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A Dual-Diode 73-GHz Gunn Oscillator

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Abstract—**It is shown that two resonant cap structures can be mounted in a common waveguide to combine power from two Gunn diodes. Approximately 80-mW power was obtained at 73 GHz.**

I. Introduction

For the design of low-noise parametric amplifiers operating in the X band and above, pump frequencies of over 70 GHz are desirable. Single Gunn devices capable of generating adequate pump power—typically, 50 mW or greater—are not readily available at the time of this writing. Although greater than 50-mW power can be obtained from IMPATT devices, these are usually not suitable because of higher noise. Therefore, schemes employing more than one device are of interest. This paper reports one such scheme.

II. The Scheme

Resonant cap structures have been used for microwave generation with Gunn or IMPATT devices in the past [1]–[3]. In such an arrangement a diode is mounted on one wide wall of the waveguide. A disk is placed on top of the diode. Bias is applied through a post mounted on the disk. A moveable short is needed on one end for tuning. In the scheme described here, two such structures are placed in a waveguide, instead of one as shown in Fig. 1. Microwave power output approximately equal to twice the power obtainable from a single diode can be achieved in this way. In a somewhat similar arrangement, Stevens *et al.* have used post-mounted Gunn diodes separated $\sim\lambda g/2$ apart in a waveguide to combine power at 16 GHz [4].

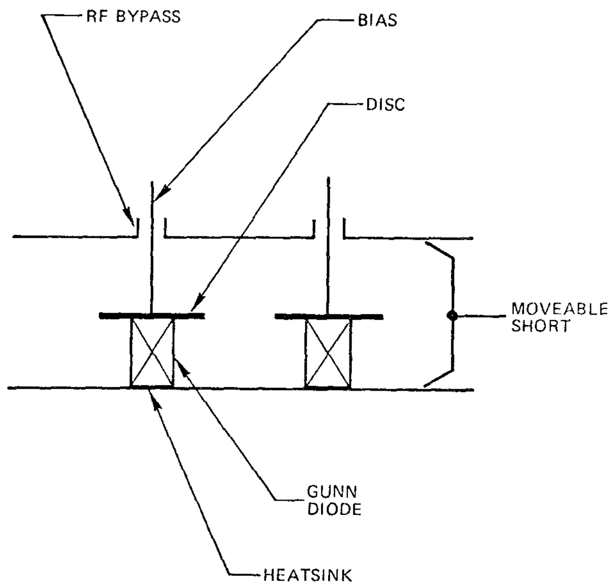

Fig. 1. Dual-diode Gunn oscillator.

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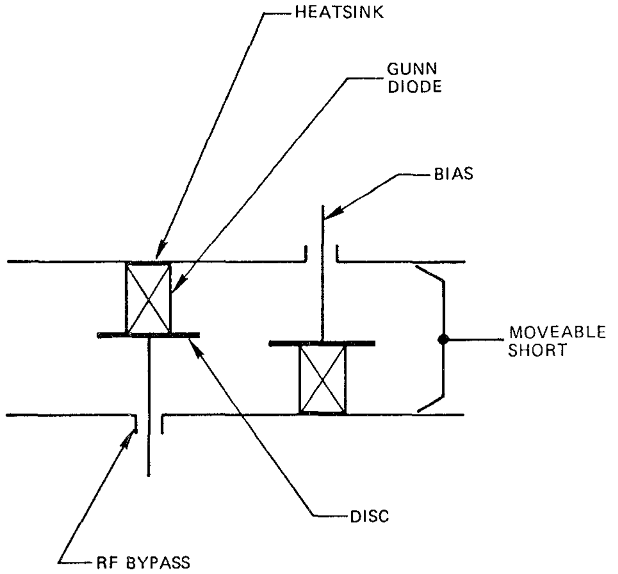

Fig. 2. This arrangement yielded the same results as the one shown in Fig. 1.

TABLE I

	Bias Voltage	Frequency	Power
Module 1	6.3 V	72.5 GHz	40.8 mW
		73.0 GHz	42.7 mW
		73.5 GHz	42.7 mW
Module 2	6.3 V	73.14 GHz	39.8 mW
Dual Diode	6.3 V	73.0 GHz	81.3 mW

III. Test Results

For the tests reported here, each diode and its resonant structure were mounted in a separate waveguide section. Each such module was tested individually and optimized for maximum power at the desired frequency. Two modules were then "stacked" with a moveable short on one end, and tested as a single assembly.

The diodes were Varian Associates-type VSW 9109. Module 1 had a provision for mechanical tuning through the side wall. Module 2 was fixed. WR-15 waveguide was used. Typical results are shown in Table I.

The operating current for the dual-diode oscillator was 1.9 A. Biasing the diodes from separate power supplies or a single power supply did not make any difference in the results.

Phase lock between the two signals was verified by observing the spectrum on a spectrum analyzer. A harmonic mixer with a stable X-band source of appropriate frequency was used for the test. It was found that Module 1 could be tuned over a band of approximately ± 100 MHz before breaking lock. With the module 1 set at the middle of the range, the oscillator was tested over a temperature range of 0–+70°C. No loss of lock was observed.

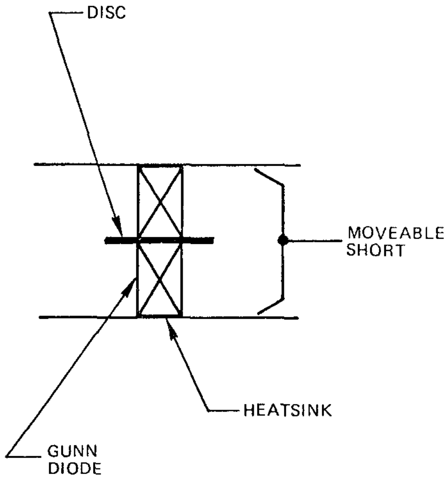

Fig. 3. Proposed power combining scheme.

Three spacings between diodes were tried—λg, $1.25\lambda g$, and $1.5\lambda g$. The results shown in Table I are for a spacing λg. Note that λg is the guide wavelength in the absence of the resonant structures. Although the short position needed readjustment when the spacing was increased to 1.25 or $1.5\lambda g$, only a small change in frequency and power was observed.

Turning one of the modules upside down as shown in Fig. 2 gave approximately the same power and frequency. This suggests that a configuration of the type shown in Fig. 3 will also combine the power output from two diodes.[1] Common bias is applied through the side wall. The diode heat sinks are attached to the wide upper and lower walls, respectively, of the waveguide. Preliminary tests were unsuccessful because of moding in an inadequate biasing circuit. It may be noted that optimizing and matching the two diode circuits is much more difficult in this case than in the case of Fig. 1 or 2. This is because testing of the individual resonant circuits without the other is not readily done. Further work in this area may be of interest.

IV. Conclusions

More than one resonant cap structure can be installed along the length of a waveguide to obtain increased

[1]It may be pointed out that it is possible to combine power from two diodes at lower frequencies by mounting them at the top and botton of a $\lambda g/2$ iris-couple waveguide cavity, mounting a common post between the diodes and applying bias to the post with a thin wire brought in through a side wall. For example, 1.2 W was obtained at 9.5 GHz from two diodes that individually produced 505 and 515 mW in a comparable single-diode cavity. In another experiment, six 200-mW diodes with three posts were mounted in a similar fashion in a common transverse plane and biased through a common wire connected to the three posts. 1.4-W power was obtained at 13.6 GHz.

power. The spacing between the diodes does not seem to be critical when only two diodes are involved, as long as the short position can be adjusted. It appears that power from more than two diodes can be combined by "stacking" more than two modules. The scheme should be applicable to IMPATT devices also.

ACKNOWLEDGMENT

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A Tunable High-Power *V*-Band Gunn Oscillator

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***Abstract*—A method of combining two Gunn devices has been developed in the 50–60-GHz band. A power output of 23.75 dBm with a mechanical tuning range of 6 GHz has been achieved. A varactor-tuned Gunn source with an electronic tuning bandwidth of 200 MHz has also been demonstrated in the *V* band.**

I. INTRODUCTION

IN MANY MILLIMETER-WAVE system applications of solid-state power sources, it is desirable to have 1) high power, 2) a good mechanical tuning range, and 3) some electronic tuning. To obtain high power at millimeter-wave frequencies, a push–pull technique of combining two Gunn devices at 42 GHz has been reported [1]. Although varactor tuning is widely used for Gunn VCO's at frequencies below 50 GHz, tuning methods for Gunn oscillators above 50 GHz have been mostly mechanical [2], [3]. It is the purpose of this paper to report the results of power combining, mechanical and varactor tuning with Gunn devices between 50 and 60 GHz.

II. DEVICES

The Gunn devices used for these experiments were made from vapor phase multiple epitaxial n-type GaAs. The epistructure was similar to that previously described by Tully *et al.* [4]. It consists of a buffer layer of 4 μm with 10^{18} carriers/cm^3, and an active layer of 2.3 μm with 9×10^{15} carrier/cm^3. The nl product for the active layer was approximately 2.1×10^{12}. The Gunn device was bonded with crossed gold-lead ribbons in a ceramic pill package which has been previously discussed by Kramer [5].

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III. TWO-DIODE OSCILLATOR

The circuit used in the two-diode power combining experiments is a reduced-height waveguide circuit as shown in Fig. 1. The impedance matching to the diode was achieved by utilizing two stages of a quarter-wave transformer at the output circuit, a tuning short, and a coaxial spacer. The diameter of the device package is 35 mil, and the diameter for the bias pin is 27 mil, and two aluminum low-pass filter. This circuit configuration has been extensively used in IMPATT oscillator and amplifier applications [6], [7], and has been analyzed recently, to include the effect of a large biasing post and proximity of the waveguide short to the device [8]. In general, the tunability of the source depends on the impedance of the device, the parasitics of the package, and the length of the coaxial spacer. The diameter of the device package is 35 mil, and the diameter for the bias pin is 27 mil, and two devices in direct contact were mounted in the manner as indicated in Fig. 1. Fig. 2 shows the power output and the tuning range for one and two devices, respectively. Device 1 was first soldered in the heat sink, then the circuit and the voltage applied to the device were optimized at 54 GHz. The maximum power output was 20.6 dBm. For comparison, similar power levels were also observed when devices of the same lot were measured in a coaxial cavity with a waveguide iris output. A frequency-tuning bandwidth of 13 GHz was achieved by moving the tuning short. Then device 2 was soldered in, and the circuit and the voltage were again optimized. The maximum power output of 23.75 dBm was achieved, which is approxi-