Acceleration and Twisting of Neutral Atoms by Strong Elliptically Polarized Short-Wavelength Laser Pulses

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We have investigated non-dipole effects in the interaction of a hydrogen atom with elliptically polarized laser pulses of intensity (0.25-100)$\times$ 10^{14} W/cm^2 with about 8 fs duration. The study was performed within the framework of a hybrid quantum-quasiclassical approach in which the time-dependent Schrödinger equation for an electron and the classical Hamilton equations for the center-of-mass (CM) of an atom are simultaneously integrated. It is shown that the spatial inhomogeneity $\mathbf{k}\cdot\mathbf{r}$ of the laser field and the presence of a magnetic component in it lead to the non-separability of the CM and electron variables in a neutral atom and, as a consequence, to its acceleration. We have established a strict correlation between the total probability of excitation and ionization of an atom and the velocity of its CM acquired as a result of interaction with a laser pulse. The acceleration of the atom weakly depends on the polarization of the laser in the considered region (5 eV $\lesssim \hbar\omega \lesssim$ 27 eV) of its frequencies. However, the transition from linear to elliptical laser polarization leads to the twisting of the atom relative to the axis directed along the propagation of the pulse (coinciding with the direction of the atom acceleration). It is shown that with increasing ellipticity the twisting effect increases and reaches its maximum value with circular polarization, while the projection of the orbital angular momentum acquired by the electron onto the direction of propagation of the laser pulse reaches its maximum value. A mechanism for n-photon resonant twisting of an atom with the transfer of helicity of photons of a circularly polarized laser field to it has been established, which may be of interest for a number of promising applications.