Photon-number discrimination using a semiconductor quantum dot, optically gated, field-effect transistor

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Detectors capable of resolving the number of photons in a pulse of light are important components for the advancement of quantum information technologies. We demonstrate photon-number discrimination using a novel single-photon detector that utilizes a layer of self-assembled InGaAs QDs as an optically addressable floating gate in a GaAs/AlGaAs delta-doped field-effect transistor. When the QDOGFET (quantum dot, optically gated, field-effect transistor) is illuminated, the internal gate field directs the holes generated in the dedicated absorption layer of the structure to the QDs where they are trapped. Confined to the dots, the positively charged holes screen the internal gate field causing a persistent change in the channel current that is proportional to the total number of holes trapped in the QD ensemble. Over time, the charging of the QDs caused by even a single photo-generated hole results in a large change in the cumulative charge transferred in the channel. This photoconductive gain makes the device extremely sensitive to photons of the appropriate wavelength. Because the change in the channel current is proportional to the number of trapped holes, the detector is capable of resolving the number of absorbed photons. Using highly attenuated laser pulses, we characterize the response of the QDOGFET cooled to 4 K. The device exhibits time-gated, single-shot, single-photon sensitivity and detects photons absorbed in its dedicated absorption layer with an internal quantum efficiency of (68+/-18) %. We demonstrate that different photon-number states produce well-resolved changes in the channel current, where the responses of the detector reflect the Poisson statistics of the laser light.