Quantum Rangefinding with Bragg-reflection waveguides

Bianca Nardi[1], Stefan Frick[1], Gregor Weihs[1]

[1] *University of Innsbruck, 6020, Innsbruck, Austria*

Classical single-photon LiDARs rely on advanced technologies and algorithms to improve photon-detection efficiency in noisy environments and in photon-starved regimes. However, for applications that require covert time-of-flight measurements, the sampling light must be indistinguishable from the background in all degrees of freedom, including the photon number statistics, and this can reduce the signal-to-noise ratio (SNR). Spontaneous parametric down-conversion (SPDC) is widely used to generate photon pairs (signal and idler) with strong spectral and temporal correlations. Additionally, each half of the SPDC-generated biphoton state exhibits a bunching behavior [1] that matches the thermal nature of the background photons. In quantum rangefinding [2], the signal photon is detected locally, while the idler hits the target, where it gets reflected before detection. The delay between signal and idler detection corresponds to the idler time-of-flight (ToF). In this way, the protocol exploits the signal and idler time correlation while it takes advantage of the thermal nature of the idler to camouflage with the background, enabling a covert ToF measurement.

In this work, we develop a quantum rangefinder based on AlGaAs Bragg-reflection waveguides (BRW) [3]. The strong second-order nonlinearity of AlGaAs makes BRWs bright telecom photon-pair sources. Telecom photons are ideal for LiDAR applications because they have higher atmospheric transmission than those in the visible spectrum. Furthermore, this platform offers a broadband SPDC spectrum, which is useful for noise-filtering techniques to improve the SNR. Finally, we demonstrate the ranging performance of a BRW-rangefinder that is robust against loss and noise, and covert for an unauthorized receiver that can only detect idler photons indistinguishable from background radiation.

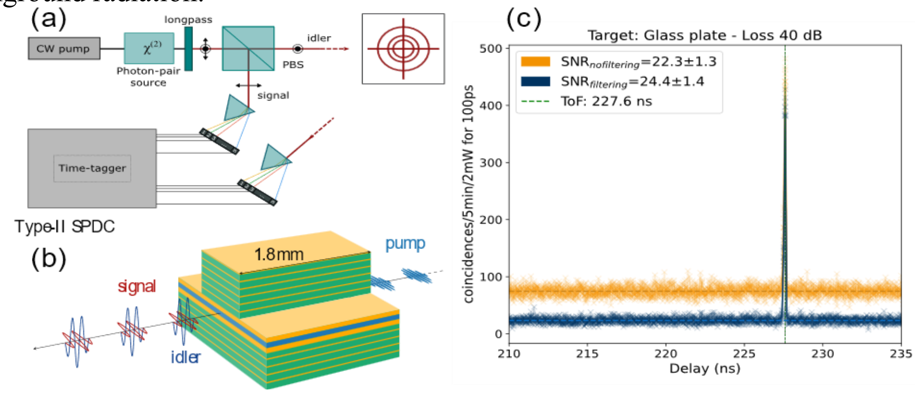

Fig. 1: *(a) Quantum rangefinding scheme, (b) SPDC in Bragg-reflection waveguide, and (c) Time-correlated histogram of the ToF measurement.*

Funding acknowledgement

This work is supported by the Austrian Science Fund (FWF) under Project 10.55776/Q3 (IGUANA) and Project 10.55776/I5061 (On-chip microlaser driven sources of indistinguishable photons for quantum networks).

References

[1] B. Blauensteiner et al., Phys. Rev. A 79, 063846 (2009).

[2] S. Frick et al., Optics Express 28, 25, 37118–37128 (2020).

[3] B. Nardi et al., Journal of Lightwave Technology pp. 1–7 (2025).