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Characterization of photon-number quantum statistics using a multi-channel superconducting detector

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Abstract: Photon-number-resolving detectors based on superconducting nanostrips enable simplified detection in few-photon regimes. Applied to one- and two-photon subtraction protocols, they reconstruct photon-number distributions of different light states at telecom-wavelengths.

Photon-number resolving detectors (PNRDs) are essential in many fields of quantum science and technology that require determining the number of photons and reconstructing their statistical distribution, such as quantum communication, quantum key distribution, and also quantum optics [1]. To extend PNR detection into the telecommunication wavelength regime, where silicon detectors are blind, superconducting devices have become particularly attractive. In this landscape, superconducting nanostrip single-photon detectors (SNSPDs) stand out as an optimal compromise between performance and practicality, owing to their relatively high operating temperatures (a few Kelvin), near-unity detection efficiency at 1550 nm, picosecond timing resolution, and extremely low dark-count rates [2].

Photon-number resolution can be achieved through single-photon detectors using several superconducting nanostrips, as each one can independently switch in the presence of incident photons. In this work, we test the reliability of a meander-shaped PNRD consisting in an array of eight superconducting NbN nanostrips. By theoretically modelling the detector response matrix, we reconstruct the photon-number distributions of both coherent and thermal states from the measured events, while implementing one- and two-photon subtraction protocols. The photon annihilation operator was implemented by means of a low-reflectivity beam splitter (BS) and two SNSPDs [3].

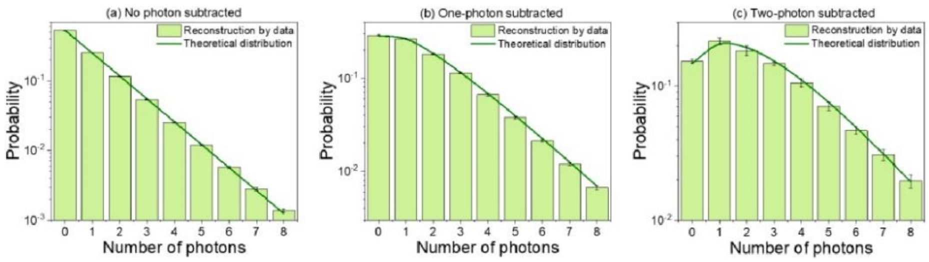

Fig. 1 Reconstructed photon-number distribution (green bars) and theoretical thermal distribution (green curve) in the case of no photon subtraction (a), one photon subtraction (b) and two photon subtraction (c).

Experimental results confirm the theoretical predictions regarding the effects of the annihilation operator on the photon number distribution of the heralded light states, with fidelities higher than 99%. It was verified that the annihilation operator does not affect a coherent state, while it doubles the mean photon number per pulse if applied to a thermal state and triples the same mean number if it is applied twice. These results highlight the role of enhanced PNRD performance in enabling novel experimental investigations in quantum optics.

References

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