Heat Pulse Studies of Quasiparticle Dynamics in Superconducting Tunnel Junction Photon Detectors

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Non-equilibrium phonons provide a valuable method for studying the interactions of carriers in low temperature photon and particle detectors, and hence of characterising their performance. Superconducting tunnel junctions (STJs) are widely used as sensitive photon detectors throughout the electromagnetic spectrum [1]. We describe investigations of the response of STJ detectors in which the effect of an absorbed photon is simulated by a heat pulse with a known phonon frequency spectrum. The equivalent photon energy of the heat pulse is calculated from the number of phonons in the spectrum with energies above the STJ energy gap. In contrast to direct photon detection the technique has high temporal and spatial resolution, and in addition has the advantage that the input pulse energy can be varied continuously over a wide range.

Furthermore, since the phonon flux incident on the detector surface area is homogeneously distributed (unlike photon or particle absorption which takes place at a specific point) diffusion effects are negligible, and the modified Rothwarf-Taylor equations can be solved analytically to model the time dependence of the current. The resulting expression consists of two exponentially varying terms. From the experimentally measured values of the magnitudes and exponents of these terms, the tunnelling times and loss times in the upper and lower electrodes can be inferred separately, in contrast to conventional modelling of STJ responsivity. Experimental results relating to a Nb detector at 1.4K and a Ta detector at 20mK previously studied at ESTEC (European Space Agency) will be described [2]. Values obtained for tunnelling times using phonons generally agree well with those obtained from responsivity modelling, whereas the loss times are usually smaller, it is believed due to excessive flux trapping. Finally the responsivity to X-ray photons calculated from the phonon results will be compared with experimental data obtained at ESTEC.

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