HIGH POWER W-BAND PULSED IMPATT OSCILLATORS

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Abstract

High peak power oscillators using double-drift IMPATT diodes have been developed in W-band. Peak powers in excess of five watts were consistently achieved, with a highest power of 5.4 watts measured at 94 GHz.

Introduction

Because of the smaller size, lighter weight, and higher resolution of millimeter wave systems, millimeter wave device and component development has received considerable interest in recent years. For radar and terminal guidance applications, a high power pulsed source is required. Because of the lower attenuation at the atmospheric windows at 35 and 94 GHz, pulsed IMPATT sources development has been largely centered at these two frequencies. At 35 GHz, pulsed power of ten watts has been demonstrated[1] using double-drift IMPATT diodes. At 94 GHz pulsed power of two watts has been achieved using single-drift IMPATT diodes[1]. In this paper, the design and development of a pulsed high power source using double-drift IMPATT diode in W-band is presented.

Device Performance

To date, seven diode lots with slightly different device parameters have been fabricated and tested; each lot is defined as diodes from one silicon wafer. Table 1 represents some of the typical results obtained from these lots. It is seen that peak power as high as 5.4 watts was achieved at 94 GHz with conversion efficiency of 6.5%. The dynamic characteristics of an oscillator showing output power, efficiency and oscillation frequency as a function of bias current are shown in Figure 1. A peak power of 4.15 watts was achieved in this case with a bias current of 2.6 amperes, which is the current limit of the pulse modulator used in this test. The results listed in Table 1 are device power obtained without isolator and adjustment of proper frequency chirp characteristics (Figure 2). When the requirements for temperature stabilization, isolation and chirp bandwidth are imposed, typically a degradation of 2-3 dB in power output is expected.

TABLE 1
W-BAND PULSED DOUBLE DRIFT IMPATT DIODE PERFORMANCE

Lot No.	V_o (Volts)	C_o (pf)	Peak P_o (Watts)	Center Frequency (GHz)	η (%)
PDW 57	15.6	2.1	3.4	94	6.2
PDW 61	18.7	2.3	5.4	94	6.5
PDW 63	18.8	2.5	2.9	85	4.5
PDW 65	19.6	2.6	4.8	86	6.2
PDW 69	15.9	2.7	2.8	92	5.1
PDW 71	16.5	2.6	5.0	95	6.2
PDW 74	16.4	2.7	5.2	94	6.5

*Data obtained with 100 nsec pulse width at 50 KHz rep. rate.

Device Design and Fabrication

The pulsed double-drift IMPATT diodes were fabricated using the multiple epitaxy technique by first growing an n-layer on top of an n^{++}-substrate, followed by a p-layer growth and a shallow boron diffusion of 0.3 μm in depth. The silicon wafers were then metallized and silver plated on the junction side to approximately 10 mil in thickness. Photolithography was subsequently used in defining and etching circular mesa diodes approximately 3.5 mils in diameter. Individual silver discs with a diode in the center were then formed by a mechanical gang punch process. The diode processing was completed by packaging the IMPATT diode in a 30 mil O.D. and 17 mil I.D. quartz ring; followed by ribbon bonding and capping. The miniature sealed quartz package lends itself for easy handling in RF evaluation as well as proper RF parasitics for impedance matching to the circuit.

The diode design was chosen on a small signal computer simulation[2] to determine the impedance-frequency characteristics as a function of current densities. Based on impedance and thermal considerations, the operating current density was determined to be 50 K Amp/cm^2. The doping concentration of the active region was determined to be 1.2×10^{17} cm^{-3}. In our diode design a symmetrical double-drift structure was assumed so that the doping concentrations of the n and p layers are equal, i.e., $N_A = N_D$. The active layer thickness was determined based on considerations of sparce charge and temperature widening effects of the depletion width. For the current density and doping concentration of interest, the depletion widths for the n and p layers were determined to be $W_A = W_D = 0.54$ μm. Using the above design as guidelines, seven diode lots were fabricated to verify the diode design; the RF results obtained from these lots are presented in Table 1.

Frequency Chirp Characteristics

A very important property of the pulsed IMPATT diode is the frequency chirp across the bias pulse. In a radar application, a properly chirped signal is often used to improve clutter rejection and glint of the system. For a pulsed IMPATT diode, this frequency chirp is a direct consequence of the IMPATT temperature variation during pulse. For a flat current pulse, the diode is at a low temperature at the beginning of the pulse and it heats up to a maximum junction temperature at the end of the pulse, the device impedance changes accordingly. In a fixed tuned circuit, the oscillation frequency thus varies according to the junction temperature change. A typical measured chirp characteristic of 94 GHz pulsed double drift diodes is plotted as a function of bias current for four diode junction diameters in Figure 2. Because the IMPATT device impedance is also a strong function of current density, the frequency variation caused by the thermal effect can be compensated by changing the operating current magnitude across the pulse. Therefore, a bias current ramp can be used effectively to control the chirp bandwidth as well as the linearity of frequency variation to meet specific system requirements.

Conclusion

High power 94 GHz pulsed oscillators have been developed using double drift IMPATT diodes. Peak power in excess of five watts have been consistently achieved at 94 GHz. By properly controlling the frequency chirp characteristics, the high power pulsed oscillators should find applications in many adverse weather radar applications.

Acknowledgement

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References

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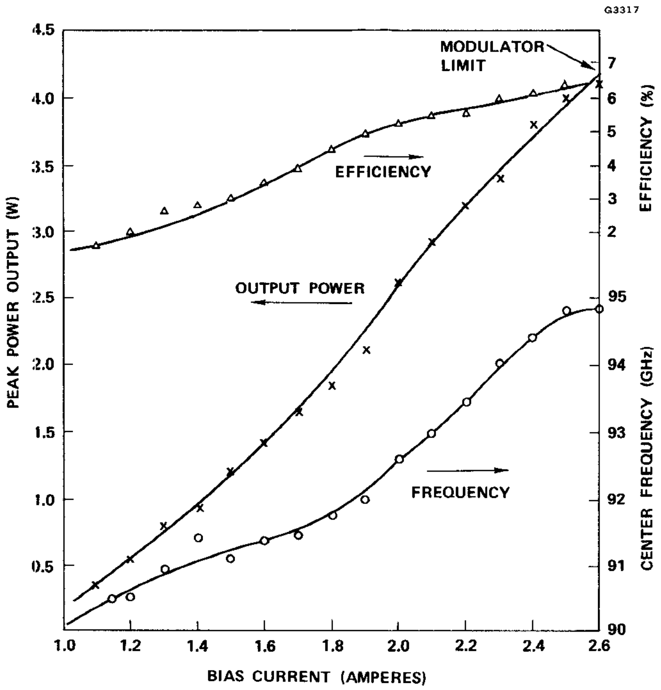

Fig. 1 - 94 GHz pulse IMPATT output power, frequency and efficiency as a function of bias current.

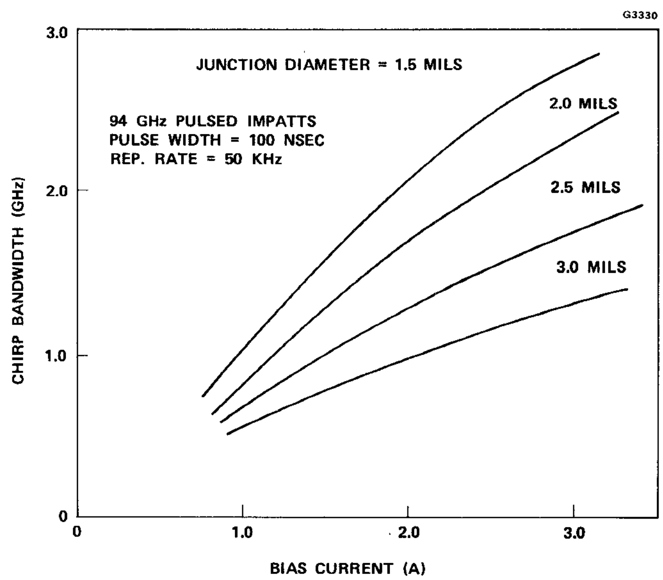

Fig. 2 - Chirp bandwidth as a function of bias current.