

### §35. Measurement of Bremsstrahlung Emission Using SX-CCD Camera

Ida, K., Kobuchi, T., Shiraga, H. (Osaka Univ.), Azechi, H. (Osaka Univ.)

In the plasma compressed by the laser, the electron density and temperature can be derived by the intensity of bremsstrahlung emission from the plasma compressed by laser. The energy range measured should be 10 – 30keV to avoid the absorption of bremsstrahlung in the plasma, because the density of the plasma can be few hundred times of solid density. The bremsstrahlung emission from the plasma,  $J_\nu$ , is given by

$$J_\nu d\nu = \frac{32\pi}{3} \left( \frac{2\pi}{3mkT} \right)^{1/2} \frac{Z^2 e^6}{mc^3} N_+ N_e \exp\left( \frac{-h\nu}{kT} \right) d\nu$$

where  $m$ ,  $k$ ,  $T$ ,  $Z$ ,  $N_+$ ,  $N_e$  are electron mass, Boltzman constant, electron temperature, atomic charge, ion density, electron density, respectively.

Soft X-ray CCD cameras with photon counting capability have been widely used in space X-ray observatory in astronomy. The amount of charge in each pixel of the CCD created by the individual X-ray photon is proportional to the energy of X-ray. Therefore the xray energy spectra can be obtained by counting the number of photons at a given intensity (photon counting mode). The soft x-ray CCD camera used in this diagnostic is a Andor DO432 with a full frame front illumination CCD detector. The imaging area has 1250(H)x1152(V) pixels and each pixel of the CCD detector is fabricated on special silicon with a size of 22.5µmx22.5µm. The readout noise is 15 electrons for 1MHz ADC. The resolution of the ADC is 7 electrons/ADC-count and the dark current is only 0.01 electron/pixel second at the cooling temperature of -70°C using multistage Peltier devices.

Figure 1 shows the spectrum of Mn  $K_\alpha$  (5.89keV), Np  $L_\alpha$  (13.93keV) and Ag  $L_\alpha$  and  $K_\alpha$  (2.98keV and 22.16keV) in the soft X-ray range emitted from the radioisotope of  $Fe^{55}$ ,  $Am^{241}$ ,  $Cd^{109}$ , respectively measured with SX-CCD detector with 50µ Be filter. The peak of the dark charge gives the offset level of intensity as zero energy. The relation between the intensity and the energy of the photon is plotted in Fig.2. The slope gives the conversion ratio from the counts to energy of 28.8eV/counts. The Fe  $K-\alpha$  line is fitted by a Gaussian plus linear and the full width at half maximum (FWHM) is 0.22keV at 5.89keV as shown in Fig.3.

The energy resolution of the soft X-ray camera is good enough to distinguish the line radiation of impurities in the plasma and continuum contribution due to the bremsstrahlung emission. Therefore the electron density and temperature of the plasma compressed by laser are expected to be measured from the absolute level and slope of the bremsstrahlung emission using soft X-ray CCD camera.

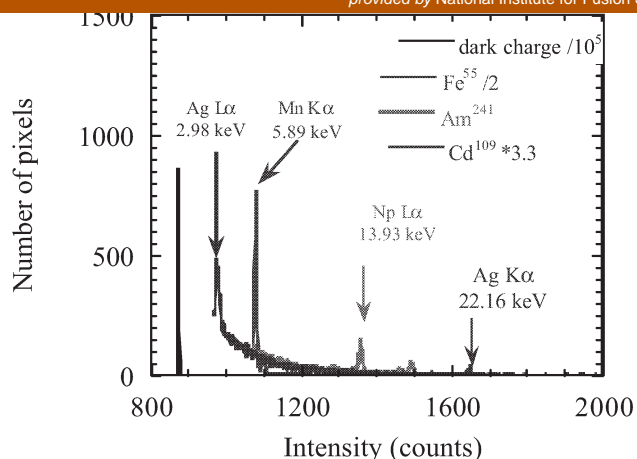


Fig. 1. Energy spectrum of soft X-ray emitted from the radioisotope of  $Fe^{55}$ ,  $Am^{241}$ ,  $Cd^{109}$ .

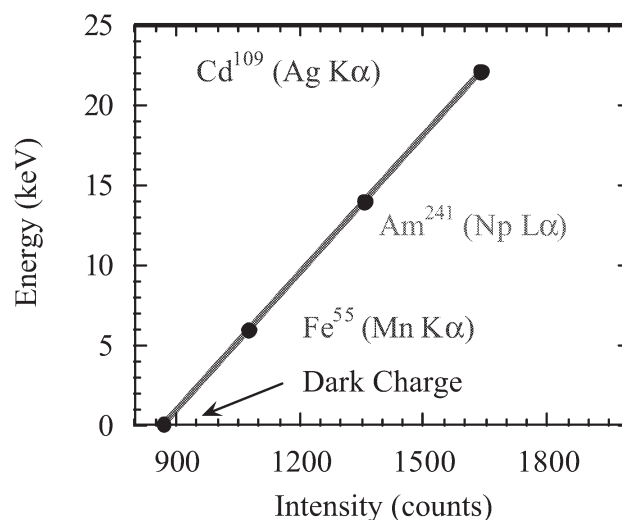


Fig. 2. Photon energy of soft Xray as a function of intensity (count of ADC).

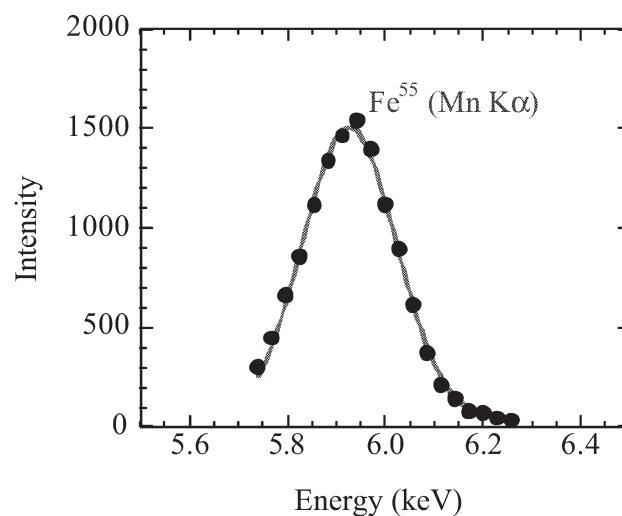


Fig.3. The spectrum of Fe  $K-\alpha$  line is fitted by a Gaussian plus linear