Noise and responsivity measurements in Hot-Electron Direct Detectors

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We present the current progress and the test results for the hot-electron transition-edge devices of nanoscale size operating at ~ 0.1-0.4 K. The ultimate goal of this work is to develop a submillimeter Hot-Electron Direct Detector with the noise equivalent power NEP = 10^{-18}-10^{-20} W/Hz$^{1/2}$ operated at ~ 0.3 K for the moderate resolution spectroscopy and CMB studies on future space telescope (e.g., SAFIR, SPECS, SPICA, CMBPol) with cryogenically cooled (~ 4-5 K) mirrors.

Using the shadow mask evaporation technique we fabricated nanoscale Ti bridges with Nb Andreev contacts. The devices were fabricated on a Si wafer and did not rely on the thermal insulation due to the membrane support normally required in conventional bolometers. The thermal conductance in our devices is set by the electron-phonon coupling, which is very weak in disordered metals at subKelvin temperatures. From the electrical measurements, the thermal conductance was found to be ~ 2 fW/K at 300 mK and ~ 0.1 fW/K at 40 mK. If the thermal fluctuation noise is dominant in the devices then such a uniquely low thermal conductance should provide the NEP required for most demanding applications.

The measurements involving detection of single NIR photons ($\lambda = 1550$ nm) allowed for determination of the bolometer thermal time constant (electron-phonon relaxation time) being of 20 µs at 200 mK and a few µs at 370 mK. The latter measurements were hindered by the limited SQUID bandwidth (100 kHz). A broadband 1 MHz SQUID is being set up for future experiments on single photon detection.

The output electrical noise measured in the devices in the voltage-bias mode was dominated by the thermal energy fluctuations (phonon noise). This was an indication that the responsivity was sufficiently high (i.e., the superconducting transition was steep enough).

The very low NEP and the high speed are a unique combination not found in other detectors. This would allow for a very high data rate in an application, though more work is needed to develop an adequate read-out/multiplexing electronics for this type of detector. Beside the extremely low phonon-noise NEP, the nanobolometers have a very low electron heat capacitance. This makes them promising as detectors of single FIR photons for the moderate resolution spectroscopy above 1 THz where the background photon arrival rate is less than the detector speed.

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