Role of the laser wavelength in the X-ray production for clusters under intense laser pulses

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The generation of an X-ray source from the interaction of rare gas clusters with a femtosecond laser has received a special attention during the last decade. A series of experimental studies with intense (< a few 10^{17} W/cm²) and short (from 50 fs to 1 ps) IR (800 nm) laser pulses allowed us to determine precisely the evolution of the X-yield as a function of the laser intensity, the pulse duration and the cluster size. Those studies, performed with argon clusters, give access to the sub-ps dynamics of the heated clusters [1], showing, in particular, that the X-ray yield is directly related to the number of clusters experiencing laser intensity above a threshold value (I_{th}). This threshold, which corresponds to the creation of highly charged ions with inner shell vacancies, may reach unexpected low values (down to 10^{14} W/cm^2), and its evolution was found to be one of the key points in the optimization of the X-ray production.

Our last experimental campaign on the LUCA (French acronym for ultra short tunable laser) facility was dedicated to the influence of the laser wavelength (λ) using this time 400 nm pulses. Largely discussed in the literature from a theoretical point of view [2], the impact of λ on X-ray emission has been barely studied experimentally. It is worth mentioning that producing well defined laser pulses at 400 nm, from 60 to 800 fs, and keeping a sufficiently high energetic flux (i.e. > 10 mJ) has required to face a technological challenge. Overcoming this issue, we have determined the X-ray yield as a function of laser intensity for different pulse durations at 800 nm and 400 nm leading to the precise evolution of I_{th}. Those complete investigations demonstrate for a significant difference in the evolution of I_{th} which leads to different behaviors of the X-ray yields with pulse duration when the laser energy is kept constant: at 400 nm, the X-ray yield decreases over the whole range of pulse durations from 60 fs, while a maximum at 130 fs is observed at 800 nm. A clear correlation between the behavior of I_{th} with pulse duration and the optimum heating time is thus enlightened. Moreover, a saturation of I_{th} at long pulse duration is observed for both wavelengths underlining that the ignition process in the X-ray production is indeed the production of Ar^{1+} around 10^{14} W/cm² which triggers the inner-shell ionization dynamics of highly charged Ar ions.

Finally, all the parameters governing the laser-cluster interaction being under control, the laser light at 400 nm is found to be not more efficient than 800 nm to produce X-rays in the keV range, in contrast to what has been reported for Xe clusters where a λ^{-6} dependence has been revealed [3].

References:
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