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Relativistic ionization probabilities of hydrogenlike ions exposed to intense laser pulses

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Synopsis The relativistic intense-field ionization of heavy hydrogenlike ions is investigated. The investigation is performed by numerical solving of the time-dependent Dirac equation. The interaction of intense laser pulses with ions is considered beyond the dipole approximation. As an example, the ionization probabilities of the hydrogenlike tin ion exposed to a strong laser field are calculated.

In the nearest future, the development of experimental facilities will allow for carrying out investigations of heavy atoms and ions exposed to extremely intense laser fields. High photon energies and intensities of laser pulses enable to study relativistic effects of an ion-laser interaction. Novel facilities are able to produce short pulses with a peak intensity of 10^{21} W/cm^2 or even higher. For example, the High-Intensity Laser Ion-Trap Experiment (HILITE) is under construction at GSI (Darmstadt, Germany) and is planned to be performed by the SPARC collaboration [1]. The rapid development of laser technologies has triggered the theoretical investigations of one-electron ions exposed to extremely intense laser pulses [2, 3, 4, 5, 6].

Previously, we developed a method for treatment of hydrogenlike ions exposed to an intense laser field [7]. In that method, the interaction with the laser field was described in the electric dipole approximation. In the present work, the method has been extended beyond the dipole approximation. The vector potential of the laser field is represented by the multipole expansion, and dependence on the spatial coordinates is expressed through the spherical Bessel functions (SBF).

Using this method, we have calculated the ionization probability of the hydrogenlike tin ion (Z = 50) initially in the ground state and exposed to a 20-cycle pulse with the carrier frequency 100 keV and peak intensity 1.56×10^{22} W/cm^2. Fig. 1 shows the partial ionization probabilities into the states with different orbital quantum numbers l. In the figure, four curves are shown in which different values of L_{max} (1 to 4) are adopted. Here, L_{max} is the maximal order of SBF retained in the expansion of the vector potential. The curves show how convergence of the partial ionization probabilities with larger l is reached when the non-dipole terms of higher orders are included in the expansion. Additionally, the calculations of the total ionization probability are performed within the dipole approximation (DIP) and beyond it (BYD); the following results are obtained: $P_{DIP} = 3.1 \times 10^{-5}$ and $P_{BYD} = 3.9 \times 10^{-5}$. The 21% difference between the results demonstrates the importance of the non-dipole effects for the laser field frequency and intensity regime used in the calculations.

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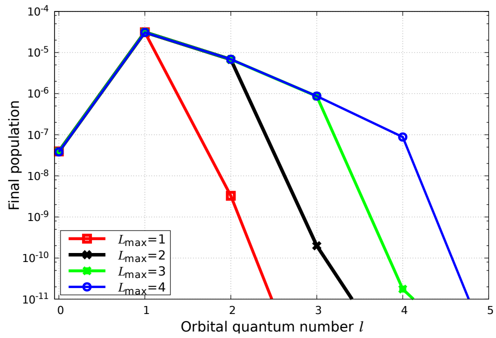

Figure 1. Final population of different continuum l-states for the hydrogenlike tin ion exposed to the intense laser pulse. L_{max} is the maximal order of SBF included in the calculations.

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