A Fixed Angle Double Mirror Filter for Producing a Pink Undulator Beam at the APS.

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Introduction

Recent advances in X-ray Photon Correlation Spectroscopy (XPCS) use the full bandwidth of an undulator harmonic in order to maximize the coherent flux for small angle X-ray scattering experiments. X-ray mirrors and filters are typically used to select a given harmonic of the spectrum. At the University of Michigan/Howard University/Lucent Technologies Collaborative Access Team (MHATT-CAT) undulator beamline of the Advanced Photon Source, we have designed a fixed angle Double Mirror Filter that will provide a "Pink" Beam (i.e., 2-3 % bandwidth) for XPCS experiments. This device uses two small mirrors, which vertically reflect a small 0.1 mm x 0.1 mm white beam in a symmetric geometry (see Fig. 1,2). The doubly reflected beam propagates parallel to the incident white beam, but is offset vertically by 35 mm. Using the standard offset of the APS allows one to stop the white beam with a standard APS beam stop. We describe below our design considerations for this instrument. We also report the results of preliminary tests of the performance. The mirrors preserve the transverse coherence of the source and filter the undulator spectrum as expected.

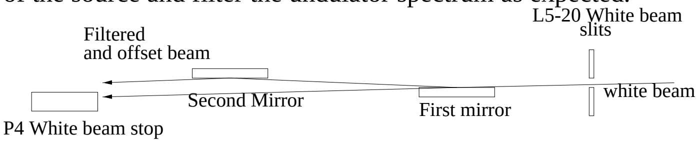

Figure 1. The double mirror filter geometry. The first mirror tank is placed just upstream of our monochromator (not shown).

Design Considerations

One typically produces a "pink beam" by tuning a mirror reflection angle so as to place the mirror cut-off energy just above the fundamental of the undulator. This places the mirror angle between 5-15 mrad. To remain consistent with the initial design of the beamline, we wanted to prevent articulation, and allow sufficient shielding from the white beam in the downstream experimental hutches. This is achieved by two symmetric vertical reflections at fixed angle with the standard APS monochromatic beam offset of 35 mm. There is room in our beamline to house mirrors before and after our cryogenically cooled double crystal Si monochromator (see Fig. 1) with a separation of 2 m. Both mirrors are housed in UHV vacuum tanks. The fixed offset and separation force us to work at a fixed angle of 8.75 mrad. A significant range of tunability can be achieved by providing multiple mirror coatings in the form of stripes. We purchased two Si flats each with Pt and Rh coatings. The maximum reflectivity of the two mirrors at the design angle is 61 and 54 % for Pt and Rh mirrors respectively. The Rh and Pt stripes extend the useful reflectivity up to 7.5 and 9 keV respectively and the tuning range of this set up is between 5.5 and 9 keV, consistent with the typical energy range used for XPCS. Within its operational range, the harmonic contamination i.e., the integrated flux 5 % above the fundamental energy, will range between 0.02 and 0.5 %. The coherent flux is shown in Fig. 2. Although the coherent flux is smaller with Rh at 5.5 keV, the beam is far less contaminated by second harmonics. The Rh strip is usable up to 7 keV.

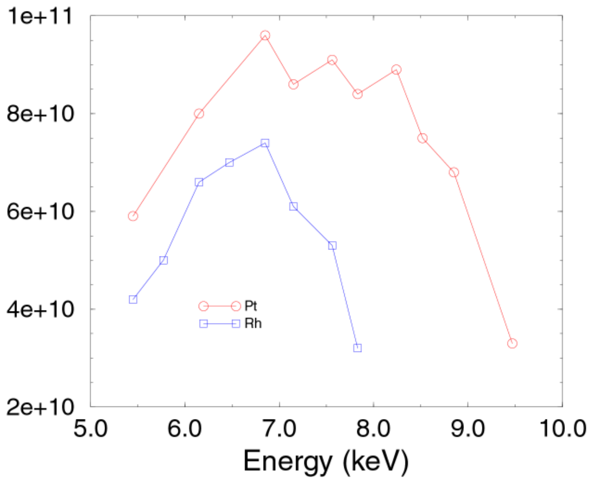

Figure 2 The predicted coherent flux for the Pt and Rh coatings.

In the field of XPCS, typical beam sizes are on the order of 5-10 μm, i.e. comparable to the beam horizontal transverse coherence length. To optimize our XPCS set up, it is critical that the optics preserve the source brightness and can endure the source power density. The maximum power density of our undulator at the lowest working energy of 5.5 keV is 145 W/mm^2. A small beam is required for XPCS, thus a white beam of 0.1 mm by 0.1 mm defined by a set of white beam slits (L5-20) will be ample. With a power of less than 1.45 W, the estimated temperature rise on the beam footprint will only be about 2 Celsius. The temperature rise is reduced substantially by the grazing incidence. Given the small power load on the mirrors, no direct cooling is planned.

Details on the Mirror tanks.

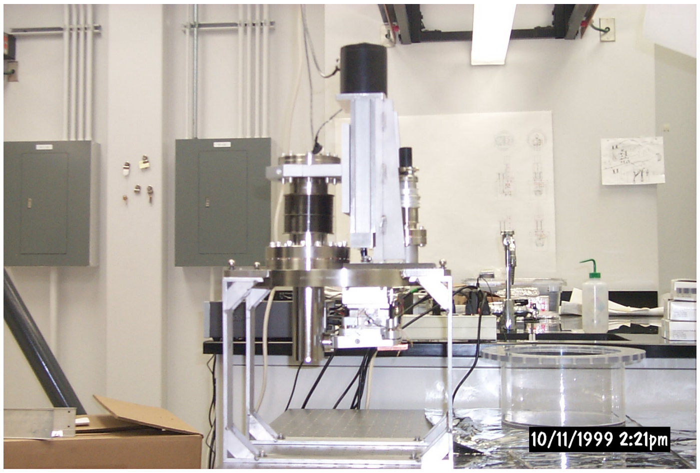
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Figure 3. Internal parts of the first mirror tank.

Each mirror is mounted on the top flange of a UHV tank (see Fig. 3). The flats have a figure error below approximately 0.86 μrad rms and roughness after coating below 1.8 Å. They are 25 mm wide by 50 mm long by 7 mm thick, and have a vertical acceptance of 0.44 mm at the working angle. The Si flats are mounted on kinematic mounts driven by three vacuum prepared Newfocus picomotors. The angular step size for this mount will be 0.3 µrad. By driving the three axes simultaneously, one can translate each mirror in and out of the beam by up to 13 mm. Angular and displacement feedback are essential when using picomotors. Tilt sensors with two tilt axes will record the absolute angular position, while one Linear Variable Differential Transducer (LVDT) will record the displacement when the three picomotors are used simultaneously. To allow for the selection of a given coating, the mirror kinematic mount is attached to a high precision slide, and driven by a picomotor with linear feedback provided by an additional LVDT. In each of the tanks, a YAG scintillator screen can be inserted to observe the main beam or reflection from the main beam. A stepper motor driven translation stage coupled to a bellow can insert the YAG and its optics in and out of the beam. The visible light fluorescence will be imaged using 1:1 optical collection focused on a TV camera. The optics is housed in a can, and is separated from the UHV environment by a Be window. This will be used for alignment purposes only.

Preliminary tests of the mirrors.

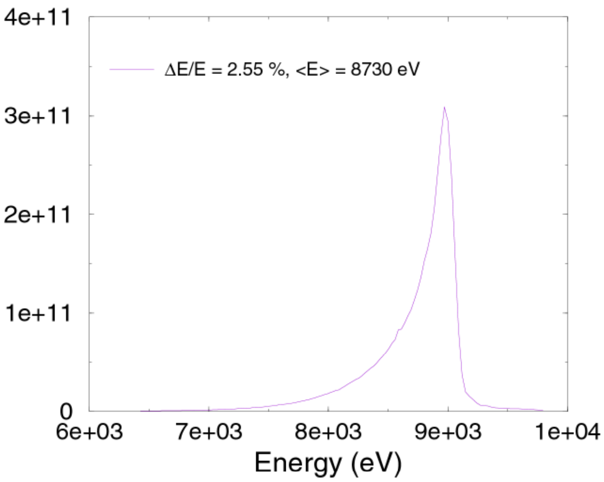

Figure 4. Measured energy spectrum of the pink beam.

Before installing the mirrors in the beamline, we performed some preliminary tests with the mirrors mounted on an optical table in 7ID-B. The two mirror angles were set to 0.45 degrees. A Ge (111) analyzer crystal was used to measure the X-ray bandwidth of the doubly reflected beam spectrum.
Fig. 4 shows the energy spectrum of the "pink beam" for an undulator energy of 9.0 keV. The FWHM of the peak is 2.55 % consistent with the FWHM of the fundamental. The bandpass is extremely sensitive to the position of the entrance aperture with respect to the center of the undulator beam.

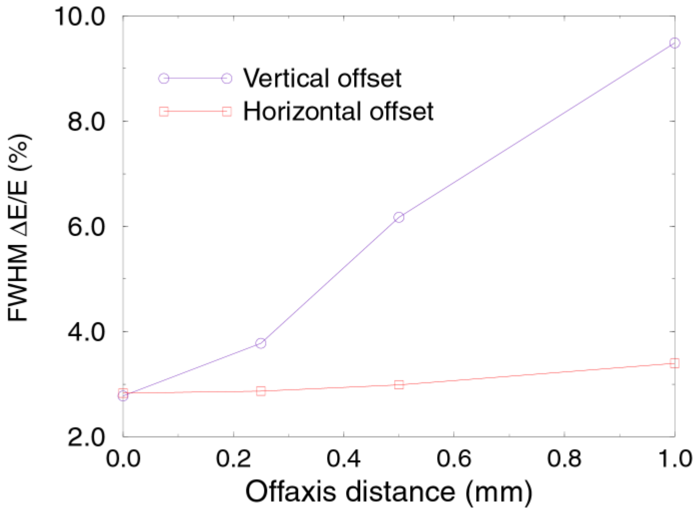

Figure 5. Effect of misaligning the white beam slits on the spectrum.

Fig. 5 shows the dependence of the bandwidth on the off-axis distance between the entrance slit and the undulator beam center. The effect is quite strong in the vertical direction. A misalignment of 0.25 mm in the vertical increases the bandwidth substantially.

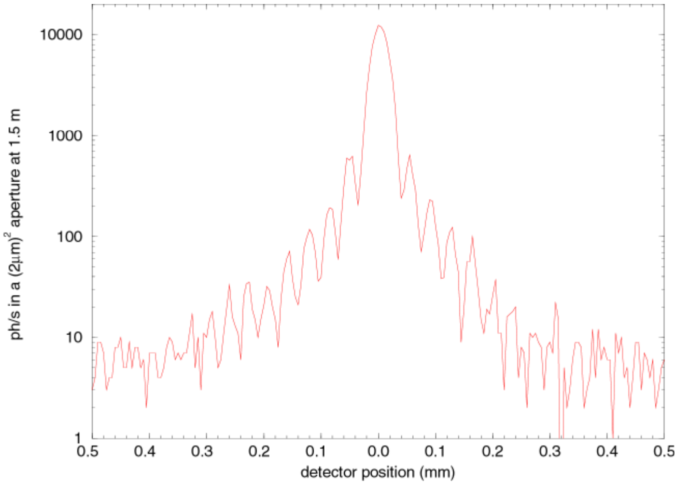

Figure 6. Vertical diffraction pattern of a 5 µm aperture.

Finally, we show that the quality of the mirror surface is sufficient to preserve the coherence of the beam. Fig. 6 shows the Fraunhofer diffraction pattern of a 5 µm by 5 µm aperture with 9 keV X-rays. Fringes with good visibility are observed in a vertical detector scan. Following these successful tests, we will install the mirror mounts in the beamline this year. This will allow for pink beam in all our experimental hutches.

Acknowledgments

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