Numerical investigation of the tri-atomic ions formation during laser ionization based on resonance saturation

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Abstract: Efficient ionization by resonance saturation has been observed in Alkali-metal vapor. This phenomenon has attracted the attention of many authors due to its importance in different fields such as astrophysics, plasma physics and photochemistry. Plasma generation induced by intense laser radiation under such conditions showed high efficiency when the laser wavelength corresponds to an absorption line of the ionized alkali-vapor. Such interaction involves many collisional ionization and excitation energy as well as radiative transfer processes. These processes find great importance in gas lasers, astrophysics and controlled thermo nuclear plasma. Accordingly in the present paper we present a theoretical investigation of plasma generation in sodium vapor induced by laser radiation tuned to the first resonance line (3s-3p) at λ=589 ns. In doing so a modified numerical model previously developed by Mahmoud and Gamal (1995) is applied. This model solves numerically a set of rate equations that describe the rate of change of the ground and excited states population as well as the temporal variation of the electron energy distribution function (EEDF), beside the formed atomic and molecular ions currents. In this model electrons are heated through, super elastic collision processes. The cross-sections and rate coefficients of the physical processes involved in this model are taken as a function of the electron energy. The model takes also into account electrons and energy loss processes. The modification involved introducing into the model new physical processes which lead to the formation of tri-atomic molecules. The equations are solved numerically using Runge-kutta fourth order technique. Computation are carried out first under the experimental conditions of Tapalian and Smith (1993) to test the existence of the formed tri-atomic ions. In this experiment a single effusive sodium atomic beam of densities $\approx 10^{12}\, atoms/cm^3$ interact a collimated CW laser beam at intensities up to $100 W/cm^2$. Then calculations are performed to find out the formed molecular ions as result of associative ionization and photo ionization processes. Secondly, a study is carried out to analyze the temporal evaluation of the EEDF, excited states population, atomic ions(formed through penning ionization ,electron impact ionization as well as photo ionization of the excited states) and molecular ions (formed through associative ionization , Hornbeck- molnar processes).This later processes are also involved during the formation of tri-atomic ions. An important finding of this investigation is devoted to the formation of tri-atomic ions. This process is found to have a noticeable effect on the generation of the seed electrons which are responsible to ignite the plasma generation.

References

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