Final Report

Final Publishable Summary Report:

The project NANOULOP aimed to combine nano-scale materials engineering with attosecond spectroscopy in order to explore novel ultrafast electronic phenomena. The long-term goal of the project was to extend the applicability of nanomaterials to attosecond pump-probe spectroscopy in order to provide a detailed understanding of fast electron dynamics in specific nanostructured devices.

First, the feasibility of injecting and controlling electric signals with optical pulses inside a dielectric on a femtosecond timescale was demonstrated. This allows for driving, directing and switching electric currents by the instantaneous light field inside a nano-patterned dielectric structure at an unprecedented timescale. The reported process can be used as a solid-state phase detector for monitoring the carrier-envelope phase (CEP) of the applied laser pulses (Fig.1.).

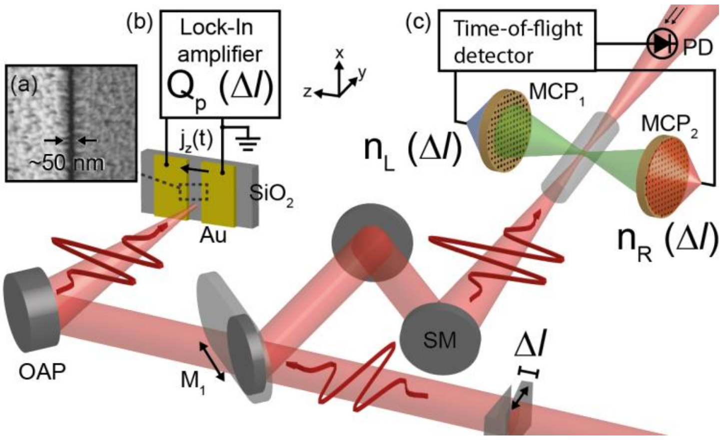

Figure 1. Measurement of the absolute carrier-envelope phase of light pulses by optical-field-induced electric currents in a solid state device.

The future of technical devices highly relies on the control design of the building blocks by means of their size, energy efficiency, electro-responsiveness, and other material properties. In this regard, nanosheets are ideal model systems to investigate phenomena in two-dimensional systems because they can be fabricated in many lateral sizes and various morphologies. Up to now, much attention has focused on graphene nanosheets for their potential in applications. On the other hand, the inorganic oxide nanosheets are also promising materials for various photonic devices, including photocatalysis, photoluminescence, photoconductivity, photonic crystal as well as for electronic and spin-electronic applications. In this regard, the fellow also contributed in the following projects:

- *Raman Spectroscopy studies on single luminescent nanosheets:* The fellow investigated luminescent inorganic oxide nanosheets including GdEuTaO (green), EuTbTiO (red) and BiSrTaO (blue) in terms of Raman spectroscopy and electroluminescence measurements. The confocal Raman spectroscopy allows monitoring of electron-phonon coupling in a single nanosheet. The project also focuses on the influence of the geometry of a single nanosheet and the number of sheet layers to the Raman spectra. The fellow collaborated with the "Matsumoto Group" from Kumamoto University, Japan for the syntheses of luminescent nanosheets and the "Hybrid Nanosystems - Nanoscale Optoelectronics Group" from Walter Schottky Institute for the Raman spectroscopy measurements.

- *Lithographic Studies of Micro and Nano Structures on Dielectrics/Semiconductors:* The project aims to create and evaluate metaldielectric and metal-semiconductor interfaces in different geometries for the studies of optical-field-induced currents in the respective interfaces. Optically injected and controlled electronic signals in a semiconductor on a similar timescale were compared with the results from silicon dioxide. The project was conducted within the on-going collaboration with Max-Planck-Institute of Quantum Optics.

- *STM studies of highly organized supramolecular systems*:

    - A molecular system of regular arrays of molecular rotors has been achieved by utilizing a single layer of Bisphenol A molecules on the very weakly corrugated Ag(111) surface.
    - The self-assembly of diethylstilbestrol on the metal surfaces of Ag(111) and Cu(111) was investigated. A variety of different two-dimensional molecular networks depending on choice of the metal surface and the annealing temperature were obtained.
    - Metalloporphyrin arrays were achieved through the interaction of $Os_3(CO)_{12}$ precursors with free-base porphyrins to investigate the catalytic functionality of the arrays.