# Robustness of polarization entanglement for long distance QKD

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Quantum key distribution (QKD) is on the brink of being deployed on a large scale. For a successful launch it is important though, that QKD devices can be incorporated into or use existing telecom networks. Although not at telecom wavelengths, QKD based on polarization entanglement has already been shown over 1.4 km outside the laboratory[1]. However, it was thought that dispersion effects, mainly polarization mode dispersion (PMD), in optical fibers will limit the use of polarization entanglement for longer distances[2]. We report the distribution of quantum correlations over a record length of 100 km in telecom fibers with such a high quality that it would be possible to extract a secret key without background subtraction.

The source on Alice's side produces non-degenerate polarization entangled photons with signal and idler wavelength being 810 nm (high detection efficiency) and 1550 nm (low fiber loss) respectively. The latter is coupled into a standard single mode telecom fiber (quantum channel) and transmitted to Bob. The signal photon is projected into one of four possible polarization states (H, V, +, -) before being detected in a Si avalanche photo diode (APD). During the polarization measurement of Alice, the idler photon also acquires a correlated polarization state which is analyzed inside Bob's unit.

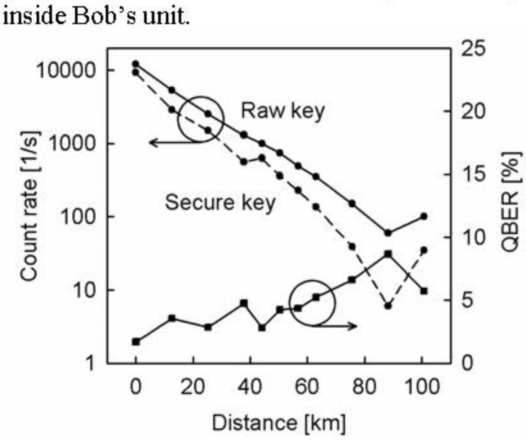


Fig. 1: Raw key rate, measured QBER and calculated Secure key rate as a function of fiber length

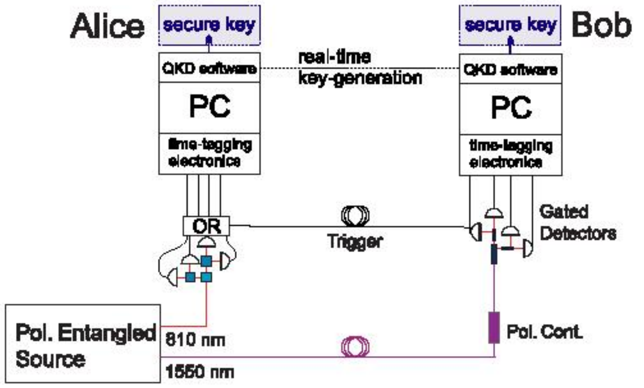


Fig. 2: Schematic of a QKD device based on polarization entanglement

In order to investigate the feasibility of fiber based quantum cryptography with polarization entanglement, the transmission and visibility were measured with respect to lengths of the optical fiber. Since we know that dispersion would limit our performance we employed non-zero dispersion-shifted (NZDS) fibers for the transmission. The count rates of the correlations and the visibility were taken after each spool of fiber (25.2 km and 12.6 km). Figure 1 shows the measured count rates together with the qubit error rate (QBER) calculated from the measured visibilites. A secure key rate is estimated from these values using realistic error corrections and privacy amplification. The secure rate drops from an initial 9000 c/s to 6 c/s at 88 km. At 100 km we have a higher key rate of 35 bit/s due to lower losses in the fiber (single spool without connectors) and hence a reduced contribution of detector dark counts to the visibility.

Since existing network infrastructures do not yet support NZDS fibers on a large scale, we also performed the full BB84 protocol using standard telecom fibers. We modified our setup to include passive polarization analysis at Alice and Bob using four detectors at each side, as shown in Figure 2. Respective detector clicks were logged on a computer using time tagging cards. Coincidence counts were analysed in real time and a QKD protocol software was employed to distil a secure key from the measurements. In this case we obtained a secure key rate of 1500 bit/s after 25 km of standard telecom fiber. For longer distances chromatic dispersion is limiting the key rate. Entangled photon sources with narrow bandwidth photons which can overcome this limitation are currently being developed.

From experimental observation we have found only minor depolarization of the entangled state caused by the optical fiber. Together with the demonstration of secure key exchange over 25 km with our fully functional QKD device we believe that polarization entanglement can be used for long distance quantum cryptography using commercially available fibers and detectors.

**References**

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2. N. Gisin et al., Rev. Mod. Phys. **74**, 145 - 195 (2002)