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Development of X-eX spectrometer

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Introduction

An ordinary Compton scattering experiment yields the so-called Compton profile $J(p_z)$, p_z being taken along the photon scattering vector. $J(p_z)$ is electron momentum density ρ ***(p)*** integrated over p_x and p_y. The method has been used to investigate electronic and magnetic property of materials. To do so in greater detail, however, it is best to obtain ρ ***(p)*** directly from experiment. The energy and momentum conservation for the Compton scattering process tells that when the momentum (and thus energy) of the incident photons is fixed, ρ ***(p)*** can be directly observed by measuring the energy and momentum of the recoiled electrons (or the scattered photons) and the momentum of the Compton scattered photons (the recoiled electrons) in coincidence mode. This method is called (X-eX) spectroscopy. In previous works the analyses of the energy of the recoiled electrons or the scattered photons were carried out by a solid state detector, thus the resulting momentum resolution was limited to about 0.4 atomic units (a.u.)[1]. Sometime ago it was noted that the single bunch operation of the KEK-PF-AR allows us to use a time-of-flight (TOF) method to improve the resolution for the energy analysis of the recoiled electrons [2].

In this report we describe our recently developed (X-eX) spectrometer which is equipped with a TOF energy analyzer to record the flight direction and the kinetic energies of the recoiled electrons and a two-dimensional position sensitive photon detector (2D-PSD) to record the direction of the Compton scattered photons. Installation of the 2D-PSD makes it possible to obtain ρ ***(p)*** over the whole momentum space in one measurement.

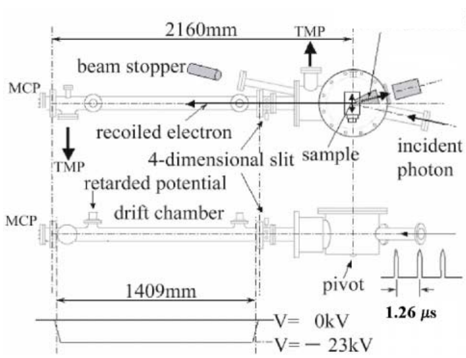

Fig. 1 Schematic view of the (X- eX) spectrometer.

Spectrometer

Figure 1 shows a schematic view of the spectrometer. The incident photons of 115.6 keV impinge on a sample. The scattered photons are detected by the 2D-PSD. The recoiled electrons go through a drift path and are detected by a microchannel plate (MCP). To improve a time resolution a retarded potential of –23 kV is applied in the drift path to slow down the recoiled electrons. An angle between the path of the incident photons and the line which connects the sample and the center of the 2D-PSD is 152.9 degrees. The angle between the path of the incident photons and the recoiled electron path is 11.1 degrees. The recoiled electron path is set along the photon scattering vector.

Figure 2 illustrates the 2D-PSD which consists of an array of $Bi_4Ge_3O_{12}$ (BGO) scintillator and a position sensitive photomultiplier (Hamamatsu R3941). The size of each BGO crystal is 2.2 mm × 2.2 mm × 15 mm. They are arrayed in 25 × 21 with 0.2 mm spacing. The position information is given by outputs of X and Y crossed –wire anodes of the photomultiplier each of which is connected to a resister chain. The measured position resolutions Δx and Δy are 2.8 mm and 3.2 mm, respectively. In the present setup these position resolutions correspond to a momentum resolution of 0.19 a.u. and 0.21 a.u., respectively. The momentum resolution of the electron branch is measured to be 0.30 a.u. by observing a TOF spectrum of the 1s photoelectrons of Au the kinetic energy of which is 34.6 keV in the present experimental conditions and very close to the average kinetic energy of the recoiled electrons. The signals from the recoiled electron branch and those from the scattered photon branch are processed in coincidence mode. The observed ρ ***(p)*** in Si is shown in the following report.

References

[1] Th. Tschentscher et al., Phys. Rev. B48, 16965 (1993).
[2] M. Itou et al., J. Synchrotron Rad. 5, 676 (1998).

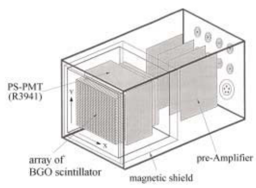

Fig. 2 Illustration of the two-dimensional position sensitive photon detector.