Laser-generated transient carbon plasmas: peculiar dynamics evidenced by optical and electrical measurements

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Carbon plasmas produced by laser ablation have important applications in the synthesis of nanostructured materials of high current interest (nanotubes, nanowires, graphene) or the deposition of diamond-like thin films. Understanding the fundamental aspects of such transient plasmas in various experimental configurations is useful for optimizing these synthesis/deposition processes. We report here a comprehensive study on the dynamics of excimer laser produced carbon plasmas, including fast ICCD imaging, space- and time-resolved optical emission spectroscopy, Faraday cup ion current measurements, ablated crater depth profiling. A peculiar V-like shape [1] of the emitting plume is evidenced and explained by the interaction of three plasma structures originating in distinct irradiance areas of the laser spot on the target. The interaction of these structures is also thought to favor an enhanced carbon dimer production [2,3], mainly through three-body recombination, at distances significantly higher than previously reported in the literature, which can find technological applications for the efficient deposition of high-quality carbon-based nanostructures.

Using Ar as background gas [1], the increased collision rate allows extended (both spatially and temporally) spectroscopic investigations of the low-emitting axial region of the unusual V-shape transient plasma. The enhancement of the dimer formation in the lateral structures is confirmed and even amplified using background gas. Furthermore, temperature and electron density values have been estimated from the spectroscopic data, providing additional proofs for the validity of the plasma dynamics scenario built for this unusual plume shape.

The carbon ions were also studied by using an electrostatic energy analyzer: the ion current gains a multi-peak structure that is assigned with different types of ions and plasma structures [4]. The physical mechanisms of the separation process are discussed. Finally, we present the first observation of oscillations in the ionic and electronic currents at long distance (17.5 cm) from the ablation target [5]. An original signal processing approach based on the short-time Fourier transform allows unveiling fine details on the temporal evolution of the oscillation frequencies.

References

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