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MONOLITHIC MILLIMETER-WAVE DIODE GRID FREQUENCY MULTIPLIER ARRAYS

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ABSTRACT

Monolithic diode frequency multiplier arrays, including barrier-N-N^+ (BNN) doubler, multi-quantum-barrier-varactor (MQBV) tripler, Schottky-quantum-barrier-varactor (SQBV) tripler, and resonant-tunneling-diode (RTD) tripler arrays, have been successfully fabricated with yields between 85% and 99%. Frequency doubling and/or tripling have been observed for all the arrays. Output powers of 2.4-2.6 W (η=10-18%) at 66 GHz with the BNN doubler and 3.8-10 W (η=1.7-4%) at 99 GHz with the SQBV tripler have been achieved.

INTRODUCTION

Quasi-optical spatial power combining techniques have, in recent years, been extensively investigated for millimeter and submillimeter power generation [1] [2] [3]. Our research efforts have been focused on monolithically integrating thousands of solid state devices to generate Watt level harmonics in the millimeter region. In addition to arrays of familiar devices such as the BNN and RTD, several new device concepts (MQBV and SQBV [4][5]) have been developed in the course of this work which promise to significantly improve the performance of frequency multipliers. Arrays of all of these devices have been successfully fabricated and tested. Several exciting results have been obtained. Improvements both in device design and in the matching system are underway to further optimize array performance.

FABRICATION AND RESULTS

(a) BNN frequency doubler array

A four-mask process based on the self-aligned aluminum Schottky diode process employed by C. Zah [6] is utilized to fabricate the BNN doubler array. Figure 1 shows an individual BNN device after fabrication. The array was then mounted on a quarter wavelength thick quartz plate. No bias is required due to the adjustment of the build-in voltage resulting from the δ doped layer (see Fig.2). The test system for the BNN frequency doubler is shown in Fig.3 except that the output filter was not used. Cutoff waveguides for the fundamental have been used to prevent contamination of the detected signal due to the pump signal. A variety of tests were employed to conclusively verify that the received signal was actually frequency doubled. All waveguide components including attenuators have been calibrated using at least two methods. The input and receiving horns have also been calibrated and compared with the theoretical values. Figure 4 displays the measured RF results. An output power of 2.4-2.6 W and a maximum efficiency of 10-18% have been achieved. The calculated cutoff frequency based on the measured low frequency parameters of this array is 280 GHz, which results in a maximum theoretical conversion efficiency of $\simeq$20%.

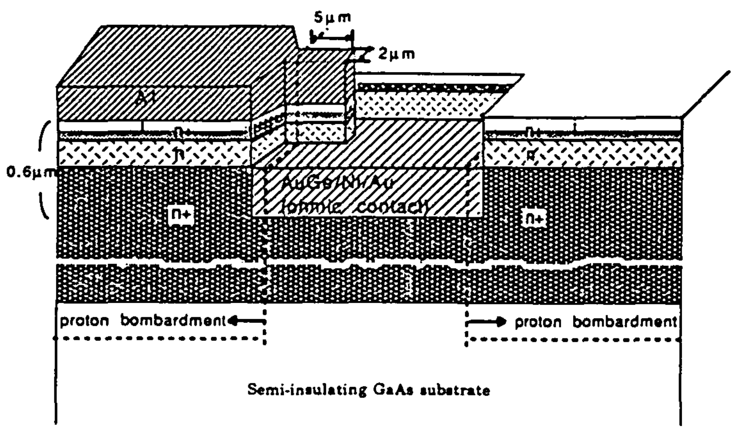


Figure 1. The fabricated individual BNN diode.

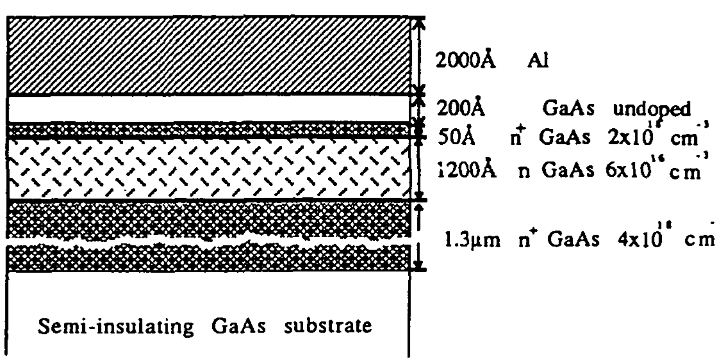


Figure 2. The profile of the BNN diode.

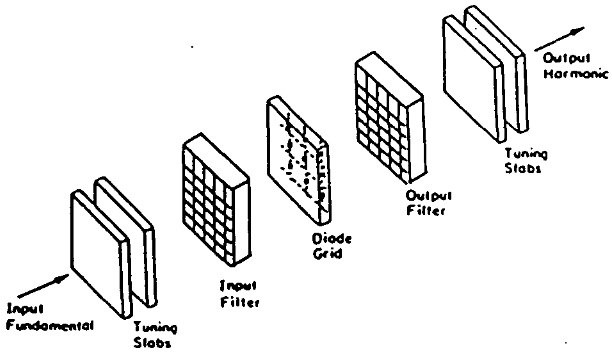


Figure 3. The frequency multiplier setup.

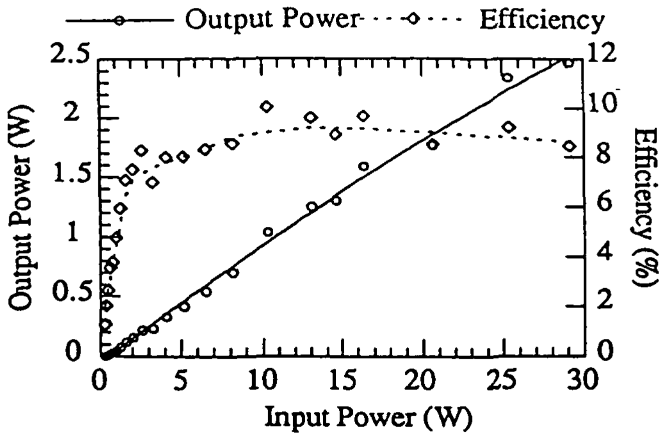
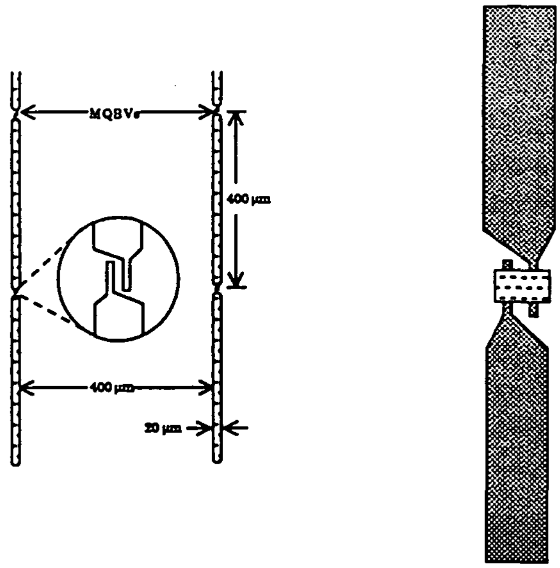


Figure 4. Measured frequency doubling output power and efficiency at 66 GHz as the function of the input power.

(b) Frequency tripler arrays

MQBV, SQBV and RTD arrays have been successfully fabricated using a back-to-back processing method [7]. As a result, all these arrays are suitable for odd harmonic generation due to the resulting symmetric C-V characteristics. Figure 5 displays the array layout. The period of each cell is 400 μm. There are 2250 devices on the MQBV array, 1300 devices on the SQBV array, and 500 devices on the RTD array, respectively. These arrays are tested using the system shown in Fig. 3. Since the input is identical for both the doubler and tripler arrays, the same input filter and tuning slabs have been used. The output filter for the frequency tripler is an inductive metal grid array [8], and quartz tuning slabs with a thickness of a quarter wavelength at the tripled output have been used for the output impedence matching. Figure 6 shows the measured output power and efficiency of the SQBV array at an output frequency of 99 GHz. An output power of 3.8-10 W and an efficiency of 1.7-4% have been achieved. Due to excessive pumping in the initial tests, the performance of the MQBV array was degraded significantly (f_c dropped from 550 GHz to 100 GHz). However, an output power of 0.1 W and an efficiency of 0.4% have been obtained for the degraded array which is in good agreement with the theoretical prediction (0.5%). Finally, a frequency tripling signal has also been observed with the RTD array. Tests are underway to measure the output power and efficiency as the function of the input power.



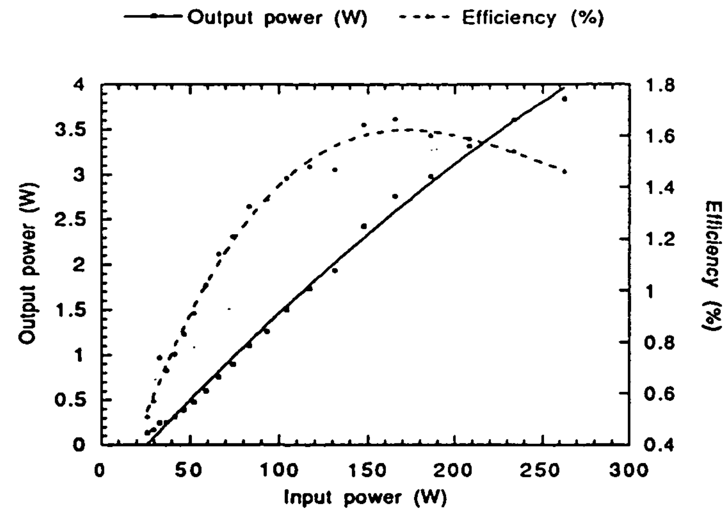


Figure 5. The MQBV and SQBV arrays layout.

Figure 6. Measured frequency tripling output power and efficiency at 99 GHz as the function of the input power.

CONCLUSIONS

BNN, MQBV, SQBV, and RTD frequency multiplier arrays have been successfully fabricated with yields between 85 and 99%. All of these arrays have yielded frequency multiplication. An output power of 2.4-2.6 W with maximum efficiency of 10-18% has been achieved at 66 GHz with the BNN doubler array; an output power of 3.8-10 W with a maximum efficiency of 1.7-4% has been achieved at 99 GHz with the SQBV array.

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