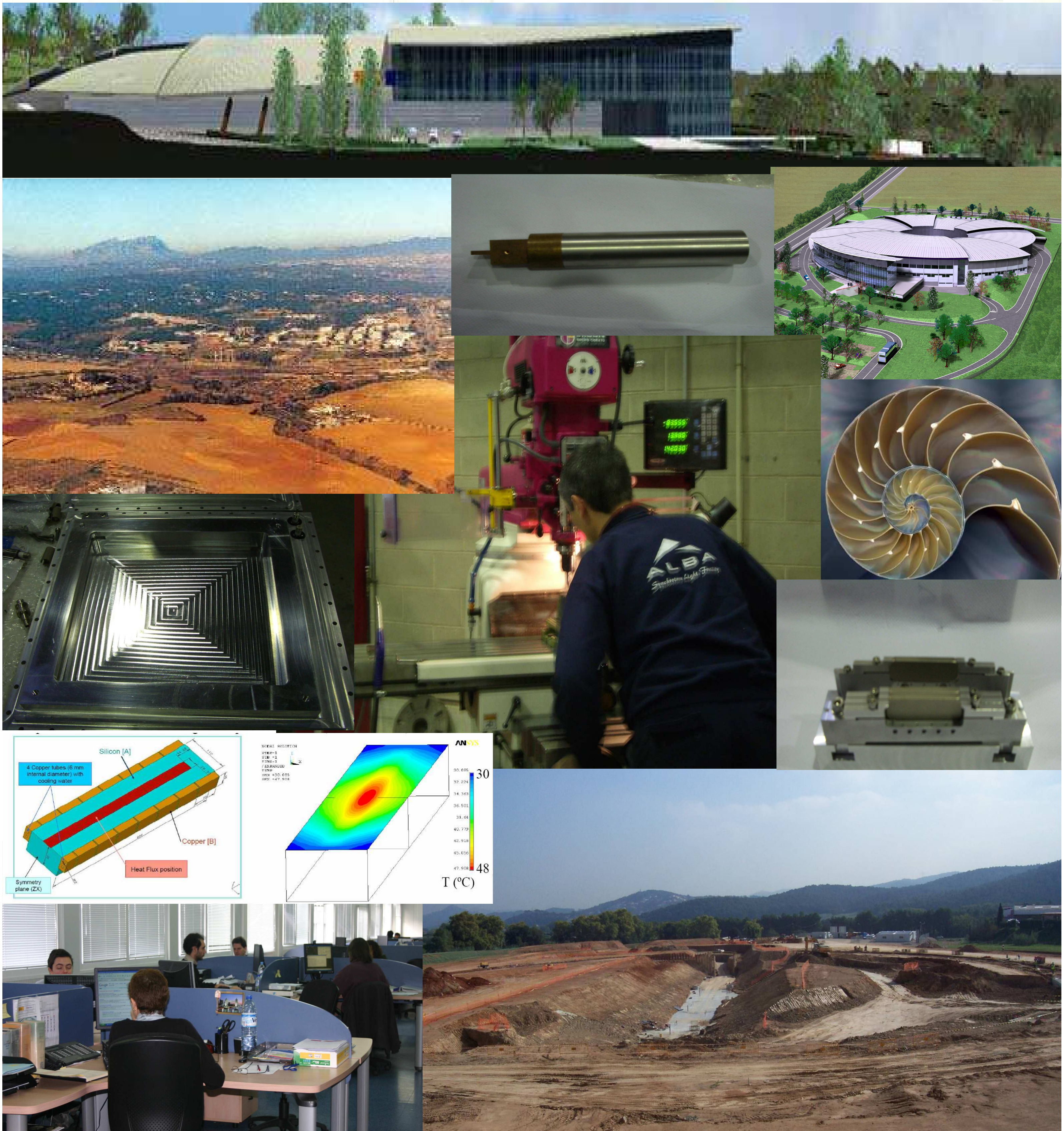
ALBA NEWSLETTER

Number 2, December 2006



INTRODUCTION

Here you have in your hands the second issue of the ALBA newsletter. It is substantially longer than the first one and contains more information, just to follow the progress being done by the ALBA project. Several colleagues suggested us to spread information on the project in a handy form that might be used in discussions and we tried to do it here. Without excluding a more systematic way of presenting technical or scientific information we have assembled information on the progress on the civil engineering, computing and control divisions, accelerator division and phase I beamlines. Please note that more information can be found in the web site of ALBA (www.cells.es).

ALBA has now (December 2006) 103 employees distributed in 16 nationalities: 67 Spaniards, 8 Germans, 7 French, 5 Russians, 4 Italians and 2 U.K. citizens among others, including some other European countries and also American, African and Asian. The gender composition of the staff is 76 men and 27 women. From February 2006 till now, 31 new staff members have been hired. In 2007 it is expected to complete the whole staff (138 persons) and during the mounting phase of the accelerators and beamlines it is planned to hire 30-40 additional people on a temporary basis as peak load personnel.

On July 27th a ceremony took place at the ALBA building site where several political authorities including Prime Minister Mr. Rodríguez Zapatero, the President of the Generalitat de Catalunya Mr. Maragall and the Minister of Science Ms. Cabrera celebrated, together with the ALBA staff and many other local political and university representatives, the start up of the construction process. The ceremony was attended by about 150 people (Fig. 1).

Fig. 1 Political representatives at the ALBA construction site

CIVIL ENGINEERING

Alba site occupies an area of 6 ha between Cerdanyola del Vallès and Sant Cugat del Vallès, about 20 km from Barcelona, at 106 m above the sea level. The building complex will have a total useful surface of 26000 m^2.The civil works at the ALBA building started last June and are following its way with no delays for the time being. By the end of November, more than 90.000 m^3 have been removed from a total of 150.000 m^3, which corresponds to a 60% of the soil breaking. Now at the ALBA site, the service gallery, which will run below the concrete slab, and the platform of the new buildings can be clearly seen (Fig. 2).

The critical area slab construction, the dimensions of which are 120 m outer diameter and 60 m inner diameter, will start at the beginning of 2007. During the first building phase, the soil will be excavated 3 m in depth in all the critical area to extract the red clays and marls which conforms the soil. They will be subsequently replaced by structural material.

The extracted soil will leave a hole of 25000 m^3 to be refilled. The projected solution for the critical slab floor area consists in 1 m thick concrete slab, supported on a 2 m thick treated soil consisting in a refill of 1.70 m of selected gravel homogenously and conveniently compacted protected by two layers of 0.15 m of poor concrete, on the top and on the bottom (sandwich mode) of the gravel. This treatment aims to have a good response of the critical slab where the accelerator and beamlines will be installed against the possible movements of the soil underneath.

The whole critical slab, which has been divided into 20 segments, will be produced one by one. The area of the single elements has been chosen in such a way that the corresponding concrete volume can be poured in one day and the corresponding work properly executed.

The ALBA tunnel housing the storage ring and the booster synchrotron will be constructed in parallel with the slab. The lateral walls, which will be cast *in situ*, and the slab will form one structural unit (Fig. 3). The nominal thickness of the tunnel walls is 1 m, although increases up to 1.65 m in some areas. The roof of the tunnel will be 1 m thick, increased to 1.4 m where needed. The front walls and the removable roof will be cast in a factory and then transported and assembled at the site. All front walls will be made of heavy concrete. The cross section of the floor area is depicted in figure 4.

June 2008 is the estimated date to finish the buildings complex of the ALBA Synchrotron Light Source.

Fig. 2 (*left*) Overall view of the site as in August 3rd 2006. (*right*) Digging the service gallery (September 2006).

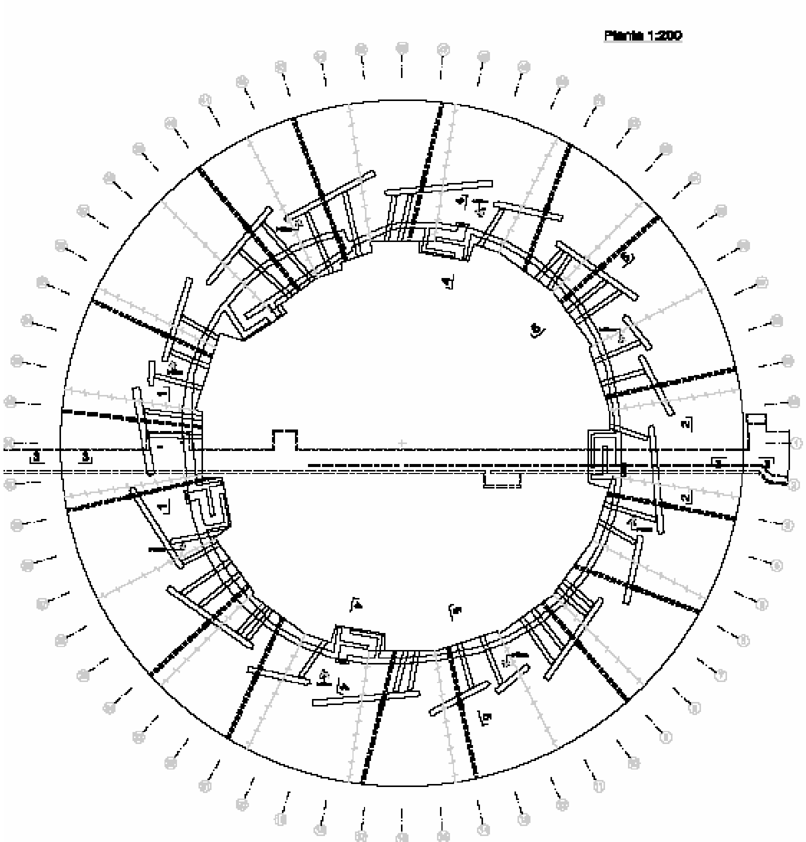


Fig. 3 Top view of the critical floor area with the walls of the ALBA tunnel and the sectors of the slab. The small external circles around the experimental hall indicate the positions of the pillars sustaining the whole building structure.

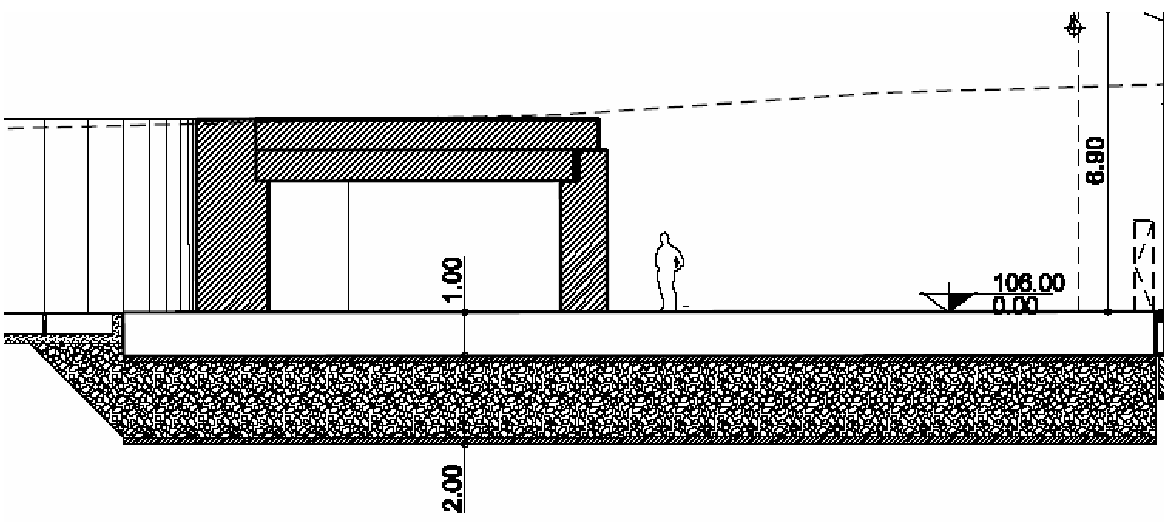


Fig. 4 Cross section of the solution for the critical floor area

COMPUTING AND CONTROL

Towards our own internet connection

ALBA is now directly connected to the Spanish Research Network with the help of the Centre de Supercomputació de Catalunya (CESCA). A large amount of work was involved in creating the necessary central services. We are now managing our own custom Linux based firewall (A Dell PowerEdge 750 with 6 independent gigabit Ethernet interfaces). The new ALBA mail system has been installed and is partly already in production, most notably the spam and the antivirus filtering. We are slowly moving towards public IP addresses while at the same time our network is growing and growing. All this work has been carried out with minimum disturbances.

New Electronics laboratory open for operation.

A new, 60 m^2 electronics laboratory was recently inaugurated (Fig. 5). The laboratory is used for testing and understanding many of the electronics and control systems necessary for the successful operation of the synchrotron and is equipped with four grounded and networked electronics cabinets, dedicated to timing, motor control, programmable logic controllers, and radio frequency projects. As well as providing a service to all the divisions, the laboratory serves as a prototype for future electronics workshops and beamlines at ALBA.

The laboratory is equipped with state-of-the-art instrumentation including an 8.5 GHz network analyzer, a 3 GHz storage oscilloscope, 100 MHz general purpose oscilloscopes, spectrum analyzer, wave form generators, surface mount soldering technology, printed circuit board production equipment and an increasing amount of stock items.

Fig. 5 The new electronics laboratory.

The Icepap collaboration signed and running

ALBA has signed a collaboration agreement with the ESRF to help in the development of the motion control system Icepap. ALBA is responsible for the low level configuration tools. A first version of these tools has been delivered to the ESRF. The collaboration is progressing very well and we will have a larger quantity of motion controllers available very early in 2007. The Icepap is a motion control system with unique features specially developed for synchrotron light sources in mind. It can currently control 2-phase stepper motors up to 8 A and 80 V with a maximum power of 330 W per motor. It can read out relative and soon absolute encoders. A multitude of synchronization lines are provided to coordinate the motion and detection in hardware in order to minimize dead time during experiments. Up to 128 of these axes can be controlled from a single master unit. This driver is expected to ease the operation of the beamlines, adding new motor scan possibilities.

A test unit has been used in the fixed stretched wire bench at the magnetic measurements laboratory and served together with other hardware and software developments carried out in the control section as a first test setup.

Machine Timing Project on its way

The timing system for ALBA will provide synchronization for the beam injection to the accelerator complex and for the diagnostics devices. After an evaluation process of different solutions, ALBA has decided to go for an event based timing system like Soleil and Diamond. The timing system has a resolution of 8ns, and jitter of 25 ps. The boards have both cPCI and PMC form factors. A first prototype was delivered at the end of November 2006 and Alba is developing the Linux drivers for these boards.

PSS system is ready for tender

The Personnel Safety System (PSS) provides safe conditions to operate both accelerators and beamlines. It will be implemented using safety PLCs compliant SIL3 (norm IEC-61508). It ensures that vaults are cleared of personnel during operation, and radiation levels outside the vaults are below a certain limit. It is fail-safe, and therefore guarantees that the beam is dumped if the system fails or any condition is lost or inconsistent. Commissioning of accelerators and beamlines need the PSS to be installed, tested and ready to be used.

ACCELERATORS

LINAC

The construction of the linear accelerator that will feed the Booster synchrotron is in progress. The design phase finished in July this year and the first factory acceptance test is foreseen in November 2007.

Vacuum

Vacuum chambers for the storage ring were awarded in September 2006. The first engineering review meeting took place on October and the end of engineering design phase is foreseen at the end of current year. In parallel, studies on the vacuum chamber deformations under vacuum have been carried out at ALBA, as well as the supports for Beam Position Monitors. With these ingredients, a whole storage ring cell has been modelled and deformations have been studied.

With respect to the Booster and transfer lines, the conceptual design of the vacuum chamber has been finished and the call for tender has been released in August. It is expected to end the Engineering phase in January 2007.

Girders

The decision to build a prototype of the long girder was made at the end of March 2006. The design has been already done and the contract for its production was signed in October. Manufacture will be finished at the end of February 2007 and then it is foreseen to be tested on March 2007. After the characterization of this girder, the estimated time for the series production (32 girders) is 12 months. Supports for Booster magnets (bracket type) are currently under study.

Alignment

Instrumentation is being procured in order to be ready for installation. At the site, 1 GPS baseline with 2 permanent stations has already been installed. This baseline will be the absolute reference for further alignment works. It has been determined by triangulation from 5 stations. Reference pillars have already been installed in the site. Next steps involve the recruitment of new personnel, installation and measurement of the alignment network and preparation of the tunnel for installation.

Laboratories

Some new, temporary laboratories have been implemented in the workshop building of the UAB University: detectors, metrology and alignment, electronics (Fig. 5), vacuum, insertion devices and magnetic measurements (Fig. 6 and 7), and RF (Fig. 8). The completion of these ancillary installations is foreseen for the first months of 2007.

Fig. 6 General view of the magnetic measurements laboratory at CELLS, showing the different measurement benches (from left to right): Helmholtz coils, Fixed stretched wire bench, Hall probe bench and Flipping coil bench. Helmholtz coils and Fixed Stretched wire are used for individual magnet characterization, whereas Hall probe and Flipping coil benches are mainly used for the measurement of larger magnetic structures (electromagnets or Insertion Devices*).*

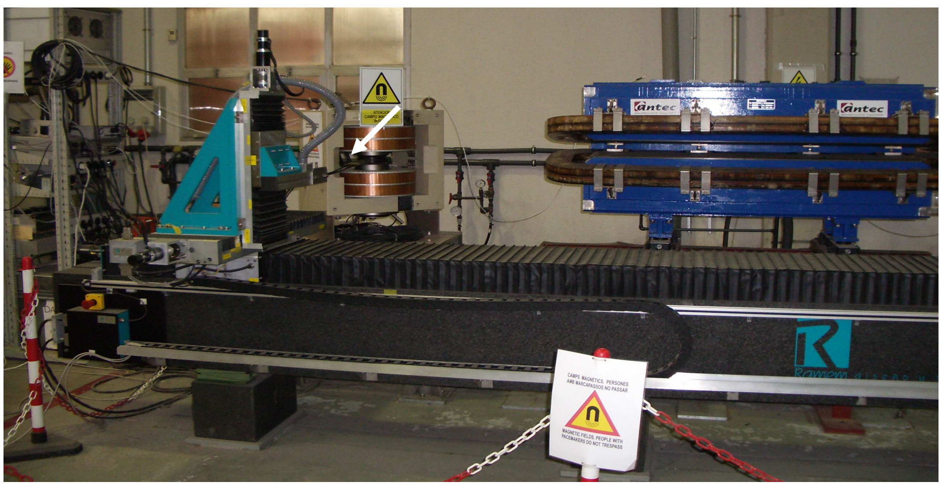


Fig. 7 The Hall probe, indicated with a white arrow, may be displaced along the x, y and z directions with an accuracy of ±50 μm. In the horizontal direction the linear span is 3 m which can be swept at 18 mm/s. Three perpendicular 1-D Hall sensors are housed at the end of an aluminium arm in to measure the 3-dimensional magnetic field components in small gap insertion devices (~5 mm) or in bending magnets. The measuring range is from -2 to 2 T with a resolution of $5x10^{-6}$ T, and a precision about $2x10^{-5}$ T, although the accuracy of the measurements strongly depends of the thermal stability of the probes, which may reach 0.01ºC. The small magnet visible in the back plane is a magnet having NMR probes which is used to calibrate the Hall sensors.

Electron beam dynamics

During the first half of 2006 the machine parameters have been frozen. The main parameters are given in Tables 1 and 2 below.

The main work concerning electron beam stability has been devoted to the study of aperture limitations induced by the beam lifetime. This is especially critical for the modellization of the effects of insertion devices on the stored beam. A number of studies have been done in collaboration with CLS and Elettra to cross-check the usual tracking codes and their suitability to simulate ALBA machine. Efforts have been addressed to model the gradient in the combined function dipole, especially for the off-momentum beam dynamics.

The beam lifetime mainly depends on the residual gas pressure, but also on the vertical aperture (gas elastic scattering lifetime), energy acceptance (gas inelastic scattering –bremsstrahlung–) and the bunch length and coupling (Touschek effect lifetime). Given an average residual gas pressure of $1.5 \cdot 10^{-9}$ mbar ALBA lattice provides lifetimes in the range of 15 to 20 h for gaps down to 5 mm (±2.5 mm) in the insertion devices without affecting the 3% of energy acceptance defined by RF, after correcting the orbit and coupling to nominal values.

Finally, the injection/extraction schemes into the Booster and the injection parameters into the Storage Ring have been calculated. Optics of the transfer lines have also been determined and frozen.

NAME	SYMBOL	UNIT	VALUE
Circumference	C	m	268.8
Energy	E	GeV	3
Horizontal Emittance	ε_x	nm·rad	4.3
Horizontal Tune	Q_x		18.178
Vertical Tune	Q_y		8.378
Natural Horizontal Chromaticity	C_x		-38
Natural Vertical Chromaticity	$C_{[]}$		-27
Momentum Compaction Factor	α_p		8.8×10^{-4}
Energy Spread	$\Delta E / E$		1.05×10^{-3}
Revolution Frequency	f_0	MHz	1.115
Horizontal Damping Time	τ_x	ms	4.1
Vertical Dumping Time	τ_y	ms	5.3
Longitudinal Damping Time	τ_E	ms	3.1
Energy Loss per Turn	U_0	MeV	1.02

Table 1 ALBA machine parameters

Source point	β_x [m]	β_y [m]	D_x [cm]	σ_x[μm]	σ_y [μm]	σ'_x [μrad]	σ'_y [μrad]
Long Straight section	11.2	6.0	14.6	270	16	20	3
Medium Straight section	2.0	1.3	9	130	8	47	6
Short Straight section	8.7	5.1	23	310	15	22	3
Bending Magnet 1	0.4	24.8	4	55	33	105	1
Bending Magnet 2	0.5	23.2	2	42	32	94	1

Table 2 Values of the beta functions, horizontal dispersions and RMS dimensions of the electron beam at the different straight sections and bending magnet sections.

Magnets and power supplies

Bending magnets of the Storage Ring are currently being manufactured. The contract was signed in August 2006 and the start-up meeting was held in September. The main aspect to highlight on the design is that the iron yoke is divided in two parts. This facilitates the installation of the vacuum chamber. The first prototype magnet is foreseen to arrive at ALBA site in May 2007, and the last shipment of series magnets in February 2008.

Regarding the quadrupoles and sextupoles, the contract was awarded to Budker Institute of Nuclear Physics (Novosibirsk, Russia) and signed in June 2006. Some small changes have been introduced in the design and currently the final conceptual design is in process of being accepted. Figure 8 shows a metrology verification of the steel laminations that will be used in the quadrupole and sextupole magnets.

Fig. 8 Measurement in the Budker Institute in Novosibirsk of the thickness of one lamination of the ensemble that constitutes the yoke of a sextupole magnet. The sheet is 0.5 mm thick and here it is sandwiched between two thicker plates for the measurement. The Budker Institute has to provide 260000 similar sheets which have geometrical linear tolerances of ±15 μm.

Concerning the magnets of the Booster, all of them have been tendered in April 2006, and the different offers submitted by a number of companies are now being evaluated. The magnets for the transfer line will be tendered before the end of the year. Relative to the pulsed magnets, the injection and extraction parameters have been refined. The injection bump is expected to be 10 mm in amplitude, and the septum magnet used for beam injection in the storage ring will be placed at 16 mm. So, the injected beam will be at 20 mm from nominal orbit of storage ring. Other decisions taken have been: the design of 3 septa will be kept similar to reduce design effort; the kickers of the storage ring will use ferrite with a ceramic chamber. Currently there are a number of on going studies in order to determine physical apertures at kicker and septum, absorber design, impedance, stray field, phase delay, pulse stability, tolerances to errors (specially critical for top-up injection). To procure these elements, it is foreseen to make a single call for tender in December 2006.

With respect to the power converters, a total of 330 current controlled power supplies will be used in the Storage ring and 80 more in the booster synchrotron. The technical specifications have been finished and tendering processes have already started (in June 2006 for Storage ring power converters and in November for Booster ring power supplies). The contract for the former has already been placed and the contract for the Booster sources is foreseen to be placed in Spring of next year.

Radio frequency and diagnostics

The radio frequency (RF) supplies to the electron beam the energy lost in synchrotron light. High power RF plants are made of six main parts: Transmitter (High Voltage power supply plus Inductive Output Tube), waveguide distribution systems, waveguide transitions to Coaxial and the so called DAMPY cavities. The construction of all parts is already in process. The kick-off meeting of the transmitter took place in October 2006, the first unit being expected to arrive at ALBA by May 2007. The waveguide systems, including the circulators, the dry loads and the standard waveguide lines, have already been tendered and awarded in October 2006. With respect to the waveguide transitions, some prototypes have been already built and have been delivered to DESY for testing. Low and high power tests have been done, and the performance fulfils the requirements.

With respect to the RF cavities, the contract to produce a 5 cells cavity was signed in April, and the design report was approved in September 2006. Delivery is scheduled for January 2007. In addition to that, the contract for procurement of 7 RF cavities for Storage ring was signed in April. Finally, the Cavity Combiner used to connect two cavities to the waveguides has been already built and it is being tested at the RF laboratory as may be seen in Fig. 9.

Concerning the low level RF control, there are two types under study, namely, digital and analog. The analog solution is cheap and provides a short group delay and a large bandwidth which can easily meet RF regulation demands. Nevertheless, an analog solution can suffer from a number of inherent errors including DC offsets, drifts and high noise level. As a result of these errors, its application is typically limited to ±0.5° of amplitude and phase stability. The digital option has the advantage of giving much more flexibility since substantial changes in the design are possible by changing the program without affecting the hardware. Stability, speed and dynamic range of the digital option are supposed to improve in few months. Decision on which type of low level RF control will be taken soon.

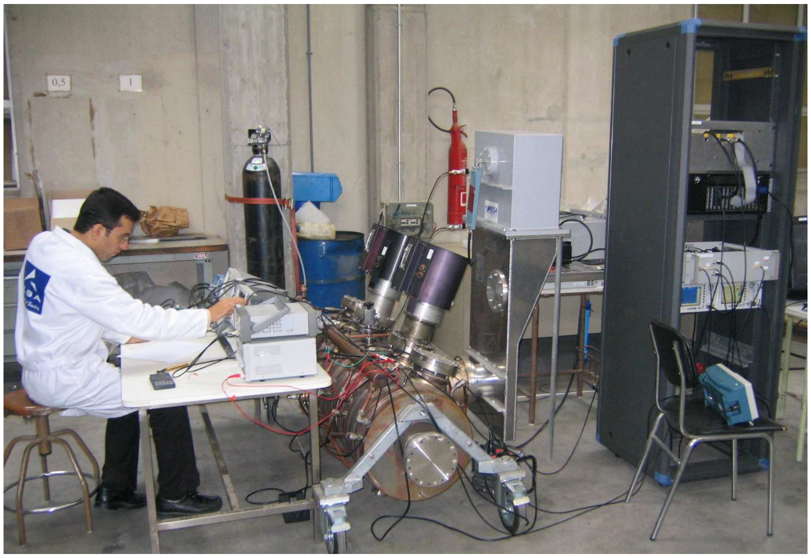


Fig. 9 Testing a RF cavity in the RF laboratory at ALBA.

Referring to the Diagnostics, it includes the following instrumentation: Fluorescent Screens to monitor the position of the electron beam during the commissioning phase, Fluorescent Screens / OTR, electron Beam Position Monitors, Striplines, Faraday Cups to measure the beam intensity, Fast Current Transformers to track the electron pulses circulating inside the storage ring, Beam Charge Monitors, DC Current Transformers, Annular Electrodes, Fast Feedback Kickers, Scrapers, Visible Synchrotron Radiation monitors and X-ray Synchrotron Radiation monitors.

These equipments are standard and based on the designs existing in other laboratories. The adaptation of the design is finished and components are being integrated in the engineering drawing of ALBA accelerators. Call for tender of the in-vacuum equipments is foreseen on November 2006. Front End for Visible Synchrotron Light and X-Ray Synchrotron Light test beamline is finalized and will be included in the general front end tendering process.

Finally, the timing system has been conceptually defined and in November 2006 it is expected to have a prototype in the laboratory in order to check its performance. It is important to note that beamlines will have access to this signal if synchronization is required.

Insertion devices and front ends

All the insertion devices feeding the first phase beamlines have been defined according to the requirements of the beamline scientists and the future users.

The main characteristics of the selected insertion devices are given in Table 3. The technical specifications of Apple-II undulators, in-vacuum undulators and superconducting wiggler are being drafted and it is expected to have them ready for tendering at the end of the current year. During the last months, the conceptual design of the conventional wiggler to feed the XAS (X-Ray absorption spectroscopy) beamline has been finished and the drafting of technical specifications has started.

Regarding the front ends connecting the photon sources with the beamlines, a review meeting to discuss and validate the specifications of the proposed design took place at ALBA on October 2006. The conceptual design is finished and work is advancing in the design of the front end components.

IVU21	**Beamlines**	Non-crystalline diffraction Macromolecular Crystallography (XALOC)
	Specs	λ_u = 21 mm, L = 2 m, B_e = 0.8 T, K = 1.6
	Status	Conceptual magnetic design finished
EU71	**Beamlines**	Magnetic Dichroism
	Specs	λ_u = 71 mm, L = 1.7 m, B_e = 0.93 T, K = 6.2 (H polarization)
	Status	Technical specifications finished
EU62	**Beamlines**	Low energy spectroscopy + PEEM (CIRCE)
	Specs	λ_u = 62 mm, L = 1.5 m, B_e = 0.88 T, K = 5.1 (H polarization)
	Status	Technical specifications finished
SCW31	**Beamline**	High resolution powder diffraction
	Specs	λ_u = 31 mm, L = 1.7 m, B_o = 2.1 T, K = 6.08
	Status	Technical specifications finished
W80	**Beamline**	X-ray absorption spectroscopies
	Specs	λ_u = ~80 mm, L = 1 m, B_o = 1.73 T, K = 12.97
	Status	Technical specifications being drafted

Table 3 Summary of the characteristics of the insertion devices of Phase I beamlines.

BEAMLINES

Macromolecular Crystallography (XALOC)

Scientist in charge: Jordi Juanhuix

Introduction

The macromolecular crystallography beamline (XALOC) will be able to cope with the structural problems related to large biological complexes, which usually crystallize in large unit cells and relatively large crystals (~200 μm). At the same time, the more conventional work involving small crystals has to be ensured to satisfy the needs of the scientific users community. To this aim, a flexible optical design involving variable focusing optics, and 2 different modes of operation (beam vertically focused/unfocused) have been incorporated into the beamline design.

The beamline proposal and following discussions with experts and users lead to define the general requirements to be fulfilled by the beamline, shown in Table 4. The experimental station will include all the equipment needed to perform wavelength-selective and wavelength-independent experiments in an automated operation.

Source

The photon source of the XALOC beamline is an in-vacuum undulator, placed in the 5th medium straight section of the ALBA storage ring (table 5). The front-end accepts the beam in an angular aperture of 0.4×0.2 mrad^2 (H×V), transmitting 1.4 kW of power out of the 2.87 kW emitted by the undulator when the current of the storage ring is 400 mA. The angular aperture can be further reduced by the cooled white beam slits placed in the front-end. Analytical studies have shown that the power delivered by the undulator can be handled by state-of-the-art cooling systems in the different optical elements without damaging the optical performances

Source	In-vacuum PPM undulator
Optics	Si(111) monochromator + KB focusing system
Photon energy range	5 – 15 keV
Photon flux at sample	>10^{12} ph/s in 0.1×0.1 mm^2
Energy resolution	$\Delta E/E$ ~ 2 10^{-4}
Energy stability	± 0.1 eV for 3 hours
Beam size at sample (FWHM)	Adjustable 50-200 μm × 20-100 μm (H×V)
Beam divergence at sample (FWHM)	<0.5 mrad, < 0.2 mrad for large unit cells

Table 4 General requirements to the beamline.

Type of ID	Sm_5Co_{17} pure permanent magnet, in-vacuum undulator
Period	21.3 mm
Number of periods	92
Magnetic length	1986 mm
Deflection parameter (K)	1.6 (at minimum gap, 5.5 mm)
Photon source size (FWHM)	309 × 18 μm^2 (H×V)
Photon source divergence (FWHM)	112 × 28-22 μrad^2 (H×V)

Table 5 Undulator and photon source parameters

Optics

XALOC optical elements are a CVD-diamond vacuum window, a removable diamond filter, a channel-cut Si(111) monochromator and a pair of mirrors (Fig. 10). The implementation of an ancillary branch fed by the diamond filter operating also as a Laue monochromator is under discussion.

After the filtering, the beam is monochromated by a symmetric Si(111), channel-cut monochromator, with a narrow gap between crystals to reduce the variation of the vertical beam offset to less than 1 mm within the useful energy range. Further downstream, the monochromatic beam is focused onto the experimental set-up (either the sample, the detector, or at some point along the optical axis nearby) by a vertical focusing mirror (VFM) and a horizontal focusing mirror (HFM) in a Kirkpatrick-Baez (KB) configuration. The mirrors will be meridionally bent in an elliptical cylinder shape. The incidence angle of the beam onto the mirrors, which will be coated with Rh, is 4.1 mrad, leading to a high reflectivity in the energy range of interest while showing a cut-off just above 15 keV. The useful optical length of the mirrors is 300 mm and 600 mm for the VFM and the HFM, respectively, which allow collecting the whole beam vertically and one FWHM horizontally.

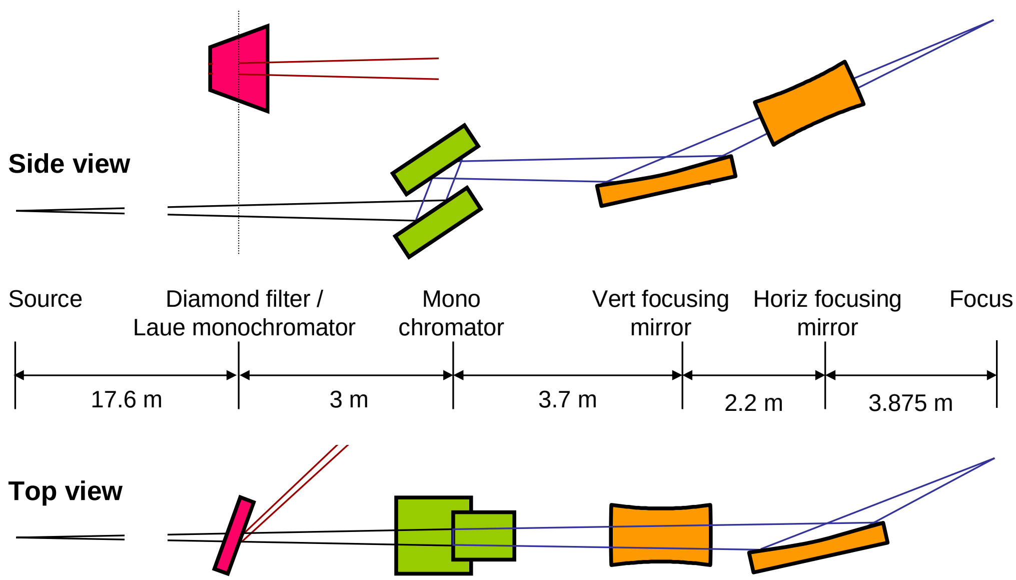


Fig. 10 Beamline lay-out.

Beam Characteristics

The focal spot size in the absence of slope errors size is 52×5 μm^2 (H×V) FWHM (Fig. 11) as determined by analytical and ray-tracing calculations. The beam size at sample can be further increased by placing the focal position away from the sample position. For example, if the focal position is set at the detector, which is assumed to have a diameter of 315 mm and placed 379 mm away from the sample (so that data at 2 Å resolution data at Se K edge can be collected), the resulting beam size at sample is 195×33 μm^2 FWHM. Note that the use of a KB system allows independent focusing conditions for the horizontal and vertical directions.

When focusing the beam out of the sample position, the long-period slope errors of the mirror surfaces may produce unhomogeneities in the beam profile at sample. Tight requirements have been specified for these slope errors to help reducing them. Even though, in case the vertical unhomogeneities (the most severe ones) affected the quality of data, the VFM could be removed from the beam path. The vertical beam size would then increase to 710 µm FWHM at the sample position while preserving the gaussian profile given by the source. In the case the VFM was removed, the beam would be adjusted using slits close to the sample.

The beam divergence at sample is about 0.57×0.09 mrad^2 (H×V) FWHM. It can be reduced by cutting the beam using the slits close to the focusing mirrors, at the expense of reducing proportionally the flux onto the sample.

The calculated flux at sample is above 3×10^{12} ph/s in the whole energy range (Fig. 12). The energy resolution, contributed by the vertical source divergence and the Darwin width of the crystal, is less than 2×10^{-4} in the 5-15 keV energy range, as agreed by both ray-tracing and analytical calculations. This energy resolution is fully compatible with Multiwavelength Anomalous Diffraction (MAD) experiments.

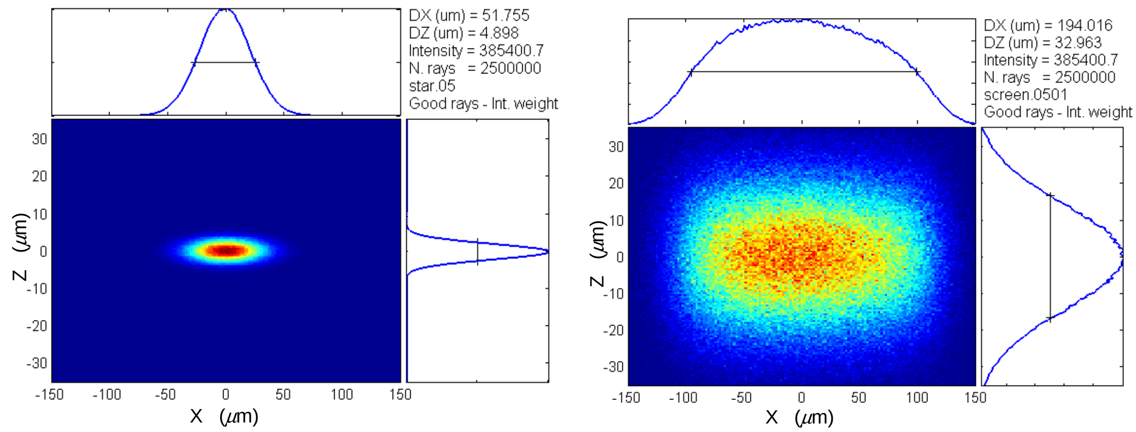


Fig. 11 Simulated beam spots at sample in two different conditions: (*left*) focused beam, (*right*) beam focused 379 mm after sample position.

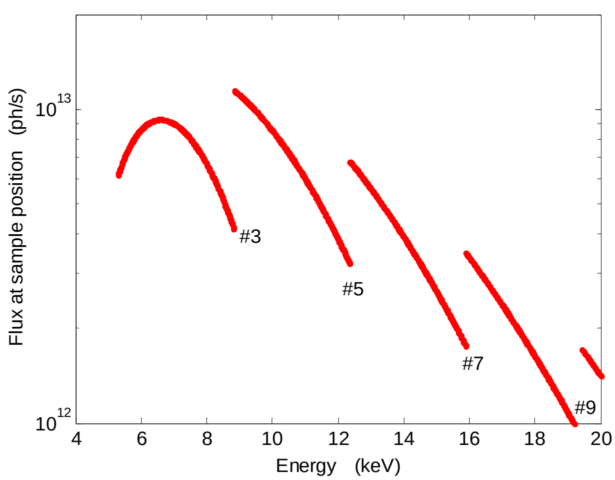


Fig. 12 Calculated flux at sample position assuming a current of 250 mA in the storage ring. Calculation takes into account filter transmission (300-µm thick, diamond), monochromator bandpass, and reflectivity and acceptance of the mirrors.

Non-Crystalline Diffraction (NCD)

Scientists in charge: Agneta Svensson and Igors Sics

Optics

The optical layout of the NCD station is defined and aims at delivering high photon flux onto the sample in the wavelength range 0.9 - 1.9 Å (6.5 – 13 keV) (Fig. 13). The first optical component is a Si(111) double crystal monochromator followed by a vertically collimating mirror and a toroidal focusing mirror with a 2:1 horizontal demagnification. It has been shown theoretically, and elsewhere in practice, that this configuration has minimal aberrations and results in a small focal spot with the approximate dimensions (RMS) σ_x = 65 µm by σ_y = 30 µm in the horizontal and vertical directions respectively. Focus is located around 42 m away from the source. This setup requires that the sample distance with respect to the detector that is positioned at 42 m from source, vary.

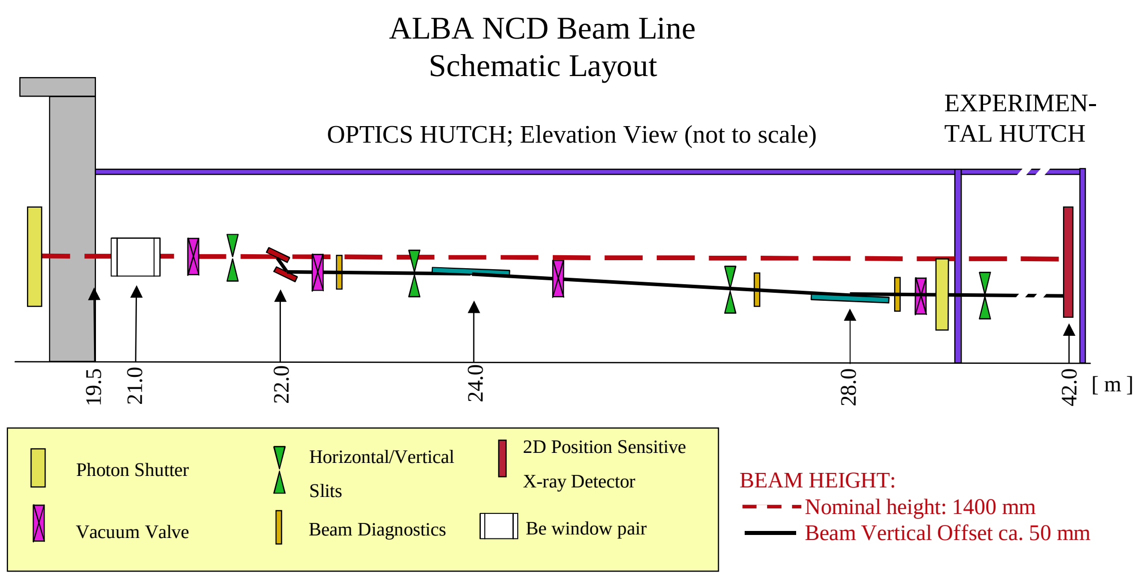


Fig. 13 Schematic layout the optical elements

Source

The beamline will use an in-vacuum undulator with a period of 21.3 mm as a photon source (Table 5). This ID will be inserted in the medium straight section 11 of the ALBA storage ring. From the calculated tuning curves (Fig. 14) one can see that 3^{rd}, 5^{th} and 7^{th} harmonics cover the needs of the user community.

Procurement

An engineering firm was contracted in July 2006 to carry out the technical specifications and engineering design for the NCD beamline. The engineering company will produce 'Call for Tender' documents and the expectation is that contracts for all components to be installed in the First Optical Enclosure will be signed throughout 2007.

End station

The detailed technical specifications for the Small-Angle-Scattering, SAXS, end station is currently under way and is expected to be ready before mid 2007. The station will be equipped with a fast area detector with high time resolution and a wide-angle x-ray scattering detector.

Microfocus

A micro-focus module will be introduced in the Experimental Hutch. The optics for this module will consist of a KB pair of horizontally and vertically focusing mirrors and a separate sample stage and will receive monochromatic photons for a fixed wavelength from the DCM located in the Optics Hutch. Hence, the station will operate in single mode, i.e. in SAXS or micro-focus mode. A detailed ray-tracing and technical specification is currently under way and is thought to be ready by spring 2007.

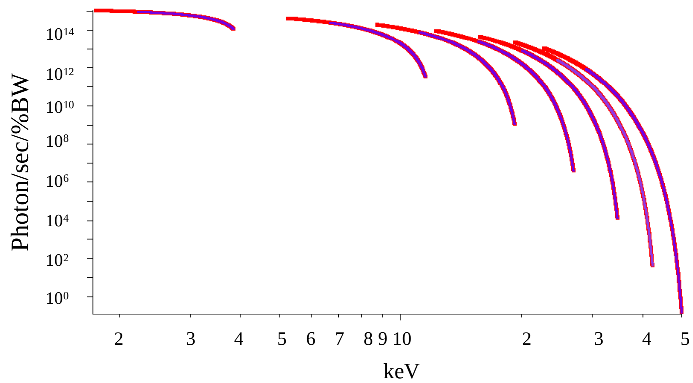


Fig. 14 Tuning curves for a IVU21 in-vacuum undulator starting at 5.5 (red line) and 7.0 mm (blue line) minimum gap normalized to a beam current of 100 mA in the storage ring. Tuning curves are calculated using SRW.

X-Ray Absorption Spectroscopy (XAS)

Scientist in charge: Konstantin Klementiev

Introduction

The XAS beamline will provide monochromatic beam in a wide energy range 2.4 – 65 keV. Besides the standard XAS measurements in transmission, fluorescence and total electron yield modes, some advanced experimental setups are under consideration: x-ray emission spectroscopy (XES) with a high-resolution secondary monochromator; x-ray magnetic circular dichroism (XMCD) with quarter-wave plates; a combination with wide/small angle x-ray scattering (WAXS/SAXS) or x-ray diffraction (XRD); micro-focusing down to sub-micrometer spot size with capillaries; quick-scans with a dedicated monochromator capable of producing a scan within a few milliseconds.

The sample infrastructure will include cryostats (liquid N_2 and He) and vacuum chambers for low-temperature/low-energy measurements; gas lines, exhausts, poison gas sensors and ample space for in-situ chemical/catalytical research. A XAS sample preparation room in close proximity to the beamline (glove box, pellet press, fume cupboards, analytical balance etc.) is planned.

Source

Photons will be generated by a wiggler. The wiggler and the beam aperture were optimized under the following constraints: (i) conventional (non-superconducting) technology, (ii) power absorbed by the monochromator below 700 W, (iii) power absorbed by the first mirror below 1 kW, (iv) ripple noise at lowest energy below 10 %. The resulting parameters for the wiggler and the flux at 100 mA storage ring current are shown in table 7.

Optics

Optical layout is shown in Fig. 15. The collimating mirror (CM) is a circular cylinder. It serves three functions: it (i) collimates the beam for better energy resolution, (ii) removes high-energy photons which would come through the monochromator as high harmonics and spoil EXAFS; (iii) absorbs heat power (up to 1kW) and thus reduces the power on the monochromator. The CM is water cooled and has three coatings for different energy ranges. To correct the thermal bump the CM needs a bender.

The double crystal monochromator (DCM) has two in-situ exchangeable crystal pairs, Si(111) and Si(311). Both crystal assemblies are cooled with liquid nitrogen to achieve Darwin width limited energy resolution at high heat load conditions.

Parameter	Value
total length	1 m
period	80 mm
num. of periods	12
minimum gap	12.5 mm
K_{max}	13
maximum field	1.74 T
critical energy	10.4 keV
total power	4.3 kW (@ 250 mA)
Power in 1.5h×0.25v $mrad^2$	1.3 kW (@ 250 mA)

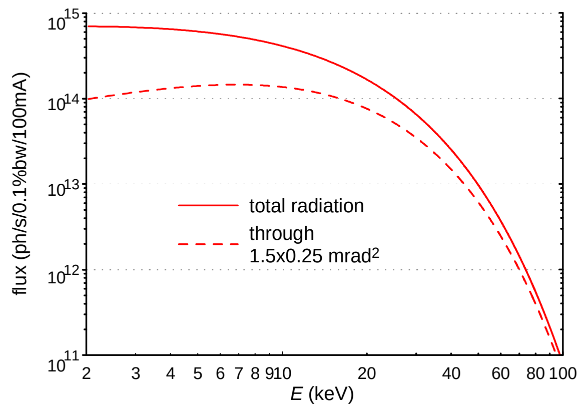


Table 7 Parameters of the wiggler feeding the XAS beamline. (*left*) Flux delivered by the wiggler at 100 mA storage ring current

The focusing mirror (FM) will probably be a single toroid coated by a Rh/Pt bilayer (Pt to have a high cut-off energy, Rh on top of Pt to mask the Pt *L* edges). The horizontal demagnification equals 2:1. The focus spot size at 2.4 – 18 keV is below 300×300 μm^2 (assuming 2.5 µrad fabrication slope error for CM and 2.5 µrad for FM and taking into account the finite element analysis results for CM at 1 kW absorbed power). The focus spot size at energies above 18 keV is 8h×0.4v mm^2. For meridional focusing at different pitch angles the FM needs a bender.

The expected photon flux at the sample (in ph/sec, at 100mA) is 10^{13} at 2–14 keV, 10^{12} at 18 keV, $2{\cdot}10^{11}$ at 30 keV, $2{\cdot}10^{10}$ at 50 keV.

Procurement

A call for tender for the procurement of the optical components will be published in January-February 2007.

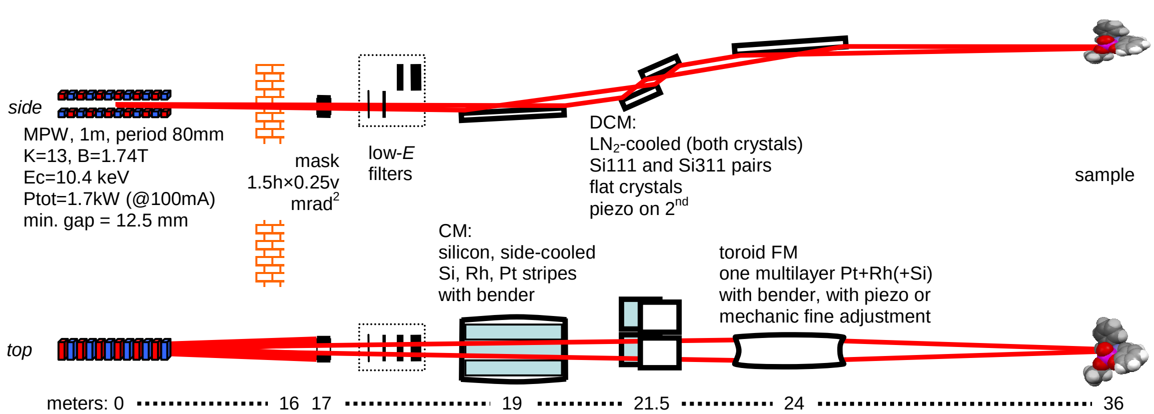


Fig. 15 Optical layout of the XAS beamline

High Resolution Powder Diffraction

Scientists in charge: Michael Knapp and Inma Peral

Introduction

The high resolution powder beamline will be devoted to five types of diffraction experiments i) high resolution powder diffraction, ii) time-resolved powder diffraction, iii) a high pressure station using diamond anvil cells (DACs), iv) single crystal diffraction in Kappa-geometry, and v) powder and single crystal diffraction under non-ambient conditions. The beamline will operate between 8 to 50 keV. This energy range covers very well the desirable range for almost any powder diffraction experiment, and at the same time it will be possible to perform both total scattering experiments, and high pressure diffraction with DACs; for which it is desirable and some times necessary to have high energy sources (E > 30 KeV). To accommodate the different experimental techniques there will be two experimental end stations, one devoted to powder diffraction and the second one to single crystal and high pressure experiments.

Source

A superconducting wiggler with short period length will serve as insertion device with a maximum critical energy of 12.5 keV and total emitted power of 19 kW. The wiggler will enable the beamline to operate within a wide range of energies, above 8 keV to 50 keV. The high heat load generated by the ID is handled either by an externally cooled mirror, a cryo-cooled monochromator and a reasonable choice of pyrographite filters. The variable K-value of the ID will be used to limit the power on the optics.

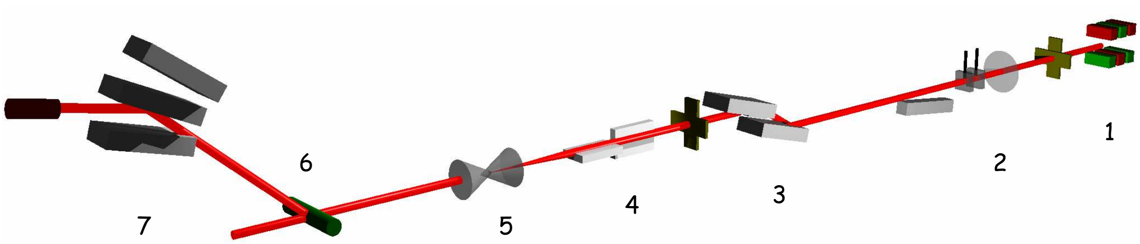


Fig. 16 Layout of the High Resolution Powder Diffraction beamline. 1: ID, 2: beam slits, filter, collimating mirror, 3: monochromator, 4: KB-mirror system, 5: DAC, 6: sample capillary, 7: Multianalyzer detector

Optics

The optics for the powder diffraction station (Fig. 16) includes a vertically collimating 1.2 m long mirror operated at 2mrad. It is coated with three stripes of different materials (Si, Rh, Pt) to adapt the reflectivity to the energy ranges. A two-crystal Bragg-monochromator that can be designed either as "Double-crystal" or as "Channel-cut" variant provides an energy resolution of typically $\Delta E/E = 2 \cdot 10^{-4}$ depending mainly on the choice of crystals (Si 111 and Si 311). The monochromator will be followed by a meridionally bendable cylinder-mirror. The mirror enables either focusing on the high pressure station (up to 27 keV) as well as partial horizontal collimation on the powder station up to 40 keV with only one mirror system. Expected flux is shown in figure 17.

Both the single crystal and the high-pressure stations need a beam diameter below 100 µm. Therefore, a KB-mirror system using multilayers is planned as an additional focusing optic for the high energy range located behind monochromator and second mirror.

End station

The technical specifications for the two experimental stations are in progress. One of the detector systems definitely to be installed is a multianalyzer detector consisting of one or two stages of 5 to 7 single counter/analyzer crystal combinations (Fig. 18). Fast area detectors like CCDs should be flexible enough to be used at both stations.

Procurement

A tender exercise for the procurement of the optical components of the beamline is currently being prepared; it is expected to be launched in January-February 2007.

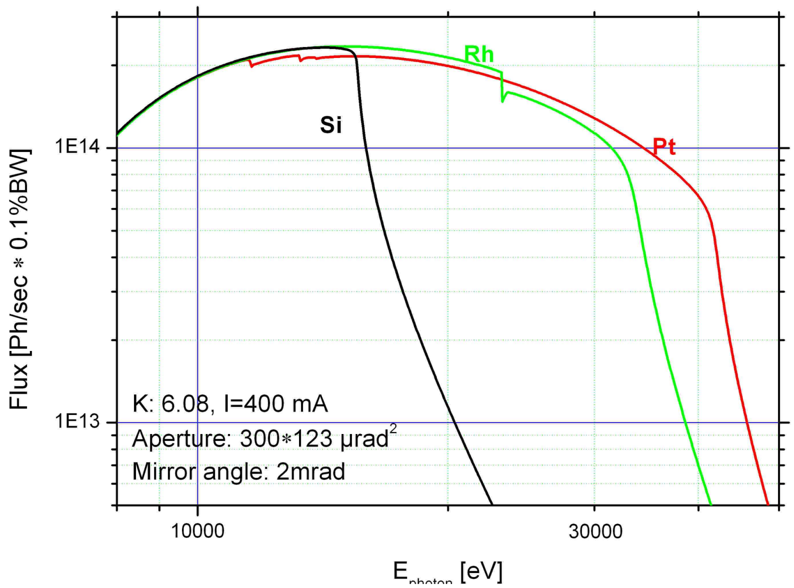


Fig. 17 Flux through 300x123 µrad aperture with 2x0.3 mm diamond window @K_{max}, I_{max}. The irradiated power of 1103 W is partly absorbed in the mirror: Si-coating (10 keV): 796 W, Rh (20keV): 332 W, Pt (40keV): 233 W.

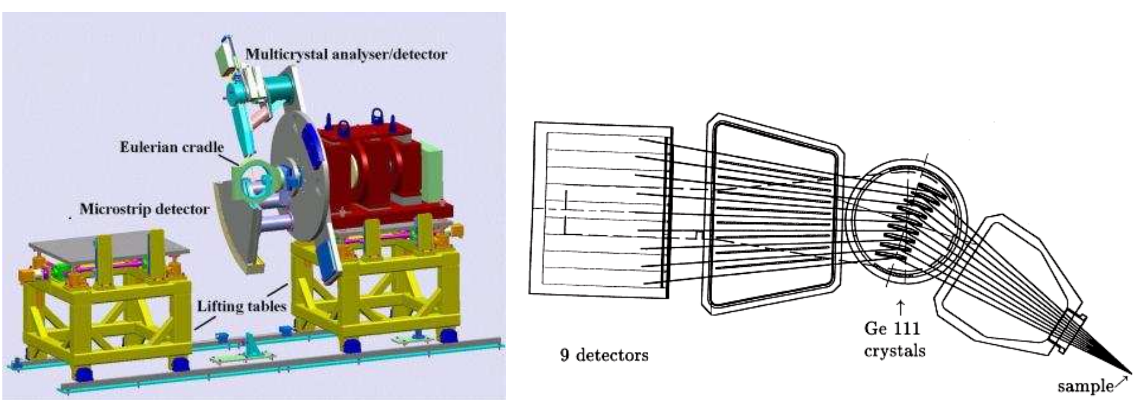


Fig. 18 (*Left*) multianalyzer detector for high resolution powder diffraction (Hodeau, SPIE Proc. 3448 (1998) 353) showing the same design planned for the ALBA beamline. (*Right*) SLS Diffractometer, it provides excellent resolution, and both flexible detector system and sample environment installation. A similar design will be implemented at ALBA.

Photoemission Spectro-microscopies (CIRCE)

Scientists in charge: Josep Nicolas, Lucia Aballe, Virginia Perez, Eric Pellegrin

Introduction

The CIRCE beamline will have the possibility of performing advanced photoemission experiments. It will have two branches feeding two separate instruments: a Photoemission Microscope (PEEM) and a Near Ambient Pressure Photoemission station (NAPP).

The PEEM instrument will allow to record photoemission images with a lateral resolution as good as 30 nm in the most favourable cases over a field of view of a few µm. The incidence of the photon beam will be rather grazing which will allow performing orientation dependent spectra performing NEXAFS while collecting the photoelectrons.

The energy resolution will allow to separate standard core level shifts from different chemical oxidation states. As the polarization of the incoming radiation will be either circular or linear, dichroic experiments will be possible either in chiral adsorbed molecules or in magnetic domain imaging. Overall, the PEEM microscope may be considered one of the most advanced instruments for characterizing heterogeneous samples down to the nanometric scale.

The NAPP instrument will be initially exclusively concentrated in near ambient photoemission although in a second stage X ray emission spectroscopy will be implemented. Near ambient photoemission is a new field with an enormous range of applications most of them still unexplored. To mention some, during surface chemical reactions in the mbar range it is possible to monitor by photoemission both the gas phase molecules and the adsorbed molecules. Photoemission from liquid surfaces or liquid electrolytes will allow determining the surface concentration of dissolved atoms or ions under different experimental conditions.

Source

Photon beam will be generated by a helical undulator of pure permanent magnet technology generating a maximum electromagnetic power of almost 3 kW in horizontal polarization (Fig. 19). Figure 20 shows the calculated flux for circular, horizontal and vertical polarization.

Optics

The optical layout is based in a SX700 grating monochromator. Figure 21 depicts the main optical components.

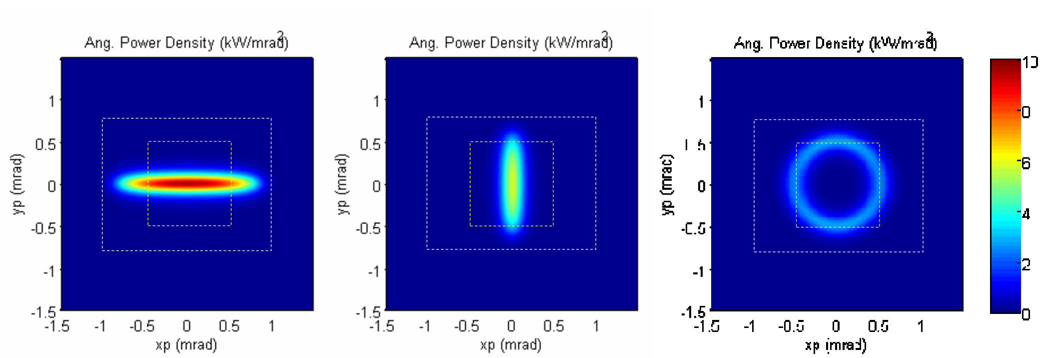


Fig. 19 Power distribution of the different polarization modes of the undulator (from left to right), horizontal, vertical and circular. Total integrated power in the horizontal mode is 3 kW.

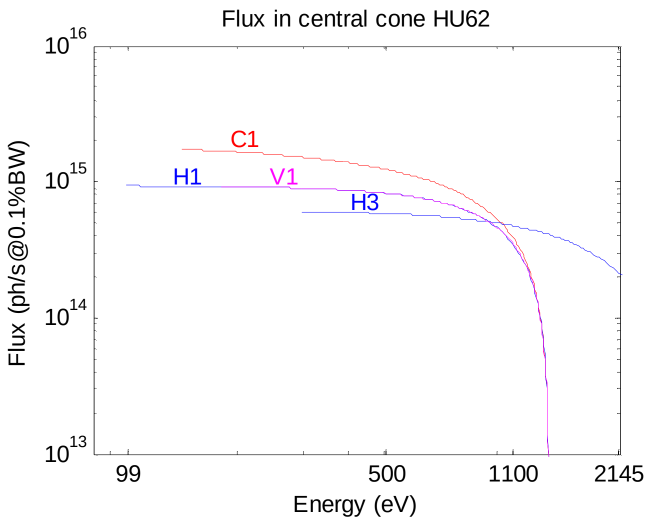


Fig. 20 Calculated flux per unit band width delivered by the helical undulator in circular polarization (C1), vertical polarization in the first harmonic V1 and horizontal polarization harmonics 1 and 3.

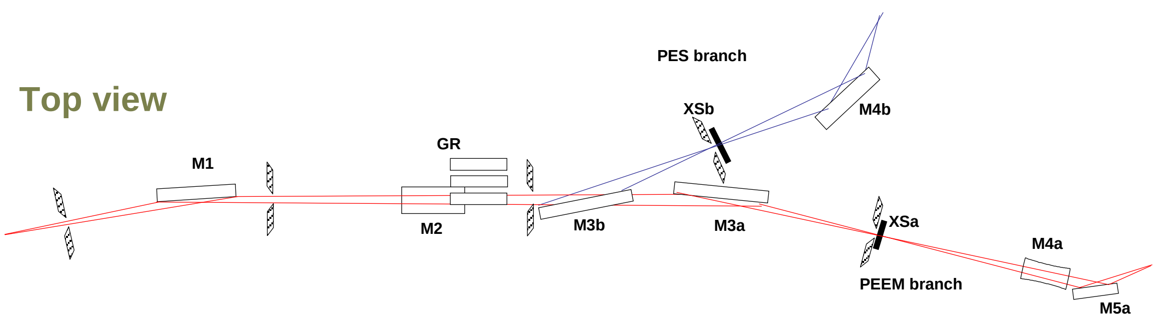


Fig. 21 Schematic optical layout of CIRCE.

Mirror M1 is a cylinder sagittally collimating in the vertical direction. It is water cooled. The light is then deflected by the plane mirror M2 and dispersed in energy by one of the three available gratings. The energy resolution of the monochromator E/ΔE will be around 5000 which is considered adequate for the experiments envisaged. The position of the exit slit selects the desired photon energy and the beam is further deflected and focused to one or the other end stations. In the NAPP station (blue branch) a toroidal mirror will be used whereas in the PEEM station the focusing will be achieved by a Kirkpatrick-Baez mirror pair.

The beam at the sample position for the NAPP station will have FWHM dimensions of 70 μm in the horizontal and 6-15 μm in the vertical direction. In the PEEM branch, the dimensions at the sample will be around 20 μm horizontal by 10 μm vertical

End stations

The general requirements of the PEEM and NAPP instruments are well defined. A detailed survey of the existing commercial PPEM instruments has been carried out. The detailed technical specs are in progress, and the call for tender is foreseen by Spring 2007.

Procurement

A tender exercise for the procurement of the optical components of the beamline was launched in July 2006. At present the offers received are being evaluated. The construction contracts are aimed to be signed early 2007 and the beamline optical components should be ready to be installed at the ALBA site by the end of 2008.

Soft X-Ray Variable Polarization Beamline

Scientists in charge: Franziskus Heigl, Alessandro Barla and Eric Pellegrin

Introduction

The soft x-ray variable polarisation beamline is dedicated to polarisation-dependent spectroscopies. It will be equipped with two end-stations: the first one will be dedicated to x-ray magnetic circular dichroism (XMCD) studies at low temperatures and high magnetic fields; the second one will host a UHV diffractometer to perform resonant soft x-ray scattering (RSXS) experiments.

Optics

The basic layout of the beamline (Fig. 22) foresees a helical undulator as source of polarised x-rays and a Monk-Gillieson type monochromator allowing one to cover the broad energy range 90-4000 eV, which includes the *L* absorption edges of the 3*d* and 4*d* transition metals, the *M* and *N* edges of the lanthanides and of U and the *K* edges of C, N, O, F, S. Focusing optics will allow one to reduce the beam spot-size to ~150 x 10 μm^2 (H x V), while preserving the possibility of working with an unfocused beam (~1500 x 1500 μm^2) for all applications requiring low flux densities on the sample (e.g. organic materials).

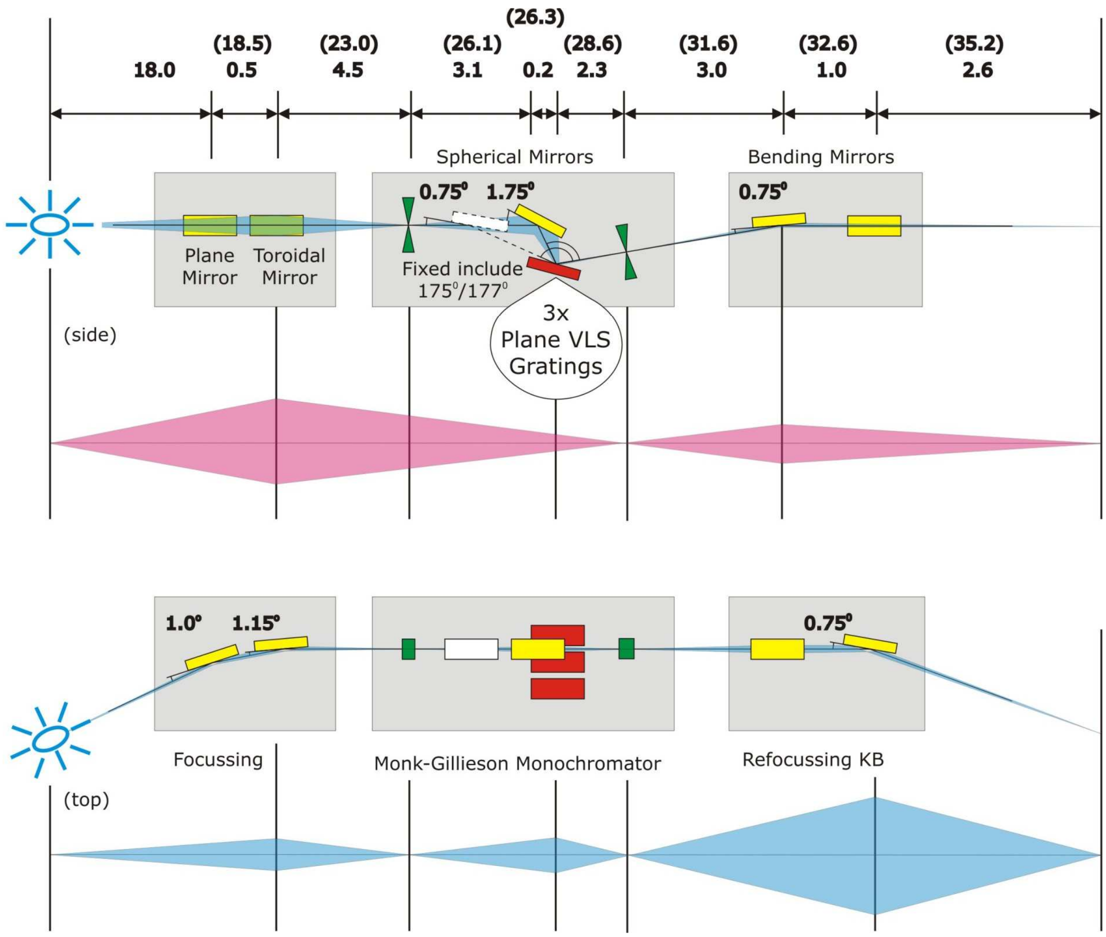


Fig. 22 Optical layout of the Soft X-Ray Variable Polarization beamline

RSXS end-station

Currently we are starting to define the characteristics of the RSXS end-station, taking into account the types of experiments which are currently and will in future be performed. The technique is extremely versatile and covers a broad range of applications: from small angle magnetic scattering to study magnetic domains, and more in general the magnetic and structural properties of nano-objects, to wide angle diffraction on single crystals to study charge, orbital and magnetic ordering. Another field which will gain in importance in the future is that of coherent diffraction, which exploits the coherence of the x-ray beam for the direct (holography or "lensless imaging") or indirect (Fourier transform reconstruction from the reciprocal space) imaging of magnetic domains and other structural and magnetic ordering phenomena in solids.

The strong absorption of soft x-rays by air imposes the construction of a fully UHV (ultra-high-vacuum)-compatible diffractometer for RSXS experiments. Moreover, adding the capability of studying *in-situ* grown samples puts even further constraints to the base pressure of the experimental chamber, which should be below 10^{-10} mbar. This might in turn have consequences on the versatility of the diffractometer itself. Currently there exist (or are under construction) about 10-15 experimental set-ups dedicated to RSXS in the main synchrotrons around the world. They can roughly be classified into two different categories:

a) Reflectometer-type chambers: these allow for simple θ-2θ scans with all motors being generally installed outside the UHV chamber. Their main advantage (their simplicity) is also their main disadvantage: the limited number of elements inside the chamber allows for very low base pressures and for the easy integration of a low temperature cryostat or of an electromagnet, but the available geometries for experiments are limited.

b) Diffractometer-type chambers: they consist of a "complete" diffractometer installed in a large UHV chamber, with most motors being generally installed inside the chamber as well. The great flexibility makes it possible to perform a larger number of experiments as compared to the chambers of the first type, but the price to pay is usually a higher base pressure (usually in the 10^{-9} mbar range) and a more limited sample environment (in terms of low temperatures or magnetic fields).

For the soft x-ray variable polarisation beamline we plan to build a chamber resembling those of the reflectometer-type (i.e. compact, with all motors outside the vacuum and with base pressure in the 10^{-10} mbar range), but with enhanced capabilities for the diffraction experiments (e.g. we plan to have the possibility for an azimuthal rotation of the sample and an optional polarisation analysis set-up for the scattered radiation). Such a chamber should also be equipped with an electromagnet to apply fields in the range of 0.1 T and a low temperature insert and will therefore also be useful to perform XMCD experiments that do not require extremely high magnetic field but rather a precise control of the field in the region around 0.1 T.

X- Ray Microscopy Beamline

Scientists in charge: Eva Pereiro López and Malcolm Howells

Introduction

The X ray microscopy beamline will be a transmission X ray full-field microscope dedicated to image biological "thick" samples from 275 eV to 3000 eV at cryo-temperatures. The goal is to be able to record tomographic data sets in few minutes with 30 nm spatial resolution.

The wide range of energies will allow working in the water window as well as at higher energies. Between the C (284 eV) and the O (543 eV) absorption edges (the *water window*), the organic materials show strong absorption contrast while water layers up to 10 µm thick are reasonably transmissive.

Working at higher energies will give the possibility to reach several interesting edges for biological, environmental and materials applications as well as to image thicker biological samples by means of phase contrast (1.5-3 keV). Moreover, the focal length and depth of focus of zone plate lenses are considerably larger than in the water window. The former is important to allow space to rotate the sample while the latter ensures that the images are true projections of the object which greatly simplifies reconstructions. A very important feature of the optical design is the possibility of performing energy resolved images thanks to the monochromator placed before the microscope. This will allow performing chemical bond specific images by taking advantage of the significant chemical shifts of some important electronic levels such as the 1s shell in C.

Source

Synchrotron light will be delivered by a bending magnet which provides a source with an aspect ratio HxV of 2 to 1

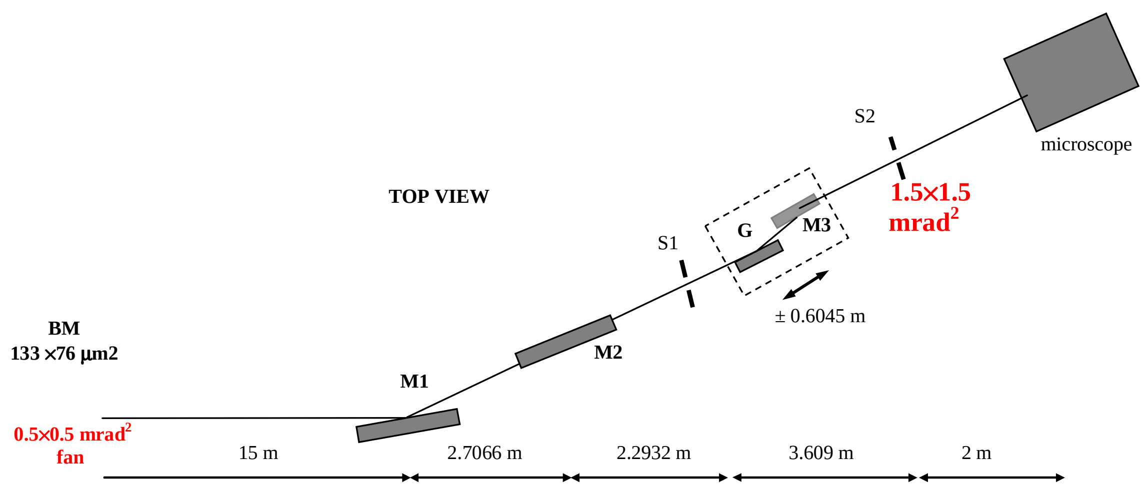


Fig. 23 Schematic optical layout of the X-ray microscopy beamline.

Optics

The optical layout is based on a Constant Length Spherical Grating Monochromator (CLSGM) that will deliver monochromatic light to an elliptical hollow glass capillary, which will, in turn, focus the light on to the sample. The transmitted signal will be collected by an objective zone plate and a magnified image will be delivered to a soft X ray CCD. Figure 23 shows the optical elements.

A 0.5×0.5 $mrad^2$ fan of radiation is extracted from the bending magnet and passes through the beamline front end and the shield wall into a small optics hutch containing two mirrors. The first mirror M1 of this Kirkpatrick Baez pair reflects in the horizontal plane and focuses light from the source on to the monochromator entrance slit S1. The 2^{nd} mirror M2 reflects in the vertical plane and focuses light from the source on to the monochromator exit slit S2. Both M1 and M2 have a magnification equal to 1/3.

A horizontal dispersive CLSGM provides monochromatic light delivered to the condenser capillary with a constant slit-to-slit magnification of unity. Four gratings as well as four capillaries will cover all the energy ranges. Optically speaking, all the ranges are equivalent and they all produce a 1.5×1.5 $mrad^2$ beam to illuminate the capillary condenser. To ensure maximum spatial resolution, each capillary will match the numerical aperture of the objective zone plate. Objective zone plates of outermost-zone width of 50 nm will be used. A spatial resolution of about 30 nm is expected. The working distances will vary with the energy ranges from 70 mm (1.5-3 keV) to 12 mm (water window). The geometrical focus size at the sample position will vary from 1.4×1.4 μm^2 for higher energies to 0.4×0.4 μm^2 for the lower ones. Therefore, the capillary will be wobbled to fill the sample with light (at least 10 µm of field of view is needed).

End-station

Discussions with the users are in progress to define the requirements of the cryo sample stage as well as the types of sample holder needed. A light microscope will be used for coarse sample positioning and a fluorescent microscope is under consideration.