STRATEGY PLAN 2021 - 2024

ANNEX B

STRATEGIES AND THEIR DEVELOPMENT TO ACHIEVE THE OBJECTIVES

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Generalitat de Catalunya
Departament d'Empresa i Coneixement

EUROPEAN UNION
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GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN

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1. ALBA II Scientific Strategy

(Objective 4.1.1, 4.1.4, 4.1.3, 4.1.5)

The evolution of ALBA to ALBA II is driven by pushing the horizon of current possible research to resolve pressing challenges of our future by developing methodologies, infrastructure and networks together with the national and international scientific community. Accompanied by interconnecting, managerial, technical, and scientific means, preparing, planning and laying the foundation for ALBA II is an essential effort for this four-year strategic plan. Building on ALBA's operational strength, its user communities leverage, and the research needs demanded by the Green Deal and other political guidelines, we are developing the scientific case, pivoting around four focus areas, namely, health, environment, energy, and information technology. The scientific case will clearly identify the grand challenges in these fields and translating it into a characterization challenge which will be mapped on the exceptional opportunities a 4th generation synchrotron source provides. From these, we are focusing on imaging structure and chemistry of heterogeneous systems on all relevant length scales and their study under working conditions, visualizing dynamics of the essential processes in these systems, exploiting novel highresolution imaging methodologies including the possibilities based on coherent radiation, and implementing big data research as a tool but also as a customer in the different methodologies.

The current **health** threat of the COVID-19 pandemic shows the paramount importance of fast and safe drug and vaccine developments not only to save the lives of thousands, but also to allow life quality and a thriving economy. Macromolecular crystallography (MX), one of our tools, has always been one of the key components in this fight, solving the structures of proteins involved in the infection processes. Using high-resolution data, active sites can be identified and infection processes can be understood, revealing ways to block the infection. In combination with big-data science, this structural information can be the basis for screening hundreds of existing drugs and participating in the activities for development of vaccines and optimized medicaments. ALBA II with its laboratory support structure and much reduced photon beamsize will relax the requirements on the protein crystal to the micrometer and sub-micrometer size, a significant enabler for fast response, and will combine a wide range of techniques including serial MX, *in-situ* crystallization experiments, and high throughput fragment screening, all tools providing fast insights in the infection mechanism. Beyond this, the interplay of the different microscopy tools, as the present transmission microscopy beamline and the cryo-electron microscopy in operation from 2022, will add information on how the potential medication or vaccine interact with membranes, individual cell organelles, cells and tissue, bridging the molecular protein community with the clinical research and ultimately directly impacting the patient's healt.

Rational governance for **climate change control, environment** safeguard and sustainable agriculture requires the understanding of complex systems and their interdependences, involving a wide range of length scales, human behavior patterns and global economic drivers. The obvious grand challenge is to visualize and understand on an atomistic level the chemistry, structure, and dynamics of the entangled and intricated subsystems and provide quantitative models and simulations which predict impacts of factors like fertilization, environmental hazards, water supply or erosion on all length scales. Such a toolbox will bring a scientific base to the development of new approaches and policies, will allow to tune these to the local conditions, ultimately creating a sustainable, practical, and thrifting economy and guaranteeing a healthy environment. Synchrotron related research has demonstrated the power of multi-length scale imaging, by providing models of the speciation and transport of elements from the atomic level using high resolution microscopy techniques to the macroscopic scale using "clever" sample and subsystem selection combined with state-of-the-art data mining approaches. More efficient catalysis processes, detection of undesired environmental waste elements like nano-plastics and heavy metals, or bio-uptake of desired nutrients by the plants are examples of current ALBA contributions.

Green energy transition will only happen with the development of new materials for efficient generation, storage, conversion, and ultimately transport of energy. The technologies of interest span a wide range, including photovoltaics, wind turbine, fuel cells, batteries, superconducting transport, generation and conversion, and specifically the full H2 and CH4 cycle. A large fraction of current ALBA user community works in these fields. The impact of ALBA II will be pronounced in the understanding of catalytic reactions which are enablers in most of these technologies. A catalyst is a complex system in which the substrate and the actual catalytic particle have multiple functions like the splitting of molecules, the storage and activation of the reactants, and ultimately the reaction to the final product. ALBA II will improve the information on the catalyst defect structure and structural changes at the atomic level which are driving forces of this complex process.

Information technology is another key enabler which impacts not only our energy needs, but transforms the way how we live. Finding new ways of computing, communicating, and storing became a thriving motor in science, technology and innovation. The evolution and maturing of both, spintronics, with a wide range of novel effects and device structures requiring unprecedented atomic precision, as well as an extensive diversity of technologies enabling transformative quantum information systems, require the imaging of structure, chemistry, and magnetic coupling with atomic resolution in complex functional devices. ALBA II with its new imaging tools will deliver the images with atomic resolution and at the same time, show the impact on band structure and relaxation behavior between electronic and phononic systems, a prerequisite for guided combinatorial as well as rational design concepts.

The ability of imaging complex system under realistic environmental and working conditions over a wide range of length scales is common ground in all these examples. ALBA II with its significantly improved brilliance will push the microscopic resolution to the nanometer range and at the same time the detection limit and the ability to study systems as tissues with sub-cell resolution to identify infection processes, plants in vivo and in their natural soil environment, the complex dynamics of transport and structural and chemical changes of catalysts performing their conversion, or the involved impact of layers from 2-dimensional materials assemblies on their electronic band structure and relaxation dynamics. A new potential instrument, the scanning hard X-ray nano probe, may work in concer with the already existing soft transmission X-ray microscope, electron microscopy and a new large field-of-view, high energy tomography system with sub micrometer resolution. In combination, a 3-D model of macroscopic objects with atomic resolution is sculped, allowing to understand the underlaying chemical processes and structure relationships which go hand in hand with transport and reaction dynamics. ALBA II' optimized data management will enable the researchers to connect these models to the larger data mining world, empowering system relevant research.

Whereas ALBA can currently follow macroscopically averaged structural and electronic changes, ALBA II will image these changes with near atomic resolution and study its dynamics with advanced time resolution, utilizing the high flux of transversally coherent X-ray. Coherent diffraction imaging and ptychography are two recent experimental techniques well adapted to the new generation light sources, which allow to achieve nanometric resolution in amorphous materials. Moreover, in partially crystalline samples, Bragg Coherent Diffraction Imaging allows determining shape and structure changes, the strain and defects with atomic resolution and assess their impact on the chemical reactions providing unique insights into the functionality of complex systems. In addition, the temporal evolution of the diffraction patterns will provide the underlying dynamics of these changes.

ALBA II, with the large data volume that will be generated and with its multimodal ansatz, will help to solve the challenges of this century and will be a part of the digital transformation in the Spanish research landscape. All the data generated and data analysis tools will contribute to the future EOSC. Providing FAIR data, e.g. data which meet principles of Findability, Accessibility, Interoperability, and Reusability, will warrant their future universal use. And, from this solid basis, Artificial Intelligence and data mining techniques will exploit the multimodal and multiple-length scale imaging concept.

2. ALBA II Accelerator development

(Objective 4.1.1, 4.1.2, 4.1.3)

The core of the upgrade of a light source from 3rd to 4th generation is the increase of brilliance and coherence fraction of the photon beam, which enhances the resolving power and analytical capabilities for investigating matter to ultimate performances. The minimization of emittance of the electron beam (horizontal dimension x horizontal divergence) in the main accelerator, the storage ring, is the starting point for such evolution, combined with the upgrade of beamline optics and technologies and completed with new state-of-the-art beamlines, fully conceived to take advantage of the new source parameters and complementing the existing instruments.

The low emittance is obtained with the so-called Multi-Bend Achromat (MBA) in the arcs of the storage ring, increasing the total number of dipoles and accordingly decreasing their bending angles. The magnet configuration of the storage ring arcs is nowadays under design, several options being considered. The most promising is so far a so called 6BA lattice, with six bending magnets of which wo antibending per arc. A schematic view of one arc and of the corresponding betatron and dispersion functions can be seen in Figure 1. With this design, an emittance of less than 200nmrad is expected, about 20 times smaller than the present one.

The evolution towards a MB achromat changes the present layout of the arcs and the number of available straight sections. At ALBA there are presently 24 straight sections (4 long sections of 8 m, 12 medium sections of 4.2 m, and 8 short sections of 2.2 m), of which one long is dedicated to the injection, three shorts to rf cavities, 9 media dedicated to IDs. Since the beam size in the long sections is larger, up to now no long section has been used for IDs. The new configuration will have 16 sections, all 4 m long, of which one will be dedicated to injection and two to rf cavities, and 13 sections for IDs. The available ports will be complemented by 8 devices under study to substitute the dipolar photon sources, plus a special one for the InfraRed Beamline. The maximum number of BLs for ALBA II is therefore 22.

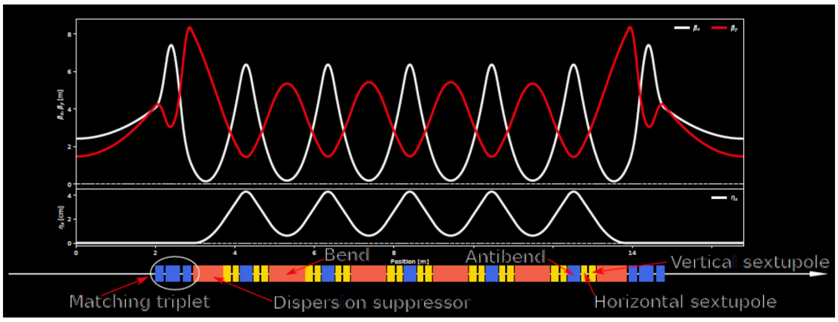

Figure 1 - Scheme of the new magnet configuration for ALBA II, with an emittance 20 times smaller than the present one in the storage ring.

Several technological development assumptions have been considered for developing the design, and they need to be demonstrated with prototyping. For the next period, prototyping of the bending, quadrupole and sextupole magnets are foreseen, as well as prototyping of small diameter NEG (NonEvaporable Getter) coated vacuum chambers with BPMs diagnostics, and of a stable and movable girder, with the aim of prototyping all the elements of one cell.

The design, the construction and part of the installation of ALBA II systems will be carried out while operating the facility with its present beamlines during the next eight years (2021-28). Then, the facility will be shut down during one year for the installation of the new storage ring components and another year will be dedicated to commissioning of the accelerator and of the new beamlines. This extremely cost-effective intervention will equip the scientific and industrial community with a state-of-the art light source for the thirties.

Figure 2 shows the change in the transverse section of the photon beam in one of the present beamlines: the horizontal dimension will be reduced by a factor of about ten. The brilliance increase, as shown in Figure 3 for the present ALBA photon sources ranges from a factor of ~10 for wigglers up to a factor of 20, in the case of in vacuum undulators, what opens the possibility of using the range of higher energy X-rays in the beamlines equipped with this type of insertion devices. Development of technologies for pushing the photon energies even further are on-going in collaboration with other LEAPS facilities. . In the next period, the intention is prototyping some of the future IDs required for ALBA II, as small period undulators (with possible SC technology), and also dedicated superbends or 3-pole wigglers to cover the needs of the present beamlines having dipoles as sources.

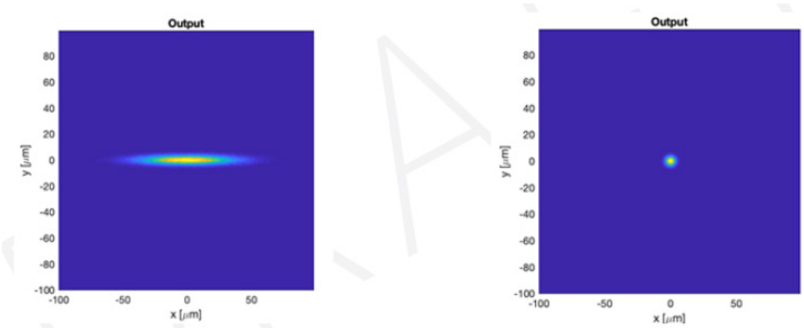

Figure 2 - Photon beam dimensions at the sample position of XALOC Beamline at ALBA and ALBA II (simulations): the horizontal dimension is reduced by a factor ~10, producing an almost round beam.

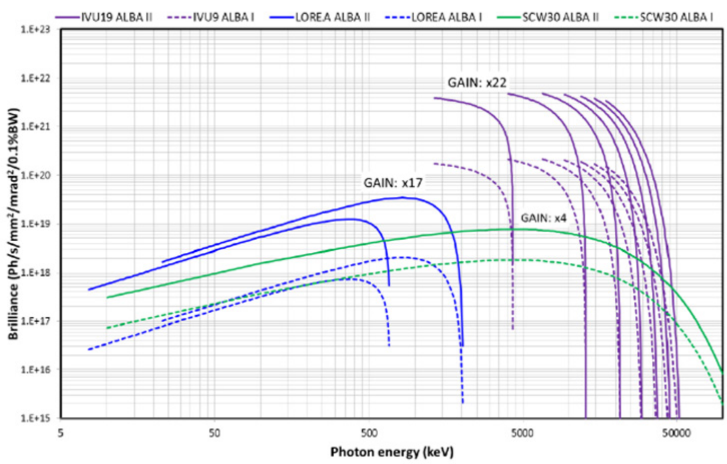

Figure 3 - Brilliance of three different types of ALBA Insertion Devices as today (dashed lines) and at ALBA II (solid lines), calculated with a reference electron beam current of 100 mA.

3. ALBA II Beamlines

(Objective 4.1.1, 4.1.4, 4.1.3, 4.1.5)

ALBA II electron beam qualities, with its nearly round beam shape and low emittance will allow a series of transformative changes in the source design, the beam delivery layout, and the individual optical and optomechanical components, providing ultimately higher spatial resolution at significant photon flux gain, a high coherent fraction of the beam over a wide energy range, and the ability to provide top of the art experimental conditions in the full energy range up to 25keV.

The construction of new Beamlines for ALBA II is geared up for exploiting these new opportunities by providing two long and fully optimized ID instruments, ready for commissioning together with the upgraded ring, employing techniques and probes either not possible at current ALBA or largely benefitting by the ring upgrade. In addition, this project will add one short ID instrument, operational under ALBA conditions but fully benefitted by ALBA II and an additional bending magnet (BM) beamline to consolidate and complement the existing portfolio of research tools to deliver the full service to the user community.

After completion of this project, ALBA/ALBA II will be nearly at full capacity leaving only one possible ID beamline undecided, plus three BM ports.

To decide the scientific program and probe capabilities of the four instruments, the community needs, the positioning of ALBA within the international competition, and the success and short comes of the existing beamline programs will be determined, guiding a gap analysis. This analysis allows to choose instruments with highest impact to the Spanish research community.

Currently, and over the course of FY21 into FY22, ALBA supported by AUSE is intensifying the direct contact with the user community using various tools of communication, including a publicly accessible colloquium series, a set of mini-workshops with Spanish and international participation, focused on various scientific target areas and probe technologies, the user meeting, a concluding workshop, summarizing the conclusions from the ongoing discussions and presenting a first draft of the science case of possible instruments, and a web-presents, disseminating the reports of the different workshops and discussion groups. This outreach activities are accompanied with reviews of the existing scientific sections and beamlines of the experiment’s division, providing an evaluation of the current programs and their effectiveness by international experts including members of the Spanish user community. At the same time, we are forming focus groups with user participations aligned on science areas and novel methodologies which will merge the results of the science case building activities with the program reviews. The resulting gap analysis will be the bases for ALBA management to strategically decide on the new beamlines to be built.

ALBA proposes to start two flagship beamlines within this strategic plan; these beamlines, fully exploiting ALBA II capabilities, will be long beamlines with an end station outside the current experimental floor, and housed in an own building, in a plot which is part of the location foreseen for the ASTIP park.

We want to emphasize that their scientific program, the provided techniques, and the technical details will be decided after the decision process described above is finished. Such a long beamline concept with source to sample distances ranging from 100-200m, provides state-of-the-art probes, allowing to push spatial and spectroscopic resolutions not possible at current ALBA. The complexity of these projects, including the civil engineering efforts, a beam transport bridging two buildings, and the required precision of optics and opto-mechanics, will require a project period of 7-8 years. By starting these projects in FY23 and FY24, we will achieve that both beamlines will be ready for commissioning after the long upgrade shutdown and providing users to the earliest prospect these exceptional probe capabilities.

The proposed short ID beamline will be a more conventional beamline which, however, will also fully benefit from ALBA II but can also be operated with restricted specifications under ALBA conditions. This and the early start in FY22 will allow to build the user program before the long upgrade shutdown and is ensuring full productivity after ALBA II starts operation.

The proposed BM beamline on the other hand is foreseen as an important response to the gap analysis; it will provide important services to cover the full spectrum of techniques and optimized instruments necessary to serve a given scientific field. In combination with the development of specific devices for substituting the present bending magnets as photon sources for current BM lines under ALBA II conditions, the BM beamline will be operational under ALBA conditions and immediately available after the long upgrade shutdown.

Some of the new beamlines will be built with long optical paths from the light source to the end stations to provide the high optical-demagnification which reduces the photon beam spots down to the nanometric dimensions. At least two of the end-stations will be located in a plot next to the ALBA parcel, which is part of the location foreseen for the ASTIP park (ALBA Science, Technology and Innovation Park, see below).

4. ALBA Accelerators Operation

(Objective 4.1.2)

The ALBA accelerators have been operating for the last years with excellent levels of reliability while, at the same time, improving and upgrading their performances

The operation nowadays is based on the design parameters, i.e. 250 mA beam current, horizontal emittance of 4.5 nmrad, and a lifetime of 20 hours. The orbit stability is better than the original requirement of 1/10 of the beam size (meaning at the ID center, a stability of 13 um in horizontal and 550nm in vertical). Nowadays, with all active feedbacks, the rms orbit stability is below 100 nm in both planes.

The +98% availability of the last period is an asset we want to maintain. This will be obtained by modernizing components and optimizing the procedures to take full advantage of the available resources. Since the systems have been operating for more than 10 years, for about 6,000 hours per year, we are now facing obsolescence risks. The strategy to follow is to renovate or even substitute the equipment according to the needs. The modernization of the equipment for ALBA will be done having in mind the requirements for ALBA II. An increase of high-level expertise personnel for operating, maintaining, designing and developing the ALBA and ALBA II accelerator systems is mandatory.

Several systems have been identified as requiring modernization, and are here listed.

a. **Digital Low-Level RF.** The actual equipment, with FPGAs (Field Programmable Gate Arrays) more than 10 years old, is becoming obsolete. The replacement of the existing one by the newest FPGA technology shall be performed, ensuring its reliable operation for the remaining ALBA operation time, and the starting of the ALBA II operation.

b. **RF amplifiers**. During the previous strategic plan period a partial modernization of the RF systems was performed, with the implementation of the Solid-State Technology for the RF amplifiers of the Booster, which is having a perfect performance, with down time at all during users's operation. We foresee the implementation of this new technology for the RF amplifiers of the storage ring. We propose the option of splitting this modernization in two phases since it is a heavy a strong hardware modification requiring not only economic but also staff resources.
c. **Linac spares equipment.** The Linac, Linear Accelerator, was the first accelerator to be operated at ALBA, already in 2008. We plan now the acquisition of spares of the main parts of this accelerator, in order to ensure its operation not only for the near future but also for the operation beyond 2030. The list includes the complete electron gun, a full high power modulator, and two of the accelerator structures (the buncher and one of the acceleration sections).
d. **SR cavity spares**. For similar reasons as presented above, it is planned developing two spares storage ring RF cavities. In these spares, improvements with respect the existing cavities will be performed, taking advantage of the accumulated experience during the last ten years. In particular, improvements in the HOM ports design, and the substitution of the ferrites inside the dampers by a coupling antenna, which shall make the cavity even more robust.
e. **BPMs and FOFB Electronics**. The actual Beam Position Monitors (BPMs) and Fast Orbit Feedback (FOFB) systems of ALBA are more than 10 years old, and their components are becoming obsolete. The renewal of the systems is needed in the near future in order to ensure the proper operation and reliability of the ALBA facility and is extendable to ALBA II.
f. **Timing System.** The current system is based on real-time processing based on FPGA devices which are already at the end of their lifecycle. The entire system requires replacement.
g. **Control System Hardware.** The current IOC controllers are based on the existing Compact PCI industry standard that is over 20 years old. A new architecture must be chosen for the future that will allow the use of modern processors, the integration of modern electronic COTS and ensure its maintainability. This change in the core components of the system involves a complete redesign of the entire control system stack.
h. **Injector Power Supplies.** The power supplies for the booster, need a much frequent maintenance and its renewal is a must in order to maintain the injector running. In preparation for ALBA II it is desirable to also upgrade the injector power supplies.

In addition, there are two improvement projects that started as development and prototyping during the previous plan that shall continue in the present one, even with additional interest since both will be essential for the future ALBA II accelerators. These are:

i. **3rd Harmonic RF System**. The 3rd Harmonic RF System is an extra RF system to be installed in the storage ring of ALBA in order to increase the bunch length and the stability of the beam. Its operational frequency will be 1.5GHz. Its installation will be highly beneficial for the operation of the actual accelerator, but it will be essential for the ALBA II storage ring. In the present moment prototypes of one cavity and one solid state amplifiers are under construction, and will be tested in collaboration with BESSY II and Petra III facilities, since they intend to use the ALBA design for their upgrade projects.

j. **Non-Linear Kicker.** The injection of the electron beam into the storage is performed in the actual accelerator with a combination of four kickers. This scheme has the side consequence of disturbing the orbit of the stored beam during the injection process. Feedbacks systems account for the minimization of such effect, but still the impact can be noticeable in some of the most demanding experiments in terms of photon position stability. The implementation of a Non-Linear Kicker for the injection scheme of ALBA will improve the stability during the injection already in ALBA. Furthermore, this development will be even essential for the new ALBA II, where the beam is smaller and the stability requirements more demanding.

We will continue fostering national and international collaborations in development and research in accelerator technologies, with the magnetic measurement and RF labs as international references. These collaborations are essential to maintain the high level of expertise of the ALBA personnel in state-of-theart accelerator's technologies which will be required also for ALBA II. Several are under way and others are starting now.

We can mention the contribution of ALBA accelerator's team to the development of the SESAME Beats beamline, with the design of the insertion device and the front end; the participation in the LEAPS Insertion Device project inside the EU LEAPS-Innov providing state of the art magnetic measurement tools; collaboration with BESSY and DESY in testing the 3rd harmonic cavity developed at ALBA; contributions to the future vacuum systems of the CERN Future Circular Collider, with the implementation of High Temperature Superconductors; the deployment of the ALBA Digital Low Level RF system in the Canadian Light Source, as well as the participation to several EU H2020 projects like XLS-Compact Light, ARIES and I-FAST.

5. ALBA Operation: Upgrade of operating Beamlines

(Objectives 4.1.2, 4.1.1, 4.1.3, 4.1.5)

The beamlines have been continuously upgraded in the last four years in order to keep the instrumentation up to date, and these activities will continue in the forthcoming years.

Among the most urgent upgrades we list the need of updating the sample environments in several beamlines, the high-pressure infrastructure of the High-Pressure User Laboratory and the gas handling system. Many of our users are progressively proposing *operando* and *in-situ* experiments in which the sample parameters and environment are changing during the experiments instead of the more classic static observations of samples. These experiments require in many cases dynamical exposure to gas mixtures and temperature and pressure cycles while X-ray data and consequently a more advance gas handling system is necessary including full computer control of gases within the beamline control system.

Changing of operation modalities, which were started during the pandemic in view of the unavailability of users onsite, will be further expanded and optimized for increasing the productivity and reducing travels.

During 2020 the remote access, which was effective since 2017 only in the MX Beamline, has been extended to other beamlines with ad-hoc solutions, which can be further optimized and standardized in the future. At present experiments with remote users are limited to those having a good degree of automatization, while for most of the experiments the presence at the beamline of the beamline scientists is mandatory.

Automatization of beamline alignment, beam focusing, detector operation, data acquisition, visualization and on-line treatment will be implemented in all beamlines and adapted for remot operation. In addition, an upgrade of the Experiment Protection System (EPS) will be carried out to cope with possible protective issues of the instruments that are usually tackled manually by the on-site scientists.

A plan of technical review of the different beamlines to be carried out during 2021 and 2022 aims at defining the major changes in the present instrumentation, all upgrades to be done considering their future in ALBA II.

Proposals include upgrades of the BOREAS end station, the CLAESS photon delivery system, the XALOC end station, an NCD remote access upgrade, the partial or total replacement of the existing soft X-ray microscope of MISTRAL, and a CIRCE photon delivery.

In the long term there is the plan of adding variable micro focusing and a side branch with Photo ElectronEmission Microscopy (PEEM) at LOREA, installing a new aberration corrected PEEM system and installing a P3 environment at MISTRAL.

6. Start and consolidate operation for beamlines in construction

(Objectives 4.1.2, 4.1.5)

During the period of this strategic plan five beamlines will start to operate and receive users. LOREA and NOTOS have started commissioning already and will open to users in summer of 2021. XAIRA and MINERVA will have users in 2022, and FAXTOR will open in late 2023. With them, ALBA will increase the number of beamlines receiving users from 8 to 13, and will add several experimental techniques to the portfolio of the facility.

Since the number of simultaneous experiments being run at ALBA will increase by about a 63% with respect to ALBA's current capacity, all transversal services and infrastructures of the facility will need to be updated in order to consolidate the operation of the new beamlines. All support services will require some degree of growth, and some of them will require specific investments, as detailed next.

The data storage capacity and the network infrastructure of the facility will need to be updated to cope with the increased rate of experimental data production. This is needed for all beamlines, but it is especially important for XAIRA and FAXTOR, which will produce a very high volume of data. These two beamlines have specific data handling requirements, which involve fast data pre-processing pipelines, high performance computing and high-capacity storage. They will therefore require deploying specific IT infrastructures.

The new beamlines will also require adapting some technical infrastructures of the facility, like the distribution of deionized water, of compressed air, and of technical gases. One of these transversal services is the helium recovery plant, which will see its production demand increased when XAIRA starts operation. Another infrastructure that will require some upgrades are the gas exhaust lines, which are foreseen for NOTOS, as well as other beamlines and laboratories.

Other groups and services that provide support to user operation will also require some upgrades. For instance user laboratories, which will receive more users, and will have new instruments to support their experiments. Another example are laboratories like vacuum, electronics or the proximity workshop, which will need to provide support, maintenance, and spares for five additional beamlines.

7. ASTIP definition and start of construction

(Objective 4.1.1, 4.1.4, 4.1.3, 4.1.5)

The integration of ALBA and later on ALBA II in the ASTIP scientific hub will enhance the **opportunities for collaboration with the participating institutes**, streaming from the Advanced Microscope Platform now in construction at ALBA which hosts instrumentation owned by several research institutions. The hub will host also the data center PIC (Port d'Informació Científica) (1), a great opportunity for enlarging the data storage and on-line capacities of the ALBA IT infrastructure.

ASTIP proposal is based on **three new centers** and the new ALBA II beamlines which enhance ASTIP scientific reach. The centers are the Complex Materials and Technologies Center (**COMTEC**), the Advanced Multiscale Bio Imaging Center (**AMBIC**), and the Innovation Hub (**SYNDUSTRY**, Synchrotron light- based R&D

towards new industrial applications). Combining the optimization of already existing resources with state-of- the-art instrumentation fully profiting of the enhanced properties of the synchrotron, will make this center almost unique worldwide. One example is the fully integrated biosafety level-3 environment connected to one of the new beamlines, enclosing the imaging and sample preparation instrumentations and a strong data-driven bio-computational: it will allow *in-situ* infection studies, essential to understand all steps of the infection pathway and will provide insights in the pathological changes of cells, tissues and even organs, empowering clinical researchers for a fast response to health threats or crises.

The center will exploit existing local and urban infrastructures and boost the research and training vocation of Cerdanyola del Vallès to a new level and will include a large auditorium and a guest house.

We describe with some more detail the three different centers.

COMTEC

ICMAB (2), ICN2 (3) and IFAE (4)are teaming up to provide expertise and instrumentation for the development of complex materials and devices, used for the clean energy revolution and the digital transition, two priorities within the European Green Deal. COMTEC will focus its capabilities in different areas including:

- High T_C superconductivity
- Energy Storage (Batteries, Supercapacitors)
- Energy Generation, Conversion and Harvesting (Photovoltaic, Thermoelectric, Vibration….)
- Sensing devices
- Quantum Materials
- Materials and devices for beyond-CMOS digital technologies
- Quantum Computing

all of them highly benefiting from the ALBA II advanced instrumentation and the capabilities of the common advanced electron microscopy facilities for nanomaterials to be installed at ALBA in 2022. With its materials research and discovery, device fabrication, operando capabilities and computational and data infrastructure, COMTEC will empower the research, innovation and industrial community, giving access to truly combinatorial approaches towards innovative materials and technological solutions.

COMTEC will be hosted in a new building (10,000 m2) with all necessary infrastructure, and equipped with new instrumentation and with already existing instrumentation provided by ICMAB, ICN2 and IFAE. It will be connected to an ALBA II end station.

AMBIC

AMBIC is a research and service platform which provides a unique combination of imaging, computational and sample growth/handling facilities geared towards fast disease control, healthcare, developmental and systems biology to the Catalan, Spanish and international molecular, cell and clinical research community. AMBIC, which joins up IBMB (5), CRESA (6), UAB and ALBA, will contribute to improving people's health by understanding the molecular mechanisms sustaining life in all its complexity, from molecules, through cells, tissues and organs, to complex organisms. AMBIC will build on the expertise and infrastructure of its partners and the ALBA II X-ray and cryo-Electron Microscopic imaging capabilities to expand the research to a multimodal, multilength scale and holistic approach otherwise not accessible. The fully integrated biosafety level-3 environment connected to a synchrotron beamline, enclosing the imaging and sample preparation instrumentations and a strong data-driven bio-computational effort is almost unique worldwide. It will allow *in-situ* infection studies, essential to understand all steps of the infection pathway and will provide insights in the pathological changes of cells, tissues and even organs. This will empower clinical researchers for a fast response to health threats or crises.

The center will be structured in five scientific units, which span all length scales of interest, computational science and one support unit:

- TEM correlative in-situ (S)TEM, AFM/STM
- Macromolecular Structure & Dynamics
- System & Cell Imaging
- Cell Biology
- Computational Biology
- Sample Preparation and Support Facility

AMBIC will be hosted in a new building (ca. 10,000 m2) with all necessary infrastructure and equipped with new instrumentation and instrumentation provided by IBMB, UAB and other UAB's campus centers, as for example CRESA. It will include a 1,000m2 laboratory connected to an ALBA II end station in a biosafety level P3 environment.

SYNDUSTRY

SYNDUSTRY will bring the benefits of synchrotron light-based R&D to the industrial sector. It will be the bridge linking fundamental research and industrial innovation, by providing the translation from industrial problems into scientific challenges where synchrotron radiation experiments can provide solutions. These capacities used to be out of range for those sectors currently not highly intensive in R&D and not familiar with nanotechnology research methods (mainly SMEs), but holding a big scope for improvement and innovation associated to a deeper knowledge of the raw materials they are using in their products/processes or the new ones they could introduce. The variable of proximity is of paramount importance in the equation of technology transfer and these facilities will allow the convergence of researchers coming from the ALBA synchrotron, the participating research centers and Eurecat-UAB, as well as engineers and technologists from the targeted companies, in order to ease the progress of collaborative initiatives and reinforce the innovation value chain. Equally important is the need for sharing common research and technological infrastructures as well as implementing a coordination strategy among these agents of the R&D value chain, with a clear guidance towards industrial research and aiming at improving policies regarding generated knowledge for the sake of both science and industry.

SYNDUSTRY will be hosted in a new building (ca. 10,000 m2) fitted out with the very latest scientific and technological equipment, both new procured ones and already existing ones provided by EURECAT-UAB.

ASTIP is one of the proposals presented to the Generalitat de Catalunya in the call for ideas for Next Generation EUrope. Its timely realization is of course strongly depending on the availability of these funds, but the concept will be in any case pursued in the future by the ensemble of involved institutions to ensure the development of such area as a powerful scientific, technological and innovative pole in the Mediterranean Area and as an added value to ALBA II which will enhance its potential.

In case of NGEU funds availability the construction could start already in 2021, and be completed by 2026. The ALBA contribution to ASTIP is already included in the ALBA II program. In case of success of the initiative, part of the ALBA II cost could be covered by these external funds, in particular the construction of the extension of the buildings for hosting the long beamlines, the beamlines which are related to COMTEC and AMBIC, and the corresponding laboratories.

8. Innovation and technology transfer

(Objectives 4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5)

Industrial services from ALBA to ALBA II

The tailored service provided to the industry as a user will be enhanced by offering a wider panoply of technical and experimental options to better satisfy the innovation needs of the industry in general and SMEs in particular. The one-stop shop service approach will nicely guide and support industry along all its collaboration and interactions with ALBA without requiring a prior deep knowledge of the synchrotron techniques. Conscientious industry problem understanding, contact with experts, synchrotron technique or techniques selection, experiment design, sample preparation, regular data collection and treatment, data analysis and interpretation by experts and final report are activities to be followed up for each particular client by the ALBA contact person. The new portfolio of beamlines at ALBA, particularly the tomography beamline FAXTOR, will open-up amazing experimental options for industry innovation such as 3D imaging of a variety of materials. Remote and mail-in service access for industry will be extended to the maximum beamlines possible as it is a powerful tool for reaching a wider spectrum of companies, especially those with less resources like SMEs. On the other hand, a strengthen network of collaborations will be harnessed to make available to industry all existing light synchrotron techniques for its translation into innovation solutions as reflected in ASTIP, in the ARIE4GD proposal and in the relevant role to be played by ALBA in the SME access to the European synchrotron facilities within the LEAPS-INNOV project.

The implementation of ALBA II will reinforce the industrial user services with enhanced imaging tools near atomic resolution and with more penetrating X-rays instruments for a more intimate examination of the structure and properties of materials and biological samples also under *operando* environments which will revitalize the industrial innovation potential. Combined with new approaches based on data analytics and data volume correlation between changes and functions will make our microscopic information available to the big-data world, including simulations and theoretical calculations, closing the loop between the micro and macro scales. All this will produce a new paradigm of knowledge generation that will accelerate the innovation cycle when adopted by the industrial sector.

ALBA II: capacitation of Spanish Industry

The construction of ALBA II is a unique opportunity for the industry as a supplier because it will imply design, development and manufacturing of new instrumentation for the new accelerator complex as well as for the new beamlines, namely magnets, ultra-high vacuum systems, RF amplifiers, optic systems, precision mechanics, robotics and digitalization, data management and control systems among others. The upgrade of ALBA will open new innovation routes for the industry, in particular for the Spanish one, that will have chance to access to new knowledge and to develop new skills required to face those challenges. Thus, technicians and engineers working for industry will be exposed to cutting edge technology and to high demanding instrument specifications that will enlarge their expertise. The value chain of the industry related to scientific instrumentation will profit from ALBA II as, besides concept and design of new tools also prototyping, verification, manufacturing and installation is contemplated. The value added will clearly be an efficient knowledge transfer and intellectual proprietary rights that will boost the transversal technology competence and the innovation capabilities of the industry. As a result, the experience and skills acquired will capacitate the industry, particularly the Spanish one, to be ready to participate in other endeavors such as new scientific infrastructures constructions or upgrades beyond the synchrotron facilities.

A proposal including most of these aspects was submitted in January 2021 to a call opened by the Spanish Ministry of Industry Commerce and Tourism (Mincotur) for the projects to be funded through the Next Generation Europe program. The proposal was presented by a consortium made of private companies, the Ineustar association (8) and ALBA. Participation in industrial related initiatives is considered key for the success of the ALBA II project and for the socio-economic impact of ALBA.

9. Data management evolution

(Objectives 4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5)

The ultimate outcome of synchrotron experiments is necessarily the generation of scientific data. Optimizing this data management is key to the success of all scientific activities at ALBA. In recent years, as a result of different technical breakthrough developments, the increase in the volume and complexity of scientific data generated in synchrotrons is unprecedented. On the other hand, the enhanced capabilities of modern IT infrastructure have allowed the systematically and massive re-analysis of datasets. This makes possible the identification of non-obvious patterns of large data collections: Data Science has flourished.

Examples of the above-mentioned developments are used in the XAIRA and FAXTOR beamlines, both of which come into operation in the next 2021-2024 period. The quantity of data that these two beamlines will generate per year will be 30 times the volume currently produced in the eight operational beamlines in 2020. One implication is obvious: a complete upgrade of the entire IT infrastructure will be required in the next three years to be able to store, process and archive this data. But there is another far broader consequence: the analysis of this amount of data requires an IT High Performance infrastructure which is not available to our users. To guarantee the scientific success of the experiments conducted at ALBA, the data services provided to end-users must be extended in these cases. Providing the user with acquisition, storage and recovery data, already a challenge for such volumes, are insufficient. Data analysis and processing tools should be available, and a flexible data pipeline configuration should be tailored during the experiment. And, to have the whole picture, these services must be made available to the user well after the completion of the experiment and outside ALBA premises. In practice, this entails a complete redesign of the entire data management architecture and involves complex challenges. One is the proper sizing of the necessary IT infrastructure.

Parallel execution of data pipelines from multiple sources implies that the system needs to be resilient to peaks in demand that will certainly occur. The IT architecture must be capable of creating resources adapted to user demand to guarantee the sustainability of the system. And service level quotas for users, in practice, must also be defined. We firmly believe that cloud computing could mitigate some of these challenges, and this has led to an ambitious investment plan in this field. Another bottleneck is the external bandwidth connection to/from ALBA.

During the first trimester of 2021 a direct connection with a dark fiber to the GÉANT network will be installed which will allow in the future to increase the bandwidth up to 45Gbps with minimum maintenance costs.

But the future cannot be envisaged without considering how the European Commission (EC) has firmly indicated the way forward to maximize the scientific outcome: the adoption of the Open Science principles. These principles point to the creation of the European Open Science Cloud (EOSC https://www.eosc.eu) (9), which is considered a policy priority by the EC. To foster its deployment, the EOSC Association has been created. ALBA has been an active member of it since its first General Assembly on December 2020. The ultimate goals of the EOSC are all the scientific data produced to be as open as possible and following the FAIR principles. FAIR stands for data being Findable, Accessible, Interoperable and Reusable. The first two terms, Findable and Accessible, implies to the creation of a Data Catalog with proper indexing which allows the retrieval of datasets via a Data Portal. The latter two, Interoperable and Reusable, implies more profound changes in the data driven science. Current ALBA's data policy (https://www.cells.es/en/users/call-information-1/bases/2017_07_data_policy_alba_approved-cr.pdf/view) was approved in 2017 (10). In it, ALBA is declared as the custodian of all the scientific data produced. However, ensuring the reuse and interoperability of data requires ALBA to extend its role to stewardship. As the data producer, we need to make sure that all necessary artifacts will be provided to the end user, including data, metadata, models and algorithms. We need to move toward an Open Science by Design model. In the following years, the current data policy must be updated to reflect these changes. And from now on, we will have to consider the fact that new data services must also be provided by the EOSC portal to third party users in the future. All the before mentioned developments cannot be carried out solely by ALBA, but in conjunction with other research infrastructures. ALBA is an active participant in the ExPaNDS (https://expands.eu) project (11) as part of the H2020 Research and Innovation programme with common objectives towards the implementation of the EOSC in the Photon and Neutron sources research infrastructures.

10. Electronics and Detectors Developments

(Objectives 4.1.1, 4.1.4, 4.1.2, 4.1.3)

The use of specific instrumentation is required for different subsystems in the accelerators and the beamlines. In these cases, specific electronics developments have to be carried out because they cannot be implemented using purely Commercial Off-The-Shelf hardware. Some examples in the accelerator are the Low-Level RF system, the electron Fast orbit Feedback System or the Timing System. In the beamlines, performant scientific instrumentation is needed for acquiring experimental data, from X-Ray detectors to extreme low-level measurements, and specific designs are also necessary around the sample environment. It has always been considered necessary to master these systems to take full advantage of the scientific capacities of ALBA. This has been achieved in different ways: building a solid background of the technical experts, participating in collaborations in instrumentation design, or designing customelectronics which has been eventually also used in other facilities. There are several successful cases of electronics designs done at ALBA that have been exported to other facilities. For example, the ALBA LLRF system is used nowadays at Diamond, MAXIV, Solaris, Sirius, and being developed for CLS, or the ALBA Em# electrometer currently used in MAXIV or SOLARIS.

Now that ALBA is gearing up towards the upgrade, an even more determined step will be taken to strengthen the groups' technical excellence. It will be crucial to take up multiple challenges to ensure the future success of the project. In particular, the next generation of semiconductor detectors will benefit from new technologies that will significantly improve spatial and temporal resolution. This, in combination with the future increase in photon flux in the sample, will allow much faster experiments. It will therefore be necessary to synchronize the various heterogeneous subsystems much more precisely. A versatile system capable of delivering such a synchronization framework will be developed over the next four years. But synchronization is just the foundation stone of the building. Even with the right trigger, the rest of the components of the control system and actuators must be able to keep up. For example, the different movements needed for the experiment execution should be able to follow with the required accuracy. Faster scans and better spatial resolutions require faster movements with greater precision at several points; complex trajectories need emerges. One option that will be investigated in the next years is the use the new slip-stick piezo-based motors which allow for very precise movements with minimum volume occupancy. Another aspect is that the new detectors and increased photon flux will bring massive data throughput requirements. One of the building blocks that will definitely be used are the Field Programmable Gate Arrays (FPGA). This technology is constantly evolving and the new generation of chips enables deterministic processing in the nano-second range and even enables the implementation of complex embedded systems inside them. The solution to use embedded applications inside FPGAs can achieve unrivalled performance during massive parallel data processing although, on the other hand, could call for higher maintenance costs in the face of future obsolescence. Over the next period, FPGAs projects will be fostered to gain an appropriate knowledge of the technology. This will allow for wellinformed decision making in the future design of FPGA-based architectures. But the whole process cannot be seen as a long road for ALBA to follow alone. For X-ray detectors, the acquisition of know-how must be enhanced by different neighboring institutes such as the IFAE or the CNM. Or, for FPGA technology, increasing expertise could be accelerated by working with experienced industry partners.

Furthermore, ALBA will collaborate on the development of a germanium-based detector for spectroscopic measurements as part of the H2020 LEAPS-INNOV call, project which is starting in the first half of 2021 and it will have an overall duration of four years.

11. Complementary Laboratories Upgrades and Exploitation

(Objectives 4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5)

Several laboratories complement the beamline experimental capabilities for all users and others provide advanced characterization capacities for both in-house technological developments and for the industry as a provider. All of them are tools for strengthening national and international collaborations.

Upgrading these laboratories is mandatory for continuing to provide such invaluable service.

The Magnetic Measurements laboratory will take the opportunity of the upcoming machine upgrades to improve the actual installations and offer its services as reference laboratory for magnetic measurements. It will also will be upgraded with a new measuring bench to measure in-vacuum and cryogenics insertion devices, as part of the LEAPS-INNOV agreement.

The RF laboratory will be the space where the RF technologies for ALBA II and other synchrotron upgrade projects will be tested in collaboration with our international partners under the LEAPS umbrella. It will be upgraded to offer a broader testing frequency range capability, namely 1.5 GHz of the 3rd harmonic cavity and 3.0 GHz of the LINAC.

The Optics and Metrology laboratory will adapt its capabilities to serve as platform for the developments on beamline instrumentation required for the future beamlines of ALBA and ALBA-II. It will be strongly involved in two work packages within the LEAPS-INNOV agreement.

Laboratories open to users (biology, chemistry, high pressure and material science) will be kept updated with dedicated budgets in accordance with needs of users. Equipping these laboratories with cutting-edge instrumentation is particularly relevant to provide a precious service to the industrial users who in countless occasions cannot prepare samples at their own premises.

Other laboratories which give support to the infrastructure activities (He liquefaction plant, vacuum and cryogenics, survey and alignment, electronics) and the mechanical workshop will be kept updated ad will start adapting their capabilities to the requirements and technologies of the future accelerators and beamline systems of ALBA and ALBA-II.

All these laboratories summed to ASTIP can become an outstanding interdisciplinary innovation hub with unique combinations of imaging and characterization tools for complex materials and for biological systems.

12. Excellence in personnel and budget management

(Objectives 4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5)

ALBA will continue developing and training the highly qualified personnel throughout all activities and functional areas. This shall contribute to attract and retain qualified staff and to the overall socio-economic impact of ALBA when persons leave ALBA towards different destinations.

The components of the career development concept shall be:

- Continue the successful student program in the current format, which is based on yearly calls for a dozen of undergraduate and master university students, in cooperation with universities, involvement in educational programs and initiatives, active participation in undergraduate education programs (e.g. “FP-dual”).
- Continue the present program of hosting PhD students in collaboration with other institutions in a cofounding scheme. Further develop the program structure, policies and career promotion efforts (e.g. ESR Early Stage Researcher day), targeting at one student per operating beamline plus approximately five students on accelerator, engineering and computing areas, including active participation in industrial PhD programs.
- Continue the present program Post-Doc Researcher program of currently 14 positions self-funded plus positions in cofounding schemes through collaboration with and without competitive grants (e.g. MSCA-COFUND, international collaborations in PD-Programs).
- Develop more structured ALBA career path policies for technical and scientific staff, accompanied by effective internal and external training plans.
- In general, pursue to increase external funding schemes to further increase capacities and potential impact..

13. Communication and outreach

(Objectives 4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5)

The communications and outreach plan will further develop the successful on-going programs at all levels: internal, towards the scientific community and towards the general public and media.

These projects include for the scientific community an annual activity report, periodical electronic newsletters, both internal and external, news and highlights.

The organization of scientific events, many of them in collaboration with LEAPS facilities, will be provided emphasizing the value of communication at all levels.

Dedicated to the general public, there will be the yearly Open Days, guided tours, both virtual and face-to-face.

The educational *Misión ALBA* project will be continued with the aim of enlarging the number of involved schools in all regions of Spain. Contact are on-going with foreign institutions which are interested in duplicating the project in their own countries.

New corporate tools will be created to improve the deployment of information inside and outside ALBA, the most significant being the renewal of the ALBA Synchrotron website, foreseen for 2022.

Furthermore, innovative ideas and projects will be explored in order to expand the targets and develop specific programs for first years of primary school or groups unfamiliar with scientific environments, such as elderly people or deprived groups.

ALBA II is an excellent opportunity for reinforcing the message to the general public of the necessity of research infrastructures for the progress and well-being of the society. Different communications actions – especially in the field of public relations - will be undertaken to highlight this relevance.

14. Health and safety

(Objectives 4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5)

The health and safety group is focused on guaranteeing a safe environment at ALBA for all staff, users, visitors, and contractors during the pandemic condition and beyond, by maintaining the priority of having each year zero accidents involving medical leave during work activity for the period 2021-24.

The contingency plan addressing COVID-19 conditions and approved last year will be updated as needed year by year to ensure its effectiveness in preserving health and safety of the ALBA community.

The conventional risk assessment and mitigation plan covers five specific areas, namely risk assessment of machinery and facilities, hygienic of working area, psychosocial aspect, ergonomics aspect and health surveillance.

For the period 2021-24, a major change of the Health and Safety Group's responsibilities is expected due to moving from an external preventive service to an own preventive model. This action is driven by the expected growth of the facility and is a legal obligation for institutions with more than 250 employees.

With a delayed start, the implementation will be done progressively during the period 2022 to 2024, starting with the first two primary areas (risk assessment of machinery and facilities, hygienic of working area), and finishing in 2024 by providing all services by ALBA besides these for Health Surveillance.

We continue extending a solid preventive culture not only to all staff but also to users, trainees, external companies or collaborators, based on the message that safety is the job of everyone and working unsafe is not an option.

This requires keeping continuously updated the preventive system, which includes preventive plan, norms, procedures, etc., emergency tools, encoded in the existing self-protection plan, and all the risk assessments.

The radiation protection rules, procedures, practices and formal documents with the changes required by *Consejo de Seguridad Nuclear* for new beamlines or other modifications in the facility will be kept updated.

15. Expanding the collaboration networks

(Objectives 4.1.1, 4.1.2, 4.1.3, 4.1.4, 4.1.5)

ALBA policy of networking has been evolving at national and international directions, each fostering the other.

The team which has gathered to present the ASTIP proposal for the future evolution of ALBA surroundings is already strengthening its ongoing collaboration and, like a tree whose roots become stronger and its fruits richer, is generating ideas which nourish the research plans of the totality. We are attracting to the hub collaborators from research institutions from all Spain to further opening its horizons and actively involving companies to enhance its innovation power.

The position of ALBA inside LEAPS and ARIE is providing a huge number of opportunities for cooperation, common developments, participation to transversal platforms open to public and private researchers, capacity to be part of the entities defining scientific priorities and related technological developments for the future of our society.

The start-up of the Iberian project of collaboration with Portugal is setting the basis for fruitful build-up of research in the well-defined areas of ALBA strategic fields.

16. CELLS complementary developments

- **eALBA: Electrons at ALBA**

  ALBA is a light source facility, but to produce the synchrotron light, electrons are accelerated in three different accelerators, the Linac, the Booster and the Storage ring. The storage ring is in continuous operation, but the Linac and Booster do operate only 3 minutes every 20 minutes, so there is the possibility of using the remaining 17 minutes to extract electrons into an experimental bunker, where experiment with electrons can be performed, for testing high energy and astrophysics detectors, for irradiation tests of material and electronics or to produce gamma photons.

  The proposal is to build such electron test facility at ALBA. It is feasible in the actual accelerator and also, in the upgrade ALBA II.

  The project consists on a extraction system from the booster, a transfer line which will allow the electrons to pass the storage ring from above, at around 2.5 m high, towards the Experimental Hall, a delivery magnet system at the end of the transfer line to shape the electron beam at the detector position, and a beam dump. Detector and beam dump will be located into a heavy concrete bunker.

- **Developments towards ultra-short pulses accelerators**

  Time resolution at ALBA present BLs is defined by the electron bunch length in the synchrotron, in the range of some 10s of picoseconds. The interest of using ultra-short pulses is growing and the proposal of developing a dedicated laboratory for new accelerator structures, also combined with laser technology, is on the table, opening the possibility of producing photon pulses of the order of 10s of femtoseconds.

  The proposal has been discussed within the Spanish community in several forums, with the idea to introduce the fast dynamics science into the Spanish scientific environment, and foster the usage of this community of FEL projects like the European XFEL, to which Spain contributes as associate member.

  The project for a short pulse, high brightness photoinjector, which will include a RF Photon Gun, a short pulse laser, and a RF klystron and a modulator, could be used as a seed for different opportunities. Some of these are Ultrafast Electron Diffraction, Infrared Free Electron Laser or a Compton backscattering energy tunable X-ray source.

  Any of these possibilities will be discussed with the Spanish scientific community, developed in collaboration with other Spanish research centers (CLPU, ESS Bilbao, CIEMAT, ...) and shall be supported by the active accelerator international community collaborations (see CLIC, CompactLight projects (12)).

- **iii) Accelerator collaborative developments**

  Being ALBA the reference center for accelerator technologies in Spain, we are prepared to contribute to any accelerator-based facilities that are envisaged in the next future. We can mention for example future initiatives as could be DONES [39], in case of success of the Granada candidature, the IV ELI Pillar, whose feasibility is still at a very preliminary stage or collaboration with a Hadrontherapy centre for treating radio-resistant or inoperable tumors. In Spain at present there are only few new (private) projects based on proton accelerators industrially produced. It would be interesting to complement the healthcare interests with some technology development, which could face carbon ion-based therapies, or new accelerator techniques for simplifying the proton-based therapies.

References

1. Port d'Informació Científica [Online] https://www.pic.es
2. ICMAB-CSIC [Online] https://www.icmab.es/
3. ICN2 [Online] https://icn2.cat/
4. IFAE [Online] http://www.ifae.es/
5. IBMB-CSIC [Online] https://www.ibmb.csic.es/
6. CRESA [Online] http:s//www.cresa.cat/
7. UAB [Online] https://www.uab.cat
8. Ineustar [Online] https://www.ineustar.com
9. EOSC. [Online] https://www.eosc.eu
10. Current ALBA's data policy [Online] https://www.cells.es/en/users/call-information-1/bases/2017_07_data_policy_alba_approved-cr.pdf/view
11. Expands [Online] https://expands.eu/
12. CLIC Compact Project [Online] https://home.cern/science/accelerators/compact-linear-collider

ALBA

Generalitat de Catalunya
Departament d'Empresa
i Coneixement

EUROPEAN UNION
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