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The photoelectron source for the cold electron collision experiment utilizing the penetration field method

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Introduction

Collisions between electrons and atoms or molecules at very low-energy, where the de Broglie wavelength of an electron become much longer than the typical size of target particles, show unique quantum effects. Recently, experimental technique for measuring the total cross section of electron scattering from atoms and molecules at very low energy below a few hundred meV (a few thousand kelvin) was developed by Field and co-workers[1]. In their technique, mono-energetic photoelectrons produced in the photo-ionization of atoms by monochromatized Synchrotron Radiation (SR) were used as an electron beam source, instead of a conventional hot filament. The photoelectrons were collected with a weak constant field applied across the photoionization region. However, it is necessary for their technique to use a special beamline dedicated for the electron beam production, because the energy width of the electron beam depends on the spot size and the band width of the monochromatized SR, which are trade-off between the photon flux of the excitation photon beam.

In the present project, we have developed a new method for producing an electron beam at very low energy for cold electron collision experiment employing photoelectron sources. The method overcomes the trade-off problem between the resolution and the intensity of the electron beam by applying the combination of the threshold photoionization of atoms and the penetration field technique[2].

The photoelectron source utilizing the penetration field method

The experiment has been carried out at the beam line 20A at Photon Factory, KEK. The monochromatized synchrotron radiation (SR) tuned just at the first ionization potential of Ar was used as a photoionization source. A cross-section of the electron scattering apparatus in the present setup is shown in Fig. 1. The photon beam was focused onto the center of the photoionization cell, filled with argon atoms. The threshold photoelectrons produced in the photoionization of Ar in the photoionization cell are extracted by the weak electro-static field formed by the peneteration field method and focused onto the entrance of the lens system of the electron scattering apparatus. The penetration field method utilizes the very weak field formed by an extraction electrode penetrating into the photoionization region through a screening electrode. The penetration field forms a saddle point in the potential distribution which has the effect of focusing and enhancing the extraction efficiency of photoelectrons. By tuning the penetration field, only the very low energy photoelectrons extracted from the photoionization region can be focused onto the entrance of the lens system while the energetic photoelectrons rapidly diverge as the energy of photoelectrons increases.

The threshold photoelectrons formed by photoionization of Ar are collected by the potential well formed by the extraction electrode of the extraction lens system and transmitted through the collision cell. The intensities of the electron beam, in the presence and absence of target gas were recorded as a function of electron energy. Total cross section for electron collisions with target can be obtained by using attenuation formula. Electron energy as low as 14 meV was achieved in the present apparatus[3].

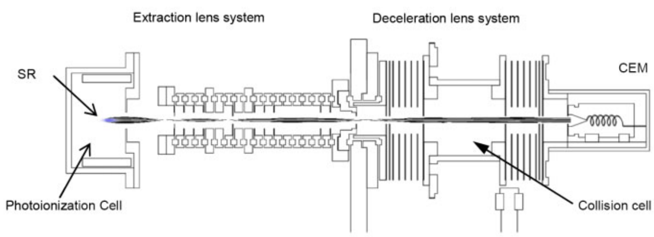

Fig. 1. Cross section of the apparatus used in the measurement of the total electron scattering cross sections. The results of the electron trajectory calculation at 0.1 eV are also shown in the figure.

References

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