Measurement of X-ray beam polarization of BL32B2 at SPring-8 using a Compton polarimeter

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We develop a photoelectric tracking gas detector using a time projection chamber technique for a cosmic X-ray polarimetry[1)]. To calibrate the X-ray polarimeter at a synchrotron facility, the polarization degree of the incident X-ray beam should be known. In order to measure the beam polarization, we build a Compton polarimeter based on the X-ray scattering processes, where the angular distribution of the scattered X-rays is sensitive to the polarization direction of the incident X-rays. The Compton polarimeter can accurately measure the beam polarization owing to its high analyzing power. We use the Compton polarimeter to measure the beam polarization of the BL32B2 beamline at the SPring-8 synchrotron facility where the gas X-ray polarimeter is verified.

Figure 1 shows the schematic view of the experimental setup. The Compton polarimeter consists of a cylindrical Be scatterer and two X-ray detectors, i.e., a Si sensor and a CdTe sensor, that face each other across the scatterer. Each detector is located 1 cm away from the Be scatterer and has a diameter of 4 mm and an effective length of 4 mm. Incident X-rays from left to right, as shown in Fig. 1, are scattered by the Be cylinder and then detected by these sensors. As the detectors rotate around the scatterer through a rotation stage, the count rates modulate with the minimum rate in the direction of the electric field vector (i.e., the polarization direction) of the incident X-rays and the maximum rate perpendicular to the vector. The count rate shows a sinusoidal curve as a function of the rotation angle (modulation curve). The polarization degree of the incident X-rays is derived from the modulation curve. We measure the polarization degree of the incident X-rays at 4.5, 6.4, and 8.0 keV.

Figure 2 shows the modulation curve for 4.5 keV X-rays. The data points are fitted by a sinusoidal model with a constant offset: $f(\theta) = a * \cos(2 * (\theta - b)) + c$, where θ is the rotation angle. The free parameters a, b, and c represent the amplitude, polarization direction, and offset, respectively. The observed beam polarization degree, $\mu_{\rm obs}$, is calculated using the equation: $\mu_{\rm obs} = a/c$. We define zero degree in the detector coordinate system when the Si detector is on top. In order to reduce the systematic error caused by beam misalignment, we calculate the average of the count rates obtained from two angles 180 degrees apart from each other. To calculate the beam polarization, P, we need to know the modulation factor, $M_{\rm sim}$, which is 100% for a perfect polarimeter and 0% for an insensitive detector. We estimate it using the Geant4 Monte Carlo toolkit[2)]. The obtained parameters, $\mu_{\rm obs}$, $M_{\rm sim}$, and P, are listed in Table 1. The beam polarization degrees at 4.5, 6.4, and 8.0 keV are estimated to be 75.9 ± 0.1%, 77.1 ± 0.2%, and 77.0 ± 0.1%, respectively.

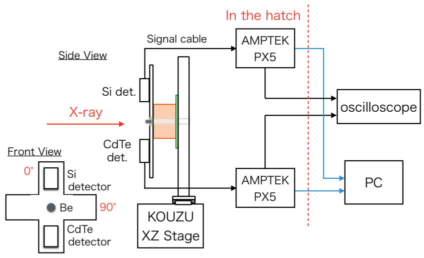

Fig. 1. Experimental setup to measure the synchrotron X-ray beam polarization. The two X-ray detectors are the AMPTEK XR100CR Si detector and the XR100T CdTe detector.

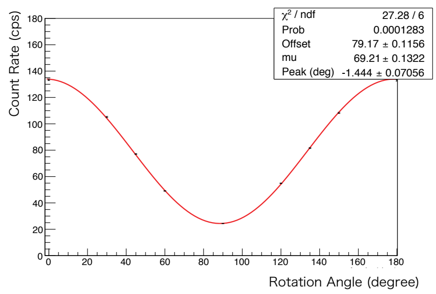

Fig. 2. Modulation curve of polarized X-rays with an energy of 4.5 keV. The red line indicates the best-fit model.

Table 1. Summary of the observed modulation ($\mu_{\rm obs}$), simulated modulation factor ($M_{\rm sim}$), and beam polarization (P)

E (keV)	$\mu_{\rm obs}$ (%)	$M_{\rm sim}$ (%)	P (%)
4.5	69.2 ± 0.1	91.21 ± 0.10	75.9 ± 0.1
6.4	70.6 ± 0.2	91.62 ± 0.05	77.1 ± 0.2
8.0	72.1 ± 0.1	93.67 ± 0.02	77.0 ± 0.1

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References
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