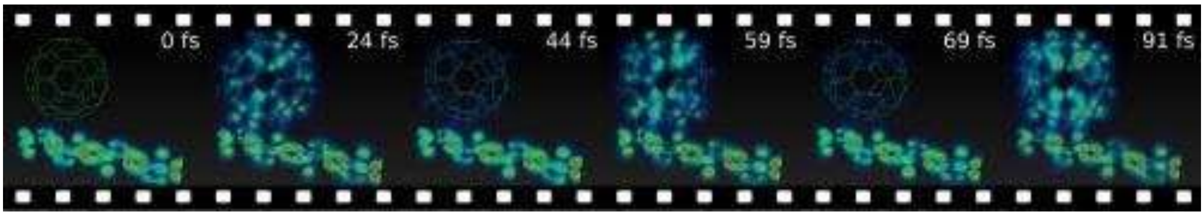
Coherent ultrafast charge and energy transfer processes in nanostructures

Christoph Lienau

Institut für Physik, Carl von Ossietzky Universität Oldenburg, 26111 Oldenburg, Germany
www.uno.uni-oldenburg.de

The function of essentially all present and future quantum devices, from quantum computers over quantum sensors to photocatalytic systems or solar cells, relies on the motion of charges and spins on ultrafast time and exceedingly short length scales. Usually these dynamics are governed by such a complex interplay between electronic and nuclear motion that their understanding is quite limited and we rely on particle-like transport models for describing the dynamics and function of those systems. In my talk, I will introduce and discuss several systems in which this classical, particle like transport regime breaks down and the wave-like coherent transport of energy and charge becomes dominant, even in disordered nanostructures and at room temperature. Specifically, I will show how (i) two nanostructures exchange more and more photons when bringing them closer together and how this energy exchange affects the optical properties of the coherently coupled system (1), (ii) we can track the ballistic motion of electrons that are photoemitted from a single nanoantenna using a new type of ultrafast electron microscope (2,3) and (iii) how charge is transported on ultrafast time scale in organic semiconductor and organic photovoltaic devices (4-7). Our studies of charge transport in organic materials give unexpected evidence for coherent charge transfer processes and outline strategies for molding the flow of charge in nanostructures by tailoring and controlling their coherent coupling to vibrational modes of the materials. These advances became possible by probing the optical properties of nanostructures with a time resolution of few femtoseconds only, faster than any of the functionally relevant vibrational modes of the material.



1. M. Esmann *et al.*, Vectorial near-field coupling, *Nature Nano*, under review (2018).

2. J. Vogelsang *et al.*, Watching charge separation in nanoantennas by ultrafast point-projection electron microscopy, *Nature: Light, Science & Appl.*, in press (2018).

3. G. Hergert *et al.*, Long-lived electron emission reveals localized plasmon modes in disordered nanosponge antennas, *Nature: Light, Science & Appl.*, 6, e17075 (2017).

4. S. M. Falke *et al.*, Coherent ultrafast charge transfer in an organic photovoltaic blend. *Science* **344**, 1001-1005 (2014).

5. A. De Sio *et al.*, Tracking the coherent generation of polaron pairs in conjugated polymers. *Nat Commun* **7**, 8 (2016).

6. A. De Sio and C. Lienau, Vibronic coupling in organic semiconductors for photovoltaics. *Phys. Chem. Chem. Phys.* **19**, 18813-18830 (2017).

7. E. Sommer *et al.*, Ultrafast nonadiabatic dynamics through a conical intersection in a donor-acceptor oligomer revealed by two-dimensional electronic spectroscopy, submitted (2018).