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Explosion of gaseous-clusters upon coupling of intense femtosecond laser pulses

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An interesting construction of laser-based table-top sources of energetic electrons, and ions require the efficient coupling of the incident (usually 800 nm) laser light with atomic cluster. The ions inside such clusters typically acquire higher charge states than expected from a single, isolated atom in the same laser pulses [1]. We have performed theoretical investigations on the dynamics of atomic clusters ($\sim Xe_{100} \cdots Xe_{10,000}$) exposed to intense laser pulses, and compared various existing experimental results with, (i) analytical model describing real experimental situation, and (ii) microscopic classical simulation for electrons and nuclei by taking into account their inter-particle interactions [2].

One of the important observable that usually probed in experiments on atomic and molecular clusters exposed to strong laser pulses [1, 3] is the kinetic energy distribution of ions. There are analytical models that have been proposed to understand the cluster explosion due to laser coupling [4, 5], but proper explanation of ion-energy spectrum is itself an area of interesting current research. We have done microscopic calculations to investigate such ion-energy spectra using single clusters (see

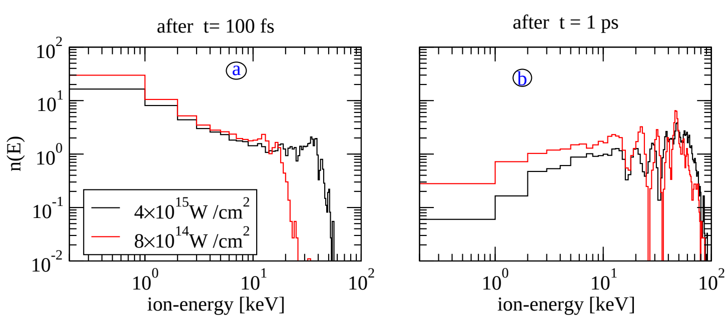

Figure 1: (a): Kinetic energy distribution of ions at the end of laser pulse. (b): Kinetic energy distribution of ions for long propagation, i.e., $t = 1$ picosecond, for Xe_{9093} clusters. The pulse length for both the propagations is 100 fs. Laser intensities are shown in the legends box.

Fig. 1). Figure 1(a), shows kinetic energy spectra after the pulse is over. Nearly identical spectra have been observed in the MPIC calculations [5] for a single cluster for a pulse length of nearly 100 fs. But this behavior changes towards lower energy regimes for longer propagations ($t \sim 1$ ps), when the pulse length is 100 fs. This particular behavior is shown in Fig. 1(b). These results do not explain the experimental results by considering a single cluster; neither in our microscopic calculations nor in MPIC calculations [5]. The reason is not improper theoretical modeling but the experimental scenario. Therefore, we have developed an analytical model which nicely explains such ion-energy spectra for the first time [6]. In this model the kinetic energy distribution of ions emerging from a cluster target illuminated by an intense laser pulse arises from three main effects: Firstly, the spatial profile of the laser beam, secondly, the cluster size distribution which is log-normal and thirdly, possible saturation effects in the cluster ionization. Under these considerations, we have the final kinetic energy distribution of ions (KEDI)

$$\frac{dP_{\rm sat}(\eta)}{d\varepsilon} = \frac{dP_{\rm both}}{d\varepsilon} - \ln\eta\,\frac{dP_{\rm size}}{d\varepsilon}\,, \tag{1}$$

where η is saturation parameter, ε is the characteristic scaled energy, $\frac{dP_{\rm both}}{d\varepsilon}$ is the energy distribution due to inclusion of cluster-size distribution and laser focus, and $\frac{dP_{\rm size}}{d\varepsilon}$ is the ion-energy distribution due to saturation of charging in the laser focus. We begin with experiments [3] on molecular clusters $(N_2)_N$

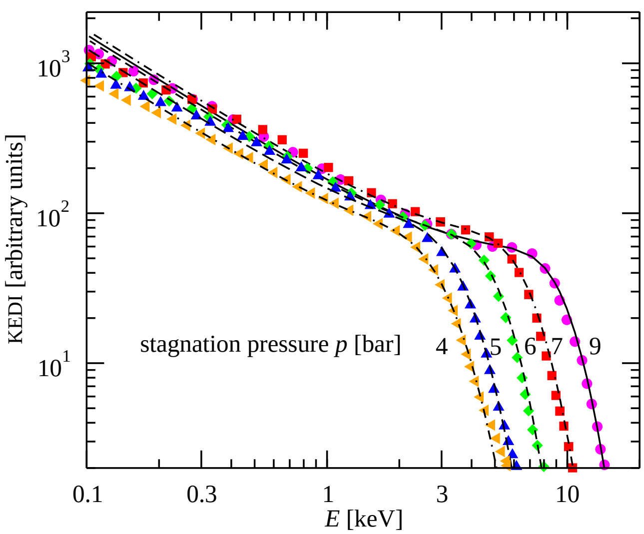

Figure 2: Ion energy spectra according to Eq. (1), shown by *lines*, fitted to experimental data [3], shown by *color/gray symbols*. Different stagnation pressures p correspond to different cluster sizes N_0.

for $N \approx 300\ldots3000$, since these data set provides a systematic study for changing the stagnation pressure p, i. e., different (median) cluster sizes N_0 (see Fig. 2). We have fitted the KEDI from Eq. (1) to each of the experimental data sets, and observe an excellent agreement. Our model reveals that each of these effects leaves a characteristic fingerprint in the ion kinetic energy spectrum, and allows one to link quantitatively experimental spectra to typical theoretical single-cluster results [6].

References

[1] T. Ditmire *et al*, Nature **386**, 54, (1997).

[2] U. Saalmann and J. M. Rost, Phys. Rev. Lett. **91**, 223401, (2003).

[3] M. Krishnamurthy, D. Mathur, and V. Kumarappan, Phys. Rev. A **69**, 033202 (2004).

[4] V. P. Krainov and M. B. Smirnov, Phys. Rep. **370**, 237 (2002).

[5] C. Jungreuthmayer *et al*, Phys. Rev. lett. **92**, 133401 (2004).

[6] Md. R. Islam and U. Saalmann and J. M. Rost, Phys. Rev. A **73**, 041201 (R), (2006).