Hot-electron Nano-bolometers for Astrophysics: Superconductor vs Normal Metal

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Abstract - Hot-electron nanobolometers (nano-HEB) made from superconducting Ti have shown a remarkable sensitivity for detection of submillimeter radiation (NEP = 3×10^{-19} W/Hz$^{1/2}$ @ λ = 480 µm). This makes them a strong candidate for the future applications in spectral or imaging arrays on telescopes with cryogenically cooled mirrors. The application that will benefit the most is a galactic line survey where a moderate resolution (λ/δλ ~ 1000) is required. To take advantage of the ultralow background conditions, a detector with an NEP = 10^{-19} – 10^{20} W/Hz$^{1/2}$ is sought in the 25-400 µm wave range. Although the superconducting nano-HEB is very close to meeting this sensitivity goal, more work is needed in order to achieve a large (~ 1000s pixels) array of such detectors. The challenge here is the necessity to multiplex a large number of readout amplifiers (SQUIDs) and also to make the system immune to the SQUID back action and crosstalk.
More recently, we conceptualized a normal-metal nano-HEB where the Johnson noise in the sensor is used as the measure of an increase of the electron temperature caused by the absorbed radiation. The noise thermometry readout is heavily dependent on the availability of a broadband and low-noise (quantum noise limited - QNL) amplifier for operation in the 1-10 GHz range. The theoretical NEP limit set by the QNL amplifier is below 1×10^{-20} W/Hz$^{1/2}$, however even a commercial amplifier with the noise temperature of 2 K would set the limit to ~ 10^{-19} W/Hz$^{1/2}$ which is among the best NEP figures achieved so far. The absence of any bias lines or SQUIDs and the enormous dynamic range are big advantages of the normal metal nano-HEB.
I present a comparison of the array architectures for superconducting and non-superconducting versions of the nano-HEB discussing their pros and cons for detection of cw radiation. The single mid-IR photon detection using superconducting nano-HEB is also discussed. This mode of operation is desirable in astrophysics for λ < 300 µm where the background photons arrive at a rate ~ 100 s^{-1}.

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Keywords (Index Terms) – Hot-electron, superconducting bolometer, Johnson noise thermometry, submillimeter astronomy.