A Compton polarimeter utilizing silicon drift detectors

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In measurements at experimental stations E4 and F1 we had developed and calibrated a compact Compton polarimeter [1] for energy resolved linear polarization analysis of Parametric X-radiation (PXR). The polarimeter employs 4 silicon photodiodes (AMPTEK Inc., X-ray detector XR-100T) viewing a planar beryllium scattering foil at a scattering angle of 110° under azimuths spaced by 45°. The polarimeter is now being used to analyze the linear polarization of PXR at forward observation angles.

In order to extend these measurements to larger observation angles where PXR polarization properties are expected to change substantially [2] we have designed and built a 90° Compton polarimeter utilizing 4 thermoelectrically cooled silicon drift detectors (KETEK GmbH, Silicon Drift Detector Module SDD 2/5) to measure the azimuthal angular distribution of photons scattered at a beryllium conus. One further detector directed at the incident X-ray beam is used for alignment purposes. The drift detectors have substantially better spectroscopic performance and rate capabilities than conventional photodiodes [1].

Initial test and calibration measurements were carried out at beamline F1 in order to determine the analyzing power and instrumental asymmetries of the drift detector polarimeter. Figure 1 shows an example of detector response asymmetries to scattered synchrotron radiation of 11 keV for different azimuthal orientations of the polarimeter. For perfectly adjusted detectors the displayed yield asymmetry would vanish. From fits to the observed rotation curves detector acceptance corrections are obtained which reduce the residual response asymmetry to the order of $10^{-3}$. Figure 2 gives the azimuthal angular distribution of Compton scattered synchrotron radiation of 11 keV as obtained for different polarimeter orientations. From the measured modulation amplitude and the known beam polarization the analyzing power is inferred to be close to unity as expected from Monte Carlo simulations. The phase of the fitted $\cos^2$-function determines the orientation of the polarization plane to within a few milliradians. As a first application the vertical profile of the degree of linear polarization of 11 keV synchrotron radiation was measured (fig. 3). Qualitatively, the linear polarization component drops as expected when moving away from the synchrotron plane. The quantitative analysis is in progress.

References


Figure 1: Polarimeter response asymmetry to scattered synchrotron radiation of 11 keV for different azimuthal orientations of the polarimeter. The measurements are used to determine detector acceptances corrections.

Figure 2: Azimuthal angular distribution of Compton scattered synchrotron radiation of 11 keV as obtained for different polarimeter orientations.

Figure 3: Measurement of the linear polarization $P$ of 11 keV synchrotron radiation outside the synchrotron orbit. ($A$: analyzing power)