Research Directions: Quantum Technologies

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What are the ultimate limits of photonic quantum memories?

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Question

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Context

Photonic quantum memories are required in many applications in quantum information science with varying performance requirements depending on specific applications. Although classical light storage has been demonstrated in time scales of minutes (Dudin et al., 2013; Heinze et al., 2013) to hours (Ma et al., 2021) in different systems, storing true single photons and single photon level coherent pulses are still limited to around a few seconds at most (Wang et al., 2021; Ortu et al., 2022; Hain et al., 2022; Stas et al., 2022). In this question, we would like to explore what the challenges for quantum memory storage for the purposes of quantum communication and the distribution of entanglement are, e.g. in quantum repeaters. Furthermore, recent work has proposed using quantum memories with hour-long storage times for quantum computation (Gouzien and Sangouard, 2021) and physically transporting single photons for astronomical interferometry (Bland-Hawthorn et al., 2021) and global quantum communications (Wittig et al., 2017; Gündoğan et al., 2023).

For example, what are the intrinsic and technical limitations to reach ultra-long storage times limited with or close to material T_1 times? These limitations could arise from a variety of sources for different physical systems: accumulating pulse errors in dynamical decoupling sequences, magnetic field alignment sensitivity, optical and magnetic field inhomogeneities, narrow-band spectral filtering, charge instabilities due to nanofabrication processes and vacuum quality. In the longer term, how can quantum information processing and computational techniques, such as fault tolerant error correction, be incorporated into photonic memory systems? This question seeks answers whether (and to what extent if yes) these issues can be addressed to reach ultra-long lifetime quantum memories.

How to contribute to this Question

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Competing interests. The authors declare none.

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