Sub-femtosecond Electron Transport in a Nanoscale Gap

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A nanoscale gap between two metallic nanoparticles is an ideal platform to exploit the interplay between electron currents and photonic excitations. The capability of the metallic gap to enhance the amplitude of the induced plasmonic field produces a variety of non-linear effects [1] which can be exploited in different applications of optoelectronics, such as optical rectification, light emission driven by DC currents, or high-harmonic generation, among others. Furthermore, in ultranarrow gaps, tunneling of electrons at optical frequencies has been found to screen the plasmonic bonding gap resonance, and activate a new distribution of optical modes characterized by optical charge transfer [2].

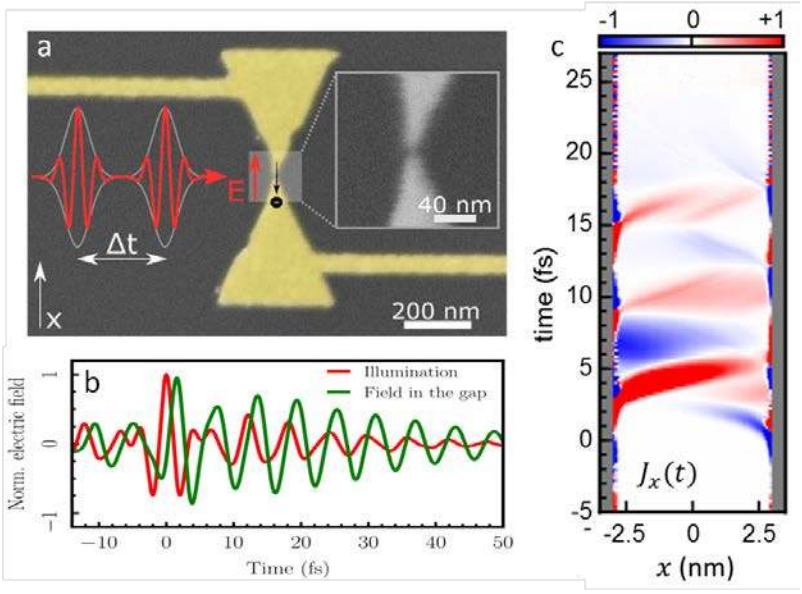

Figure: (a) Experimental set up. (b) Incident (red) and induced (green) single-cycle optical pulses. (c) Calc. of electron current within the gap.

Here we address the complex dynamics of photoelectrons driven by single-cycle optical pulses in nanoscale gaps (see panels a and b in the figure). By solving the Schrödinger equation within the framework of Time-Dependent Density Functional Theory (TDDFT), the currents of the electrons photoemitted across the gap can be monitored, identifying ultrafast electron bursts where electron quiver occurs when the amplitude of the induced field at the plasmonic gap is reversed within the optical cycle (see panel c in the figure). The properties of the amplitude and carrier-envelope phase (CEP) of the incident pulse, together with the gap length determine the complex electron dynamics [3]. Experimental measurements of the current autocorrelations for pairs of such pulses with controlled relative delay between them, confirms the ultrafast dynamics of the photoelectrons in the gap and its complexity [4].

References:

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[2] K.J. Savage *et al*., Nature **491**, 574 (2012).
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[4] M. Luwig *et al*. Nature Physics (2020).