HIGH POWER 94-GHz PULSED IMPATT OSCILLATORS*

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ABSTRACT

High peak power oscillators using double-drift IMPATT diodes have been developed in W-band. The diodes were operated with 100 ns pulsewidth and 0.5 percent duty cycle. Peak power of 13 watts were consistently achieved. As a best result, over 15W peak power was achieved with selected diodes.

Introduction

The rapidly increasing demand in millimeter-wave radar systems has created an urgent need for high power W-band solid-state transmitters. At 94 GHz, pulsed power of two watts has been achieved using single-drift IMPATT diodes.[1] A double-drift IMPATT oscillator producing 5.4 watts has also been reported.[2] This paper reports the development of a pulsed source which consistently produced 13 watts peak power output.

Device Development

The double drift diode was chosen because of its established high power and efficiency capabilities, as well as its high device impedance for easier circuit matching to achieve optimum performance. The diode design is based on a symmetrical double-drift region structure as shown in Figure 1, which has equal doping densities in the n and p regions. The primary design consideration is the impedance and the frequency characteristics of the diode as a function of current density. Epitaxial layer thickness and doping concentration are determined using small signal[3] computer simulation. The operating current density was determined to be 1×10^5 amp/cm^2 and the doping concentration to be 1.3×10^{17}/cm^3. The depletion width widening caused by space charge and temperature effects has been included in the calculation of the active epi thickness.

The double-drift structures were first formed by multiple epitaxial deposition. After thinning, the silicon wafers were then metalized. Photolithography was used to etch and isolate individual silicon devices on the wafer. The individual devices were ultrasonically separated apart, and then packaged in a 30 mil quartz ring to reduce capacitance and loss. Cross strap bonding to the devices was used to reduce the parasitic inductance.

Oscillator Development

The basic circuit used for testing the IMPATT diodes consists of a reduced height waveguide with a diode mounted at the end of a 27 mil diameter bias pin. An anodized aluminum insert was used as the low pass filter to isolate the dc bias circuit from the RF cavity. An adjustable short was employed to achieve the maximum output power and proper operating frequency. To match the load impedance to the diode, a quarter wavelength Chebychev step transformer was designed in the output of the circuit to transform the impedance level from the reduced waveguide to the full height waveguide.

Oscillator Performance

The diodes were operated typically with 100 ns pulsed width and 0.5 percent duty cycle. Peak power of 13 watts has been obtained consistently for lot No. DDW 67 with a zero voltage capacitance of 4.5 pf and breakdown voltage of 14.8 volts. Efficiency was typically eight percent. The bias current to the diode and output video pulse of the oscillator are shown in Figure 2. Typical frequency chirp is about 1 to 2 GHz and the power variation across the pulse is less than 2 dB. Output power, efficiency and oscillation center frequency as a function of bias current are shown in Figure 3. It is seen the power and center frequency of the oscillator decrease as the bias current is reduced.

In many system application, a coherent source is usually required. Figure 4 shows the spectrum of a 6 watts injection locking source. The oscillator was first optimized to provide a minimum chirp of about 500 MHz with a spectrum as shown in Figure 4a. The oscillator was then injection locked by a stable source with a locking gain of 13 dB with the spectrum shown in Figure 4b. Figure 4c is the expended spectrum of Figure 4b. It is seen by injection the noncoherent pulse IMPATT source with a highly stable source, highly coherent output is achieved for Doppler-radar applications.

Conclusion

W-band IMPATT oscillators using double-drift diodes have been developed. Peak power of 13 watts with 8 percent efficiency has been consistently achieved. The power levels achieved are sufficient for many millimeter-wave radar applications in both the incoherent and coherent modes.

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References

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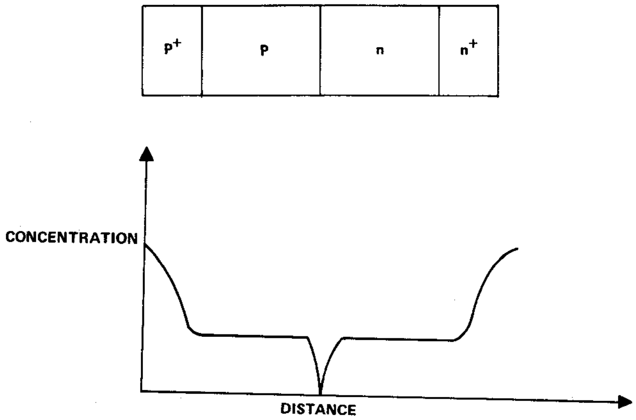

Figure 1. Double-drift IMPATT diode structure.

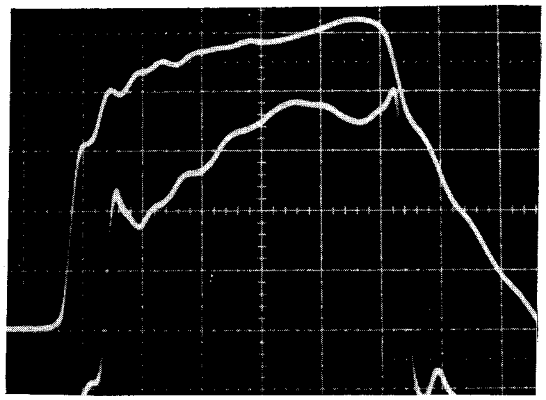

Figure 2 Oscilloscope picture of input current (top trace) and output video pulse (bottom trace). Horizontal: 20 ns/div. Vertical: 2A/div. (cuttent), 20 mV/div. (video).

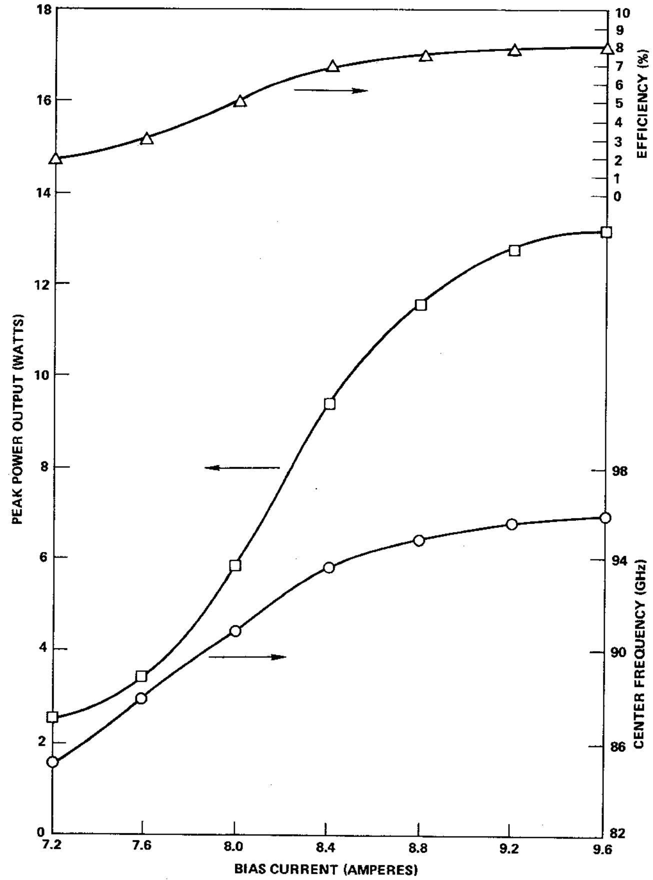

Figure 3 Output power, frequency and efficiency vs bias current.

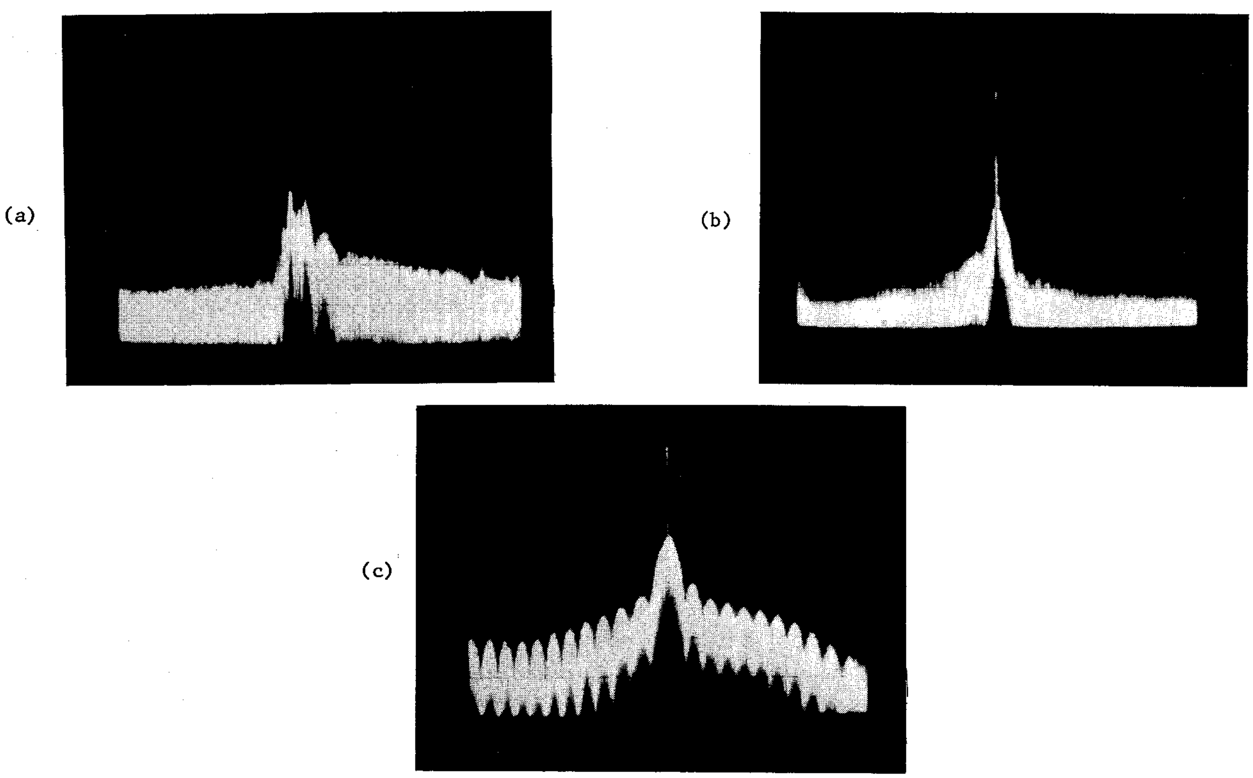

Figure 4 Spectrum of six watt minimum chirp source. (a) Free running. Horizontal: 200 MHz/div. Vertical: 10 dB/div. (b) Injection locked with 13 dB gain. Horizontal: 200 MHz/div. Vertical: 10 dB/div. (c) Same as above except horizontal: 5 MHz/div.