Measurement of the emittance using crystal optics

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Introduction

The sizes and the angular divergences of the undulator radiation were measured in the horizontal and the vertical directions using two crystals in (++) arrangement in both directions.

The error (broadening or blurring) due to the undulator and the crystal optics was reduced at the high energy X-rays. Blurring due to the undulator in standard deviation scales inversely proportional to the square root of the X-ray energy and the blurring due to the crystal optics is smaller with higher order crystal planes. The intrinsic rocking curve width, for example, is as small as 0.8 μrad for a Si333 crystal plane at the X-ray energy of 55 keV. The expected electron beam sizes and the expected electron beam divergences are significantly larger than the instrumental functions (blurrings mentioned above). Therefore electron beam emittance can be safely deduced from the X-ray measurement of the undulator source.

Experimental Setup

For measuring the emittance of the undulator source, it is better to choose small K-value (large gap) for the undulator radiation. The reason for this is that (i) the heat load on the first optical component (standard crystal monochromator) is reduced and (ii) the flux at higher order harmonics is reduced. By such consideration, undulator gap was selected to be 33 & 40 mm which corresponded to the K-value of 0.2 and 0.1, respectively. The peak energy for the 3 rd order harmonics, 55 keV, was carefully determined by measuring the on-axis flux at various energies. For this measurement, off-axis flux in the vertical direction was exluded by placing an analyzer crystal downstream of the monochromator in (++) arrangement([1]).

For measuring the size of the source, a beam monitor (cooled-CCD) or a two-dimensional slit system was used([1]). The cooled CCD (Hamamatsu Photonics, C4880-17, with a 10 μm phosphor) has the position resolution of about 20 μm.

For measuring the angular divergences, the rocking curve measurements of the crystals in (++) arrangement were done. These measurements were done in horizontal and vertical directions([1]).

Contamination on the surface of the first monochromator crystal was found to disturb the image or the angular distribution of the source. Therefore, the first crystal was adjusted so that the surface without the contamination is illuminated by the X-rays.

Experimental Results

The results of the measurements are summarized in the following table, together with the size and angular divergence of the electron beam (assuming the betatron coupling constant of 1%). The estimation of the blurring due to the undulator and due to the crystal rocking curve width are also shown. From the table, we can safely conclude that the instrumental function (blurrings) is small enough for reliably deducing three parameters of the electron beam, but is not small enough for the vertical size.

References

1.Y.Kohmura et al., in preparation

parameter	horizontal size (sigma, μm)	vertical size (sigma, μm)	horizontal divergence (sigma, μrad)	vertical divergence (sigma, μrad)
measured X-ray source	383	41	20	3.3
designed electron beam (at coupling constant=1%)	381	27.6	18.2	2.5
blurring due to undulator (*magnetic field error neglected)	0.8(@55keV)	0.8(@55keV)	3.9(@18.5keV)	2.3(@55keV)
blurring due to finite rocking curve width	37(@55keV)	37(@55keV)	2.5(@18.5keV)	0.8(@55keV)

Table.1 The parameters obtained by the measurement of the undulator beam together with the designed value of the electron beam of the storage ring. The blurring due to the error of the magnetic fields of the undulator and the finite rocking curve width of the crystals are also listed.
(*)The effect of the magnetic field error on the broadening is under investigation.