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Ultrafast nano-optics: Surface plasmon polariton dynamics in metallic nanostructures and novel electron sources

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Ultrafast nano-optics is a novel and rapidly developing research area, focusing on the imaging, manipulation and control of optical fields on nanometer length scales. In my talk, I will give an introduction into the field and discuss two specific, recent research topics in this area.

In the first part, I will try to demonstrate how spatially and temporally highly resolved optical techniques allow for unraveling some of the unusual and unexpected optical phenomena in metallic nanostructures, such as, e.g., the controversially discussed enhanced transmission of light through periodic arrays of nanoholes in metal films [1]. A series of recent experiments [2,3] shows that a detailed microscopic understanding of the spatio-temporal dynamics of surface plasmon polaritons is of key importance for clarifying the underlying physical phenomena.

This knowledge will be used to demonstrate a novel quasi-point-like electron source with a time resolution of only about 10 fs. The key idea is to make use of local optical field enhancement at the apex of ultrasharp metal tips with radii of curvature of only few tens of nm. By illuminating ultrasharp gold tips with 7-fs pulses from an 80 MHz Ti:sapphire oscillator we could recently demonstrate [4] the emission of an intense flux of up to 10^7 electrons per second from a nano-spot not more than a few tens of nm in diameter. By probing the intensity dependence of the electron yield as a function of tip bias voltage, we show that these electrons are generated by multiphoton-excitation from a highly nonthermal transient electron distribution within the metal tip. Since we observe pronounced electron signals even in the absence of bias voltages, we can directly use these tips for tip-enhanced near-field electron imaging. First successful experiments demonstrate near-field imaging of local electric fields with about 20 nm spatial resolution. The potential of this new electron source for attosecond science and ultrafast electron diffraction will be discussed.

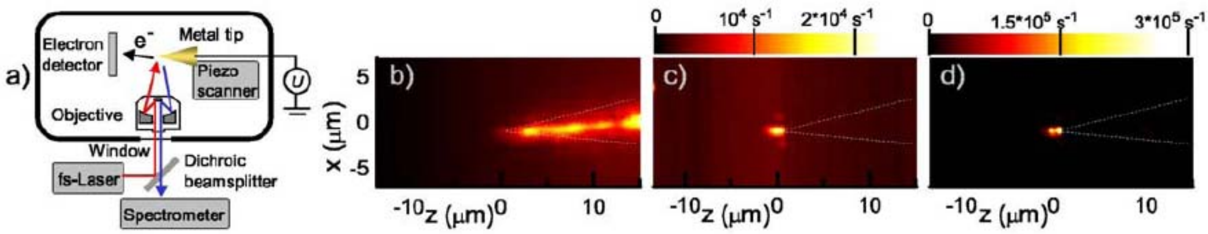

Fig. 1: (a) Schematic of the experiment. (b) Spatial scan of the fundamental laser light backscattered from a sharp gold tip (indicated by the dotted lines). The scattered light is imaged by moving the tip through the focus of the femtosecond laser, spectrally resolving the scattered light in the far field. (c) Nonlinear second harmonic and continuum generation localized at the very end of the tip . (d) Simultaneously recorded electron emission.

[1] T. W. Ebbesen et al., Nature 391, 667 (1998).
[2] C. Ropers et al. Phys. Rev. Lett. 94, 113901 (2005).
[3] K. G. Lee *et al.*, Nature Photonics 1, 53 (2007).
[4] C. Ropers, D. R. Solli, C. P. Schulz, C. Lienau, and T. Elsaesser, "Localized Multiphoton Emission of Femtosecond Electron Pulses from Metal Nanotips", Phys. Rev. Lett. 98, 043908 (2007).