Free-space and Fibre-coupled Single-photon Detector Comparison

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Accurate characterisation of a single-photon avalanche diode (SPAD) detectors is essential when comparing optical power scales in the single-photon regime. In such comparisons, device 'imperfections' are a major source of uncertainty: free-space devices suffer from spatial nonuniformities — including interference effects [1] — whilst fibre-coupled devices are limited mainly by the coupling repeatability [1, 2]. Here, we examine these features for two free-space coupled SPADs and a fibre-coupled SPAD in detail by comparing detector response and nonuniformity measurements made at both NIST and NPL. We explore methods to reduce them, leading to improved measurement agreement, and we highlight issues in extracting detection efficiency values from measurement data and consider afterpulsing noise.

Figure 1 shows one free-space detector's spatial responsivity map, with the optical coupling position of each detection efficiency measurement indicated. Measurement agreement was improved by reducing the laser's coherence (right image), reducing interference effects intrinsic to the device, thereby increasing the responsivity uniformity.

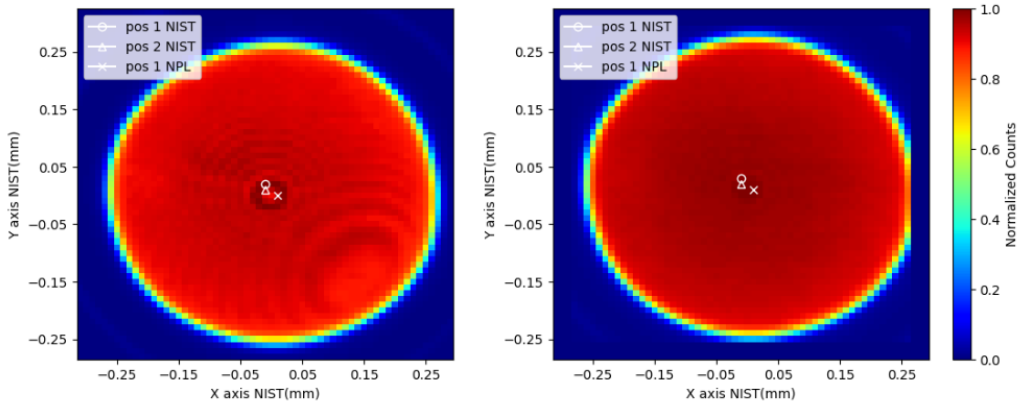

Fig. 1: *Free-space spatial responsivity map when measured with a laser operated above (left) and below (right) lasing threshold.*

This study highlights the sensitivity of SPAD-based measurements to optical coupling and applies a method to reduce non-uniformities, decreasing measurement uncertainty. The results show that detector efficiency measurements in Figure 1 agree to within 2.3% above, and 0.66% below, the lasing threshold, supporting more robust and reproducible comparisons involving SPAD detectors. Fibre-based results fall within the 1.4% uncertainty associated with the coupling repeatability.

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References

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