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SILICON SOLID STATE PHOTOMULTIPLIER

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A detection quantum efficiency higher than 83% is required to perform a detection loophole free test of Bell's inequality. The highest quantum efficiency of 76% was reported with an avalanche photodiode operated in a Geigher mode[1], which still falls short of the requirement. A solid state photo multiplier (SSPM) is another candidate which utilizes an avalanche of electrons in shallow impurity band. It's quantum efficiency is projected to be higher than 93%, however, the measured value as a system had been less than 70% because of it's high sensitivity to infrared photons (up to 32μm) and an operating temperature of 6.5K.

We developed a cryostat system where photons can be directly focused onto the detector from outside through a highly transparent($\sim$ 97% at 700nm) set of windows, which attenuated the thermal radiation by more than 10^{-14}. The thermal photons reaching the detector were reduced with very tight shielding to below several hundred. The reflected photons at the detector surface ($\sim$ 16% at 700) were recollected by a refocusing mirror ($\sim$ 99% reflectance) inside the cryostat. The signal was processed with wide-band amplifiers to achieve pulses of 2ns width, which are purely limited by the capacitance of the device itself. The highest quantum efficiency of 88$\pm$ 5% at 694nm was observed with a bias voltage of 7.3V at 6.5K. The dark counts at this point were 2.0×10^4, most of which were caused by the internal mechanism of the device. We also found that the dark counts of the VLPC increases roughly as the exponential of the quantum efficiency with changing temperature or bias voltage.

Two features of SSPM, a well-defined pulse height for a photon detection event[2] and local generated avalanche phenomena, suggested a unique capability for distinguishing between a single-photon and two-photon detection event. We confirmed it using twin photons by parametric down conversion, and found that the height of the pulse for a two-photon detection event is approximately double that of a single-photon detection event. Such capability may be used to improve the security of quantum cryptography.

[1] P. G. Kwiat, A. M. Steinberg, R. Y. Chiao, P. H. Everhard & M. D. Petroff, Phys. Rev. **A 48** R867 (1993).

[2] J. Kim, Y. Yamamoto & H. H. Hogue, Appl. Phys. Lett. **70** 2852(1997).