Optical response of strained and unstrained silicon cold electron bolometers

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We describe the optical characterisation of two silicon cold-electron bolometers each consisting of a small (20 um x 20 um) island of degenerately doped silicon with superconducting aluminium contacts. Radiation is coupled into the silicon absorber with a twin slot antenna designed to couple to 150 GHz radiation through a silicon lens. The first device has a highly-doped silicon absorber (the control device), the second has a highly-doped strained silicon absorber. We show that the presence of a straining layer in the bolometer's absorber improves the detectors responsivity by a factor of 25. We also show that this increase can be explained by a decrease in the coupling between the electrons and the phonons in the strained detector. We measure device sensitivities of 8 x 10^-16 and 7 x 10^-17 W/sqrt(Hz) for the control and strained devices respectively at a base temperature of 350 mK when absorbing radiation from an external 77-Kelvin source.

We read out the detectors using a pair of low noise JFET amplifiers which are both coupled to the device at the input but are decoupled from each other. The device noise is measured by cross correlating the outputs of the two independent amplifiers to reduce the contribution of the amplifiers. We validate the noise measurement using cold resistors and verify that we are able to measure Johnson noise down to a level of 300 pV/rtHz even though the input referred noise of each JFET amplifier is 1.4 nV/rtHz. This technique can be used to measure photon noise or device noise in the presence of amplifier noise for other detectors such as KIDs. We measure the response time of the detectors from the frequency dependence of the phonon and photon noise and optically using a chopped (up to 100 kHz) 150 GHz coherent source to have an upper limit of 1 microsecond corresponding to the RC rolloff of the readout electronics. The theoretical response time is on order of 10 ns. Given the measured temperature dependence of the responsivity around 350 mK, we expect the sensitivity to improve by at least a factor of 30 simply by operating the detectors at 150 mK instead of 350 mK. Additional improvement in sensitivity can be obtained by reducing the silicon island area.