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Quantum noise contribution to NbN hot electron bolometer receiver

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***Abstract*— Superconducting NbN hot electron bolometer (HEB) mixers are so far the most sensitive detectors for heterodyne spectroscopy in the frequency range between 1.5 THz and 5 THz. To reach the ultimate receiver noise temperatures in the high end of the THz range (3-6 THz), it is crucial to understand their fundamental noise contribution from different origins. With increasing frequency, the classical output noise contribution should remain unchanged, but the quantum noise contribution is expected to play an increasing role [1].**

This paper reports the first dedicated experiment using a single NbN HEB mixer at a number of local oscillator frequencies between 1.6 to 4.3 THz to address and quantify the contribution of the quantum noise to the receiver noise temperature.

We used a spiral antenna coupled NbN HEB mixer with a bolometer size of 2 μm×0.2 μm. In order to minimize uncertainties in the corrections of the optical losses, we use a vacuum hot/cold load setup [2] to eliminate the air loss, and an uncoated elliptical Si lens. Although other components, a 3 μm Mylar beam splitter and a QMC heat filter, also introduce frequency dependent optical losses, they can be accurately calibrated. Furthermore, to reduce uncertainties in the data, we measure Y-factors responding to the hot/cold load by fixing the voltage, but varying the LO power [2]. As LO, we use a FIR gas laser.

We measure the Y-factor at the optimal point at different frequencies by only varying LO frequencies, but keeping the rest exactly the same. We obtain DSB receiver noise temperatures, which are 842 K (at 1.6 THz), 845 K (1.9 THz), 974 K (2.5 THz) and 1372 K (4.3 THz). After the correction for the losses of the QMC filter and the beam splitter, the noise data show a linear increase with increasing frequency.

Using a quantum noise model [1] for HEB mixers and using a criterion for which the classical output noise must be constant at different frequencies, we analyze the results and find the excess quantum noise factor β to be around 2 and that 24 % of the total receiver noise temperature at 4.3 THz (at the input of the entire receiver) can be ascribed to quantum noise. Clearly the quantum noise has a small but measurable effect on the receiver noise temperature at this frequency.

We are still analyzing different alternatives of interpretation for the mismatch loss between the bolometer and the spiral antenna.

[1] E. L. Kollberg and K. S. Yngvesson, "Quantum-noise theory for terahertz hot electron bolometer mixers," IEEE Trans. Microwave Theory and Techniques, 54, 2077, 2006.

[2] P. Khosropanah, J.R. Gao, W.M. Laauwen, M. Hajenius and T.M. Klapwijk, "Low noise NbN hot-electron bolometer mixer at 4.3 THz," *Appl. Phys. Lett.*, 91, 221111, 2007.