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 **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 $\eta =< a >$ of the field's phase transition into a coherent state with photon condensation is zero. However, the average number of photons $\overline{n} =< a^{+}a >\neq 0$, 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,

which take place10 GeV and higher energies. The effect of acceleration of electromagnetic showers development in crystals is of the widest interest when it manifests itself in crystalline scintillators used in electromagnetic calorimeters of detectors used in high-energy physics and orbital gamma-telescopes. Besides the development of compact crystalline detectors and gamma-telescopes, among the presently studied applications are the production of intense positron beams intended for further acceleration in the designed linear and ring colliders, the process of absorption of gamma quanta by crystals in order to weaken the unwanted background in the experiment to search for a violation of the Standard Model of fundamental interactions in the decays of neutral K-mesons, as well as the use of crystals to facilitate the production of secondary beams of gamma quanta and high-energy positrons at proton accelerators. A newly developed program for the full simulations of high-energy electromagnetic showers in the oriented crystals that combines the methods for describing coherent processes of scattering, radiation, and pair production in a crystal lattice at high energies and small deviations of particle momenta from the crystalline directions with the GEANT4 toolkit algorithms for simulating similar processes in the approximation of an amorphous medium at low energies and large deflections is announced.

Electric field of a charged ring located in the equatorial plane of Kerr black hole

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Electric field of a static charged ring that is located in the equatorial plane of Kerr black hole is calculated by numerically solving the Teukolsky equation. Lines of electric force are constructed and its structure analyzed for different values of the radius of the ring, mass of black hole and the angular momentum of black hole. The applications to astrophysical models of active galactic nuclei are discussed.

Studying the properties of ratchet systems by the Green's function method

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The Green's function method is an effective tool that a researcher can use to analyse the properties of systems being disturbed by external perturbations. For ratchet systems, such perturbations are fluctuations of the spatially periodic potential energy of a Brownian particle, which can initiate a particle directed motion. To obtain analytical expressions for the average velocity of an overdamped motion of a ratchet, one should use Green's function of diffusion in a stationary periodic potential and construct a perturbation theory in small fluctuations [1]. Nontrivial frequency and temperature dependences of the average velocity of the ratchet with a stationary sawtooth potential, dichotomously modulated by a spatial harmonic perturbation, were obtained in Ref. [2]. This presentation reports on the obtained Green's function of diffusion in a stationary stepwise potential and the properties of ratchets with various functional forms of dichotomous fluctuations of nanoparticle potential energy. The results obtained clarify what distortions in the shape of the stepwise potential lead to the ratchet motion in one direction or another.

[1] V. M. Rozenbaum, I. V. Shapochkina, L. I. Trakhtenberg. Green's function method in the theory of Brownian motors. Physics Uspekhi 62, 496 (2019)
[2] V. M. Rozenbaum, T. Ye. Korochkova, I. V. Shapochkina, L. I. Trakhtenberg. Exactly solvable model of a slightly fluctuating ratchet. Phys. Rev. E 104, 014133 (2021).

Bound states in the continuum in non-Hermitian layered structures

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Bound states in the continuum (BICs) are localized nonradiating modes of open resonators providing numerous new effects and applications in modern nanophotonics. In this talk, I start with