On-chip, photon-number-resolving, telecom-band detectors for scalable photonic information processing

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We demonstrate the operation of an integrated photon-number resolving transition edge sensor (TES), operating in the telecom band at 1550 nm, employing an evanescently coupled design that allows the detector to be placed at arbitrary locations within a planar optical circuit. This concept eliminates the scalability problems associated with probing optical modes from the end facets of integrated circuits when using fiber-coupled single photon detectors. The device consists of a UV-written silica waveguide and a tungsten TES deposited onto the waveguide structure. The waveguide structure used was written by use of a UV laser writing technique designed to alter the index of a Ge-doped silica core layer, the underclad being a 17 μm layer of thermally grown silicon oxide. No top cladding was fabricated, to maximize the evanescent coupling to the TES. The planar core/cladding layer refractive index contrast was 0.6 % with a core layer thickness of 5.5 μm. The UV-written channel had a Gaussian index-profile with a contrast of 0.3 % and a width of about 5 μm. The TES dimensions were 25 μm x 25 μm x 40 nm with wiring to the tungsten achieved using niobium. The TES is photon-number-resolving, meaning the detector can distinguish the energy correlated to the absorption of not only a single photon (click detector), but energy correlated to the absorption of several photons. Figures 1 and 2 show the experimental results when detecting a pulsed coherent state with mean photon number of about 1 and wavelength of 1550 nm. Figure 1 shows the histogram of detected pulse heights for the pulsed coherent input state. Clear separation of individual photon peaks is achieved and up to 5 photons are resolved in the guided optical mode via absorption from the evanescent field into the TES. Figue 2 shows raw output traces of the evanescently coupled TES. The detection efficiency of a photon that is in the waveguide is 7.2 ± 0.5 %. The coupling efficiency from our laser source into the waveguide structure is 47.9 ± 5.2 %. The detection efficiency of these devices can be improved by elongating the detector along the waveguide structure to increase the absorption length. In addition, multiplexing several TESs along the waveguide will further increase the systems performance. Also, the waveguide core thickness can be reduced to increase the mode overlap of the guided mode with the detector. We are currently pursuing all of these approaches and will present our progress in developing these detectors with higher system detection efficiency.

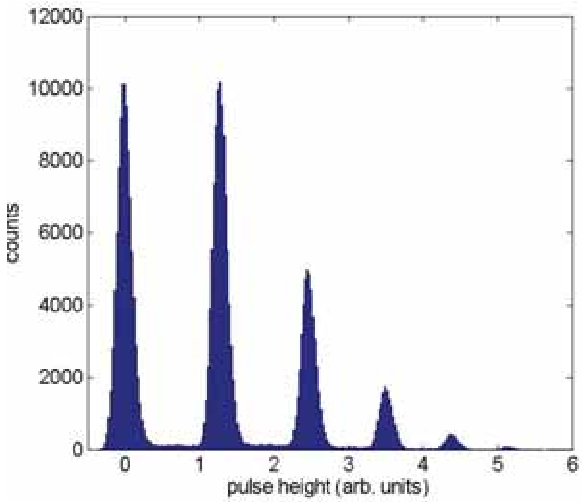

Figure 1: Photon pulse height distribution for a measured coherent state with a mean photon number of about 1.

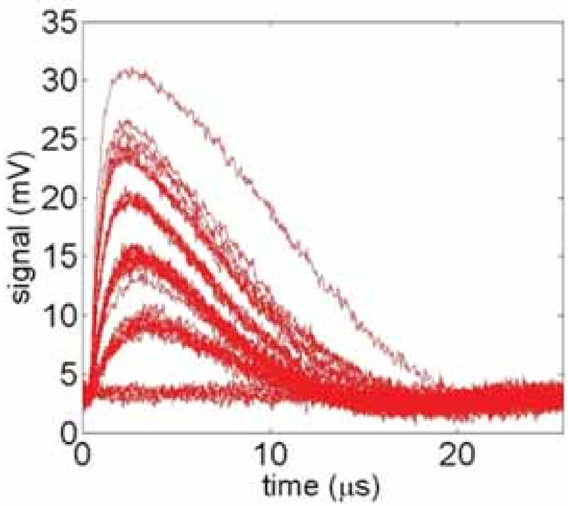

Figure 2: Electrical TES output traces for different numbers of photons in the weak laser pulse; the photon number resolving capability is clearly visible here