Nanoplasma formed by an ultrashort hard x-ray pulse in Xe clusters

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Synopsis Recent studies revealed that nanoplasma is formed when an XFEL pulse interacts with any nano-object, but the formation process itself has never been decrypted and its time scale was hitherto unknown. With the help of improved time-resolved ion methodology using a near infrared laser pulse as probe, we studied the early stage of the process. We observed a surprisingly fast population (~12 fs), followed by a slower depopulation (~310 fs) of highly excited atomic fragments generated in the process of nanoplasma formation. Inelastic scattering of Auger electrons and interatomic Coulombic decay are suggested as the key mechanisms responsible for the population and depopulation of these states, respectively.

The understanding ultrafast reactions induced by X-ray Free Electron Laser (XFEL) pulses is of fundamental interest, and of crucial importance for the use of XFEL pulses for structural determination studies. Recently, it was reported that a nanoplasma is formed when an atomic cluster is irradiated by an XFEL pulse in the hard X-ray regime [1]. We conducted a femtosecond time-resolved study on the nanoplasma formation from a Xe cluster irradiated by an intense XFEL pulse.

In the present experiment, Xe clusters with an average size of 5000 atoms were irradiated by XFEL pulses (5.5 keV, 10 fs FWHM) at SACLA. A NIR-probe laser (800 nm, 32 fs FWHM) was used for further ionizing the excited Xe atoms created in the early stages of the nanoplasma formation. The Xe^{1+} yield (the dominant ion fragment) was measured as a function of the time delay between the XFEL-pump and the NIR-probe pulses. We used an arrival timing monitor [2] for measuring the temporal jitter between the XFEL and the NIR pulses on a shot-to-shot basis, and therefore improved the time-resolution of the pump–probe experiment down to a few tens of femtoseconds.

The results revealed an ultrafast population (~12 fs) and depopulation (~310 fs) process of excited states of the Xe atoms in the cluster during the nanoplasma formation. The measured time-constants suggest that electron collisions and interatomic relaxation processes [3] are among the primary mechanisms responsible for nanoplasma formation upon irradiation with intense hard X-rays.

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References

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