Carrier-Envelope-Phase Sensitive Interferometric Autocorrelations by Coherent Nanotunneling

Markus Ludwig(1), Tobias Rybka(1), Felix Ritzkowsky(1), Alfred Leitenstorfer(1), and Daniele Brida(1)
(1) Department of Physics and Center of Applied Photonics, University of Konstanz, D-78457 Konstanz, Germany, e-mail:daniele.brida@uni-konstanz.de

Recently we demonstrated that single-cycle pulses of minute energy content can still be exploited for driving extreme optical phenomena at the nanoscale. In particular we employed a gold circuit displaying a nanoscopic gap at the tip of a nanoantenna. The strong electrical bias provided by the field contained in ultrashort optical pulses was harnessed to drive the tunneling and the ballistic acceleration of electrons to generate a current through the free space gap with PHz bandwidth [1]. This non-perturbative process is fully coherent with the driving radiation and occurs within half-cycle of the near-IR carrier wavelength. In this work we exploit this concept for interferomeric autocorrelation measurements performed by acquiring the current driven by two identical replicas of the single cycle laser pulse. The pulses are set at a variable delay in a Mach-Zehnder type interferometer and then focused tightly onto the nanocircuit equipped with a single bow-tie plasmonic nanoantenna. The electronic currents resulting from the nanotunneling are measured as a function of delay and carrier-envelope-phase of the pulse pair.

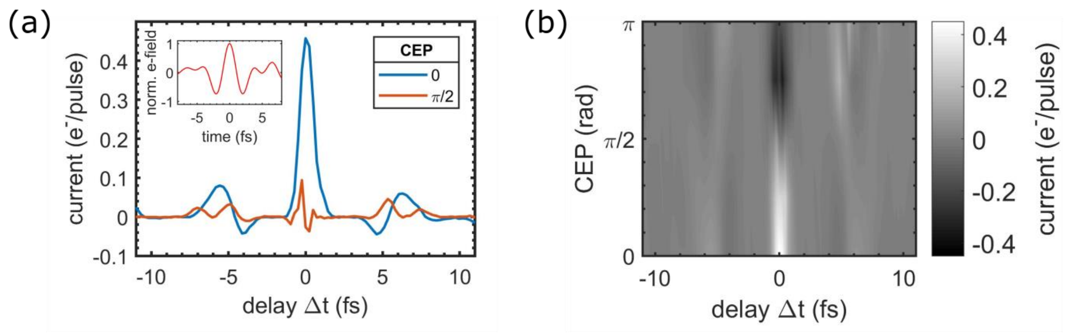

Figure 1. Carrier-envelope phase sensitive autocorrelation measurement. (a) Autocorrelation traces as a function of time delay Δt measured for a carrier-envelope phase of 0 (i.e. cosine-like pulses), corresponding to maximum total current, and π/2 (sine-like pulses). Inset: temporal profile of the pulses used in the experiments as characterized by two-dimensional spectral shearing interferometry. (b) Color map of nanotunneling current as a function of delay between the two driving pulses and as a function of their carrier-envelope phase.

In detail, we have performed interferometric autocorrelations that exploit the electric currents coherently driven at the gap of a single nanodevice (Figure 1). These measurements are performed in an extremely nonlinear regime that is achieved even at the minute pulse energies of few pJ. Despite this unusual regime for high field phenomena, we can still directly reconstruct the temporal profile of the driving pulses with the additional achievement of employing a carrier-envelope-sensitive technique. In the future we aim to apply this method to a regime of transport where multiple electrons are transported within a sub-cycle of optical radiation with the capability of observing correlation effects due to the extreme confinement of the ultrafast currents at nanometric dimension and sub-cycle timescale.

1. T. Rybka, M. Ludwig, M. F. Schmalz, V. Knittel, D. Brida und A. Leitenstorfer, "Sub-cycle optical phase control of nanotunnelling in the single-electron regime", *Nature Photon.* **10**, September 2016, pp. 667–670, doi:10.1038/nphoton.2016.174.