Macroscopic Photon-Number Resolution with Sub-Poisson-Noise Precision

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Photon counting is a cornerstone of quantum optics used for many applications, such as photonic quantum computing [1]. We demonstrate macroscopic photon-number resolution from 0 to beyond 9000 photons per pulse while surpassing the Poisson-noise limit by at least 8 dB across this entire range and reaching sub-single-photon precision up to 274 photons (see red point in Fig. 1). Our detector combines temporal- and spatial-multiplexing with intrinsic photon-number resolving superconducting nanowire single-photon detectors (PNR SNSPDs). In total we have 128 temporal and 8 spatial bins, yielding 1024 total detection bins, each utilizing PNR based on arrival-time measurements. We rigorously calibrate each bin via a recent detector model [2] by following the analysis from [3] for every bin. This yields precise measurements of the photon number with a measurement variance below the Poisson-noise limit on a shot-by-shot basis (see colored dots in Fig. 1). Operating at a repetition rate of 80 kHz, this corresponds to precise photon counting to approximately 100 pW of optical power, bridging the gap between single-photon detectors and conventional power meters. Large-scale photon-number-resolving detection and its analysis tools will be essential for characterizing increasingly macroscopic quantum systems and for applications in precision metrology and optical power standards.

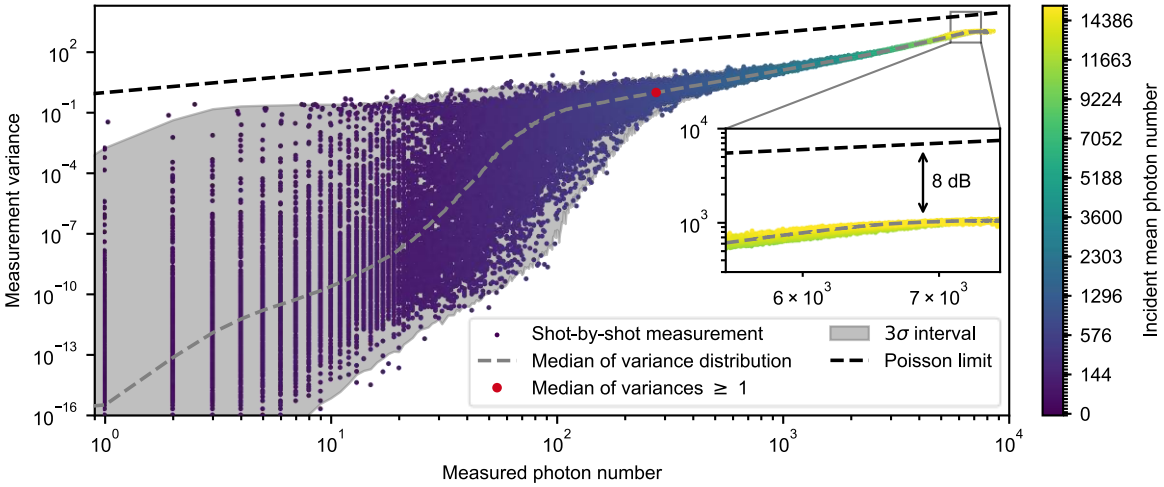

Fig. 1: *Measurement variance vs. measured photon number for 10^3 shots for all 125 incident mean photon numbers from 0 to 15393 (corresponding to different colors). Every dot is a shot-by-shot measurement of mean and variance, all of which lie at least 8 dB below the Poisson-noise limit (black dashed line). The red point at a mean of 274 indicates sub-single-photon precision, as the median of the variance distribution of a given measured mean is <1.*

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References

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