

Experimental and Theoretical Investigations of Laser-Produced Plasma Dynamics

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An overview of the results obtained by the Lille and Iasi research groups over the last decade on the characterization of transient plasma plumes generated by ns-laser ablation is presented. Electrical (mainly Langmuir probe) and optical (fast gate intensified CCD camera imaging and space- and time-resolved emission spectroscopy) methods have been applied to experimentally explore the dynamics of the plasma plume and its constituents. Optically, the visible-emitting regions of the plasma form two structures with different lifetimes and expansion velocities. The results obtained by electrical probes are in good agreement with the optical observations. For example, in terms of the ionic current recorded by a Langmuir probe, the two-plasma structures are evidenced as two arrival times. The first part of the transient signal exhibits an oscillatory structure. In order to reproduce the experimental observations, a hydrodynamic model in a non-differentiable space-time has been established. By using the conservation laws of the particle number, momentum, and energy, the plasma expansion has been numerically simulated. The splitting of the plasma plume into two patterns has been successfully reproduced. The transient aluminum target currents recorded for various laser beam energies are also analyzed. The plasma splitting process and ion oscillations are in agreement with our previous probe measurements. Voltage–current dependencies confirm the existence of non-Maxwellian electron distribution through the hot and cold electrons.

New results are also presented along with this overview, regarding the characterization of the plasma produced by fs-laser ablation from pure metallic targets. Time dependence of Langmuir probe current and total collected charge are discussed in terms of a shifted Maxwell-Boltzmann distribution function, and from probe characteristics plasma temperature and average charge state are calculated. The analysis of current-voltage characteristics at various delays after the laser pulse gave access to the temporal evolution of ion density, electron temperature and plasma potential. Target materials of various physical properties (atomic mass, thermal constants) are used to find possible correlations with resulting plasma parameters.