INFLUENCE OF DEEXCITATION PROCESSES ON THE DYNAMICS OF LASER-EXCITED ARGON CLUSTERS

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The excitation of atomic clusters by intense infrared laser pulses leads to the creation of highly charged ions and to the emission of energetic photons. These phenomena, which follow from ionization processes occuring in the cluster, depend significantly on the population of ground states and excited states in the laser-produced nanoplasma [1]. This makes it necessary to account for collisional excitation and deexcitation processes. We investigate the interaction of femtosecond laser pulses with argon clusters by means of a nanoplasma model. Considering laser-excitation with single- and double-pulses, we analyze the role of excitation and deexcitation processes in detail, and calculate the yield of highly charged ions and of energetic photons in different wavelength regimes. For clusters with initial radii $12 \leq R_0 \leq 35$ nm, the temporal evolution of different plasma parameters was simulated including the number density of the free electrons, the electron temperature, and the population of different ionic charge states. Special emphasis was placed on the effects stemming from the consideration of excitation and deexcitation processes, which are important in order to correctly describe the population of excited states and the asso- ciated photon emission. By taking these processes into account in an extended nanoplasma model, we calculated the photon yield from laser-excited clusters. After introducing the different physical processes of the model and their theoretical description – such as tunnel and collisional ionization, the lowering of the ionization energies, the heating, and the expansion of the cluster – numerical results for the ionization dynamics were discussed in the case of the ground state model, in which excited states were neglected. In a second step, excited states were incorporated in the model. To this purpose, individual energy levels were bundled into combined states within a simplified level scheme. Excitation cross sections were calculated and collisional excitation rates were found via an averaging with respect to the electron distribution function and over one laser cycle, whereas the rates for collisional deexcitation were obtained by means of a relation between excitation and deexcitation cross sections. It was found that with the inclusion of excited states, the ionization dynamics is accelerated, and higher ionic charge states are reached at the end of the laser-cluster interaction. The incorporation of excited states leads to a reduction of the electron temperature because the free electrons lose energy in excitation processes. Moreover, the free electron density is increased due to the enhanced ionization dynamics. For smaller clusters, a second Mie resonance is observed, resulting in a larger heating and a faster expansion. The population of ionic charge states is only slightly modified by deexcitation processes. However, these processes play an important role for the population of ground states and excited states, which in turn significantly determines the emission of radiation from laser-excited clusters. Within a double-pulse excitation scheme, a maximization of a certain ion yield was found to appear at a certain delay time in the case of a smaller pre-pulse followed by a larger main pulse. Here the inclusion of excited states resulted in a flattening of the curves, i.e., the region of "optimal" delay times was broadened. By assuming a Boltzmann distribution for the individual levels within the combined states, the emission of radiation was investigated. The photon yield from the excitation of outer-shell electrons was computed, and by introducing additional particle species with a K-shell vacancy, also the emission from inner-shell excitations was considered, showing a qualitatively good agreement with other theoretical as well as experimental results.

References

[1] M. Moll, M. Schlanges, Th. Bornath and V.P. Krainov, Influence of excitation and deexcitation processes on the dynamics of laser-excited argon clusters, Phys. Rev. A, Vol. 91, N 3, 033405 (2015)