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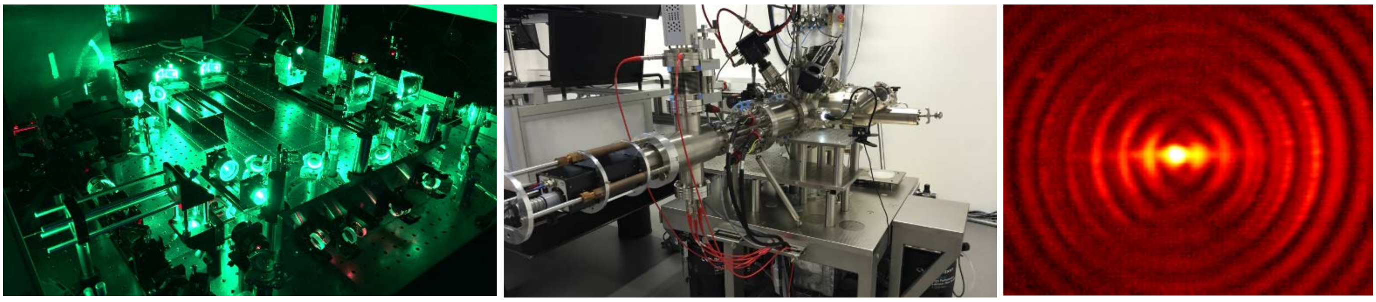
Spatiotemporal dynamics of nano-scale light-matter interactions in metasurfaces and atomic membranes

The control and characterization of light on length scales shorter than the diffraction limit (~0.5 λ) requires shaping or probing of the photonic states by nano-scale matter. Therefore, basically all nanooptical effects are coupled states of light and excited matter. Hence, the exploration of optics down to the nanoscale requires detailed knowledge about strong light-matter interaction at these ultrashort length scales. This interaction typically concerns the electronic states and happens on ultrashort time scales of a few femtoseconds. The experimental observation of such effects hence requires tools probing simultaneously the electronic matter states and the photonic states with nanometer spatial and femtosecond temporal resolution.

The aim of this project is to study such ultrafast nanoscale dynamics in semiconductor metasurfaces, which are hybridized with plasmonic antennas, nanowires, and atomic membranes like graphene or MoS_2. To achieve this goal new experimental techniques with unprecedented temporal and spatial have to developed. Besides scanning nearfield optical microscopy (SNOM), laser driven photoemission electron microscopy (PEEM) is such a technique, which probes directly the electronic excitation of matter with the spatial resolution of an electron microscope. Temporal resolution is obtained by triggering the photoemission by few-cycle laser pulses (~6 fs). These ultra-short laser pulses give access to dynamical processes, inaccessible to electronic measurement systems. Laser driven PEEM is thus an ideal probe to study the photo-induced electron dynamics in the building blocks of photonic nanosystems. A typical project will combine advanced instrumentation of fs lasers and ultra-high vacuum systems for electron microscopy with the physics of several novel quantum systems and metasurfaces.

Depending on the abilities and preferences of the candidate the following subjects would be covered

- Experimental investigation of the ultrafast dynamics of laser-excited solid state nanosystems
- Nanotechnologies for the realization of hybrid nonlinear photonic nanosystems and metasurfaces
- Theoretical modeling and numerical simulation of the spatio-temporal dynamics of light and electrons on the nano-scale below the diffraction limit based on rigorous solutions of Maxwell's equations coupled to material models



Left: Dual channel OPCPA system for the generation of ultrashort laser pulses in a pump-probe configuration. Center: PhotoEmission Electron Microscope - PEEM. Right: Electron-photon wavepackets on a ring-type nanoantenna.

References

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Further information: www.iap.uni-jena.de/nano-quantum-optics