§67. Development of Hard X-ray Imaging System for QUEST

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The x-ray spectroscopy for 2-dimensional imaging is important for the diagnostics in plasma physics. A current key technique for the x-ray spectroscopy is primarily based on electron excitation. The semi-conductor technology makes it possible to measure an x-ray spectral image. However, the dynamic range is restricted to be 1 bit/pixel/shot to measure photon energy. Then, the intensity of x-ray must be reduced to avoid pile-up phenomena. In addition, more than 100 shots must be taken in order to obtain the spectrum.

In plasma sciences it is necessary to use high dynamic-range-imaging detectors, since the x-ray intensity is strong. It is therefore important to research an x-ray spectroscopic method for extremely high-counting-rate imaging. For the purpose the application of photo-absorption technique is proposed for the x-ray spectroscopy[1)]. In the first fiscal year, an assembly equipped with an aluminum filter is developed to measure the x-ray spectral image.

Energy resolution is calculated from the absorption coefficient[1).] The energy resolution is also depending on the dynamic range of the detector[1)].

Figure 1 shows the schematic view of the assembly used in a calibration experiment. The x-ray detector is a 1-mm-thickness-CsI implemented CCD. The dynamic range is 16 bit. The CsI is sensitive to hard x-rays in an energy range from 20 keV to 60 keV. The x-ray source is a synchrotron radiation. The experiment is carried out at the BL-14C of photon factory in KEK. In the experiment the rotation velocity of the filter is set to 1 rpm. The exposure time of the CCD is set to 1 s.

The gray scale images obtained with the CCD are depending on the thickness of the filter. The spectral image is transformed from the gray scale images by using Mellin transform[1)].

In the present experiment it is monitored that the optical axis is highly stable as shown in Fig.2. The secondary diffracted beam can fully go through the pin hole, since the horizontal width of the beam is approximately 0.3 mm.

Figure 3 shows the experimental result by using the monochromatic x-ray of E = 30 keV. The time-evolution of the transmitted intensity is consistent with the calculation predicted from the motion of the filter and the absorption coefficient. The spectrum, intensity, and optical axis of the x-ray beam are enough stable to obtain the spectral image. The calibration has been carried out in the energy range from 20 keV to 40 keV with 1 keV interval.

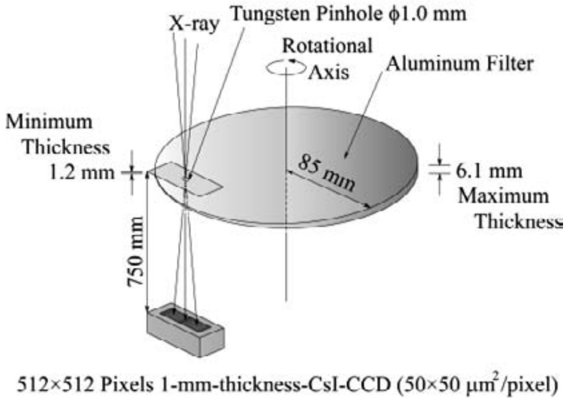

Fig.1. Schematic view of the assembly. The thickness of the aluminum filter on the optical axis continuously changes by the rotation. The rotation velocity is adjustable from 1 rpm to 10,000 rpm.

Fig.2. Measured image (64×64 pixels) of secondary diffracted beam (E = 30 keV) through 1-mm-diameter-tungsten pin hole from Si(222) tandem crystal monochrometer at the BL-14C. The fundamentally diffracted beam is absorbed with a 10-mm-thickness-aluminum filter. As an additional absorber, 8-mm-thickness-aluminum filter is used to prevent from the over flow of the CCD. The maximum signal of the CCD is maintained to be half of the dynamic range.

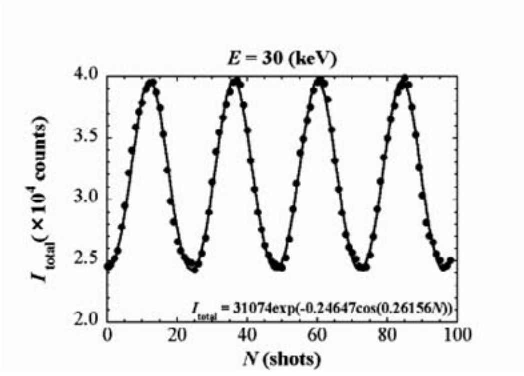

Fig.3. Experimental result on the calibration of the assembly. The solid circles and line represent measured intensities and a line calculated from the geometry shown in FIG.1, respectively. The vertical and horizontal axes represent the intensities and the number of shot, respectively.

1) S.Muto and LHD Experimental Groups, Plasma and Fusion Research (2013), **8**, pp.2402140-1~4.