Benchmarking Quantum Key Distribution by mixing single photons and laser light

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Quantum key distribution (QKD) stands out as one of the major applications of quantum technologies, alongside quantum computing and quantum sensing. To benefit from the no-cloning theorem, QKD protocols require the information to be carried by single photons, typically done with strongly attenuated laser pulses. Yet this approach is fundamentally limited by the Poissonnian photon number statistics of laser light: multi-photon emissions cannot be suppressed independently from single-photon emissions. Quantum-dot single-photon sources (QDS), on the other hand, appear as promising candidates for QKD with high single-photon purities, although their limited collected brightness remains challenging to ensure high Secret Key Rate (SKR).

We propose a hybrid approach where the information is encoded with a mixture of single photons generated by laser pulses and a QDS embedded in a micropillar cavity. We derive a mathematical description of the incoherent mixing of both sources to implement the BB84 protocol, showing excellent matching between theory and experimental data. By tuning the amount of laser light, we compensate for the limited collected brightness of QDS, while maintaining the benefit of high single-photon purity over long distances. Our model also enables a thorough investigation of advantage scenarios for QDS. Explicitly, we highlight an efficiency threshold for unconditional advantage of QDS over laser as well as insights on the interplay between single-photon purity and collected brightness in the performances of BB84.

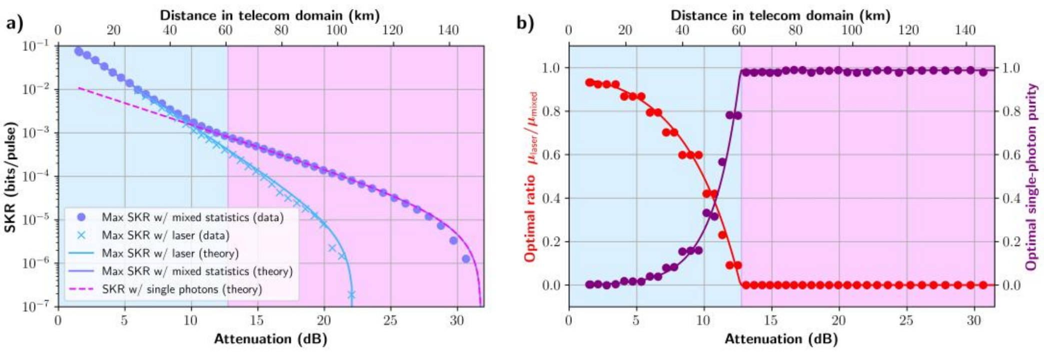

Figure 1: a) The SKR is measured over several attenuations for multiple amounts of laser light used by Alice. The maximum SKR obtained for each attenuation is plotted (purple dots) and compared to the theoretical model (purple solid line). b) Comparison of the experimental (symbols) optimal relative laser mean photon number (red) and single photon purity (purple) with our model (solid lines).

[1] Y. Portella et al., arXiv:2510.26377 (2025)
[2] M. Bozzio et al., *npj Quantum Inf.* **8**, 104 (2022)
[3] N. Maring et al., *Nat. Photon.* **18**, 603-609 (2024)