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DUAL BEAM VISUALIZER - INTENSITY MONITOR FOR LUCIA BEAMLINE AT SOLEIL SYNCHROTRON

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Abstract

LUCIA is a micro-focused beamline dedicated to X-ray fluorescence and X-ray absorption spectroscopy at SOLEIL Synchrotron. With its recent optical upgrade and photons flux increase, the three pink-beam diagnostics of the beamline have been upgraded to sustain a beam flux reaching 10^{13} ph/s and a power deposition of 20 W/mm². This paper presents the thermomechanical study and the realization of new diagnostic detector adapted to the current constraints of use, making possible to both visualize the shape of the pink beam and to measure its intensity simultaneously in the same compact device. The X-ray beam is visualized by a piece of Al_2O_3 - Cr ceramic, soldered to a copper heat sink, whose fluorescence image detected in visible light with a suitable camera and optical system. The measurement of the photonic intensity is made by a polarized CVD diamond used as a photosensitive element, the current reading is made by a suitable low noise current to voltage amplifier. The design of this dual beam visualizer and intensity monitor, made by the SOLEIL Detector group with thermomechanical studies done by the Mechanical Design Office, will be presented in details in this paper. In-lab measurements will be also presented.

INTRODUCTION

The LUCIA beamline [1] is dedicated to micro-X-ray Absorption Spectroscopy (µXAS) and micro-X-ray Fluorescence (µXRF) experiments in "tender" X rays range of energy 0.6 - 8 keV. The range of energy offered by LUCIA allows µXAS experiments at the K-edge of the elements from sodium (Na) to iron (Fe) and L-edges of nickel (Ni) to gadolinium (Gd) and to the M-edges of rare earths and actinides. It makes it possible to apply these two non-destructive techniques to the measurement of heterogeneous samples, to make elementary maps at the photon spot scale (2 µm × 2 µm), and to describe the local environment around these elements. In order to adjust the beam on the focusing and low-pass mirror, and on the monochromator, the beamline has several imagers and intensity monitor in pink beam. The monochromatic beam is finally sent on a sample placed on an x-z translation stage. (Fig. 1).

Typical imagers consist of a YAG scintillator screen placed perpendicular to the beam and a visible light camera oriented at 45 ° to the screen. The intensity monitors consist of AXUV100 diode in the direct beam. Both are motorized for insertion/extraction.

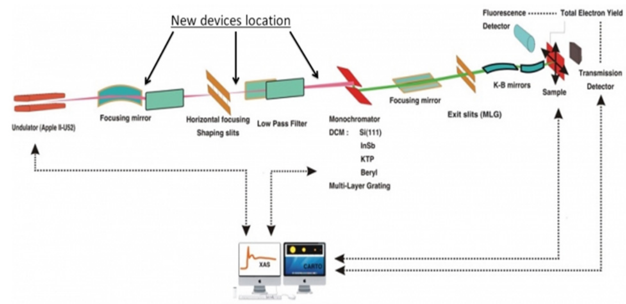

Figure 1: General layout of the Lucia Beamline.

TECHNICAL ISSUES

As a result of an upgrade of the first focusing mirror of the beamline, and a gradual increase in the intensity of the SOLEIL electron beam, the diagnostic elements of the line have undergone constraints exceeding their initial design limit. Degradations and alterations of their performance have appeared over time.

In addition, the orientation of the camera with respect to the scintillator screen requires closing the diaphragm of the camera to increase the depth of field. A long exposure time is necessary to compensate for the loss of light. This prevents detection of beam movement and creates latency during direct visualization of the beam for adjustment of optical alignments. This device had to overcome these limitations.

TECHNICAL SPECIFICATION

The new diagnostic devices must meet several functional needs:

- Image and monitor the X-ray beam;
- Totally extractable;
- Compatible with the pink beam properties;
- A incident power density of 20 W/mm²;
- A maximum beam size of 300 µm (H) × 1.2 mm (V).

The new diagnostics must also take into account technical constraints specific to the beamline:

- The imager and the intensity monitor must be designed on a single package (compact design), but will not be used simultaneously;
- They must be compatible with a level of 10^{-8} mbar vacuum;

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- The scintillator screen and the camera optics will have to be perpendicular to ensure completeness of the beam in the same focal plane.

MECHANICAL DESIGN

Soft X-Ray Pink Beam Imager

Due to radiation hardness, thermal constraints and beamline energy, a Al_2O_3 ceramic scintillator has been chosen for X-rays conversion to visible light (~ 650 nm). This ceramic of 1 mm thick (AF995R Durox from Solcera, Moissy-Cramayel, France) is brazed directly on the copper finger to ensure holding and effective cooling (Fig. 2). This scintillator plate is placed at 45° from the X-ray beam axis. A camera and its objective, located in air, record the scintillator visible image through a classical optical viewport. (Fig. 3).

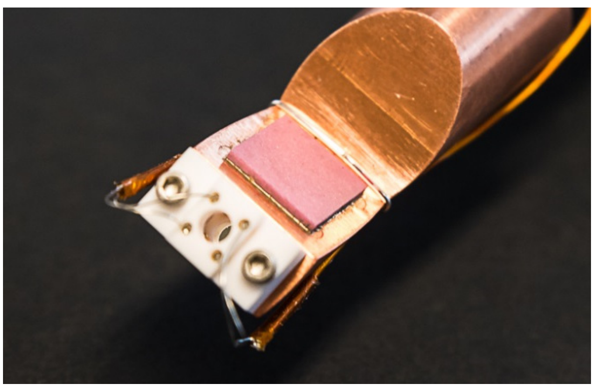

Figure 2: Brazed ceramic on copper finger.

In order to collect a maximum of light and to produce image with a good resolution, a lens with a large optic aperture is necessary. The ceramic scintillator screen is placed perpendicular to the optical axis. This allows us to use an objective with a larger resolution than the previous imager. An Edmund MMS R4 optics with an Obj-11 lens were chosen. The camera and its optics are located on the air side, and record the scintillator image through an optical quality viewport.

Camera is a *SOLEIL standard* Basler camera. Model acA1300-60gm with 1296 × 966 pixel resolution and with 3.75 × 3.75 µm² pixel size. These setup properties are given in table 1.

Table 1: Final Camera System Characteristics

Working distance	141 mm
Field of view	6.7 × 5.0 mm
Magnification	1.1
Image pixel size	4.8 µm
Resolution	36.0 lp/mm

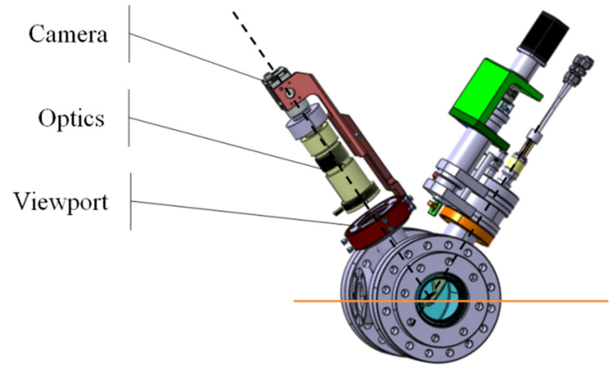

Figure 3: Camera and optics (modelized).

Soft X-Ray Pink Beam Monitor

As for the scintillator, the intensity monitor has to face with radiation hardness, thermal constraints and beamline energies. To record the X-ray beam intensity a high-purity single-crystal chemical-vapor-deposition (sc-CVD) diamond (from Element 6, Berkshire, UK) with a 50 µm thickness and a 200 nm Al deposit has been used as solid "ionization chamber" detector (Fig. 4).

Synchrotron beam tests have shown that for a wide range of photon energies from 0.2 up to 25 keV, the diode-like responsivity of diamond sensors is predictable, and efficient to provide absolute power measurements for sources of known energy bandwidth [2-3].

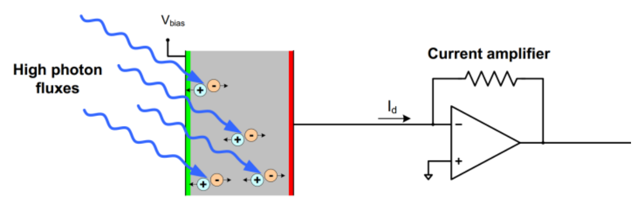

Figure 4: Photon conversion & readout principle.

The sc-CVD Diamond is glued to the same copper holder than the ceramic. It is positioned by centering pins and held in position by four Feinmetall pins made of gold-plated beryllium copper (HV compliant). These pins ensure contact with the Al electrode and allow the collection of charges created by the interaction of X-ray photons with diamond (Figs. 2 & 5). Four wires connect these pins to a UHV-BNC feedthrough where a low noise current to voltage amplifier located in air (FEMTO DDPCA300 low-current amplifier) allows recording the X-ray photocurrent generated.

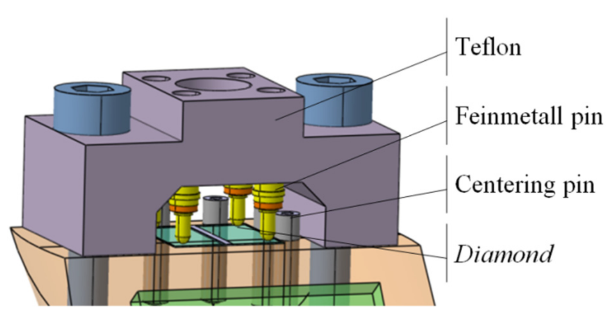

Figure 5: Diamond with holding system.

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Manipulator and Motorization

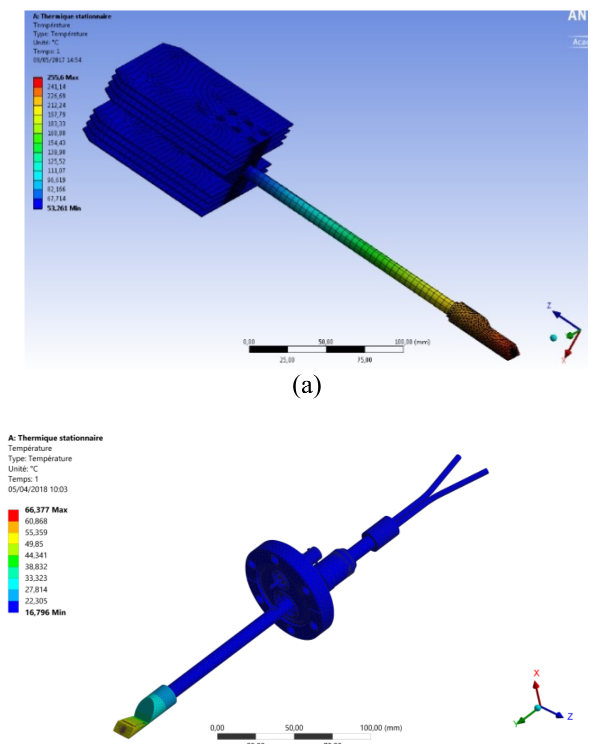
The manipulator allows insertion and extraction of the ceramic screen and diamond in the beam, on a single axis. It is a commercial part (ref ZLMT25) of Vacgen (St-Leonard-on-Sea, UK). Because of air/vacuum pressure difference, it requires a 1.2 N.m momentum for extraction.

It is motorized by a *SOLEIL compliant* stepper motor and a moto-reductor.

THERMAL STUDIES

A thermal study has determined the most efficient cooling system between air or water. It deals only with the diamond, as it is the most critical element in the system, because of its distance from the cold point of the copper rod, and its lower thermomechanical resistance. The study was based on a system modeled under ANSYS. The maximum power of the beam absorbed by the diamond (30 W) on a spot size of 300 µm × 1.2 mm (H × V) has been use for the simulation. The results with air cooling show a hot spot at a maximum temperature of 255° C as illustrated on Figure 6 (a). On the contrary, water cooling limits the hot spot to 66° C (see Figure 6 (b)).

As the maximum admissible temperature on sc-CVD is 100°C, water cooling is the only exploitable option.



(a)

(b)

Figure 6: Thermal simulation of cooling with air (a) and water cooling (b).

INSTALLATION ON BEAMLINE

The installation of three complete dual beam visualizer-intensity monitors was made with success in June 2018 on the beamline. First images were recorded by the camera to adjust the closing of the beamline front-end diaphragm as shown of Figure 7. Other tests are on-going.

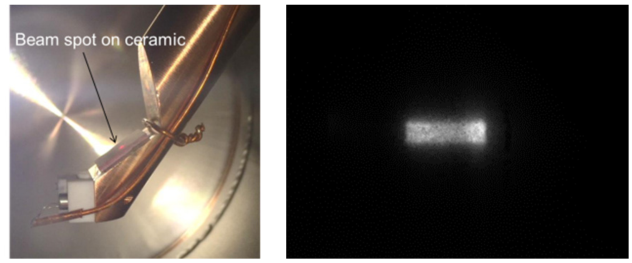


Figure 7: First beam image of LUCIA beam 653µm (H) x 206 µm (V) obtain with the new imager placed just before the monochromator.

CONCLUSION

A new concept of dual system (beam visualizer + intensity monitor) has been designed, realized and installed with success on the LUCIA beamline at SOLEIL synchrotron in June 2018. First tests of the new devices are very promising.

Nevertheless, some adjustment of the mechanics remains to be done as well as a characterization of the diamonds for the measurement of intensity.

This concept can be reused for now on other beamlines and especially for SOLEIL upgrade.

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