LISA: the Italian CRG beamline for x-ray Absorption Spectroscopy at ESRF

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LISA: the Italian CRG beamline for x-ray Absorption Spectroscopy at ESRF

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Abstract. LISA is the acronym of **L**inea **I**taliana per la **S**pettroscopia di **A**ssorbimento di raggi X (Italian beamline for X-ray Absorption Spectroscopy) and is the upgrade of the former GILDA beamline installed on the BM08 bending magnet port of European Synchrotron Radiation Facility (ESRF). Within this contribution a full description of the project is provided.

1. Introduction

LISA is the name of the new beamline that will replace GILDA [1] at the BM08 bending magnet port of ESRF. The beamline will be dedicated to X-ray Absorption Spectroscopy and its main characteristics will be:

- high sensitivity for the analysis of diluted samples;
- high spectral and mechanical stability for the collection of low noise XAS data in transmission mode;
- use of grazing incidence/total reflection data collection in linear dichroic mode for surface analysis;
- data collection in differential mode;
- combined multitechnique *in situ* data collection for extreme conditions or *in operando* experiments.

Achieving these targets requires particular care about the quality of the beam spot in terms of homogeneity, spatial and energy stability, reduced size and divergence. To carry out the outlined research programs, the beamline has to fulfill several requirements. First, it has to cover a wide energy range (ex. $5 < E < 70$ KeV) to carry out structural analysis (using XAS at the K absorption edge) of technologically crucial materials like catalysts (containing Mo, Pd), hydrogen reservoirs (Nb, Pd), protonic conductors (In, Ba, Ce, Zr), solar cells and transparent conductors (In,Sn), luminescent and advanced magnetic materials (Rare Earths). Furthermore, it has to provide a beam with reduced divergence, in order to carry out experiments based on X-ray reflectivity, Grazing Incidence and linear dichroic mode. This will allow the structural analysis of thin films, interfaces or the interaction between adsorbed species and model surfaces, as needed for example in anisotropic magnetic materials or environmental science. The upgraded instrument has to provide an intense sub-mm beam in the whole energy range for studies under (moderate) extreme conditions of high temperature or pressure and for pump-probe experiments with electric field or light excitation. And, finally, the optics should be compatible with the new

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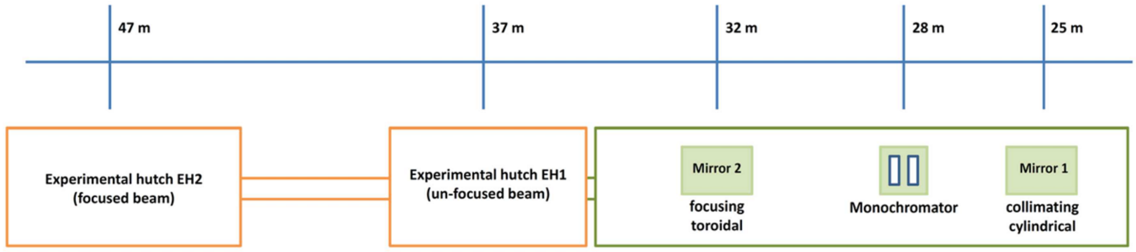


Figure 1. Sketch of the proposed beamline: the Optic Hutch (OH) contains all the main optical elements whereas the experiments are carried out in the Experimental Hutches EH2 (focused beam) and EH1 (unfocused beam). In the upper part of the picture the distance of the various elements from the source is indicated.

source that will be available after the upgrade of the ESRF ring that will consist in a 2 poles wiggler with a limited horizontal divergence (1.6 mrad) [2].

2. Technical design

2.1. Layout

The layout of the beamline is shown in Fig.1 and will consist in three cabins: an Optical Hutch (OH) and two Experimental Hutches (EH1 and EH2). The OH will contain the optical elements to monochromatize and focus the beam in the middle of the second experimental hutch EH2. Here, there will be the main experimental setup consisting in two sample stations mounted on a long granite bench. A first experimemtal hutch (Experimental Hutch 1, EH1) will be used for experiments with a non focused beam such as EXAFS in transmission mode.

The beamline optical scheme will consists in a collimating first mirror, a double crystal monochromator and a focusing second mirror. The beamline will use mirrors in the energy range 5-40 keV while above 40 keV the monochromator will be the only optical element.

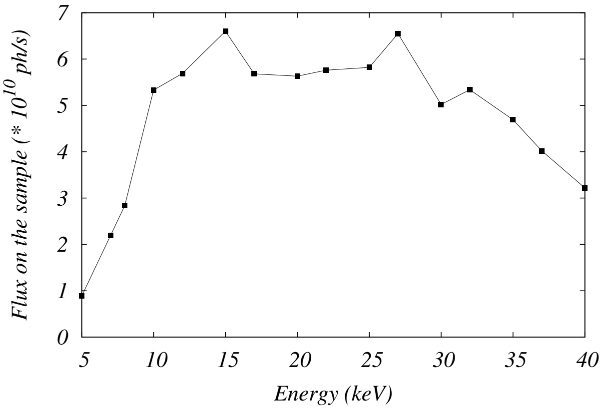
2.2. X-ray source

The beamline will be built on the high field part (0.85 T) of the BM8 bending magnet of ESRF. At this point the X-ray source has size $75\mu m$ (H) $\times$ $32\mu m$ (V) FWHM. The source is located at 25 m from the first optical element. The realization of the new lattice of ESRF [2] will lead to a two pole wiggler source with smaller size ($13 \times 4\mu m$) and an increased distance (+2.5 m) from the Front End. The design is such that it will be possible to cope with these changes and to exploit at maximum the foreseen new features.

2.3. Mirrors

The problem of beam focusing is a major issue for the present project. To meet the requirements stated in the scientific case it is necessary to have at the same time high brilliance, flux and beam homogeneity, conditions that are difficult to meet at the same time. Although proposed long agon in literature [3] only recently a considerable interest for toroidal mirrors has emerged driven by the achromaticity of these elements and the strong technical improvement of these devices emerged in the latest years. A mirror-based focusing scheme has been adopted for recently designed beamlines at APS [4], B18 at DIAMOND [5], the ROBL beamline at ESRF [6], the CLAESS beamline at ALBA [7]. This solution has been retained for the present project as it ensures at the same time a high intensity and homogeneous beam with a reduced size.

The first mirror will have a cylindrical shape and it will be used for collimating the beam to



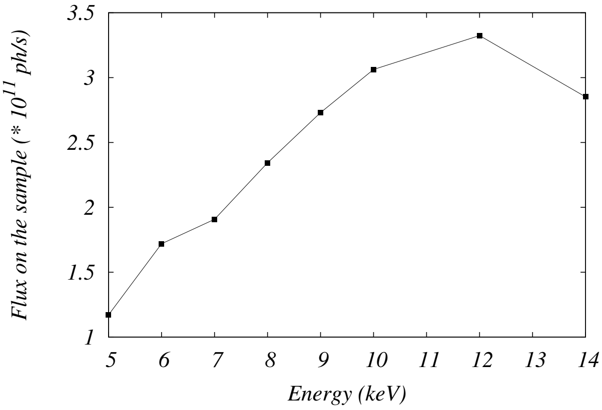


Figure 2. Flux foreseen on the focal spot in the case of two possible crystal planes for the monochromator: Si(311) left, Si(11), right. For the EH1 the flux will be about an order of magnitude lower due to the lack of focalization. The electron beam energy was fixed at 6 GeV and the current at 200mA. The input acceptance was 1mrad hor. and 43 μrad vert. On the focal spot the beam size is calculated to be 103 μm hor. and 143 μm vert. FWHM and a divergence of 50 hor. $\times$ 4 vert. mdeg.

achieve an instrumental energy resolution well below the core-hole width of the K edges in the energy range of interest. This mirror will have 2 stripes: Pt and Si in order to cover the whole energy range harmonic free. Si will cover the region 5-15 keV whereas Pt will cover 15-40 keV. The second mirror will have a toroidal shape and will focalize the beam in a 2:1 condition. It will consist in two cylindrical channels dug in a single bendable silicon substrate. This solution has been shown to minimize the impact of chromatic aberrations in the focal spot [4] and keep at a moderate value the overall length of the beamline. The part between the channels section of the second mirror will be left flat to make available to users a non focused beam. Both mirrors will work at 2 mrad incidence angle. A pair of Pt-coated plane mirrors (already present on the beamline) working at 10mrad will be used to reject harmonics in the lowest part of the energy range.

2.4. Monochromator
The monochromator will be a fixed-exit device with a single rotation axis and will use flat crystals cooled with liquid nitrogen. Two pairs of crystals will be mounted to access the whole energy range: Si(311) will cover the interval 5-40 keV ensuring high energy resolution, whereas Si(111) crystal will be used to obtain high flux in the region 5-15 keV. The crystals will be permanently mounted inside the monochromator and the change will be realized by simple horizontal translation of the instrument.

2.5. Ray Tracing
A detailed Ray-Tracing calculation of the parameters of the beamline has been carried out using the SHADOW code [8]. The new beamline is shown to provide a high photon flux ($10^{10} - 10^{11}$ ph/s) in a wide energy range and a small beam size in compliance with the experimental requirements cited in the previous sections (See Fig. 2). The constraint of having a source with a low horizontal divergence in the future limits the flux presently available but an increase of about a factor 2 is foreseen by calculations with the 2 pole wiggler parameters.

2.6. Endstations

The beamline will have two experimental hutches (EH) with the main hutch (EH2) be designed for applications requiring a focused beam. The setup will consist in a long granite bench carrying detectors (ion chambers and Ge multi-element fluorescence detectors) and two sample stations. The first experimental station will host a vacuum chamber containing two manipulators: one for standard XAS experiments in fluorescence mode and the other for ReflEXAFS experiments. The second block will be a versatile table with basic translation/rotation stages to be used to mount bulky experimental setups and for combined multi-technique experiments. The first experimental hutch EH1 will be designed for the collection of high quality XAS spectra in transmission mode with un-focused beam. The standard beamline sample environment will include a liquid helium/nitrogen cryostat, a cell for chemical gas-solid reactions and an oven for high temperature measurements up to 1500 K.

3. Conclusion

The design of the new Italian beamline at ESRF "LISA" has been presented. A description of the X-ray optics scheme as well as the layout of the experimental stations has been given. The full project is foreseen to be operative in about two years.

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