

Progress Report FP6 – RadioNet – AMSTAR

May – October 2004

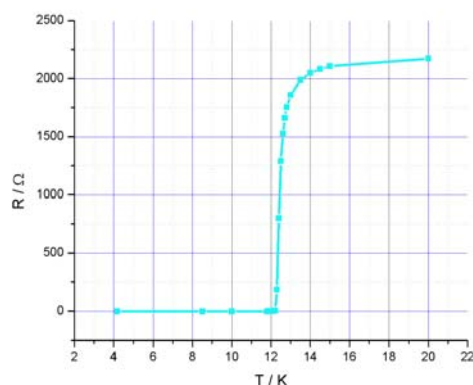
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W.P. HEB-Mixer film fabrication and optimization

This work package concerns the development of phonon-cooled Hot Electron Bolometers (HEB) Mixers for observations above 1 THz (SOFIA) with the goal of fundamental study and optimization of ultra-thin NbN film parameters.

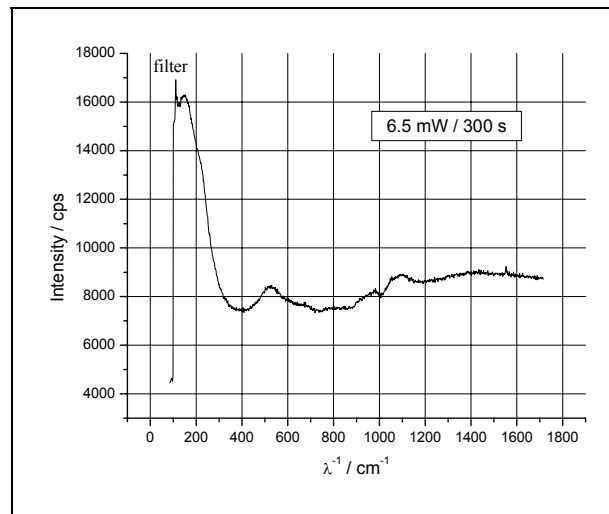
The heterodyne detection of weak THz signals in radio astronomy with ultra-thin superconducting microbridge bolometers necessitates optimized NbN film qualities to allow mixing with IF bandwidths up to 10 GHz. In this first step the following activities has been started:

- Production of 100 nm thick NbN films by RF sputtering of niobium in a nitrogen/methane/argon atmosphere to control the process parameters and the superconducting transport parameters of the deposited films ($T_c \sim 15$ K, resistance ratio ~ 0.96 , specific resistance $\sim 130 \mu\Omega\text{cm}$).
- Production of ultrathin (3 – 5 nm) NbN films on fused quartz with a 15 nm thick MgO seed layer ($T_c \sim 12$ K).

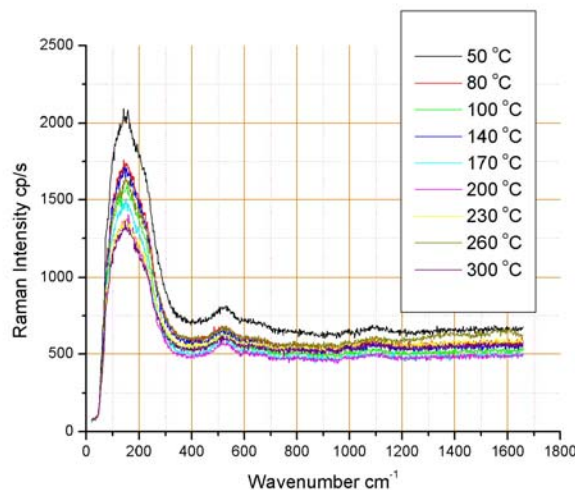


- Determination of the optical constants of the deposited NbN films by means of ellipsometry (complex refractive index $\mathbf{n} = 1.89 - i \cdot 4.36$). The large value of the adsorption coefficient corresponds to a light penetration depth of about $\delta = 5$ nm. Therefore, Raman spectroscopy is a useful method to investigate very thin NbN films and their acoustic properties for the phonon cooling mechanism.
- Measurement of acoustic phonon density of states of thick and ultrathin (3 - 5 nm thick) NbN films by Raman spectroscopy. The measurements will help to derive the acoustic phonon matching for the realization of high IF bandwidths

in the future HEB devices. A first result (phonon wavenumber $\sim 150 \text{ cm}^{-1}$) is shown in the following figure:

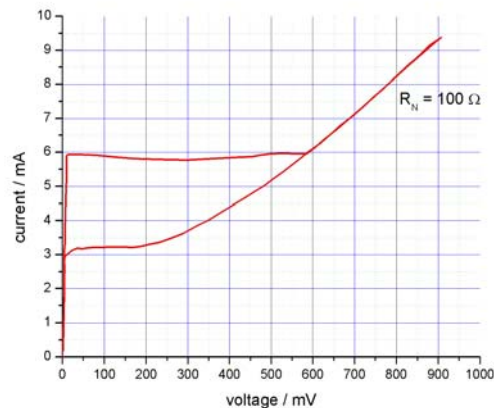


- The evaluation of the crystalline film growth and the corresponding superconducting transport properties depending on the substrate temperature (range: room temperature to $700 \text{ }^\circ\text{C}$) during the deposition process will be carried out in the near future. Raman spectra for different deposition temperatures are already measured in the range of room temperature until $300 \text{ }^\circ\text{C}$. In this low temperature range the spectra show similar behaviour. For higher temperatures a calibration procedure is necessary and will be done in the next fabrication step.

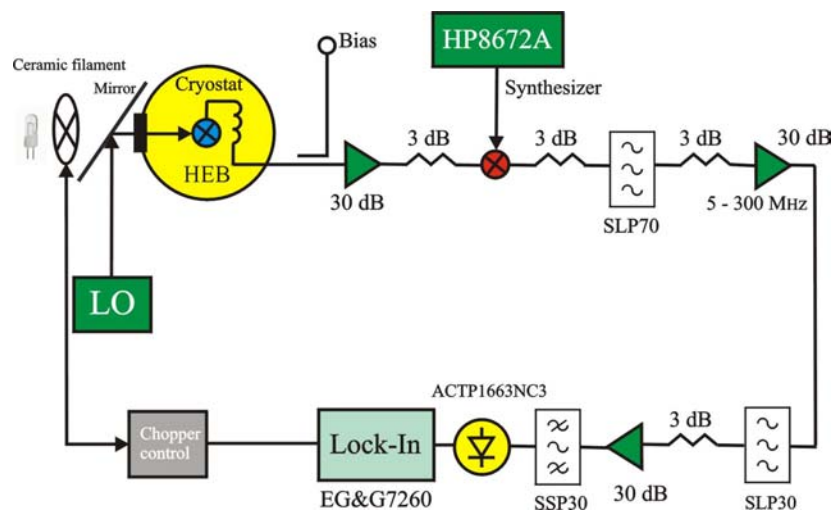


- The design and manufacturing of a 230 and 650 GHz photolithographic mask set for HEBs (3 chromium masks) with 0.5 and 1 micron bridge length for rapid IF bandwidth measurement up to 10 GHz is completed.
- Fabrication of a first batch on fused quartz / 15 nm MgO / 5nm NbN.

The DC I/V-characteristics of the HEB test device is drawn in the following picture:



- Preliminary mixer measurements at LO frequency of 230 GHz in the LHe-cryostat shows an IF bandwidth of about $\Delta f = 2$ GHz. The NbN film deposition temperature in this first test device was room temperature. We used the following bandwidth measurement setup:



Publications:

- T. A. Scherer, M. Frommberger, M. Schicke, K. Schuster, “Development of Phonon Cooled Hot-Electron-Bolometers (HEB) for Applications in THz Radioastronomy”, Proc. Of the 29th Int. Conf. On Infrared and Millimeter Waves, 12th Int. Conf. On Terahertz Electronics, Sept. 27 – Oct. 1 2004, Karlsruhe, Germany.
- T. A. Scherer, M. Frommberger, M. Schicke, K. Schuster, “Entwicklung Phonon-gekuehlter Hot-Electron-Bolometer (HEB) fuer Anwendungen in der THz-Radioastronomie”, Kryoelektronische Bauelemente 2004, Goslar, Germany, 12. – 14. Sept. 2004.