Absolute quantum advantage in light microscopy

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State-of-the-art microscopes use intense lasers that can severely disturb biological processes, function and viability. This introduces hard limits on performance that only quantum photon correlations can overcome. In this talk I will report recent work from my laboratory which demonstrates this absolute quantum advantage [1]. We show, specifically, that quantum correlations enable signal-to-noise beyond the photodamage-free capacity of conventional microscopy. Broadly, this represents the first demonstration that quantum correlations can allow sensing beyond the limits introduced by optical intrusion upon the measurement process. We achieve this in a coherent Raman microscope, which we use to image molecular bonds within a cell with both quantum-enhanced contrast and sub-wavelength resolution. This allows the observation of nanoscale biological structures that would otherwise not be resolved. Coherent Raman microscopes allow highly selective biomolecular finger-printing in unlabelled specimens, but photodamage is a major roadblock for many applications. By showing that this roadblock can be overcome, our work provides a path towards order-of-magnitude improvements in both sensitivity and imaging speed.

[1] Catxere A. Casacio, Lars S. Madsen, Alex Terrasson, Muhammad Waleed, Kai Barnscheidt, Boris Hage, Michael A. Taylor, and Warwick P. Bowen, Quantum-enhanced nonlinear microscopy, in print Nature (2021). Available at: arXiv:2004.00178.