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Ultrafast imaging of nanoclusters with intense x-ray laser pulses

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Ultrafast x-ray scattering opens the door for unprecedented insight into the structure and dynamics of matter with atomic resolution. Any sample in an x-ray laser flash, however, will be converted into a highly excited, non-equilibrium plasma during the pulse. The scatter signal itself is sensitive to changes in the electronic structure of the sample leading to distortions of the signal intensities with respect to the ground state configuration. On the other hand, the information about the electronic structure carried by the scatter signal can be exploited to gain insight into transient electronic states on the femtosecond time scale of the x-ray pulse. We have performed single shot – single particle scattering experiments on clusters to investigate the interplay between excitation and scattering in nanoscale objects with x-ray pulses from both, the FLASH and LCLS free electron lasers. Atomic clusters have been proven ideal to investigate the interaction between intense light pulses and matter in a wide spectral regime from the infrared to x-rays due to their finite size and simple electronic structure. Spectroscopy data recorded in coincidence with the scattering patterns revealed strong power-density dependent ionization dynamics of the clusters. The scattering patterns themselves provide information on the 2-dim as well as 3-dim structure of clusters and of cluster ensembles. Modeling the scattering patterns indicates that the optical constants of the clusters, which are inherently coupled to its electronic structure and thus charge states, change during the femtosecond pulse. Time resolved experiments with pump – probe techniques have started which allow following the time evolution of cluster ionization up to several ps.