Young-type interference effects in heavy-ion collisions with diatomic molecules

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Synopsis. We review and present new theoretical progress concerning coherent electron emission from simple diatomic molecules by the impact of fast ion beams. Furthermore, we compare the corresponding results with existing experimental measurements. Different physical mechanisms of the studied reaction are analyzed.

Coherent electron emission from molecular targets has been a subject of main interest in atomic collisions stimulated by the work of 1966 by Cohen and Fano [1]. They theoretically obtained that oscillation patterns should appeared in photoionization cross sections of nitrogen and oxygen molecules. Their comparison with experimental data seemed to confirm their prediction. However, clear evidence of the effect was given only 35 years later, when interferences were experimentally found in double differential cross sections of electron ionization of hydrogen molecules impacted by fast Kr^{34+} ions [2]. Electrons are emitted coherently like from the proximities of both molecular centers in phase or out of phase, producing thus an oscillatory behavior of the resulting spectra. The analogy with the Young two-slit experiment was immediate. In the case of our interest, electrons are not scattered from the molecular centers but emitted from them. Following reference [2], numerous studies were developed showing an incessant activity in the field. They were possible due to the seminal advance of experimental capabilities, which allows nowadays the feasibility of kinematically complete experiments. We will focus our interest mainly on the contributions of the present author (reading of a review article by Ciappina et al. [3] is recommended), in particular where the Continuum Distorted Wave - Eikonal Initial State model was employed.

Within this theoretical description, for enough fast projectiles, the collision time was considered to be smaller than the vibrational and rotational molecular ones, so that the target was supposed as fixed in its original position during all the reaction. Moreover, the process was reduced to a one active electron, assuming that the passive electrons (the ones that remain bound to the target) stay as frozen in their initial orbitals. A two-effective center approximation was used to describe the target continuum.

Calculations of fully, triply and doubly differential cross sections are presented and when possible compared with experimental data.

The spectra for molecular hydrogen are shown as a function of the final electron velocity for randomly oriented molecules at fixed emission angles or as a function of the emission angle for given target orientations. Constructive or destructive interferences appear according to the molecular alignment.

The case of impact of protons on the asymmetric HeH^+ target is also presented, showing that interference patterns still appear in the final electron angular distributions for fixed molecular orientations. Comparisons with the case of photoionization is given.

The case of multiple orbitals nitrogen and oxygen molecules by ion impact was also analyzed, showing that signatures of coherent emission appears in the electron angular distributions for molecular orientation parallel to the incident velocity, but not when ionization from all orbitals is considered for randomly oriented targets.

Some comments on doubling frequency emission where the electron is emitted from one center and scattered then by the other one, interfering with the electrons directly ejected from the first center will be given.

References

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