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Correlation between X-ray yield and electron spectra in laser-cluster interaction

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Synopsis Measurements of electron energy distribution obtained for several experimental conditions show evidence for a strong correlation between X-ray yields and the high energy part of the electron spectra in laser-cluster interaction.

A fascinating feature in laser-cluster interaction is the production of keV X-rays even, at low IR laser intensity (< a few 10^{15} W/cm²) [1]. These results have demonstrated that a very efficient heating mechanism occurs on a very short time scale (before the cluster disintegration) producing electrons with energy higher that the inner-shell binding energy of the cluster atoms (E ≥ 4keV in the case of Argon clusters) [2, 3]. Spectroscopy techniques for both X-rays and keV electrons are thus two complementary tools to probe the dynamics of this interaction on a femtosecond time-scale.

It is worth mentioning that by changing the laser intensity, one can gain insight on the electron heating mechanisms, while tuning the laser pulse duration reveals the competition between those heating mechanisms and the cluster expansion [3]. We have already demonstrated that the X-ray yield is controlled by two factors: i) the number of emitting clusters, proportional to the effective focal volume and ii) the number of X-rays emitted per cluster, driven by the single cluster dynamics, in which electron heating mechanisms and ionic motion (responsible for cluster expansion) guide the inner-shell ionization probability. In particular, the observed pulse duration maximizing the X-ray emission is completely explained by the interplay between the growing number of X-rays produced per cluster and the decreasing number of emitting clusters when increasing the pulse duration [3].

Recently, we have improved our experimental set-up by adding an electron spectrometer to perform systematic studies with both type of spectroscopy under the same experimental conditions. We found that for two specific pulse durations (50fs and 180fs) for which the X-ray yield is the same, the electron energy distribution is quantitatively equivalent as shown by triangles and circles on figure 1. Conversely, when the X-ray yield (N_X) is divided by a factor of 3, for a longer pulse duration (1100fs), we clearly observe a strong reduction in the emission of energetic electrons (>4keV) on the electron spectrum (squares on figure 1). These preliminary results show evidence for a strong correlation between the X-ray yields and the high energy tail of the kinetic electron distributions and reinforce the scenario of the interaction dynamics proposed in a recent theoretical model developed by J. Burgdörfer et al. In these mean-field Monte-Carlo simulations, energetic electrons are produced by the combined effects of the charged cluster's monopole field and the laser field enhanced by the polarization of the cluster [3,4].

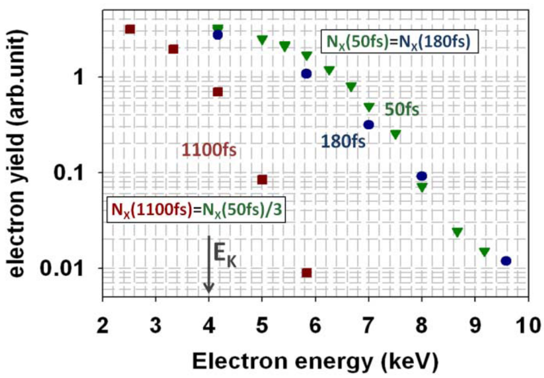

Figure 1. Electron energy distribution for 50fs (triangles), 180fs (circles), 1100fs (squares) laser pulse durations at 25mJ and for argon clusters ($N=2.10^5$at/cluster)

If the heating mechanisms are now quite well understood, the ionic motion is not yet implemented properly in the simulations while it plays a major role for long pulse duration. The new results, combining X-ray and keV electron spectroscopy, obtained as a function of intensity, polarization and pulse duration of the laser should provide new clues on the physics of clusters under intense laser field.

Further investigations of the electron heating efficiency within a cluster are currently under progress by shortening the laser wavelength (switching from 800 to 400 nm).

References

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