

A logarithmic optical detector for single photons and bright light

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We demonstrate an optical pulse energy detection scheme with a dynamic range of over 140 dB, centered around the single photon level. By splitting a macroscopic pulse into many pulses in time, we send up to 390 μW average power at 500 kHz repetition rate onto a standard superconducting single photon detector, using the decaying pulse power to extract useful information. Thus we bridge the gap between single-photon detectors and optical power meters, ideal for calibration tasks, as well as experiments where a high dynamic range is required. This setup can be easily used both to characterise single photon detectors without the need to insert calibrated attenuators, and to test the non-classicality of quantum states of light.

To achieve this, we exploit the fiber loop multiplexing scheme as introduced by Banaszek and Walmsley [1] (Fig 1 top). While the response of this device in the low light regime is well studied [3, 2, 4], here we target a regime in which the probability of the first bins firing is saturated to unity. This level is different to the damage threshold, at which the detector response is permanently changed (and no subsequent bins fire). We show that for superconducting nanowire single-photon detectors (SNSPDs) the detector damage threshold is far above the saturation limit, which enables us to investigate bright states with these single-photon detectors. High dynamic range has been shown at the single-photon level with transition edge sensors, however their technical requirements and readout are more involved [5].

We experimentally demonstrate two different configurations for the loop architecture. First, in the low-light regime, we actively switch the incoming pulse into the loop, then couple out a constant fraction. This is achieved using a fast free-space EOM and a polarising beam splitter [6]. We investigate the statistics of thermal, coherent, and heralded single photon states of light, uncovering non-classicality using a measure recently introduced in [7]. We also investigate the passively coupled case, in which the beam splitter reflectivity remains fixed. Care must be taken to overcome polarisation-dependent changes to the detection efficiency of each bin, for which a polarisation-maintaining fibre in the loop is required. We use this passive configuration to investigate the response of the device to both bright and single-photon light levels. Fig. 1 (bottom) shows, on a logarithmic scale, the saturated detector for 2.36 nW incident power (measured between the loop and detector).

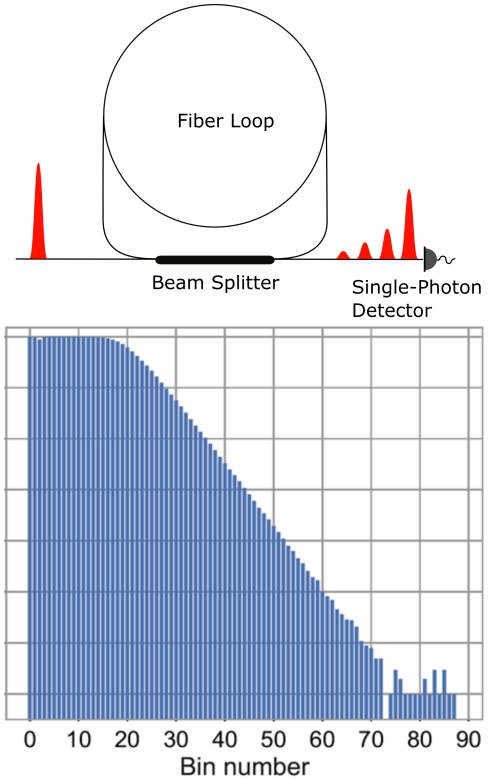


Figure 1: Top: Fiber loop multiplexing scheme [1]. Bottom: Example of the click probability per bin given a measured power of 2.36 nW after the loop. Here the saturation region, the linear decay region and the noise floor caused by dark counts can be easily identified.

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