Direct Detection Effect in Hot Electron Bolometer Mixers

A. Baryshev, J.J.A. Baselmans, S.F. Reker
SRON National Institute for Space Research, Landleven 12, Postbus 800, 9700 AV Groningen, The Netherlands

M. Hajenius, J.R. Gao
SRON National Institute for Space Research, Sorbonnelaan 2, 3584 CA Utrecht, The Netherlands and *Kavli Institute of Nanoscience, Delft University of Technology, Lorentzweg 1, 2628 CJ Delft, The Netherlands*

T.M. Klapwijk
Kavli Institute of Nanoscience, Delft University of Technology, Lorentzweg 1, 2628 CJ Delft, The Netherlands

Yu. Vachtomin, S. Maslennikov, S. Antipov, B. Voronov, and G. Gol'tsman
Moscow State Pedagogical University, Moscow 1199992, Russia

Abstract

NbN phonon cooled hot electron bolometer (HEB) mixers are currently the most sensitive heterodyne detectors at frequencies above 1.2 THz. They combine a good sensitivity (8-15 times the quantum limit), an IF bandwidth of the order of 4-6 GHz and a wide RF bandwidth from 0.7-5.2 THz. However, for use in a space based observatory, such as Herschel, it is of vital importance that the Local Oscillator (LO) power requirement of the mixer is compatible with the low output power of present day THz LO sources. This can be achieved by reducing the mixer volume and critical current. However, the large RF bandwidth and low LO power requirement of such a mixer result in a direct detection effect, characterized by a change in the bias current of the HEB when changing the RF signal from a black body load at 300 K to one at 77 K. As a result the measured sensitivity using a 300 K and 77 K calibration load differs significantly from the small signal sensitivity relevant for astronomical observations. In this article we describe a set of dedicated experiments to characterize the direct detection effect for a small volume quasi-optical NbN phonon cooled HEB mixer.

We measure the direct detection effect in a small volume (0.15 μm · 1 μm · 3.5 nm) quasi-optical NbN phonon cooled HEB mixer at 1.6 THz. We found that the small signal sensitivity of the receiver is underestimated by approximately 35% due to the direct detection effect and that the optimal operating point is shifted to higher bias voltages when using calibration loads of 300 K and 77 K. Using a 200 GHz wide band-pass filter at the 4.2 K the direct detection effect virtually disappears. Heterodyne response measurements using water vapor absorption line in a gas cell confirms the existence and a magnitude of a direct detection effect. We also propose a theoretical explanation using uniform electron heating model.

This direct detection effect has important implications for the calibration procedure of these receivers in real telescope systems.