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Imaging the structure and dynamics of helium nanodroplets with intense X-ray pulses

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The intense coherent X-ray pulses from short-wavelength Free-Electron Lasers (FEL) have opened up the possibility to take "snapshots"of individual free-flying nanoparticles with Coherent Diffraction Imaging (CDI), without the need to fix the samples on a substrate. In a single irradiation, especially fragile, short-lived or unique nanoscale structures, such as single viruses, aerosols, and even superfluid helium nanodroplets can be made visible. Following the pioneering experiments on helium nanodroplets with xenon decorated vortices by the Vilesov group [1] a vivid research field has evolved around the morphology of helium nanodroplets and embedded dopants in presence or absence of quantum vortices. We have contributed to this new research direction with clarifying the three-dimensional shapes of helium nanodroplets [2] and determining the onset of vortex formation in helium droplets from gas expansion [3].

The femtosecond snapshots taken with single-shot single-particle CDI make the method also ideally suited for resolving changes in nanoparticles in time and space after irradiation with an optical laser pulse. We have recently found that doped helium droplets undergo strongly structured fragmenting due to dopant-induced plasma ignition [4].

Even ultrafast changes in the electronic properties, e.g. through ionization are imprinted in the coherent diffraction patterns [5], especially when near-resonant wavelengths are used for probing. But the temporal evolution of such ultrafast alterations could not be investigated with the typical pulse durations of tens or hundreds of femtoseconds. In this regard, the current advent of intense few-femtosecond and sub-femtosecond pulses from X- FELs and high-intensity laser-based High Harmonic Generation (HHG) is opening up new pathways towards resolving electron dynamics in nanoscale matter in time and space.

References

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