Quantum Enhanced Sensing

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The process of measurement is the cornerstone of all quantitative sciences and technology. The field of quantum metrology utilises the intrinsic sensitivity of quantum mechanical systems to make measurements of physical parameters with precision beyond that feasible in a classical world. The potential impact is widespread, ranging from basic science to high-tech industry. In practice, however, studies of quantum-enhanced sensing have been mostly confined to proof of principle demonstrations that fall short of genuine quantum enhancement, a consequence of loss and decoherence. Further, the overwhelming body of work has studied the estimation of a single parameter, while many practical optical tasks, such as imaging, involve the estimation of multiple parameters. A key challenge is to develop robust and sophisticated techniques for use in real measurement tasks, even in the presence of noise.

Remarkable advances in the hardware of quantum optics in the last few years have enabled new fundamental tests of quantum mechanics. In this project we aim to leverage these technical advances in the realm of metrology to develop and demonstrate quantum-enhanced sensing strategies with an emphasis on measurement tasks that extend beyond single parameter phase sensing. In the laboratory, we will use the latest in light sources, including squeezed and photon number states, exploiting the inherently multi-mode capabilities of light to create large entangled systems. The state of the art in detection, including single-photon capable CCD cameras, will enable efficient measurement. These experimental capabilities will be applied to real world tasks, such as imaging and microscopy.

First-year Project: The first year project will contribute to the construction of a quantum-enhanced microscope. In this project, quantum squeezed light will be used to enhance a protocol based on stimulated emission, where intrinsic intensity fluctuations currently limit resolution. The initial demonstration will focus on a concentration measurements, with future extension towards biological samples. This first year project will provide an introduction to quantum metrology alongside hands-on experience in experimental quantum optics.

PhD Project: Building on the initial project, the PhD will proceed to develop an interferometric protocol for squeezing-enhanced imaging. This research naturally extends to the regime multi-parameter estimation, where the development of tailored sources of entangled light and multi-mode detection will facilitate quantum enhanced-estimation in complex problems in real-world settings.

The student will work within a small team including researchers affiliated with the Quantum Information Technologies (NQIT) and Quantum Imaging Technologies (QuantIC) quantum technologies hubs. These consist of a large and vibrant community of quantum researchers giving the student an opportunity to explore both fundamental and technological aspects of quantum optics and optical quantum information.