CFEL SCIENCE

SEMINAR

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Scattering of adiabatically aligned molecules by nonresonant optical standing waves and grazing incidence atom and molecule optics

Different from other point-like particles such as atoms or electrons, manipulating molecules with an optical field is always affected by state-dependent molecular alignment. However, the state-dependent alignment has been ignored in the analysis of recent experimental results. We studied the effect of rotational state-dependent alignment in the scattering of molecules by optical fields. CS_2 molecules in their lowest few rotational states are adiabatically aligned and transversely accelerated by a nonresonant optical standing wave. The width of the measured transverse velocity distribution increases to 160 m/s with the field intensity, while its central peak position moves from 10 to −10 m/s. These changes were well reproduced by numerical simulations based on the rotational-state-dependent alignment but cannot be modeled when ignoring these effects. Moreover, the molecular scattering by an off-resonant optical field amounts to manipulating the translational motion of molecules in a rotational-state-specific way. Conversely, our results demonstrated that scattering from a nonresonant optical standing wave is a viable method for rotational state selection of non-polar molecules.

If time allows, I would like to introduce another project of our group, grazing incidence matter-wave optics. Since Estermann and Stern proved de Broglie's hypothesis on particles' wave nature for atoms and molecules, various atom optics experiments have been realized with their scattering from a surface. In most of those investigations, crystalline surfaces that are smooth at the atomic level and that have been kept clean under ultrahigh vacuum conditions have been

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used. For microscopically rough surfaces, it was generally accepted that atoms would not be coherently reflected at near-normal incidence but would undergo diffuse scattering. The restriction on the surface quality has hindered the development of reflective atom-optical components other than those surfaces. However, it was recently demonstrated that, under grazing incident conditions, an atom or molecule can be reflected from a surface via quantum reflection or multiple-diffraction reflection. The grazing incidence results in a small velocity component perpendicular to the surface, which allows the particle to be reflected from the surface with a finite probability before it touches the surface. This reflection mechanism beyond classical mechanics is quantum reflection. Additionally, when an atom or molecule is scattered off an array of half-planes at grazing incidence, it is coherently reflected by multiple diffractions above the edges of half-planes. We call this reflection mechanism multiple-diffraction reflection. The nature of the two reflection mechanisms allows rough surfaces to work as atom-optical components. Therefore, we can use commercial optical components, easily-made microstructures, and newly-developed material such as 2D materials as components in matter-wave optics. In this part, I will present our studies on quantum and multiple-diffraction reflections of atoms and molecules and their applications for manipulating atoms, molecules, and fragile exotic clusters such as He_2 and He_3, which will lead us to the establishment of grazing incidence atom and molecule optics.