Characterization of a novel setup for hard x-ray spectroscopy and polarimetry at very high fluxes

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X-ray spectroscopy is a powerful tool for the diagnosis of plasmas being produced in fusion devices, celestial objects and in the interaction of high-power lasers or ion beams with matter. It is also known that radiative processes like bremsstrahlung, radiative recombination and characteristic transitions occurring in plasmas may exhibit distinct anisotropic and polarization features. In general, an anisotropic plasma tends to produce polarized radiation, and by photon polarimetry and/or angular resolved measurements one can investigate the anisotropic, and thus non-thermal features of the plasma [1, 2].
While single photon spectroscopy up to roughly 20 keV can be performed using standard x-ray CCD cameras, precise studies in the hard x-ray regime are often hampered by the lack of adequate detector technology. This is due to extremely high fluxes in combination with low repetition rates being typically found at plasma sources which generate x-rays up to the MeV regime, e. g. high-power laser facilities. Here, the operation of standard unsegmented, large-volume detectors leads to photon pile-up in the detector or requires unrealistic long acquisition times in order to obtain single photon spectra. Thus, state-of-art studies of hard x-ray spectra originating from plasmas still rely on low-precision techniques like stacks of several filter materials in front of an image plate [3]. However, with the recent development of pixelated CdTe sensors equipped with the Timepix readout chip [4, 5], energy-resolving detectors have become available that combine a high granularity comparable to x-ray CCDs with the high-stopping power of a high-Z detector material.

In this report, we present a setup optimized for Compton spectroscopy and linear polarimetry of incident x-rays up to a few hundred keV based on such detector systems, see Fig. 1. Here, two 1 mm thick CdTe detectors with up to 256×256 pixels record the radiation which is Compton scattered within a low-Z target. Compton spectroscopy aims for the reconstruction of the incident x-ray spectrum from the spectral distribution of the scattered photons and is in particular well-suited for fluxes being too high to expose the detector directly to the incident radiation [6]. As for photon energies below about 1 MeV the Compton cross section varies only slightly, the efficiency and consequently the amount of flux reduction of the scattering setup is mainly determined by geometry, namely the solid angle covered by the CdTe detectors. Similarly, the spectral broadening due to the dependence of the scattered photon energy on the longitudinal Compton scattering angle ϑ can be adjusted.

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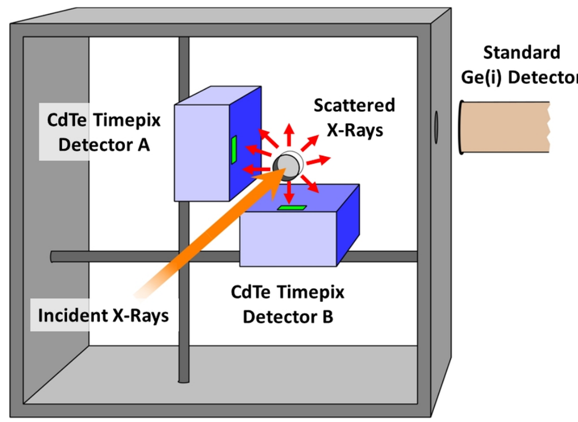

Figure 1: Setup for Compton spectroscopy and polarimetry consisting of two pixelated CdTe detectors and a scatter target, as it was used in the test measurement at DESY.

Moreover, the degree of linear polarization P_L of the incident radiation can be obtained by means of Compton polarimetry, which is based on the asymmetry of the scattered photon emission pattern with respect to the azimuthal scattering angle φ, see [7]. Assuming that the CdTe detectors are located at 0° and 90° with respect to the incident photon electric field vector, the linear polarization is given by $P_L = M(N_{0^\circ} - N_{90^\circ})/(N_{0^\circ} + N_{90^\circ})$, with M denoting the modulation factor depending on the photon energy and the experimental setup. If the orientation of the polarization is unknown, this quantity can also be obtained by rotation the detectors around the scattering target.
Recently the setup from Fig. 1 was used in a test measurement at the PETRA III synchrotron facility at DESY where high-intensity, highly polarized photon beams between 50 and a few hundred keV were impinging on the scatter target. The analysis of the obtained data is still ongoing.

References

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