

5. Conclusion

SNSPDs are ideal detectors for optical QIS experiments at telecom wavelengths, having both reasonable quantum efficiency and rapid response with low dark counts. We have presented quantum tomography of TM-SNSPDs with photon resolving capability with the help of a fiber network. The experiments were carried out at the main telecom wavelengths (1310 nm, 1550 nm) at repetition rates of up to 4 MHz, taking into account two polarizations and a range of bias points ($0.7-0.9 \times I_c$). Linear behavior of binary and TM detectors was observed in our experiments, which is confirmed by the reconstructed POVM. In the case of a binary detector, the coefficient of the reconstructed POVM element of the click-event was observed to be zero for the zero-photon component and increases to 1 for higher photon-number components. The detection efficiency calculated from the POVM elements of the best device (Fig. 4(b) and Fig. 3(d)) in our setup had $\sim 18\%$ efficiency at 1550 nm at $I_b = 0.9 \times I_c$. A time-multiplexed detector, as a photon-number-resolving detector, has more outcomes ranging from, for example, no-click to N-clicks. In some of the earlier PNR SNSPD demonstrations such as reference [21], the detectors were operated in the non-linear regime (i.e. biased very low) to study the multiphoton detection statistics. In our experiment, the detectors were biased at $0.9 \times I_c$ and the fiber time multiplexing network was employed to explore the PNR configuration. The POVM element of each outcome gives a distinct sensitive region, which confirms that the detector has a capability to (partially) resolve the input photon number. The POVM element of the N-click event has a similar behavior as that of the click event of a binary detector, showing the response of the detector when it is saturated.

SNSPD device technology is improving rapidly [12]. It is reasonable to foresee construction of a fast, photon number resolving TM-SNSPD, using highly efficient ($>50\%$) SNSPDs, with fast recovery times (~ 1 ns) integrated on to a waveguide circuit platform. There are also various future paths to be explored in pursuit of a rigorous assumption-free characterization of SNSPDs. Notably, the inclusion of complete wavelength-, polarization- and phase information in the Hilbert-space will give a comprehensive definition of the SNSPD. This method will thus provide a full description of the detection unit in QIS experiments relying on photons.

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