IDQ

SWISS QUANTUM

Redefining Measurement

Use Case: QKD over 400 km

QKD beyond 400 km using ultra-low-noise SNSPD

UNIVERSITÉ DE GENÈVE

Research Field: Quantum Key Distribution	
Country: Switzerland	

Experimental need	Solution	Results
Telecom wavelength single-photon detectors with high detection efficiency and ultra-low dark count rate	Superconducting nanowire single-photon detectors (SNSPDs) with tailored optical spectral	QKD over record-long distance with standard optical fibers, opening new possibilities for secure communication in existing telecommunication networks

Experimental need

Since its first experimental demonstration, extending QKD's range has been a highly sought-after research objective with ensuing commercial impact. The limiting factor is set by the cumulated optical losses, preventing the majority of photons to reach the receiver. As with most telecommunication systems the key metric to optimise is the signal-to-noise ratio (SNR). Detector noise reduction is key to enhance the system SNR in single-photon detection-based systems. Indeed, the optical signal exponentially decays with distance, whereas detectors' dark counts remain constant. As a result, beyond a certain fibre length the SNR becomes too small, and the QKD's key transmission rate decreases to nearly zero.

The team at the Group of Applied Physics (GAP) – Quantum Technologies at University of Geneva have been involved in QKD research activities for several years with the objective to extend the QKD distance range capabilities. They have previously developed free-running ultra-low-noise InGaAs/InP SPAD-based single-photon detector to demonstrate QKD over more than 300 km of optical fibres [1], a detector design that was largely adopted by ID Quantique and used in ID230 Infrared single-photon detectors. Superconducting nanowire single-photon detectors (SNSPDs) were then considered to further improve QKD distance performance. SNSPD technology has demonstrated high potential to deliver higher efficiency and lower dark counts than semiconductor-based detectors.

Solution

The GAP Quantum Technologies team, in collaboration with IDQ, has been developing SNSPDs offering detection performance specifically tailored to satisfy the needs of such demanding experiments. The reduction of detector noise was a key ingredient here and low dark count rate SNSPD were designed and produced.

In the experiment [2], the pulses sent by Alice at a wavelength of 1550 nm propagated through hundreds of kilometers of optical fibre (up to more than 400 km) and were detected by Bob's SNSPDs. To reduce the detector dark counts, an additional fibre filter cooled down to 40 K was carefully added to cut off the black body emission of the optical fibre connected to the detectors. This reduced the dark count rate to an impressive 0.1 Hz, about 2 orders of magnitude lower than typical SNSPD dark count rates,which are limited by spurious photons from black body radiation. With these technical enhancements, the probability of a dark count when a photon is expected could be reduced to less than 10^{-11}.

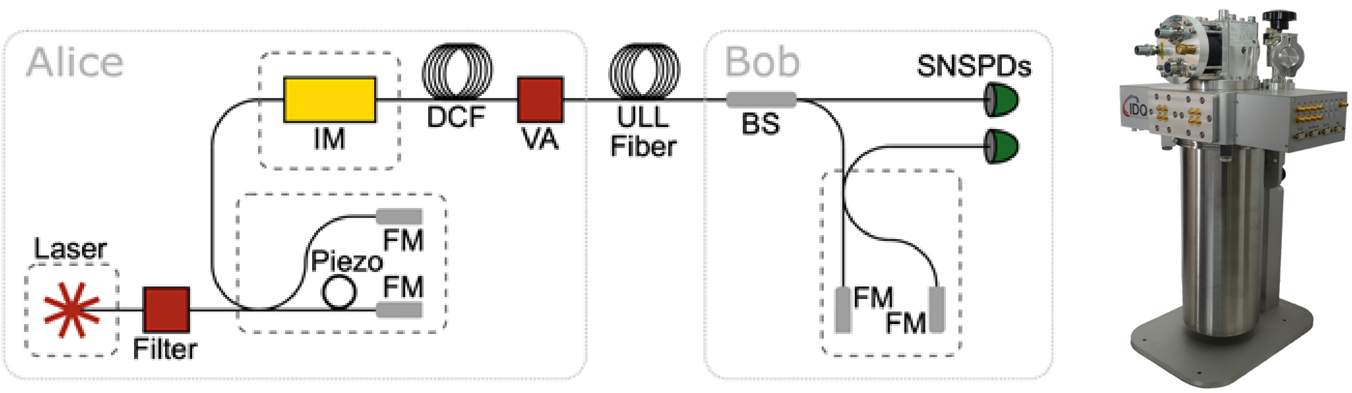

FIG. 1. Left- Experimental setup of QKD over 421 km, from [2]. Right- ID281 system

Results

Thanks to the detectors low number of dark counts and to the use of an ultralow-loss fibre combined with a modification of a loss-tolerant protocol, the research team in Geneva could establish secure keys with very good rates over extended distances without any need of repeaters. For fiber lengths ranging from 251 to 404 km, the experimental scheme achieved key rates that were about 100 times higher than previous demonstrations over the same distances. Notably, the key rate remained positive up to a record distance of 421 km. The increase in the key rate was enabled by a QKD setup developed by the same authors, featuring one of the highest repetition rates (2.5 GHz) ever demonstrated in QKD experiments. The researchers also proved the system' stability and reliability by running it continuously for more than 24 hours.

[1] B. Korzh et al., "Provably secure and practical quantum key distribution over 307 km of optical fibre", Nature Photonics. 2015, vol. 9, 163-168 (2015)

[2] A. Boaron et al., "Secure quantum key distribution over 421 km of optical fiber", Phys. Rev. Lett. 121, 190502 (2018).

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