APS 2-ID BEAMLINE, UPGRADE TO CANTED CONFIGURATION *

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MEDSI 2016 — MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON RADIATION EQUIPMENT AND INSTRUMENTATION

Abstract

To provide independent operation of the two 2-ID beamline experimental stations, a new canted beamline design is being developed. The constraint of keeping the existing front end limits the canting angle. The optimal canting angle was determined to be 400 μrad and is achieved by using a permanent magnet. A coil is added to the canting magnet to provide a steering adjustment of maximum 40 to 50 μrad. In order to increase the beam separation as well as to provide power filtering and higher harmonics rejection for the downstream optics, a dual mirror system with focusing capability is used as the first optic at approximately 28 m from the center of the straight section. The inboard mirror (2.6 mrad) reflects the inboard beam outboard while the outboard mirror (4.1 mrad) reflects the outboard beam inboard. The beam presented to the dual mirror system is defined by two 1 mm x 1 mm apertures. The maximum power absorbed by each mirror is 200 W. Two vertically deflecting monochromators with minimum offset of 17 mm are located in the First Optical Enclosure on the outboard branch. The monochromator for the inboard branch is located in the corresponding experimental station.

Canting Magnet

The canting magnet is a permanent-magnet that introduces a bend of 400 μrad. The ability to adjust the bend by a small amount is desired so the electron beam can be steered independently through the two undulators. A coil is added to the canting magnet to provide a steering adjustment of 40 to 50 μrad, maximum. That limitation on the steering adjustment avoids potential issues with power level increases on downstream masks. The cant centerline is offset 0.61 mm outboard of the traditional centerline (positive canting).

Source

The X-ray source for the beamline consists of two 2.4-m-long undulators with a period length of 3.3 cm (U33), one for each branch, located symmetrically about the center of the straight section. The period may be further optimized in the future.

Beamline Layout

The 2-ID beamline infrastructure consists of three existing shielded enclosures, three mini-hutches and shielded transport. The mini-hutches are existing as well and are relocated as needed. The shielded transport is a new design. The schematic layout of the major optical and shielding components is shown in Fig. 1.

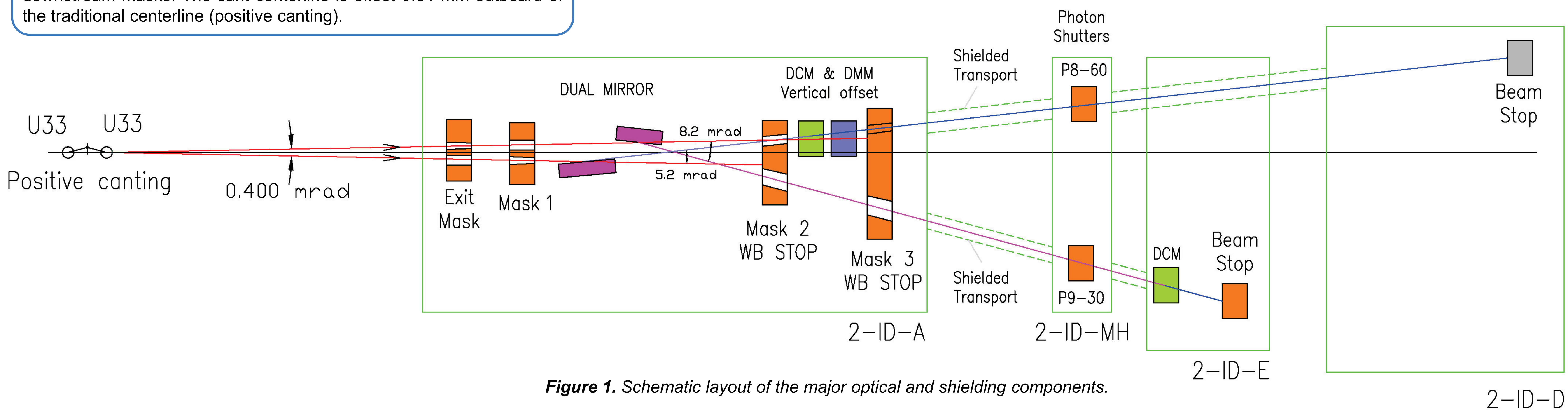

Figure 1. *Schematic layout of the major optical and shielding components.*

Dual Canting Mirror

In order to increase the beam separation as well as to provide power filtering and higher-harmonics rejection for the downstream optics, a dual mirror system with focusing capability is used as the first optic at approximately 28 m from the center of the straight section.

The mirrors are mounted in a vacuum chamber, facing each other, in a staggered configuration, see Fig. 2. The mirror motions are completely independent of each other. The system is provided with a one-time-change of the relative distance between the mirrors from 11.1 mm, for the current beamline configuration, to 28.0 mm for 1 mrad canting compatibility in the future. This way the lateral translation is maintained to a small range of ± 6 mm for stability.

The beam separation at the monochromators is between 38 mm and 56 mm. The beam-defining apertures of 1 mm^2 reduce the absorbed power into the mirrors to 208 W. The inboard mirror (IM) focuses horizontally onto a beam-defining aperture 6.25 m downstream, and the outboard mirror (OM) focuses horizontally onto a beam-defining aperture 6.43 m downstream. OM minimum bending radius is 2.6 km. IM minimum bending radius is 3.9 km.

The cooling is achieved via a typical "cooling slot and fin" design and Indium/Gallium eutectic as interface layer. The meridional RMS slope error is expected to be ≤ 0.3 μrad and the RMS micro-roughness after coating ≤ 2.5 Å. The mirror supports are designed to minimize exposure to scattered radiation, and are protected by shields. In addition, a shield is installed between the two mirrors to prevent Compton scattering produced by the IM from reaching the OM.

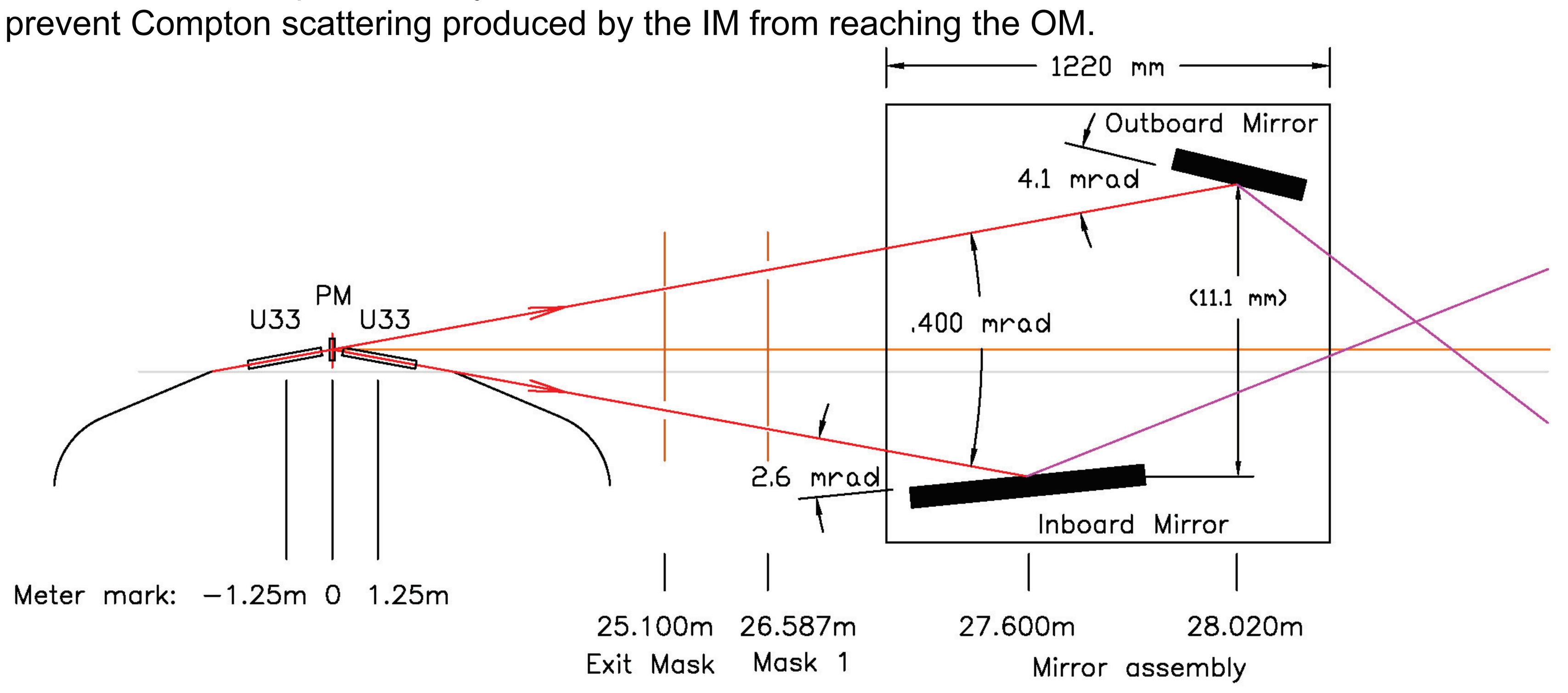

Figure 2. *Schematic of the staggered mirror system.*

Beamline Shielding Components

Primary and Secondary Bremsstrahlung Collimators

The primary bremsstrahlung radiation is stopped at the end of the First Optics Enclosure (FOE) by using the FE collimators and three beamline collimators. By using three instead of two beamline collimators, the minimum vertical offset of the monochromators located in the FOE has been reduced from 25 mm to 17 mm. In designing the secondary bremsstrahlung collimators (SBC), the OM was considered the worst scattering target in the FOE and the design follows the internal guidelines.

Masks

There are four masks in the beamline layout, all located in the FOE.

The Exit Mask intercepts the two canted WBs at full size in the horizontal (about 12 mm) and 7.2 mm in the vertical direction. In the worst case scenario, the canting angle is 350 μrad and the beams are overlapping at the Exit Mask by 3.2 mm and are 8.8 mm center to center. The power density distribution was calculated using SRUFF [1]. Table 1 shows the FEA results for the Exit Mask and Mask 1 for the worst case scenarios.

Mask	Material	Incident angle	Beams overlap	Power (W)	Peak power density (W/mm^2)	T_{max} (°C)	$T_{wall\text{-}max}$ (°C)	σ_{max} (MPa)
Exit Mask	GlidCop	1.5°	Yes	9928	278	259.2	148.2	295.5
Mask 1	Copper	2.0°	No	977	248	98.3	51.9	85.3

Table 1. *Exit Mask and Mask 1 thermal and stress analysis results*

Mask 2 intercepts the misteering cone of both focused pink beams (PBs), and stops the inboard WB and partially intercepts the outboard WB if either or both mirrors are retracted. Neither the limit switches, nor the possible hard stops of the mirrors pitch are interlocked in the Personal Safety System and therefore Mask 2 was designed to handle the entire angular range [2]. For certain mirror angles, the PB of one branch can overlap the WB of the other branch. Also, the PBs can overlap each other. The focused beam size was estimated as an ideal focal spot size: $F_{ideal} = 2.35 \times \Sigma_{RMS} \times M$ [3], where Σ_{RMS} is the RMS radiative source size and M is the demagnification.

Mask 3 intercepts the misteering cone of the inboard PB, and stops the outboard WB and the out-board PB. The OM and IM incident angles of 3.6 mrad and 2.1 mrad, respectively, are the minimum angles for which the PBs pass downstream through the Mask 2 apertures. The mirrors can focus onto Mask 3 at these angles. Table 2 shows the FEA results for the for Mask 2 and Mask 3 for the worst case scenarios. Mask 2 and Mask 3 are suitable for CuCrZr single-piece construction [4].

Mask	Material	Incident angle	Beams overlap	Beam	Beam size H (mm)	Beam size V (mm)	Power (W)	Peak power density (W/mm^2)	T_{max} (°C)	σ_{max} (MPa)
Mask 2	Copper	4°	Yes	Outb WB	1.21	1.21	215.6	156.2	126.9	111.1
				Outb PB	0.399	1.16	109.7	237.0		
Mask 3	Copper	7°	No	Outb WB	1.37	1.37	215.6	121.3	104.6	76.8
				Outb PB	0.166	1.33	109.2	496.9		

Table 2. *Mask 2 and Mask 3 thermal and stress analysis results*

Photon Shutters and Beam Stops

The PB Photon Shutter absorber as well as the PB End Station Beam Stop have normal incidence to the beam. There is no significant demagnification of the beam in the horizontal direction at these devices and therefore the peak power density is relatively low (49 W/mm^2 at the Photon Shutter). The T_{max} and σ_{max} are well below the typical values. The Monochromatic Beam Photon Shutter and the End Station Beam Stop consist of Tungsten and Lead, respectively. The heat load output of the DMM is under 1 W.

References

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* Work at the Advanced Photon Source is supported by the U. S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. DE-AC02-06CH11357.

The Advanced Photon Source is funded by the U.S. Department of Energy Office of Science