Abstract

Quantum technologies are expected to revolutionise the world. From fast quantum computers through secure quantum communications to precise quantum sensing, quantum protocols promise to outperform their classical equivalents. But in order to achieve that we need robust quantum hardware and protocols which are useful even when that hardware is imperfect. An obvious consideration are losses and inefficiencies but it is equally important not to make unfeasible assumptions. One such example is generating single photon states from a source which is naturally multi-photon under the assumption that the creation of multi-photon components is small.

This thesis proposes two protocols which avoid making this assumption by including all components of the generated states. With this approach we take advantage of the possibilities given by multi-photon states, which include ease of generation and robustness to losses.

The first protocol is an entanglement distribution protocol. We show that the generated multi-photon bipartite entanglement is robust to very high losses in the transmitting channels. As an example we analyse the protocol in settings which point towards its potential application in quantum communications, namely we consider scenarios of Earth-space transmissions or through very long optical fibres. Our entanglement distribution protocol achieves a quadratic improvement of transmission rates compared to the typically used polarization-entangled photon pairs.

The second protocol is designed to provide quantum-enhanced sensitivity in optical phase measurements. Indeed, the multi-photon bipartite entangled states generated with our setup are shown to be robust against losses in the interferometer and perform at least as well as the shot noise limit, the maximal precision achievable with classical light, even at very high losses. The scheme provides an additional possibility of tuning the multi-photon states towards the optimal states which is advantageous if the level of noise in the system is known.

These two examples show that multi-photon technologies are in fact feasible and efficient, and that their properties allow them to outperform protocols based on single photon states.