QED Approach to Atoms, Ions and Nuclei in a Super Strong Laser Field. Nuclear Quantum Optics

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A consistent QED approach [1,2] is applied to studying the interaction of the atoms and ions of plasma with an super intense electromagnetic (laser) field. Method bases on description of atom in a field by the k- photon emission and absorption lines. The lines are described by the QED moments of different orders, which can be calculated with the use of the Gell-Mann and Low S-matrix adiabatic formalism (T=0). In relativistic version the Gell-Mann and Low formulae expresses an imaginary part of the energy shift Im E{a} through the QED scattering matrix, including interaction of atom with electromagnetic field and field of the photon vacuum. We present QED S-matrix energy formalism (T not equal 0) for calculation of the spectral lines shape in dense plasma. For any atomic level we calculate Im E{a}(w) as function of the laser pulse central frequency w (resonant curve). We calculate the moments for resonance, connected with concrete atomic a-p transition (a,p-discrete levels; k photons is absorbed). To calculate the moments we need to get the expansion of E{a} into the perturbation theory series. Numerical modelling carried out for H, Cs, Ar, Yb, Tm atoms and H-, Li- and Ne-like ions. QED approach to description of radiation atomic lines for atoms and ions in plasma is generalized on a case of the confined atomic systems. Modelling nuclear ensembles in a super strong laser field provides opening the field of nuclear quantum optics and is carried out in our work too. The direct interaction of super intense laser fields in the optical frequency domain with nuclei is studied and the AC Stark effect for nuclei is described within the operator perturbation theory and the relativistic mean-field (RMF) model for the ground-state calculation of the nucleus [3,4]. We find that AC-Stark shifts of the same order as in typical quantum optical systems relative to the respective transition frequencies are feasible with state-of-the-art or near-future laser field intensities.

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