Quantum-enhanced interferometry with large heralded photon-number states

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We introduce novel probes which show robustness to photonic losses and are capable of surpassing the shot noise limit in conditions of substantial photonic loss.

The probes are created by combining two heralded photon-number states from independent SPDC sources on a beam splitter which is part of a Mach-Zehnder interferometer (see Fig. 1(a)). We quantify the precision of the optimal optical phase measurement with the quantum Fisher information. It depends on the total number of photons detected in the heralded modes and their difference. We show that the probes approximate the performance of the optimal states as a function of signal transmissivity in the entire range where N00N states are no longer optimal (see Fig. 1(b)). In fact, our probes are shown to perform at least as well as the shot-noise limit for any amount of loss. In addition, the photon number difference (Δ in Fig. 1(b)) determines the best photon number configuration for a particular range of losses. We observe that probes with a small difference provide a greater quantum advantage but are more sensitive to losses.

We experimentally implement our scheme where we herald entangled probes of sizes up to $N = 8$ and measure up to 16-photon coincidences. Although due to experimental imperfections we were not able to surpass the shot noise limit without postselection, we demonstrate that our probes' sensitivity derives from multiphoton interference and that they are robust to losses, thus paving the way towards scaling up quantum-enhanced interferometry and implementing multiphoton quantum technologies in real-life applications.

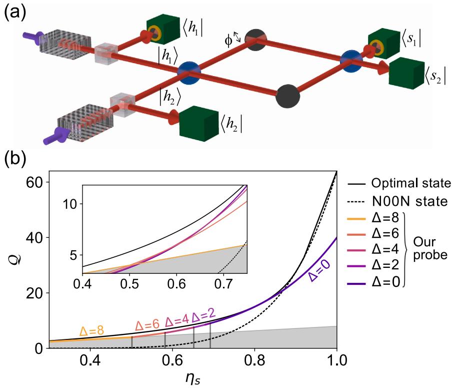

Fig. 1: (a) Example setup to generate our novel probes. (b) Quantum Fisher information calculated for 8-photon probes inside the interferometer as a function of the signal transmissivity which is assumed to be equal in both interferometer modes.

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