EXPERIMENTAL FACILITIES ENGINEERING

New High-Heat-Load Front End for Multiple In-line Undulators at the Advanced Photon Source

Y. Jaski

Advanced Photon Source, Argonne National Laboratory, Argonne, IL 60439

ABSTRACT

A new high-heat-load front end is being designed to handle a maximum total power of 21 kW with a peak power density of 590 kW/mrad^2. This is about 3.8 times the heat load compared with current operation of a single 3.3-cm-period, 2.4-m-long undulator (undulator A) at 100 mA stored beam current. This front end is scheduled to install for IXS at APS sector 30 during September 2004 shut down and for Nano-CAT at APS sector 26 during January 2005 shut down. This front end will allow operation of three in-line undulators A at k=2.0 with 150 mA, or two in-line undulators A at k=2.76 with 180 mA. In this poster, the overall front-end high-heat-load management plan is discussed and front-end layout and aperture design are presented. A new design concept is used in key high-heat-load components such as photon shutters, fixed masks and exit mask to handle the high power density. The design and thermal analysis of these components are presented.

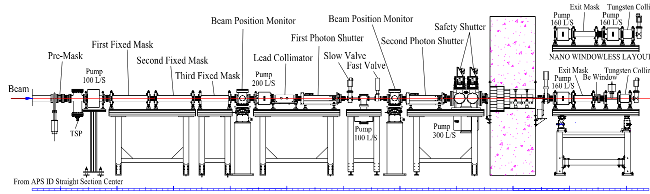


Fig. 1. Front End Layout For IXS and Nano-CAT at APS.

1. HIGH HEAT LOAD MANAGEMENT

The layout of the front end is shown in Fig. 1 and the apertures of both IXS FE and Nano FE are shown in Table 1. As we learned from the canted undualtor front end design[1,2], the power density can be handled by a surface horizontally incident to the beam is much higher than that vertically incident to the beam. This is because the horizontal size of the beam is larger than the vertical size by a factor of k. The footprint will be thin and long when the beam is incident to the surface horizontally versus wide and short when the beam is incident to the surface vertically. For a grazing incidence beam device like masks and shutters, the beam footprint can be treated as a line heat source. The power per unit length of the footprint governs the heat transfer characteristics. The FE design uses the following strategies:

a) Avoid beam vertical incidence – all masks and shutters have only beam horizontal incidence.

b) Avoid traditional box-cone-shaped fixed mask design to avoid large stress in the corners.

c) Use thin Glidcop plate for beam striking surface to get the best material strength. Thin Glidcop plate has much higher yield and ultimate tensile strength compared to thick Glidcop bars or rounds.[5]

2. ANALYSIS AND DESIGN

The design of FM1, FM2, PS1 and PS2 uses the same design concept. FM1 and FM2 are horizontal masks. The PS1 and PS2 are horizontal masks as well at the open position. An actuator installed at the downstream end of PS1 and PS2 can actuate horizontally to shut the beam off. PS1 and PS2 are designed identically (shown in Figure 2). The thermal analysis of PS1 for Nano-CAT is shown in Figure 3. The PS1 is made by brazing the left and right halves together. One half is made of OFHC copper only. The other half, which intercepts the beam at the closed position, is made of OFHC copper with an explosively bonded Glidcop face plate. The design of FM3 and exit mask uses the same concept. Both of them are made by brazing the left and right halves together to form a V-shaped block. A slot is machined into each half before brazing to form the desired aperture size. An exploded view of the solid model of the IXS exit mask is shown in Figure 4. The two halves will be pinned together before brazing to ensure the precision of the aperture. When FM3 or the exit mask is aligned to the beam, only the center portion of the beam will pass through the aperture, the outer portion of the beam will be absorbed in the horizontally tapered surfaces. All fixed masks and photon shutters are water cooled with wire coil inserts to enhance the cooling film coefficient [4]. The total power, peak power density, thermal and stress analyses were calculated for all the fixed masks and photon shutters in the FE, and the results are tabulated in Table 2.

Table 1 IXS-CAT and Nano-CAT Front-End Component Apertures Compared to FE v1.5 [3]

Aperture (mm×mm)		IXS FE	Nano FE	FE v1.5
First Fixed Mask (FM1)	inlet	38(H)× 47(V)	Same as IXS	38(H) × 26(V)
	outlet	20(H) × 47(V)	Same as IXS	20(H) × 12(V)
Second Fixed Mask (FM2)	inlet	24(H) × 47(V)	Same as IXS	24(H) × 16(V)
	outlet	5(H) × 47(V)	Same as IXS	11(H) × 6(V)
Third Fixed Mask (FM3)	inlet	9(H) × 47(V)	9(H) × 47(V)	21.5(H) × 14(V)
	outlet	4(H) × 2(V)	4(H) × 3(V)	12.7(H) × 5.2(V)
Lead Collimator	optical	14(H) × 12(V)	Same as IXS	32(H) × 20(V)
	shielding	20(H) × 18(V)	Same as IXS	38(H) × 26(V)
First Photon Shutter (PS1)	inlet	10(H) × 47(V)	Same as IXS	20(H) × 20(V)
	outlet	5(H) × 47(V)	Same as IXS	
Second Photon Shutter (PS2)	inlet	10(H) × 47(V)	Same as IXS	20(H) × 20(V)
	outlet	5(H) × 47(V)	Same as IXS	
Safety Shutter	optical	16(H) × 14(V)	Same as IXS	16(H) × 14(V)
	shielding	16(H) × 14(V)	Same as IXS	16(H) × 14(V)
Wall Collimator	optical	20(H) × 14(V)	Same as IXS	32(H) × 20(V)
	shielding	32(H) × 26(V)	Same as IXS	38(H) × 26(V)
Exit Mask	inlet	11(H) × 47(V)	11(H) × 47(V)	21(H) × 11(V)
	outlet	3(H) × 1(V)	3(H) × 2(V)	3(H) × 2(V)
Be Window	outlet	4(H) × 2(V)	4(H) × 3(V) (Commissioning only)	3.6(H) × 2.6(V)
Exit Tungsten Collimator	optical	14(H) × 7(V)	Same as IXS	14(H) × 7(V)
	shielding	14(H) × 7(V)	Same as IXS	14(H) × 7(V)

Table 2 Total power, peak power density, thermal and stress analyses for the IXS FE (Three UA, k=2.0, I=150 mA, center of source is 1.25 m downstream of the center of the straight section) and Nano FE (Two UA, k=2.76, I=180 mA, center of source is at the center of straight section), h=1.5 w/mm2°C, T_0=25.6°C.

	Distance to Source (m)	Horizontal Incidence Angle	Total Power at the Component (Watt)	Peak Surface Incidence Power Density (W/mm^2)	Max. Temperature (°C)	Max. von Mises Stress (MPa)
FM1 (IXS)	15.95	0.86°	13720	32.1	236	404
(Nano)	17.2	0.86°	21070	30.3	242	418
FM2 (IXS)	16.65	0.91°	13720	31.1	236	404
(Nano)	17.9	0.91°	21070	29.6	241	417
FM3 (IXS)	17.25	0.86°	12790	27.3	218	370
(Nano)	18.5	0.86°	16190	26.1	223	383
PS1 (IXS)	19.05	1.0°	8800	25.8	222	377
(Nano)	20.3	1.0°	11740	25.2	230	394
PS2 (IXS)	21.15	1.0°	8800	20.8	197	329
(Nano)	22.4	1.0°	11740	20.6	207	349
Exit Mask (IXS)	24.05	1.5°	8800	23.9	215	364
(Nano)	25.3	1.2°	11740	19.4	210	356

References:

1. Y. Jaski, E. Trakhtenberg, J. Collins, C. Benson, B. Brajuskovic, and P. Den Hartog, "Thermomechanical Analysis of High-Heat-Load Components for the Canted-Undulator Front End", MEDSI 2002 proceedings, 2002. pp. 390-397.
2. Christa Benson, Emil Trakhtenberg, Yifei Jaski, Bran Brajuskovic, Jeffrey Collins, Patric Den Hartog, Mark Erdmann, Erika Rossi, Oliver Schmidt, William Toter, Greg Wiemerslage, "Mechanical Design of a Front End for Canted Undulators at the Advanced Photon Source", SRI 2003 Proceeding.
3. Deming Shu, Mohan Ramanathan, Tuncer M. Kuzay, Nucl. Instrum. and Methods. A 467-468 (2001) 762-766.
4. J. Collins, C. Conley, J. Attig, M. Baehl, "Enhanced Heat Transfer Using Wire-Coil Inserts for High-Heat-Load Applications", MEDSI 2002 proceedings, 2002. pp. 409-419.
5. "Glidcop Dispersion Strengthened Copper Glidcop AL-15", Technical data sheet, North American Höganäs (SCM Metal Products, Inc.), 2002.

FIGIRE 2 Solid model of PS1 and PS2 mechanical design

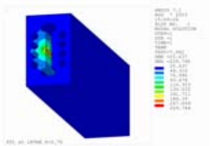


FIGURE 3 Nano-CAT PS1 temperature (°C) profile.

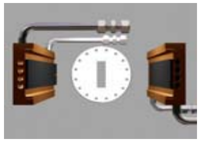
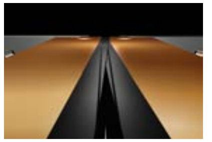
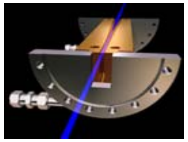


FIGURE 4 Exploded view of the IXS-CAT exit mask.



Close up view of the exit mask aperture design



Lower half of the IXS-CAT exit mask showing beam enters from upper right and exits at lower left.

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. W-31-109-ENG-38.

Argonne National Laboratory is operated by The University of Chicago under contract with the U.S. Department of Energy, Office of Science.