B.S.T.J. BRIEFS

A $\frac{1}{4}$-Watt Si PνN X-Band IMPATT (IMPact Avalanche Transit Time) Diode

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An output of 250 mW CW at 12 GHz with an efficiency of 2.8 percent was obtained from an Si PνN diode.

Previously[1] we discussed characteristics of Si PνN IMPATT (IMPact Avalanche Transit Time) diodes. In that study the emphasis was primarily in understanding device properties rather than extending their output power. In those diodes, the input power had to be kept less than 2 watts to avoid device burnout. The average microwave power output was about 10 mW with the efficiency seldom exceeding 1 percent. However, by immersing the diode holder in liquid nitrogen, and thus increasing heat flow, it was shown that the diodes were capable of CW output on the order of 100 mW in the X-band (8.2 to 12.4 GHz). The main deterrent to increased output power was the fairly large thermal impedance from junction to package.

To relieve the heating limitations, we recently mounted similar diodes with junction side down[2] which allowed us to apply input powers as large as 10 watts without lowering the ambient temperature. Fig. 1 shows the output and efficiency vs input plot for the best diode. The oscillation was measured in the 50 mil high waveguide circuit used by De Loach and Johnston.[3] The breakdown voltage was 54 volts. At the highest input the current density is about 2,000 A/cm^2. The efficiency is still increasing. This is a feature of the pνn structure in contrast to the Read structure which shows efficiency saturation at lower current density.[4] The oscillation frequency at the highest input current was 12.04 GHz; as the input current was decreased the frequency decreased by 0.2 GHz.

The microwave output was observed on the Hewlett-Packard spectrum analyzer 851A/8551A. Fig. 2 shows the spectrum observed with another diode from the same slice. The width of the signal is less than the bandwidth of the spectrum analyzer (1 kHz).

It appears that a substantial further increase in efficiency and output power should be possible. The small-signal analysis of a theoretical model, which simulates the actual structure, indicates that the per-

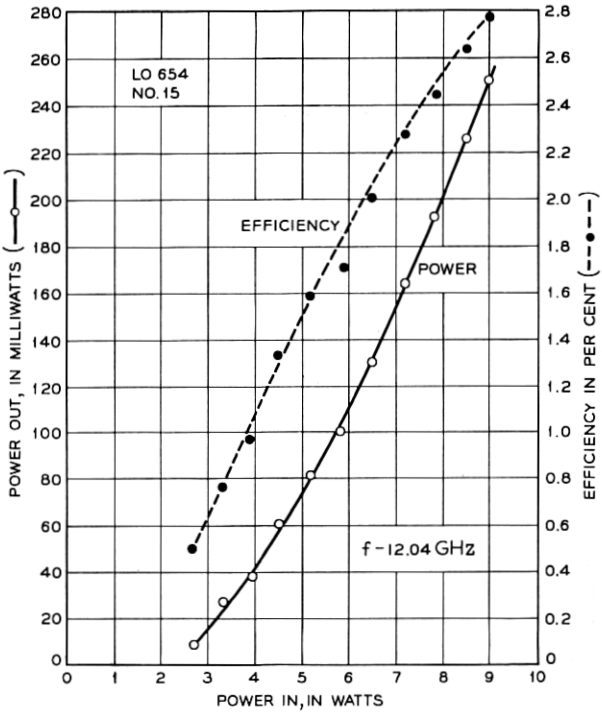

Fig. 1 — Output power and efficiency vs input power.

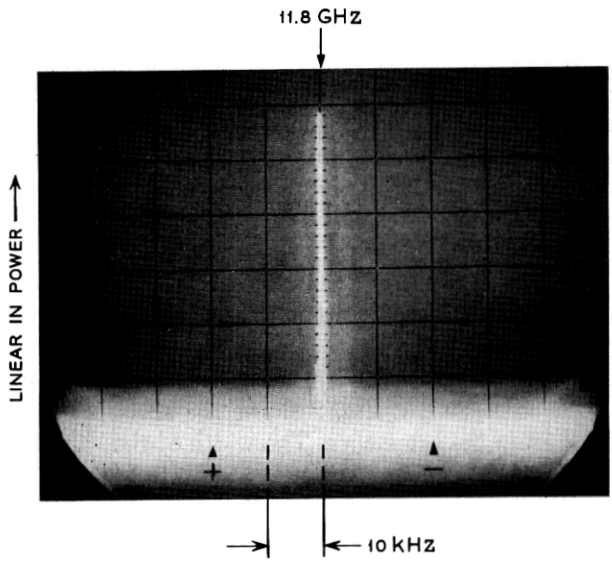

Fig. 2 — Spectrum of oscillation.

formance still keeps improving with increasing bias current. In addition, the thermal impedance calculated from the diode geometry and thermal conductivity of silicon should be much smaller than the observed value.

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REFERENCES

1. Misawa, T., Silicon Transit Time Avalanche Diode, IEEE Electron Devices Meeting, Washington, D.C., October, 1965 and to be published.
2. This method of mounting was used by De Loach and Johnston. Private communication.
3. De Loach, B. C. and Johnston, R. L., Avalanche Transit-Time Microwave Oscillators and Amplifiers, IEEE Trans. Electron Devices, *ED-13,* January, 1966, pp. 181–186.
4. Johnston, R. L. and Josenhans, J. G., Improved Performance of Microwave Read Diodes, Proc. IEEE (Correspondence), *54,* March, 1966, pp. 412–413.

Errata

A Note on a Type of Optimization Problem that Arises in Communication Theory, by I. W. Sandberg, B.S.T.J., *45,* May–June, 1966, pp. 761–764.

On page 763, replace the equation

$$\| u \| = \sum_{j \varepsilon \mathfrak{F}} | u_j |,$$

with

$$\| u \| = \sum_{j \notin \mathfrak{F}} | u_j |.$$

On the same page, replace equation (7)

$$\rho \triangleq \sum_{n \notin (\mathfrak{F} - \mathfrak{F}')} \left| \sum_{j \notin \mathfrak{F}} g_j x_{nj} \right| - \sum_{n \notin \mathfrak{F}} \left| \sum_{j \notin \mathfrak{F}} (g_j - c_j^*)\, x_{nj} \right| > 0 \tag{7}$$

with

$$\rho \triangleq \sum_{n \varepsilon (\mathfrak{F} - \mathfrak{F}')} \left| \sum_{j \varepsilon \mathfrak{F}} g_j x_{nj} \right| - \sum_{n \notin \mathfrak{F}} \left| \sum_{j \varepsilon \mathfrak{F}} (g_j - c_j^*) x_{nj} \right| > 0 \tag{7}$$