Time-dependent study of laser-assisted charge transfer in low energy ion-atom collisions

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Synopsis We theoretically study the charge transfer in low-energy ion-atom collisions exposure to laser pulses. To solve the time-dependent Schrödinger equations for nuclear dynamics, we adopt a multi-configuration time-dependent Hartree algorithm (MCTDH) with a prior knowledge of potential energy surface, dipole transition and coupling matrix elements. Our results show that charge-transfer probability can be significantly modified by the appropriate laser field. The sensitivity to the delay time and laser pulse length is found and discussed.

Heavy particle collisions exposure to external environment, e.g., plasma and electromagnetic field, exist ubiquitously in many related fields study, such as astrophysics and laboratory plasma, where the cross sections and rate coefficients are important input atomic data required in the plasma transform simulation. In this context, the investigation of influence of external fields on heavy particle collisions is of significance for both fundamental research and practical applications.

In the previous work[1,2], laser-assisted charge transfer in ion-atom collisions have been extensively studied using different theoretical models, in particular at intermediate to high energies. For one-electron systems, e.g., He^{2+} + H, the most popular method is to solve the time-dependent Schrödinger equation (TDSE) for electrons and meanwhile treat the motion of the nuclei as a line trajectory. This semi-classical treatment is fully suited for the impact energy larger than ~keV, where the projectile moves swiftly and the scattering angle is negligible. However, this is not true when the collisional energies decrease to ~eV, where the quantum effects of nuclei play an important role in the excitation and charge transfer processes.

In this work, we aim to study the charge transfer in low energies (~eV) $H^q(q=\pm1,0)$ + Li collisions in the presence of external laser fields. To this end, we represent nuclei by quantal wave packets whose dynamics is associated with single or coupled electronic potential energy surface, which can be analyzed by solving the TDSE for nuclei. To integrate TDSE efficiently, we used a MCTDH method [3], which has been demonstrated to be applicable in the treatment of a wide range of problems [4].

In Figure 1, the charge-transfer probability between the $1^2\Sigma^+$ ($H^-(1s^2)$+$Li(1s^22s)$) and $2^2\Sigma^+$ ($H(1s)$+Li^- $(1s^22s^2)$) states in H^- + Li collisions are presented for different laser pulse lengths and compared with that of the field-free case in the energy range of [0.3 eV , 1.3 eV]. It is clear that external laser field can cause a significant modification of the charge-transfer probability, both on the position and the profile of the resonance peaks, but it depends sensitively on the pulse length as well as the incident energy. Further analysis will be performed for the external laser field effects on the cross section and state population in the ion-atom collisions.

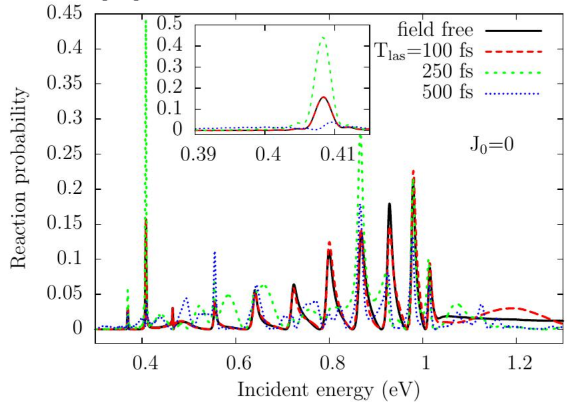

Figure 1. The charge-transfer probabilities with and without external laser field are presented in H^- + Li collisions in the energy range of [0.3 eV, 1.3 eV]. Note that the results of three different pulse lengths T_{las}=100 fs, 250 fs, and 500 fs are shown. The inset shows a close-up for the peak around 0.41 eV.

References

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