In-line quantum repeaters

QCRYPT 2016 poster submission

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Quantum repeaters are devices that extend the range and increase the rate of a quantum communication (such as quantum key distribution or entanglement distribution protocols) beyond what is possible with a lossy bosonic channel alone. The best one can do without repeaters is set by the TGW/PLOB bounds [1,2], and it is our aim to break such fundamental limits.

The original architectures of quantum repeaters are based on heralded entanglement generation and purification, with the additional cost of two-way communication [3]. Our architecture can still be thought of a lossy channel with black boxes placed at some intervals, but it reduces the complexity of the operations and it avoids the need for communication by having the system interact unitarily with a fresh ancilla in each station and 'give off' the errors acquired from photon loss.

We know that quantum error correction guarantees the existence of a black box that does the job [4] and that whatever interaction the box is implementing, it has to be non-gaussian [5]. In our work we investigate which interaction in such black boxes can have a repeater-type behaviour without going for a full quantum error correction structure. In a first step, we consider abstract unitaries generated by Hamiltonians. The simplest Hamiltonian that we found involves the interaction between a single-mode system and a single-mode ancilla. Despite its simplicity it accomplishes the task egregiously: with the right choice of parameters we reach well above the TGW/PLOB bounds and we can cover in principle any distance. Furthermore, we found a whole class of other solutions based on conditions that resemble those of quantum error correcting codes with which one can explore the performance of many inequivalent interactions.

As our solution involves as little as two optical modes, it bears a great potential for being approximated by optical non-linear interactions. This is a first important step towards the future deployment of a quantum infrastructure.

[1] Takeoka et al. Nat. Comm. **5,** 5235 (2014)

[2] Pirandola et al. arXiv:1510.08863 [quant-ph]

[3] Muralidharan et al. Sci. Rep. **6**, 24063 (2016)

[4] Muralidharan et al. PRL **25,** 250501 (2014)

[5] Namiki et al. Phys. Rev. A **90**, 062316 (2014)