NanoPhotonics:
Ultrafast Control of Nanoparticles, Nanoantennas and Single Quantum Emitters

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Abstract

In my group, we aim to squeeze light down to the smallest nanoscale and fastest femtosecond scale; with these nano-femto-tools we can talk to individual molecules, Q-dots, proteins & plasmonic antennas. Here I will focus on the concepts to control interactions with quantum emitters both in space and time, specifically using optical nanoantennas and phase shaped fs pulses.

For spatial control, single photon emitters are brought in the near field of optical resonant antennas for nanoscale excitation and enhancement of the emission into multipolar radiation patterns, with full command of symmetry, multipole parity, rates and polarization. With state-of-the-art antenna fabrication the excitation can be confined to 10 nm scale, while the emission can be enhanced up to 1000 times, reaching towards strong coupling in the weak cavity limit.

For temporal control, phase shaped fs pulses are exploited to drive single quantum systems and resonant antennas to dynamically control both their fs response and nanoscale fields. As examples we tackle vibrational response and Rabi-oscillations in individual molecules at ambient conditions; and closed loop control of two-photon excitation of single quantum dots.

Finally, as an application of the spatio-temporal control, I will address the role of quantum effects in photosynthesis. Surprisingly within individual antenna complexes (LH2) of a purple bacterium it is observed that ultrafast quantum coherent energy transfer occurs under physiological conditions. Quantum coherences between electronically coupled energy eigen-states persist at least 400 fs, and distinct, time-varying energy transfer pathways can be identified in each complex. Interestingly the single molecule approach allows tracking coherent phase jumps between different pathways, which suggest that long-lived quantum coherence renders energy transfer robust in the presence of disorder.

In conclusion I hope to apprise the NanoPT2016 audience as to the potential of nano-femto tools

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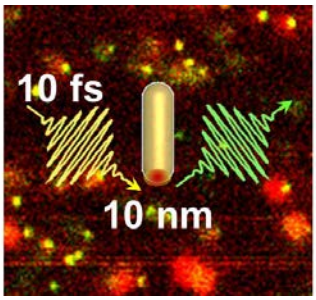

Figure: Nano-femto-photonics, combining optical nanoantennas with phase controlled femtosecond pulses