Time-resolved nanospectroscopy in an ultrafast Transmission Electron Microscope based on a laser-driven cold field emission source

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The advent of ultrafast Transmission Electron Microscopes (UTEM) has brought about new techniques either to tailor the free electron pulses used in UTEMs (photon gating, coherent control using multicolor phase-locked optical fields) or investigate the optical excitations of nanosystems in the energy domain [1-5]. Photon-Induced Near-field Electron Microscopy (resp. Electron Energy Gain Spectroscopy) allows mapping the spatial (resp. spectral) distribution of optical near-fields confined in the vicinity of dielectric discontinuities such as the surface of nano-objects for instance. The ability to easily synchronize ultrashort free electron pulses with the optical excitation of the sample in UTEMs is essential for the observation of strongly nonlinear electron/photon interactions. The investigation of the optical response of densely packed semiconductor nanostructures in time-resolved cathodoluminescence with good signal to noise ratio requires high brightness ultrashort electron pulses to maximize the CL yield from nanoscale regions of the sample. Therefore, high brightness femtosecond electron sources are essential for state of the art nanospectroscopies as they maximize the number of electrons in real space, momentum space and time.

In this context, we have developed a UTEM based on a laser-driven cold field emission source that generates ultrashort, high brightness electron pulses at a tunable repetition rate. Electron emission is obtained by tightly focusing a femtosecond laser beam inside the electron source of a CFEG-TEM. Light injection and collection from within the objective lens is achieved with a high numerical aperture by means of an optical set-up involving a parabolic mirror and a dedicated detection system.

We will report on this new kind of UTEM and first illustrate its potential on PINEM experiments. These experiments will enable us to characterize the spectro-temporal properties of the ultrashort electron beam generated by the laser-driven CFEG. Second, time-resolved cathodoluminescence on confined semiconductor nanostructures will be reported showing the potential of the instrument for the investigation of closely packed light emitters.

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