Optimization of laser plasma dynamics towards high order harmonic generation applications

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Synopsis This work investigates the differences in the plasma plume expansion dynamics on using a single pulse (SP) and double pulse (DP) scheme for generating plasma. The detailed investigation on the hydrodynamics would facilitate devising the picosecond (ps) laser produced plasma (LPP) for applications like high-order harmonic generation (HHG).

The plasma is generated using 60 ps laser pulses at 800 nm delivered from a modelocked Ti: Sapphire laser (Quantronix) focused to a spot size of $\sim$ 80 μm using a 500 mm plano-convex lens onto the surface of a 99.99 % pure 50 mm 50 mm 3 mm Al target (ACI Alloys Inc, USA) kept in nitrogen ambient at a pressure 10-6 Torr. Details of the experimental setup can be found elsewhere [1].
The plume dynamics has been recorded for various time delays (t_d s) up to 500 ns from 30 ns with 10% gate width (t_w) for energies (E_r) ranging from 100 μJ to 600 μJ using an intensified charge couple device (ICCD). The experiment is carried out for SP and DP schemes. Time of flight of the plume is analyzed to get similar information as in optical time of flight (OTOF) [2] measurements; except for the fact that current technique explains the total plume dynamics rather than a particular species as in OTOF. The plume comprises of two components, fast and slow where the slow components show larger intensities irrespective of E_r except for 100 μJ. It is also noted that the emission increases with energies for both fast and slow components. DP scheme has advantages over SP, in terms of emission from the plasma as well as the plume structure. DP has more angular spread showing a trend similar to nanosecond plasma while SP expansion resemble a fs plasma. Interestingly plume splitting is present for all DP cases, wherein it happens at large delays when compared with the SP case. Additionally, fast species are found with higher emission intensity when compared to SP. Emission counts is larger for DP schemes at 100 μJ-500 μJ, 200 μJ-400 μJ and 300 μJ-300 μJ compared to all other combinations. Fast species reaches distances up to $\sim$ 20 mm in most of the double pulse cases which is supported by the observation of emission from highly charged species at larger distances. This shows that fast species are mostly the highly charged species with larger velocities $\sim$ 40 km/s whereas the average velocity of slow species is found to be $\sim$ 5 km/s.

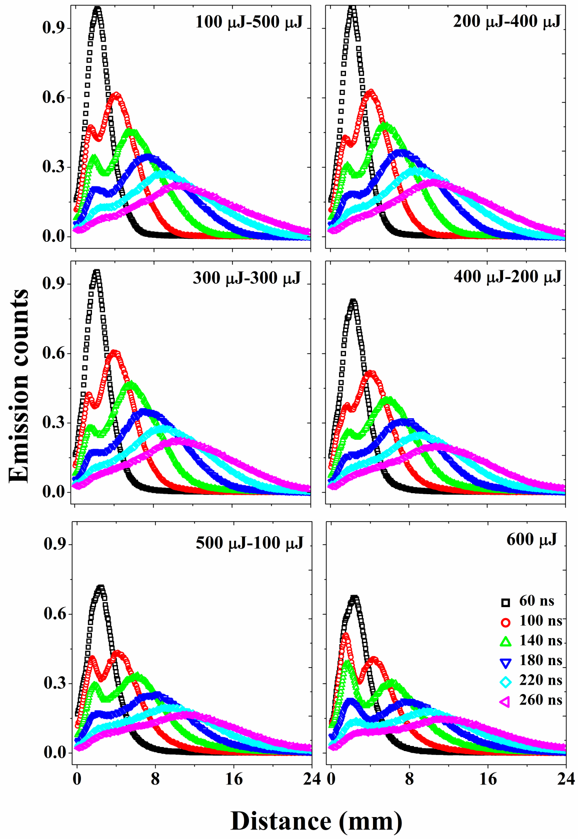

Figure 1. Emission counts for various delays for different energies. X μJ-X μJ indicate the DP scheme and X μJ indicate the SP scheme.

DP scheme shows a more spherical expansion of the plasma plume compared to the SP scheme. Spherical nature indicates more homogeneity in the plasma plume which would facilitate their use in applications such as HHG that requires phase matching conditions in the medium.

References

[1] N. Smijesh et al. (2016) *Physics of Plasmas* **23**(11) 113104

[2] N. Smijesh et al. (2013) *J. Appl. Phys.* **114**(9) 093301

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