Multiplexing of entanglement-based quantum key distribution systems on optical fiber link.

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Quantum key distribution (QKD) protocols based on pure single-photon transmission over long-distance optical fiber suffer from limited key generation rates. Overcoming this limitation remains a major challenge to the realization of practical and scalable quantum communication networks.

Here, we demonstrate multiplexing of entanglement-based QKD signals over optical fiber as an approach to increasing the key generation rate on the same quantum communication link and enabling independent QKD systems to share the same transmission medium. Two commercial BBM92 QKD systems operating at 1558 nm and 1530 nm for QKD signal transmission and using high-fidelity polarization-entangled photon sources were implemented and characterized on the PTB campus network and wavelength-multiplexed onto a single "dark" fiber link using custom coarse wavelength-division multiplexing (CWDM). The performance of the multiplexed systems was evaluated over fiber lengths ranging from 2 km to 102 km (a campus network fiber of 2 km extended by fiber spools) and compared with the performance of the individually deployed systems on the link. At short distances, the multiplexing setup resulted, for each channel, in a modest reduction in secure key rate due to insertion loss, but this penalty diminished with increasing distance. Beyond 25 km, the multiplexed configuration yielded higher key rates on the dark-fiber link for each individual channel. Dark fibers in deployed telecom networks may exhibit substantial parasitic noise originating from neighbouring classical communication fibers, as our measurements show. The CWDM-based multiplexing architecture inherently suppresses out-of-band noise, leading to improved key rates in noisy or shared fiber environments. In total, multiplexed system shown in Fig. 1 (operating at 1530 nm) achieved a secure key rate increase by a factor ranging from 1.14 at 52 km to 2.2 at 102 km compared with single-channel transmission.

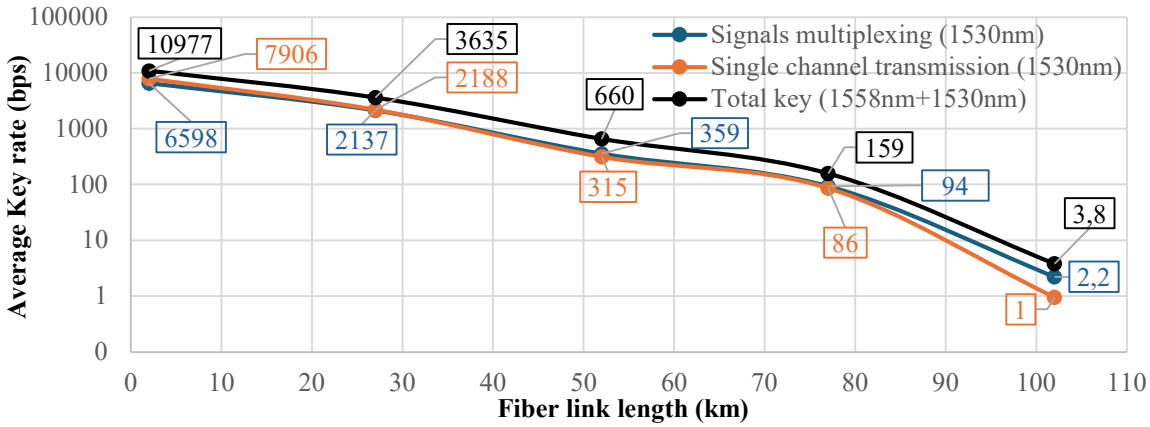

Fig 1: *Average key rate generated by QKD systems in different configurations vs. fiber link length*

These measurements demonstrate that field-deployed quantum communication networks capable of supporting multiple QKD signals - either to increase the overall key-generation rate or to serve multiple users by sharing optical fiber links among independent QKD systems - are feasible without significant performance degradation and can potentially provide performance enhancement.

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