Multi-Parameter Quantum Estimation Based on Multiphoton Interference with Single Photons and Squeezed Light

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Quantum interference is one of the most intriguing phenomena in quantum physics at the very heart of the development of quantum technology in the current quantum industry era. It underpins fundamental tests of the quantum mechanical nature of our universe as well as applications in quantum computing, quantum sensing and quantum communication.

I will give an overview of multiphoton sensing techniques enabling to experimentally approach the ultimate quantum sensitivity, given by the quantum Cramér-Rao bound, by employing sampling measurements which resolve the inner degrees of freedom, such as time, frequency, position, and polarization, of single photons interfering at a beam splitter [1–7]. In particular, this includes: the multiparameter 3D localization of single emitters for applications in super-resolved single-molecule localization microscopy, by circumventing the requirements in standard direct imaging of camera resolution at the diffraction limit, and of highly magnifying objectives [8, 9]; the multiparameter 3D estimation of the momenta of single photons beyond current quantum and classical techniques; superresolution of incoherent sources in spatial and temporal imaging beyond the Rayleigh limit [10, 11].

I will also show novel quantum interference techniques with squeezed light for the measurements with Heisenberg-scaling sensitivity of multiple parameters in linear optical networks [12–15]. Applications can range from environmental sensing to high-precision biomedical imaging, characterization of nanomaterials, navigation, gravity tests and quantum networks of high-precision clocks.

This research opens a new paradigm based on the interface between the physics of quantum interference, quantum sensing and quantum exponential speed-up with experimentally feasible ”real world” photonic sources.

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