Determining the Advantage of Quantum Radar

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In recent years there have been a number of claims made about the potential for quantum-based technologies to significantly enhance standoff imaging and ranging ("quantum radar"). Motivated by the possible improvements, there have been multiple experimental demonstrations since 2019 in both the optical and microwave domains, all claiming some form of quantum enhancement over classical radars. For instance, using correlated photon pairs in the microwave domain Luong *et al.* [1] has seen an improvement in signal-to-noise ratio (SNR) of between 3-4 dB when comparing their quantum system to a classical noise radar. Similar results were obtained by Barzanjeh *et al.* [2], with additional comparisons with an "optimal" classical radar showing a few dB "quantum advantage" in SNR if the amplifier noise could be removed from the detection channels. These improvements are close to the maximum improvement suggested by theory of 6 dB.

Here we present our work modelling the performance of a quantum illumination experiment in the microwave domain. For instance, Figure 1(a) shows the quantum enhancement of a quantum radar system over both a classical noise radar and "optimal" homodyne detection schemes, all operating at cryogenic temperatures. As can be seen, this enhancement scales with the entangled photon signal strength. Figure 1(b) shows the performance of a quantum and classical noise radar as a function of distance to the target. Here we can see that the $1/R^4$ geometric loss affects both the quantum and classical radars in the same way – i.e., the quantum radar is robust to loss. Through this modelling we are aiming to provide an estimate of the advantage provided by a quantum-based radar compared to currently-deployed radar systems and, therefore, identify where it could potentially find practical applications going forward.

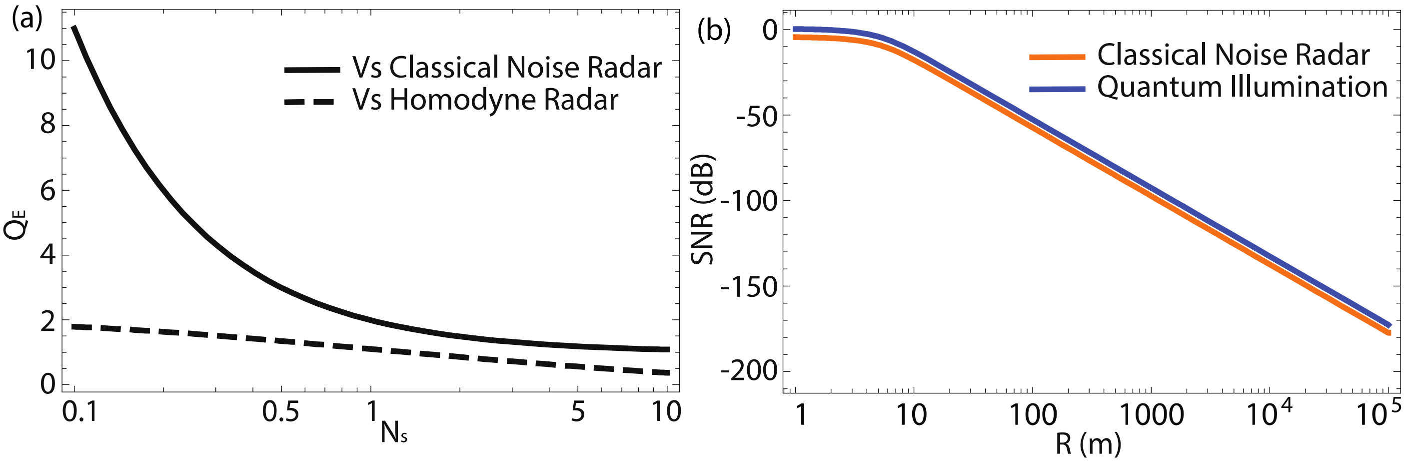

Figure 1: (a) Quantum enhancement Q_E (i.e., improvement in SNR) as a function of entangled photon signal strength N_s for two different classical radars. (b) Normalised SNR as a function of range to target R with quantum illumination and classical noise radar.

[1] D. Luong *et al.*, *IEEE Trans. Aerospace Elec. Systems* **53**, 2041 (2019).

[2] S. Barzanjeh *et al.*, *Science Advances* **6**, eabb0451 (2020).