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Ultrafast Transmission Electron Microscopy and its Nanoplasmonic Applications

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Understanding matter at the dynamic and microscopic levels is fundamental for our ability to predict, control and ultimately design new functional properties for emerging technologies. Reaching such an understanding, however, has traditionally been difficult due to limited experimental methodologies that can simultaneously image both in space and time. Ultrafast transmission electron microscopy (UTEM), a newly emerging field, offers the means to overcome this limitation by merging the femtosecond domain of pulsed lasers with the nanoscale domain of transmission electron microscopes. With UTEM, it is possible to capture ultrafast events in real space, diffraction and even spectroscopy.

In this particular contribution, we emphasize the plasmonic imaging capability of UTEM in space and time. Localized electric fields that are induced optically exhibit unique phenomena of fundamental importance to nanoplasmonics. UTEM enables direct visualization of these fields as they rise and fall within the duration of the excitation laser pulse (few hundreds of femtoseconds) with several nanometers of spatial resolution. This imaging approach is based on an inelastic photon-electron interaction process, where the probing electrons gain energy equal to the integer multiple of the photon quanta (2.4 eV in these experiments). This new phenomenon in electron energy loss spectroscopy and its fundamentals will be discussed. Furthermore, images, and movies, of plasmonic near-fields of particle dimers, nanoparticles with different sizes and shapes, particle ensembles and standing-wave plasmons at the step edges of layered-graphene strips are presented. These results establish UTEM as a tool with unique capabilities to approach nanoplasmonics.

Primary author: Prof. YURTSEVER, Aycan (INRS-EMT)

Presenter: Prof. YURTSEVER, Aycan (INRS-EMT)

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