Development of an electron-atom Compton scattering apparatus: Towards time-resolved imaging of atomic motions in momentum space

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Synopsis We have developed a multi-channel apparatus for electron-atom Compton scattering to study the momentum distribution of atoms in a molecule. It has an ability to cover almost completely the azimuthal angle range available for the quasi-elastic electron Rutherford backscattering. This ability has enabled us to increase remarkably the signal count rate by nearly three orders of magnitude compared to existing setups as well as to examine anisotropy of the velocity distribution of target atoms in a beam from the angle resolved spectra.

Recently, it has been shown that keV electron scattering at high momentum transfer $\boldsymbol{q}$ can be used as a new technique for direct observation of the momentum distribution of atoms in a molecule [1]. Within the framework of the impulse approximation, the scattering process is simply described by a billiard ball-type collision between the incident electron and a single atom in a molecule. Then, the target atom with mass M and momentum $\boldsymbol{p}$, before the collision, acquires a recoil energy given by $E_{\rm rec} = q^2/2M + \boldsymbol{q}\cdot\boldsymbol{p}/M$, and it can be measured by observing the energy loss of the incident electrons. In order to fully explore potential of this new technique, we have developed recently a multi-channel apparatus that combines the features of both a spherical electron energy analyzer and a large-area position sensitive detector and thus achieved much higher signal count rate than ever before [2]. Thereby, it has opened the door to time-resolved imaging of momentum-space atomic motions during a chemical reaction. In order to get such information, however, contributions of the center-of-mass motion must be excluded from experimental raw data. Here, we have examined how energy loss spectra measured for rare gas atoms in their ground states are affected by the velocity distribution of a target gas beam.

The experiments were conducted at an incident electron energy of 2.0 keV by using our multichannel spectrometer [2], which accepts quasi-elastically backscattered electrons from the target at a scattering angle of 135°±0.4° over the azimuthal angle ϕ range from −72.5° to 72.5° and from 107.5° to 252.5°. Since the observable is the distribution of the momentum component of the scattering atom projected onto $\boldsymbol{q}$, one may see some difference between spectra measured in the forward (ϕ = 0°) and backward (ϕ = 180°) scattering geometries with respect to the propagation direction of the target beam, if contributions of the center-of-mass motion are noticeable.

Figure 1 shows a preliminary result of the energy loss spectra of He measured at ϕ = 0° and 180°. The observed differences in peak position as well as in band shape between the two spectra clearly indicate that not only contributions of the center-of-mass motion but also its anisotropy are not negligibly small in the case of He. In the presentation, we will show experimental data measured for other rare gas atoms also and compare the experimental data with associated theoretical spectra that take into account the velocity distribution of the gas beam. The target-atom mass dependence of contributions of translational motion to the energy loss spectra will be discussed.

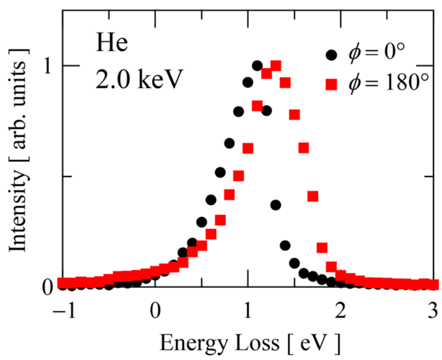

Fig. 1 Electron energy loss spectra of He measured at ϕ = 0° and ϕ = 180°.

References

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