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Long-baseline interferometry using single photon states as a non-local oscillator

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Abstract

Recent proposals suggest that distributed single photons serving as a 'non-local oscillator' can outperform coherent states as a phase reference for long-baseline interferometric imaging of weak sources [1,2]. Such nonlocal quantum states distributed between telescopes can, in-principle, surpass the limitations of conventional interferometric-based astronomical imaging approaches for very-long baselines such as: signal-to-noise, shot noise, signal loss, and faintness of the imaged objects. Here we demonstrate in a table-top experiment, interference between a nonlocal oscillator generated by equal-path splitting of an idler photon from a pulsed, separable, parametric down conversion process and a spectrally single-mode, quasi-thermal source. We compare the single-photon nonlocal oscillator to a more conventional local oscillator with uncertain photon number. Both methods enabled reconstruction of the source's Gaussian spatial distribution by measurement of the interference visibility as a function of baseline separation and then applying the van Cittert-Zernike theorem [3,4]. In both cases, good qualitative agreement was found with the reconstructed source width and the known source width as measured using a camera. We also report an increase of signal-to-noise per 'faux' stellar photon detected when heralding the idler photon. 1593 heralded (non-local oscillator) detection events led to a maximum visibility of ~17% compared to the 10412 unheralded (classical local oscillator) detection events, which gave rise to a maximum visibility of ~10% – the first instance of quantum-enhanced sensing in this context.