§16. Design of Detector Equipped with a Beryllium Filter for X-ray Spectroscopy in LHD

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Photo-absorption effect is applied to x-ray spectroscopy in order to obtain energy, spatial, and time resolutions, simultaneously. It is important to obtain the resolutions simultaneously, since impurity transport in plasmas can be estimated.[1)] An assembly of x-ray detector equipped with a beryllium filter is also designed to measure x-ray spectrum in Large Helical Device (LHD). It is the characteristic feature that the thickness of the filter continuously changes across optical axis. Incident spectrum can be inverted from the transmission intensity through the filter.[2)] The measurement range and energy resolution are theoretically predicted from the absorption coefficient of the filter as is shown in Fig.1.[2)] In the case of beryllium, the measurement range is from 1 keV to 10 keV. The maximum energy resolution is 3.12 in that energy region. Above 10 keV the energy resolution remarkably decreases, since the derivative of the absorption coefficient decreases due to compton scattering. The actual energy resolution becomes also smaller, since the energy resolution is reciprocally proportional to the time resolution.

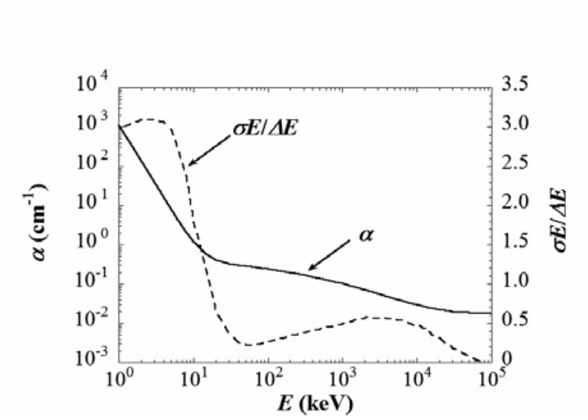

Fig.1. The absorption coefficient and the energy resolution of the beryllium. Solid line is the absorption coefficient. Broken line is the energy resolution, where σ is a parameter representing the actual resolution.

The geometrical configuration of the design is illustrated in Fig.2. The assembly basically consists of the filter, a pinhole, and a linear array. The array receives x-rays pass through the filter. The pinhole close to the filter is for the measurement of x-ray image. The thickness of the filter continuously changes from 0.1 mm to 5.0 mm. Then, the x-ray above 1.0 keV can pass through the filter. The filter rotates 180°, when the thickness changes from minimum to maximum. Consequently, incident spectrum is obtained in an every half rotation. The time resolution to obtain the spectrum is controlled by the rotation velocity of the filter. The assembly will be installed at a bottom port of LHD. The distance between the pinhole and the mid plane of LHD plasma is 5.0 m. Then, the spatial resolution on the mid plane is 30 mm. Accordingly, the assembly can cover 600 mm length in the radial direction with a 20-channels-linear array.

The rotation of the filter is expected to play an important rule. In the pixels, electric signals are not excited by only the incident x-rays. Signals also give rise to due to thermal excitation, mechanical, and acoustic vibrations. However, such noise sources have no relation against the rotation of the filter. Only the signals excited by the x-rays synchronize. Then, the assembly can reject noise signals.

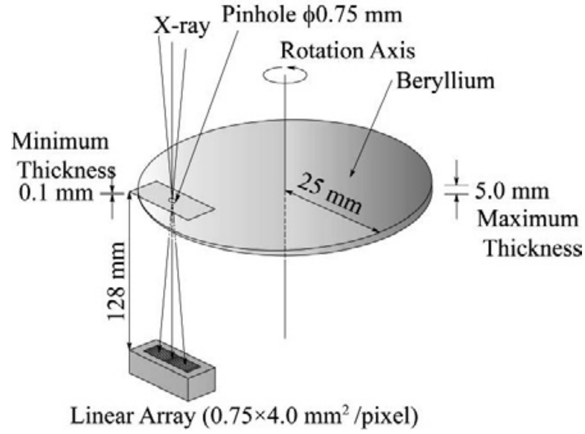

Fig.2. The geometrical configuration of the assembly.

The incident spectrum is analyzed from the observed result.[2)] Then, the actual energy resolution is dependent on an analytical method and the static error of the signals. The analytical method by using a computer is also being developed. Currently, the limit of the parameter σ is equal to 0.2. In the x-ray region between 1.0 keV and 10 keV, impurity lines can be resolved by the present method. The static error of the signals is also important to estimate the actual energy resolution. The static error is proportional to the square root of counting rate. The counting rate is estimated from the emissivity of the LHD plasma, the geometrical configuration of the assembly, and accumulation time. The integrated emissivity between 1.0 keV and 10 keV is 6.0×10^{20} photons/m^3/s in the case of typical NBI plasma of LHD[3)]. The time resolution of the linear array is 100 μs. The transmission intensities are measured 100 times. Then, it takes 10 ms that the thickness changes from minimum to maximum. The counting rate is estimated to be 6.0×10^3 counts/pixel/100 μs. Accordingly, the relative static error is 1.3 %, which is corresponding to the parameter σ of 3.0×10^{-2}. In the case of LHD the static error is small enough to resolve the impurity lines.

1) S.Muto and S. Morita, Plasma and Fusion research **2**(S1069),1-4, 2007.
2) S.Muto, PCT WO/2009/113606(2009).
3) S.Muto and S. Morita, Plasma and Fusion research **3**(S1086),1-4, 2008.