

Submillimeter-Wave Sideband Generation using a Planar Diode Array

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Abstract

An array of planar Schottky diodes is used to mix the output of a far infrared laser with a microwave source to generate tunable sidebands around 1.6 THz. The double sideband power was measured by heterodyne detection for a calculated output power of 5.9 μ W with a 28 dB conversion loss.

I. Introduction

Over the past several years, instrumentation needs in the remote sensing and radio astronomy communities have steadily increased the demand for local oscillator sources operating at submillimeter wavelengths [1,2]. Tunable sources of submillimeter-wave radiation are rare. Far infrared lasers operate at discrete lines with no more than 200 MHz of tunability, and solid state sources drop off significantly as they approach 1 THz. Generation of tunable sidebands by using a whisker-contacted Schottky diode in a corner cube mount to mix a microwave source with a submillimeter laser has been demonstrated to produce 10.5 μ W of output power at a drive frequency of 1.6 THz [3]. Whisker-contacted Schottky diodes have been the forerunner for sensitive detectors but the recent trend has been to replace these devices with planar Schottky diodes [4]. Compared to their whisker-contacted counterparts, planar devices are rugged and more easily permit circuit topologies based on multi-diode configurations, but have not yet resulted in better performance [5]. A quasi-optical array of planar Schottky diodes allows a convenient blend of optical and microwave technology appropriate for mixing submillimeter-wave and microwave frequencies with greater power handling capabilities. In this paper, we use a 6x6 planar Schottky diode array to generate sidebands using a CO₂ pumped far infrared laser at 1.6 THz and a 1-20 GHz microwave source.

II. Design and Fabrication

The sideband generator array contains 36 planar Schottky diodes in a bowtie array placed on a quartz substrate. A drawing of the array is shown in figure 1. The microwave radiation is applied through the coplanar transition which is widened to an SMA connector. The laser power is incident perpendicular to the array and a mirror is placed behind the array for impedance matching. The array was monolithically fabricated on GaAs then a novel fabrication technique was used to remove the GaAs substrate and replace it with quartz [6]. The quartz provides a lower dielectric constant allowing a larger unit cell (70 μ m compared to 30 μ m) and has resulted in better bandwidth in simulations [7]. The array was designed to have large signal microwave frequencies modulate the impedance seen by the small signal laser power to produce small signal sidebands.

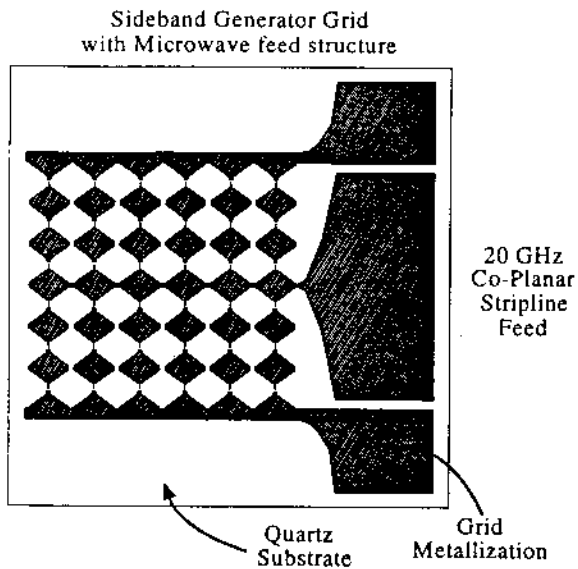


Figure 1: Bowtie array on quartz substrate with planar Schottky diodes at the feed point and microwave coplanar feed.

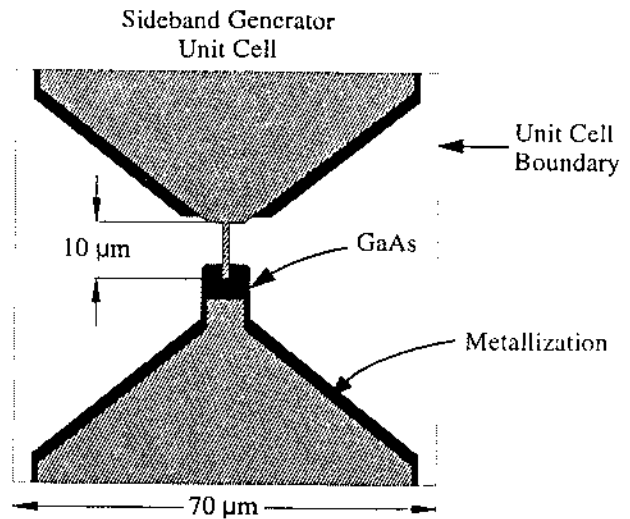


Figure 2: Unit cell of bowtie array showing finger contacting GaAs.

III. Side Band Measurement

A CO₂ pumped far infrared laser at 1.6 THz was mixed with a microwave source using the planar array of Schottky diodes. The sidebands were measured by heterodyne detection using a 1T23 whisker-contacted Schottky diode in a corner cube mount. Figure 3 shows a block diagram of the measurement setup. One laser was used to pump both the sideband generator and the detector. The Mach-Zehnder diplexer was used to couple half of the laser power to the sideband generator and half to the corner cube detector, while coupling all the generated sidebands to the corner cube. The laser power and the sidebands were mixed in the corner cube detector reproducing the microwave frequencies which were then measured on a spectrum analyzer (HP 8565B). The laser path to the sideband generator could be blocked to determine the microwave power radiated directly to the corner cube detector. Since the sideband generator is an array of devices the laser power is small signal for each individual device, thereby insignificantly affecting the microwaves emitted directly from the array. Below 15 GHz the radiated component

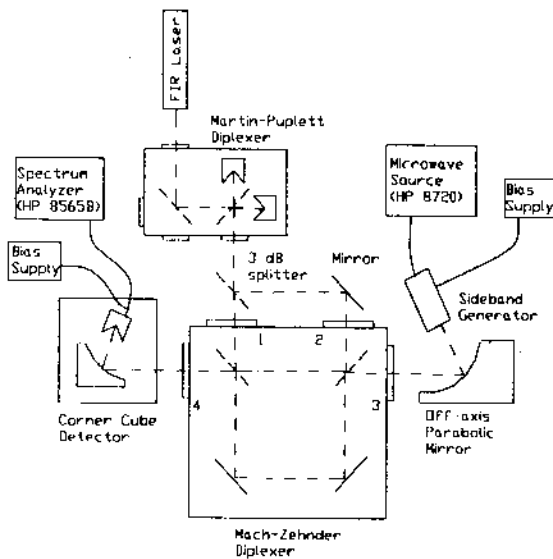


Figure 3: Block diagram of measurement system

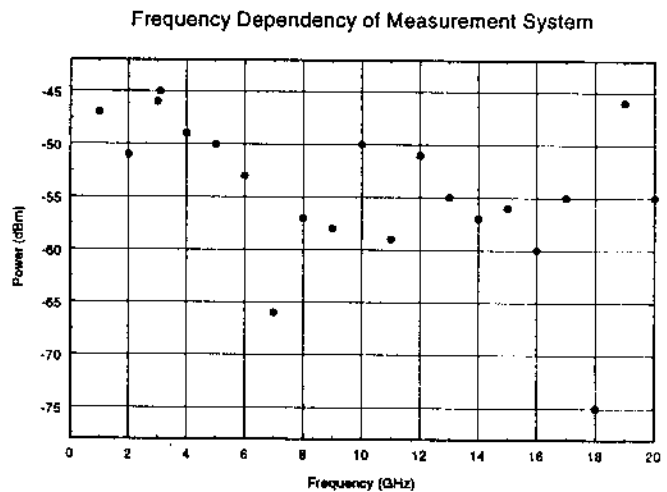


Figure 4: Sideband power measured by the spectrum analyzer as a function of frequency. The data at 19 and 20 GHz are dominated by direct radiation.

was insignificant compared to the sidebands. The estimated sideband power was calculated by correcting for the conversion loss of the corner cube detector which was determined from a hot/cold noise temperature measurement. The experiment was first performed using a 1T23 whisker-contacted Schottky diode as the sideband generator resulting in $7\mu\text{W}$ of double sideband power (24 dB conversion loss) which is comparable to other results in the literature. The planar array produced $5.9\mu\text{W}$ of double sideband power (28 dB conversion loss) at 1.8 GHz. The tunability of the sidebands was demonstrated by changing the frequency of the microwave source as shown in figure 4. The power was optimized at each frequency, so the frequency dependency is predominantly due to the Mach-Zehnder diplexer.

IV. Summary and Future Work

The array produced sideband power levels close to those produced by the whisker-contacted Schottky diode in a corner cube mount. The array, biased at 2.8 V and 7 mA, only had a 20 mV video response to the laser power as opposed to several volts for the microwave power. This demonstrates the large signal nature of the microwave source and the small signal nature of the laser power. The array is capable of handling much more input laser power than a single device sideband generator. The system was designed to produce sidebands in the reflected power analogous to the technique used with corner cubes. However, unlike corner cube sideband generators, power can transmit through the array. An array designed for transmissive sideband generation, analogous to a mechanical chopper, would simplify the system. The array could be placed at the output of the laser directly modulating the laser beam eliminating the need for beam splitters.

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