Optimisation of quantum illumination-based radar and lidar with noise, loss and gain-added single photon detection

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Quantum illumination can be used to detect a target via scattered light or improve imaging at low light levels in the presence of high background noise. It has been employed at the single photon level in quantum lidar systems that rely on two-mode squeezed vacuum states whose modes are in principle perfectly correlated in photon number. Simple single-photon threshold detectors can then pick out the weak signal from the bright background noise and experiments have demonstrated a remarkable ability to do this [1]. At radar frequencies progress has been slower, largely due to the absence of microwave sources of the required states and detectors sensitive at the single photon level. However, both these limitations are being challenged by recent proposals and experiments [2, 3].

Here we provide a unified frequency-independent framework for these systems and develop probability-based criteria for optimising target detection. Surprisingly it is not always useful to improve detector quantum efficiency, no matter how weak the scattered signal light [4, 5]. There is an optimal value of efficiency that can be significantly less than unity (Fig. 1). If the detector is too efficient it will be better to attenuate the signal. Even more counterintuitively, adding extra photon noise can sometimes improve target detection. We also examine situations where the signal is amplified before detection. This is not unusual in the microwave region but is not done in quantum optics because of the required added noise that inevitably degrades a quantum signal. Any signal and noise entering an amplifier will experience the same gain, but the added noise means that the signal to noise ratio of the output must be lower. However, we find that there are cases in which preamplification improves detection of target objects, counter to this standard quantum optical canon.

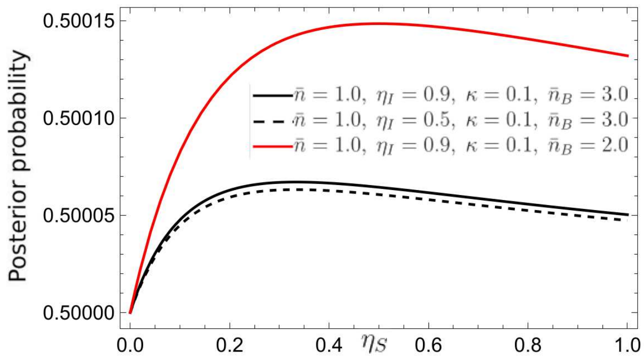

Fig. 1: *Averaged posterior probability of target detection for a single shot of a quantum lidar versus signal detector quantum efficiency for various idler efficiencies and background noise levels.*

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References

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