CONCEPTUAL DESIGN STUDY OF X-RAY MICROSCOPY BEAMLINE AT THE SAGA SYNCHROTRON LIGHT SOURCE

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Abstract

We conceptually designed the microscopy beamlines at the Saga 1.4-GeV Synchrotron Light Source (Saga SLS). At the Saga SLS two X-ray microscopes (XM-I, XM-II) are planned. The XM-I composes of a scanning transmission X-ray microscope (STXM) and a scanning photoemission microscope (SPEM) in the energy range from 280eV to 530eV (“water window”). The scan-spot will be 50nm diameter at the photon flux of about 10^9 photons/sec. On the contrary, the XM-II using synchrotron light from a 7.5-T wiggler is an imaging type microscope in the 1~6keV X-ray energy region with using a focusing optical element. The spatial resolution of the microscope is considered to be down to sub-100nm.

1 INTRODUCTION

The X-ray microscopy project is in progress at the Saga 1.4-GeV Synchrotron Light Source (Saga SLS) that is now under construction in Saga prefecture in Japan. The Saga SLS is a compact third-generation synchrotron light source that has six insertion devices (undulators, wigglers) and 20 front-ends in all [1]. A scanning type microscope (XM-I) in the energy range from 280eV to 530eV (“water window”) and an imaging type microscope (XM-II) in 1~6keV X-ray energy region are proposed in the microscopy project. In this paper we report the conceptual design of both microscopy beamlines.

2 WATER WINDOW MICROSCOPE

The scanning X-ray microscope generates the microscopic image of a sample by a raster-scanning in a focused X-ray beam. The synchrotron light (SL) from the insertion device is suitable for the microscope because of the low source emittance and the high brightness rather than the SL from a bend-magnet. In particular a partial coherent part of the undulator SL can be in principle focused into a diffraction-limited spot on the sample. Then, the scanning type microscope using the undulator SL has been increased and become a useful analytical tool for applications in biomedical, material and surface science [2]. The water window is most suitable for getting an absorption image of organic (carbon and nitrogen containing) materials because of its higher absorption than the water. Development of the scanning type microscope in the water window region has been mainly furthered in the Stony Brook (NSLS)[3], the ALS [4] and the BESSY[5]. Our proposed scanning microscopy beamline will be placed at the 33-m long beamline (BL-13) at the Saga SLS. Our optical system is similar to the principle adopted at the ALS. A photon source (undulator), the optical system and the end-stations are discussed in the following.

2.1 Undulator

In order to realize the diffraction-limited spot and cover the water window region in a first harmonics, we will adopt the 3.5cm-period undulator. Table 1 indicates the properties of the undulator. The undulator will be placed at the straight section (LS4) of the 1.4-GeV storage ring.

Table 1: Properties of the undulator

Type	Halbach
Period length	3.5 cm
Number of periods	72
Bo	0.58 T
K max	1.9
Energy range	190 ~ 532 eV(1st) 569 ~ 1600 eV (3rd) 948 ~ 2660 eV (5th)

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Figure 1 shows the calculated photon flux of the 3.5cm-period undulator according to the K-value range (0.1 ~ 1.9) in the first, a third and a fifth harmonics at the Saga SLS. The 3.5cm-undulator SL covers the energy range of 190 ~ 532 eV in the first harmonics. Moreover, the third and the fifth harmonics undulator SL cover up to 2keV X-ray energy. The maximum photon flux is ~10^{15} photons/sec.

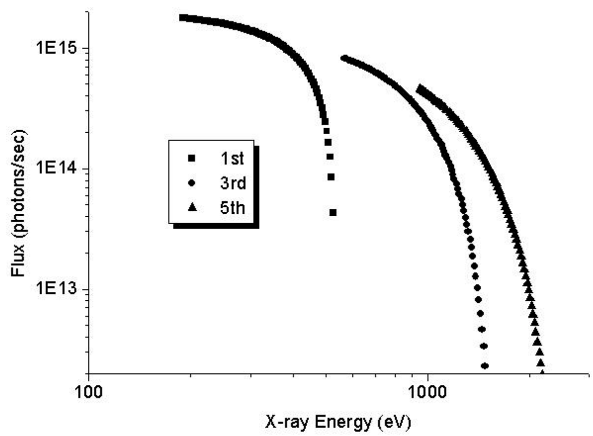

Figure 1: Photon flux of 3.5cm-period undulator (K=0.1~1.9).

2.2 Optical system

Figure 2 schematically indicates the whole layout of the soft X-ray microscope. The optical system of the microscope composes of a pre-mirror, a monochrometer, and end-stations. Our planned monochrometer has a plane grating that can achieve a monochromaticity as high as ~3000 (E/dE).

2.3 End-stations

A scanning transmission X-ray microscope (STXM) and a scanning photoemission microscope (SPEM) will be in series placed at the end of the BL-13 beamline. The end-stations have a similar optical configuration to one that has already opened for users at the ALS beamline 7.0.1[6]. The focusing optical element, an order selecting aperture (OSA) and a detector are set in the end-stations. We will use the Fresnel zone plate (FZP) as the focusing optical element. The outer most zone width of the FZP determines the spot size of the microscope. The 20nm outermost zone width of the FZP had been already developed [7,8]. When the storage ring is operated in a low emittance mode of 15nm-rad[1], the microscope focuses the soft X-ray down to a diameter of less than 50nm. The photon flux on the sample is estimated at over 10^9 photos/sec.

3 1 ~ 6KEV X-RAY MICROSCOPE

The proposed full-field imaging type microscope in the spectral range between 1 and 6keV X-ray generates a contrast image of thick specimen corresponding to the K-absorption edge of medium-light elements such as Na, Mg, P, S, K and Ca. Such an imaging type microscope was developed at the ESRF (ID-21)[9], while higher energy X-ray microscopes using the ID-SL has been progressed at the ESRF(ID-22)[10], the APS[11], and the SPring-8[12]. The microscope will be placed at one of three separate blanch-lines (BL-16) from a 7.5T super-conducting wiggler [1]. The incoherent SL is better than the coherent SL for the photon source of the image type microscope [13].

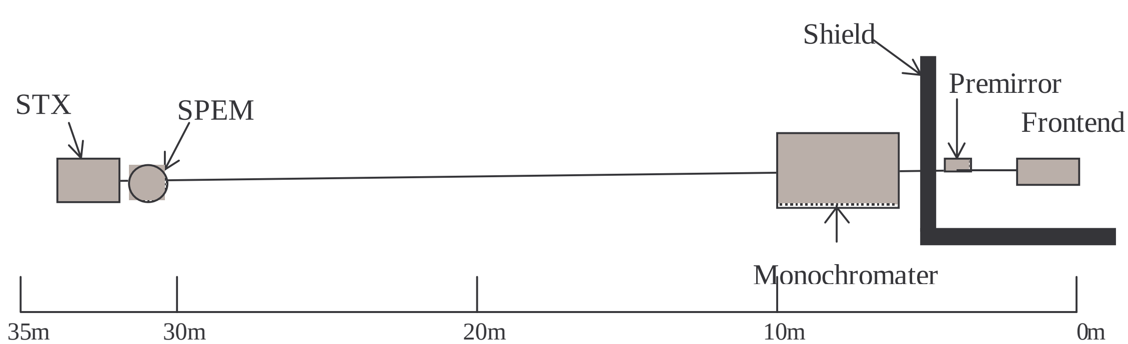

Figure 2: Schematics layout of the XM-I beamline.

Figure 3 shows the whole layout of the 1 ~ 6 keV X-ray beamline for the imaging type microscope schematically. The microscope composes of the 7.5T super-conducting wiggle, the pre-mirror, a double crystal monochrometer (DCM) and a transmission X-ray microscope (TXM). The brightness of the SL from the 7.5T super-conducting wiggle is over 10^{13} (photons/sec/mrad^2/0.1%BW) in the 1~6keV X-ray energy region. The spatial resolution of the microscope is expected to be down to sub-100nm using the FZP.

4 CONCLUSIONS

The conceptual design of two microscopes at the Saga SLS has been described. The scanning type microscope will be a rare facility in Asian countries. Moreover, the microscopic applications in the soft X-ray energy region will be developed in Asia, because the Saga SLS, which is located in the northern part of Kyushu-island in Japan, is very close to the Asian continental. On the contrary, the imaging type microscope has a potential to develop unique applications in the 1~6keV energy region which are relatively unexplored.

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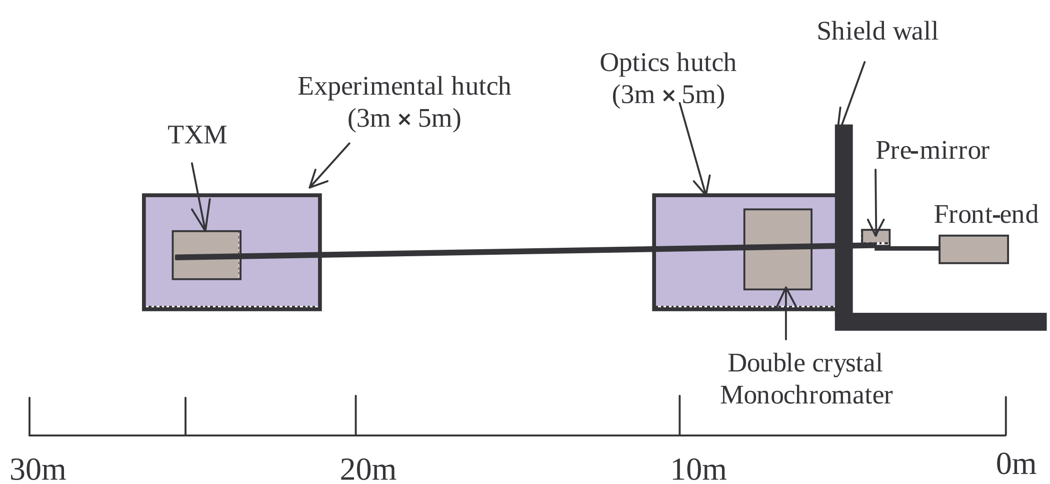

Figure 3: Schematics layout of the XM-II beamline.