STRATEGIC PLAN 2013-2016

Caterina Biscari, David Fernández,

Salvador Ferrer, Miguel Angel García Aranda,

Gastón García, Lluis Miralles, Francis Pérez,

Alejandro Sánchez, Mariano Sazatornil

ALBA – CELLS

www.cells.es

Ctra. BP-1413, Km 3.3 – E-08290

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1.1 INTRODUCTION

Synchrotron light emitted by accelerated electrons is used worldwide by an ever increasing community of Physicist, Biologist, Chemists, and many other scientist and industrial users to investigate fundamental properties of matter, as atomic or microscopic structures, chemical and electronic properties, either in static or with changing configurations. The wide spectral range, the narrow collimation, the energy definition, the tuneable polarization, the partly coherent nature and the temporal structure make it a valuable instrument to probe and unravel details of the matter up to nanoscale levels or beyond. In Spain a dynamic Synchrotron Light (SL) user community counts scientists of great value and experience, usual visitors of the most advanced SL international facilities.

The evolution of synchrotron radiation facilities is usually schematized into generations and the parameter distinguishing the different generations is the brightness: the number of photons per time and spatial unit within a given energy bandpass.

The third generation light sources appeared in the nineties and are well represented around the world, as will be illustrated later in the document, due to its wide range of applications, number of users and size of infrastructures well-fitting national laboratories. It is based on low emittance (electron beam dimensions and divergences) rings filled with insertion devices boosting the photon production.

ALBA is a 3rd Generation SL facility located in Cerdanyola del Vallès, Barcelona, Spain, and it is the newest source in the Mediterranean Area. It is governed by a public consortium created in March 2003: the Consortium for the Construction, Equipping and Exploitation of the Synchrotron Light Source, hereinafter referred to as CELLS, owned and financed in equal parts by the Spanish and the Catalonian Administration.

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

The ALBA vision is to become a centre of excellence in Synchrotron Light Scientific and Industrial applications and to achieve the status of a recognized world class facility in its field. Its mission is to research in, deliver and maintain methods and techniques with which to conduct cutting edge Synchrotron Light based research and development, to add value to the Spanish scientific and industrial communities.

The decision of building a SL laboratory in Spain was taken in 2002, after several years of studies and proposals for the creation of an accelerator based infrastructure. Pushing by the growing SL Spanish user community and interest of the Catalunya Region for hosting a large research facility were determining for the birth of ALBA. After the constitution of the Consortium the final detailed design project started in 2004. The facility is based on a chain of accelerators which produce, accelerate up to 3 GeV and store in a synchrotron ring electron beams which emit SL ranging from infrared up to hard X-ray of tens of keVs. Up to 31 ports (16 bendings and 15 IDs) are available to extract the light as well as the space for the corresponding beamlines (BLs) and related experimental hutches. Buildings for conventional technical systems and for specialized laboratories complete the facility.

ALBA construction spans a period of time between 2006 and 2010. Commissioning of the accelerator has been done by stages starting in 2008, in parallel with the installation of technical systems and seven phase I BLs. The first beam was stored in the synchrotron in 2010. In 2011 the

BL commissioning started and in 2012 the phase I BLs have progressively come into operation. At the beginning of 2013 the accelerators and the seven BLs are operating for the users.

The initial ALBA BLs can be classified into three groups according to their main scientific application areas: Life Science, Condensed Matter Physics and Chemistry (with applications in Materials Science and different multidisciplinary areas), as will be later explained.

Two user calls have been opened since 2011, with a proposal response of about 200 per call, leading to an average overbooking factor of about 2. Eighty per cent of the proposals come from Spain, and up to 15 countries are represented in the remaining 20%. ALBA is offering beamtime through the European Network in the framework of the FP7 programs CALIPSO and BioStruct-X.

ALBA is a public institution serving academic world and public research institutes. At the same time one of its strategic priorities is fostering of industrial R&D activities through technological transfer and private utilisation of beamtime.

First industrial users are performing feasibility studies to check the fitting of ALBA instruments to their R&D programs, mainly on pharmaceutical, adhesives, detersives and catalytic systems.

A SL facility has a very relevant potential in terms of fostering the development of the so-called science industry. Exposed to excellent scientific cases (as guaranteed by a robust peer-review scheme for beam time access), in which frequently the limits of state-of-the-art instrumentation become critical, advanced service facilities are the ideal environment for the birth of new instrumentation concepts, which are then developed in collaboration with technological industries. It is very common that these very particular industrial capabilities are generated in the close geographical environment of such facilities.

As an example of the very wide interdisciplinary range of SL techniques, it can be mentioned that activities on cultural heritage have just started to be developed in collaboration with the Museo Nacional de Arte de Catalunya (MNAC) specialized in Romanic art.

We can state that the first essential goal of the project has been fulfilled, as described in the previous strategic plan [1] which spawned the period 2010-2014: the accelerator complex is operating in a stable manner and the seven BLs comprised in the initial portfolio of the facility are open to external users. First publications based on data taken at ALBA are thereby appearing.

The main targets for the next few years are: the consolidation of stable and efficient operation of the facility, towards higher and more stable flux; the development of the facility via the construction of new BLs; the upgrading of capabilities in the existing ones; and in-house steered developments, both scientific and technological, eventually in collaboration with external institutions and companies.

ALBA is also ready to contribute to the development of new related facilities in similar fields in order to serve the scientific community and to exploit its technical expertise, taking advantage of all possible synergies for cost-efficient development of the Spanish map of scientific infrastructures.

ALBA is located inside the ‘Parc de l’ALBA’, where other research and technological institutions are or will be set in the future. This cluster represents a strategic regional scale action, with the possibility of becoming a powerful motor of scientific, technologic and business activities in the South of Europe, with potential for creating thousands of jobs.

Synergies between ALBA and the neighbouring universities and research centres, including the Universitat Autònoma de Barcelona (UAB) and CSIC research centers as ICMAB and ICN , in whose immediate vicinity it is placed, are an added value to ALBA scientific outreach and potentialities. Means of collaboration are already exploited and will increase in the future. The Bellaterra campus hosting a number of cutting-edge research organizations and institutions will also help in boosting synergies.

1.2 ALBA DESCRIPTION

The ALBA infrastructure, placed in Cerdanyola del Vallès, few kilometres west of Barcelona, hosts the electron accelerators providing the photon flux, the experimental hall with the Phase I beamlines (BLs) and space for a total number of 31 BLs, the technical areas, laboratories and workshops. The description of the different systems follows. Figure 1 shows an aerial photo of the whole ALBA area.

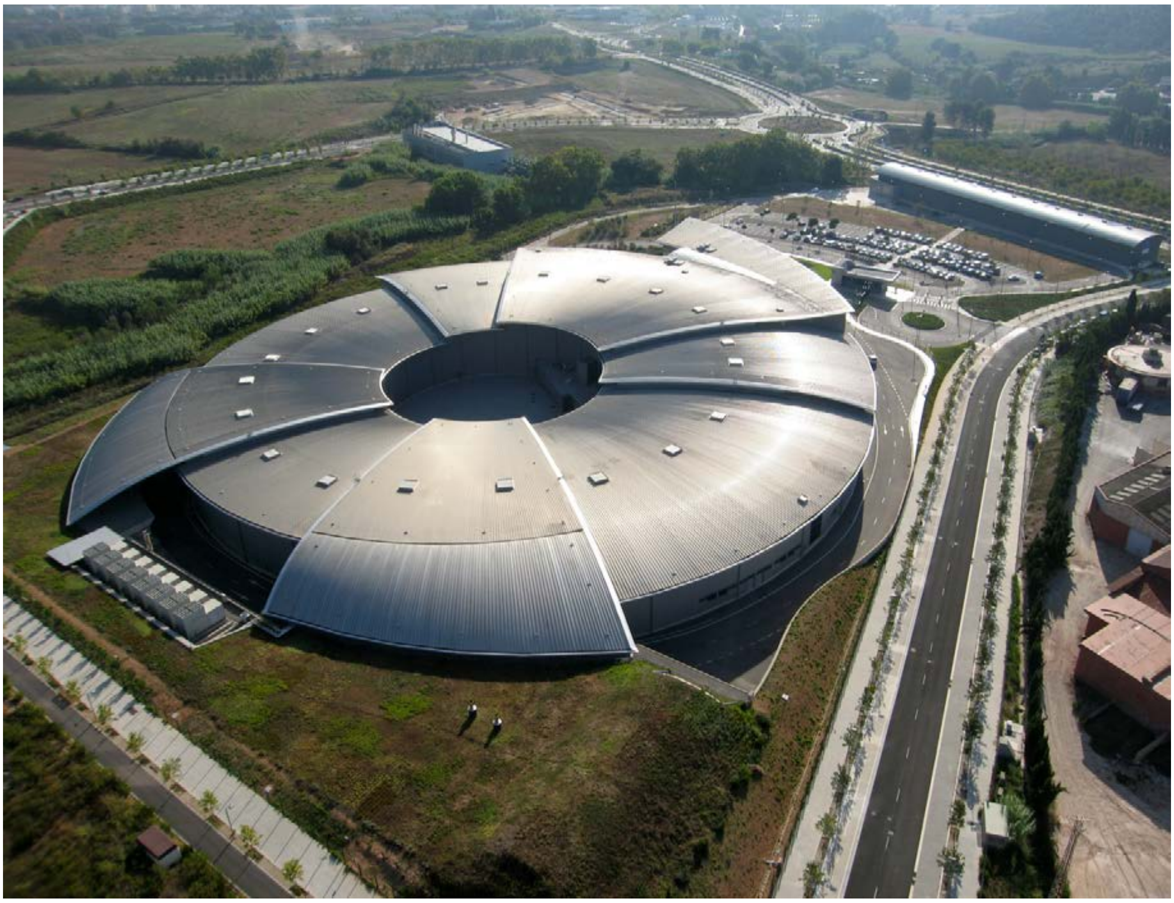


Figure 1 - ALBA aerial view

1.2.1 Accelerators

The scope of the accelerator complex is to deliver photons in a broad range of useful photon energies for the user's community.

A schematic lay-out of the ALBA accelerator complex is shown in Figure 2. The Linac delivers electron beams of 110 MeV to the Booster, where electrons are further accelerated to 3 GeV. The beam is injected into the Storage Ring (SR), and stored for hours or days to provide synchrotron radiation to the users. When working at full exploitation, the maximum intensity in the SR is 250 mA.

The facility is designed to work in the so-called *top-up* mode, a process that ensures a beam intensity almost constant in the SR: when the beam decays below a certain limit (say, around 2%), electrons are added to the circulating beam. This guarantees a constant thermal load on the optical elements of the beamlines, which is a crucial requisite for their stability.

This chapter describes the present status, features and outlook of the ALBA facility, with special stress on the lattice, injection scheme, and the main individual systems composing the ALBA accelerator complex.

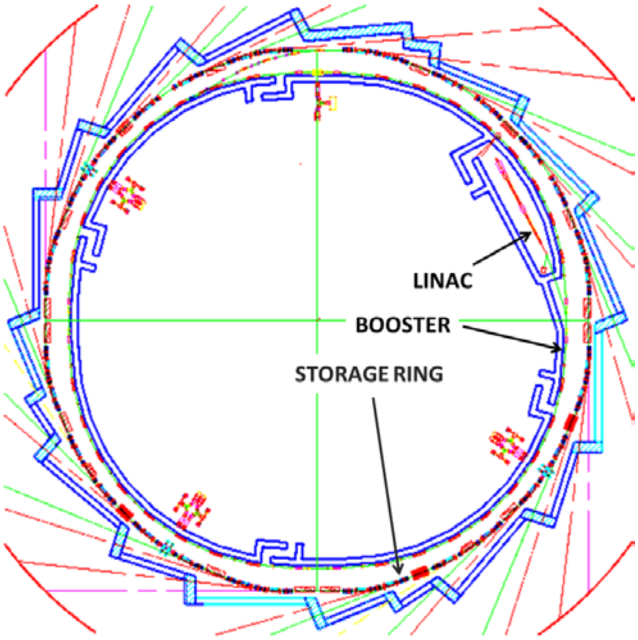


Figure 2 - Schematic lay-out of the ALBA Accelerator.

1.2.1.1 Linac

The ALBA Linac (see Figure 3) is a 12 m long accelerator commissioned in 2008, which generates and accelerates electrons up to 110 MeV in two modes of operation: single and multi-bunch mode. The single bunch mode provides from 1 to 8 isolated bunches with a maximum charge per bunch of 2 nC; while the multi-bunch mode generates trains of a total charge up to 4 nC, with a number of bunches that ranges between 28 to 512, spaced by 2 ns.

Figure 3 - 110 MeV ALBA Linac view

The Linac is made of a 90 kV thermo-ionic gun that generates the electrons, which are immediately accelerated by several Radio Frequency (RF) systems. First, the bunching system compresses and accelerates up to 15 MeV the electrons from the gun using standing waves cavities. Next, acceleration up to 110 MeV is done using two travelling waves sections with constant RF gradient working at a 3 GHz frequency. The 30 kW power required for each of the accelerating sections is provided by two klystrons.

The beam size and divergence are controlled through a magnet system that includes solenoids, quadrupoles and correctors. Finally, a set of diagnostics elements including Fast Current Transformers (FCT), Fluorescent Screens (FS), and Beam Position Monitors (BPMs) allows a proper monitoring of the Linac performance. Currently, the Linac delivers a 1 nC beam of 110 MeV with an emittance of 20 nm rad and an energy spread of 0.2%. The Linac repetition rate is 3.125 Hz, in precise synchronism with the Booster accelerator.

1.2.1.2 Booster

The Booster accelerates the Linac beam from 110 MeV to 3 GeV in a ramp of 145 ms. The process is repeated in a 3.125 Hz rate, in which the magnet power supplies and RF system both ramp up to accelerate the beam, and ramp down to receive the next incoming Linac beam.

The Booster magnets are arranged in a four-fold symmetry, where each quadrant consists of 8 unit cells surrounded by 2 matching cells. The unit cell is composed by one dipole together with one FOcusing and one DefOcusing quadrupole, forming a regular FODO type lattice. The dipole is actually a combined function magnet, which includes a quadrupolar field for further focusing in the vertical plane. Furthermore, the matching cell includes sextupoles to control the chromatic effects. In total, the Booster has 40 bending magnets, 60 quadrupoles, 16 sextupoles and 72 correctors; the latter allow a proper beam orbit control.

The RF system is based on a 5-cell Petra type cavity [2] and is able to deliver a maximum voltage of 1 MV at 500 MHz and 5 mA current (the maximum that the LINAC can supply). In the accelerating process to 3 GeV, the power increases up linearly from 100 W to 35 kW using one 80 kW Inductive Output Tube (IOT), which is identical to those in the Storage Ring.

The Booster lattice and its large circumference (249.6 m) provide one of the smallest emittances for injection in a synchrotron: 9 nm rad at the extraction energy. This eases high injection efficiency between the Booster and the SR, which is a valuable feature for the top-up operation. Table 1 gives the main Booster and SR parameters.

1.2.1.3 Storage Ring

The SR was commissioned in October 2011, and it is open to external users since May 2012. Today, ALBA offers an electron beam with an emittance as small as 4.6 nm rad, which puts the facility in direct competition with the latest light sources in operation in Europe, like Soleil (France) [3] or Diamond (UK) [4]. Table 1 summarizes the main parameters and Figure 4 shows a view of the tunnel with both Booster and SR elements. Such a small emittance is achieved by a careful choice and arrangement of magnets, the so-called machine *lattice*, which allows an appropriate beam control along the machine.

Storage Ring Lattice

The ALBA SR circumference is 268.8 m long, and its lattice is an expanded Double Bend Achromat (DBA) model with a fourfold symmetry that divides the machine in four quadrants, which in turn are composed by four basic cells: two *matching* and two *unit* cells. The compact arrangement of magnets is intended to leave as much space as possible for the installation of Insertion Devices (ID).

Figure 4 - Booster (left) and SR (right) inside the ALBA tunnel

Table 1 - Main machine parameters of the ALBA SR and Booster at 3 GeV

	Storage Ring	Booster Extraction
Beam Energy	3 GeV	3 GeV
Natural Hor Emittance	4.6 nm*rad	9 nm*rad
Tunes (hor / ver)	18.15 / 8.36	12.42 / 7.38
Natural Chromaticity (hor / ver)	(-40.0 / -25.6)	(-17.0 / -9.6)
Momentum Compaction Factor	0.88×10^{-3}	3.6×10^{-3}
Energy Spread	1.05×10^{-3}	0.96×10^{-3}
Revolution Time	896 ns	832 ns
Damping Times (hor / ver / long)	(4.6 / 8.0 / 6.4) ms	(4.6 / 8.0 / 6.4) ms
Partition Numbers (hor / ver / long)	(1.3 / 1.0 / 1.7)	(1.75 / 1.0 / 1.25)
Energy Loss per Turn	1.2 MeV	0.625 MeV
Harmonic Number	448	416

The SR is composed of 32 dipoles, 112 quadrupoles, and 120 sextupoles. As in the Booster, the dipoles are combined function magnets that not only include a dipole field (1.42 T), but also a quadrupolar component that focuses in the vertical plane. This reduces the number of required quadrupoles and frees space to allocate IDs. Together with the 120 sextupoles, the quadrupoles determine the Twiss parameters, which describe the electron beam characteristics along the machine. In particular, the β-function in the vertical plane is minimized at the ID location, thereby maximizing the photon brightness for the users. Figure 5 shows the lattice in one of the ALBA quadrants. Note that dispersion at the straight sections is kept finite, and a reasonable large horizontal β-function is designed at the long straights to easy the injection process.

This lattice configuration permits straight sections of different lengths: a) 4 *long* sections of 8 m, b) 12 *medium* sections of 4.2 m, and c) 8 *short* sections of 2.2 m. Table 2 shows the beam sizes at the ALBA straight sections and at the dipole, which are the possible photon source point locations.

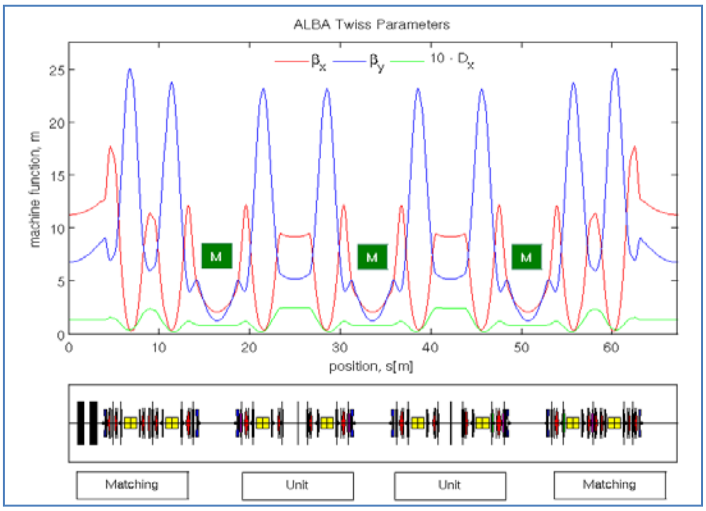


Figure 5 - ALBA Twiss parameters in one quadrant. The label "M" marks the location of the Medium Straights, where most of the IDs are located. The magnets arrangement is specified at the bottom plot, together with the Matching and Unit cells.

Table 2 - Beam characteristics at source point locations

Location	Length	σ_x (μm)	σ'_x (μrad)	σ_y (μm)	σ'_y (μrad)
Long	7.97	270	21	16.2	3
Medium	4.19	131	47	7.6	6
Short	2.6	315	23	15.1	3
Dipole		57	116	24	2

The lattice configuration is flexible enough to allow changing machine parameters like tunes or chromaticities, which define the machine performance. The individual quadrupole power supplies add flexibility to the optimisation of the lattice, in particular to enlarge the dynamic aperture and the energy acceptance, two key aspects for providing both efficient injection and long beam lifetime. The latter is mainly affected by the RF system, which is described next.

Storage Ring Radio Frequency System

The 500 MHz Storage Ring RF system serves to restore the energy lost due to synchrotron radiation (1.2 MeV/turn) and to provide an energy acceptance of 3% with an RF voltage of 3.6 MV. This allows beam lifetimes in the order of 15 hours, which ensures a good beam decay and spaces the top-up process to at least several minutes.

The RF system is composed of six 160 kW Continuous Wave (CW) plants. Each plant consists of two 80 kW IOTs, combined through a Cavity Combiner to feed an individual resonant cavity. This is a normal conducting High Order Mode (HOM) damped cavity, whose design has been focused on avoiding Couple Bunch Instabilities induced by the beam.

Beam Orbit Control

The required photon stability is achieved by keeping the electron beam orbit in the sub-micron level with an active feedback system. The orbit is monitored using 120 Beam Position Monitors (BPM) installed around the machine, and is controlled using 120 corrector magnets, which are embedded in the sextupole magnets to save space. Orbit data analysis and correction is currently done at a 0.5 Hz rate, but ALBA is being equipped to increase this rate up to 300 Hz using a fibre optics network.

Insertion Devices

ALBA Insertion Devices (IDs) were designed to provide the required photon energy and brightness to the existing beam lines. Presently there are six IDs at ALBA, located in the medium straight sections. One beam line uses the synchrotron radiation directly from a bending magnet.

Table 3 shows the main characteristics of the IDs and Figure 6 the range of photon energy and brightness delivered by the bending magnets and the existing IDs.

Table 3 - ALBA Insertion Devices

Beamline	Experiment	ID type	ID name	Magnetic Min gap (mm)	Period Length (mm)	N. of periods	Magnetic Length (mm)
BL04	Powder diffraction	Superconducting wiggler	SCW-31	12,4	30,16	58,5	1764
BL11	Non-Crystalline Diffraction	In-vacuum undulator	IVU-21	5,7	21,6	92	1987
BL13	Protein Crystallography	In-vacuum undulator	OVI-21	5,7	21,6	92	1987
BL22	X-Ray Spectroscopies	Multipole wiggler	MPW-80	12,5	80	12,5	1000
BL24	Photoelectron Spectroscopies	Apple-II undulator	EU-62	15,5	62,36	27	1684
BL29	X-Ray Magnetic Circular Dicrhoism	Apple-II undulator	EU-71	15,5	71,36	22,25	1588

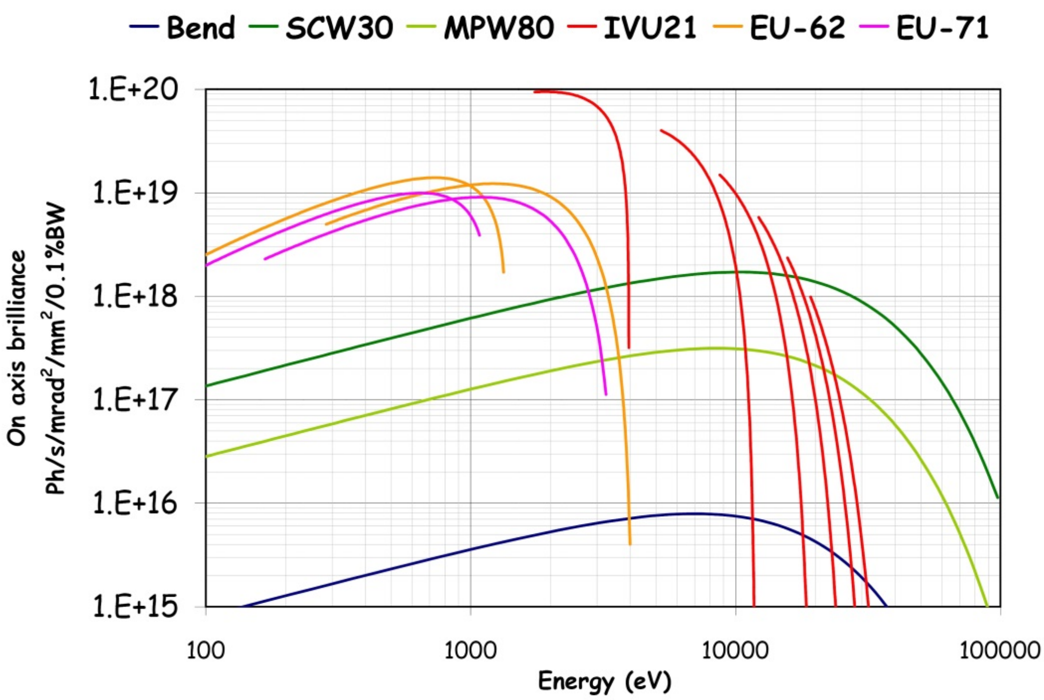


Figure 6 - Brightness of ALBA photon sources as a function of the energy

1.2.2 Beamlines

The seven ALBA Phase I Beamlines were chosen among the proposals submitted by the Spanish scientific community in 2004 through an evaluation process led by the Scientific Advisory Committee (SAC), according to the strengths of the scientific case, the weight and quality of the future user community, their technical feasibility and quality, and approved by the Rector Council of ALBA [1].

We can classify them into three groups for their main scientific applications: i) those devoted to Life Sciences (**Life**); ii) those devoted to Condensed Matter Physics (**Phys**), especially magnetic structures, electronic properties and Nanoscience; and iii) those devoted to Chemistry (**Chem**) with applications in Materials Science and different multidisciplinary areas. Their main characteristics are summarized in Table 4 and their layout in the experimental hall depicted in Figure 7. The original proposals of the beamlines and their conceptual design reports can be found at the ALBA web site [5]

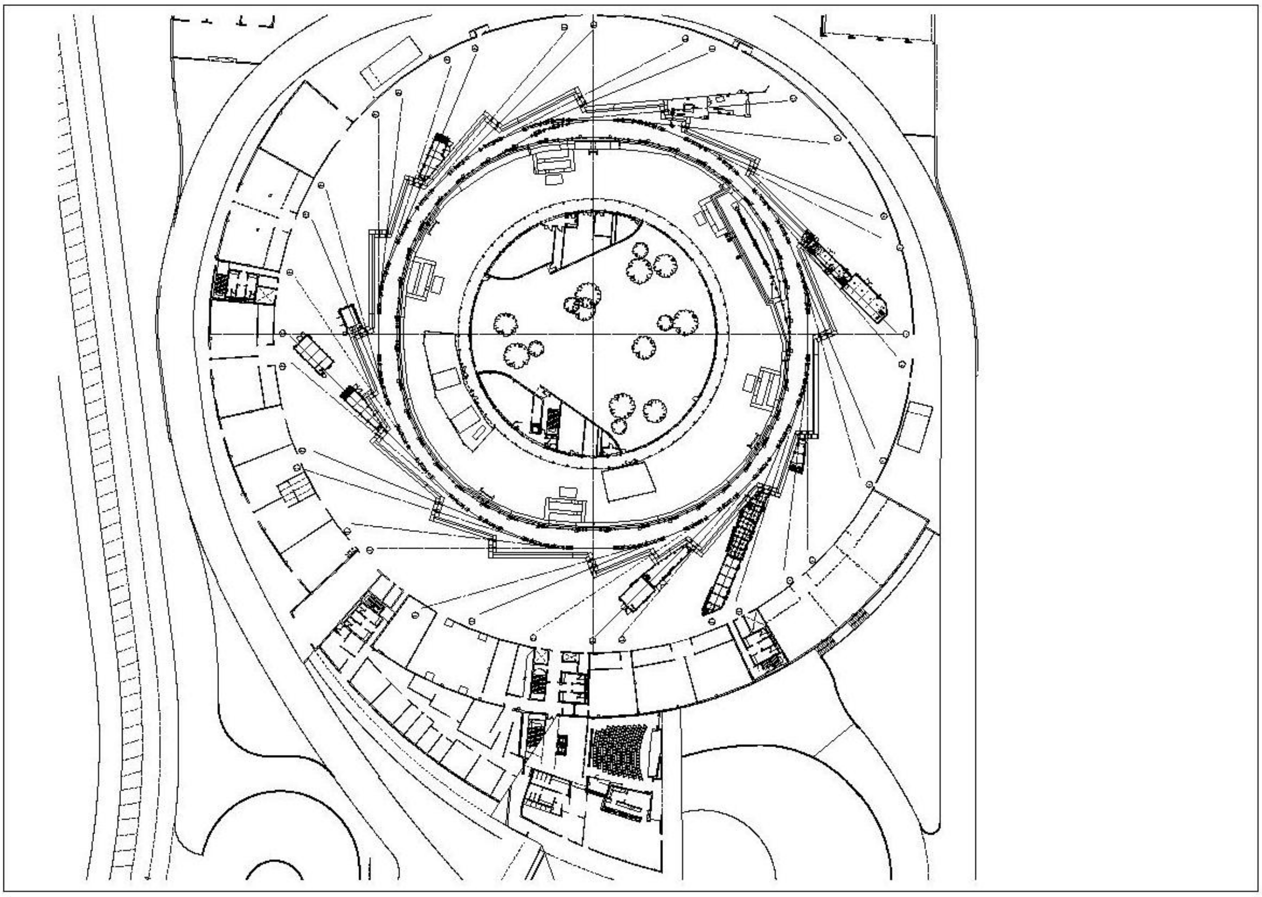


Figure 7- Layout of ALBA phase-I Beamlines

The conceptual design of the beamline optics was carefully studied in all cases with ray tracing analysis. Call for tenders were launched in the period 2006-2008 which were followed by the manufacturing process of the different components. In parallel, the beamline infrastructure and safety hutches were defined and manufactured. After the beamlines were installed and their components were tested and commissioned, the first friendly users were accepted to carry on simple experiments that served to ascertain the performances of the beamlines. The first beamline open to users was Boreas on May 2012. After this, all the beamlines have been accepting friendly and official users from summer to the end of 2012. During 2013 the first scientific results started to arrive. At present all the beamlines have been practically completed except one of the two end stations at Boreas and the emission spectrometer at Claess (which is an ancillary equipment of the beamline) that are still under construction. The characteristics of the BL are now shortly described.

Table 4 - Main characteristics of ALBA Phase I Beamlines

Port	Name	End stat	Sect	Experimental techniques	Scientific applications	Light source
4	**MSPD**	2	Chem	High resolution powder diffraction High pressure diffraction	Structure of materials, Time resolved diffraction, High pressure experiments	SC wiggler
9	**MISTRAL**	1	Life	Soft X-ray full field transmission X-ray microscope.	Cryogenic tomography of biological objects. Spatially resolved spectroscopy	Dipole
11	**NCD**	1	Life	High resolution small and wide angle X-ray scattering/diffraction, protein scattering experiments	Structure and phase transformations of biological fibres, polymers, solutions. Time resolved X-ray studies	In vacuum und
13	**XALOC**	1	Life	X-ray diffraction from crystals of biological macromolecules	Macromolecular crystallography	In vacuum und
22	**CLÆSS**	1	Chem	EXAFS, XANES, Quick-EXAFS	Materials science, chemistry, time resolved studies, cultural heritage	MP wiggler
24	**CIRCE**	2	Phys	Photoemission microscopy (PEEM) Near atmospheric pressure photo-emission (NAPP)	Nano-science and magnetic domain imaging (PEEM), Surface chemistry (NAPP)	Apple II und
29	**BOREAS**	2	Phys	Circular Magnetic Dichroism Resonant Magnetic Diffraction	Magnetism, surface magnetism and magnetic structures	Apple II und

1.2.2.1 BL04 - MSPD: Materials Science and Powder Diffraction Beamline. [6] [7]

BL04 (MSPD) beamline (see Figure 8) 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 3 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 (MythenII) for time resolved experiments (down to a few ms timescale).

This beamline is also equipped with a second experimental end-station dedicated to experiments of diffraction under high pressure with diamond anvil cells 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 SuperConducting (SC) 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 (silicon(111) double crystal monochromator).

The main components of the high-resolution end-station are: high-resolution powder diffractometer; multicrystal analyser with point counting detectors; 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: diamond-anvil cells; CCD detector, Rayonix SX165.

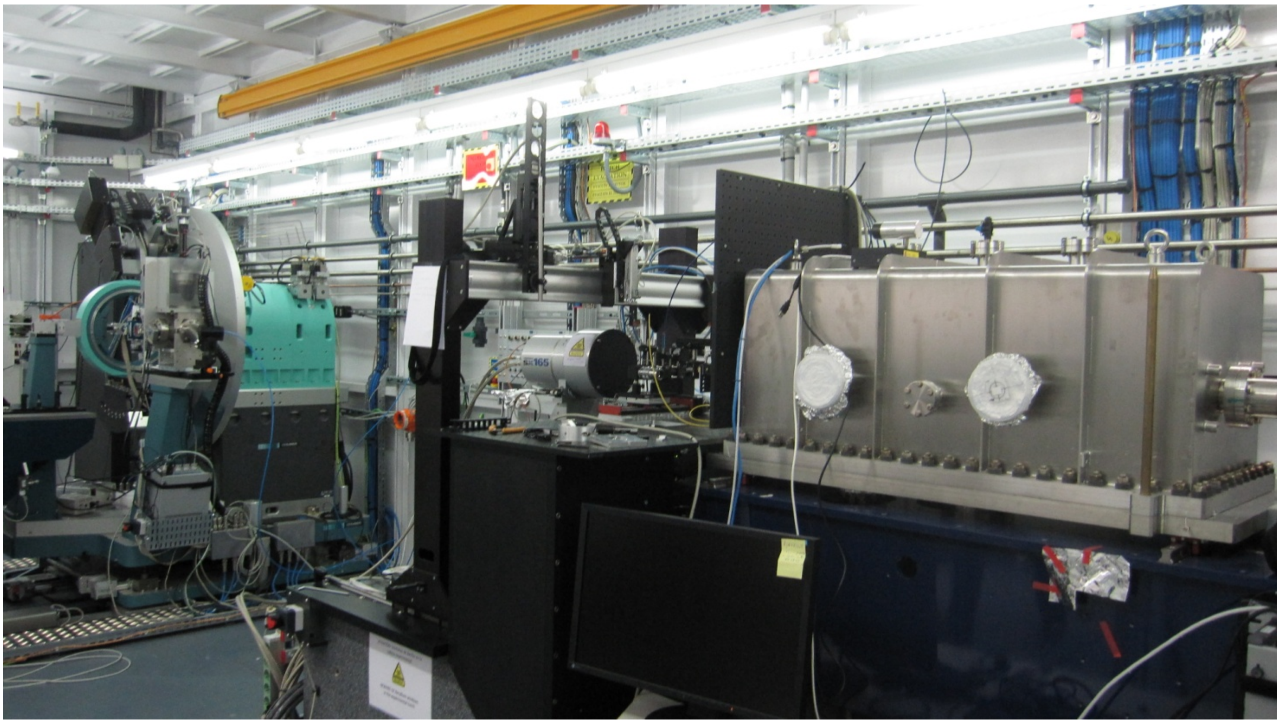


Figure 8 – MSPD experimental hutch

1.2.2.2 BL09 - MISTRAL: X-Ray Microscopy Beamline. [8]

BL09 (MISTRAL) beamline (see Figure 9) 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 three 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.

Figure 9 – MISTRAL experimental hutch

The main components of the end-station are: full-field transmission cryogenic with tomography capabilities; charge coupled device (CCD) detector (PIXIS).

1.2.2.3 BL11 - NCD: Non-Cristalline Diffraction Beamline. [9]

BL11 (NCD) beamline (see Figure 10) 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.

Figure 10 – NCD experimental hutch

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).

1.2.2.4 BL13 - XALOC: Macromolecular Crystallography Beamline. [10]

BL13 (XALOC) beamline (see Figure 11) 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).

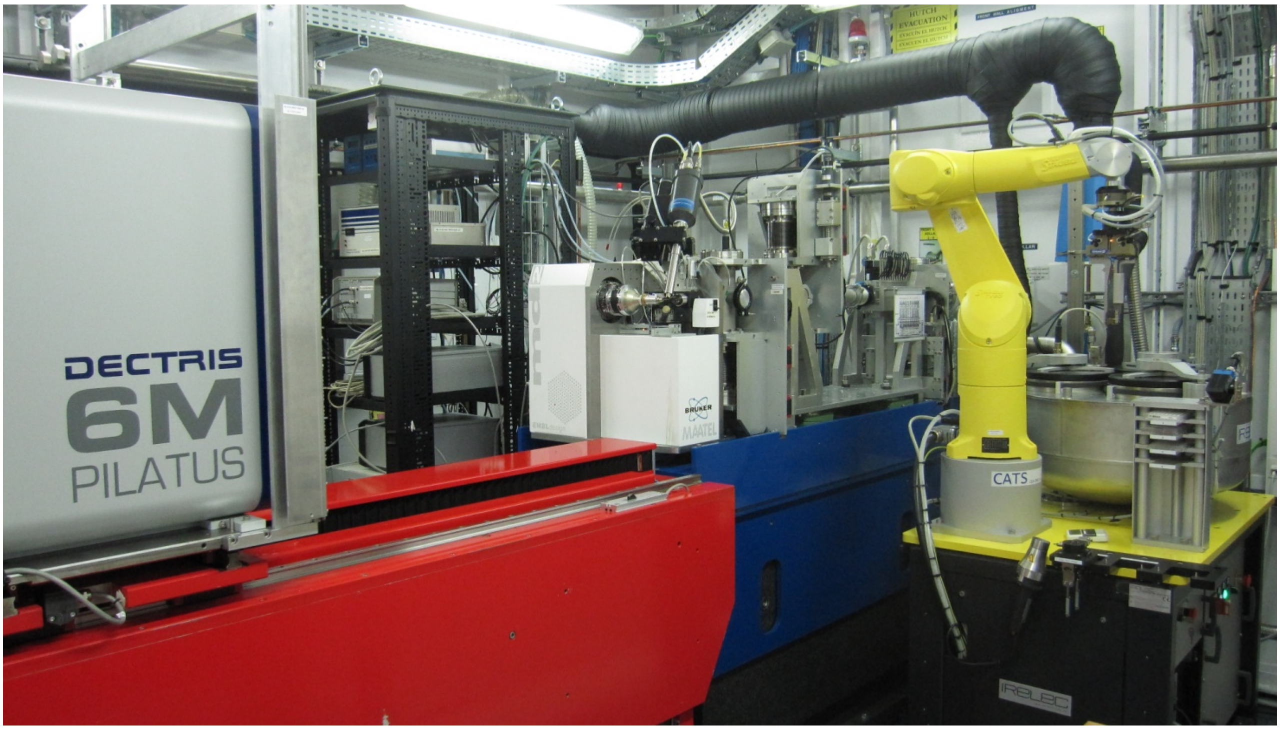


Figure 11 – XALOC experimental hutch

1.2.2.5 BL22 - CLÆSS: Core Level Absorption & Emission Spectroscopies Beamline. [11]

BL22 (CLAESS) (see Figure 12) 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 (see section 3.1 below).

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).

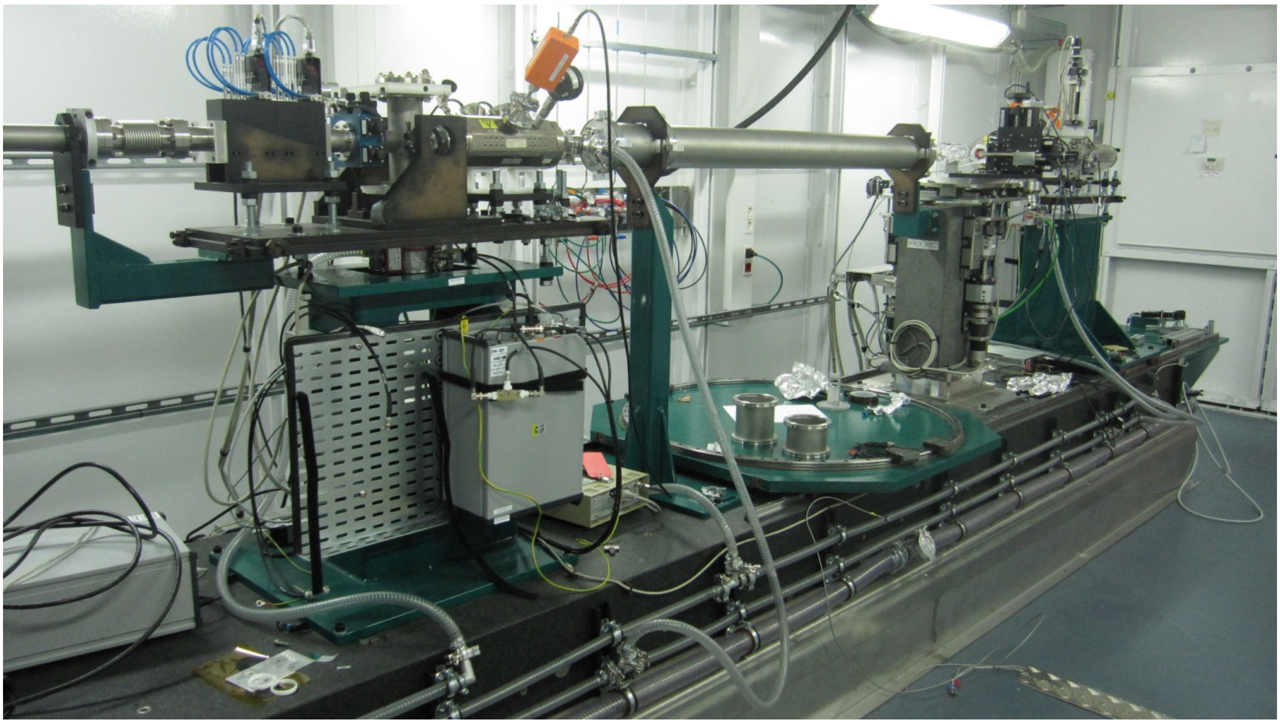


Figure 12 - CLÆSS experimental hutch

1.2.2.6 BL24 - CIRCE: Photoemission Spectroscopy and Microscopy Beamline. [12]

BL24 (CIRCE) (see Figure 13) is a photoemission spectroscopy and microscopy beamline with a 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 light source is an APPLE-2 helical undulator. 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). The two end-stations, as explained above, are equipped with: a Photoemission Electron Microscope and Low Energy Electron Microscope; and Near Ambient Pressure Photoelectron Spectroscopy setup.

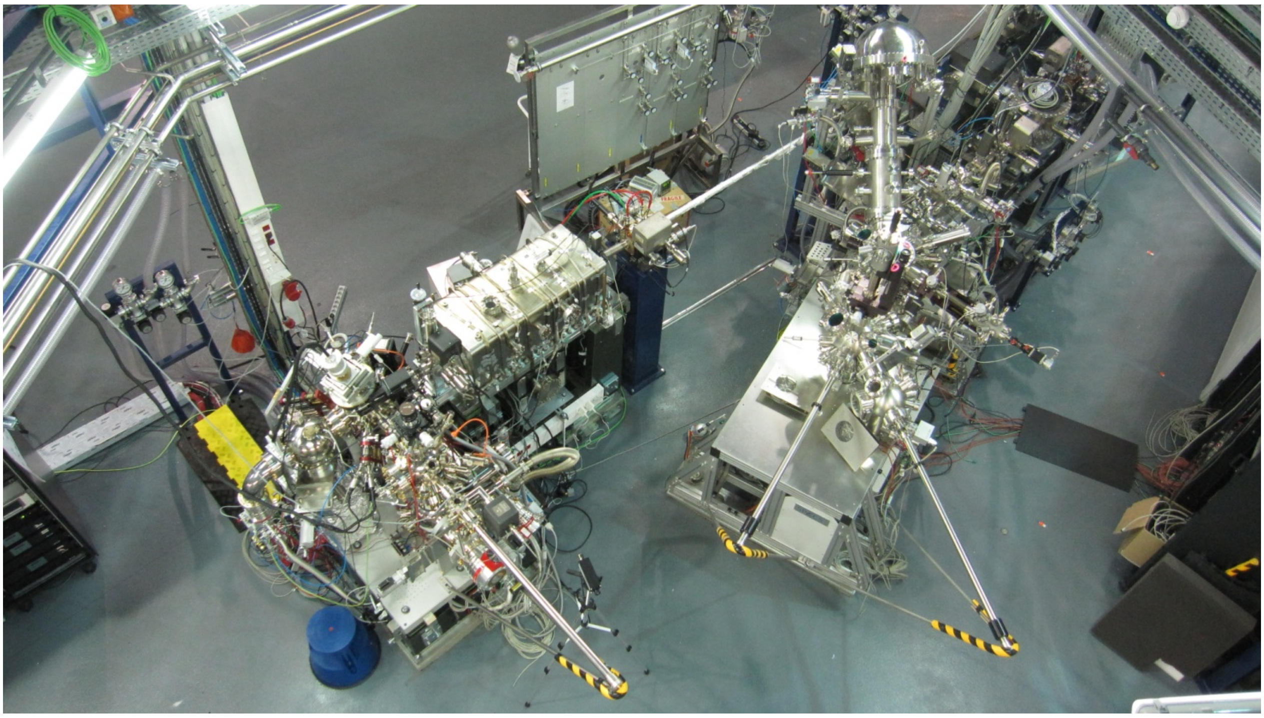


Figure 13 – CIRCE experimental hutch with the two end stations

1.2.2.7 BL29 - BOREAS: Resonant Absorption and Scattering Beamline [13]

BL29 (BOREAS) (see Figure 14) 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 6 T along the beam axis and up to 2T in the plane perpendicular to the beam.

The second experimental end-station will be 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).

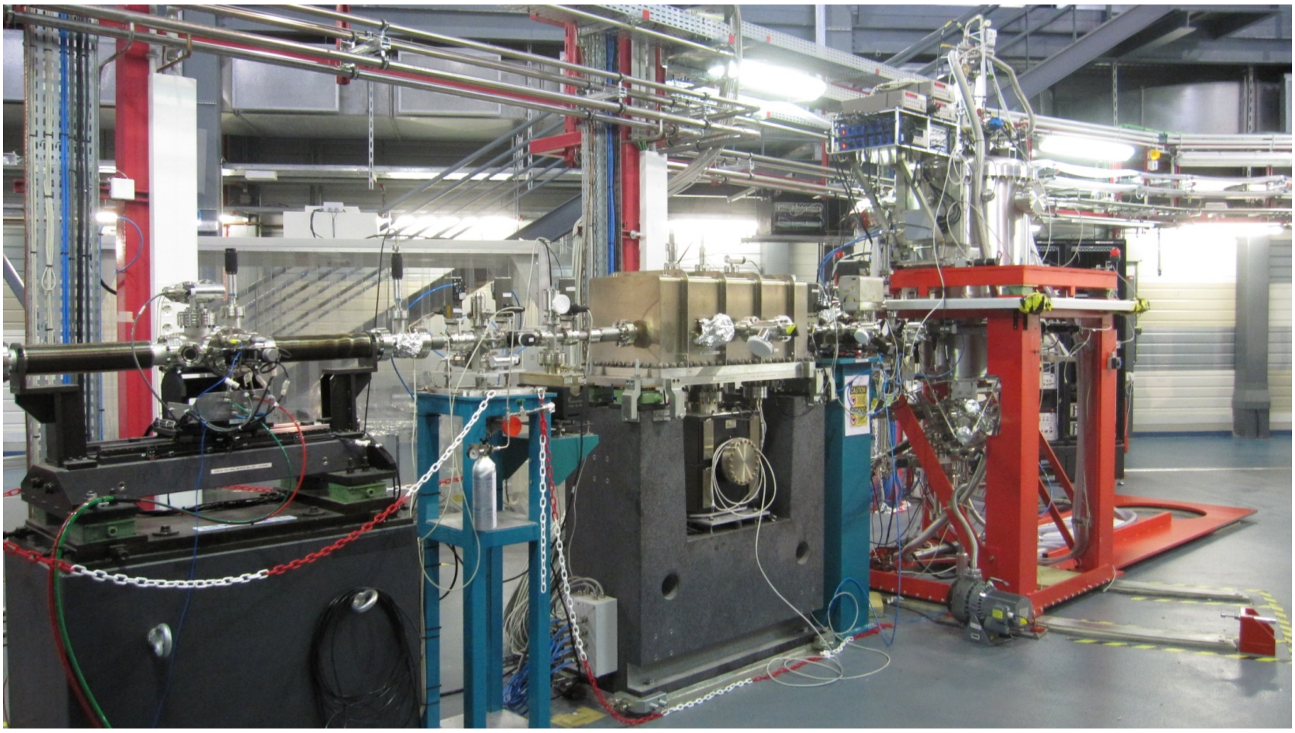


Figure 14 – BOREAS Experimental hutch

At the moment there is one end-station in operation (XMCD/XMLD end-station). The second one (soft X-ray magnetic scattering station) is in construction (see section 3.1. below) and it should welcome its first users in spring-2014.

1.2.3 Control and data acquisition system for the accelerators and beamlines

The control system is one of the essential elements of ALBA. Its architecture and key elements are described in the present section.

Typically equipment is located in the tunnel or in the hutches of a Beamline and their controllers and electronics are installed in cabinets outside the shielded areas. This results in hardware being distributed all over the place. With this highly distributed installation, we needed as a general rule, distributed software combined with a fast and robust fieldbus. Ethernet was made the standard for both control networks and fieldbuses. This makes the installation homogeneous, easy to maintain and guarantees a good longevity of the components.

The control and data acquisition system is largely based on open source applications distributed under the Lesser General Public License. It uses TANGO [14], an object oriented distributed framework, first started at the ESRF and nowadays developed in a collaboration of seven international installations including ALBA.

Inspired in the success of the TANGO collaboration, ALBA decided to start the creation of a generic SCADA (Supervision, Control And Data Acquisition), enlarging the scope of the TANGO project to provide standard graphical and command line interfaces, as well as a flexible environment for macro execution. This project was named Sardana [15]. It is a multiplatform mostly written in Python and Qt. Today Sardana controls all Beamlines and Accelerators at Alba, and has already been adopted in other international installations such as DESY in Germany and Max-IV in Sweden as well.

Sardana provides optimized and standardized access to the hardware, generic graphical interfaces, save/restore of configuration and settings, software synchronization and macro execution. A powerful sequencer, which manages the edition and execution of macros and sequences, is mandatory in any experimental station in a synchrotron, and extremely useful in all cases. It forms a scientific SCADA suite, covering the weaknesses industrial SCADAS have for scientific applications, and enlarging the scalability of scientific packages.

Sardana was conceived as a solution for a synchrotron, but is extendable to other scientific laboratories, like neutron sources or ion beam facilities. It is flexible and scalable. It has been designed for suiting large installations like a particle accelerator, or smaller such as experimental stations, or small labs.

1.2.4 **Laboratories and support facilities**

In addition to the Accelerators and the Beamlines, ALBA is complemented with a series of laboratories which give support to the users and allow further tests and improvements of the installation by the ALBA scientist.

Most of these laboratories are also used to give support to the external collaborations of ALBA, like the RF, magnets and optics labs.

1.2.4.1 Optics and Metrology laboratory [16], [17]

This laboratory is devoted to carry out the surface metrology of the large mirrors used in the beamlines, up to 1.5 m long, with arbitrary figure, and with sub-nanometer accuracy. It also allows for the physical metrology of the beamline positioning systems, such as the mechanical performances, and vibration behaviour of optical components.

The main instruments available at the laboratory are the following: a nanometer optical measuring machine (NOM) developed in house; a 100 mm aperture Fizeau interferometer, with about 8 reference surfaces with different radii of curvature. For the physical metrology, one autocollimator Elcomat Vario 40, and one Differential Interferometer Renishaw ML10, including optics for straightness and flatness measurement, as well as several linear and rotation motorized stages.

The laboratory can model the optical performance of beamlines by analytic modelling as well as by ray-tracing simulation using the ART package, developed in-house. Other packages available include grating efficiency, reflectivity and advanced source modelling. Tools for the analysis of measured surface data and calibration of mechanical benders are also available. This includes optimization algorithms to correct residual slope errors by means of controlled elastic deformation of the mirror substrate.

The laboratory has performed the characterization and calibration of all the mirrors and gratings of the facility, including the correction of the surface error of one mirror below one nanometer. The laboratory has also characterized the mechanical performances of all the critical positioning systems of the beamlines at ALBA.

1.2.4.2 Chemistry laboratory

This laboratory is intended to prepare samples for experiments at the beamlines, to perform basic synthesis and to carry out off-line spectroscopic measurements. It consists of a series of chemistry benches, cupboards, an area for gas usage and two fume hoods for handling solid and liquid samples, respectively.

The laboratory is equipped with standard laboratory utensils, a press for pellet preparation, a rotary evaporator, a Schlenk line, a tubular oven and a glovebox.

1.2.4.3 High-Pressure laboratory

The laboratory is equipped with the instruments necessary to load and prepare the diamond anvil cells for diffraction experiments, such as the following: basic laboratory tools to handle chemicals in powder form, and to handle and prepare the diamond anvil cells; set of diamond anvil cells (two of Almax type and one membrane cell); optical microscope with μm resolution and large working distance; micro precision eroder to prepare the gaskets that will hold the samples between the diamond anvils; in-house developed pressure calibration system that uses the ruby R1 fluorescence.

1.2.4.4 Materials Science laboratory

The Materials Science laboratory is aimed at being used for solid state sample preparation and equipment setup activities. It includes basic equipment such as: spot welder; optical microscope; ultrasonic baths for UHV cleaning; diamond wheel saw; sample pellet press; laminar flow workspace plus UHV clean tools.

A small UHV test chamber for the testing of sample preparation tools such as evaporators, sputter guns, etc… is also available. In-vacuum evaporation of metallic films can be performed with a vacuum furnace.

1.2.4.5 Biological samples laboratory, including P2 lab

These laboratories are used to carry out Molecular Biology/biochemical procedures and manipulations that are needed to obtain and/or prepare biological samples for the beamlines: BL09-MISTRAL, BL11-NCD, and BL13-XALOC. These laboratories are equipped to deal with biological samples that require biosafety levels 1 and 2 (P2 laboratory).

The main components of the laboratories are: cold room (4 °C), chemical storage cabinets, fridge/freezers & incubators, fume hood, desktop centrifuges, microcentrifuges, scales, microscopes, solution spectrophotometer, plunge freezer, standard laboratory glassware and tools, icemaker, glassware washer, water ultrapurification system, Polymerase Chain Reaction (PCR) equipment, electrophoresis equipment, cell dismembrator, ultrafreezer (-86 °C), biosafety cabinet (P2) and autoclave (P2).

1.2.4.6 Laboratory of magnetic measurements, MAGLAB

In this laboratory accurate magnetic measurements (100 ppm) of high magnetic fields (up to 2 T) can be carried out for up to 2 m long structures. Magnetic fields in 3D volumes, with a high degree of spatial accuracy (30 μm), can be measured. It allows the measurement of accelerator magnets as dipoles, quadrupoles and sextupoles, as well as combined function magnets. Insertion Devices and long magnetic arrays can also be measured and characterized.

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.

The laboratory can also model and optimize magnetic designs using 3D simulation tools as Radia or Opera.

1.2.4.7 Laboratory of radiofrequency, RFLAB

This laboratory is devoted to tests and calibration of RF components and complete subsystems: Low Level RF, waveguide components 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 CSN (Consejo de Seguridad Nuclear).

The infrastructure includes: High Voltage Power supply (36kW-4A), IOT RF amplifier (80kW), waveguide equipment (directional couplers, circulator, adaptors), low level electronics, personal safety system, water cooling, compressed air.

The available instrumentation includes: signal generator, high bandwidth oscilloscopes, spectrum analyser, network analyser, and RF powermeters.

The laboratory can also model and optimize RF designs using the 3D simulation tool Microwave Studio.

In this laboratory the whole RF system of ALBA have been tested, conditioned and calibrated, it allows also for testing of the new improvements and upgrades. In addition, with its modular design, it allows the test of other RF systems with different frequencies and power levels.

1.2.4.8 Vacuum laboratory

This laboratory is equipped to give service to vacuum system with a clean room where vacuum systems assemblies, tests, ALBA vacuum systems operation and maintenance and design of new vacuum equipment can be performed. This laboratory has been instrumental for the assembly and preinstallation of the complete ALBA accelerators vacuum system. At a later stage the laboratory has been available also for BL vacuum instrumentation assembly and testing.

Among its equipment we can mention the following: pumping equipment (movable pumping stations up to 300 l/s, root, turbo, ion, TSP and NEG pumps measurement (Full range gauges 1000 mbar to 1e-9mbar, HV cold cathode gauges, Pirani sensors, leak detection (Helium leak detectors, RGA units), bakeout equipment, laminar flow cabinets (3,5x2,5m, 3x2m, 1x1m)

1.2.4.9 Survey & Alignment

This laboratory provides survey and alignment services, fiducialization, positioning and metrology, with resolutions of 0.5 μm (position) and 1 μrad (angle) and accuracy of the order of 10 μm.

It includes Laser trackers, 3D measurement arms, angular measurement systems, theodolite, digital and optical levels and an inclination sensor device.

This instrumentation has been successfully used to align the whole ALBA accelerator complex, and the whole instrumentation of the phase I BLs.

The whole ALBA equipment is now linked to a dense network of reference points, which is periodically surveyed, with the result of deciding total or partial realignment campaigns whenever convenient.

1.2.4.10 Transversal Laboratory

This laboratory is equipped to provide extensiometry (stress and deformations) and vibration analysis service.

It includes an extensometer HBM MGC plus electronics with single and double axis extensiometry gauges; data acquisition Catmaneasy software; a vibration measurement device with 4 accelerometers 500 mV/g 1-12000Hz, and 4 accelerometers 2.5 V/g 0.2-3000Hz.; and a seismograph Guralp CMG-6TD 30s to 100 Hz.

1.2.4.11 Electronics laboratory

This laboratory is equipped with electronics instrumentation and control support for beam-lines and accelerators.

Its measurement capabilities go from semiconductor characterization to low level measurement, impedance characterization, high voltage probing, high accuracy timing signals below picoseconds measurement or design of high speed digital buses.

It also includes all the means for building equipment prototypes, e.g. manufacturing, mounting and assembly of Printed Circuit Boards (PCB), or any other electronics support needed in the facility.

More than 200 different equipment are used in the lab: oscilloscopes (200MHz to 3GHz), multimeters, LCR meter, current probes (different ranges), high precision current and voltage amplifiers, high voltage power supplies, arbitrary signal generators, RF generators, different soldering and unsoldering tools, picoammeters, lock-in amplifiers, high voltage insulation meters, motor controllers, interpolators, electrometers...

The electronics laboratory has contributed to the design and prototyping of numerous equipment and components of accelerators and beam-lines, e.g. High Voltage Splitters, Alba Electrometers, Fast Interlock Modules, Interlock Concentrators, among others.

Furthermore, the electronics laboratory is the environment where complex systems for accelerators and beam-lines are simulated. Different test benches modelling the future upgrades of the accelerators and Beamlines are or have been built there. The synchronization timing system, the Icepap motor controller, the Equipment Protection System, or the Fast Orbit Feedback System are few examples, where the concept is proved and the different releases of the control system are tested. In addition, the electronics laboratory manages a large repository of instrumentation, interfaces and electronic components accessible for the use by beam-line scientists, accelerators physicists and users when required.

1.2.4.12 Mechanical workshop

ALBA workshop is a 380 m^2 facility aimed at giving production capabilities for single parts, prototyping and mini-series as well as transport and manipulations giving service to all the company teams' production demands.

It has production capabilities up to 1 m length parts, assembly, adjustment and alignment, tools and tooling, mechanical metrology and a 6 m^2 clean room and welding capabilities with MMA, TIG MMA and Microplasma.

In addition to standard workshop equipment, the ALBA workshop is equipped with several high precision machining tools and its accessories, as given in Table 5, two forklifts, two vans and one 24 Ton truck.

Table 5- High Precision machining tools available at the ALBA mechanical workshop

Equipment	*Dimensions [mm]*	*Accuracy [mm]*
Production: Machine tools		
Semiautomatic multipunch Lagun Milling machine tool	800x300x450	±0.02
Numeric control Kondia milling machine tool	650x300x300	±0.05
Semiautomatic lathe Pinacho	Ø500x 1500	±0.02
Micromachining Enco lathe	Ø120x 300	±0.02

1.2.5 Engineering capabilities

CELLS Engineering division provides the technical support related to the construction and operation of the facility.

The areas of expertise include Civil Engineering, Mechanical, Vacuum, and Cryogenics Engineering, Survey and Alignment, Finite Element Analysis (FEA) calculation and Project Management. The Engineering Division operates on the fields of infrastructure design, construction, maintenance, instrumentation design, project office, prototyping, workshops and labs exploitation, design office, logistics and transport, security and access control.

The division has the capability to provide the technical and managerial support required along the full lifetime of a project, from the design phase to the exploitation. 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.

The engineering division participates on collaborations with other research institutions for the development of instrumentation, the contribution being centred on the fields of mechanics and vacuum. A good example is the recent collaboration with the Ultra-short Pulsed Laser Facility (CLPU, Salamanca, Spain), where full engineering process including, design, production follow-up, assembly and commissioning of high stability vacuum chambers has been undertaken.

Cutting edge engineering methodologies and techniques are applied on high demanding components. Vibrational analysis, thermo-mechanical coupled simulations, and ultrahigh vacuum Montecarlo simulations have been combined to produce the most suitable design according to the specifications. The component as-built results have been verified by accelerometer based techniques, precision survey measurements and vacuum tests. The full compliance with the specs has been demonstrated.

And finally, the division establishes collaborations with industry, as for instance the application of predictive maintenance techniques to research facilities.

1.2.6 Computing capabilities

CELLS Computing and Controls division supports users research and experiments by providing personalized hardware and software solutions. These solutions match service levels adapted for the purpose of tailoring high-performance, easy to use and high-availability for control systems, data acquisition, personal safety, equipment protection, data analysis, information technologies services and information systems.

The control systems for accelerators and beam-lines involve more than 400 racks, 6700 equipment, 18000 cables, 150 diskless computers and programmable logic controllers and over 600 motorized axes. It keeps a historical database in the order of ten thousand signals, concurrently available for debugging or diagnosis.

The system manages the synchronization of a few hundred elements at the level of a nanosecond, occasionally few picoseconds, and the positioning and motion of experimental components on the nanometer range. A configuration management database is the central repository for the installation, serving both for hardware installation and maintenance and software automatic code generation tools. The database includes cables, connectors, racks and equipment, their respective documentation and configuration.

Sharing and reusing knowledge with other institutions has proven to be remarkably beneficial. One good example is the Icepap Motor controller initially developed at the ESRF and in collaboration with ALBA since 2006. At ALBA there are more than 600 motors installed in the beamlines and accelerators and every new beam line would require an average of 70 new axes. The Icepap is now mature, powerful, flexible and cost effective, making it highly attractive and the natural choice for the new installations.

Besides the specific infrastructure involved in the control and data acquisition of accelerators and beam-lines, the computing division operates and maintains the central services, such as the central storage with a current capacity of 256 TB, reaching 500MB/s from beam-line´s detector, and the backup services with a net capacity of 600 TB on the Tape library. The network provides an aggregated bandwidth in the order of 400 Gigabits per second distributed on about 5000 connections with 500 Megabits per second with the Internet.

A large collaboration related to data management is the PanData intiative, which comprises thirteen word class European research institutes. The PaNdata Open Data Infrastructure (PaNdata ODI) project, supported by the European Comission, is working on the implementation of a federated data infrastructure, catalogues, and authentication systems and optimized data analysis.

The areas of expertise of the computing division include among others, industrial and scientific control and data acquisition, data processing and analysis, PLC programming, electronic design, cabling and electronic infrastructure, network and system administration, web services, content and document management, financial and various administrative services.

The service catalogue relies on this infrastructure and know-how, providing support and assistance to about 150 internal and more than thousand external users through the service desk. The user office processes an increasing number of few hundreds beam time proposals per year.

The computing division manages projects and services following a number of best practices and guidelines, enthused by the Prince2 methodologies and Information Technologies Infrastructure Library. Projects and services are devoted to facilitate the beam-lines and accelerators to operate reliably and to allow new techniques and experiments. The continual service improvement focuses on increasing the efficiency and optimizing the costs. The effectiveness is measured in a regular basis aiming to early detection of deficiencies and proposing corrective actions.

1.2.7 General infrastructures

ALBA is sited on a plot of land of about 60000 m^2, placed within the Parc de l'ALBA area, wherein an attraction pole for scientific and technological activity is being fostered, around ALBA, as explained in further detail in section 2.4 below.

This site has undergone extensive geological studies since the middle of 2004, including detailed identification of sub-soil composition, long-term stability, vibration levels, etc. There is now reasonable confidence in the suitability of the site in terms of long-term soil stability and vibrations levels sufficient to ensure the necessary mechanical stability of the Critical Floor Area (CFA), i.e. the area on which the complex of accelerators and the beam-lines are/will be placed.

The more stringent mechanical stability requirement is the one of the Critical Floor Area (CFA), which are summarized in Table 6.

The solution adopted for the base of the CFA consists of a 1m thick concrete slab, constructed from 20 segments. The segments were produced one at a time and subsequently joined by shuttering boards and with longitudinal re-enforcing bars going through the shuttering. The area below the slab had been previously treated with a ca. 2 m thick refill of selected gravel, homogenously and suitably compacted for additional stability, and sandwiched between two layers of poor concrete for protection.

Table 6 – Mechanical stability requirements of the Critical Floor Area

Dimensions of the corona in the CFA within which stability requirements apply	
Inner diameter	ca. 60 m
Outer diameter	ca. 120 m

Estimate of loads on the CFA corona	
Total static load	10.000 Tm
Distributed static load	1,5 Tm / m^2
Maximum load on a point	5 Tm / m^2
Dynamic load	2 Tm

Floor differential displacements	
Slow relative displacements	< 0.25 mm/10 m/ year
	< 0.05 mm/10 m/month
	< 10 µm/10 m/ day
	< 1 µm/10 m/ hour
Maximum differential displacement over the whole perimeter	< 2.5 mm/ year

Floor deformability because of loads	On application point	At 2 m
Static load of 500 kg	6 µm	1 µm
Dynamic load of 100 kg	-	1 µm

Vibrations		
Vertical amplitudes	< 4 µm	From 0.05 – 1 Hz
	< 0.4 µm	From 1 – 100 Hz
Horizontal amplitudes	2 µm	

The architectural complex consists of three main areas/buildings: technical buildings - of ca. 7500 m^2 -, the main Hall – of ca. 18500 m^2 - placed over the slab but with decoupled foundations, and the office/personnel wing – with ca. 4000 m^2. The main Hall and the office/personnel wing share a common roof with metal cladding that allows the indirect entrance of natural light, but avoids temperature variations inside the building. It should be noted that in addition to the mechanical stability requirements demanded from the CFA, there also are the equally critical requirements on thermal and electrical stability. The total electrical power installed is 12 MW. Table 7 summarizes the required specifications for thermal and electrical stability.

The mechanical installations, comprising air conditioning, cooling, treatment and distribution of water arriving from the mains network, and fluids (i.e. natural gas, diesel, compressed air and technical fluids) were included as part of the Buildings Project. The combination of the roof design and the internal air conditioning and temperature regulation equipment ensure that below a height of 4m in the Experimental Hall and inside the tunnel the ambient temperature are maintained within specifications.

Cold and hot energy production is carried out centrally and respectively obtained from water condensation in a cooling tower and by means of a condensation tank and a vapour tank. These plants are placed in the Technical Building. Distribution of hot and cold water is achieved via pumps also installed in the Technical Building. Distribution of chilled and de-ionized water is carried out via 4 circuits to the: service area and LINAC; Booster; Storage Ring, and; beam-lines.

Water is treated with ion exchange and reverse osmosis units. The various gases and fluids are stored and/or delivered from source (e.g. natural gas) at the Technical Building and distributed to the rest of the facility thereafter.

Table 7 – Thermal and electrical stability in the Infrastructure

Thermal Stability	
Within the Ring Tunnel	23 ± 0.2^{o}
In the Experimental Hall	23 ± 1^{o}

Electrical Stability	
Long power cuts (t > 0.6s)	< 1 per year
Medium duration power cuts (0.4s < t < 0.6s) and ΔV > 12% in 2 phases	< 3 per year
Short duration power cuts (t < 0.4s) and ΔV > 8% in 3 phases	< 3 per year

Other Electrical data	
Voltage Supply	25 kV
Expected power Consumption	9 MW

Regarding electrical installations, earth connection of < 0.2 ohm is achieved via a 1mx1m reticule made of naked, buried copper wire of 50 mm^2 cross section. The reticule is re-enforced with copper-steel spokes and joined to an equipotential net of galvanized steel that is imbedded in the floor of the Hall. This net is also joined to a perimeter ring of naked copper, again with a cross-section of 50 mm^2. All earth networks are joined together into a single equipotential net. Two emergency diesel generators (720kW each) are installed in the Technical Building to back up static un-interruptible Power Supply units, UPS, in case of failure of the external supplies. Dynamic UPS, i.e. flywheels, are available as filters for short-lived dips in the mains with autonomy of 12 seconds which gives enough time to allow the mains to re-stabilize.

ALBA has to operate so that the possibility of an uncontrolled shutdown due to power supply failure is minimal. Therefore, apart from the question of stability that is handled internally with the various technical appliances referred to above, there must be a redundancy in the external sources of the energy. Redundancy has been achieved as follows: ALBA can get energy either from a sub-station - named Codonyers - sited nearby and/or from a co-generation plant – named ST4 – also situated in the immediate vicinity of CELLS. CELLS is a minor partner in the society that operates the ST4 plant.

ALBA is connected to Codonyers via a double dedicated electrical line. The 220 kV to 25 kV transformer as well as the high voltage positions are exclusively dedicated to ALBA use. In this way ALBA receives the benefit of the higher rigidity to earth of the 220 kV bar. In addition, ALBA is connected to the cogeneration plant ST4 that can also provide CELLS with electrical power as well as warm and chilled water. So, with this scheme ALBA's energy requirements can be obtained from either the public electrical network at transport voltage or from the co-generation plant.

1.2.8 Structure and activity description of the Health&Safety Group

The H&S group is the adviser to the CELLS Director in all occupational health and safety aspects, whether they are related to conventional or radiation protection risks.

The tasks assigned to the group of H&S are related to the prevention of the occupational hazards that is contained in the Spanish Law 31/1995, in particular:

- *All aspects involving the companies' activity coordination that is developed by the Spanish Royal Decree 171/2004.*
- *The implementation of the Self-Protection Plan at CELLS, as it is stated in the decree from the Generalitat de Catalunya 82/2010.*
- *All aspects of radiation protection of the ALBA facility, which are detailed in the Spanish Ministry of Industry, Tourism and Trade Order ITC/528/2011 where the ALBA Synchrotron facility is classified as radioactivity First Class facility. All functions herein are assigned to the Radiological Protection Service (SPR-Servicio de Protección Radiológica) of ALBA, authorized by the Nuclear Safety Council (CSN-Consejo de Seguridad Nuclear), as stated in the December 15th 2010 CSN meeting.*

CELLS has an external Prevention Risk Service (SPA-*Servicio de Prevención Ajeno*), which covers all the assets of the prevention risks, including medical monitoring. Furthermore, the SPA has assigned to CELLS an occupational risk technician to comply with all aspects that the Spanish legislation requires. In relation to the prevention of conventional risk, the H&S group is responsible for:

- Checking, reviewing and advising on the reports, procedures and safety data sheets.
- Organising the training on prevention of different occupational hazards subjects.
- Providing the support and advising the Division Heads and the workers direct managers (the so-called Controllers) in the prevention of occupational hazards.

The SPR (which is part of the H&S group) is responsible for guaranteeing that the Spanish legislation on radiation protection issues is implemented and followed and ensuring that the specific regulations approved by the CSN for the ALBA facility are implemented and followed by its staff.

All the tasks carried out by the H&S group described above apply to CELLS staff, external contractors, facility users and visitors.

The H&S group is also responsible for establishing the criteria and evaluating the ALBA users experiment proposals, in all the subjects related with health and safety (either conventional or radiological), and to ensure that all the proposals follow the labour prevention risk standards.

1.2.9 Human Resource Organizational Structure

The personnel structure of CELLS defined during the construction of the facility, based on a Director's office and 5 Divisions, is kept with few modifications in this initial operation period, while the number of staff members in several of the groups has been redefined.

The Director's office includes the Radiological and Conventional Safety Office, the Users Office, the Liaison Office for Proprietary Research, the Communication Office and the Competitive Project Office. All these offices are still understaffed to efficiently fulfil the ever increasing demands which are related to the User Operation both public and proprietary, the duty to transmit to the society information on our research results and potentialities, the necessity to obtain external funds on a national and international basis.

The Divisions leading the exploitation of the facility are the Experiments Division, captained by the Scientific Director of the facility, and the Accelerator Division, under the Accelerator Director. The technical support, including maintenance and new development realization, is given by the Engineering Division and the Computing and Control Division, whereas administrative support is given by the Administration Division.

The Experiments Division includes the scientific staff, which for each BL is envisaged to consist of at least 3 BL scientists plus a PostDoc. A transversal group dedicated to Optics, Metrology and direct technical BL support completes the Division. In the future the Division staff will increase when new BLs will be in construction and operation.

The Accelerator Division includes the groups dedicated to: Beam Physics; Radiofrequency and Linac; Insertion Devices; Accelerator Operation. It is responsible for the accelerator operation and includes the staff needed to operate 3 shifts/day including weekends in order to reach the foreseen 6000 hours per year. The Division structure will evolve when new projects will be started.

The Engineering Division includes an Infrastructure Section which takes care of the infrastructure maintenance, including the technical systems like electrical plants and cooling systems. The Transversal Section is providing support to accelerators and BL, through the Project Office, the Technical Workshop, the Alignment group and the Vacuum group.

The Computing & Control Division is responsible for the Accelerator and BL Control and Data Acquisition Systems, the Network and information technologies general services, the Management Information Systems (MIS), document management and Web services. An Electronics Section completes the Division staff.

The Administration Division provides the administrative support to all CELLS activities, including Legal Services, Human Resources, Secretariats and Financial Support to Management.

Staff numbers are given in section 3.4 below.

1.2.10 **User visits during first years of operation**

1.2.10.1 Non-proprietary users

Two public calls for non-proprietary users have been launched so far. The first one was published in November 2011 and it was used to allocate beam time since the opening of each of the 7 phase I beamlines. Although the first call for proposal was meant to allocate beamtime during 2012, the period for experiments was extended to March 2013 due to the high number of good quality proposals. Therefore, the call results were published in two steps: proposals with awarded beamtime in the period May-December 2012 and proposals with awarded beamtime in the period January – March 2013. The first official user visited ALBA on May 2012 to perform an experiment on BOREAS BL.

The second call was issued in September 2012, for allocation of beamtime from April 2013 to March 2014. In both cases ca. 200 experiment proposals were received.

The nationality of the proposal is defined by the home institution country of the main proposer (similar definition for the Autonomous regions in case of Spanish proposals).

In the first call Alba User Office received 203 proposals: 167 proposals from Spain, 33 from the European Union and the rest from Asia and USA. If we consider the Spanish proposals: 44% were Catalan, 27% from Madrid, 5% Basque Country, 4% Andalucía, 3% Aragón, 2% Galicia and the rest came from Canary Island, Asturias, Baleares and Cantabria. If we also consider co-proposers, the main percentages do not vary but the small percentages change a bit and some other CC.AA. (Autonomous regions) like Castilla-León also appear in the list.

The nationality distribution of the second call is very similar, with a slightly higher representation of international proposals.

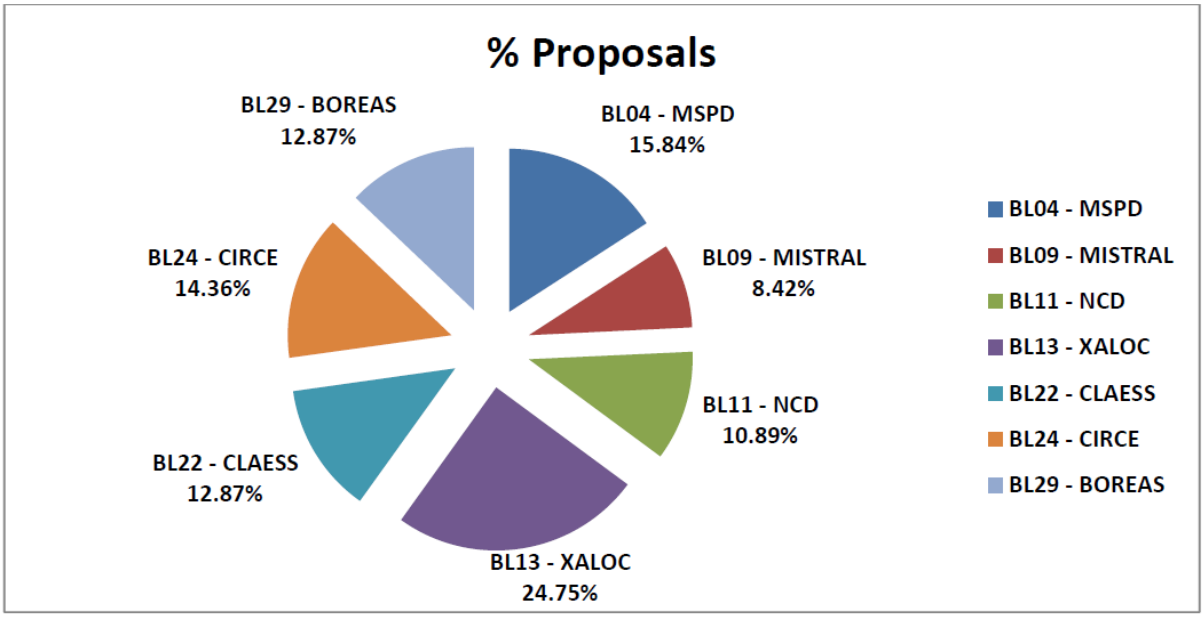


Figure 15 - User proposals received in the first call (November 2011) classified per BL. A total of ca. 200 proposals were received.

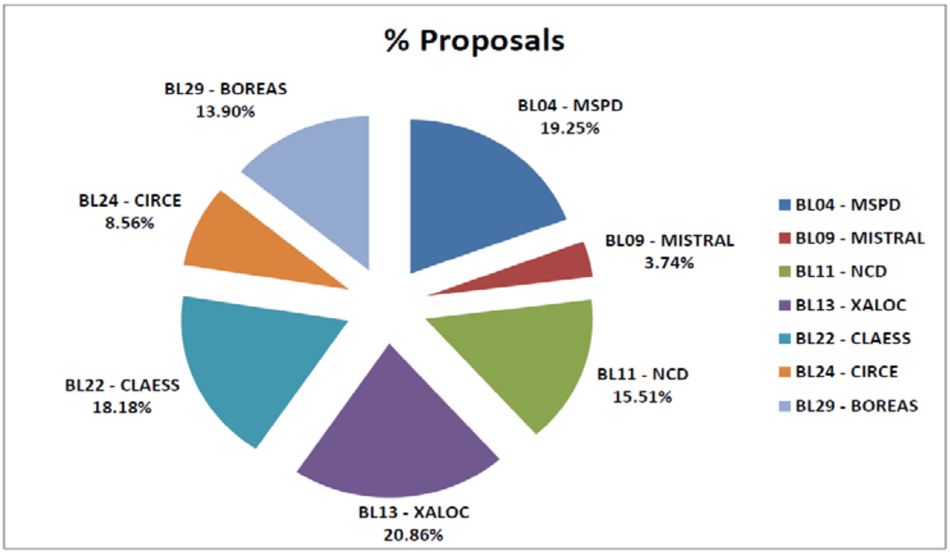


Figure 16 – User proposals received in the second call (September 2012). Again ca. 200 proposals were received

Error! Reference source not found. and **Error! Reference source not found.** show, as a reference, the distribution of received proposals in the first two user calls by target beamline. The chart illustrates the good matching between the choices made for phase I BLs and the actual interests of the user community. Notice that BL09 MISTRAL is the one which serves a smaller, emerging community, due to the novelty of the technique offered therein.

1.2.10.2 Proprietary users

Proprietary users have been approached by ALBA already during the construction period, and this has allowed to have the possibility of offering the BL to the first industrial users at the very beginning of operation.

The companies interested cover a wide range of fields such as pharmaceutical, nanomedicine, adhesives, food, home care, personal care, chemical, etc… In some cases the collaboration is in a very advanced stage like the one with the German multinational Henkel, leader on laundry and home care, beauty care and adhesive technologies. In this case a collaboration agreement has been signed and feasibility studies on real samples have been carried out. This collaboration goes beyond a standard one as a postdoc position is fully funded by Henkel. The person occupying that position will start to work in a few months and will be involved in the Henkel experiments at ALBA providing detail feedback of the results including a full data interpretation to Henkel. This is perfect win-win collaboration among both organizations that ALBA might use as a model in the future.

In other cases extensive contacts are being taking place like with Almirall the biggest Spanish pharmaceutical. Some experiments have been identified and they are intended to be carried out in the near future. In this case hiring a person co-funded by Almirall and the regional government is being agreed. This person would be fully involved in the Almirall experiments and data analysis which can also be used for his PhD thesis. This figure is called “industrial doctorate” which brings together the academic and the industrial worlds. ALBA could also use it as another collaboration model in the future.

With the remaining cases the situation varies depending on the company. In some cases contacts are going on to define the potential experiments to be carried out. ALBA is considering the possibility to provide data interpretation whenever possible.

Finally some other customers are coming through research institutions providing like in the chemical and in the cultural heritage areas.

1.3 THE LEGAL STATUS OF CELLS; ITS GOVERNING AND ADVISORY BODIES, AND USERS' REPRESENTATION

1.3.1 CELLS' legal status and institutional commitment

The basis of the creation of CELLS is to be found in a Protocol of Intent signed between the administrations of the Spanish State and of the Catalan Autonomous Government on the 14th of March 2002. The 2nd clause of this Protocol of Intent establishes that both administrations will bear an equal share of the costs of the construction of a Synchrotron Light Source, and its 3rd clause states that "the concrete terms and conditions of such collaboration will be defined through a Collaboration Agreement".

A year later, on the 14th March 2003, the Collaboration Agreement was signed (BOE núm. 81, DOGC núm. 3858, del 4 de abril) between, at the time, *Ministerio de Ciencia y Tecnología* (Ministry of Science and Technology) - nowadays the *Ministerio de Economía y Competitividad* (Ministry for Economy and Competitiveness) - and the *Generalitat de Catalunya* (Autonomous Government of Catalonia) through its *Departament d'Universitats, Recerca i Societat de la Informació* (Department of Universities, Research and Information Society) – nowadays the *Departament d'Economia i Coneixement* (Department of Economy and Knowledge). The Agreement was to constitute a public consortium owned and jointly supported with an equal share by the Spanish and the Autonomous Catalan administrations. The Agreement was published in the official journals of both administrations. It included the financial plan of the project. At the same time the regulations (or statutes) of the Consortium were approved. The two institutions participating in CELLS committed to an equal share of the construction costs of the Synchrotron Light Source. Since then two addenda to the Collaboration Agreement have been signed in order to enlarge the number of beamlines from five to seven and to assure the financing of the Consortium during the next years.

1.3.2 Governing Bodies: Executive Commission and Rector Council

The Statutes of the Consortium foresee two Governing Bodies with joint membership, namely: a Rector Council, that was constituted on the 12th of June 2003 and in which the two administrations that propelled the Project are represented and an Executive Commission that was constituted on the 25th of June 2003.

Membership of the Rector Council consists of a Chairperson, a vice-Chairperson, four delegates from the Spanish Ministry, four delegates from the Catalan Government, the Chairperson of the Executive Commission agreed by the two administrations and the Secretaries. In order not to break the equilibrium, the Chairperson of the Executive Commission and the Secretaries do not have voting rights.

The Chair of the Rector Council rotates annually between the Ministers. Whoever of these two people does not occupy the Chair, automatically takes the vice-Chair position that, therefore, also rotates accordingly.

The Executive Commission consists of a Chairperson, two delegated members of the Rector Council from each one of the administrations there present (i.e. four delegates in total from the Rector Council), the Director of the Consortium and the Secretaries.

The Rector Council upon a proposal by the Chairman of the Executive Commission appoints the Director of the Consortium. The appointment is of an indefinite nature.

The Consortium regulations confer all executive competences within CELLS to either the Rector Council or to the Chairman of the Executive Commission. The Director, upon taking the position, has whatever executive rights and duties these bodies delegate.

1.3.3 **Mission, structure and operation of Advisory Bodies**

The statutes of CELLS contemplated two advisory bodies, namely the Scientific Advisory Committee (SAC) and the Machine Advisory Committee (MAC), whose appointment, function and composition would be agreed by the Rector Council upon a proposal by the Executive Commission.

MAC was the consultative organ of the Consortium in relation to the construction of the accelerators and to the production of SL. Once the accelerator systems had finished their construction and commissioning and were in operation for the production of synchrotron light, its role has been absorbed by SAC, which is at the moment the only external advisory body.

SAC is the scientific consultative organ of the Consortium. It comprises a maximum of 10 and a minimum of 8 people with recognised international prestige in fields related to the activities and objectives of the Consortium, including accelerator technologies, now that MAC is not anymore active. Members will be named by the Rector Council from proposals by the Administrations in the Consortium. The Rector Council will also define the functions of SAC and the norms of internal behaviour. SAC meets on average twice a year and the Chairperson of the Spanish Association of Synchrotron Users (AUSE) and the Chairperson of the Executive Commission are invited to attend as Observers. The Statutes contemplate that the Director should chair both the SAC meetings. However, it has become customary that the members elect a person from within their ranks to discharge this function.

The current role of SAC is, at the request of the Director, or on its own initiative to give its opinion or advice to the Director on any scientific/technical matter related to the scientific exploitation of the SR source. This includes the very important function to review proposals for beam-lines, to advice on their ranking of interest and to follow through and advice during their construction and future exploitation.

1.3.4 **User proposal evaluation panel**

User proposals are evaluated by an international panel, formed by experts. Two cycles of user proposals have taken place. In both cases numerous proposals were received, evaluated for technical and safety feasibility by ALBA and for scientific merit by the external panel. The panel members analyse the proposals remotely and meet together at ALBA for a final meeting, from which the scientific merit ranking within each BL emerges. Finally beamtime is awarded, based on this ranking and according to the total beam availability. This scheme, similar to the one used by other SL facilities, is a very efficient way of having an excellence-filtered scientific case input to the activity of the facility.

1.3.5 **User representation: the Spanish Association of Synchrotron Light Users (AUSE)**

The Spanish users of SL have been organized within an association known as the Spanish Association of Synchrotron Light Users (Asociación de Usuarios de Sincrotrón de España, AUSE). Although totally independent of ALBA, AUSE, among other things, channels and represents the interests and objectives of the user community of ALBA. “De facto” AUSE has played a very important role as the institution through which the proposals emanating from the user community for the first set of beam-lines at ALBA were channelled. This proved a very effective way to converge to a set of beam-lines that overall represented best value for money at the time.

They play the same role for the proposal of the second phase beam lines that, unfortunately and because of the economic situation are not yet in construction. We propose that AUSE will continue to be part of this process and its Chairperson will continue to be an observer at the SAC meetings of ALBA.

1.4 CELLS VISION AND MISSION STATEMENT

1.4.1 Vision

To become a centre of excellence in Synchrotron Light Scientific and Industrial applications at European level and to achieve the status of a recognised world class facility in its field.

1.4.2 Mission Statement

To research in, deliver and maintain methods and techniques with which to conduct cutting edge Synchrotron Light based research and development, in such a way that knowledge and added value are pumped into the scientific and industrial communities, particularly the Spanish ones, with the ultimate goal of contributing to the improvement of well-being and progress of society as a whole.

1.4.3 Guiding principles

To discharge its mission and achieve its vision, CELLS will be guided by the following principles:

- *i)* *Enhance expertise and promote the utilization of Synchrotron Light by working with the Spanish and international scientific communities;*
- *ii)* *Keep itself at the forefront of Synchrotron Light Science by conducting and enabling competitive research and providing the most advanced SL technologies;*
- *iii)* *Provide a state of the art Synchrotron Light service to the scientific and industrial communities and operate the ALBA facility with the highest efficiency, with a clear user-oriented policy.*
- *iv)* *Provide a multidisciplinary environment that fosters innovation through scientific and technical collaboration, mainly in the Synchrotron Light and accelerator sciences and related topics, always having the user community as a reference;*
- *v)* *Foster industrial involvement and partnerships, both using synchrotron light as a tool, developing instrumentation therein and doing technology transfer, thus promoting commercial opportunities and economic development, both in large and small-medium size industries;*
- *vi)* *Promote the optimization of resources by offering the complementary capabilities developed at ALBA to other scientific and technological institutions via collaborative agreements;*
- *vii)* *Contribute to the training of a highly skilled work force that will feed back into science, industry and society;*
- *viii)* *Actively participate in the development of the public perception of Science, and;*
- *ix)* *Collaborate across borders to promote the exchange of people and ideas.*

2. CRITICAL ANALYSIS

2. CRITICAL ANALYSIS

2.1 ALBA STRENGTHS, WEAKNESSES, OPPORTUNITIES AND THREATS

2.1.1 Strengths

ALBA is the result of the work of a team made up of experts and young staff, which has constructed on a green field the largest scientific infrastructure in Spain. This impulse is strength for its future.

The joint ownership of ALBA and its Chairmanship at the Minister level is a double protection in the present situations of economic crisis.

ALBA is one of the most competitive 3rd Generation SL sources in the world. Its compact design allows a low emittance and therefore high flux, even with a relatively short circumference and a medium size laboratory.

It is a user facility, thus meaning it has a dynamic environment in which users both from National and International Institutions contribute to the scientific output and growth of new ideas and techniques.

ALBA phase I BLs have been chosen and designed so as to be at a world-class level in their respective fields, and have a good match to the needs of the Spanish user community. Some of them have a particularly high level of originality, which will likely generate interesting scientific projects and attract collaborations with top level groups worldwide. We are briefly mentioning them here, referring for more details to Chapter 1.2.2.

- *The cryo-tomography soft X ray microscope of MISTRAL is the third one operating worldwide and is producing top level results in cell 3D imaging.*
- *The Near Ambient Pressure Photoemission instrument of CIRCE, recently come into operation, dedicated to photoemission of organic surfaces, is the sixth instrument of this kind worldwide.*
- *The fluorescence spectrometer, now in commissioning, of the CLAESS beamline will be one of the few instruments worldwide performing inelastic hard X ray scattering. It will strongly enhance the possibilities of the beamline in terms of spectroscopic mapping of the fluorescence radiation emitted from the samples and will have unique operation modes.*
- *The MARES instrument, now under construction, to be installed in the BOREAS beamline, will allow performing soft X ray reflectivity of magnetic samples while applying a 2T magnetic field of a variable orientation in order to keep the field direction fixed relative to a surface crystallographic direction. It will be unique worldwide.*

ALBA has a huge potential for expansion in terms of new beam-lines and instrumentation with which to exploit the photon range and the brightness of the source and, thus, the possibility to adapt to emerging scientific challenges, including the hosting of long insertion devices and space possibilities of long beamlines.

ALBA Accelerator team is the first group within Spain which has dealt with the design, construction and operation of a complex accelerator infrastructure and has built up experience in all its technologies. It is now an active member of international collaborations for state of the art accelerator physics and technology, offering key contributions to new synchrotron light facilities or other accelerator based projects

ALBA Experiments team is the reference within Spain for the manipulation and use of Synchrotron Light.

CELLS can flexibly recruit people as the personnel are contracted via usual work contracts. This confers to CELLS an unusual flexibility compared to other public research organizations in the country.

The staff - that is on average young and mostly motivated – and the structure of CELLS are adaptable to new requirements.

CELLS has a multicultural/international identity, with several repatriated Spanish nationals as well as non-Spanish fellows. These staff bring with them valuable experiences and know-how. Moreover, it facilitates international contacts.

CELLS has acquired and developed important know-how in the management of large scientific projects and follows best practices. For example, CELLS financial/accountancy software has become a desirable object for other Spanish organizations.

CELLS has the capability to integrate/develop new instrumentation/equipment into a complex facility.

CELLS has effectively networked itself with other national and international facilities through a series of bilateral agreements and European projects.

Infrastructures and laboratories developed during the ALBA construction, like magnetic measurements, RF power, vacuum and metrology laboratories, are now available for future developments, and for establishing collaborations with other institutions, offering and sharing their utilization.

BL cutting edge technology, together with highly qualified and motivated teams, will be ready to provide instruments and support to private SL users from all over the world, with competitive cost.

CELLS can foster SL related R&D activities in Spanish industries, especially in its surroundings, which owns one of the most developed industrial context in Spain.

CELLS provides a leading edge technological and scientific work and training environment allowing its staff to reach an outstanding knowledge on the field. It is proven by the large amount of ALBA staff continuously hired by well recognized international R&D institutions.

CELLS provides a variety of educational and training programs: a Master on Synchrotron Radiation, jointly with the UAB, stays of PhD students, post-doc positions.

English as a working language leads to the international character and allows collaborations with other large scientific institutes.

2.1.2 Weaknesses

There is limited tradition in the owner administrations on how to manage and develop multidisciplinary scientific facilities or on how to plan for their sustained funding. This carries the threat of stagnation and may put ALBA at a disadvantage relative to competing SL sources, e.g. Soleil, Diamond, SLS, etc.

The transition from construction to exploitation is depriving ALBA of some of its key R&D people. Hiring and training new persons will need effort and time.

Some groups are below critical mass, including industrial and competitive project offices.

The personnel numbers in CELLS do not allow for redundancy of functions. This is threatening in the event of an unexpected departure of some key people.

2.1.3 **Opportunities**

The geographical location of ALBA makes it the only SL source in the whole of the South West of Europe (Portugal and South of France). There is a large catchment area available to CELLS, both from the point of view of academic and industrial applications. The catchment may extend to Northern Africa and Latin America because of geographical and cultural reasons, respectively.

The facility is located in a region with many research institutes (CERCA and CSIC) and many of the best Spanish Universities, and next door to the so-called ALBA Science Park. This offers clear opportunities for basic R&D and for applications with the private sector.

CELLS is located in the vicinity of a major university, thus allowing synergies and establishing strong links with academic groups.

CELLS is in the immediate vicinity of Barcelona, a city that is attractive to international and young staff members.

Given its core know how, CELLS is in a good position to act as agent for Spanish involvement in international facilities requiring accelerator know-how.

CELLS does have the potential to generate many bi-products of either commercial or strategic value.

CELLS could place itself as a motor of Spanish technological applications by establishing close links with industrial institutions.

CELLS is training university graduates/post-graduates in accelerator technology, instrumentation and in the applications of SL.

ALBA has the available floor to install new beam-lines, well beyond what is expected to use in the immediate future. Third countries, foreign R&D institutions or companies may have a BL with a relatively modest investment at ALBA. The timing of this effort is very critical, since in a few years from now other new facilities may pose a strong competition in attracting such investments.

2.1.4 **Threats**

The most important threat is that ALBA becomes a second class facility due to its loss of international attractiveness. This may happen if the funding is unsecure or decreasing and no new projects are undertaken and if the qualified scientists leave the facility due to the lack of stimulating perspectives and to the declining salaries.

The present economic situation in Spain generates uncertainty feelings on the future. It is pushing international staff to abandon the country, also in view of the education and labour market for their children. It complicates the attraction of highly qualified Spanish scientists working abroad, and foreign staff, who are also worried by the poor job market availability for their partners.

The highly qualified ALBA staff, responsible for the design, construction and start of operation of the facility, is presently tempted to leave the infrastructure. Beyond the reasons given above, there is the reality that international scientific infrastructures, searching for experienced people, are offering high qualified positions, strongly competitive from the economical point of view and very interesting from the scientific one.

The present restrictions to cover the vacancies and the prohibition to offer permanent contracts strongly complicate to overcome the above threats.

There is a much larger number of beam-lines, therefore a much broader scope of experimental possibilities, in other 3rd generation SL facilities, e.g. Soleil, Diamond, SLS, etc. , which, added to their competitiveness in terms of salary offers, might handicap ALBA in recruiting first class staff. This may reflect also in difficulties in attracting talented users.

The current slowdown in new beam-lines construction with respect to the original planning combined with the fact that very advanced 3rd generation sources are being built elsewhere (Max-IV, NSLS-II) may hamper the capabilities of ALBA to keep up as a world-class facility. A few years delay may mean that ALBA loses the chance to build up a first-class scientific activity in certain areas.

There is little local industry with expertise in the maintenance and R&D of the type of sub-systems that are/will be needed at ALBA.

CELLS might have to rely too heavily on the foreign market for the development of products with high added value and with an innovative technological aspect, unless the Spanish science-driven industries are strongly supported by public policies. This may affect the agility in the response time to emerging new requirements.

2.2 RELATIONAL ANALYSIS

Nowadays there are 51 Synchrotron Light facilities in the world, with an ubiquitous distribution, which covers all regions with the exception of Central America and Africa, as shown in Table 8.

Table 8 – Synchrotron Light facility distribution in the world

North America	9
South America	1
East Asia	19
West Asia	3
Europe	18
Oceania	1

This ubiquity is unsurprising if the crucial role played by SL in fundamental and applied research is taken into consideration. It is indeed part of the analysis of the strengths and weaknesses of ALBA to compare its performance with that of other SL facilities of relatively recent construction. There are many parameters that determine the quality of a SL facility such as the achievements of its science program, the quality of its R&D, the efficiency of operations, etc. (see section 2.6 for a number of performance indicators). However, as ALBA is starting operations these performance indicators will not be meaningful until some historical data are available and, therefore, we will restrict the comparison to ALBA design parameters and experimental beamlines.

The source parameters crucial in determining the potential of the light source are the photon spectral range of utilization and the brightness of the source. The former gives the potential for different applications and different fields of research whilst the latter, determines the ultimate quality of the data. The spectral range of the emitted photons increases with the square of the electron energy as this is indeed the main factor defining the critical energy – i.e. the photon energy that corresponds to the median of the emitted photon power - whilst the brightness of the emitted radiation is determined by the electron beam current and emittance, this last defining the source size and divergence. In order to get high brightness, low emittance must be achieved.

In order to compare ALBA with other SL sources one must make the distinction between medium energy SL facilities, typical of national installations like ALBA, and high energy facilities such as the ESRF, Spring-8 or the APS that are international or continental facilities meant to complement national/medium energy facilities. Among those there is a somewhat anomalous SL source, Petra-III that has originated from recycling an accelerator originally used for high-energy physics. Today Petra III is the high-energy SL source with the best performance parameters (i.e. has the largest useful photon energy range with the lowest emittance). Regardless of these considerations and as shown in Table 9, ALBA compares very favourably with the ESRF, Spring-8 and the APS in terms of emittance, although Petra III is well ahead. Obviously, given its energy, ALBA cannot pretend to compete, nor it is meant to do so, with the photon energy range available at these complementary facilities.

For the above reasons we will restrict our comparison to medium energy 3rd generation sources, as ALBA is the last 3rd generation SL source in Europe that has come into operation. Table 9 compares those types of operating facilities, under “sources in operation”, sorted by increasing emittance. ALBA is only slightly bettered by that of Soleil and Diamond, whilst its energy is identical to that of Diamond and somewhat higher than Soleil’s. In other words, ALBA is on the top performers among medium energy SL facilities.

Table 9 - Third generation synchrotron light sources

NAME	LOCATION	E(GeV)	C (m)	I(mA)	ε(nm rad)
Sources in operation					
DIAMOND	Chilton, UK	3.0	560	300	2.7
SOLEIL	Paris, FRANCE	2.9	354	500	3.1
ALBA	Barcelona, SPAIN	3.0	269	250	4.6
SSRF	Shanghai, CHINA	3.5	396	300	4.8
SLS	Villingen, SWITZERLAND	2.4	240	400	5.0
BESSY	Berlin, GERMANY	1.9	240	270	5.2
ALS	Berkeley, USA	1.9	197	400	6.8
ELETTRA	Triestre, ITALY	2.4	260	320	7.0
ASP	Melbourne, AUSTRALIA	3.0	216	200	8.6
MAX-II	Lund, SWEDEN	1.5	90	200	9.0
PLS	Pohang, KOREA	2.5	281	180	12.0
SPEAR-3	Stanford, USA	3.0	240	500	18.0
CLS	Saskatoon, CANADA	2.9	171	500	18.0
TLS	Hsinchu, TAIWAN	1.5	120	300	25.0
INDUS-II	Indore, INDIA	2.5	173	300	58.0
ANKA	Karlsruhe, GERMANY	2.5	240	110	70.0
High Energy Sources in operation					
PETRA III	Hamburg, GERMANY	6.0	2300	100	1.0
SPRING-8	Himeji, JAPAN	8.0	1436	100	3.0
APS	Chicago, USA	7.0	1060	100	3.0
ESRF	Grenoble, FRANCE	6.0	844	200	3.8
New sources in construction					
MAX-IV	Lund, SWEDEN	3.0	528	500	0.3
NSLS II	Brookhaven, USA	3.0	620	500	1.5
TPS	Hsinchu, TAIWAN	3.0	518	400	1.7
SOLARIS	Krakow, POLAND	1.5	96	500	6.0
SESAME	Amman, JORDAN	2.5	133	400	27.0
Proposed new sources					
SIRIUS	Campinas, BRAZIL	3.00	518	500	0.3
CANDLE	Yerevan, ARMENIA	3.00	224	350	8.4

Notwithstanding the above, we point out that there are new SL sources under construction such as MAX-IV in Sweden, NSLS-II in the USA and TSP in Taiwan - three 3 GeV sources with an essentially diffraction limited vertical emittance – and SOLARIS in Poland, a 1.5 GeV based on MAX-Lab technology. A new 3 GeV SL has been proposed in Brazil, SIRIUS, to replace the existing one. Most of those new facilities will outperform ALBA as they enter into operations in the future.

Once stated that the size of a synchrotron is mainly defined by the beam energy, due to the energy scaling of magnetic rigidity (see Figure 17 showing the relation between energy and length of the 3rd generation light sources), the other two parameters which affect directly the ring size and therefore its cost are the emittance and the number of straight sections where hosting insertion devices.

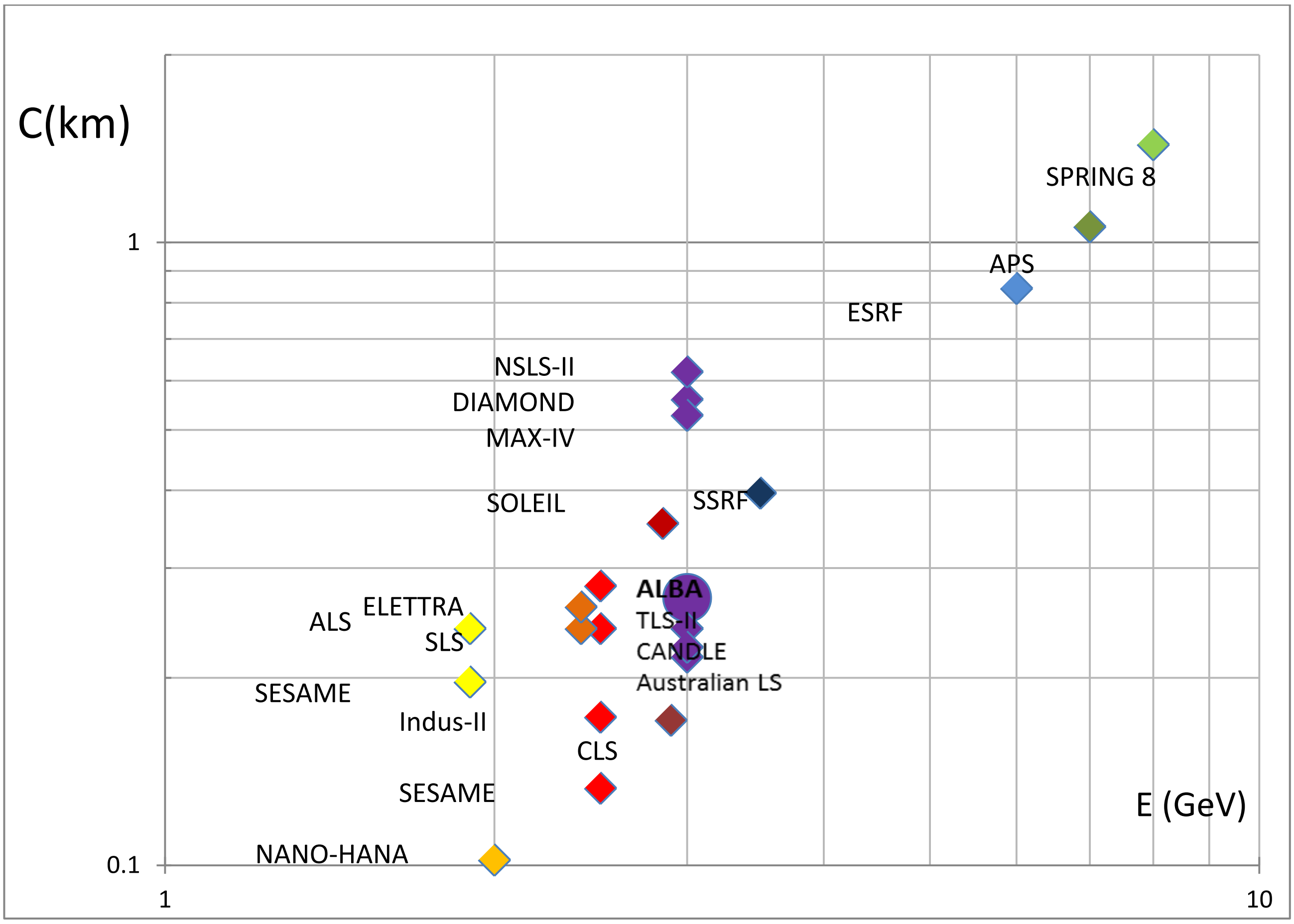


Figure 17 – Length as a function of beam energy of 3rd generation light sources. ALBA is represented with a circle

The emittance, which is the result of the equilibrium between quantum excitation due to the photon emission in bending magnets and the radiation damping provided by RF cavities, decreases when the dispersion function in the dipoles is minimized. Increasing the number of dipoles per arc and the focusing among them is the usual trend in the lattice design of the so-called Ultimate Storage Rings (USR) with the aim of reaching the diffraction limit. This leads to lengthen the total circumference. A figure of merit has been defined [18], which relates emittance (ε), circumference (C) and energy (E).

$$M = \varepsilon \frac{C^3}{E^2}$$

The lower this parameter, the more optimized the lattice design. The trade-off between low emittance, large number of available straight sections and budget constraints has been remarkably solved in ALBA, whose design between the sister facilities built in the same years is the most compact, as shown in Figure 18, where the figure of merit M is plotted, separated by different construction dates, and in Figure 19 where the circumference over the number of available straight sections is shown.

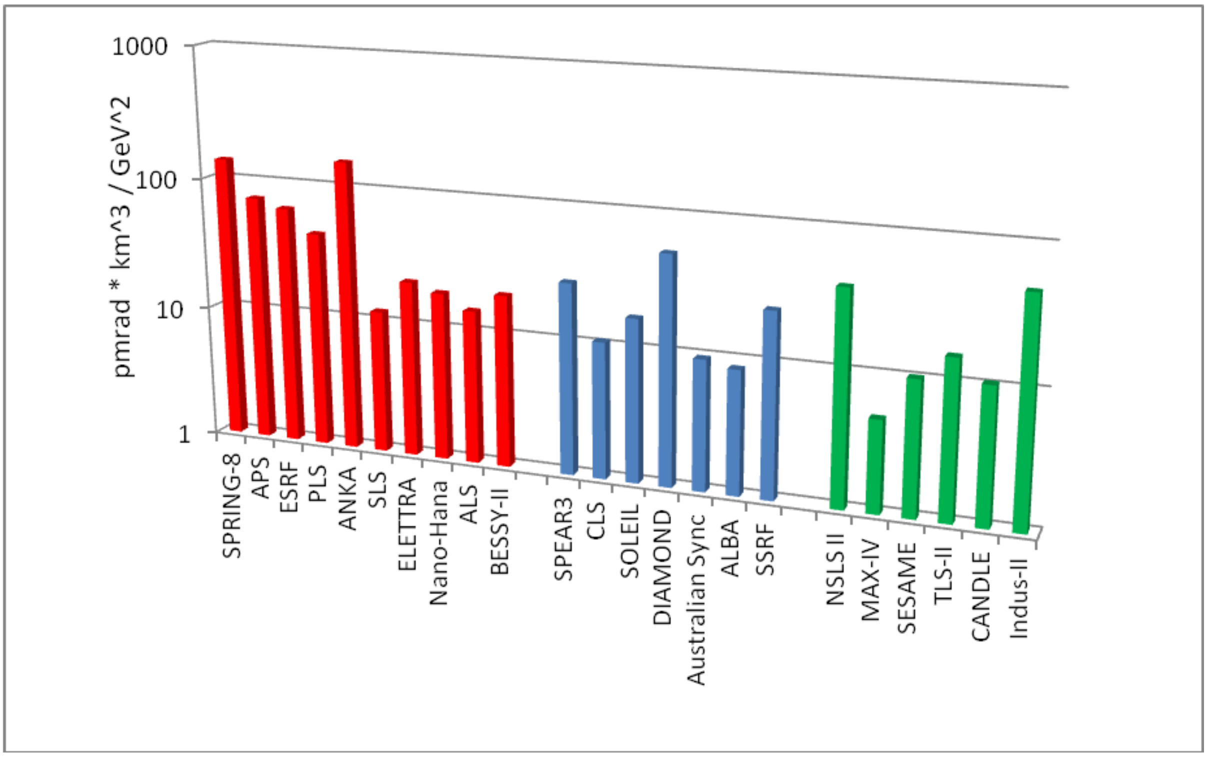


Figure 18 - Figure of merit M for 3rd generation light sources – Colours separate different construction dates

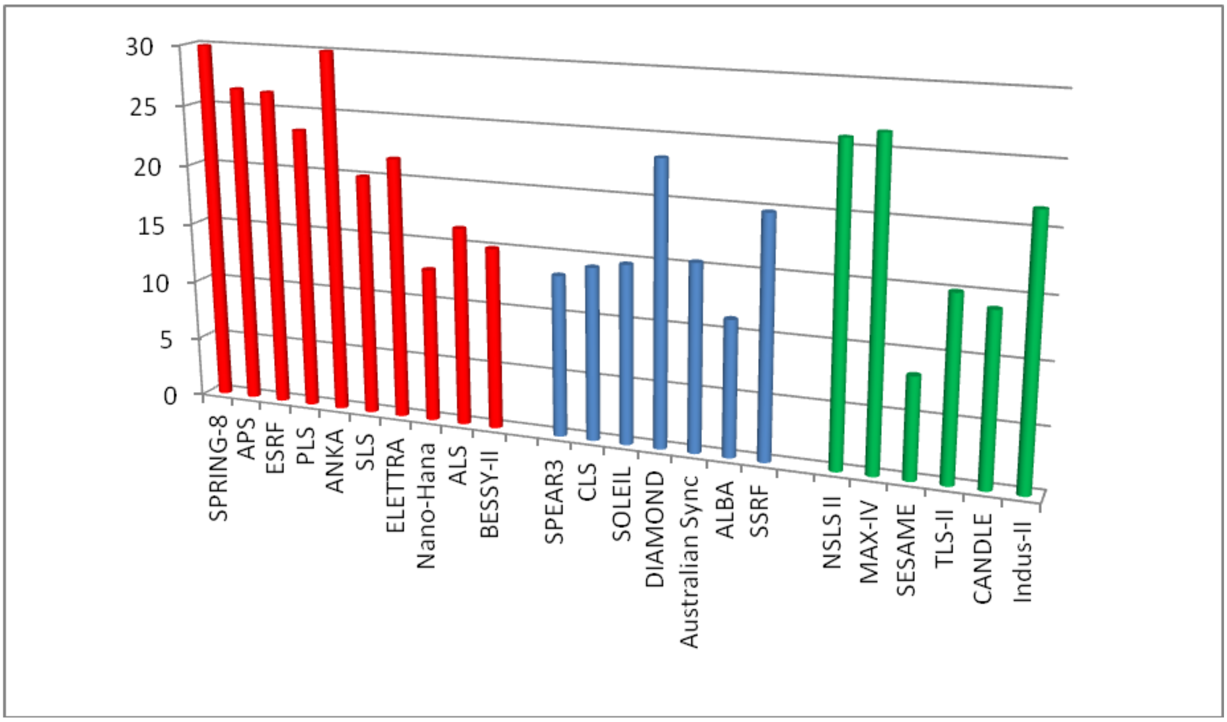


Figure 19 – Circumference over number of available straight sections

In particular, the perimeter of ALBA is significantly smaller than that of Soleil and less than half of Diamond's. Indeed ALBA has, within this group of medium energy 3rd generation light sources, the maximum number of straight section (available for insertion devices) per unit perimeter length. Thereby ALBA has a specially optimised design which will be very cost-effective once the straight sections will be fully used for insertion devices, and the corresponding BL will be built.

Turning the focus to the beam-lines, other SL facilities similar to ALBA are currently equipped with many more than ALBA as it is illustrated in Table 10. The difference becomes even more striking if the BLs in progress is considered. Therefore the current number of BLs is the usual one for a starting SL facility like ALBA, however the number of BLs in progress is a concern since the offer of SL techniques in the near future will be very narrow compared to competing sources, to attract advanced users and to position ALBA in the forefront of the SL facilities.

A low number of BLs has also implications in the facility effectiveness indicated by the ratio persons versus number of BLs. The highest ratio is shown by ALBA in Table 10 (see ALBA-2013). It comes from the fact that an important number of persons are required, such as mechanical engineers, software engineers, accelerator physicists, etc…, just to provide light to one single BL.

That ratio improves considerably with the number of BLs and it turns to be among the most competitive of the list when reaching 22 BLs by 2020, which is not yet the maximum number that ALBA could host, but it the number proposed in this strategic plan.

Table 10 - Comparison of ALBA with sister facilities in terms of BL and staff

NAME	LOCATION	Operating BL	BL in progress	STAFF	Persons /op BL	Persons/ total BL
ELETTRA	Italy	26	2	320	12	11
CLS	Canada	14	8	210	15	10
SOLEIL	France	26	3	360	14	12
DIAMOND	UK	20	11	450	23	15
SSRF	China	7	29	300	43	8
ALBA-2013	Spain	7	0	160	23	23
ALBA-2020	Spain	14	8	275	20	12

In conclusion, the facility performance should be improved continuously and the portfolio of beam-lines offered should be broadened to keep ALBA competitive. Consequently, realistic but ambitious plans for accelerator's improvements from one side and new beam-lines with advanced SL techniques from the other side must be set and accomplished. Precisely these concepts are the backbone of the present strategic plan.

2.3 COMPETITIVE ANALYSIS OF ALBA ADVANTAGES

First of all it has to be stated that SL is an essential tool for science and to address key societal challenges such as industry developments, biology, life sciences, energy science, diseases studies, medical applications, materials science, earth and environmental sciences, physics, chemistry, etc… As such ALBA is an extremely valuable R&D infrastructure for a country like Spain. ALBA is a brand new facility providing state of the art beamline characteristics as shown previously in section 1.2. In 2012 the transition from the commissioning phase to the operation phase was accomplished. More than 3100 hours beam-time were delivered with an average availability of 85% and beam stability better than 0.6 μm vertically. In 2013, it is fully operative, being the latest facility in the word to enter into operations. All those achievements constitute very important milestones that allow providing a very competitive beam quality.

The ALBA BLs are in operation and they have shown an excellence performance corroborated by the good results obtained so far. The X-ray cryo-microscopy beamline is one of the three existing worldwide; it allows full field tomography studies with a 2D spatial resolution of 20 nm. The Core Level Absorption and Emission Spectroscopies beamline (CLAESS) is equipped with a fast monochromator which will allow to record EXAFS spectra in the 100 ms range to monitor the spectra of chemical reactions in heterogeneous catalysis using “in operando” conditions. At the Photoemission beamline (CIRCE) a unique and innovative technique will be available, that is still in its infancy worldwide, as it is the “near ambient pressure photoemission” (NAPP). The Non Crystalline Diffraction (NCD) beamline devoted to time resolved X-ray scattering/diffraction from polymers, BL11, will offer the possibility to carry out unique structure/functional experiments with time resolution in the millisecond time domain. The Materials Science and Powder Diffraction (MSPD) and the Macromolecular X-ray Diffraction (XALOC) beamlines are equipped with the latest generation high resolution detectors. Finally the Resonant Absorption and Scattering (BOREAS) beamline allows magnetic studies under 6 T magnetic fields generated by a SC magnet.

On the other hand, ALBA is placed in a privileged location, since there are numerous research institutions, including hospitals, and universities in the surrounding area. They are dealing with research in a variety of scientific and technological fields where the SL techniques are very useful. Many of them provide services or have contracts with industrial customers that will also need advanced SL techniques. That will foster collaborations and create important synergies. The vicinity area is also prolific in industries providing many opportunities for collaboration such as pharmaceutical labs, multinational companies and other intensive R&D industries. A collaboration agreement has been signed with a multinational and contacts are being held with other industries.

ALBA is a very young facility oriented to giving excellent service to our users (customers). Unlike other research institutions, the time devoted to our own research is a very low percentage of the total available, our main goal being to provide a good service to our customers. That represents a significant paradigm change and it is another clear competitive advantage.

The organization of ALBA is very dynamic with very young and motivated staff. The transition from installation to operations has been just completed. It allows a very quickly adaptation to any new need, in particular the ones coming from the users. This capability of adaptation will remain as ALBA shows a high potential of growth and more organization changes are probably to come.

It is very attractive for scientists and engineers, in particular young people, to work at ALBA since they get trained and reach a high professional level in a very short period of time in an international environment. It has some drawbacks for the institution, as it opens the opportunities to be hired by other foreign institutions with better economic conditions (as it has often happened). However this is overall a clear advantage for ALBA.

It should be also mentioned that ALBA is near a cosmopolitan city with good communications, a variety of services and enjoying a Mediterranean weather which add more subtle advantages.

In summary, ALBA is offering a range of SL techniques with state of the art equipment, highly motivated staff to provide good services to academic and industrial users, and a great environment.

2.4 ANALYSIS OF SOCIAL AND ECONOMIC IMPACT

2.4.1 Cost-benefit study

In 2003 the ALBA project was submitted to a cost-benefit analysis and an economic impact study realized by a group of economists lead by Prof. José García Montalvo [19] The study considered two separated periods: the investment (2003-2008) and the operation (2009-2033) periods according with the initial project (five beamlines). After the construction period was finished, in 2010, a new study was done for the real investment (2003-2010) with seven beamlines and for the operation period (2011-2035).

Its main results were similar to the first study and are condensed in the following Table 11 and Table 12

Table 11- Cost benefit study result

	Investment period (2003/2010)	Operating period (2011/2035)	TOTAL
Impact on gross production	301 M€	896 M€	1,001 M€
Added value	140 M€	414 M€	554 M€
Employment: Direct Indirect and induced	463 166 297	269 162 107	732 328 404

Table 12 - Economic analysis results

Net present value (NPV):	Inflation 2%	Inflation 2.5%	Inflation 3%
With a 5% discount rate	70.4 M€	98.4 M€	128.7 M€
With a 4% discount rate	112.7 M€	147.7 M€	185.5 M€
With a 2.5% discount rate	199.0 M€	248.4 M€	301.8 M€
Benefit/cost B/C ratio	1.26	1.35	1.43
Internal return IRR	7.2%	7.9%	8.6%

2.4.2 Current situation

2.4.2.1 Location

As said before, the ALBA synchrotron is located in a recently urbanised zone within the metropolitan area of Barcelona, in the municipality of Cerdanyola del Vallès, called "Parc de l'ALBA", which is state-owned.

The "Parc de l'ALBA" has been designed as a science park mainly for the establishment of research institutes and centres and technology industries.

The managers of the Park have been using the synchrotron facility, with our consent, as a pole of attraction which not only favours the establishment of this kind of centres and industries, a task of great difficulty nowadays given the general economic situation, but also the development of the logistic facilities (apartments, restaurants, etc.) required for a park of this nature.

Due to the crisis situation the development of the Parc de l'Alba is slower than expected. But the presence of ALBA has attracted already several important companies: SENER central services (including NTE), IBM CPD (including the CPD of La Caixa), T-Systems CPD and a building for La Caixa services.

2.4.2.2 Job creation

Direct jobs:

With the start of the operation of the ALBA synchrotron in 2013 172 direct jobs have been created, with the following characteristics:

- *Scientists: 58 higher graduates (especially in the areas of Physics, Chemistry and Biology), 12 medium graduates*
- *Technologists: 65 higher graduates (among which 25 from the areas of industrial engineering and 40 from the area of computing, electronics and telecommunications), 13 medium graduates in the same areas*
- *Other graduates:Higher 10 jobs, Medium 4 jobs*
- *Other jobs: 10 administration jobs*

Among the fixed jobs generated, 160 correspond to structural staff positions and 10 to temporary ones.

In addition to this, by obtaining specific resources (from the State or the European Community) or through agreements and partnerships with the industry, there are around ten more highly qualified temporary contracts generated each year.

Indirect jobs

The number of indirect jobs created is calculated to be about 25 in areas such as maintenance of facilities, restoration, security services, cleaning services, etc.

Induced jobs

It has been calculated that the average number of annual jobs induced by the exploitation of the facility amounts to 82.

2.4.2.3 Net salary income generated

Net salary income generated by the 172 people employed in the synchrotron represents an annual amount of 5.3 million euros, which leads to a significant volume of consumption around the synchrotron facility.

2.4.2.4 Taxes

The synchrotron activity generates payments of different taxes, especially to the State and, to a lesser extent, to the local authorities, as well as contributions to the Social Security, arising, in some cases, from the payment of salaries and, in other cases, from the performance of the activity itself (Companies Tax, VAT, Nuclear Security Council Tax, Real Estate Tax, etc.).

Payment of the said taxes represents revenue for public administrations for the following amounts:

State taxes, 1.8 million euros

Social Security Contributions, 2.4 million euros

Local taxes, 30 thousand euros per year

2.4.2.5 Commerce

The economic activity generated by the operation of the facility represents, in terms of operating expenses, an annual amount around ten million euros taking into account the indispensable investments on replacements for the correct operation of a facility of this nature.

From this amount, approximately four million euros correspond to the power consumption supplied by a polygeneration plant expressly built to provide the synchrotron with electrical power, cooling and heating.

From the remaining six million euros, approximately five of them are spent in supplies from national trade and industry companies, while approximately the remaining one million euros are spent in the acquisition of foreign goods.

2.4.2.6 Users

The operation of the synchrotron involves access by users from very different origins, who stay some days in the facility in order to perform their research, and need accommodation, provisions, transport, etc.

In total, the number of researchers who access the facility during a year exceeds one thousand, among which approximately 85% come from Spain and 15% from abroad, especially from the European Union. Along the Spanish users, 50% are coming from communities other than Catalonia.

The economic activity which this represents in terms of transport, provisions and accommodation approaches half a million euros per year.

2.4.2.7 Training

One of the active policies followed by the Consortium Management, in accordance with the vision defined in our Strategic Plan, is related to training, internal, for the personnel of the Consortium, and external, mainly oriented towards training university students.

Figure 20 Leaflet publicizing the joint master imparted by UAB and ALBA.

With regard to internal training, the consortium budgets include an important item for contracting training courses, attending scientific and technological conferences and performing all kind of seminars, workshops, etc.

With regard to external training, especially but not exclusively addressed to university students, it takes different forms.

On the one hand, under an agreement with the Universidad Autónoma de Barcelona, the Consortium and its personnel take part very actively in the University MASTER: "Generation and Applications of Synchrotron Radiation", for which ten students have already enrolled in the 2012-13 term.

Figure 20 shows the leaflet of the Master course for next years.

On the other hand, the Consortium facilitates the stay of all kind of students in the facility, so that they may carry out their academic practices, whether such practices are part of their curriculum or not; in this regard, students are accepted to perform: practical training in companies, final degree papers and projects, PhD stays, other stays financed by the European Union through the Leonardo and Marie Curie programmes, etc.

It is worth noting that the Consortium has also ten positions for postdoctoral researchers who stay for three years and specialise in the technologies and use of synchrotron light. The postdocs contribute to user support and carry out research projects.

Further to this active policy of attracting students to a stay in the synchrotron, PhD students will be admitted in the near future so that, after the signature of the appropriate agreements, they may prepare their theses in the synchrotron.

Finally, the facility also accepts Vocational Training students for internships in companies.

2.4.2.8 Promotion

A relevant number of activities of scientific character are carried out by ALBA staff, such as the organisation of workshops and conferences, attracting an important number of scientists from Spain and abroad. An example of this was the organisation in the year 2011 of the International Particle Accelerator Conference (www.IPAC11.org) in San Sebastián, with more than one thousand participants and whose local chairman was a member of the ALBA staff. Workshops, conferences and seminars are routinely organized by the ALBA staff, ranging among all scientific fields represented in the infrastructure and beyond. A not exhaustive list can be found in [20].

It is also worth noting the presence of the Consortium with its own stand presenting the ALBA synchrotron and its facilities in different science fairs.

Furthermore, one of the features of the policy to which the Consortium Management adheres is the promotion of the facility, making it known to local residents and especially addressed to groups relating to education, whether they be teachers or students, and for secondary school, high school and university.

In recent years the number of people visiting the installation has approached three thousand per year, through a dedicated visit programme, concentrated on shutdown weeks. In addition year 2012 has seen the first ALBA open day. The event was organized in December 2012 and was a complete success. Ca. 1000 visitors were received in a single day. Visitors were frankly enthusiastic about the event, which was covered by about one third of the total ALBA staff, on a voluntary basis. A strong team-building atmosphere was perceived by many of the participants, which is one further reason to repeat the experience yearly from 2013 onwards. In the nearest future it is expected that the total number of visitors, including the regular visit programme and the open day event, approaches five thousand, which can be considered a significant impact in the dissemination of science and technology among the local population.

Finally, within the advertising policy, some facility premises are offered to financial, services and industrial companies so that they may use them for conferences, meetings, events, etc. These companies, before holding their meetings or events, are guided on a visit to the synchrotron and its facilities, which eventually generates a small economic activity in general.

2.4.2.9 A catalyst for technological development

Since the start of the ALBA synchrotron construction project, it has been an incentive for development and innovation for different companies, not only for those relating to the design and drawing up of the project and subsequent construction, given the special characteristics of a work of this kind, but also for those relating to scientific-technological equipment and instrumentation, which has allowed them to acquire an important know-how specialised in this kind of facilities.

Furthermore, as shown in one of the strengths, as a catalyst for technological development and also, as indicated in 2.4.2.1, as the core facility for the development of the "Parc de l'ALBA", the synchrotron favours technological, industrial and logistic development.

In this regard, new employments have been created with the establishment of a cafeteria which serves the Consortium staff as well as users, visitors and, in general, all those who work in the facility. And, more significantly, a polygeneration plant has been built, as mentioned in section 2.4.e), with an investment of around 20 million euros.

In order to take advantage of the attraction of a facility such as the synchrotron and with the aim of fostering technological and industrial development, the possibilities offered by the current regulation are now being analysed regarding innovative public contracts, competitive dialogue or public-private partnerships which may favour such development. It is important to stress here that ALBA, as a scientific facility, has the privileged position of being directly exposed to excellence-filtered scientific cases, in which the interplay with yet-to-be-developed instrumentation is very critical. Therefore the opportunity of generating synergies and new developments in collaboration with the science industry is really at reach. Figure 21 attempts at illustrating this potential for interplay with industry.

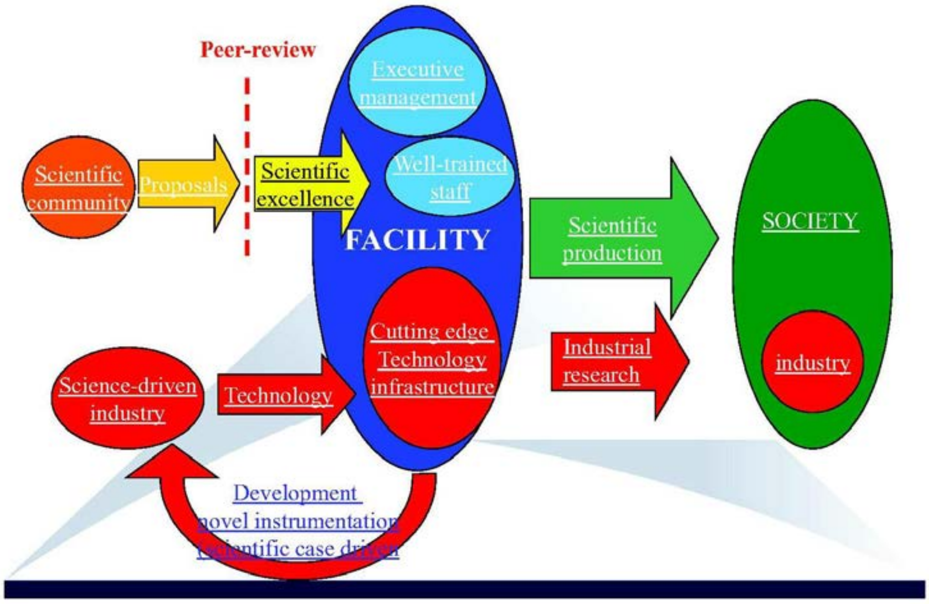


Figure 21 - Diagram illustrating the interplay of a facility with the science industry.

2.5 ANALYSIS OF ANNUAL USER CAPACITY OF THE INFRASTRUCTURE

2.5.1 Operational hours per year

A well-established operation calendar model has been developed, once experience has been gained during the start of operations, mainly in year 2012, in which ALBA underwent the transition from commissioning to operations. The scheme, that will be used from 2015 on, is based on two long runs, separated by two long shutdowns (summer and winter, about 5 weeks each). Each long run is composed by a sequence of alternative short runs (3-6 week long) and short shutdowns (normally 1 week). Days devoted to startup of the instruments and machine physics are concentrated after the end of each long shutdown (typically a full week) and also set after the end of each short shutdown (2 days). All these rules lead to operation calendars of a maximum of 6000 hours per year, wherein ca. 10% is used by machine startup, the rest being available as effective beamtime. The ALBA policy is to divide this effective beamtime among external users (70%) and internal usage (10% for accelerator physics, 10% for BL commissioning, maintenance and upgrade, 10% for in-house research). The beamtime available for external users is used in two ways: non-proprietary-research awarded via public calls which are evaluated by an international panel; and direct allocation to proprietary-research.

2.5.2 Proposed run-up to routine operations

The numbers given herein correspond to the asymptotic regime which ALBA has as a target. As staffing has been gradually completed, a ramp up of operation hours has been started since 2012, year in which external users arrived gradually to the different BLs, starting in May. Years 2013 and 2014 are planned as a transition period, with a total of 5200 and 5700 hours, respectively, whereas 2015 should already be a standard operation year, with ca. 6000 hours, the exact amount depending on ad-hoc calendar optimization. This figure of operational hours per year is well in line with similar SL facilities across the world.

2.5.3 Modes of access by the entitled, non-entitled and international scientific community

ALBA has the vocation to broaden and internationalize its user community as much as possible by attracting the best scientific proposals and programs regardless of where they come from. Already in the first two calls for user proposals a significant fraction of the proposals received (ca. 20%) came from non-Spanish institutions. The policy followed by ALBA in this respect is that the ranking for user access is done taking into account only the scientific and/or technical merit of the proposal. The rationality of this approach has been amply demonstrated in other Large Scale Installations where whenever the overriding policy for access to the installation has been only the excellence of the scientific proposals; the returns have always led to important developments in know-how and knowledge that have enriched the facility and its broader user community at large. On the other hand, travel and subsistence subsidies for users are limited to those affiliated to Spanish institutions. If international money is available (for instance through EC projects) ALBA will/would cover the expenses of international users similarly to Spanish users. This is already being done successfully for European ones via EC projects (BioStruct-X and CALIPSO).

2.5.4 **User office and users' travel and subsistence (T&S)**

ALBA has a User office, presently staffed with 3 full-time positions. Its role is to organize the calls for proposals, collect them, distribute them to the reviewers, provide secretarial assistance to the reviewers, collect the information, provide feed-back to the authors of the proposal about the outcome, organize the schedule, organize the safety training and reception of visiting users. In addition, it takes care of the travel and accommodation requirements of review panels and visiting users, as well as keeping an updated information service, with records of users, successes and failures, user feedback comments and publication records. In addition to all these activities, the User office is taking up the responsibility of organizing a yearly User's meeting, in close collaboration with the Experiments division.

The activities of the User office involve a close collaboration with the Experiments division and the Liaison Office for Proprietary Research, while receiving a very intense support from the Computing division.

2.5.5 **Policy on proprietary research and Liaison Office**

Most of ALBA users will be involved in research that upon completion will be published in the public domain, i.e. non-proprietary research. However, ALBA, like any other modern SL facility, has significant potential for R&D in the proprietary domain, i.e. research leading to commercial benefits. Proprietary users are dealt with applying the following basic rules:

- *Access to beamtime is direct, without the need of periodic calls.*
- *Reference fees are being established yearly, based on the overall operational cost of the facility, total number of operation hours and total number of BLs. As a reference, the fee for 2013 is 499 € per hour of beamtime. Fees will gradually go down as operation hours increase and furthermore as new beamlines come into operation. Fees shall clearly establish the different options wherever available (like offline data analysis, for example).*
- *Proprietary user access is being actively promoted. To that end an industrial liaison office is being established already in 2013, as it will be explained further below. Active policies are being designed and implemented along the period 2013-16 in such a way that proprietary users are attracted (commercial strategies) and that a high level of priority is given to these activities at all levels inside the structure of CELLS (internal promotion strategies).*

It is evident from the previous considerations that the access costs are sufficiently high to make it necessary to demonstrate to potential customers the usefulness of SL applications. The importance of establishing communications with potential proprietary users arises not only because companies in general are not aware of the potential of SL applications and, therefore, without a significant effort in proselytising it is very unlikely that this potential will be realized, but also because most scientists involved with SL applications do not understand the requirements of proprietary researchers. It has been demonstrated elsewhere (e.g. SRS in the UK or the CLS in Canada) that to establish this two-way communication is absolutely necessary to attract industrial customers. This is a slow process that requires the full time commitment of dedicated staff. So, as a pump-priming initiative, an Industrial Liaison Office is being set-up at ALBA. The main objective of this office is to promote industrial usage of SL technologies and to attract this kind of customers to ALBA. This office is initially staffed with 1 full-time position and should ideally reach 3 full-time staff by the end of 2016. Expertise from ALBA's scientists and technologists will be co-opted whenever necessary. The objective must be that in five years, i.e. by 2017, the office activities should be self-funding from customers revenue.

In addition to standard proprietary user access to beamtime, the Industrial Liaison Office shall deal with the access of external users to other technological resources available at ALBA, such as the specialized labs built and equipped during the initial construction and now having some availability for collaborations (magnetic measurement lab, metrology lab, RF high power lab, etc…).

This office will also take care, as it grows in staff, of promoting and supporting competitive funding projects in ALBA.

2.5.6 Users meetings

A significant factor in the success of a facility like ALBA relies on establishing communication channels with its user community, as well as maintaining a continuous promotion for and search of prospective users. This is the reason why almost every SL facility periodically organizes User's meetings. In most SL facilities this is done once a year, but occasionally this might happen every six months.

We propose to have an annual User's meeting in our site, where selected users will be invited to communicate their scientific/technical advances; ALBA will seek the user's opinion about the quality of the support provided; users will be encouraged to voice their future requirements; etc.

The User's meeting is essential as part of a feed-back loop that is necessary for the early identification of problems or opportunities. The first ALBA User's meeting has been organized to take place in September 2013 (http://albausermeeting2013.cells.es), in coordination with the AUSE meeting, at the ALBA site.

In addition to the yearly User's meeting, ALBA is already very active on organizing different events linked to obtaining a good communication with its user community. As a reference, four such workshops or courses have been organized at ALBA during the period 2012 [20]. A similar number of events is planned to take place during 2013.

2.6 MEASUREMENTS OF EFFICIENCY

2.6.1 Performance Indicators

The criteria for evaluating the performance and results of the installation, or performance indicators, that we use are the following:

a) Total number of delivered shifts/year versus the number of scheduled ones.
b) Number of delivered user shifts/year versus the number of scheduled ones
c) Hours of user beam, i.e. the sum of delivered station hours to users
d) Accelerators' efficiency, i.e. hours delivered versus hours scheduled
e) Number of accelerator failures and reasons
f) Mean failure duration for accelerators
g) Mean time between failures for accelerators
h) Number of scientific papers arising from experiments divided by the number of experiments
i) Efficiency per beamline, i.e. hours delivered versus hours scheduled
j) Number of failures per beamline and reasons
k) Mean failure duration per beamline
l) Mean time between failures per beamline
m) Number of user groups/year
n) Number of user visitors/year, i.e. mean size of user group
o) Station shifts requested versus station shifts allocated (per beamline)
p) High-impact publications/beamline/year
q) Publications/beamline/year
r) PhD degrees awarded from work carried out at the facility
s) Number of foreign visiting scientists/per year
t) Industrial income
u) Patents and industrial outcomes

2.6.2 Registry of Actions of the facility

The facility will keep a registry of the above defined performance indicators for every beam time allocation period, i.e. on a six monthly basis. Experience elsewhere has shown that information on the publication record of users resulting from work carried out at the facility is hard to come by. This information will be required as part of the six monthly round of proposals for beam time.

2.6.3 Planning for evaluations

ALBA has a Scientific Advisory Committee (SAC), which is described elsewhere in this document. We propose that the Rector Council of ALBA should, in addition, set up a regular review of the facility and commit to the outcome of the review. This should occur once every four years, just at the end of the period established as the scope of a given strategic plan. As ALBA is coming into full operation in 2013, it is reasonable that the first evaluation covers the period 2013-16, scope of the present strategic plan and that it is done in 2017.

In addition to this global facility evaluation, it is planned to organize beamline-specific reviews also every four/five years. To that end ad-hoc peer-review panels will be set up case by case. Phase I beamline reviews shall start in 2015 and be scheduled in such a way that within the temporal scope of the present strategic plan (i.e. until the end of 2016) all 7 beamlines have gone through their first review process.

3. OBJECTIVES 2013-2016

3. OBJECTIVES 2013-2016

ALBA reached at the beginning of 2013 the full operation of the phase I beamlines, being all of them open for users, as it has been shown in previous chapters, but still the full capacity of the facility, from the point of view of the Beam Lines and of the accelerator, has not been achieved.

The objectives proposed for the period 2013-16, in view of making the facility a national and international reference in photons science, are the subject of this chapter, starting with plans for taking the currently existing capabilities to full exploitation (Section 3.1), mainly upgrade of existing BL and completion of the accelerator potentiality, followed by ALBA future evolution (Section 3.2) and by further possibilities for the development of the CELLS consortium (Section 0). Finally human resources needs, budget, schedule and monitoring issues are analysed in sections **Error! Reference source not found.** and **Error! Reference source not found.**.

3.1 FULL EXPLOITATION OF PRESENT INFRASTRUCTURE

3.1.1 Scientific strategy

The scientific and technical development plans of ALBA in the next four years are based on several concepts:

a) ALBA is a user facility providing photons and the ancillary equipment to the Spanish and international community to perform a variety of characterization techniques ranging from crystallography to spectroscopy and imaging.

b) As leading scientific facility in Spain, ALBA aims to develop activities in additional new areas and with new technologies not necessarily related to the present largest demands of the users but with views in the future.

c) A continuous effort on maintenance and upgrade of accelerators and beamlines is required to compare at the same level with leading synchrotron laboratories worldwide, which implies human and economic resource availability.

d) In concordance with the European Strategic Programme for Horizon 2020, which focuses on maximizing the impact and added value of the current investment programmes, synergies are strongly looked for in order to use the allocated funds in the most efficient way. This will be achieved through collaborations with the scientific institutions located in the immediate vicinity of ALBA, as well as other key Spanish organizations.

In the next few years the first ALBA priority is the full exploitation of the present infrastructures, together with the affordable development of specific scientific areas, which will define the path toward new BL investments. Combining the possibilities of upgrading the already operating beamlines with this development will boost the project outcome. ALBA has identified three scientific areas where such synergies will be effectively exploited: nanoimaging for nanoscience and nanotechnology, pump-and-probe experiments for investigating the dynamics of physical, chemical and biological processes and finally coherent diffraction-related techniques.

We highlight that the involvement of the interested scientific community is mandatory. The first ALBA user meeting (and 6th AUSE meeting), albausermeeting2013.cells.es/ to be held at ALBA on the first week of September 2013, will initiate this discussion on the basis of the present document.

3.1.1.1 Nanoimaging

The evolution of SL related science is nowadays largely driven by scientific problems involving very small samples as nanodots, nanomagnetic devices or interfaces, small particles in catalysts, dust particles, small crystals of proteins and viruses, etc… Thanks to the low emittance machines and to the progress in optics, micromechanics and detectors, SL methodologies are advancing towards characterization of single nanometer-size objects. In some sense SL sources are following a track similar to what electron microscopy did more than a decade ago aiming to reach the atomic level. Micro and nanometric focusing techniques are being developed in order to image, diffract or get spectroscopy information on single nm-size particles. In parallel, the emittance of the electron beams in the new planned machines is intended to get closer to diffraction limited sources.

Focusing to the nanometer scales requires extremely good mirrors in terms of shape errors. Good polishing techniques, methods of compensation of residual errors and appropriate metrology are required since in fact it is the metrology at the end that determines the limits of the polishing techniques. At ALBA we have accumulated experience in the last few years and we currently have working mirrors in beamlines with residual slope errors of 50 nrad, which were achieved with a combination of accurate metrology and high precision mechanics. In this sense ALBA is well positioned worldwide. We propose to apply the advances in this discipline to the construction of a new beamline, as described in Section 3.2.

3.1.1.2 Time resolved pump-probe experiments

Dynamical studies of physical, chemical or biological processes have been one of the specific research fields in modern synchrotrons due to the high available photon flux and to the inherent time structure of the source. Processes with characteristic time scales from minutes to seconds are routinely investigated with standard techniques. Modern 2D detectors allow faster and faster acquisition frame rates. Specifically at ALBA we will soon have a prototype of a 1.3 Mpixel photon counting detector that will be able to acquire images at 500 Hz allowing ms processes to be investigated.

Fast processes at the sub-nanosecond temporal resolution have also been investigated in the last decade thanks to the temporal time structure of the synchrotron pulses. At ALBA the temporal width of the pulses is *ca*. 20 ps and this sets the lower resolution limit available with the present configuration and operation mode of the machine. Alternative accelerator parameters and electron beam manipulation will be investigated in order to reduce this limit. The interval between two consecutive pulses with standard filling of the accelerator is 2 ns and in single bunch filling this interval is 896 ns. In between these two values any interval can be chosen.

Pump probe techniques allow performing “movies” of fast repetitive processes and they have been widely used in synchrotrons in experiments of structural biology, magnetism and chemistry among others.

The implementation of pump probe methods at ALBA would increase the scientific attractiveness of most beamlines. At CIRCE, BOREAS and MISTRAL time resolved magnetization processes could be investigated by applying pulsed magnetic fields, at NCD or MSPD structural changes induced by laser or electric field pulses, and at CLAESS changes in the XANES intensities at selected photon energies after sample excitation. The implementation of pump probe techniques at ALBA requires essentially to acquire the corresponding “know how” of different filling modes of the storage ring, of timing and synchronization techniques and also the development of excitation sources and appropriate sample environments. ALBA does not propose to build a specific beamline for this type of research but cost-effectively implement this methodology in selected beamlines.

3.1.1.3 Coherence-based methods

Coherent diffraction signals encode the intrinsic structure of the tested volume beyond the information on the average structure retrieved by incoherent X-ray beams. The proper use of largely coherent X-ray beams is opening new channels for the determination of micro- and nanostructural properties in hard condensed matter as well as in biological materials. The local characterization based on coherent methods allows to overcome the resolution limit imposed by the minimally achievable beam size.

Furthermore, the application of coherent X-ray beams is nowadays in its infancy and is driven largely by the new and upcoming X-FEL facilities. The introduction of some of these methodologies and technologies at ALBA will allow to profitably use the X-FEL facilities, including European XFEL at Hamburg, by the Spanish community. ALBA proposes to initially introduce this methodology at the NCD beamline and later on build a specific beamline dedicated to it.

3.1.2 **Beamline upgrades**

In the next paragraphs, key developments for the seven ALBA phase I beamlines are highlighted. These actions are meant to increase the scope and competitiveness of the portfolio of available scientific techniques that we offer to our users. The list of upgrades is not intended to be exhaustive but to note some crucial improvements.

3.1.2.1 BL04 MSPD.

The MSPD beamline dedicated to high-resolution (HR) and high-pressure (HP) powder diffraction has the following planned upgrade for the next years. *i) Optimization to carry out Pair Distribution Function experiments* (also known as total scattering experiments). This technique, highly valuable for so-called *real samples* (disordered materials, nanocrystals), perfectly matches with the high energy (up to 50 keV) reached on BL04. A large area 2D detector adapted to high photon energies is required in order to be able to record data within reasonable time spans; *ii) Establish a rapid access mail-in program.* In order to build up such a program and as well boost the Powder Diffraction station efficiency for simple, standards experiments, the acquisition of a robotic sample changer is required. *iii) Low temperature sample environment.* Actually, the lowest reached temperatures on HR station is 80 K. Pushing down to 5 Kelvin is desirable for tackling problems involving interplay of magnetic, electronic and crystal structure properties (e.g superconductive, magnetoresistive, feroic materials). A cryostat suitable for the HP station and CLAESS beamline is foreseen. *iv) High temperature sample environment in the HP endstation.* Including a laser heating option in the HP station will offer the possibility to reach the extreme temperature *and* pressure conditions as observed in the inner earth mantle. *v) Implementation of residual stress experiments.* This upgrade essentially addresses the user community devoted to research on engineering materials. *vi) Implementation of an on-line visualization device at the HP endstation.* This upgrade will allow mesh scan microdiffraction at micrometer resolution typically used in cultural heritage and catalysis studies.

3.1.2.2 BL09 MISTRAL

Correlative Microscopy: Structural Cell Biology is a wide new area where the need for a detailed structural and functional description of the different cell components must be correlated with a topological map of these components at the whole cellular level. The structural and functional studies on complex cellular processes, such as cell division or differentiation, can then be inserted into a cartographic description of the whole cell. Mistral TXM is dedicated to cryo-tomography which provides 3D information of whole cells (up to 10 μm thick) at a spatial resolution of 60 nm.

To achieve such a cartographic description, we have to target relevant biological features inside the cell with X-rays. One approach for this is to label the specific structures with fluorescent markers, taking advantage of the development of these markers in optical microscopy in the past decades, and to correlate visible light fluorescence images with X-ray projections of the same vitrified cell, to collect the tomographic data set at the region of interest which contains the targeted feature. For this purpose, an in-line fluorescence microscope has to be developed allowing for localization at a magnification of 100X. Without this correlation, the capabilities of X-ray imaging will be hampered as there will be no way to ensure that the collection of tomographies is done at the relevant biological features to be able to answer specific scientific problems.

In addition to research in biology, MISTRAL is also suited to perform magnetic domain imaging by using the circular dichroism contrast method. A pulsed magnetic field of ~2T will be implemented and applied to investigate the dynamics of domain wall displacements on magnetic samples grown on silicon nitride membranes. In addition, a running collaboration with the Centro Nacional de Microelectronica at the Campus of Bellaterra will allow investigating liquid samples encapsulated in silicon nitride membranes.

3.1.2.3 BL11 NCD

This beamline is dedicated to small-angle X-ray scattering (SAXS), wide-angle X-ray scattering (WAXS) and grazing-incidence small-angle X-ray scattering (GISAXS). Four main upgrades will be carried out, namely: *i) Installation and commissioning of the imXPAD detector for SAXS.* This state-of-the-art 2D pixel detector will have outstanding characteristics/performances (active image area ≈150×150 mm^2; 1,3Mpixels; pixel size: 130 μm; frame rate: 500 frames/s; dead time between frames: ≤1 ms; read out time: 1 or 2 ms (for 16 or 32 bit images, respectively); and maximum count rate: >10^{11} photons/s). The implementation of this detector will open up the millisecond time-regime for SAXS experiments such as polymer changes and muscle contraction studies; *ii) Installation and commissioning of a microfocus setup.* The current beam size at the sample position is of the order of a few hundreds of micrometres. Although being optimum for many experiments, there are several scientific cases that require much smaller beams like heterogeneous polymer blends or tiny samples. These cases would be covered by a set compound refractive lenses focusing the beam down to 10×3 μm; iii) *Implementation of techniques to take profit from the coherence of the beam.* NCD is well suited for coherent diffraction studies due to the small source size and to the large sample-to-detector distance. This will allow to implement coherent diffraction (i.e., lensless) imaging and X-ray photon correlation spectroscopy techniques. The implementation of these techniques will allow ALBA to enlarge the portfolio of scientific cases; and *iv) An automatic sample changer for solution scattering experiments.* A sample changer will allow the beamline to perform high throughput experiments and hence, test numerous samples in short time improving the existing user experiments considerably, particularly in solution scattering, and attracting interest from the pharmaceutical industry. The use of a BioSAXS robot has already been successfully tested by other beamlines in the field.

3.1.2.4 BL13 XALOC

XALOC is dedicated to the structural determination of macromolecules by single crystal diffraction. A first upgrade of the beamline consists in adding a refocusing mirror, which would reduce the horizontal beam size by a factor ~4. XALOC, with a resulting focal spot of ≈12×6 μm^2 FWHM (H×V), would become a microfocus beamline. The main upgrade of the beamline is the construction of a complete ancillary branch beamline, in which a multipurpose end-station can be installed. This branch is a cost-effective opportunity to have an extra X-ray beam, which is extracted from an existing optical element (a diamond Laue monochromator). The main characteristics of the beam are: i) fixed photon energy = 9.041 keV, monochromatic; ii) beam of ≈0.7×0.7mm at sample position naturally focused by the Laue monochromator; iii) slave operation from XALOC (as the branch would be fed by the same undulator); and iv) possibility of using focusing optics, e.g. compound refractive lenses or compact KB mirror set.

Multipurpose Fixed Energy End-station. This station will provide a platform to characterize the crystals in the crystallization plates and will mount them on standard pins using the CrystalDirect and NewPin developments from EMBL (which would be the only genuine new equipment required). This Crystal Diagnostic Station does not exist in Spain, and is under consideration in few facilities abroad. It would convert ALBA in a hub of crystal production and characterization, ensuring a continuous flow of users. Complementary, by adding a sample changer and a single-axis in-house diffractometer, the branch beamline can be converted in a reliable Crystal Screening Station, which could also feed crystals to XALOC. Additionally, this end-station will also allow carrying out instrument development such as detectors and, particularly, mirrors for X-rays, boosting the activities on instrumentation currently being done at ALBA. Consequently, ALBA will be equipped with a whole flexible, cost-effective end-station, with in-house instrumentation and sound scientific case.

3.1.2.5 BL22 CLAESS

This beamline is dedicated to advanced hard X-ray absorption techniques. The main development at CLÆSS beamline for the next three years will be to finish the design and the full integration of an X-Ray Emission Spectrometer. This in-house developed instrument will allow performing High Energy Resolution X-Ray Fluorescence Spectroscopy (HERFS), X-Ray Emission Spectroscopy (XES), X-Ray Raman Scattering (XRS) and Resonant Inelastic X-Ray Scattering (RIXS). This upgrade will bring in a range of additional scientific opportunities that will place CLÆSS at the forefront of its peer beamlines at other national synchrotron facilities.

The CLÆSS beamline requires a low temperature cryostat able to reach ~4K. This equipment is essential since a large community of users of this beamline studies the electronic and lattice properties of strongly correlated electron systems. These materials show very interesting phenomena, usually at low temperatures, such as ferroelectricity, multiferroicity or superconductivity, among others. This cryostat would be a common equipment shared between the MSPD and the CLÆSS beamlines.

3.1.2.6 BL24 CIRCE

CIRCE is a variable polarization soft X-ray beamline with two experimental stations: PhotoEmission Electron Microscope (PEEM) and Near Ambient Pressure Photoemission (NAPP).

In the PEEM endstation, the beamline team intends to develop the application of electric and magnetic fields *in situ* for the study of magnetic nanostructures and multiferroic materials. To this end, we will also develop linear dichroism imaging and spectromicroscopy (circular dichroism has already been demonstrated). A project for electron beam gating for time-resolved experiments will also be started, in order to take advantage of the time resolution of the synchrotron X-ray pulses for dynamic studies.

In view of time-resolved pump-probe microscopy studies of dynamics in magnetic materials the PEEM end station would strongly benefit from the availability of a fast Ti:sapphire laser as a *common* infrastructure device for the four end stations at the CIRCE and BOREAS beamlines (see below). Together with the above upgrade of the PEEM electron optics this would enable CELLS-ALBA to access the picosecond time domain for studying dynamic processes in advanced materials using the laser beam either as a direct pump (optical pumping or heating) or as an opto-electrical trigger (e.g., via an Auston switch). Apart from the laser system, further fast electronic equipment will be needed to fully exploit the high intrinsic time resolution (20ps bunch length) of the synchrotron.

In the NAPP endstation, a project on a liquid micro-jet system will be started in order to measure radiation sensitive samples such as organic molecules in solution. Spectroscopies on liquid micro-jet samples propagating inside vacuum systems allow for reducing the irradiation dose by nine orders of magnitude since the samples are constantly renewed during the jet process. This opens completely new possibilities regarding the study of organic molecules as novel electronic materials, the characterization of biomolecules in their native liquid environment, surface composition and segregation phenomena of ions in solutions, adsorption of gas molecules on surfactant layers on liquid films, etc.

3.1.2.7 BL29 BOREAS

Pulsed and quick varying magnetic fields extension: endstations, fast sample exchange chamber. Electronics for pulsed high magnetic fields will become available at ALBA later this year (2013), and this is a natural domain for BOREAS to extend into. Sample holders suitable for small conventional coils driven by pulsed electronics or small coil manipulators will be designed to enhance the endstations with pulsed magnetic fields, thus exploring capabilities for higher magnetic field and/or time resolved experiments. Opportunities for pulsed field experiments other than of magnetic nature will also be considered. Pulsed and or quick varying magnetic fields produced by a permanent magnet system ("magnetic mangle") are also under consideration for implementation within a fast sample turnaround test mini-chamber under development. The above approach includes the usage of the fast Ti:sapphire laser mentioned above as a common beamline infrastructure device for performing time-resolved absorption as well as X-ray magnetic circular dichroism experiments based on pump-probe techniques.

Furthermore, another important project should be implemented. - *Spectral purity enhancement of the beamline: harmonic rejection mirror system.* BOREAS delivers a high flux ($>10^{12}$ photons/s) with high resolution ($E/\Delta E>10^4$) over an extended soft X-ray photon energy range of 80-4000 eV covering strong dipolar transitions at the absorption edges of C, N and O; 3d transition metals; or 4f rare earths. It can also reach rather unexplored territories such as rarely available mid energy edges (4d transition metals atoms) that have so far been difficult to access, especially when using circular polarized light.

BOREAS endstation 1. Extending absorption spectroscopy with partial fluorescence yield detection approaches: partial fluorescence/electron yield detection. The energy-resolved analysis of the so-called photo-absorption fluorescence yield, which is usually referred to as partial fluorescence yield, provides a powerful enhancement of the capability to resolve a bulk absorption signal from multicomponent samples, and access new physics from dilute or buried sample systems.

BOREAS endstation 2. Extending scattering endstation with soft X-ray polarimetry capabilities: in-vacuum soft X-ray polarimeter. The beamline capabilities for soft X-ray polarization control would be incomplete and/or its potential largely underexploited, if they would not be complemented with a polarization analysis of the scattered beam coming from the sample inside the MARES end station. As in the optical regime, polarimetry (or ellipsometry) techniques exploiting magneto-optical or related effects on the polarization of light include a strong potential and sensitivity for the investigation of complex samples including magnetic, orbital, and spin ordering.

3.1.3 **Accelerator full exploitation**

The complete achievement of design operating conditions for the whole accelerator facility is the main goal for the years 2013 and 2014. It can be summarized in two main projects that are already being carried out:

- *Operating in Top Up mode*
- *Reaching the nominal operation current of 250 mA*

3.1.3.1 Top Up Mode of Operation

Top Up Mode of Operation is a process by which the electron beam current is kept almost constant along time. When it decays below a certain threshold (say, 98% of its initial value), the accelerator complex automatically triggers a beam injection and recovers the initial beam current in the Storage Ring (SR).

Top Up is a common feature of all Synchrotron Light Sources of new conception, and it is being considered or implemented as upgrade in the older ones. It allows the users to operate continuously along the day without the interruption due to the re-injection process. In addition, the quality and efficiency of data acquisition is greatly improved because the source power is stable. All the equipment, from the accelerators to the beam line optics and instrumentation, are also thermally stable.

Setting up this mode of operation brings together the development of two main projects: the safety requirements and the injector chain optimization.

Safety Requirements

The users are only allowed to operate without interruption if all the Safety Requirements are fulfilled. For this reason, a complete simulation analysis is being carried out, and crosschecked with radiation measurements throughout the experimental hall. Furthermore, the Personal Safety System (PSS) is being upgraded with extra precautions and safety monitoring systems, in a common work between the Accelerator and the Computing Divisions, as well as the Safety group, to avoid any possible scenario for a potential radiation hazard.

Injection Optimization

The re-injection process requires a careful optimization of the Injector System, which can only be achieved through a thorough knowledge of the operation dynamics along the whole accelerator chain. The aim is to provide short re-injection times, for which a maximum reliability of the different accelerator systems and subsystems is needed. For this reason, several subprojects of optimization are underway, including Linac, Booster, SR injection, Operation Procedures, RF, Beam Stability and Insertion Devices.

3.1.3.2 Operation Current of 250 mA

Increasing the current to 250 mA will increase the photon flux by a factor of two with respect to the present situation, where the operation current is 120 mA. This will allow performing measurements with higher precision thanks to the improvement of the signal to noise ratio of the data acquisition.

This increase of current shall not be achieved in a trade-off with the photon flux stability. The thermal stability provided by the Top Up mode of operation is referred to “long” drifts occurring in time scales of minutes or hours. Short term stability in scales of seconds or even oscillations in the MHz range shall also be guaranteed. ALBA foresees two kinds of mechanism to counteract these possible beam oscillations: from seconds or ms (Fast Orbit Feedback) to high frequency oscillations that can reach up to 250 MHz (Transverse Feedback System).

Fast Orbit Feedback

Stable photon fluxes are achieved by keeping the electron beam orbit in the sub-micron level with an active feedback system. The data given by the 120 BPMs installed around the machine is analysed by sectors, and it provides the settings of the 120 SR corrector magnets which keep the orbit within bounds. The goal is to control the orbit below 10% of the beam size in both planes, which means below the micro-meter level for the locations with Insertion Devices.

At ALBA, this is currently done at a 0.5 Hz rate (with the so called Slow Orbit Feedback – SOFB), but the user community requires ALBA to reach up to 200 Hz rate (Fast Orbit Feedback). This will be used to damp the oscillations produced by, for example, the variation in the Insertion Devices gaps. To achieve this goal, ALBA is being equipped with a fiber optics network and fast CPU/FPGA cards. The system is expected to be commissioned in 2013.

Transverse Fast Feedback System

The interactions of the electron beam with the surrounding vacuum chamber and other accelerator components produce wake fields that are trapped inside the chamber. These fields act back into the own particle beam and make the beam unstable, eventually producing detrimental effects like fast beam oscillations or even beam losses. These effects are highly non-linear and often only occur above certain current thresholds.

When increasing the electron beam current up to 250 mA, it is expected that these instabilities will become a beam current limitation. In order to control these effects, ALBA plans to set up a Transverse Fast Feedback System. The beam oscillations produced by these instabilities are counteracted by a system that includes feedback kickers in both horizontal and vertical planes (already installed in the Storage Ring), controlled by electronics cards that are able to damp the oscillations up to 250 MHz.

3.1.4 User service objectives

Section 2.5 describes the target numbers for yearly operation hours, along with the main activities of the User Office, whose work implies close collaboration with Experimental Division, Safety Office, Communication Office and Liaison Office. This inter-disciplinary activities coordination as well as users services are facilitated if a powerful Web Portal is developed.

During the following years, and with the support of Computing Division, the objective is to develop a Digital User Office (Alba User Office Portal) with the goal of archiving all information, providing a platform for evaluation of proposals, feed-back and tracking of the experiments, schedule, users reception, safety issues related to experiments, funding and refund requests, etc. This Portal will allow an updated information service, with records of users, successes and failures, user feed-back comments, publication records, etc...

The portal will have different views and roles (external academic researchers, proprietary researchers, International Reviewers, beamline staff, Safety officer, Management & User Office) and the main ‘’modules’’ are listed below:

- *Module I. User registration and Proposal submission (divided in academic research, proprietary research and in-house research)*
- *Module II. Evaluation of proposals*
- *Module III. Experiment schedule*
- *Module IV. Access of Users to Alba*
- *Module V. Safety issues related to a visit (safety training on-line, safety declarations, etc),*
- *Module VI. General tracking of users and experiments*
- *Module VII. Experiment feedback form and scientific experiment reports*
- *Module VIII. Publications*
- *Module IX. Refund requests*
- *Module IX. Communications*
- *Module XI. Statistics*

The goal is that Alba User Office Portal becomes a reference in Europe (user-friendly platform for the different roles, even for user facilities others than synchrotron radiation based) and collaborations are established with other European User Offices. Actually, a European account for synchrotron users has already been proposed inside the Umbrella European Project as well as common file types for the databases of European synchrotrons.

One other aspect of user services which must be mentioned at this point is user accommodation. At the moment this is covered by a hotel located at the nearby university campus (UAB). Several mobility measures have been taken in order to make facility access as practical and flexible as possible (electrical bikes, shuttle bus, etc…). However it is fair to say that having a guesthouse at walking distance from ALBA would add to the comfort and efficiency of users. With the current BL portfolio (phase I) a guesthouse would not have enough clients. However, one should consider studying carefully whether this would become economically viable upon reaching some critical value in terms of number of operating BLs. It would be convenient to do such study within the period 2013-16 so that, eventually, it could be decided to take some step in the direction of having a guesthouse during the next four-year period (2017-20).

3.1.5 Proprietary User Attraction

The proprietary research is mainly carried out by companies or by research institutions with industrial customers. Whereas in the second case the own research institutions are normally familiar with the potential SL applications this is not the case for the companies. For that reason promotion campaigns among the companies to let them know our capabilities and to attract them will be performed. The Industrial Liaison Office will develop a variety of activities such as organization of events at the ALBA premises focused on SL applications for the companies or industries, programming of guide tours exclusively for companies showing them ALBA capabilities, planning of visits to specific companies explaining the potential of ALBA, organization of a publicity campaign, etc…

Once a particular company is willing to use our facility the provided service should meet high standards and cover its needs in order to keep the company engaged as a customer. This is particularly delicate as the companies demand a service which usually includes the full analysis and interpretation of the experiment whereas the SL facilities are usually dimensioned to only provide the raw data of the experiments with no additional data analysis, which is the typical need of the non-proprietary users. In this regard the Industrial Liaison Office will also play an import role to not only attract companies but maintain them as loyal customers. The Office staff will devote time to understand the research problems of the companies, link them to the appropriate scientists within ALBA and obtain useful information from the experiments reporting them to the industrial clients. This full service is real value added to the companies and to the society in general.

3.1.6 In-house research & development

The mission of ALBA is to develop, deliver, and maintain methods and techniques with which to perform cutting edge synchrotron based research and development. In order to successfully accomplish this mission it is essential that in addition to providing excellent support to their user community – this is indeed the essential justification for the funding of the facility - ALBA's scientific staff must engage in, and lead, their own research programs. This research may be either independent or collaborative with outside groups. ALBA management encourages this second option wherever possible/applicable.

It is of outmost importance that some facility staff is involved with research that it is driven by the desire to understand a system - i.e. performing a more academic type of research - by using the experimental stations available at the facility. In general, collaborative approaches should be a preferred option for this type of endeavour. In this way there is no need to duplicate infrastructures that might be necessary for the preparation of samples and their appropriate characterization that are already available in some external institutions. Furthermore, synergy benefits are clear when strong internal and external research groups work together with a common final objective. Ideally, the funding for this type of research should be secured by research grants applications within competitive calls. In this way the peer-review system will ensure that the research objectives are worthy of support. In addition to its scientific value this type of research is needed because it provides the motivation for the scientific staff at the facility to keep the instruments they are responsible for at the peak of their performance which is a basic requirement for the success of their own research. However, an initial economic help from the internal ALBA resources may be needed to help developing research groups within ALBA that can be in a good shape to subsequently apply for competitive research grants.

There is another type of in-house research that can be even more important for the long-term scientific competitiveness of the facility. This is the research that starts by identifying an important scientific question or program that can only be addressed by a sustained effort in the development of new methods, instrumentation or technologies. In fact, a (cursory) study of the history of Synchrotron Radiation shows that this kind of research has led to the development of most of today's techniques that are available to external users at existing SL facilities. This kind of research is normally - but not necessarily exclusively - carried out by independent in-house research. It is very unlikely that the visiting users will have either the technical expertise, or the infrastructure, or the know-how, or the time to develop instrumentation and techniques in response to emerging scientific challenges. In general this is the role of the scientific personnel in the facility and in order to fulfil this responsibility it is essential that they have an R&D program of their own. We propose that - as it is practically the case everywhere else - this kind of research should be funded directly from the budget of the facility. However, management will ensure that appropriate review of the proposals and subsequent follow up are carried out.

Management should also ensure that the balance between these two types of in-house research is right. Too much of the former and the facility becomes stagnant and, at best, can only progress by copying what it is being done elsewhere. Too much of the latter and essential resources needed to support the daily users' needs are diverted away. Therefore, the expertise of SAC is needed to advise Management on this balance.

The ALBA PhD program was already described in section 2.4.2 within the education/training initiatives. However, this program is also (briefly) dealt with here because of its important consequences for and synergies with the in-house R&D activities. ALBA management is already starting to develop the guidelines for the program to be in place in 2014. The preferred option, wherever possible, is to have PhD positions co-funded (and co-supervised) with external institutions, wherein the PhD research project is agreed upon in such a way that it aligns to the scientific interest of both parties. These actions should yield future applications for funding within competitive national and international research grant calls. Although collaborative research with external groups is the preferred option, fully-internal PhD positions are not ruled out if they are strongly justified within strategic R&D areas.

Finally, one should not forget that providing means to the scientific staff of ALBA for carrying out cutting edge research is the most important step that must be taken in order to keep and attract internationally recognized scientific/technical staff.

3.1.7 Laboratory upgrades

The ALBA laboratory upgrades described below are taking two different approaches:

- Improving the core capabilities of ALBA for technological developments, directly impacting in a positive way on the new BL construction programme and its synergies with the Spanish industry. This applies particularly to the upgrade of the Optics and Metrology laboratory (section 3.1.7.1), which is proposed to be funded by ALBA budget.
- Implementing scientific tools complementary to synchrotron radiation techniques, in order to foster synergies with external research centres and/or universities. This type of upgrades are concentrated on the laboratories of Chemistry, Materials Science and Biological samples, and they should eventually be undertaken and funded via collaborations with external institutions.

These two different strategies are implemented properly in the resource analysis presented below in section **Error! Reference source not found.**.

3.1.7.1 Laboratory of Optics and Metrology

This auxiliary laboratory is equipped to carry out metrology of large optical surfaces (up to 1.5 m long) with arbitrary figure with sub-nanometer accuracy (lambda/1000). It allows metrology of positioning systems, mechanical performances and vibrations of optics components.

The proposed upgrade includes four pieces of equipment to better characterise the optics elements: i) *Interference microscope (roughness-meter)*. This instrument will measure the roughness of the optical surfaces of mirrors, gratings and crystals. This is the surface errors with spatial periodicities around a few microns. It is required to guarantee the proper reflectivity of these surfaces, which may be affected by oxidation, coating processes, or exposure to the beam. *ii) Atomic force microscope.* This instrument is intended to measure the micro roughness of the optical surfaces of mirrors, gratings and crystals, as well as the Groove profile and Groove density of gratings. This is required to characterize the optical properties of gratings, and to guarantee their diffraction efficiency. iii) *Scanning bench.* A granite bench with the required platforms would allow the measurement of mirrors facing to the side or facing down. This is required to measure mirrors in their working orientations, so as to account for the deformation induced by gravity. iv) *High spatial resolution sensor for the ALBA-NOM*. A new angle sensor for the ALBA-NOM based on shearing interferometry, would provide higher spatial resolution than the current autocollimator head, as well as better accuracy.

3.1.7.2 Laboratory of Chemistry

The following spectroscopic instruments can be considered for an upgrade of the Chemistry Lab:

- *Raman spectrometer*
- *IR spectrometer*
- *UV-Visible spectrometer*

It would be of advantage to have this kind of instrumentation available in the chemistry lab for an offline characterization of samples. These instruments would be also used on the beamline for specific occasions, when a multi-technique approach would be required during a beamtime. It is important to provide the chemistry lab with spectroscopic techniques since a large number of samples studied at ALBA beamlines need to be characterized and their chemistry investigated by some of these ancillary techniques, complementing the information obtained by X-ray based techniques. Specifically, we aim to have Raman, Infrared and UV-Visible instruments. They can provide information on vibrational and rotational modes of a system as well as on electronic transitions produced by UV-Vis light. They are also planned to be used in combination with XRD and XAS at the MSPD and CLÆSS beamlines, respectively, when a multi-technique approach is required. This is of particular importance for the catalysis community to study catalytic reactions under realistic *operando* conditions.

3.1.7.3 Laboratory of High-Pressure

No upgrade is required.

3.1.7.4 Laboratory of Materials

The upgrade of the materials science laboratory is aimed at three main purposes:

• The pre-characterization of samples with an electron spectroscopy tool such as XPS upfront a beamtime in view of an efficient use of the synchrotron photon beam on well-characterized samples, especially in the context of surface-sensitive techniques as provided at the CIRCE and the BOREAS beamlines.

• Offline orientation, cutting, and polishing of single crystals

• Providing the required basic equipment for contacting and testing micro-structured samples with an internal electric circuitry for experiments at, e.g., the CIRCE PEEM endstation.

Regarding the topic (i), it is intended to make use of the proven analytical power of XPS to characterize solid state samples as well as sample surfaces in order to warrant their quality in view of an upcoming beamtime without unnecessarily losing ‘precious’ beamtime. Since this XPS setup would be integrated into the overall “UHV suitcase” concept presently active at ALBA, samples (or sample surfaces) could be transferred between the various CELLS-ALBA end stations and other nearby facilities such as the in-house AFM/STM-setup without quality losses.

Regarding topic (ii), precisely knowing the orientation of the single crystal before an experiment is a fundamental requirement. For scattering experiments it is fundamental, but even for XMCD and XMLD is important. It can be of interest for the thin-film community to double check the orientation of the substrate. Surface quality is critical to observe magnetic signals of single crystals in resonant magnetic X-ray scattering (RMXS), which is one the main applications of the MaReS end station. A careful polishing is thus needed. Finally, the iteration cut-polish-Laue scatter-recut/re-polish-Laue scatter... allows for obtaining any desired polished surface from a bulky piece of single crystal. Furthermore, in some systems someone may wish to work on two different directions in one same unique crystal. It is important to note that no similar machine is available in the area (and probably in the rest of Spain). This could be also used as a facility for external researchers.

Besides covering the basic needs for contacting micro structured samples – which is a basic requirement for performing time-resolved experiments at the PEEM end station – topic (ii) is also of outmost usefulness when it comes to the remediation of damaged sample contacts of samples that have been brought in by outside users. Empirical experience at other PEEM setups has shown that shorts between the PEEM sample stage and the extractor lens often leads to damaged contacts that would inhibit the continuation of an experiment without the possibility of fixing this kind of problem on short notice.

3.1.7.5 Laboratories of biological samples

These laboratories are used to carry out Molecular Biology/biochemical procedures and manipulations that are needed to obtain and/or prepare biological samples. The upgrade will consist in acquiring basic equipment (such as ultracentrifuge, FPLC chromatography, cell disruptor) in order to allow expressing and purifying a given protein. With this upgrade, the users of the biological laboratories of ALBA will be able to deal not only with prokaryotic cell systems but with yeast/mammal ones that are commonly used to study human proteins. This upgrade will also allow us to obtain purer soluble proteins and to obtain integral membrane proteins and assay their solubility/stability.

3.1.8 **Computing & Control development**

Accelerators and beam-lines need cutting edge controls and electronics installations to accomplish the increasingly demanding experiments and operations. High precision positioning and synchronization, pump and probe experiments combined with large detectors and higher data rates widely operated in continuous scans as a regular basis, will require further investments in various fields to preserve the competitiveness of Alba in the following years.

Developments on electronics and detectors are key disciplines in which Alba needs to keep a deep know how. Electronic developments have strongly contributed to the performance of accelerators and beam-lines. Upgrades of electrometers, together with other data acquisition electronics are crucial to match the requirements of higher data rates, data sampling and synchronization capabilities necessary for the new generation control systems based around continuous scans.

Moreover, faster scans and large detectors will result in further needs concerning central data archiving capabilities, backups, computing power for data processing, and network bandwidth.

Data will be acquired and locally stored in the instrument related computers, being later migrated or copied to the central storage facility for long term custody. Well-defined formats will be used together with an associated on-line catalogue for handling data and metadata.

All data and metadata will be managed subject to the data protection legislation. Data obtained as a result of non-proprietary access to Alba will reside in a public domain with Alba acting as a custodian. Access to raw data and the associated metadata obtained from an experiment is restricted to the experimental team for a period of 3 years after the end of the experiment. Proprietary users will own raw data and metadata obtained as a result of their access to Alba. These users shall agree with Alba on any particular data managing conduct before starting the experiment.

The results obtained in the facility will be long-term stored, although not permanently, by Alba. It will not be the responsibility of Alba to fully curate the data or to ensure compatibility with external software packages.

Alba is and shall remain a reference as an institution, contributing with both state-of-the-art research and development and computing technologies. The management information systems, and in particular the field of electronic administration requires close attention, facilitating the interaction between different administrations and improving the service to citizens.

3.1.9 Contacts with universities and research institutions

In addition to the training collaborations addressed in section 2.4 above, CELLS is exploring the possibility to have the so-called Joint Appointments with a number of educational and research institutions. These are people who have part time educational or institutional duties with an educational/research institution but conduct their research and work partially or exclusively at the Facility. The obvious advantage to, for example, a University department is that they have a continuous presence at the facility and, therefore, a deeper familiarity with the potentials offered as well as the access to facilities with the same rights – and obligations – as all of CELLS staff. On the other hand this approach allows the Facility a number of benefits such as to count on staff that can officially act as academic supervisors or to have access to brilliant students at an early stage.

3.2 ALBA FUTURE EVOLUTION

ALBA objectives, as detailed in the previous Strategic Plan [1] which covered up to 2014, will be fulfilled in the very near future. The stagnation provoked by the economic situation has slowed down the foreseen development of new beamlines.

It will be shown hereafter that the time span between the design stage of a BL and its operating mode cannot be shorter than four years. In order to keep the installation active and competitive it is therefore fundamental to draw an aggressive though realistic plan for the completion of the experimental facilities in the infrastructure and the evolution of the photon source characteristics.

This paragraph sketches our view of the program for the coming years, notwithstanding that any of the proposed projects will need scientific and technical review in due time.

3.2.1 New beamline proposals

The scientific strategy of ALBA for the next four years was outlined In section 3.1.1. Three key scientific areas were identified and discussed: nanoimaging, pump-and-probe experiments and coherent diffraction-related techniques. In order to develop these fields, and in addition to implementing related cost-effective upgrades in existing beamlines, ALBA proposes to construct new beamlines as discussed just below.

Let us highlight that new beamlines investment will boost the efficiency of the whole facility as the large investment for the infrastructure, accelerator complex and the computing services has already been carried out.

It is considered that the design and construction of fifteen beamlines should be started during the years 2013-2020 (see Table 13), with a rate of two per year.

We are presenting the scientific justification of the first seven beamlines (see Table 13), to be started during the 2013-2016 period. The description of their basic concepts and usages has been produced inside the ALBA community, while there has been no time for a debate within the Spanish user community. This document will be presented at the AUSE/ALBA meeting in September 2013 as the basis for the discussion and the prioritization of the future BLs. A short description of these seven BLs follows.

3.2.1.1 Infrared microspectroscopy beamline, MIRAS

MIRAS (from the Spanish: Microespectroscopía Infrarroja con RAdiación Sincrotrón) was one of the approved beamlines of Phase II. MIRAS is devoted to infrared spectro-imaging. The dedicated front end (number 1) has been identified. The vacuum chamber which has to be installed in the bending magnet to extract the radiation was already designed and built during the construction phase of ALBA and is presently stored in ALBA premises. A preliminary design of the optics layout is in progress. One of the key elements is the mirror that will collect the IR radiation and reflect it back to the storage ring tunnel in order to be transported to the experimental hall. The transport optics will consist in several flat and focusing mirrors adjustable with high precision mechanics.

The engineering (conceptual design and production drawings), assembly and qualification metrology tests can be performed at ALBA, thanks to the cumulated expertise of ALBA technical divisions. The manufacturing of the parts will be partially performed at the ALBA workshop and also in nearby external workshops that have already produced precision mechanical parts in the past. The aim is to “do” most of the beamline transport optics with local resources including parts of the vacuum hardware as specially designed UHV chambers. The IR beam will be delivered to the experimental hall where two commercial IR microscopes will be installed for different purposes as it was defined in the approved beamline proposal document.

The beamline conceptual design was supposed to start in 2011 according to the resolution of the "Consejo Rector" of Dec 21, 2009 but it has been postponed due to economical restrictions.

Table 13 - Proposed new beamlines at ALBA

Propose d order	Beamline	Source	Energy/ wavelength	Experimental techniques	Scientific field	Cost	not e
8-2013	MIRAS	bending magnet	IR: 10-100 μm	spectroscopy, imaging	biosciences, material science	low	(1)
9-2014	Instrument developm.	bending magnet (8)	5-20 keV	optics detector development	instrumentation: mirrors, detectors	low	(2)
10-2014	Nano-focusing	in vacuum undulator (9)	5-20 keV	spectroscopy, imaging	materials science, environment	very high	(3)
11-2015	LOREA	long period undulator	4 -100 eV	angular resolved photoemission	nanoscience, cond. mat. physics	high	(4)
12-2015	Absorption Diffraction	bending magnet	5-20 keV	absorption, diffraction	cultural heritage, material science industrial research	med	(5)
13-2016	Coherent-diffraction	in vacuum undulator (9)	5-20 keV	coherent diffraction, μ-diffraction	biosciences, material science	high	(6)
14-2016	Micro PX	in vacuum undulator (9)	5-20 keV	micro crystallography	biosciences	high	(7)

(1) Strong support from the scientific community. High external support for design phase. Partial funding from users through the microscope. Help to local innovation as the construction of most parts will be local.
(2) For detector program: collaboration with IFAE and microelectronic CSIC institute. For mirrors: profiting from the optics and metrology laboratory. Help to local innovation as the construction of most parts will be local.
(3) Profiting from the optics and metrology laboratory. Incorporation to the nanobeam technologies. Very strong synergies with the emerging area of Nanoscience and Nanotechnology, very well represented at several key research centers recently created in Spain
(4) Involvement of the strong community in angular-resolved photoemission. Insertion device locally designed and produced.
(5) Collaborations with important local and national institutions including museums. Profit from the very rich cultural patrimony. Also industrial uses.
(6) Profiting from the optics and metrology laboratory. Incorporation to the coherence-based techniques and technologies.
(7) Benefits the strong local and national structural biology communities
(8) An alternative option to be considered would be to install this BL at the phase I BL XALOC ancillary branch (see section 3.1.2.4)
(9) One of the possible developments, as explained in 3.2.6.1, is developing a cryoundulator, instead of a standard in-vacuum one.

3.2.1.2 Instrument Development Beamline

A beamline devoted to testing and developing instrumentation is proposed. During the construction phase of ALBA, experience has been acquired in optics, mechanics, metrology and beam diagnostic devices. In order to continue and enlarge the developments in these methodologies, it is planned to construct a dedicated beamline which specifically would be used to test optical components as highly polished mirrors or gratings, mechanical performances of sample stages and similar set ups in terms of temporal drifts and vibrations, and to characterize and calibrate detectors or beam diagnostic devices, etc.

Several types of X-rays detectors that are being locally developed at IFAE and microelectronics institute of CSIC can be tested and developed. Collaboration in this matter has already been initiated. In addition this beamline would be offered to the European project collaborations where most of the European Synchrotron facilities are involved, aiming to develop and characterize new X rays detectors.

ALBA proposes that this beamline is not open to external users through the regular user call, but exclusively devoted to development/innovation of instrumentation, both for in-house and collaborative developments. It can be installed on a bending magnet port and equipped with a cooled Si monochromator plus and experimental station consisting on an optical table and modular equipment to allow flexibility on the experimental setups. A second possibility to be explored would be to install this beamline as an ancillary branch of the existing phase I BL XALOC (see section 3.1.2.4 above).

3.2.1.3 Nanofocusing beamline

The cumulated experience at ALBA and the strategic actions referred in 3.1.1 lead us to envisaging the development of a new beamline able to focus hard X rays from 1 μm down to ca. 30 nm. This beamline will be able to perform transmission imaging (absorption and phase contrast), fluorescence XANES spectra and diffraction, conventional and with a fully coherent beam, on individual nanoparticles. The beamline must have some intermediate focusing and a final focusing stage based on KB optics located as close as possible to the sample, around 100 mm. The achievement of such small focal spot size is technically challenging and requires a long beamline, to be extended outside the current ALBA building.

Two choices for the placement of the port are being investigated: one corresponding to a long straight section, provided with a minibeta in order to reduce the effective source size in the horizontal direction, and with available space for a BL up to 200 m long, and the other in a medium straight section, corresponding to a maximum possible length of ~70 m.

The horizontal size of the focal spot depends on many other factors as for example the diffraction limit dimension determined by the actual size of the focusing mirror. The endstation housing the sample and the last pair of focusing mirrors design will also be critical. In addition to the small nm-sized focusing, the beamline should operate with larger fields of view in order to localize the region of interest in the sample. This might imply to include a focusing Fresnel zone plate to magnify the beam dimensions and define an operation mode of the instrument as a conventional full field transmission microscope.

In summary, this is a challenging beamline and several design options have to be carefully studied. Collaboration with other facilities such as the ESRF and Soleil, which are at present building similar beamlines, will be essential.

3.2.1.4 Low-energy ultra-high resolution angular photoemission beamline, LOREA

LOREA, LOw-energy ultra-high-REsolution Angular photoemission for complex materials, was the second beamline approved for the phase II of ALBA.

Since the advent of the modern energy dispersive electron energy analysers which allow to collect simultaneously a significant portion in the Brillouin zone, angular resolved photoemission (ARPES) has experienced a strong boost in the scientific community and it has proven to be extremely useful for the understanding of the electronic structure of graphene-based material, topological insulators and other advanced materials.

The beamline was approved at the same time as MIRAS, but since its funding has been postponed, only a few preliminary design considerations have been carried out. The photon source has been investigated by the group of insertion devices of the ALBA accelerator division. A suitable device will be made with conventional electromagnets with magnetic coils and soft iron yokes using the same technology of the storage ring dipoles. A set of individual magnets will be mounted in the appropriate orientations to generate vertical and horizontal periodic fields driving the electrons to helical trajectories generating synchrotron radiation with elliptical polarization. The periodicity of the fields was calculated to be ca. 200 mm, which leads to a high spectral flux in the range 4-100 eV for a device of 6 m length (30 periods) installed in a long straight section at ALBA (ID26). It is considered that the adjustable support frame and the magnets could be engineered at ALBA and manufactured in Spain. The ulterior magnetic metrology would be carried out at ALBA.

3.2.1.5 Absorption Diffraction Beamline

It is planned to build a beamline that combines absorption spectroscopy (XANES and EXAFS) and powder diffraction in a single end station installed on a bending magnet. A focusing optics should deliver a beam of ca. 50x50 μm^2 at the sample position. The end station has to have a 2D detector for powder diffraction, detectors for fluorescence EXAFS and a scanning sample stage with appropriate resolution. This would be a versatile beamline which would serve several communities. In particular there is an increasing user community in Spain working in the area of Cultural Heritage which is a field of growing importance in synchrotron facilities. In most cases the users require to perform laterally resolved EXAFS and diffraction measurements to characterize their samples. The combined Absorption/Diffraction capabilities will make this beamline very useful in other fields such as industrial research and Materials Science.

3.2.1.6 Coherent diffraction imaging beamline

Resolution beyond the limitations given by the detector and X-ray optics can be achieved with methods working in reciprocal space. Coherent diffractive imaging (CDI) techniques bypass the need for high-numerical aperture X-ray optics by “phasing” diffraction patterns. Measured in the Fraunhofer far field, the intensity distribution of coherent light scattered by a specimen can be related to the wave field directly past the specimen. However, only intensities are measured, and the phase information needs to be “retrieved” through analytical means. CDI is insensitive to aberrations and manufacturing limitations of optics and can yield highly resolved images with quantitatively interpretable contrast.

Several CDI techniques are evolving and one key methodology is Ptychography. This methodology was proposed as a novel phase retrieval method in the 1960s in the context of electron microscopy, and it has been currently expanded to synchrotron data. Different diffraction signals experience different phase shifts upon movement of the illumination source, and when diffraction orders overlap a characteristic beating can be observed, in which the phase is encoded. The overlapping of the probed volume with coherent X-ray allows to robustly retrieve the phases and so to reconstruct the studied samples.

For non-crystalline samples, forward coherent diffraction imaging can be used for cell structure imaging and other structures on the nano-length scale. For crystalline samples Coherent X-Ray Diffraction allows not only reconstructing the shape of nano-crystals but also provides 3D information about parameters such as the internal stress.

The coherent diffraction beamline will exploit the transverse coherence length of the X rays in the vertical and horizontal directions. To preserve the coherence, windowless beamline layout and suitable optics are necessary. In particular the quality of the mirrors has to be such not to introduce significant distortions in the wave front. A detailed optical design involving wave front propagation is required which is a step further than the common designs based on ray tracing. A set of accurate pinholes and/or accurate slits will select the transversally coherent part of the beam that will impinge on the samples. The lens-less diffraction patterns will be obtained by locating the samples in appropriate supports which have to allow accurate positioning in the beam along the horizontal and vertical axes to perform precise raster scanning.

3.2.1.7 Microcrystal Protein Crystallography

The Micro-crystal Macromolecular Crystallography beamline was the third one approved for the phase II of ALBA. In this case approval was obtained subject to proving, once operations were started, that the user demand was high enough to justify it. At present an increasing proportion of protein crystallography projects involve very small crystals (a few μm in lateral dimensions) due to the difficulties of the crystal growth process. To cope with such tiny single crystals, a beamline with suitable focusing optics was proposed. Basically it will likely be very similar to the phase I Macromolecular Crystallography beamline XALOC except that the focusing KB mirrors will be closer to the sample to achieve small focus. A precise sample rastering stage will also be required to diffract from several different parts of the sample.

3.2.1.8 Other BL proposals for the period 2016-2020

Any planning for very long periods will be revisited, based on experience, results, new technologies, new subjects of research, etc. In any case some ideas of possible future developments are being already discussed, and a short list of the most interesting ones is given in Table 14, also as possible backups of the BL defined in Table 13.

Table 14 – BL technologies being considered for the period after 2016

Beamline	Source	Energy/ wavelength	Experimental techniques	Scientific field	Cost
Hard X-ray imaging	SC wiggler	30-100 keV	tomographic imaging	paleontology, cultural heritage	high
Circular Dichroism	bending magnet	UV: 125-280 nm	protein folding	biosciences	low
Surface diffraction	in vacuum undulator	5-20 keV	grazing X ray diffraction/GISAXS	surface/interface sciences	high
Medical imaging	SC wiggler	30-100 keV	imaging	medical diagnosis research	very high

3.2.1.9 Location of the new beamlines

The present experimental hall has still most of its space free, and the exercise for locating the beamlines listed in Table 13 has been done following the same approach of evenly filling the available space. The main services for the BLs had been pre-emptively provided during the construction, and this makes the installation of any new BL relatively simple.

Figure 22 shows tentative locations of the proposed seven new beamlines, those which would start design/construction within the period 2013-16. MIRAS can be located at exit port 1**,** Absorption/Diffraction at 3, Coherent Diffraction at 6 (medium straight section) Nanofocus at port 8 (long straight section), Micro Protein Diffraction at 15 (medium straight), Instrument Development at 18 and LOREA at 26 (long straight).

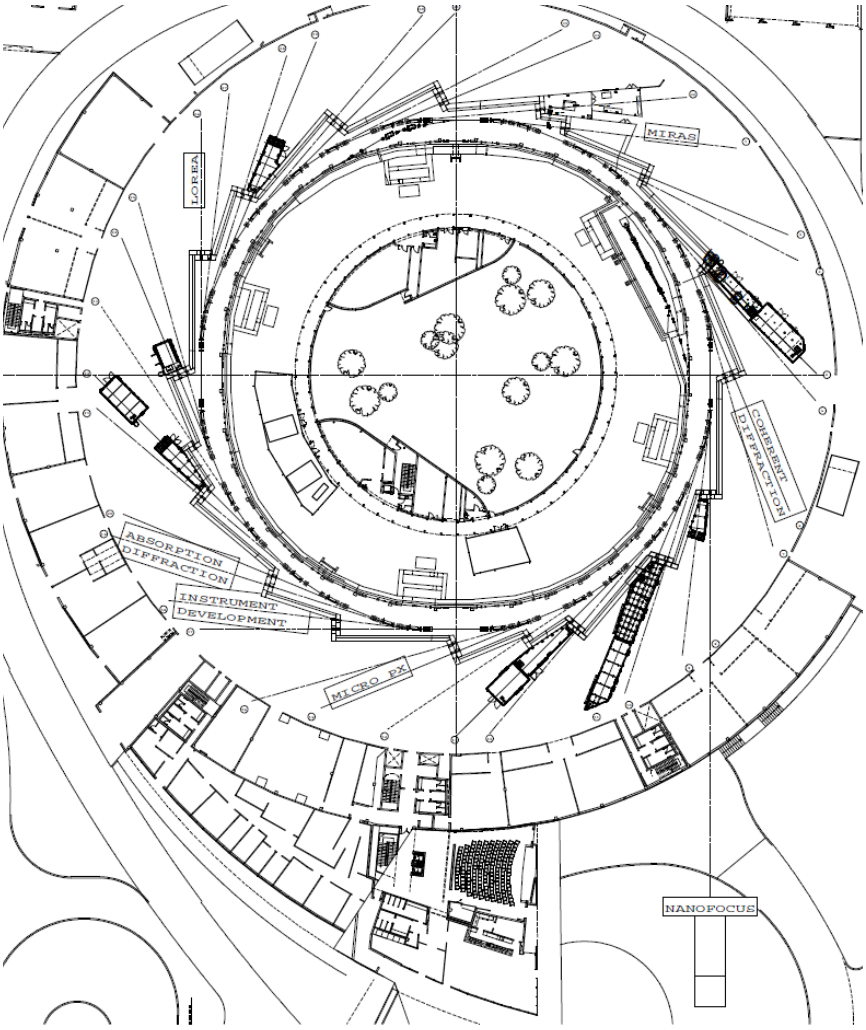


Figure 22 - Tentative location of the next seven beamlines to be constructed, with the Nanofocus BL hutch outside the building

3.2.2 Methodology for the selection of new beamlines

Eight proposals for ALBA Phase II beamlines were presented to the 10th SAC meeting held on April 20-21, 2009. The eighth proposal, corresponding to a teaching beam line, was not evaluated by SAC as the criteria that applied to this beam line are not compatible with the criteria set out for the other ones. At the 11th meeting, SAC analysed and ranked the proposals and presented the outcome to the ALBA Rector Council meeting on December 21st. The Infrared micro-spectroscopy (MIRAS) and the Angular Resolved Photoemission (LOREA) beamlines were approved for construction and a third beamline devoted to micro-diffraction for macromolecular crystallography was approved under certain conditions. The wording of the Rector Council was: "…informa favorablemente la construcción de la línea experimental de "micro difracción", si bien, la construcción de esta línea experimental debería comprometerse después de constatar la existencia de una demanda suficiente por parte de la comunidad científica que justifique su construcción" which indicates that the decision, by the ALBA director, of the construction of this beamline is conditioned to a sufficient demand of the interested scientific community. In practice it is considered that the construction of this beamline should be considered when the phase I Macromolecular Crystallography beamline (XALOC), optimally developed, reaches a stable high oversubscription.

At present, the decision of constructing MIRAS and LOREA is still considered valid and therefore it does not need to be re-discussed. As a matter of fact the design of MIRAS is already in an advanced stage thanks to the internal work and external collaborations, which means that the timing of this beamline is shorter than for others.

Therefore, approval of the remaining beamlines by ALBA Council is mandatory. The remaining five proposed beamlines (see Table 13, above) have been internally discussed in ALBA and the user organization AUSE will be duly informed and its recommendations considered. As it was previously described, the first ALBA user meeting (and 6^{th} AUSE meeting), albausermeeting2013.cells.es/ will be held at ALBA on the first week of September 2013. We will advance this document and a discussion on the basis of the scientific strategy herein is expected.

Additional beamlines could be proposed either with the traditional way followed in phase I and II (working group from AUSE) or as separate initiatives either from ALBA or by external consortia.

Irrespective of the origin of the proposal(s), the approval by ALBA Council should be based on previous positive evaluations by ALBA director and SAC.

3.2.3 Possibility of new beam-lines from foreign/external resources

ALBA management is actively engaged in looking for external funding for building beamlines. We have identified two main possibilities: i) countries that may be interested to build 'Collaborating Research Group' (CRG) BLs; and ii) (co-)funding from Horizon2020 within the infrastructure program.

CRG-type beamlines have been successfully constructed and operated at the ESRF as well as at national synchrotrons like Petra-III (in Hamburg, Germany). The concept of CRG-BL is that an interested country builds a BL in a foreign synchrotron to boost the synchrotron science that can be carried out by its scientific community. An agreement/contract is signed in such a way that a fraction of the beamtime (typically close to 50%) is given back to the owner(s) of the synchrotron in exchange for the photons. ALBA management is identifying countries in and outside Europe and addressing part of the efforts towards this end.

On the other hand, some EU financial support could be found within the schemes of the Research and Development Programmes and the Structural Funds. However those funding schemes are usually based on the fact that a significant part of the costs or investments are born by the receiving country.

ALBA management is identifying organizations from other countries potentially interested on investing at ALBA and is aware of the EU financial support opportunities, to actively look for complementing the main investments needed for the ALBA development plans.

3.2.4 Timeline for construction of new beamlines

Based on our previous experience an estimate of the timeline for the construction of an average beamline spans a four-year period. Table 15 shows a simplified breakdown of an average BL building schedule.

Once the budget is approved and the BL responsible has been hired, work starts with the conceptual design, which involves extensive ray tracing to define the expected optical performances of the beamline. Further work is required to define the technical specifications and then to launch the tender exercises for procurement of the components. The manufacturing step spans typically one year. During this time interval the infrastructure of the beamline is constructed (cabling, fluids, safety hutches…) to be ready when the optical components and the instrumentation of the end station are delivered. Then installation of optics and end station proceeds. Finally, within the last year, installation is completed and commissioning takes place. A very preliminary time schedule of the proposed new BLs, slightly adapted to accommodate the particular complexity of one of them (the nanofocusing one), is presented in

Table 16.

Table 15 - Timeline for the construction of an average beamline

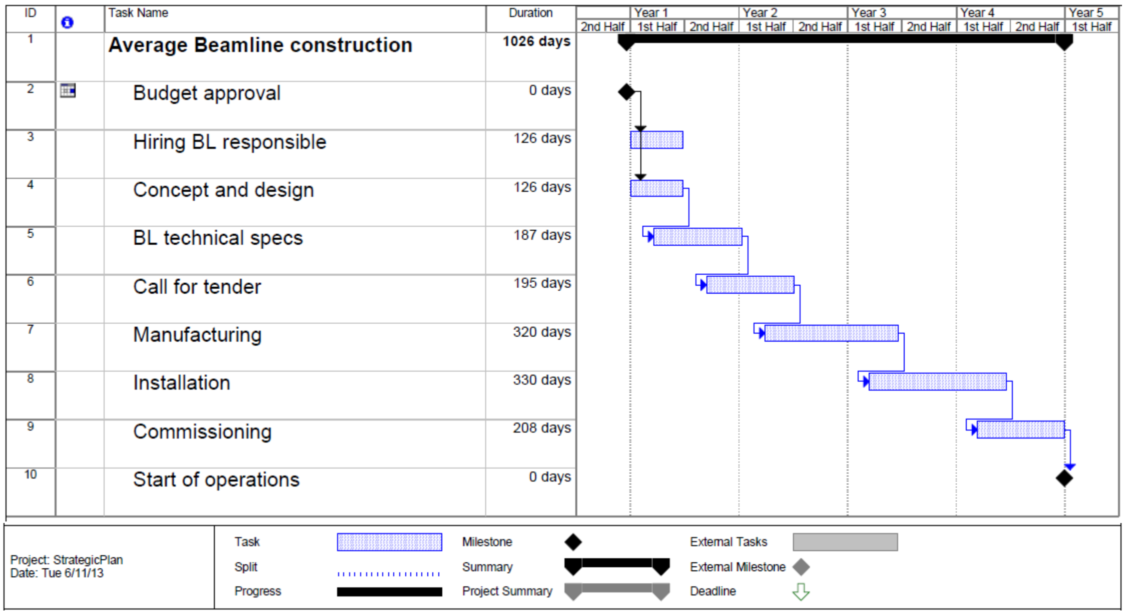
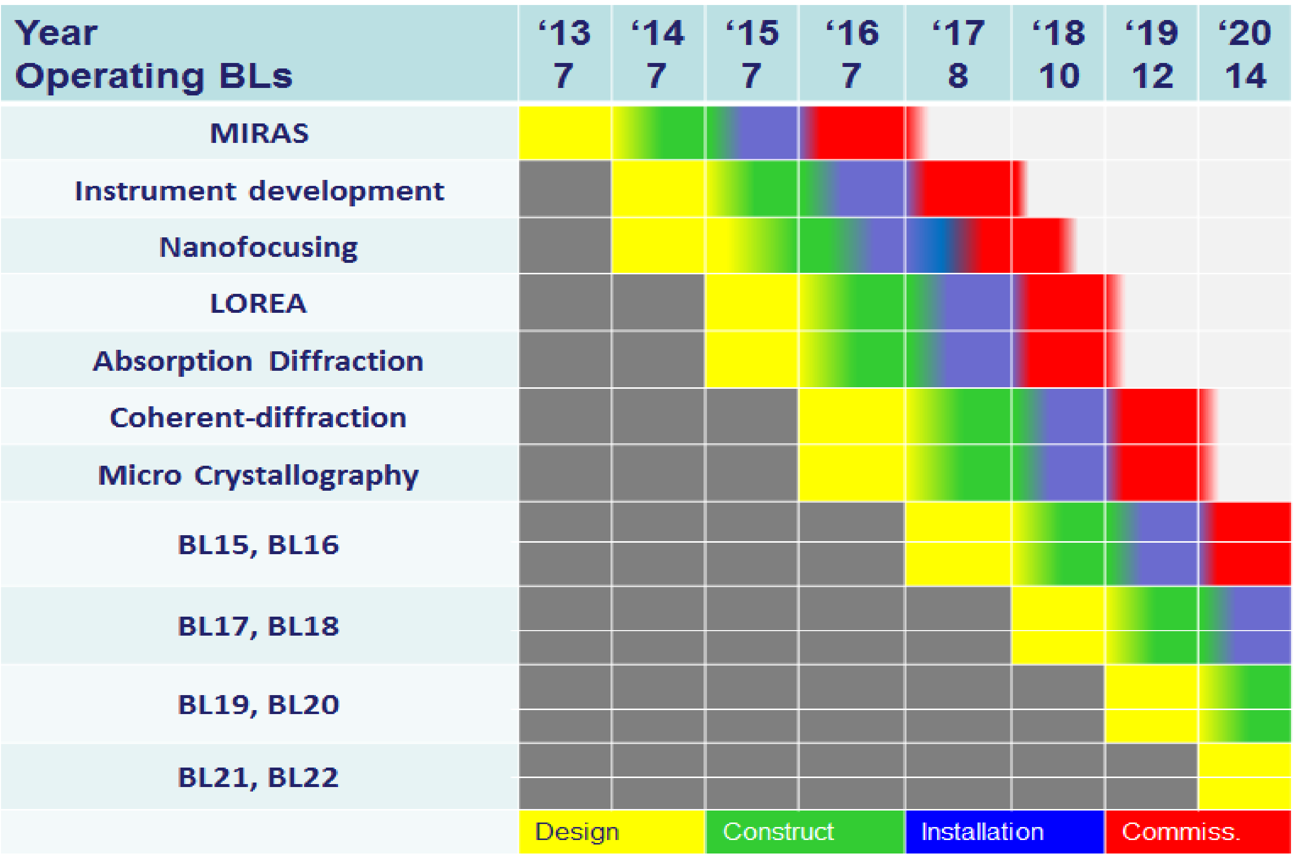


Table 16 - Proposed beamline construction schedule



3.2.5 **Detector R&D**

Detectors are one of the key areas of instrumentation in synchrotron light applications. This statement, which would have been correct at any moment during the past 40 years, is becoming even more critical with the latest developments, mainly linked, but not limited to time-resolved experiments. ALBA phase I beamlines are equipped with sophisticated state-of-the art detectors and, in some cases, with customized detection systems having involved relevant R&D effort, typically in joint venture with the so-called science-industry.

The operation of the existing systems at ALBA, along with a few developments which have been undertaken so far, has been handled by BL scientific staff, with the essential support coming from the service divisions (in the areas of mechanical engineering, electronics and controls). Whereas this approach has allowed having competitive beamlines built, commissioned and brought into operation, it is evident that playing a role in forefront developments in detector technology, with its enormous potential in terms of synergy with the science-industry, can be compromised without specific R&D detector activity in ALBA.

The critical mass needed to create a full detector R&D group, as our direct competitors have, implies an effort (in terms of funding and manpower) which should be carefully considered as compared to other options, like boosting the construction of new beamlines. Therefore, an intermediate approach is herein proposed.

The target would be to develop a suitable collaboration scheme with Spanish institutions having enough critical mass for detector R+D activities, wherein ALBA would play the key role of cross-linking to synchrotron radiation scientific cases and to existing international collaborative frameworks (like the European Detector Collaboration Consortium, where all main European synchrotron light sources are represented and where ALBA is currently playing practically as an observer). Some activities in this direction are already being initiated, particularly focused on the potential of ALBA as a test facility for detector performance. An illustrative example is the collaboration recently initiated with the CNM (microelectronics institute located at the UAB campus).

In order to undertake this activity with a limited, but sustained effort and propitiate further opportunities for the future, it is proposed to have one full-time scientist working in the area of detector R&D starting in 2015, with the clear target of fostering involvement in collaborations, obtaining competitive funding (mainly via EC calls) and making possible to go for more ambitious goals in the next four-year period (2017-20).

3.2.6 **Accelerators New Investments**

The ALBA Storage Ring has seventeen straight sections for the installation of Insertion Devices and any other equipment for light production or beam optimisation. At the moment six of these straights are filled with IDs serving six of the beamlines. Eleven are still usable to further expand the ALBA capabilities.

The following upgrades will be pursued for the period 2013-2016 and beyond:

- *New IDs installation, which is complementary to the chapter 3.2.1.*
- *3rd Harmonic cavity (HC), to increase beam lifetime and stability.*
- *Mini Beta section, to produce small horizontal beam size for the nano focusing BL.*
- *Femtoslicing, to produce very short light pulses of 100s femtoseconds.*

In addition, alternatives lattice and operation modes will be pursued:

- *Short bunch operation: Low alpha optics and 3rd HC*
- *Single bunch operation.*

3.2.6.1 Manufacturing and installation of new IDs

New insertion devices will be needed as photon beam sources, for the new beamlines proposed in the previous chapter.

The strategy to approach the procurement of new IDs will be substantially different from that used for the beamlines built in the 1st phase. In the past, all IDs were outsourced, CELLS being only responsible of technical specifications and conceptual design. Because of that, all main suppliers were foreign industries or research institutes. Spanish companies could only do some partial contributions as subcontractors and the know-how transfer to local industries was very limited. However, during the follow-up of construction, installation, commissioning and operational test, CELLS acquired detailed know-how about IDs, and currently is capable to produce reliable detailed designs and therefore pull the local industry and stimulate knowledge transfer. In particular, the ALBA magnetic measurement laboratory has valuable experience in measuring such devices.

The IDs for the proposed new beamlines are the helical undulator based on electromagnets, in-vacuum undulators using permanent magnets and superconducting wiggler. Other beamlines are based on bending magnets and therefore no associated ID is needed.

Low energy elliptical undulator for LOREA

This ID is based on normal conducting coils, and will be fully designed in-house. There are some local industries with high expertise in the production of electromagnets for accelerators that are good candidates to build the main parts. With respect to the power supplies and its control, also local industries with enough technical capabilities have been identified.

Requirements for this ID are: (a) Range of energies in horizontal polarization: 6-50 eV; (b) Minimal photon flux: 10^{14} Ph/s/0.1%BW; (c) aperture through which photon flux should be estimated: 1 x 1 $mrad^2$. Optimum design for this device leads to an undulator with a period of 200 mm and a total length to be determined. It is to be installed in a long straight section. From the point of view of vacuum, a 3 m NEG coated chamber will be needed. Pole tip magnetic field in horizontal polarization mode will be 0.675 T and fundamental energy 5.3 eV.

Cryoundulator for Nanofocusing, Coherent diffraction imaging, Macromolecular crystallography and Surface Diffraction beamlines

For these beamlines, it can be considered to build four identical cryoundulators with a period of 18.4 mm and a magnetic length of 2 m, Bo being 0.807 T and fundamental energy 2.4 keV, as an alternative to standard in-vacuum undulator. In the case of the nanofocus beamline, if a long straight section is chosen for the ID, the total available length needs to be carefully analysed, in order to place the longest possible undulator together with the magnets for the mini-beta section.

We would take advantage of the Intellectual Property rights for own use acquired with the in-vacuum undulators procurement for the 1st phase. The design of those undulators was done with the aim to include liquid nitrogen cooling in the magnetic girders.

CELLS will act as integrator of different parts of the new ID. On the one side, mechanical carriage can be outsourced as we have identified local companies qualified to produce it. On the other side, CELLS would change the vacuum design to be adapted to new measurement techniques that are currently being developed at magnetic measurement laboratory. Finally, with respect to the magnetic design, we propose to use hybrid design, but this point should be maintained open until further development of beamline requirements.

Superconducting wiggler for Hard X ray imaging beamline

For this beamline, we propose a superconducting wiggler similar to that used today at BL04-MSPD, the superconducting wiggler SCW30. It has a period of 30.0 mm and a magnetic length of 2 m, Bo being 2.1 T. This ID is the state-of-the-art technology in superconducting wigglers and it is performing very well in the current location.

In this case, CELLS has not know-how enough to build the device, so the proposal is to use the same procedure as used for BL04 photon source: collaboration between CELLS and BINP in Novosibirsk, in order to allow further developments in controls and correction magnets, according to the experience acquired during current operation of SCW30 at ALBA.

3.2.6.2 Third Harmonic Cavity

The installation of a third harmonic cavity in ALBA has been foreseen since the design stage. It is a radiofrequency cavity which operates at three times the fundamental frequency of the accelerator. For ALBA, this means 1.5 GHz.

Depending on the mode of operation it can enlarge or shorten the electron beam length. In lengthening mode, it increases the lifetime of the electron beam and the stability threshold. These two aspects are very important for a stable user operation. In shortening mode, it reduces the bunch length and can help for special operations like the production of coherent THz radiation.

The strategy that we will follow to procure this system will involve in-house design and production in collaboration with Spanish industry. This project is a key one in order to transfer to local industry the know-how of radiofrequency cavity fabrication, power generation and controls.

3.2.6.3 Minibeta Section

The introduction of a mini-beta section in one of the straight sections of the storage ring is a requirement of the nanofocusing beamline.

The nanofocusing beamline requires beam sizes of the order of nm in the horizontal plane at the sample location, which translates to beam sizes of the order of a few μm in the horizontal place for the source size.

In the present optics the beam sizes at the center of the straight sections are larger by almost one order of magnitude (see Table 2).

By changing locally the optics with additional quadrupoles one will be able to decrease the beta functions and correspondingly the beam sizes. Adequate simulations will indicate the number of quadrupoles to be added, which will range between 4 and 8.

In addition to the introduction of the additional focusing, because of its length, and the small beam size, this beamline will have extremely tight stability requirements. In terms of hardware this calls for two additional beam position monitors (BPM), probably supported on INVAR stands and also additional fast orbit correctors to be added in the orbit feedback loop.

3.2.6.4 Alternative Operation Modes

Once the storage ring operation is well settled and the nominal parameters are reached, new development in the modes of operation can be envisaged, including where needed new hardware, in order to enhance the photon production and offer extended capabilities to users. In addition to investigate lower emittance lattices, other possibilities are being considered, and shortly described hereafter.

Single Bunch Operation

Operation of the Storage Ring in single bunch mode is important for beamlines performing time-resolved experiments. The ALBA Linac has already been designed to operate in single bunch mode and tests have been successfully performed in which a single bunch coming from the Linac has been accelerated in the booster and injected into the storage ring with a current of 10 mA.

Users making use of this single bunch require a high purity on the population, i.e. electrons only on the selected bucket, and no electrons on the other buckets. Generally the ratio between populated and unpopulated buckets shall be better than 10^5:1.

In order to ensure this condition one has, first, to measure the bunch population with a ratio better than the beamlines requirement and second introduce electron cleaning methods. The electron cleaning is ensured by the already installed transverse feedback system which uses a Libera bunch-by-bunch front-end.

A gated photon counting system which operates on the visible light range is required to measure the purity of the bunch. First steps towards the installation of this set-up have been performed, although further investigations are required.

Short bunch operation: Low-alpha lattice and 3rd Harmonic Cavity

There exists a user community of the TeraHertz (THz) region of the electromagnetic spectrum ready to perform a variety of spectroscopy experiments. In order to fulfil the required broadband and high flux, coherent synchrotron radiation (CSR) needs to be created in the ALBA Storage Ring. This can be achieved by reducing the electron bunch length (which at ALBA is typically 5mm) to the equivalent THz wavelength: below the mm range.

The bunch length in a storage ring depends on the so-called momentum compaction factor, or simply, “alpha” (α, which relates the energy deviation with the longitudinal orbit deviation). One way to reduce the bunch length is by reducing the parameter alpha, whence the name “low-α” mode. A second method is using a 3rd Harmonic Cavity (HC). These two methods are foreseen in the near future at ALBA.

Low-α Mode

The parameter α can be reduced modifying the ALBA SR lattice by tuning the quadrupole settings. In particular, the “low-α” mode corresponds to zero integral of the dispersion at dipoles along the ring, which means that particle orbit lengths are independent of its energy (isochronism). Increase of emittance and of the maximum betatron functions is foreseen due to the need of increasing horizontal focusing for the isochronism condition.

Moreover the dynamic aperture needs to be optimized since degraded performances with respect to the nominal optics are expected in terms of injection efficiency rate and beam lifetime. For all these, a compromise shall be found for the transverse coupling to satisfy both the THz and the hard X-ray community.

The exploration of the “low-α” mode through the evaluation of all parameters, including polarity changes in the magnets power supplies, is being addressed. It is important that ALBA performs the necessary steps to provide this flexibility to the user community, as other Light Sources (Soleil, Diamond, and ANKA), which already offer the possibility of this mode of operation. ([21], [22] & [23])

3rd Harmonic Cavity

The bunch length can be directly controlled by varying the main RF voltage. However, increasing the bunch length by reducing the RF voltage has the detrimental consequences of a reduction of the energy acceptance and shorter lifetime. On the other hand, shortening the bunch length by increasing the RF voltage requires the use of high power sources.

The proper method to control the bunch length while still keeping the main properties of the electron beam consists on changing the slope of the RF voltage, which can be achieved using the 3rd HC, already described above, which will also allow to flexibly control the bunch length.

Examples of 3rd HC used for bunch lengthening, providing the beam with a flatter voltage potential well than the usual one, are in operation at SLS and Elettra (see Ref. [24]). One example of a cavity used for bunch shortening is found at Super-Aco (see Ref. [25]), where the bunch length is reduced by a factor of 2 by using a steeper voltage potential well than the usual one.

3.2.6.5 Femto-slicing facility at ALBA

The feasibility of a femto-slicing facility to allow research in ultrafast X-ray science by pump-probe experiments using electron-beam slicing will be studied. The facility is to be located in one long straight section of ALBA Storage Ring. The technical description of such a set-up is similar to that installed at SLS. [26]

The technology of this facility is based on the Optical Klystron device, seeded by a short pulse lasers (<100 fs). This laser pulse is used to resonantly interact with the electrons in the SR travelling along an undulator –modulator–, leading to an energy modulation and thus inducing the formation of thin slices of the relativistic electron beam. The energy modulation has to be sufficiently large (about five times the electron beam rms energy spread) for transverse (angular or spatial) separation of the modulated slices from the core beam by means of a dispersive element. In a subsequent undulator –the radiator–, the two slices of electrons of opposite energy modulation and the core beam will emit X-rays into different directions, and thus the short radiation pulse from the slices can be extracted while the core beam radiation is blocked. This so-called “slicing technique” was first demonstrated at a bending magnet at ALS [27] and then implemented at BESSY to generate sub-ps soft X-rays (1–2 keV) of variable polarization in an undulator [28]. The SLS-FEMTO source currently under operation is producing light in the range of 4 - 14 keV, with a flux of linear horizontal polarized light based in the 11th / 13th harmonic of undulator emission, ca. 10^5 ph/s/0.1% BW and a pulse duration of < 120 fs.

Adaptation of SR optics will be mandatory, in order to compensate for the dispersive section needed between modulator and radiator. Working point and chromaticity effects should also be addressed and compensated.

3.3 CELLS FUTURE EVOLUTION

The achievement of creating in a green field the largest Spanish scientific infrastructure and lead it to full operation in few years should be exploited as the foundation for new scientific and technological projects. Now that the facility is well set forth, while maintaining as first priority the exploitation of the available infrastructure, starting the evaluation of new enterprises feasibility is mandatory also in order to open the horizon to the present staff.

The experience on synchrotron radiation production, the know-how on accelerator systems, both unique in Spain, joint to the experience in user service, administration, large technical infrastructure systems, have a natural evolution in new projects.

Expanding the wavelength and/or brightness range in the photon production and exploitation, following the model of most synchrotron light facilities, is the first opportunity. Several are the possibilities and the collaboration with communities with longest tradition on new acceleration techniques can be used as field of discussion for the better choice.

In the following some possible evolution paths for the facility are shortly mentioned.

3.3.1 Photon Factory Evolution

In order for CELLS to continue being the reference in Spain of Science with Photons it has to evolve to cover two aspects which cannot be well covered with a circular accelerator: extremely short pulses with very high brightness and photons of high energy.

These two aspects are developed in the following two points.

3.3.1.1 Short Pulses High Brightness photon science in the IR range

The ALBA synchrotron light source produces electromagnetic radiation mainly in the X-ray region and with pulses in the range of ps, not allowing time resolved experiments. A source of radiation in the Infrared (IR) part of the electromagnetic spectrum with short time duration for time resolved experiments will be an excellent complement to the existing facility. Science to be performed with IR comprises condensed matter physics and the border between optics and electronics.

Similar facilities, aiming at producing high brightness in the IR range have been proposed in the past [29], or are presently under construction [30].

An *RF photocathode* shall be used as an electron source to produce high brightness electron beam. In an RF photocathode a laser beam illuminates a cathode generating electron bunches by photoemission process. The cathode is placed into an RF accelerating structure which extracts and accelerates the electron bunches. Maximum pulse charges are in the range of 5-10 nC and pulse lengths less than 1 ps can be achieved.

Requirements of the gun are to produce short electron bunches with energies in the range of a few MeV and high repetition rate. One of the challenges for the gun is to operate reliably over long periods of time. Typical laser used are of the Ti_Sapphire type.

The photocathode shall produce a variety of pulse structures from a single bunch to a multibunch beam including hybrids mode.

The electrons generated by the photocathode will be accelerated to energies between 100-200 MeV using a *Linac* structure. The choice of the most appropriate frequency, whether S or C band, will be the subject of dedicated R&D. Control of the transverse dynamics is done through the use of solenoids and steerer magnets along the Linac structure. In parallel to energy gain, the bunch shall also be compressed. Different schemes for bunch compression can be used, as for example the velocity bunching along the accelerating structure or magnetic compressors.

An *undulator* working over the wavelength range from 200 μm to 10 μm will provide a powerful source of radiation in the THz range, which will complement the existing ALBA synchrotron light source. Pump and probe experiments can be developed by the use of the photocathode laser.

3.3.1.2 High Energy Photons

Laser Acceleration

The use of Laser Plasma Acceleration (LPA) enables the development of very compact accelerators. While acceleration in typical Storage Rings is made using RF cavities that confine electric fields in the order of 10MV/m on a m-scale length, using plasma acceleration electric fields in the order of 10GV/m are achieved on a μm-scale length.

LPA is a relatively new field of research [31], recently rising major interest and intensive R&D also in view of being used for medical applications. It is foreseen that in the future the technology will evolve to develop colliders, light sources, and even homeland security applications. It is essential that ALBA now includes in its future the possibility of participating in this new field of investigation.

The basic lay-out includes the installation of a drive laser followed by an electron injector. The following element combines the high density plasma, which is excited by the laser pulse and creates a wakefield. The electron beam is accelerated by this wakefield, and travels along inside the wakefield itself until it eventually reaches the same speed. While conventional accelerators are limited by the dielectric breakdown of the accelerating tube, the maximum fields in plasmas is defined by mechanical qualities and turbulence, but is generally several orders of magnitude stronger than with RF accelerators.

Applications focus on key advantages of Laser Plasma Accelerators:

• Compact high (and low) energy accelerators based on ultra-high gradient

• Hyperspectral radiation

Revolution in laser technology is essential for continued success:

• The better the laser, the better the accelerator

• Development of high peak power, high average power lasers with high efficiency

• Industry to get involved with National labs and Universities

Compton Back scattering system

Compton Back Scattering (CBS) is a promising method to implement a high-brightness, ultra-short, energy tunable X-ray source at accelerator facilities and at laser facilities using laser wake field acceleration. The basis of this system is to generate X-ray pulses through the interaction of laser pulses with the electron bunches delivered by the accelerator in a head-on collision.

When a relativistic electron beam interacts with a high-field laser beam, intense and highly collimated electromagnetic radiation will be generated through Compton Back Scattering (CBS). Through relativistic upshifting and the relativistic Doppler effect, highly energetic polarized photons are radiated along the electron beam motion when the electrons interact with the laser light. For example, X-ray radiation can be obtained when optical lasers are scattered from electrons of just tens-of-MeV beam energy (as a reference, the ALBA Linac provides beams from 15 – 125MeV).

The X-ray pulses directly inherit the properties of the electron beam and the scattering geometry, like pulse duration and energy, while the photon flux depends mainly on the laser characteristics. As an example, ASTEC, a proof-of-principle project has been build using an accelerator of 30MeV, and the X-ray pulses of 10^7 photons, with spectral peaks ranging from 0.4 – 12nm, and peak spectral brightness up to 10^{21} photons/s $mm^2 mrad^2$ 0.1%, [32].

Because of the attractive properties of the radiation produced, many groups around the world have been designing, building, and utilizing Compton sources for a wide variety of purposes (industrial, medical, security…). ALBA can collaborate with the ICFO (Institut de Ciències Fotòniques) in Castelldefels and/or the CPL (Centro de Láseres Pulsados) in Salamanca to merge their "Laser know-how" with our "Accelerator know-how" to prepare for the construction of a new facility, increasing the synergies among the excellent science centres in Spain.

3.3.2 Partnership with other institutions

ALBA is able to offer to the Spanish research groups an unprecedented level of support in terms of sample characterization and access to complementary techniques. ALBA shares the site, Bellaterra campus, with other major scientific institutions: UAB (Universidad Autonoma de Barcelona), CSIC (Consejo Superior de Investigaciones Cientificas), and CERCA (Centres de Recerca de Catalunya) institutes; and is very close to Barcelona where several universities and research organizations are located.

It is clear that joining forces together will improve the efficiency and save costs. One way to realize this is the partnership concept developed in the Grenoble campus. There, the Partnership for Structural Biology (PSB) was established by a Memorandum of Understanding in 2002 by the European Molecular Biology Laboratory (EMBL), the European Synchrotron Radiation Facility (ESRF), the Institut Laue Langevin (ILL) and the Institut de Biologie Structurale (IBS) to provide a unique environment for state-of-the-art integrated structural biology. This initiative type was extended in 2009 by establishing a new Partnership for Soft Condensed Matter (PSCM). Other partnerships are in the pipeline.

The concept of a 'one-stop shop' may be developed in these 'Partnerships' dedicated to a specific discipline which will allow researchers to make the best use of the new facilities. ALBA is exploring the possibility to establish partnerships with key organizations to carry out research at the forefront of science and technology. Structural biology and nanoscience/nanotechnology are two self-evident candidates but a decision has not yet been taken. Furthermore, the limited availability of economic resources and personnel, and the needs and strategies of the surrounded institutions, implies that the establishment of these partnerships has to be very carefully analyzed and negotiated.

3.3.3 Contribution to National and International Projects

The construction of the ALBA accelerator complex has created at CELLS large groups of expert of scientists, engineers and technicians on the state of the art accelerator technologies.

This expertise comes from the steps required for the construction of such a facility as ALBA, starting with the conceptual design and following with the engineering design, fabrication follow up, acceptance test procedures, installation and set into operation of each accelerator component (magnets, vacuum chamber, RF system, diagnostics, etc) as well as the whole accelerator commissioning.

This know-how is nowadays used for the successful operation of ALBA, and will be used for the future upgrades of the CELLS accelerators.

This means, that currently, ALBA is the main group in Spain involving scientists, engineers and technicians expert in accelerator science and technology.

ALBA has also laboratories and infrastructures created to test accelerator parts that have a strong potential in the post-construction scenario. Moreover, the existing accelerators can be used as test bench for new developments in diagnostics, light generation, beam controls, RF, power supplies and vacuum. This potentiality should be applied to new projects and developments.

To this end, ALBA is already collaborating with other laboratories and research centers, as well as private companies, in the development of new accelerator technologies. We list hereafter the main ones.

3.3.3.1 CERN

Currently ALBA is collaborating in the CLIC project, the proposal for a future linear collider, whose core team is based at CERN, where the CTF3 test facility is currently in operation, with main results on high gradient high frequency RF structures.

In this framework, CELLS is collaborating in testing diagnostic instrumentation, in particular beam steering devices and in studies of beam dynamics.

3.3.3.2 SESAME

SESAME is a synchrotron light source facility, currently being built in Jordan, under the UNESCO patronage. SESAME is a unique joint venture that brings together scientists from its members Bahrain, Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, the Palestinian Authority and Turkey. Alongside its scientific aims, the project aims to promote peace in the region through scientific cooperation.

The European Commission and CERN agreed to support the project, and ALBA is contributing through the measurement of the combined magnets of the storage ring accelerator.

In addition to that, representative of ALBA are member of both the SESAME Machine and Scientific Advisory Committees.

3.3.3.3 MaxLab

MAX-IV is the synchrotron light source of new conception being built in Lund, Sweden. ALBA did design and prepare the technical specifications of the vacuum system for both the 1.5 GeV and the 3.0 GeV rings.

Also, ALBA evaluated the possible beam instabilities that may affect the Max-IV rings and proposed possible mitigations from the mechanical design stage

3.3.3.4 IFMIF-ITER project

IFMIF/EVEDA (*International Fusion Materials Irradiation Facility / Engineering Validation and Engineering Design Activities)* is one of the three projects of the Broader Approach Agreement between Japanese government and EURATOM signed in 2007 concurrently with the start of ITER Organization. IFMIF includes three main facilities: the Accelerator facility, the Target facility, and the Test facility.

ALBA participates to the Accelerator project collaborating in the RF system design, in the magnetic measurements and giving consultancy in areas as power converters and girder systems.

3.3.3.5 XFEL.EU project

ALBA has contributed to this European project, leaded by DESY in Hamburg, through the construction of a number of undulator frames by local industry. These undulator frames will be a significant part of the Spanish in kind participation in the project.

3.3.3.6 ELI collaboration

The Extreme Light Infrastructure (ELI) is a European project dedicated to research in ultra-short timescales. The facility is based on four sites, or pillars, three of which are assigned to the Eastern part of the European Community, Czech Republic, Hungary and Romania [33]. The highest intensity pillar (ELI IV) location is still to be decided.

ALBA has recently joined the consortium headed by INFN which is proposing to build the accelerator systems for the 3rd ELI Pillar, ELI-NP, a Nuclear Physics facility based on Compton Back Scattering. The consortium is formed by both public institutions and companies, each of which is contributing to a special subsystem.

The contribution of ALBA is centered on magnetic systems measurements, RF measurements and Control systems design specifications.

Being a partner in one of the existing ELI pillar infrastructure construction can pave the road for a future candidature of Spain as host country for the IV Pillar, for which collaboration between ALBA and institutions like the CLPU of Salamanca [34], and the ICFO from Barcelona [35], could have a strong role.

3.3.3.7 ESS project

ALBA has already participated in the European Spallation Source through the measurement of magnet prototypes. The aim of ALBA is to enlarge this collaboration, by establishing a stronger relationship with the Spanish contribution to ESS through ESS Bilbao.

3.3.3.8 National collaborations

In addition to that, ALBA is well positioned to lead the Spanish accelerator community within collaborative agreements and to become the reference center in accelerator technologies. In this sense, ALBA can offer expertise and test infrastructures as:

- RF systems and test laboratory
- Magnetic structures design and measurements laboratory
- Vacuum design and test laboratory
- Expertise in accelerator beam dynamics
- Expertise in beam diagnostics
- Expertise in real time control systems
- Expertise in high power and high stability power supplies

ALBA is currently pushing collaborations with other Spanish institutions like CIEMAT, IFIC, Bilbao-ESS, CMAM-UAM, CAN-US. Sharing the existing facilities and expertise in order to create a critical mass of Spanish institutions it is possible to compete at international level in equal conditions with other European institutions and increase the current participation quote in new international projects of big science. This collaboration is the so called Spanish Group of Accelerator Sciences and Technologies.

Also, other Spanish projects, including proton therapy accelerators or Linacs for ions acceleration can and should benefit from our expertise and cooperation.

3.4 RESOURCES

3.4.1 Human Resources

In this section the human resources needed for the implementation of this strategic plan are reviewed, indicating for each new activity the extra resources to be added to those already present. The previous strategic plan [1], which was written for the period 2010-14, carefully analysed and explained the staff numbers meant to secure the stable operation of ALBA with 7 BLs and with a duty cycle of 6000 h/year, and corresponded to a final staff number of 164 for the year 2014. Much experience has been gained on the operation of the facility since 2009, and this number still remains valid.

The programme for upgrades of the ALBA facility, explained in section 3.2 above, includes the construction of new BLs, and new investments in the accelerator systems as central items. Whereas the other minor upgrade activities can be managed within the manpower envelope explained above, it is essential that each new BL and accelerator upgrade comes along with both dedicated staff and an overhead of general support staff. Altogether, any additional BL which has come into full operation needs 3 staff scientists and 3 technical support staff (including all areas, direct and indirect support). In addition, a proportional increase of the postdoc programme is needed, as well as additional administrative support (including general support, user office, industrial/project office, etc…) and PhD students. Each new BL, as explained in section 3.2, undergoes a long process from design to full operation, with intermediate steps for construction and commissioning. The most convenient ramp of staff incorporation for each new BL is summarized in Table 17. PhD students are not included there, but they are counted in the following when total staff is considered. Going more into details the first two beamlines proposed in Table 13 will need a lower number of staff, since part of the design is already on-going and the commissioning and operation will be partly covered by the present staff. These considerations are taken into account later when total number of staff will be calculated.

Table 17 – Average extra staff for a new BL

Year	**1**	**2**	**3**	**4**	**5 on**
Phase	Design	Construction	Installation	Commissioning	Operation
Scientist	2	2	2	3	3
Technical support	1	2	2	2	3
Administrative support				1	1
PostDoc					1

Table 18 shows in the first three rows the increase in beam staff for the accelerator upgrades (AU) realisation which are described in 3.2.6, including related technical support, and an extra operator for the achievement of 6000 yearly hours of operation. The minimum internal staffs for starting the development of new accelerator projects (ND), as described in section 3.3, is shown in the last two rows. To be pointed out that any new project will need dedicated personnel, including operators, not considered in the table, part of which we expect to cover with external funding.

Data shown above, together with the schedule for new BLs as given in section 3.2, plus an increase of one unity since 2015 (to be dedicated to several aspects as for example a biology expert for safety, R&D on Detector, Industrial office, etc) yield a total increase of staff numbers which are summarized in Table 19 (PostDocs and PhD students not included). The total staff evolution corresponds roughly to 27 % increase by 2016 and 72% by 2020 with respect to nowadays.

Postdocs, PHD students and external contracts count today up to 20 units (12% of internal staff). Figure 23 shows the evolution of the total number of staff, including the external staff with the hypothesis of maintaining the same percentage of today. These features compare pretty well with those reported in Table 10 where other facilities staffs are shown.

Table 18 – New staff for accelerator upgrades (Section 3.2) and start of new project development

Year	2013	2014	2015	2016	2017	2018	2019	2020
AU - Scientist		2	3	3	4	4	4	5
AU - Technical support		2	4	5	6	7	7	7
6000 h - Operator		1	1	1	1	1	1	1
ND - Scientist			1	3	4	5	5	5
ND - Technical support					1	3	4	4

Table 19 – Overall staff evolution for ALBA facility to cover new ALBA investments (sections 3.1-3.2)

Year	2013	2014	2015	2016	2017	2018	2019	2020
Operation hours per year	5200	5700	6000	6000	6000	6000	6000	6000
Operation 7 BLs (staff)	158	162	164	164	164	164	164	164
New BLs (staff)	2	8	17	26	38	53	68	83
Accelerator Upgrades (staff)	0	5	9	12	16	20	21	22
Extra (safety, Liaison office…)	0	0	1	2	3	4	5	6
Total staff	160	175	191	204	221	241	258	275
Total staff + PDocs, PhD, ext.	180	197	215	229	248	271	290	309

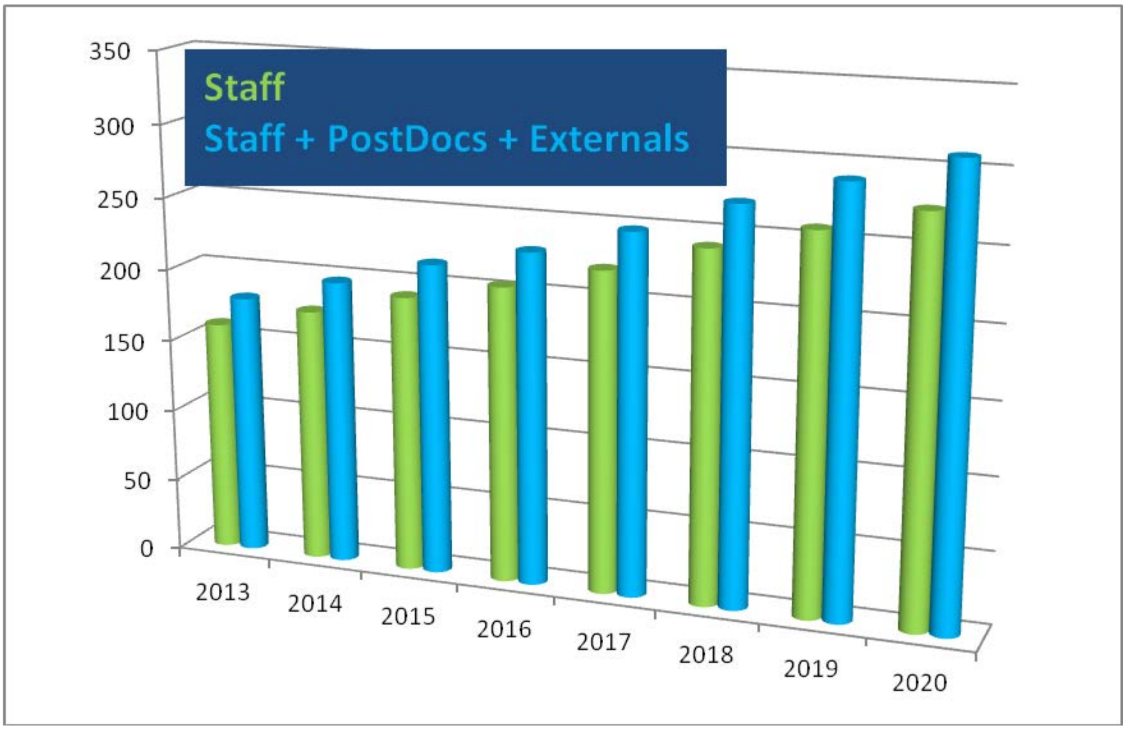


Figure 23 – Proposed evolution of ALBA staff needed to accomplish the program proposed in Paragraphs 3.1 and 3.2

3.4.2 **Budget**

3.4.2.1 Budget for operation and investments

The operation and maintenance budget for the next years without considering any upgrade or evolution of the facility is based on the present year budget projected for future years at current prices. This is the minimum needed to run the infrastructure with the present layout. Table 20 shows the corresponding values, as presented to the CELLS governing bodies elsewhere.

Table 20 - Budget for Phase I BL operation and maintenance in M€

	2013	2014	2015	2016	2017	2018	2019	2020
Staff (PostDocs included)	9.1	9.4	9.7	10.1	10.5	10.9	11.3	11.8
Energy	3.5	4.0	4.6	5.3	6.1	7.0	8.0	9.2
Other current expenditure	4.8	4.9	5.1	5.2	5.4	5.5	5.7	5.9
Users	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8
Operational investment	1.7	1.8	1.9	1.9	1.9	2.0	2.1	
Loan return	11.7	11.7	11.7	11.7	11.7	11.7	11.7	11.7
Total	31.5	32.5	33.7	34.9	36.3	37.9	39.6	41.5

3.4.2.2 Budget for laboratories, Phase I beamline and accelerator upgrades

A preliminary cost evaluation of BL and laboratory upgrades as described in 3.1.2 and 3.1.7 has been prepared. In order to complete the upgrades by 2016 the cost profile can be spread along four years, with a total average budget per year of ca. 0.3 M€. Notice that most of the laboratory development possibilities outlined in 3.1.2 are envisaged as collaborations with external institutions, wherein funding should not come only from the ALBA side. We will not present here the cost breakdown per year and per proposed upgrade, which will be submitted to prioritizing according to the available resources.

The XALOC ancillary branch accounts for an extra 1.5 M€, as reported to the ALBA governing bodies, in the hypothesis of using all possible in-house developments, to be spent during the same period (2013-2016).

On the other hand, accelerator upgrades, as proposed in section 3.2 above, have also been quantified and implemented in a pluriannual investment plan, which is summarized altogether in Table 23 below.

3.4.2.3 Budget for new BL construction and operation

The budget necessary for an average new BL is shown in Table 21 below and represented in Figure 24. An average investment cost of 5 M€ (staff excluded, while ID and Front/End is included) is considered as a reference. The cost of the associated staff is calculated with an average salary of 54 k€ (including patronal part) for the first year and a yearly increase of 3%. Table 17 and Figure 24 summarize the total cost.

Table 21 – Average BL cost breakdown in M€

Year	1	2	3	4	5
Phase	**Design**	**Construction**	**Installation**	**Commissioning**	**Operation**
BL cost	0.50	0.50	2.50	1.5	0.50
# Staff	3	4	4	6	8
Staff cost	0.16	0.22	0.23	0.36	0.5
Users/panel	0	0	0	0	0.1

Notice that most of the investment is done on years 3 and 4, whereas the cost associated to manpower rises gradually along the whole period. The fifth year, in which the BL should be in operation, is included for the sake of completeness, together with the users associated costs. The estimated cost (staff excluded) for running an operating BL, with the reposition/operational investments necessary to keep it competitive along the years is estimated as 10% of the initial investment. These numbers are illustrated graphically in Figure 25 which includes also the 6th year with a 3% increase of the overall cost accounting for inflation rate.

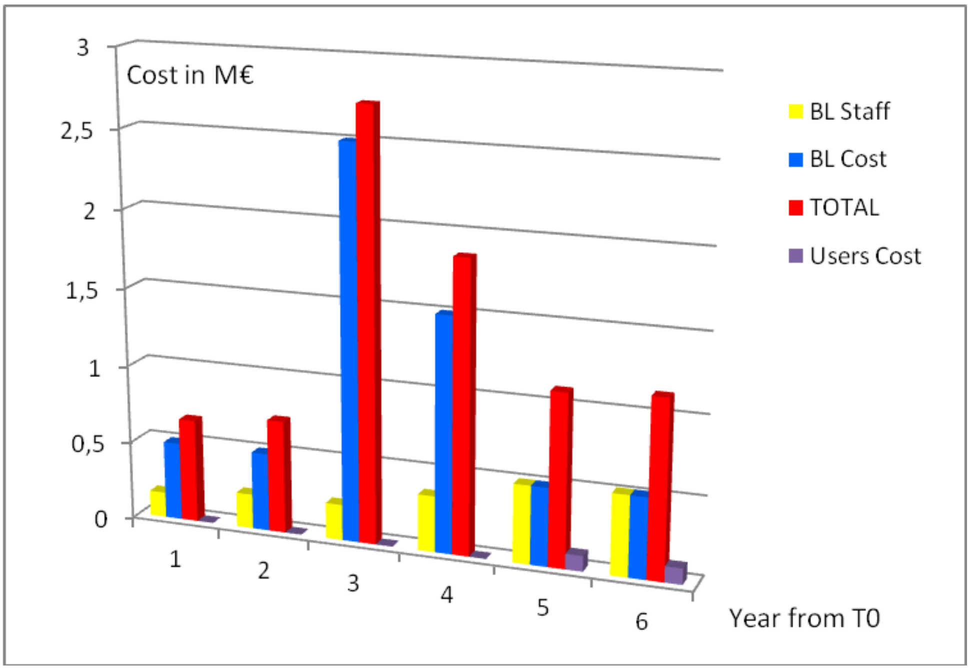


Figure 24 - New BL profile average cost in M€, including related staff and operation.

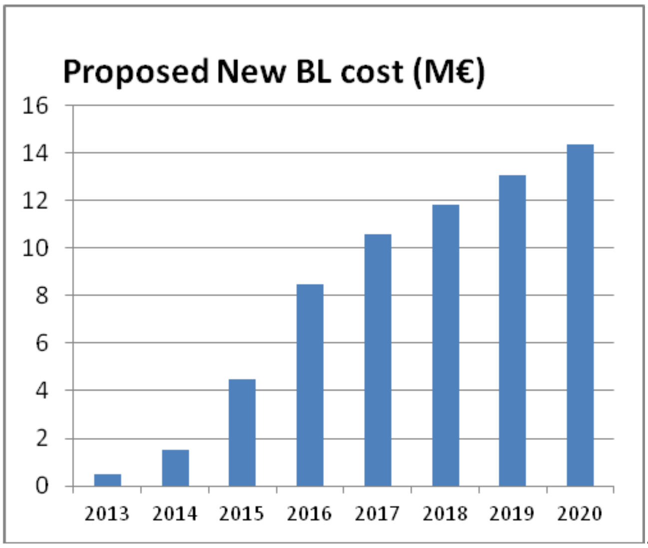
The total cost profile linked to construction and operation of the whole set of proposed BLs described in section 3.2, taking as a basis the schedule there given in

Table 16, is listed in Table 22 and shown in Figure 25. The table contains also the cost associated to accelerators and laboratories upgrades. To be considered that the costs are approximate and without contingency.

Table 22 – Overall cost of New BL, Accelerator and laboratories upgrades (staff not included)

Year	'13	'14	'15	'16	'17	'18	'19	'20
# New BLs (design, constr., commiss.)	1	3	5	7	9	11	13	15
# New BLs in operation	0	0	0	0	1	3	5	7
Total New BL cost per year (M€)	0.5	1.5	4.5	8.5	10.6	11.8	13.1	14.3

Accelerator and labs upgrade cost (M€)	0.3	0.8	1.4	2.9	2	0.5	0	0



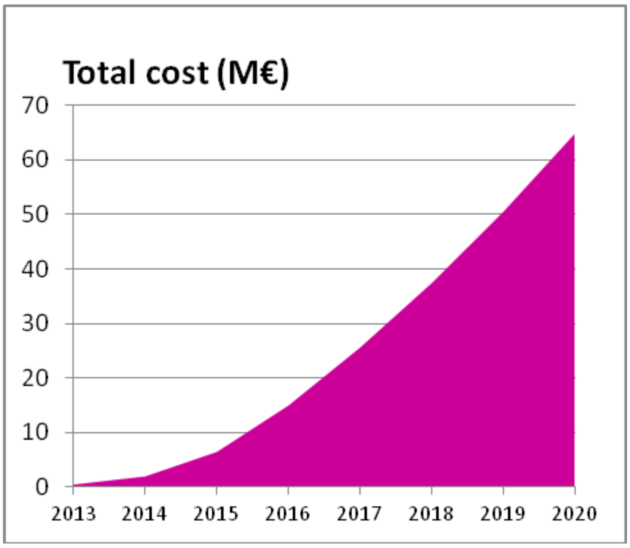


Figure 25 - Total cost of new BLs as described in 3.2, not including personnel

3.4.2.4 Total budget (years 2013-2016, and further outlook)

The total budget of ALBA for the years 2013-2016, including the operation with the present BLs (Table 20), their upgrades, the construction of the new BLs as explained in 3.2, the corresponding increase in operation and staff costs, the accelerator upgrades proposed in 3.2.6, is summarized in Table 23. No new projects or evolution of the facility are here included.

In order to have a preliminary indication of the economic outlook of the facility until 2020, the exercise has been extended until that date. To be pointed out that the relative yearly increase is higher in the next few years, due to the need of investments in upgrades and the restarting of BL construction. Once reached the final regime, with the rate of 2 BL projects per year, the yearly increase on the total budget is less than 10%..

Table 23 – Total budget including proposals of paragraph 3.2 in M€

	2013	2014	2015	2016	2017	2018	2019	2020
Basic Operation (7 BL, present)[1]	31.5	32.5	33.7	34.9	36.3	37.9	39.6	41.5
New BLs plus upgrades	0.8	2.3	5.9	11.4	12.6	12.3	13.1	14.3
Extra staff cost (including postDocs)	0.1	0.7	1.5	2.4	3.5	5.0	6.4	7.8
Total	32.4	35.5	41.1	48.7	52.4	55.2	59.1	63.6
Yearly percentage increase		10%	16%	18%	8%	5%	7%	8%

[1] Includes loan return (11.7 M€ per year)

3.5 TIMELINE

The tentative timeline of the present strategic plan is summarized in this paragraph. Figure 26 shows the proposed schedule. The expanded timeline is shown only for the first BL as an example, and an average total time from the approval to the operation of four years is taken as reference. We are aware that this period may vary depending on the BL complexity and available staff and funding resources.

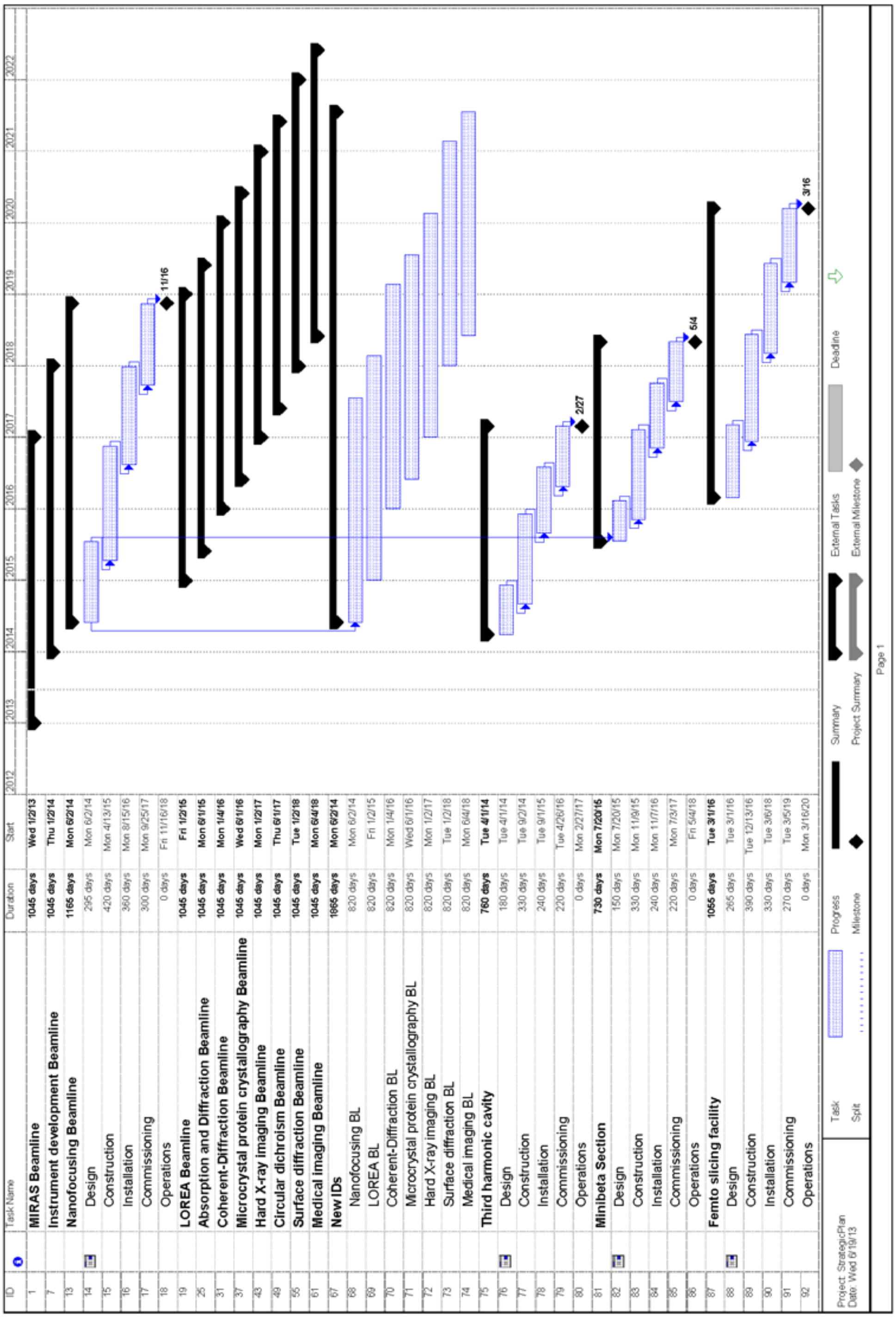


Figure 26 - Tentative schedule for new BL installation

4. SUMMARY OF ACTIVITIES AND RESOURCE REQUIREMENTS

4. SUMMARY OF ACTIVITIES AND RESOURCE REQUIREMENTS

ALBA is at present the largest scientific infrastructure in Spain, and is the result of a strong investment of National and Regional administration.

ALBA staff has demonstrated high level scientific, technological and administrative competences building on budget and almost on schedule a modern laboratory, comparable to sister facilities born in countries with long traditions in the construction and operation of large scientific infrastructures, like France and UK.

During the last years the facility has reached regular accelerator operation and the beamlines have undergone intensive commissioning. Two user calls have been opened, and up to 400 proposals for experiments have been submitted. The first user came on May 2012 and since then all beamlines have hosted users. The first industrial users are using the infrastructure. The achievements of the principal activities proposed in the previous Strategic Plan 2010-2014 are shown in Table 24.

Table 24 - Achievements according to the objectives of the previous strategic plan (2010-14)

PRINCIPAL ACTIVITIES FROM PREVIOUS STRATEGIC PLAN (2010-2014)		CURRENT STATUS (2013)
i)	Finalize the commissioning of the facility and move over to routine operations for the existing program, i.e. the complex of accelerators and 7 beam-lines.	Accelerators complex and the 7 beamlines are currently in routine operations with users
ii)	Ramp up the number of operating hours/year until the maximum of 6000 hours is reached by 2014.	In 2012 the facility operated 4272 hours; the plan for 2013 is 5200 hours, 5700 hours for 2014. and 6000 hours for 2015
iii)	Initiate a new beam-line program with the construction at a rate of three beam-lines every two years, with a construction /commissioning time of four years per beam-line, so that by the year 2030 the facility is operating at full capacity.	No new beam-line initiated due to no funding availability
iv)	Deliver the SASE-3 undulators to the European X-ray Free Electron Laser.	Contribution to EXFEL renegotiated as the Ministry requested. Delivery provided within that new scope.

The situation of ALBA has evolved from a scenario of installation and commissioning in 2010 to another scenario of almost full operation in 2013. That is an extremely relevant achievement since the last Strategic Plan. Unfortunately no new beam-lines have been started yet as no funding is currently available. That is a key issue for the future of ALBA as pointed out in the previous and in the current Strategic Plan.

Based on those grounds the main goals proposed for this period 2013-2016 are as follows:

1. **Ramp up the number of operating hours/year to 6000.**
2. **Bring the current accelerator and beam-lines to full exploitation conditions by 2016.**
3. **Increase and consolidate the community of non-proprietary users, with a continuous improvement policy, based on having user service as a priority.**

4. **Generate and retain a client portfolio of proprietary users.**
5. **Initiate a new beamline program with the construction at a rate of two beam-lines every year, with a construction/commissioning time of four years per beam-line, so that by the year 2026 the facility is operating at full capacity.**
6. **Launch an accelerator upgrade program to expand the capabilities of the current one.**
7. **Study different possibilities for a new Photon Sources program including collaboration with other infrastructures.**

The summary of total capital and human resources required to carry out the full program of activities addressed in this Strategic Plan is shown in Table 25.

Table 25 - Resource needs summary

YEAR	2013	2014	2015	2016
PRESENT PROGRAM				
STAFF FOR OPERATIONS	158	162	164	164
SALARIES	9.1	9.4	9.7	10.1
OPERATIONAL EXPENSES	31.5	32.5	33.7	34.9
NEW BEAM-LINES AND UPGRADES PROGRAM				
STAFF	2	13	27	40
SALARIES	0.1	0.7	1.5	2.4
INVESTMENT AND EXTRA OPERATION	0.9	3	7.4	13.8
FULL PROGRAM				
TOTAL STAFF	160	175	191	204
SALARIES	9.2	10.3	11.5	12.6
GRAND TOTAL FOR FULL PROGRAM	32.4	35.5	41.1	48.7

ALBA is today the newest synchrotron radiation facility come into operation in the world. In a few years strong competition with facilities being built around the world will be in place. Running at long the facility with only Phase I BLs does not properly exploit the possibilities of the initial investment. Furthermore, the global scientific interest of such an approach would only deteriorate as time goes by. We therefore feel a strong need of timely development of new instruments, for which proposals are being developed and presented in this document.

Now is the moment to capitalize the investment. There exists a high risk of losing it if present restrictions on staff hiring and lack of new funding are maintained longer.

Effort to optimize available resources, both human and financial, will be cure of the management. All possible funding means will be investigated and tried, within the Administration shelter.

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