Carl von Ossietzky
Universität
Oldenburg

Institut für PHYSIK

PHYSICAL COLLOQUIUM

INVITATION

Monday, 14.11.2022, 4.15 p.m., Room W02 1-148 and per
video conference: https://meeting.uol.de/b/anj-2vc-j6s-fwe

speaks

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About

"Coupling single electrons and photons: From high-Q photonics to heralded particle 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 this colloquium, I will briefly introduce the UTEM methodology, combining state-of-the-art TEM with ultrafast optical spectroscopy, 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 and characterized by event-based spectroscopy [1]. The two- and three-electron states show a surprisingly strong energy correlation of about 2 eV, and state-sorted beam caustics reveal a characteristic shift of the virtual source.

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.

Recent progress in coupling single electrons to high-*Q* integrated photonic microresonators will be discussed [2], 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 [3]. 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

[1] R. Haindl, A. Feist, T. Domröse, M. Möller, S. V. Yalunin, C. Ropers, Coulomb-correlated few-electron states in a transmission electron microscope beam. arXiv:2209.12300 (2022).
[2] J.-W. Henke, A. S. Raja, A. Feist, G. Huang, G. Arend, Y. Yang, F. J. Kappert, R. N. Wang, M. Möller, J. Pan, J. Liu, O. Kfir, C. Ropers, T. J. Kippenberg, Integrated photonics enables continuous-beam electron phase modulation. *Nature*. **600**, 653–658 (2021).
[3] A. Feist, G. Huang, G. Arend, Y. Yang, J.-W. Henke, A. S. Raja, F. J. Kappert, R. N. Wang, H. Lourenço-Martins, Z. Qiu, J. Liu, O. Kfir, T. J. Kippenberg, C. Ropers, Cavity-mediated electron-photon pairs. *Science*. **377**, 777–780 (2022).

All interested persons are cordially invited.

Prof. Dr. Christoph Lienau