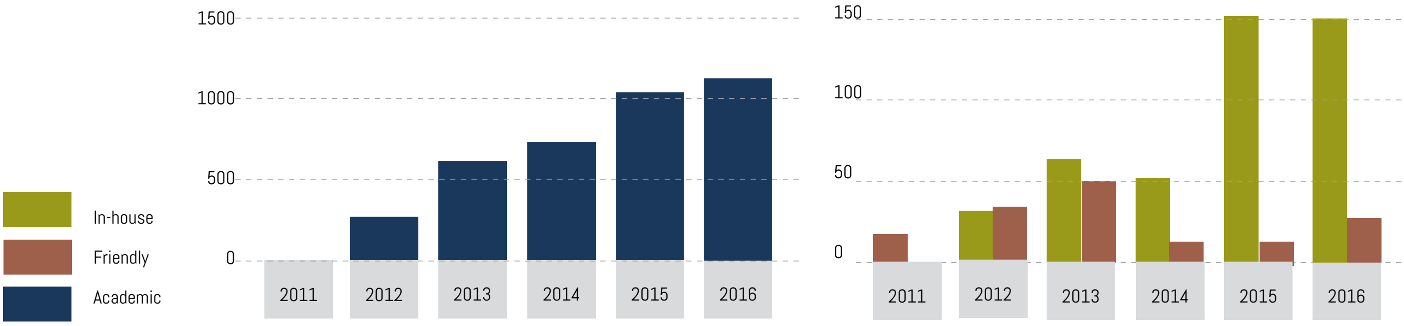


Figure 12 – Yearly number of users on competitive calls, in-house research collaborators and friendly user (note the different vertical scales on the two graphs).

The academic research is organized through the public competitive user calls. One call per year was opened for the period 2012/2014 and two yearly calls since 2015. The technical feasibility of each project is analyzed by the beamline scientific teams and the safety feasibility by the Health and Safety group. The scientific excellence priority is assessed by three independent evaluation subpanels related to the fields of life science, material science and condensed matter, all of them integrated into the formal Beam Time Review Panel (BTRP), as declared in the ICTS database.

As specified in Table 2, the yearly offered time has been increasing, and has reached now the steady state. The number of proposals received has followed a similar trend, maintaining an average oversubscription of about 2, spanning an interval between 1 and 4, according to the different beamlines and endstations. Figure 13 shows the total number of proposals submitted and granted per year and the percentage of foreign proposals (right), which has increased from the initial 17 % to a maximum of 40%, with a tendency to stabilize. The Spanish distribution per CC.AA. of submitted proposals is shown in Figure 14 up. Summing all the calls, researchers from up to 35 countries have submitted proposals, and up to 28 countries have been granted. Germany, Italy, France and UK are, in this sequence, the most represented. The granted international proposal ratio is close to 35%. Figure 14 shows the 2016 international distribution.

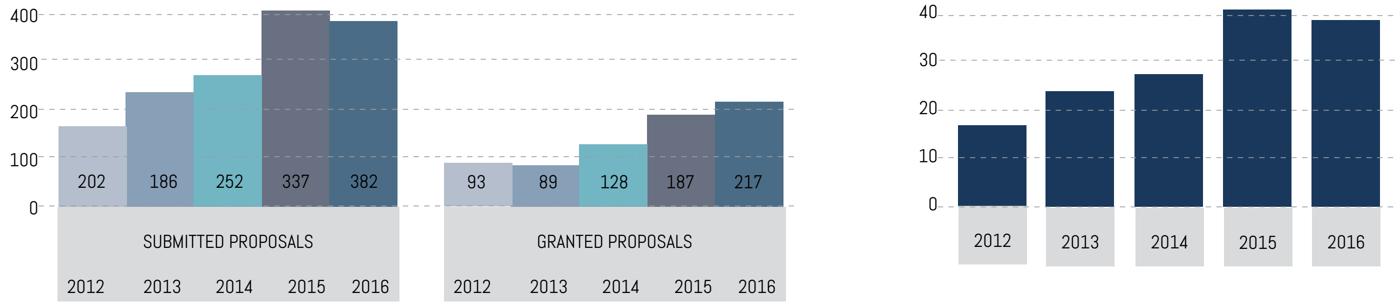


Figure 13 – Historical of submitted and granted academic proposals, and international submitted percentage.

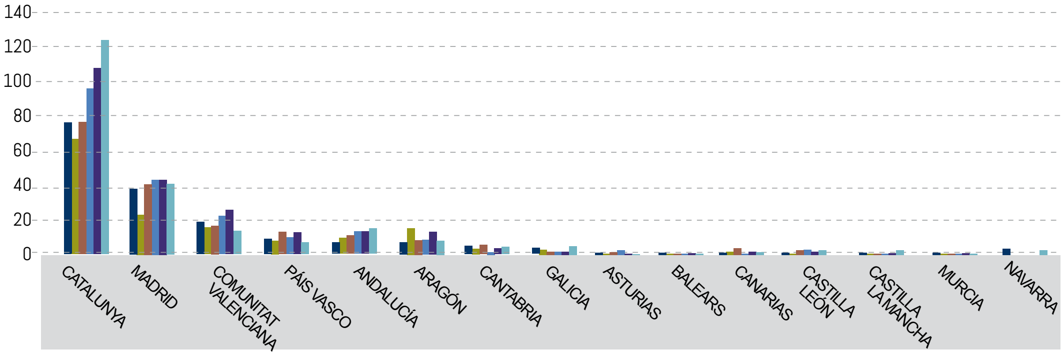
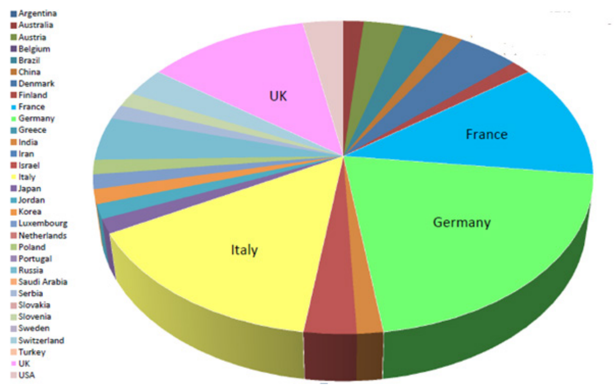


Figure 14 – Historical distribution of national submitted proposals per CC.AA. and distribution of international participation to 2016 call.



d2 INDUSTRIAL USERS

ALBA is fully committed to provide Proprietary Research as a powerful tool for promoting industry research and innovation and for maximizing the societal impact, having thus achieved one of the main goals of previous strategy plan.

The synchrotron light techniques are mainly driven by cutting edge scientific challenges which represent powerful tools for the industry research and developments paving the way to boost industry competitiveness. However, the companies are not always aware of their potential and in general they tend to perceive this type of research facilities as expensive and unfriendly. The main goal of the established Industrial Liaison Office (ILO) is precisely to attract industrial customers and to provide them full support when working with ALBA, which goes well beyond the support provided to the non-industrial users. So far the results obtained have demonstrated the appropriateness of the approach which provides a "one-stop shop" service.

The policy for proprietary access has been set based on industrial user needs such as direct beamtime access, reference fees, mail-in access, remote access and data analysis. Collaboration with external research expert organizations is a key ingredient to provide an integrated industrial service. Even if not foreseen in the previous strategic plan, international collaboration with ILOs from other synchrotrons has been developed as it is considered essential for providing a competitive service.

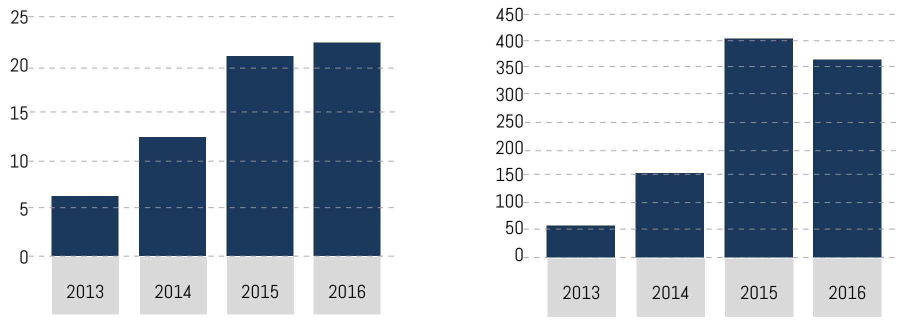


Figure 15 –Accumulated industrial beamtime users and number of industrial beamtime hours .

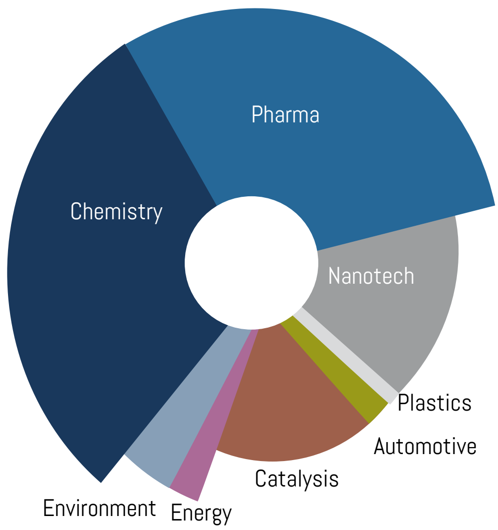


Figure 16 – Industrial usage per sector.

The proprietary user access has been largely promoted by industrial visits, participating in industrial association meetings, providing presentations in congresses, publishing industrial publications and through social media. Furthermore since 2014 yearly sectorial industrial workshops at ALBA premises have been organized, with more than fifty participants per workshop. In particular the workshops were dedicated to chemical industries in 2014 [34], to pharmaceutical industries [35] in 2015 and to cements, ceramics and glasses [36] in 2016.

That activity and a motivated staff have led to reach by the end of 2016 a portfolio of 23 different industrial customers (see Figure 15) using our beamlines, ranging from small to large companies, national and international. The industrial usage in 2016 (about 370 h) is slightly more than 1% of the total beamtime (about 31000 h). An intensive outreach is being carried out among the different industrial sectors to increase that usage. The sectors are shown in Figure 16, being the most represented Pharma and Chemistry.

The impact of ALBA use in industry is actually broader, since 27% of the academic proposals were labelled as “industrial relevant”.

The Scientific Advisory Committee (SAC) advises the ALBA Director on: scientific choices, means to optimize efficient usage of accelerators and research facilities, strategy, collaborations, industrial links, etc.

SAC members are appointed by the Rector Council, upon proposal from the Director, for a renewable two-year term. Their expertise covers all scientific fields represented in the ALBA community, plus technical knowledges. At present SAC includes two accelerator specialists as the Machine Advisory Committee (MAC, specifically devoted to advising the Director in relation to the construction of the accelerator complex) was discontinued when the facility entered regular operation, before the start of the period 2013-16. Special attention to gender balance is devoted when proposing SAC members.

The present members of the SAC at the moment of submitting this document are:
Andreas Jankowiak, Helmholtz-Zentrum Berlin; Valérie Briois, Synchrotron Soleil; Amina Taleb-Ibrahimi, Synchrotron Soleil; Wim Bras, Oak Ridge National Laboratory; Pedro Fernandes-Tabares, Max-IV; Martín Martínez-Ripoll, Instituto de Física y Química Rocasolano-CSIC; Trinitat Pradell, UPC Universitat Politècnica de Catalunya; Oliver Seeck, DESY; Ian Robinson, Brookhaven National Laboratory, chair; Marco Stampanoni, Paul Scherrer Institut.

In addition to SAC ALBA has a ***Beam Time Review Panel*** (BTRP), as explained above in this document and as included in the ICTS database. BTRP reviews experiment proposals received for each public call, with excellence as the main criterion and proposes to ALBA management the corresponding beam time allocation. At present the BTRP has three subpanels according to research subjects which meet simultaneously in order to better analyzing proposals in subjects of difficult classification.

Specific committees or expert panels are created on special topics when necessary. This was the case for example for the technical and scientific special review of the NCD beamline before starting its renovation during 2016.

The construction and management of a large facility as ALBA has no precedent in Spain both in complexity and investment. When the project was approved in 2003 a careful analysis led the decision of the owner administrations to constitute a consortium ruled by a Rector Council, chaired by the highest level representative of the two funding administrations, annually alternating. The formula has been proved adequate in the sense that now ALBA is a reality, the construction has been done in time and budget and the commissioning and first years of operation have been successfully achieved.

As explained in Part I, CELLS is a public Consortium with its own regulations. The Management of CELLS is assured by a divisional structure which has proved to be effective from the initial construction phase up to now. Figure 17 shows the present internal organizational chart of the Consortium.

The structure is distributed as:

- ***Accelerator Division***, which takes care of the operation, maintenance and development of the whole accelerator systems.
- ***Experimental Division***, which includes all experimental beamlines, each of them with its own team, a section for optical and metrology development, a section for specific technical and operational support of the beamlines, and the User Office.
- ***Engineering Division***, which deals with the infrastructure operation and maintenance, and with mechanical engineering, vacuum and alignment.
- ***Data Acquisition and Control Division***, which includes Control Systems for accelerators and beamlines, electronics and power supplies, Management Information Systems, and IT Systems.
- ***Administration Division***, which includes Human Resources, Legal Service, general administration and secretaries.

Three offices, directly reporting to the Director, complete the organization:

- ***Industrial Liaison, competitive funds and knowledge transfer Office***, dedicated to the relationships with industries for usage of our services or for innovation, and to the management of national and international competitive funds.
- ***Health and Safety Office***, whose main role has been already mentioned in the document.
- ***Communication and Outreach Office***, also mentioned before.

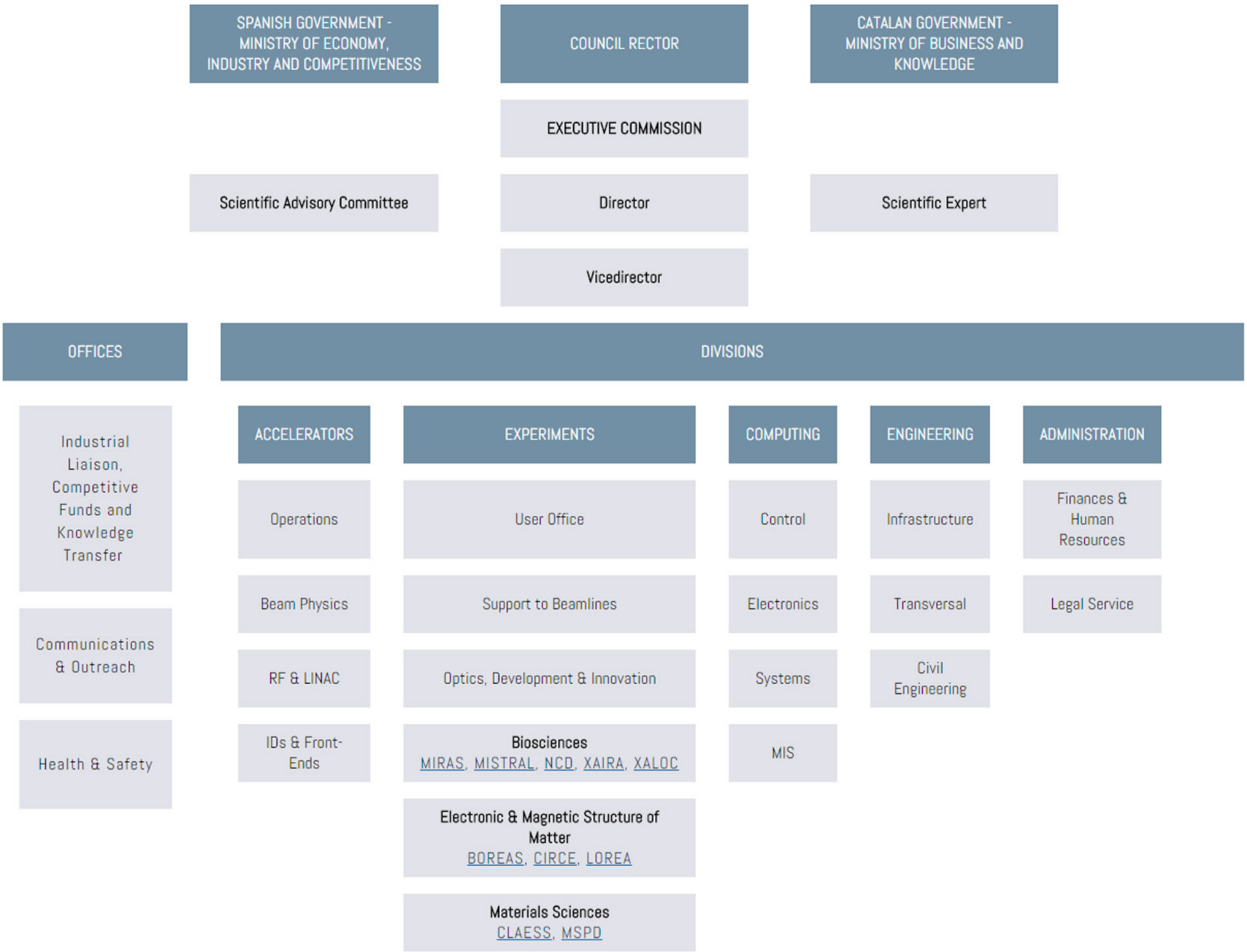


Figure 17 – Organizational Chart.

g STAFF

In the evolution of ALBA personnel we have mainly followed what was planned in the previous SP, adding staff whenever a new project was approved, even if due to the mentioned difficulties we have been forced to reduce the extra staff to a minimum. In particular in the previous SP we considered eight people were to be added for any new beamline. This rule was not followed for the Phase II Beamlines, where a reduction of more than 40% was applied, using the existing technical services to cover for the extra workload. The experience done during these last years, in which both operation and construction of new beamlines have coexisted in the facility, has given us the opportunities of developing a new model for the future staff incorporation for each new beamline that will be in the SP for the next period.

Staff numbers and details, according to the organigram presented above, are given within the ICTS database, taking as a reference date the end of 2016. On that date 187 positions are reported (notice that, as established in the rules for the ICTS database, only structural positions have been included therein, leaving aside those funded by fixed-term external projects). Such positions map all the functions directly or indirectly linked to the role of ALBA as a research infrastructure.

The ALBA personnel at the end of 2016 are 209 people, including postdocs and personnel hired by external funding. To be mentioned it is about 10% lower than forecasted few years ago. The foreign participation is more or less constant at about 21% and the percentage of women is constant around 26%.

The internal organization of ALBA is optimized to attend users. ALBA runs accelerators and experiments with minimum downtimes thanks to a high quality support. The operation of the accelerators relies on the operators group which is present in the control room 24x7. Incidents preventing the operation are monitored and addressed as fast as possible thanks to the additional support of the on-call services whenever required. The support to experiments affecting one beamline is from 7am to 11pm from Monday to Sunday during operation. The support to accelerators, infrastructures and incidents in general affecting more than one beamline is 24 hours.

Out of working hours and when the synchrotron operates, the critical incidents are addressed via the on-call systems, counting eight persons per week in the support divisions and covering a wide range of disciplines: control systems for accelerators, beamlines, Protection Systems and PLCs, electronics instrumentation, vacuum, cooling systems, power distribution and infrastructures. The time to fix an incident in nominal conditions is typically one or two hours, although the unpredictable variety of conditions and instrumentation failures can occasionally lead to substantially higher resolution times. The experience on continuous operation of ALBA has suggested the introduction of the new figure of floor coordinators, responsible of the overall scientific operation during nonsocial times and holidays. They take care of survey activities, respond to safety issues, give support to the accelerator control room, and manage the on call services existing in all the divisions. They can also carry out some basic user support as they can react in case of failures of equipment. This figure has added robustness in the operation reliability.

Each beamline has a team of four people (beamline scientists and postdocs) assisted by the necessary technical personnel from other divisions. Usually a graduate student completes the beamline team. The beamline personnel offer support to external users and carries on its own in-house research, often in collaboration with external users. This research is an asset for the facility, for maintaining it at the forefront of the technology, providing a better service to external users, attracting the best worldwide experimental groups, offering competitive instruments to industries.

h STRATEGIC PLAN

ALBA was approved after several independent studies analyzing the feasibility of a Synchrotron Light Source in Spain evaluated by the Spanish Committee for Large Scientific Facilities. The formal design stage of ALBA took place from 2003 to 2006. The construction and the commissioning were completed in the following six years, with user's operation starting in May 2012.

A first strategic plan (SP) for the period 2010-2014 was established in 2009 [37]. It addressed the transition from the end of construction – year 2010 -, followed by commissioning and optimization – years 2010 and 2011 - to routine operation – year 2011 onward. A second SP for the period 2013-2016 was developed in 2013 [38] just after the beginning of the operation. In both cases the SP was shared with the ALBA Scientific Advisory Committee and endorsed by it.

Both SPs were requested by one of the administrations involved in the consortium, reviewed by external panels, and obtained excellent evaluations. They have been the basis of the activities thereafter planned and realized.
For the period 2017-20 ALBA has done an intensive planning work and prepared the contents of a new (third) SP, again with the support and endorsement by SAC. Such plan is ready to be adapted to the format requirements and submitted to the administration when requested.

The uniqueness of certain instruments, summed to the availability of usual synchrotron radiation techniques at the forefront of technology, has fructified and during these first years of operation more than 700 experiments have been carried out in the different beamlines. The total number of users visiting our facility was shown in Figure 12. Let's mention here that during 2016 there were more than 1400 visits spread in all the beamlines.

The performance of a user facility is routinely assessed first of all by the associated scientific production, which starts appearing slowly during the first years of operation. In fact a significant fraction of the experiments publish their results after a period of time which can be as long as three or even four years, and even the upload of publications may suffer several month delays.

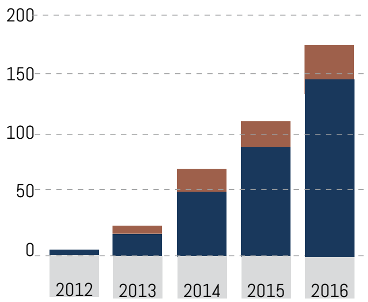
The number of peer reviewed publications based on granted beamtime, one of the main performance indicators for a photon source, is shown in Figure 18. The yearly number is still growing since we are a young facility, and in the last year has reached values similar to those of long operating facilities when normalized to the number of beamlines.

The performance indicator which is normally used to account for the quality of the scientific production is the percentage on the total number of publications with a high impact factor. In photon science this corresponds to impact factor larger than 7. In our case the average percentage during the period 2013-16 is 19% of the overall number of publications. This ratio is at a very high level when compared with sister, more mature, synchrotron facilities (for example at ESRF it is of the order of 17%). Some example of high impact publications have been shown in the introduction.

The total cumulative number of publications generated by ALBA, including the ones just mentioned, plus those related to instrumentation, proceedings, other scientific collaborations and outreach, as shown on the right in Figure 18 is almost 800 by the end of 2016. The publications generated during the period 2013-16 have been uploaded to the ICTS database.

The number of structures deposited in the Protein Data Bank (PDB) repository has been increasing steadily over the years from day one of user operation, reaching at the end of 2016 more than 200 structures [39] in line with other European long established beamlines. All research groups in Spain are using regularly XALOC for both testing the crystals for optimization and collecting the final data set to be used for structure deposition.

The distribution of scientific users by research area is shown in Figure 19 for the year 2016 chosen as a typical example. The largest communities of users come from properties of matter, chemistry, biology and macromolecular crystallography, with smaller communities from biomaterials, environment and cultural heritage.



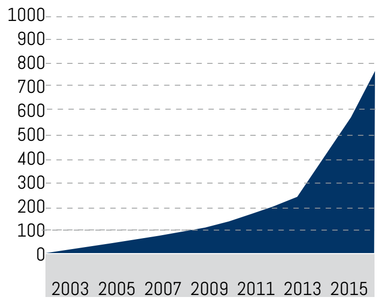


Figure 18 – Left: yearly peer-reviewed publications based on ALBA beamtime (in red those with an IF >7). Right: total cumulated publications on all scientific and technical areas including conference proceedings.

At the same time as providing SR for the research departments of industries, ALBA is a hotbed for technological developments and a tool for qualifying local industries in a competitive environment.

At the early days of ALBA there were practically no specialists in developing the photon source scientific instrumentation in Spain, and during the construction period, due to compelling time and cost effectiveness, the choice of non-national companies was often obliged. There are, in any case, examples of early technology transfer as, for example, the girders of the SR constructed by a Spanish company or the knowhow of the engineering company which designed and built the infrastructure building, both companies now fully competitive in the international market.

Special attention has been put in the recent years in involving local companies in ALBA technological developments. The whole ALBA technical and scientific staff works in constructive collaboration with national industries, while the Industrial Liaison Office provides the specialized support to innovators and inventors, including intellectual propriety registrations, licensing contracts, industrial collaboration projects and industrial PhD students.

Let's mention two examples: an electrometer comparable to the best of the world market especially suited for measuring low electron currents has been developed and is sold to international facilities as Max IV, ESRF and Soleil; the successful project with the Centro Nacional de Microelectrónica de Barcelona (Consejo Superior de Investigaciones Científicas) for producing 10μm thickness photodiodes. The project concluded with a utility model and the product commercialized by Alibava [40], a CNM-CSIC spin-off. In 2016 we continued working on the subject to produce four quadrant thin diodes both in silicon (Si) and in Silicon carbide (SiC).

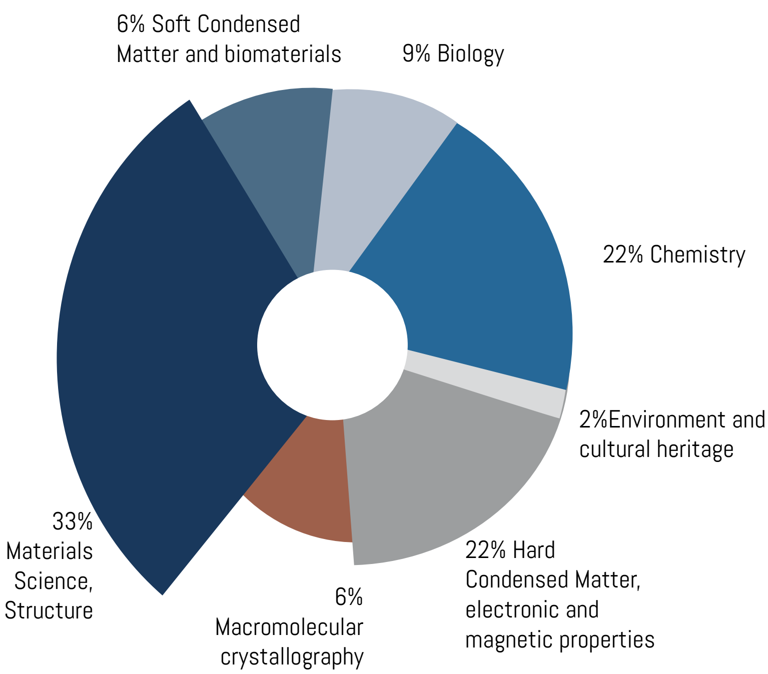


Figure 19 - Distribution of scientific users by research area

We are here reporting the economic description since 2011, when accelerators and beamlines were commissioned and first friendly user experiments carried out, in line with the information uploaded in the ICTS database.

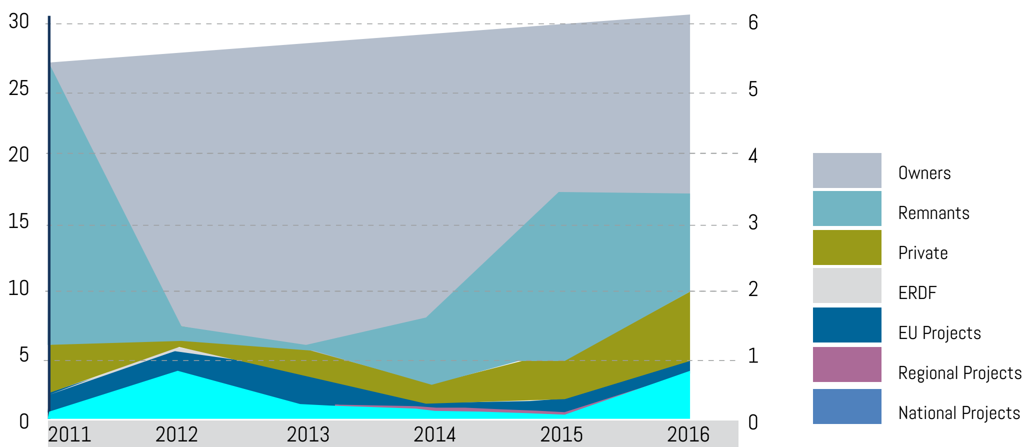
This period has been influenced by the economic crisis which started in 2008, implying a significant reduction of the science budget in Spain. The funding of the ICTS is based on national funding, allocated 50% by the central government and 50% by the regional one. Both have always supported the regular management of the Consortium and ALBA has been one of the few scientific and technical centers whose operational budget has not suffered any cut. This fact has been successfully exploited to consolidate the operation.
ALBA staff participates to competitive project calls, both at Spanish and European level. Thanks to the high maturity level reached by the ALBA scientists and engineers, 40 national and international grants have been awarded to our institution in the last four years, these last mainly from the 7th Framework and H2020 European research programs. These collaborations contribute keeping ALBA interconnected with major national and international research centers and are used to boost the in-house research and upgrade instruments.

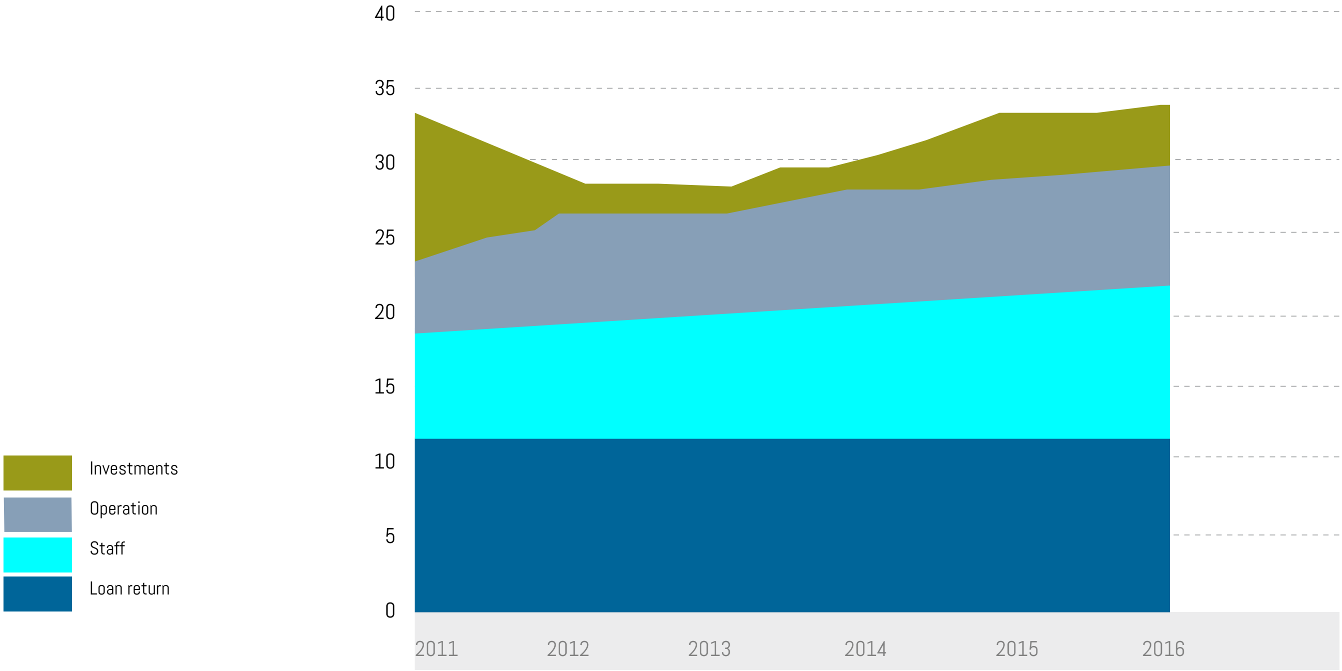
Another small percentage of the whole budget is represented by incomes derived by offering our services both to private and public institutions. We include here not only the part corresponding to beamtime or lab time but also all those collaborations with institutions with whom we have agreements to provide specialized systems. This was the case in 2011 of the agreement with MAX IV for the design of their accelerator vacuum system or more recently the agreement with CLPU for the design and construction of the PW laser vacuum chamber.

The need of extra funding for the infrastructure development has not been satisfied. It has been partly compensated using resources coming from private incomes and remnants. Only in 2014 Phase II was started using own resources while waiting for the 2014-2020 ERDF assignment. The quantity of the order of 2M€, yearly used for upgrading existing beamlines, accelerator systems, data infrastructure and civil infrastructure, will need to be increased in the future.

Table 5 and Table 6 summarize incomes and expenses of the last six years. In Table 5 remnants cover the needs when total income is reported to be lower than total expenses. We include also in Figure 20 and Figure 21 a graphical representation of the economic profile.

To be mentioned that when we report expenses we are not including VAT, and we are still waiting the refund of VAT corresponding to the period 2013-2016.





YEAR	OWNERS	NATIONAL AND REGIONAL SUBSIDIES	EU SUBSIDIES	ERDF	PRIVATE	REMNANTS	TOTAL
2011	27.76	0.13	0.28	0.00	0.76	4.25	33.17
2012	28.24	0.78	0.31	0.03	0.31	0.00	29.67
2013	28.74	0.25	0.54	0.00	0.29	0.00	29.81
2014	29.25	0.23	0.01	0.00	0.31	0.99	30.79
2015	29.77	0.14	0.17	0.00	0.64	2.53	33.24
2016	30.31	0.80	0.11	0.00	1.00	1.56	33.78

Table 5 – Income per year during the last six years (M€) .

YEAR	LOAN RETURN	STAFF	OPERATION	INVESTMENTS	TOTAL
2011	11.73	7.16	5.19	9.09	33.17
2012	11.73	7.52	7.35	2.69	29.29
2013	11.73	8.27	648	2.60	29.08
2014	11.73	9.08	747	2.51	30.79
2015	11.73	9.66	8.03	3.82	33.24
2016	11.73	10.37	7.59	4.09	33.78

Table 6 – Expenses per year during the last six years (no VAT included) (M€).

k PUBLIC OWNERSHIPS

CELLS, the Consortium for the Construction Equipment and Exploitation of a Synchrotron Light Source, is a public consortium shared at equal parts by the Spanish Administration and the Autonomous Catalan Government. According to Spanish laws, all consortia must be public. The presence of a nonprofit private organization is allowed, but that is not the case of CELLS.

The facility operated by CELLS is the Synchrotron Light Source ALBA.

l OPEN COMPOSITION

According to the ALBA rules, the presence of other (nonprofit) entities in the consortium is not only possible but fully supported, even if the opportunity has not yet arisen.
ALBA is totally open to users of the whole scientific-technological and industrial community, national and international.

The selection of users is regulated through a public and transparent access protocol that prioritizes the applications for use of the infrastructure on the basis of the scientific excellence of the proposals decided by a Beam Time Review Panel (BTRP).

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Signed by:

Caterina Biscari

24th October 2017

ALBA

Generalitat de Catalunya
Departament d'Empresa
i Coneixement

GOBIERNO
DE ESPAÑA
MINISTERIO
DE ECONOMÍA, INDUSTRIA
Y COMPETITIVIDAD