Finite Element Analysis of XY-slits for the Front End of the SPring-8 Undulator Beamline

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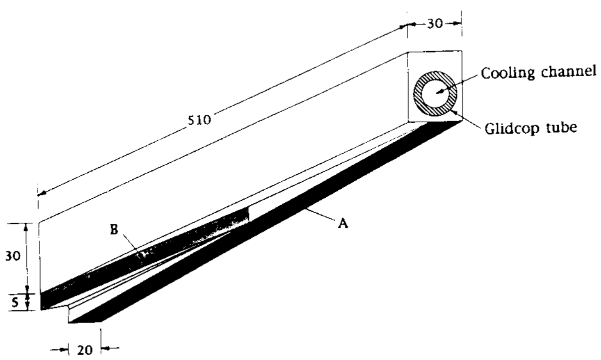
The total power radiated from insertion devices of SPring-8 will be in the range of 3 - 15 kW and in some cases will be as high as 18 kW. Such intense beam gives rise to a very severe problem of high heat load, in which peak power density reaches a few hundred watts per mm2 on a normal incidence surface. The most frequently used method for reducing the heat load is the utilization of filtering materials in order to cut off low energy photons. A set of filters made of graphite foil will be used as one of the front-end-components to reduce the heat load in order to protect other components, e.g. a Be window [1] and a first optical element. Even with such reduction the residual heat load for those components is still high, so that the power load on the first optical element leads to larger thermal gradient in this optical element and hence to larger internal stress and larger thermal distortion of the surface. Therefore, further reduction of the heat load is extremely necessary and can be achieved by limiting the photon beam spatially by means of XY-slits in front of the Be window.

The photon beam will impinge on the XY-slits with a 500 W/mm^2 peak heat flux in the worst case. Therefore, in order to reduce the heat load, the footprint of the beam on the XY-slits should be spreaded out over 10 - 100 times the normal incidence area by intercepting the beam at a small angle. This means that the XY-slits should be of the grazing incidence type. In this report, we describe a thermal analysis of the XY-slits to be placed in the in the front end of the pilot-undulator beamline of SPring-8 (λ_u : 32 mm, N:140, l:4.5 m) by using finite element analysis (ANSYS).

It is important to have knowledge of the spatial distribution of the synchrotron radiation. The opening angles (FWHM) of the fundamental radiation from the undulator will be 0.04 mrad in the horizontal direction and 0.018 mrad in the vertical direction. However, the spatial distribution of radiated power is much larger than that of fundamental radiation. [2] When we pay attention to the fundamental radiation, most off-axis photons could be waste. We may cut these waste photons by the XY-slits without losing the desired on-axis photon flux.

Figure 1 shows a design concept of L-shaped XY-slits, which is based on L5 slits in the



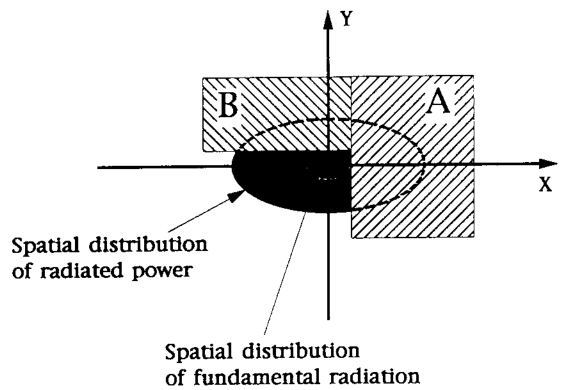


Fig.1. (a) L-shaped XY-slits. Numbers are the lengths in units of mm. Both A and B act as slit plates. (b) Schematic view of the spatial distribution of radiation as seen by an observer facing the beam. Shaded parts A and B correspond to the slit plates shown in (a).

APS standard components library [3,4], for the front end of the SPring-8 pilot-undulator beamline. Both TZM (molybdenum with small additions of Ti and Zr) and Glidcop were considered for the block material. In the case of TZM, the slit block was cooled indirectly by an OFHC cooling tube (filled with copper mesh) brazed inside the block (or tightly fitted with good thermal contact). On the other hand, the Glid-cop-slit block was directly cooled by water with enhanced heat transfer technique. [5] In order to minimize the downstream scattered x rays from the slits, a knife edge configuration was employed.

We assumed a total power of 10.7 kW and a power density of 500 W/mm^2 to be achieved in the worst case. A convective heat transfer coefficient of 1 W/cm^2°C was employed for conservative calculations. Finite element analysis showed that the maximum temperatures on the slit surface reached about 610 °C for the case of full irradiation of the slit material made of TZM and 260 °C if it is made of Glidcop. When the TZM XY-slits was adjusted so as to limit the beam to 2x1 mm^2, the calculated maximum surface temperature of the face plate was about 380 °C. An optimization of cooling channel will reduce the surface maximum temperature.

References

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