

Theoretical study on laser-assisted electron momentum spectroscopy of helium

Andrey A. Bulychev^{*1}, Konstantin A. Kouzakov^{†,§2}, and Yuri V. Popov[§]

^{*} Joint Institute for Nuclear Research, Dubna 141980, Moscow Region, Russia

[†] Department of Nuclear Physics and Quantum Theory of Collisions, Faculty of Physics, Lomonosov Moscow State University, Moscow 119991, Russia

[§] Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow 119991, Russia

Synopsis Ionization-excitation of helium by fast electron impact at large energy and momentum transfer and in the presence of a linearly polarized laser field is considered theoretically. The momentum profiles of He for transitions to the $n = 1$ and 2 states of He^+ are discussed.

The first theoretical analysis of electron momentum spectroscopy (EMS), that is, the $(e, 2e)$ method at high impact energy and large momentum transfer, in the presence of laser radiation was performed only recently [1]. The analysis was carried over for atomic hydrogen, which is a benchmark system for EMS. However, from the viewpoint of experimental realization, a helium atomic target seems to be more convenient and “easy-to-use”. Therefore, we study theoretically the laser-assisted EMS of helium, mainly focusing on ionization-excitation processes (clearly, those are absent in the hydrogen case).

We present and analyze the results of numerical calculations of the triple differential cross sections (TDCS or momentum profiles) for the laser-assisted $(e, 2e)$ processes on helium in symmetric noncoplanar EMS kinematics. In the discussed kinematics, the scattered and ejected electron angles are $\theta_s = \theta_e = 45^\circ$, the incident electron energy is $E_0 = 2079$ keV, and the scattered and ejected electron energies are $E_s = E_e = E$. The TDCS is studied as a function of the recoil-ion momentum value q by scanning the out-of-plane ejected electron angle ϕ_e . The laser photon energy is chosen to be $\hbar\omega = 1.17$ eV (Nd:YAG laser), so that it is well below the energy of the transition from the ground to the first excited He state. The laser intensity is $I = 4 \times 10^{12}$ W/cm², so that the laser electric field amplitude is much weaker than the intraatomic field. This low-frequency and low-intensity regime validates the use of perturbation theory for treating field-dressed He and He^+ states. The latter calculations are made in the so-called length gauge (L-gauge) [2].

Figure 1 presents the results for transition to the $n = 2$ state of He^+ in the case of no net photon absorption by the colliding system ($N = 0$). The laser polarization vector is per-

pendicular to the plane formed by the incident and scattered electron momenta ($\text{LP}\perp$). In contrast to the field-free results, the laser-assisted momentum profiles exhibit marked oscillations. These oscillations are a typical manifestation of the laser-field effect on the incoming and outgoing electrons [5].

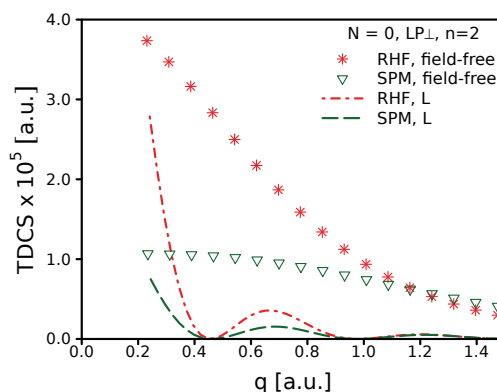


Figure 1. TDCS as a function of the recoil-ion momentum q . Calculations using the Roothaan-Hartree-Fock (RHF) [3] and Silverman-Platas-Matsen (SPM) [4] wave functions of He are shown.

References

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¹E-mail: bulychev@theor.jinr.ru

²E-mail: kouzakov@srd.sinp.msu.ru

