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Resonant-Tunneling Oscillators and Multipliers for Submm Receivers

T. C. L. Gerhard Sollner
Lincoln Laboratory, MIT
Lexington, Massachusetts 02173

Resonant tunneling through double-barrier heterostructures has attracted increasing interest recently, largely because of the fast charge transport it provides [1]. In addition, the negative differential resistance regions that exist in the current-voltage (I-V) curve (peak-to-valley ratios of 3.5:1 at room temperature [2-4], and nearly 10:1 at 77 K, have been measured) suggest that high-speed devices based on the unique character of the I-V curve should be possible. For example, the negative differential resistance region is capable of providing the gain necessary for high-frequency oscillations [5]. In our laboratory we have been attempting to increase the frequency and power of these oscillators [6] and to demonstrate several different high-frequency devices.

Oscillators and mixers

Our recent room-temperature, millimeter-wave oscillator results are summarized in FIGURE 1. The initial experiments at 20 GHz were performed in a coaxial circuit, but the other resonators were made in waveguide. In particular, the oscillations around 30 and 40 GHz were achieved in WR-22 and WR-15 resonators, respectively [6]. A significant improvement in the quality of the devices, especially the use of thin AlAs barriers in place of AlGaAs barriers, resulted in oscillations near 55 GHz in the WR-15 resonator. The oscillations near 110 GHz were obtained with the same AlAs-barrier material in a WR-6 structure, and those at 200 GHz used a WR-3 resonator [7]. As can be seen from FIGURE 1, progress to higher frequencies of oscillation has been a rapidly increasing function of time. However, to continue in this direction will require material with a higher cutoff frequency. The derivation of the maximum frequency of oscillation, marked f_{max} in FIGURE 1 for each MBE-grown wafer, is described in Sollner et al. [8]. There it is concluded that optimized materials may be capable of fundamental oscillations as high as 1 THz. More information on oscillator design, frequency limits, and material growth parameters can also be found in Brown et al. [6] and Goodhue et al. [4].

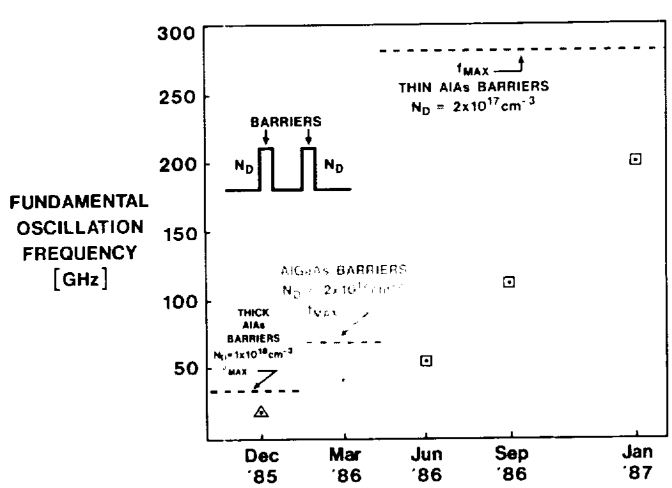

FIGURE 1. Resonant-Tunneling Diode Oscillators

Resistive multipliers

The undulations of the dc I-V curve of a resonant-tunneling diode suggests that there should be large harmonic content to the current waveform, leading to an efficient harmonic multiplier. Shown in FIGURE 2 is the experimental power spectrum for a resonant-tunneling diode when mounted in a 50-Ω coaxial circuit and pumped at 4.25 GHz. The most striking feature of this spectrum is the fact that the fifth harmonic provides the largest available power after the fundamental. This would simplify the design of mm-to-submm wavelength multipliers significantly.

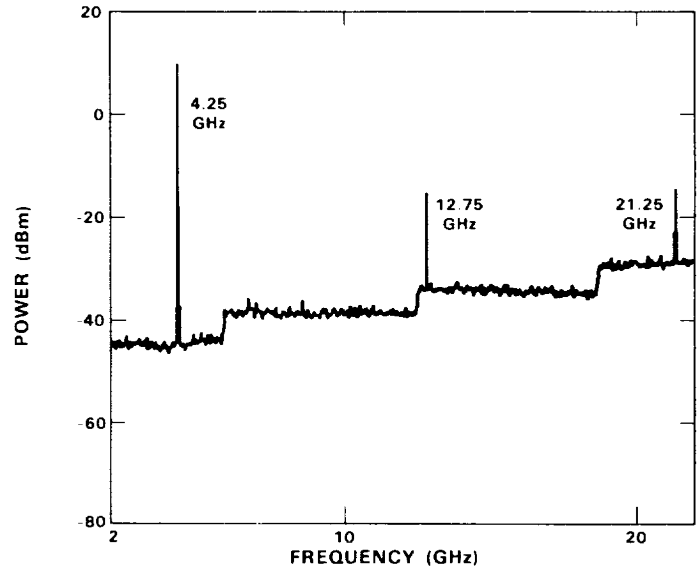

FIGURE 2. Multiplier Power Spectrum

Although the measured efficiency of about 0.5% is competitive with existing multipliers, it is significantly less than the theoretical prediction. This discrepancy can possibly be attributed to the circuit, which does not allow independent tuning of the harmonics. Ideally, one would want to terminate the fifth harmonic with a resistance greater than the source resistance. These concepts are also applicable to higher harmonics, and work is continuing in that direction.

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