

# PHOTON BEAM IMAGER AT SOLEIL

M. Labat\*, J. Da Silva, N. Hubert, F. Lepage,  
Synchrotron SOLEIL - L'Orme des Merisiers, [91 191] Gif-sur-Yvette, France

## Abstract

In one of the long straight sections of SOLEIL is installed a pair of canted in-vacuum undulators for the ANATOMIX and NANOSCOPIUM beamlines. Since the upstream undulator radiation can potentially damage the downstream undulator magnets, an accurate survey of the respective alignment of the two devices is mandatory. An XBPM has been initially installed for this purpose in the beamline frontend. For redundancy and further analysis, an X-ray imager was then designed and added just downstream the XBPM. It is made of a diamond plate that can be inserted into the upstream beamline frontend at low current. We present the commissioning of this new device together with its first results in operation.

## INTRODUCTION

The SOLEIL synchrotron light source is now in operation since 2006 [1]. The storage ring consists of 16 cells, with 24 straight sections of variable lengths, for undulator insertion. In one of the long straight sections, the so-called SDL13, have been installed two horizontal canted undulators [2]. Both undulators are in-vacuum undulators with periods of 20 mm initially, and 18 mm since 2018. The upstream undulator delivers hard X-rays to the NANOSCOPIUM beamline, for nanoscale imaging experiments. The downstream undulator delivers hard X-rays too, to the ANATOMIX beamline dedicated to tomography experiments. The two beamlines are designed to be operated simultaneously.

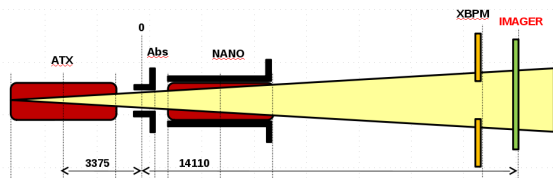


Figure 1: SDL13 (Long Straight Section in cell 13) layout. 0: middle of the straight section. ATX: ANATOMIX and NANO: NANOSCOPIUM undulators. Distances given in mm.

The horizontal canting angle in between the undulators is 6.5 mrad while both insertion devices are separated by about 7 m. Therefore, as illustrated in Fig. 1, the upstream undulator radiation passes through the downstream undulator before reaching the beamline. In nominal operation, both upstream and downstream undulator gaps are set at 5.5 mm, which is found of the order of the vertical aperture of the upstream undulator radiation inside the downstream undulator. In this initial layout, the upstream undulator can seriously damage the downstream undulator magnets.

\* marie.labat@synchrotron-soleil.fr

This is the reason why an absorber has been installed in 2016 in order to shadow the NANOSCOPIUM undulator magnets from the ANATOMIX undulator radiation. The schematic of this absorber, with respect to the electron and ANATOMIX photon beams is presented in Fig. 2. It is a piece of copper with an asymmetric 90 degrees U-shape. Its vertical aperture is 2.8 mm and its geometry was studied in detail in order not to jeopardize the performance of the storage ring in terms of collective effect induced instabilities, beam losses, injection efficiency and beam life time. It can be retracted when needed, thanks to a remote controlled pneumatic translation.

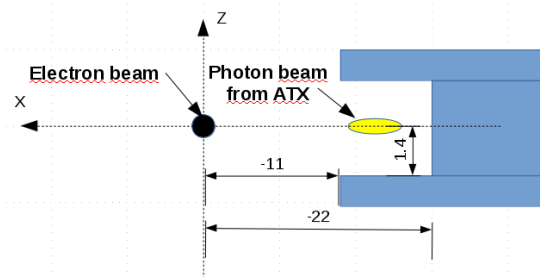


Figure 2: Schematic of the absorber installed in the middle of the SDL13.

If the upstream undulator, the absorber and the downstream undulator are properly aligned, the safety of all equipments is guaranteed. But any drift from the nominal setting (slab distortion, large temperature variations, human intervention, undulator offset adjustment, storage ring girders re-alignment, misteering of the beam, etc...) can have dramatic consequences. This is why a careful survey of the relative alignment of those three critical equipments is required.

At the first stage of this two canted-undulators project, a double XBPM was installed in the double beamline front end [3]. It enables the simultaneous measurement of the NANOSCOPIUM and ANATOMIX photon beam positions at the exit of the straight section. A couple of years later, it has been decided to give a redundancy to this diagnostic, using an X-ray imager. This paper presents the design, commissioning and operation of this imager.

## IMAGER DESIGN

### Specifications

The imager specifications were the following: (i) Image the ANATOMIX X-ray photon beam in the beamline frontend, (ii) Image the shadow created by the absorber on the ANATOMIX radiation pattern, (iii) Image the shadow (or its absence) created by the NANOSCOPIUM undulator on the

Content from this work may be used under the terms of the CC BY 3.0 licence (© 2018). Any distribution of this work must maintain attribution to the author(s), title of the work, publisher, and DOI.

ANATOMIX radiation pattern. The imager was not necessarily ment to be operated at full stored current, i.e. 500 mA, but could be used at low current during dedicated machine time.

### Imager Location

In order to operate the XBPM and the imager simultaneously, and therefore check their relative agreement on the alignment metrology, the imager had to be installed downstream the XBPM. It is indeed a destructive diagnostics. Given the all-ready built frontend geometric constraints, the imager was installed right behind the XBPM.

### Principle

The imager principle is the following. When an X-ray photon beam passes through a diamond disk, it hits diamond imperfections (Nitrogen) and consequently deposits energy. This energy is released via visible light emission by the material. Following, an imaging system simply images this visible light on a camera to retrieve the initial X-ray beam pattern. The imager then simply consists of a CVD diamond disk and of a visible imaging system.

### Simulations for Design Purposes

To refine the imager design, the SDL13 radiation content in the frontend was simulated under SRW [4]. The radiation pattern at the imager location is shown in Fig. 3. Two spots are visible: one resulting from NANOSCOPIUM undulator and one resulting from ANATOMIX undulator.

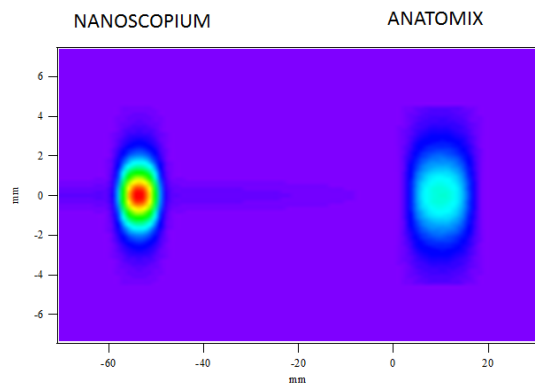
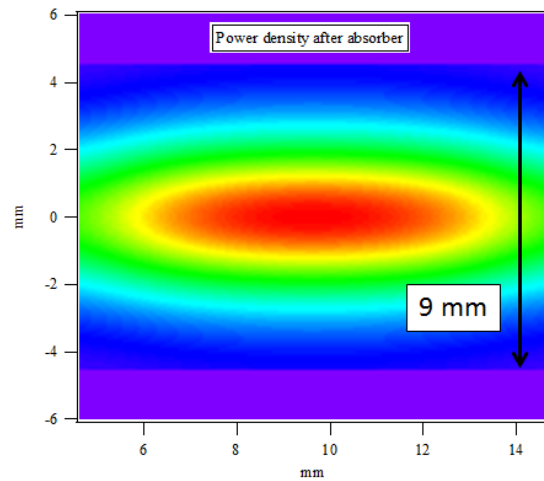
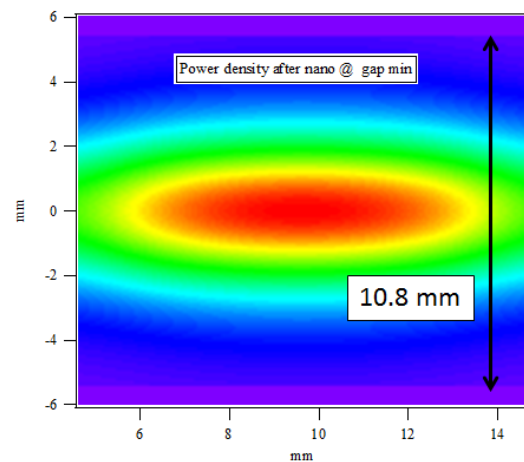


Figure 3: SDL13 undulators radiation pattern simulated with SRW at the imager location, i.e. 14110 mm downstream the straight section middle.

When the absorber is inserted in the middle of the straight section, it creates a shadow on the ANATOMIX radiation pattern which is shown in Fig. 4(a). The shadow starts at +/- 4.5 mm in the vertical plane (no shadow in the horizontal plane). When the NANOSCOPIUM gap is closed, it creates a shadow that starts at +/- 5.4 mm. Therefore, the imaging field of the imager should be at least larger than +/- 5.5 mm so that both shadowings can be imaged. Adding some margin, a minimum field of +/-7 mm was taken into account for the design.



(a) With absorber, without NANOSCOPIUM undulator.



(b) Without absorber, with NANOSCOPIUM undulator.

Figure 4: ANATOMIX radiation pattern simulated with SRW at the imager location (a) with the absorber inserted, (b) without absorber but with the NANOSCOPIUM undulator closed at 5.5 mm.

Looking at the ANATOMIX radiation pattern, the shadow corresponds to a step in intensity from the illuminated zone to the shadowed zone by 10 units for a maximum intensity at the radiation centroid of 120 (see Fig. 5). For an accurate measurement of this step location, the imaging system dynamic range should therefore be larger than 1000.

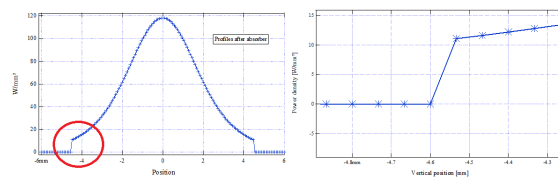


Figure 5: Vertical profile of the ANATOMIX radiation at the imager location. SRW simulation.

Additional thermal simulations were done to give the maximum current sustainable by the diamond: 20 mA.

## The Imager Components

A dedicated vacuum chamber was inserted in the beam-line frontend to house the imager vacuum components. It is installed right after the XBPM vacuum chamber. This vacuum chamber allows the insertion of a diamond disk on ANATOMIX radiation path, not on NANOSCOPIUM radiation path.

The diamond disk is made of CVD diamond and was realized by Diamond Materials. It is a 36 mm diameter disk, tilted by 40° degrees to allow its imaging from the outside of the vacuum chamber. It was brazed on a copper ring for heat evacuation with a meniscus for thermal dilatation under operation. A 30 microns silver coating was added to increase the thermal conductivity. A 3D picture of the diamond disk is shown in Fig. 6.

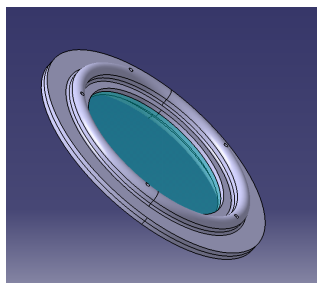


Figure 6: 3D view of the diamond disk brazed on its copper ring.

The diamond is water cooled. The water flows around the diamond disk inside the copper ring for an optimized heat exchange. The cooling system is shown in Fig. 7.

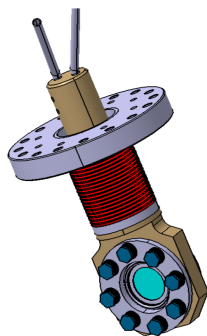


Figure 7: 3D view of the diamond cooling system.

The diamond mounted in its cooling system can be inserted/extracted remotely thanks to a pneumatic jack shown in Fig. 8. The insertion is achieved in the horizontal plane and for machine security reasons, it is by default extracted thanks to two springs.

Finally, the imaging system consists of a commercial objective (RICOH FL-BC7528-9M with a CVO extender 1.5X) and of a CMOS camera (ACE Series acA1920-50gm camera). The imaging is achieved through a lead glass viewport located on the top of the vacuum chamber. The imaging system together with the whole imager are shown in Fig. 9.

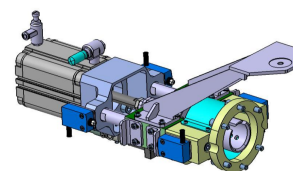


Figure 8: 3D view of the diamond insertion stage.

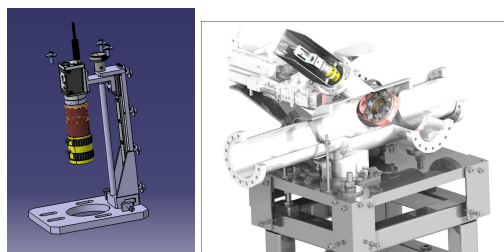


Figure 9: 3D view of the imaging system (left) and of the whole imager (right).

## IMAGER COMMISSIONING

The imager was installed in August 2017. A picture of the system installed is shown in Fig. 10.

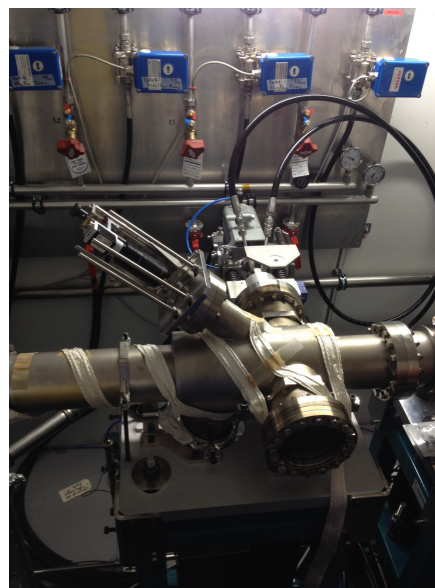
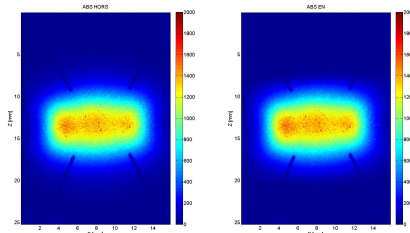


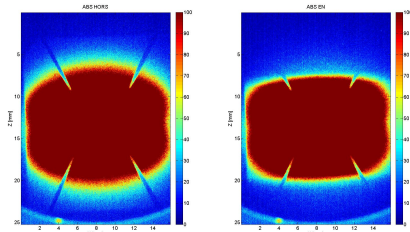
Figure 10: Picture of the imager installed on the SDL13 beamline frontend.

The first step of the commissioning consisted in centering in the horizontal and vertical directions the imaging system, to position the diamond center at the center of the camera sensor. This was achieved manually, using precision screws on the imaging system mechanics. The second step consisted in adjusting the focussing of the imaging system to reach the highest resolution. The diamond imperfections were used for that, manually adjusting the objective setting. The ANATOMIX pattern was successfully observed at the very first trial as shown in Fig. 11, and the photon flux was large enough already at 6 mA. However, it revealed that to visu-

alize the shadowing from NANOSCOPIUM undulator or from the absorber, it was necessary to saturate the centre of the image. We even sometimes add a numerical mask at the center of the image to help the metrology.



(a) Color max = 2000.



(b) Color max = 100.

Figure 11: ANATOMIX radiation patterns recorded with the imager with two different color scales. Left images are absorber extracted while right images are absorber inserted.

## IMAGER OPERATION

The imager is in operation since October 2017. It is used in routine to check several aspects of the SDL13. At the beginning of each week of operation, the imager and the XBPM measurements are recorded while closing the NANOSCOPIUM undulator gap to check that the signal is hardly decreased and therefore that NANOSCOPIUM undulator remains in the shadow of the absorber. Each time the absorber or the undulator are moved, and after each shutdown, both diagnostics measurements are also recorded versus the electron beam vertical position in the ANATOMIX undulator (making bumps in the undulator, see Fig. 12) and versus the NANOSCOPIUM undulator offset. Those three systematic measurements enable a reliable check of the relative alignment of the ANATOMIX undulator, the absorber and the NANOSCOPIUM undulator. Up to now, XBPM and

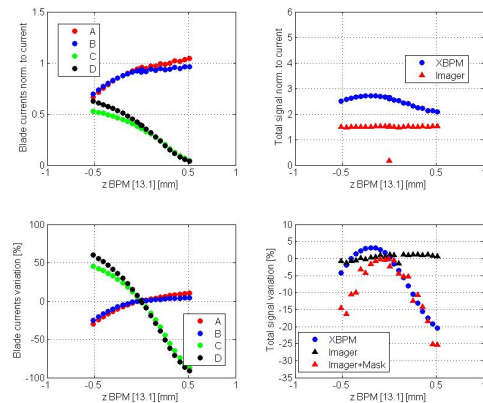


Figure 12: XBPM and imager records versus electron beam vertical position in the ANATOMIX undulator. Absorber is inserted and NANOSCOPIUM gap is opened.

imager measurements have been found in good agreement and helped solving misalignment issues.

## CONCLUSION

For the survey of the SDL13 alignment and consequent safety of its equipment, an imager has been designed, commissioned and installed in the beamline frontend. This imager provides with a redundant diagnostic with respect to the pre-existing double XBPM. The understanding of its images is sometimes more easy than the understanding of the XBPM position measurements, due to the presence of the absorber in between the two insertion devices.

## REFERENCES

- [1] L. S. Nadolski *et al.*, “Progress status for the 10 year old SOLEIL synchrotron radiation facility”, in *Proceedings of IPAC2017*, Copenhagen, Denmark, (2017).
- [2] L. S. Nadolski *et al.*, “Operating simultaneously two in-vacuum canted undulators in synchrotron SOLEIL”, in *Proceedings of IPAC2017*, Copenhagen, Denmark, 851-854 (2017).
- [3] N. Hubert *et al.*, “Design of a new blade type XBPM”, in *Proceedings of IBIC2014*, Monterey, CA, USA, 687-690 (2014).
- [4] O. Chubar, *Proceedings of SPIE - The International Society for Optical Engineering*. 9209. 920907. doi:10.1117/12.2062100