Laser-assisted electron momentum spectroscopy of H_2^+

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Synopsis Electron impact ionization of the hydrogen molecular ion in the presence of laser radiation is studied theoretically. The kinematical regime of high impact energy and large momentum transfer is considered. The influence of a laser field on the target is taken into account using a quasistatic states model, whereas its effect on the incoming and outgoing electrons is described by the Volkov functions. For the field-dressed target, the molecular bond oscillation factor, extracted from the electron momentum distribution, demonstrates a significantly different behavior compared to the case of the unperturbed target.

Electron momentum spectroscopy (EMS) is a well-established technique that utilizes an $(e,2e)$ ionization to study electron momentum distributions in atoms and molecules [1]. Recent advances in the EMS have allowed to combine the $(e,2e)$ EMS spectrometer with a laser system, which has opened the door to several novel applications of this method. One of them is the laser-assisted EMS [2], where the EMS measurements are conducted on the atomic and molecular targets in the presence of laser radiation. This allows one to probe the laser effects on the electronic structure of the investigated target.

While the laser-assisted EMS has not been implemented experimentally yet, the theoretical analysis of its potential has already been carried out for the simplest atomic targets, such as the H and He atoms. In the present work, we extend this method to molecular targets, performing a theoretical analysis for the case of the laser-assisted EMS of the H_2^+ ion. The EMS kinematics involves high impact energy and large momentum transfer in such a way that the $(e,2e)$ ionizing collision is very close to the free electron-electron collision. This validates the use of the binary-encounter and first Born approximations for the S matrix of the process. In order to discard the possible photoionization and photodissociation effects and to neglect the laser influence on the nuclear motion, the case of a low-frequency laser field of relatively weak intensity is inspected. The laser field action on the target electron is taken into account within a quasistatic states approach, which goes beyond the usual perturbation theory.

In the case of a laser field with frequency $\hbar\omega = 1.55\,\text{eV}$ and intensity $I = 1.55 \times 10^{11}\,\text{W/cm}^2$, we found that the laser-induced modification of the target electron momentum distribution can be seen most clearly by comparing the bond oscillation profiles [3] corresponding to the field-dressed and unperturbed states of the target. Even for the moderate field strength, the bond oscillation interference factor exhibits notable sensitivity to the employed model of the dressed target state [4] (see Fig. 1).

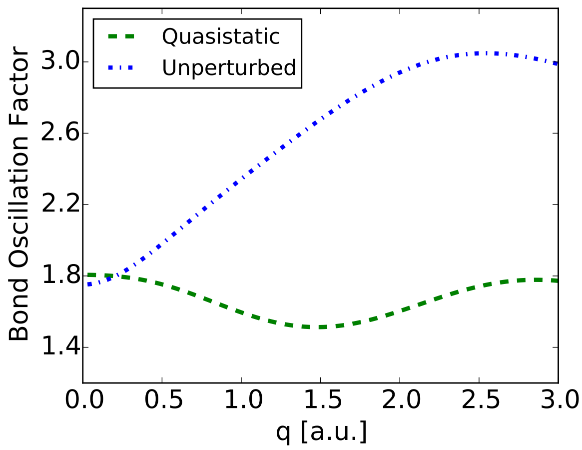

Figure 1. The bond oscillation factor for the cases of the quasistatic and unperturbed target states when the collision is accompanied by emission of one photon.

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References

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