

Beam Splitting Mirror for Advanced Photon Source Sector 34

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Abstract. The insertion device beamline at APS sector 34 is intended for tandem operation of two, high brilliance, experimental stations. Each station will require only a small fraction of the total cross-sectional area of the undulator beam, allowing both to operate simultaneously without compromise. A Coherent X-ray Diffraction (CXD) station will be supplied with pink beam from a horizontally reflecting, beam splitting mirror, while a Micro-Focus Diffraction (MFD) station will operate with white beam that passes beside the mirror. Use of a mirror as a beam splitter requires good thermal and mechanical stability from the mirror and its associated positioning system. The mirror substrate is liquid nitrogen cooled to minimize the thermal bump and increase its thermal conductivity. The principal motions of the mirror (2 translations, 2 rotations) are handled outside the chamber and passed into vacuum via two sets of bellows.

The 34-ID beamline of the Advanced Photon Source (APS) is intended to operate in a tandem configuration, simultaneously supplying two experimental stations with x-ray

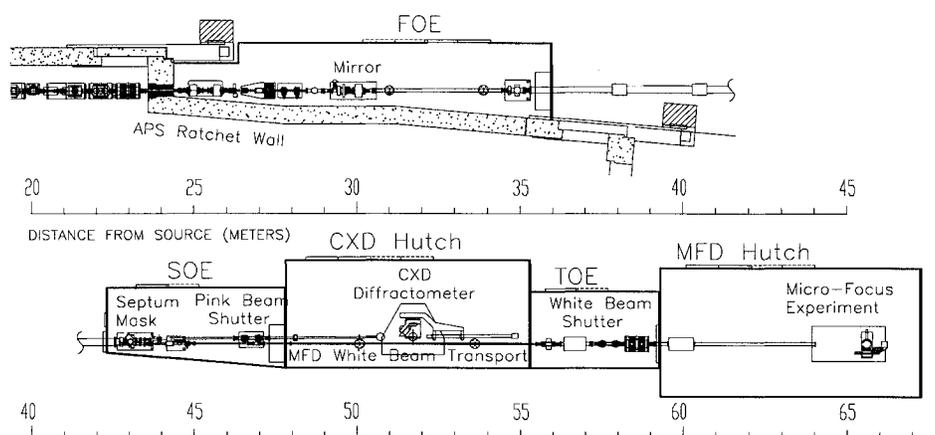


FIGURE 1. APS Sector 34-ID floorplan. The First, Second and Third Optical Enclosures (FOE, SOE, TOE) contain beamline components while the Coherent X-ray Diffraction (CXD) and Micro-Focus Diffraction (MFD) hutches are experimental stations.

flux from a single insertion device (ID). One station will house an x-ray micro-focus diffraction experiment, while the other will be dedicated to coherent scattering (see figure 1). Each of these experiments requires the high brilliance of an undulator

source, but neither can use more than half of the total flux in the central bright region of the undulator cone. These two facilities are ideally suited to share an ID provided that a simple way can be devised to split the beam. Previously, beam splitting has been achieved by transmission monochromators (e.g. thin diamond¹), but this causes spectral modification of the entire beam. A simpler method is to reflect away a portion of the cross section with a horizontally deflecting mirror. The major concerns that guide the design of such a mirror are preserving the coherence of the x-ray beam, handling the high heat load generated by an undulator source, and devising an adequate positioning system. Several of the consequences of using a mirror to split the beam are the need for a high heat load mask to catch small angle missteerings of the reflected beam, and the severe space limitations in the first experimental station due to the proximity of the transport for the unreflected beam.

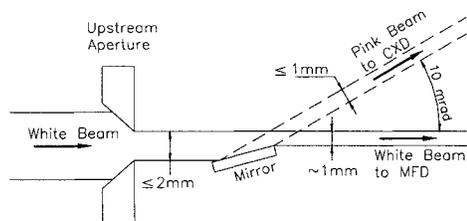


FIGURE 2. Beam sharing schematic

Our mirror optic is a polished, Si (111) substrate, 220mm long and 30mm x 30mm in cross section. Two 8mm wide coated stripes, platinum and rhodium, run the length of the mirror. The remainder of the surface is left as bare silicon, so that three options exist for the high energy cut-off of the reflected spectra. The mirror is oriented to horizontally reflect a 1mm x 1.5mm portion of the “white”, undulator radiation. The reflected “pink” beam diverges from the white beam at an angle of 10 milliradians and passes into the Coherent X-ray Diffraction (CXD) station (see figure 2). The white beam is used in the Micro-Focus Diffraction (MFD) station. The experimental geometry of the MFD experiment fixes the vertical aperture at ~1.5mm, while a desire for flexibility in the pink beam station lies behind the acceptance of horizontal beams up to 1mm in width. Because the reflected beam is used for coherent scattering, the mirror must have a finish sufficient to preserve the coherence of the incident x-rays. The mirror should be adequate if it has slope errors on the order of 10 μ rad or less and surface roughness of a few angstroms. Initial tests on the commissioning mirror show an RMS slope error of ~1 μ rad and roughness of ~1.5 \AA before the coating process.

The thermal characteristics of the mirror are critical. If we were to use water cooling on a mirror with a similar cross-section to ours, we would estimate a “thermal bump” on a 1mm wide heated spot to induce large slope errors on the order of 0.25mrad. Since the coefficient of thermal expansion for silicon below 130K is less than a fifth of its value at room temperature, and the heat conductivity is much higher, our mirror will be cryogenically cooled to minimize these heat-induced distortions by at least a factor of 20. Liquid nitrogen is gravity-fed to a reservoir bored directly into the copper block to which the mirror is bolted (see figure 3). The mirror optic is held between this block and a copper bracket to allow heat to flow from both the upper and lower faces. Indium gaskets are placed at the Si-Cu interface to increase the heat transfer from the mirror to the cooling block. Mounting bolts pass directly through the substrate and spring washers are used to distribute the clamping forces evenly. The ends of the substrate are beveled to improve cooling of the beam-cutting edge. A molybdenum shield is placed

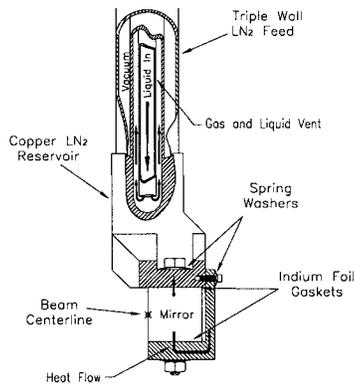


FIGURE 3. End view of mirror with cutaway of cooling block

in its mount. The chi motion is responsible for vertical steering of the pink beam and is provided by a rotary table. A crossed pair of linear tables provide horizontal and vertical translations of the mirror. The horizontal motion controls the width of the pink beam, while the vertical selects between the three reflective stripes on the mirror surface. The horizontal and vertical translations and the chi angular motion are all

on the upstream end of the mirror mount to prevent the direct white beam from hitting the end of the mirror.

The positioning system includes two angular and two linear motions. The theta motion sets the horizontal deflection of the pink beam. The entire table that supports the mirror vacuum system rotates on a rotary bearing (see figure 4a). The theta angle is adjusted by a micrometer drive at the end of a 0.8 m long arm. The position of the arm will be read by a linear optical encoder with a resolution of one half micron, giving $\sim 0.6 \mu\text{rad}$ accuracy in measuring theta. In normal operation, theta will have a fixed value of 5 milliradians, but a 3.5° range is possible to account for misalignments of the mirror optic in

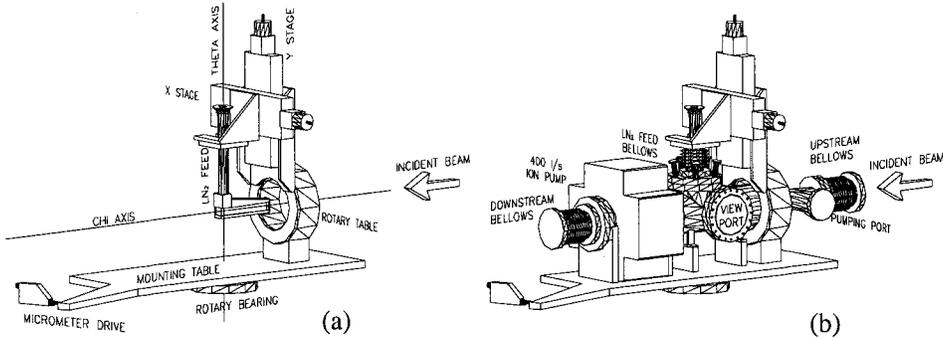


FIGURE 4. (a) mirror positioning system. (b) vacuum chamber and bellows.

passed to the mirror through a bellows on the top of the mirror vacuum tank (see figure 4b). The liquid nitrogen feed also passes through this bellows and constitutes the mechanical link between the positioning system and the mirror. The theta motion is passed by means of two bellows, positioned 0.5m upstream and downstream of the mirror to balance the vacuum load. Provision has been made to fine tune theta by pushing on the upstream end of the mirror mount with a piezoelectric linear motor. We anticipate using this motor, in conjunction with a beam position monitor, to compensate for vibrations of the mirror brought on by LN_2 boil-off. Since the theta angle is adjustable, the vacuum joint that separates the CXD beam transport from the MFD beam transport must be shielded. A "septum" mask has been designed, which can dissipate the full power of the pink beam if the mirror is missteered. The mask face is contoured to a convex surface as shown in figure 5. The taper angle steepens with

