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Entanglement distribution, teleportation, and QKD over a 14-km urban fiber link

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The application of existing telecom fiber infrastructure for quantum communication protocols enables efficient development of quantum networks [1]. It also entails multiple challenges, since existing infrastructure in an urban region is often underground or paired with the electrical overhead power line, and prone to environmental influences which cause fluctuations in polarization mode dispersion, photon travel times, and polarization dependent loss.

Here, we present the characterization and application of a 14.7 km long deployed fiber link in the Saarbrücken urban area as a quantum channel. The link connects our ion trap laboratory on the campus of the Saarland University with a receiver station on the campus of the University of Applied Sciences, with a point to point distance of 5.5 km. It comprises 1278 m of overhead cable and several patch stations. An efficient polarization correction scheme is employed, following the technique of [2], to ensure high-fidelity transmission of single-photon polarization qubits.

As elementary quantum network protocols, entanglement distribution and quantum-state teleportation [3] from a 40Ca^+ ion quantum memory are demonstrated, both utilizing a bright, high-fidelity entangled photon pair source and polarization-preserving quantum frequency conversion [4].

As a perspective we report on the status of a demonstration of device-independent quantum key distribution [5] over this fiber link, using atom-photon entanglement generated in single-photon emission from 40Ca^+ ions [6].

[1] H. Kimble, *Nature* 453, 1023–1030 (2008).

[2] F. Hocke, Diploma thesis, TU Munich (2007)

[3] E. Arenskötter et al., arXiv:2301.06091 (2023)

[4] E. Arenskötter et al., *NPJ Quantum Inf.* 9, 34 (2023)

[5] R. Schwonnek et al., *Nat Commun* 12, 2880 (2021)

[6] M. Bock et al., *Nat Commun* 9, 1998 (2018)

Primary author: ESCHNER, Jürgen (DPG, EPS)

Co-authors: Dr KUCERA, Stephan (Universität des Saarlandes); Dr ARENSKÖTTER, Elena (Universität des Saarlandes); Mr HAEN, Christian (Universität des Saarlandes); Mr JONAS, Meiers (Universität des Saarlandes); Mr BAUER, Tobias (Universität des Saarlandes); Prof. BECHER, Christoph (Universität des Saarlandes)

Presenter: ESCHNER, Jürgen (DPG, EPS)

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