Comparison of x-ray sources generated from sub-ps laser-plasma interaction on clusters and solid targets

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This is an investigation of the difference between the x-ray emission of nanometer cluster targets and that of solid targets, when they are irradiated by a sub-relativistic laser pulse [1]. Special effort is made to provide comparable conditions and observables and to emphasize the specific role of target geometry. The behavior of the x-ray-emission level with respect to the laser duration shows a clear difference between target types. In solids, the x-ray-emission level monotonically increases with respect to the laser pulse duration, while an optimal duration of a few hundred femtoseconds is evidenced in clusters. The x-ray duration is determined with a time-resolved x-ray-absorption experiment through a laser-heated copper sample [2, 3]. It is observed to be one order of magnitude shorter with clusters than with solid targets.

These results are interpreted by a geometrical effect. While a solid target provides a near-critical density area for a long time, where the laser energy can be efficiently deposited, a nanometer expanding cluster very efficiently absorbs the laser energy when the critical density is crossed. Then it quickly turns into under-dense plasma where the absorption is drastically reduced. In close correlation, the spherical hydrodynamic expansion of the cluster accelerates the drop in density and temperature, which shortens the x-ray emission.

This interpretation is corroborated with numerical simulations coupling a one-dimensional hydrodynamic code (plasma heating and expansion) with a collisional-radiative code (postprocessed x-ray emission). The behavior of the x-ray emission level with the laser duration is well reproduced by calculations, as well as the measured x-ray duration, including the ability to produce sub-picosecond x-ray pulses with clusters for time-resolved applications.

References

[1] F. Dorchies *et al*., Physical Review E **98**, 033212 (2018).
[2] N. Jourdain *et al*., Physical Review B **97**, 075148 (2018).
[3] F. Dorchies *et al*., Review of Scientific Instruments **86**, 073106 (2015)