Thermal and Figure Analyses of Premirrors for an Undulator Beamline

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In the third generation synchrotron radiation facilities, an X-ray mirror has been considered as a candidate of the first optical element to reduce the heat load on a monochromator crystal and to collimate the divergent beams. It is important to keep the optical performance of the premirror under the large heat power. We simulated the thermal deformation of the premirror on a SPring-8 undulator beamline with a simple cooling system and examined the ability of a simple elastic bending device with the finite element analysis using ANSYS.

The incident photon flux on the premirror was calculated with the computer codes SPECTRA[1] and OEHL[2]. In the simulation, the parameters of undulator were set to be l =3.2 cm, N =140, L=4.5 m, K =1.66 and I =0.1 A, corresponding to the first harmonic energy of 8 keV and the total power of 5.6 kW. A graphite filter of 200 μm thickness and a Be window of 500 μm thickness are assumed to be set upstream of the premirror. The opening of the mirror entrance slit was set to eliminate the unwanted off-axis radiation, which reduces the incident total power to some extent. The Pt-coated mirror of the surface area of 500 x 50 mm^2 was placed at 35 m downstream from the undulator with a glancing angle of 5 mrad.

With the instrumentational parameters described above, the peak absorbed heat flux density on the mirror surface was 1.1 W/mm^2. The total power was 440 W for the beam footprint of 200 x 2 mm^2. Figure 1 displays an indirectly cooled mirror model used in the simulation. A pair of water cooled blocks contact with the mirror surface via a liquid In-Ga layer. The heat transfer coefficient in the channel water flow was estimated about 12200 W/m^2K at the coolant temperature of 30 ℃ by calculation. We decided to adopt Si, SiC and Glid-Cop for substrate materials considering to the thermal characteristics and the reliability.

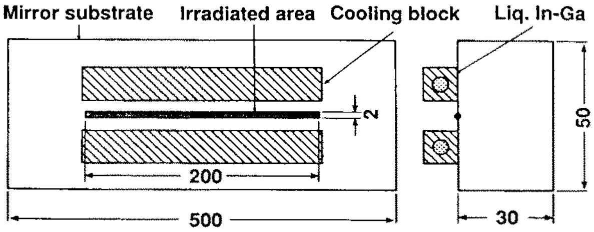

Fig.1 A model of indirectly water cooled mirror.

The simulation code first calculated the thermal deformation induced on the premirror surface. The results showed that the mirror surface parabolically swelled. Si substrate showed the best thermal performance due to its excellent thermal characteristics. The thermal slope error of the mirror surface in the sagittal direction was less than 5 μrad being negligibly small, and more than 10 μrad in the meridional direction which is not negligible.

We next simulated the performance of a four point load bending system to compensate for the thermal slope error and to get cylindrically bent figure in the meridional direction with also taking into account the effects of the gravity sag. The calculation showed that the correction of the mirror surface leads to the residual slope error less than 0.5 μrad (Fig.2) in the irradiated area of the first harmonic radiation. More detailed report was presented in ref.[3].

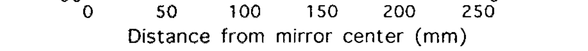

Fig.2 Residual slope error from the desired cylindrical shape for the thermally deformed mirror with loading bending force and flux density distribution of the first harmonic. The force-load points and fulcrums are at 245 and 205 mm from the mirror center, respectively. The radius of curvature in the central area is achieved 5.6 km for the bending force 60 N.

References

[1] H.Kitamura, Synchrotron Radiation Calculation Program for PC, SPECTRA ver.3.1.

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[3] T.Uruga, K.Ohtomo and H.Yamaoka, Rev. Sci. Instrum., **66**, 2251 (1995).