**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 $10^{14}$ W/cm$^2$ about 8 fs duration. The study was performed within the framework of a hybrid quantum-quasiclassical approach in which the time-dependent Schroedinger equation for an electron and the classical Hamilton equations for the center-of-mass (CM) of an atom are simultaneously integrated [1]. It is shown that the spatial inhomogeneity $\mathbf{kr}$ 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 [1,2]. 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 momentum of the accelerated atom). It is shown that with increasing ellipticity the twisting effect increases and reaches its maximum value with circular polarization, at this point the projection of the orbital angular momentum acquired by the electron onto the pulse propagation reaches its maximum value. Further exploration of the possibilities for producing accelerated and twisted atoms with electromagnetic pulses is of interest for a number of prospective applications.

[1] V.S. Melezhik, Quantum-quasiclassical analysis of center-of-mass nonseparability in hydrogen atom stimulated by strong laser fields. J. of Phys. A56 (2023) 154003.
[2] V.S. Melezhik and S. Shadmehri, Acceleration of neutral atoms by strong short-wavelength short-range electromagnetic pulses. Photonics 10 (2023) 1290.

**Photon condensation in non-classical states in the Gauge invariant Dicke Model**

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We investigate the ground state of two physically motivated modifications of the Dicke model. The first modification corresponds to particles whose phase space contains only two states, for example, particles with spin 1/2 or artificially created qubits. The second modification describes two-level systems that arise as a result of truncating the full Hilbert space of atoms to two levels that are in resonance with the electromagnetic field and are described by the gauge-invariant Dicke model. We demonstrate that the behavior of these systems is qualitatively distinct in both cases. In particular, in the first scenario, a phase transition into the state with a non-zero amplitude of the classical field is possible, while in the second case, the so called order parameter $\eta = \langle a \rangle$ of the field's phase transition into a coherent state with photon condensation is zero. However, the average number of photons $\bar{n} = \langle a^{+}a \rangle \neq 0$, and the collective excitation in the system manifests a non-classical "squeezed" state of the field. We analyze the observable characteristics of both systems in a wide range of variations of their parameters.

**Simuations and Applications of the High-Energy Elecromagnetic Showers in Oriented Crystals**

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The 70-th year history of investigation of the effect of coherent increase in both the radiation intensity and probability of pair production in crystals is reviewed with the emphasis on the prediction and study of synchrotron-like processes by professor V.G. Baryshevsky and his school,