Quantum-dot-based quantum relay operating at telecom wavelength

J. Huwer[1], M. Felle[1,2], R. M. Stevenson[1], J. Skiba-Szymanska[1], M. B. Ward[1], I. Farrer[3], R. V. Penty[2], D. A. Ritchie[3], and A. J. Shields[1]

[1]*Toshiba Research Europe Limited, 208 Science Park, Milton Road, Cambridge CB4 0GZ, UK*
[2]*Electrical Division, Department of Engineering, University of Cambridge, 9 J.J. Thomson Avenue, Cambridge CB3 0FA, UK*
[3]*Cavendish Laboratory, University of Cambridge, J.J. Thomson Avenue, Cambridge CB3 0HE, UK*
contact: jan.huwer@crl.toshiba.co.uk

Quantum relays [1] are a key technology to extend the range of present quantum cryptography systems and future general purpose optical quantum networks. The underlying physical principle is to perform teleportation of photonic input quantum bits, which can effectively reduce noise in long-distance photon-transmission scenarios. Most interesting for cryptography applications is that the security of the quantum channel is unconditionally guaranteed, even if the entanglement resource or the relay itself are located at untrusted nodes of the network.

Photon sources based on non-linear processes have a long history in photonic teleportation experiments, enabling pioneering work, most recently even over metropolitan distances [2,3]. However, the number statistics of these sources follow a Poissonian distribution, typically increasing error rates and requiring operation at very low intensities and implementation of sophisticated security protocols. Semiconductor quantum dots have proven to be a promising alternative entangled photon source, with true single-photon emission enabling intrinsically secure implementations of quantum relays [4].

In this work, we demonstrate for the first time a semiconductor-based quantum relay which is operating at standard telecom wavelength (O-band) [5], therefore being compatible with existing telecom-fiber infrastructure. For implementation of a standard 4-state QKD-protocol with weak coherent input states, the system achieves mean fidelities above 88%. In addition, we demonstrate that the relay is sufficiently robust against frequency detuning of the input state, making it compatible with standard off-the-shelf telecom laser sources. Further characterization of the relay with process tomography reveals teleportation for arbitrary input states opening up the route for future operation with different communication protocols.

The results represent a significant advance in demonstrating feasibility of semiconductor light sources for the development of infrastructure-compatible quantum-communication technology for multi-node networks. The use of purely sub-Poissonian entanglement sources might bare practical advantages, especially for security-sensitive applications.

References

[1] B. C. Jacobs *et al.*, "Quantum relays and noise suppression using linear optics", Phys. Rev. A **66**, 52307 (2002).
[2] R. Valivarthi *et al.*, "Quantum teleportation across a metropolitan fibre network", Nat. Phot. **10**, 676 (2016).
[3] Q. Sun *et al.*, "Quantum teleportation with independent sources and prior entanglement distribution over a network", Nat. Phot. **10**, 671 (2016).
[4] C. Varnava *et al.*, "An entangled-LED-driven quantum relay over 1 km", npj Quantum Information **2**, 16006 (2016).
[5] J. Huwer *et al.*," Quantum-dot based telecom-wavelength quantum relay", arXiv:1704.07765.