Max-Planck-Institut für Struktur und Dynamik der Materie

Max Planck Institute for the Structure and Dynamics of Matter

Monday, November 21st, 2022 – 10:00 a.m.
CFEL Seminar room IV (Bldg. 99)

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Bringing light into electron microscopy: From ultrafast plasmonics to heralded single-photon sources

The interaction of intense light fields with matter is pivotal in various physical contexts, ranging from coherent control schemes in atomic physics to steering the flow of energy in solid-state systems. In particular, joining free-electron beams with ultrafast lasers facilitates the probing of nanoscale dynamics in ultrafast transmission electron microscopy (UTEM) and opens the field of free-electron quantum optics.

In my talk, I will briefly introduce the UTEM methodology that combines state-of-the-art TEM with optical pump-probe spectroscopy [1,2], show selected applications in the study of ultrafast dynamics, and discuss the coherent coupling of electrons and photons down to the single particle level.

High-coherence few-electron pulses are generated at a laser-triggered Schottky field emitter [2] and event-based spectroscopy reveals a strong energy correlation of about 2 eV in the two- and three-electron states [3]. Harnessing the inelastic scattering of such ultrashort electron pulses at strong optical fields facilitates nanoscale imaging of confined modes, transverse optical phase plates, or even the attosecond shaping of electron beams [4].

Recent progress in coupling single electrons to high-*Q* integrated photonic microresonators will be discussed [5], enabling highly efficient continuous-wave optical phase modulation of electron beams and nanoscale-μeV spectroscopy of a photonic mode.

Furthermore, using a low-current stream of electrons, spontaneous scattering at the empty cavity creates electron-photon pair states [6]. The single photons generated in the waveguide (1550-nm wavelength) and corresponding electron energy loss (0.8 eV) are detected in coincidence. In analogy to spontaneous parametric down-conversion, this mechanism enables heralded single electron or photon sources.

In summary, these results provide an essential step towards novel hybrid quantum technology coupling single electrons and photons, as well as the capability for sub-Poissonian electron lithography, quantum-enhanced electron imaging, and Fock-state photon sources.

References

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[3] R. Haindl et. al. arXiv:2209.12300 (2022).
[4] F. J. García de Abajo, V. Di Giulio, *ACS Photonics*. **8**, 945–974 (2021).
[5] J.-W. Henke et. al., *Nature*. **600**, 653–658 (2021).
[6] A. Feist et. al., *Science*. **377**, 777–780 (2022).

Host: Franco Bonafé

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