Contribution ID: **3** Type: **Oral**

Entanglement-based quantum key distribution using a deterministic quantum dot photon source

Monday, 28 September 2020 14:15 (15 minutes)

Entanglement-based protocols for quantum key distribution (QKD) provide additional layers of security compared to single-photon prepare-and-measure approaches, despite presenting the challenge of a less immediate hardware implementation. As remarkable technical achievements have been used to demonstrate entanglement-based QKD over longer and longer distances [1], the main opportunity for further development is related to multiphoton emission. This is a fundamental limitation for state-of-the-art photon sources based on spontaneous parametric down-conversion, which can be solved using deterministic quantum emitters. Here we focus on semiconductor quantum dots, which can generate nearly on-demand photon pairs with record-low multiphoton emission [2] and Bell state fidelity currently up to 98% [3]. We experimentally demonstrate the viability of this technology in a realistic urban communication scenario [4]. We employ a modified asymmetric Ekert protocol and perform QKD comparing two choices of quantum channel: over a 250 m single-mode fiber and in free-space between two buildings across the campus of the Sapienza University of Rome. The key exchange is successfully performed with error rates of 3–4%, well below the protocol threshold, and with substantial violations of the Bell inequality. The results are discussed in relation to the technical solutions employed for transferring the signal and to the current state of development of the source. In this regard, an outlook is presented based on the latest and foreseen advances in source design that can lead to unprecedented pair emission rates and boost secure key exchange over long distances.

[1] Yin J., et al., Nature 582, 501–505 (2020).
[2] Schweickert L., et al., Applied Physics Letters 112, 093106 (2018).
[3] Huber D., et al., Physical Review Letters 121, 033902 (2018).
[4] Basso Basset F., Valeri M., et al., arXiv:2007.12727 (2020).

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Session Classification: Invited