Experimental Results from a Water-cooled Monochromator with Micro-channels on an ESRF Wiggler Beamline

Hitoshi YAMAOKA[1)], Daniel Häusermann[2)], Andreas K. Freund[2)], Michael Krumrey and Åke Kvick[2)]

1) SPring-8, Kamigori, Ako-gun, Hyogo 678-12, Japan
2) European Synchrotron Radiation Facility, BP-220, F 38043, Grenoble Cedex, France

A water-cooled monochromator with micro-cooling channels has been tested on a wiggler beamline at the European Synchrotron Radiation Facility[1]. The device consists of a thin silicon wafer bonded to the grooved surface of a thick block of silicon.

The main steps of the manufacturing process of the Si bonding are the following: (i) thin cooling channels are cut in the upper surface of the block and inlet and outlet cooling channels are machined through the 40 mm block of substrate, (ii) the substrate surface is polished, (iii) oxide layers about 1 μm thick are grown on the back of the 600 μm wafer and on the top surface of the substrate block, (iv) the wafer and substrate, both in the same crystallographic orientation, are pressure bonded at room temperature and annealed at about 1100°C for a few hours, (vi) excess oxide is removed by etching. Although crystal bonding is also possible without oxide, the oxide layer gives a stronger bonding and thus this safer option was chosen[1, 2]. The wafer and substrate were n-type float-zone crystals identical to that of the BL-16 monochromator[3].

The areas of the wafer and substrate of the crystal are 100x97 mm^2 and 110x110 mm^2 respectively and the effective area of the cooling channels is 60x50 mm^2 The heat load experiments were performed at a Bragg angle of 8.75 degree and a 111 energy of 13 keV. The monochromator was 41 m from the source, and a higher incident power was used to verify the heat load effects observed earlier and find out the limitations of this cooling scheme. All attenuators were removed and the intrinsic low heat load rocking curve was measured by opening the wiggler gap instead of changing the stored current. At 80 mm the incident power was only a few watt. Calorimetric measurements were also performed for the different beam sizes used. The water flow rate was around 10 l/min., but the water pressure was reduced to 1 kg/cm^2 with a flow velocity and Reinolds number of 3.2 m/s and approximately 1800, respectively. The effect of incident beam size on rocking curve width was measured for a wiggler gap of 80 mm. The result was an increase of the 111 width from 9.0 to 13.2 arc seconds for a change in vertical beam size of 1 to 34 mm along the crystal surface. These values should be compared with the Gaussian convoluted theoretical value of 6.0 arc seconds. This beam size effect suggests a crystal curvature of the order of 1 km, and this was confirmed using two methods: scanning a narrow slit in front of the detector and interferometric measurements of the crystal surface. When compared with the width obtained at a wiggler gap of 80 mm, the heat load tests at a gap of 20.3 mm showed a degradation of the 111 rocking curve of 1.4 arc seconds at 1 kW total power and 0.38 W/mm^2 mean power density (50 mA ring current), and 2.5 arc seconds at 1.4 kW, 0.53 W/mm^2 (71 mA ring current). In both cases the beam footprint was 34x78 mm^2, that is essentially the full beam size. The dependence of peak and integrated intensities on the measured input power, varied by changing the incident beam size, is shown in Fig. 1. Up to a power of about 0.9 kW the dependence of peak intensity is linear, but beyond this point a deviation can be seen.

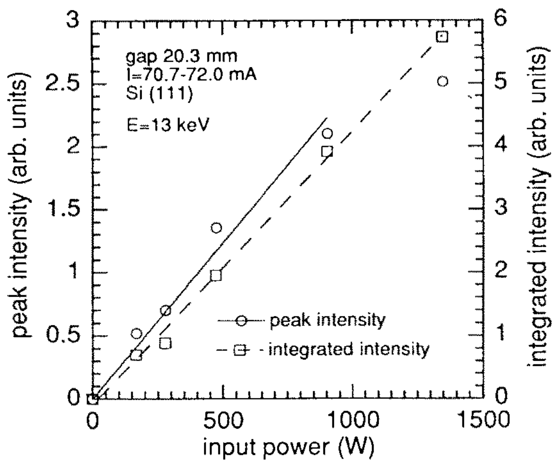

Fig. 1 Dependence of the 111 rocking curve peak and integrated intensities on the measured input power. The largest beam footprint was 5.2x78 mm^2.

References

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