Unraveling the ultrafast real-space dynamics of near-fields in low-dimensional nanosystems

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Understanding the ultrafast evolution of low-dimensional materials under non-equilibrium conditions plays a fundamental role in deciphering the mechanism governing chemical and physical functions. Real-space visualization provides an invaluable information for a design and engineering of new generation nanoscale ultrafast devices. Of particular need in a direct visualization are plasmonic devices, used for molecular sensing, electro-optical conversion and non-linear optics, as they rely on a subtle spatial distribution of quickly-evolving and plasmonic fields.

Although an enormous effort has been devoted to the comprehension and improvement of these materials and devices, the capability of investigating their dynamic behavior is hindered by the difficulty of simultaneously studying their evolution in space and time at the appropriate scales. The traditional characterization techniques and the steady-state theoretical models are both not adequate for describing their non-equilibrium behavior. Instead, a novel approach for visualization of matter with high temporal and spatial resolutions, together with momentum and energy selection, is indispensable to fully exploit their potential.

Ultrafast electron microscopy (UEM) has been recently developed with the capability of performing time-resolved imaging, diffraction and electron-spectroscopy [1]. The high scattering cross-section for electron/matter interaction, the high spatial resolution (down to the atomic scale), the ultrafast temporal resolution and the high energy selectivity of UEM represent the key elements that make this technique a unique tool for the dynamic investigation of surfaces, interfaces and nanostructures.

In this contribution, we will address a plasmonic visualization capability of the near-field variant of UEM, called Photon-Induced Near-Field Electron Microscopy (PINEM). In particular, we will concentrate on the multi-pulse approach, which allows to significantly improve temporal resolution. By virtue of multi-pulse PINEM it is now possible to visualize and control the dynamics of the plasmonic near-field dynamics with nanometer spatial and sub-femtosecond temporal resolutions.

References

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