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New routes to imaging the classical and quantum dynamics of finite systems

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When compared to atoms and solids, the collective and correlated electron dynamics in finite systems under intense light fields can be substantially modified, enhanced and controlled by local near-fields [1-3]. Near-fields result from electronic polarization and charge separation can unfold on femtosecond or even attosecond time scales [4]. In this talk, two novel routes for characterizing the classical and quantum aspects of the underlying light-matter interactions at the nanoscale will be discussed. Though being fundamentally different conceptually, both schemes have come in reach with current short-wavelength FEL sources providing multicolor pump-probe pulses with exquisite control over the timing.

The first scenario – the "nanoplasma oscilloscope" – is motivated by previous theory work [5-7] on the XUV ionization of clusters and aims at tracing the complex evolution of space-charge potentials in laser-illuminated nanostructures. Such information is inaccessible with scattering methods such as coherent diffractive imaging but important for the understanding of non-linear plasma formation dynamics, radiation damage and relaxation processes in finite systems. Preliminary experimental data from a recent beam time at FERMI and the related theoretical analysis will be discussed.

The second scenario – the "quantum coherent diffractive imaging" (QCDI) - aims at exploring the non-linear response of extended nanosystems through near-field driven coherent quantum dynamics. A promising route to tracing spatiotemporal population dynamics is the analysis of respective signatures in single-shot diffraction images. We simulated the nonlinear response of Helium droplets under resonant 1s-2p excitation as a model using a coupled quantum-electromagnetic simulation based on a few-level approximation and utilizing the finite-difference time-domain method. The nonlinear modifications of the diffracted field through coherent bound state dynamics will be presented [8]. Our results illustrate the potential for spatiotemporal characterization of collective excitation dynamics in nanosystems and motivate new metrologies in the emerging field of quantum coherent diffractive imaging, paving the way into the realm of attosecond quantum imaging.

References:

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