Ultrafast nano-optics: watching electrons move

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Probing and manipulating the motion of electrons in complex solid state, molecular or biological nanostructures in real time is a fundamental challenge in contemporary physics. It is expected that an increased understanding of the underlying microscopic processes may result in quite a number of novel applications, e.g., in optical and quantum information technology or in photovoltaics. The experimental methods allowing to visualize these complex processes, in particular time-resolved light-, x-ray and electron microscopy, are currently undergoing an extremely rapid development. In my talk, I will present recent experimental progress achieved in Oldenburg in this direction. Specifically, I will discuss the role of quantum coherence for ultrafast charge separation processes in organic solar cells [1,2]. Using recently ultrafast two-dimensional electronic spectroscopy, I will provide strong evidence for persistent vibronic quantum coherences in prototypical polymer and solar cell materials at room temperature and will discuss their effect on the light-induced charge separation in these systems. Moreover, I want to describe some new experimental approaches for ultrahigh space- and time-resolution light [3,4] and electron microscopy [5,6] developed in our group. I will discuss specific types of plasmonic nanolenses which allow to funnel few-cycle optical light pulses into spots with diameters of much below ten nanometers. These nanolocalized light sources not only allow us for the first time to perform coherent, spectrally broadband optical spectroscopy of single nanostructures with five nanometer spatial resolution but also enable an entirely new approach for ultrafast electron microscopy with extreme time resolution. Out most recent progress in this direction will be presented.

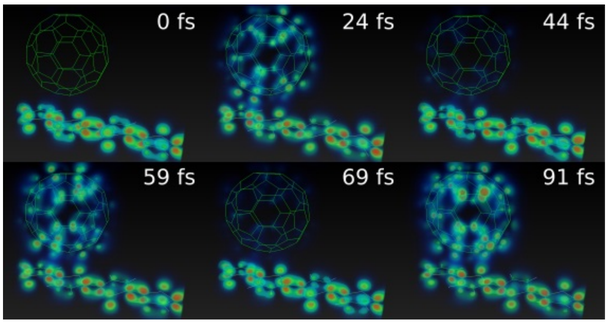

Figure: Real time simulation of the coherent charge transfer dynamics between polymer and fullerene moiety in a P3HT/PCBM thin film photovoltaic device [1]

[1] S. M. Falke *et al.*, Coherent ultrafast charge transfer in an organic photovoltaic blend, *Science* **344**, 1001 (2014).

[2] C. A. Rozzi *et al.* Quantum coherence controls the charge separation in a prototypical artificial light harvesting system. *Nature Comm.* **4**, 1602 (2013).

[3] S. Schmidt, *et al.* Adiabatic Nanofocusing on Ultrasmooth Single-Crystalline Gold Tapers Creates a 10-nm-Sized Light Source with Few-Cycle Time Resolution. *ACS Nano* **6**, 6040-6048 (2012).

[4] S. F. Becker, *et al.*, Gap-Plasmon-Enhanced Nanofocusing Near-Field Microscopy, *ACS Photonics* in press (2016).

[5] B. Piglosiewicz *et al.* Carrier-envelope phase effects on the strong-field photoemission of electrons from metallic nanostructures. *Nature Photon.*, **8**, 37 (2014).

[6] J. Vogelsang *et al.* Ultrafast Electron Emission from a Sharp Metal Nanotaper Driven by Adiabatic Nanofocusing of Surface Plasmons. *Nano Letters*, **15**, 4685 (2015).