

NIOBIUM SUPERCONDUCTING DIFFUSION-COOLED HOT-ELECTRON BOLOMETER MIXERS ABOVE 1 THz

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Superconducting hot-electron bolometers are a promising option for low noise heterodyne detector systems at frequencies above 1 THz. Since the mixing process in these devices relies on heating of the electron gas, they do not suffer from the upper frequency limitation set by the superconducting energy gap, as is the case for SIS mixers. They are also much faster than more conventional bolometers, such as those made from indium antimonide, and can therefore operate with intermediate frequencies of several GHz. This combination of useful properties makes superconducting hot-electron bolometers ideal candidates for molecular spectroscopy in the fields of astrophysics and atmospheric chemistry. The heterodyne performance of this device is expected to be independent of frequency up to several tens of THz. While recent measurements have shown promising results at ~0.5 THz, our current experiments are designed to test this prediction above 1 THz.

The device used is a 0.15 μm wide and 0.30 μm long niobium film with an approximate thickness of 10 nm that is fabricated on a crystal quartz substrate together with a planar double dipole antenna, Fig.1 & Fig.2. The device chip is glued to the back side of a quartz hyperhemispherical lens. A quarter wavelength thick quartz chip with a reflecting gold layer is glued to the surface of the device chip to remove the back lobe of the dipole antenna and to improve its radiation pattern. The lens with the attached device chip is mounted in a holding fixture, aluminum wires are bonded to provide DC and IF connections, and the assembly is cooled to 2.6 K in a vacuum cryostat. A hyperbolic polyethylene lens attached to the holding fixture is used to increase the f-number of the assembly. An evacuated box is attached to the cryostat window, containing a hot load (300 K) and a cold load (77 K), a chopper wheel for switching between the loads, and a beamsplitter for coupling local oscillator power into the beampath.

Figure 3 shows an unpumped DC I-V curve of the device at 2.6 K, as well as an I-V curve that is pumped at 1267 GHz by a submillimeter wave gas laser using CF_2H_2 . The effective

RF coupling bandwidth of the receiver in a direct detection mode was measured to be ≈ 730 GHz with a Fourier transform spectrometer (FTS), Fig.4 . The bolometer is both broadband and sensitive enough to observe the direct-detection response to the hot and cold loads, without LO applied. This allows the difference between the amounts of RF power coupled from a hot (295 K) and a cold (135 K) load to the bolometer to be roughly estimated at 0.25 nW by observing the shift in DC dissipated power required to maintain a constant device resistance when switching between the two loads. The losses in the optical path between the loads and the bolometer were approximately 6.3 dB, most of which came from the beamsplitter used (2.6 dB), the cryostat window (1.5 dB) and from the impedance mismatch between the dipole antenna ($\approx 50 \Omega$) and the bolometer ($\approx 150 \Omega$). From these data and the measured bandwidth, the resistive losses in the antenna plus all other unknown RF signal path losses is estimated to be less than a few dB.

The next step is to perform Y-factor measurements. However, first we will eliminate standing waves in the LO path, and install a 100 GHz wide mesh filter into the optical path to limit the broadband direct response. We also plan to confirm the heterodyne response by using either a GaAs photomixer, a backward wave oscillator (BWO) or a gas cell as signal source.

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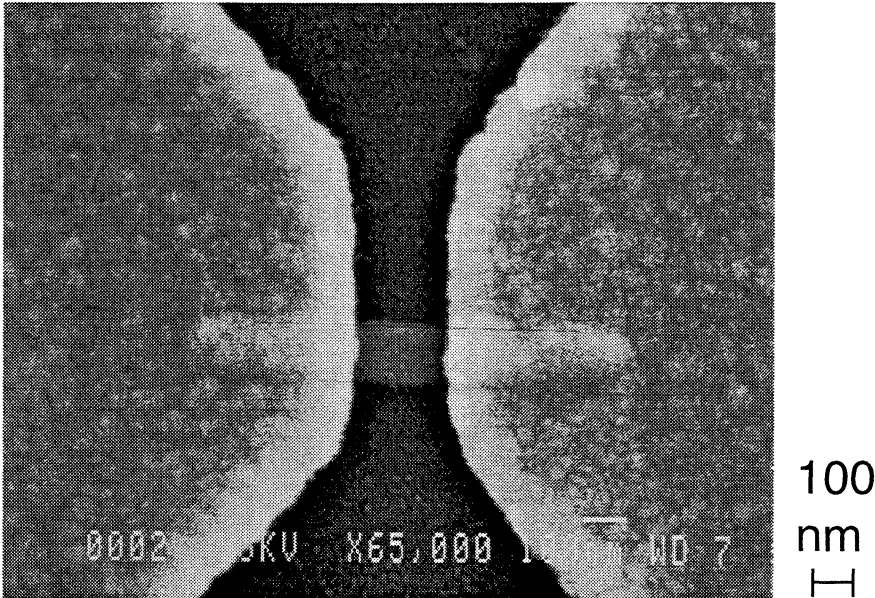


Fig.1: A niobium bolometer.

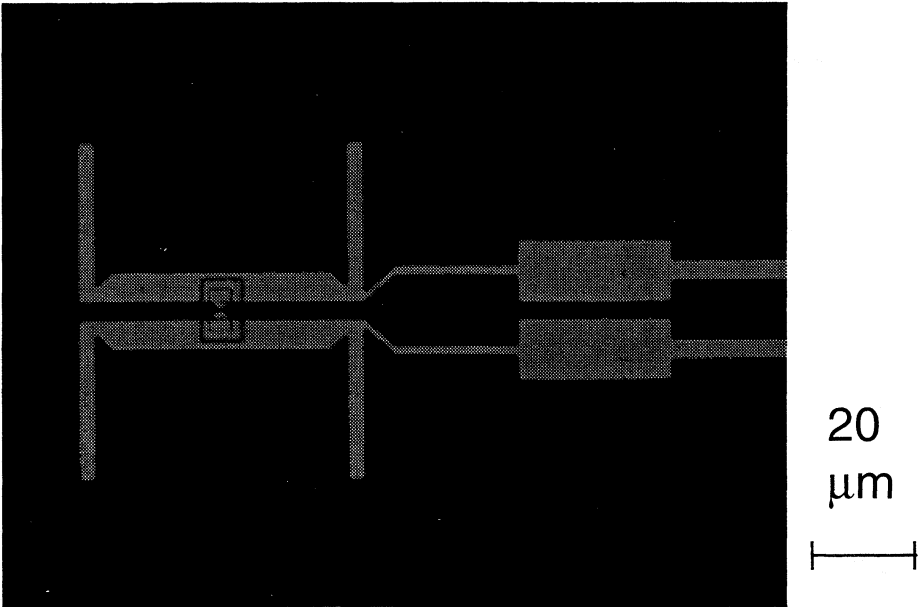


Fig.2: A double dipole antenna.

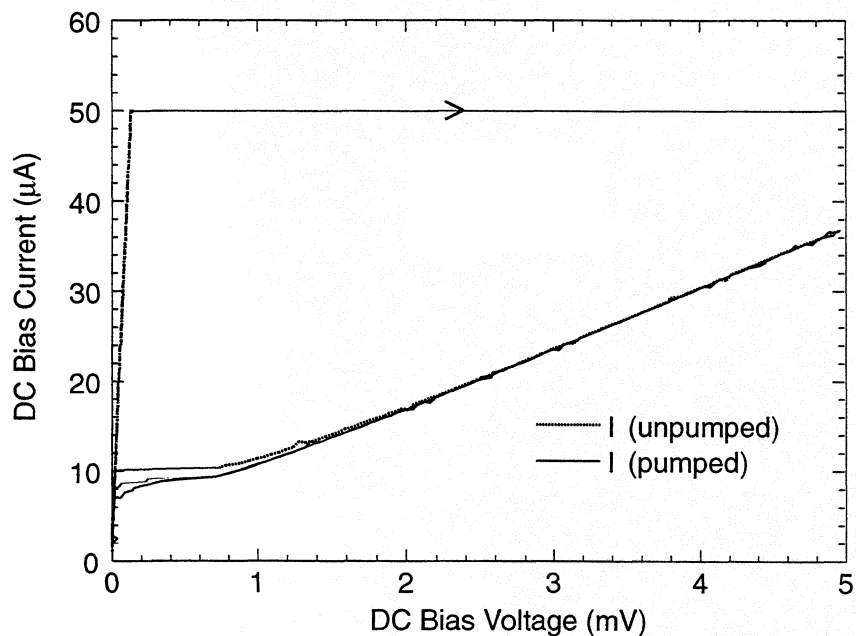


Fig.3: Unpumped and pumped IV curves of a bolometer. The pump frequency is 1267 GHz, and the ambient temperature is 2.6 K

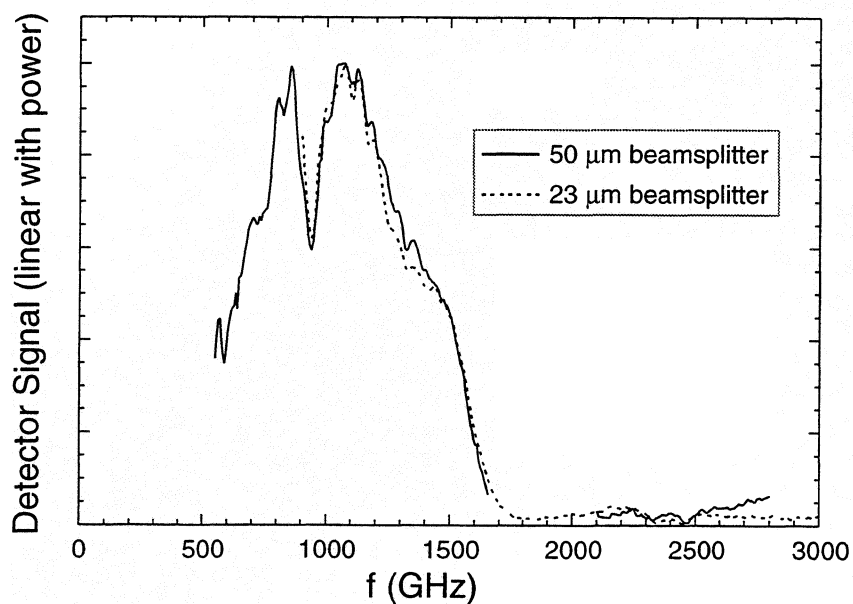


Fig.4: Measurement of the antenna/bolometer coupling bandwidth using an FTS. The dip at ≈ 950 GHz may be caused by the optical mismatch between the narrow beam of the receiver and the f-6 beam of the FTS. The data were corrected for the frequency dependencies of the two beamsplitters.