A single-photon 'click' detector for microwave light

N. J. Lambert[1], M. Edwards[1], A. A. Esmail[1], F. Pollock[2], B. W. Lovett[3], A. J. Ferguson[1]

[1] *Microelectronics Group, Cavendish Laboratory, J. J. Thomson Avenue, Cambridge, CB3 0HE, UK*

[2] *Clarendon Laboratory, Parks Road Oxford, OX1 3PU, UK*

[3] *School of Engineering & Physical Sciences, Heriot-Watt University, Edinburgh, EH14 4AS, UK*

We demonstrate a single-photon click detector in the frequency range 30 GHz to 50 GHz. The device is based on a superconducting double dot, with readout via quantum capacitance measurement. We show that the detector threshold can be tuned, and establish its linearity.

Single photon detection at visible and IR frequencies is a well-established technology, but the task becomes more difficult as the photon energy decreases. Microwave photons have energies 10000 times lower than those detected by silicon avalanche photodiodes and single photon detection at these energies would be of considerable interest, for example in the quantum information applications of circuit quantum electrodynamics[1]. Whilst the Hanbury-Brown – Twiss effect has been observed for microwave frequencies[2], this is the first time a click detector has been demonstrated for photons at these energies.

We have fabricated a superconducting double quantum dot, with two Al islands connected via Josephson junctions to each other, and tunnel junctions to normal leads. The energetics of a normal double dot is characterized entirely by the charging energy (E_c) of the islands. In our superconducting device the superconducting gap (Δ) and the Josephson energy act as additional energy scales, breaking the symmetry between even and odd parity charge states. For a sufficiently low value of E_c / Δ odd parity states, which involve quasiparticles, are energetically unfavourable.

To probe the state of our device, we use r.f. reflectometry. In particular, we measure the quantum capacitance of the system [3]. We can distinguish even parity and odd parity states with a signal to noise ratio of ~4 and a bandwidth of 100kHz.

By the application of a magnetic field, the ratio between E_c and Δ can be changed. We tune the device so that a quasiparticle state is energetically accessible by absorption of a single non-equilibrium microwave photon. This change in parity is readily measurable, and so we can detect the absorption of the photon.

Single shot time domain measurements taken at the (2,0)/(0,2) degeneracy show stochastic switching between the (2,0) and (1,1) states. We attribute this to the absorption of background microwave photons by the device. We demonstrate the device operating as a 'click' detector of photons by applying microwaves in the 30-50GHz range. The photon count is linear with applied microwave power, and by changing the applied magnetic field, we can change the detection threshold.

[1] D. Bozyigit *et al*. Nature Physics **7**, 154–158 (2011)
[2] Y.-F. Chen *et al*. Phys. Rev. Lett. 107, 217401 (2011)
[3] K. D. Petersson *et al.* Nano Letters **10**, 2789-2793 (2010).