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Ultrafast processes and single shot imaging of clusters with intense soft x-ray radiation from the FLASH free electron laser

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For many potential experiments with free electron lasers it is of fundamental importance to study how the absorption and ionization properties of nanoscale systems develop in the short-wavelength strong-field domain. For such investigations, atomic clusters are ideal targets as hidden energy dissipation into surrounding media is virtually absent. We have performed first experiments about the soft x-ray laser pulse - cluster interaction with a combined spectroscopy and imaging approach. The new data show qualitatively different processes for (soft) x-ray pulses from the optical strong field regime. Electrons are emitted from the clusters in a direct multistep photoionization process and plasma type absorption is not significant. Resonant excitation of Xe clusters at 90 eV and power densities exceeding 10^{14} W/cm^2 yield high charge states of up to 9^+. The investigation of core - shell gives evidence for efficient charge redistribution within the cluster, leading to explosion of the cluster outer layers and recombination of the nanoplasma core. For single-shot imaging of clusters with intense short wavelength radiation a new detector system has been developed. Mie calculations indicate that the optical constants of the clusters, which are inherently coupled to its electronic structure and thus charge states, change during the femtosecond pulse. The results show that ultra fast scattering is a promising approach to study transient states of matter on a femtosecond time scale.