GUNN OSCILLATOR AS A FREQUENCY MEMORY DEVICE

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Introduction. Microwave oscillators based on Gunn or avalanche effects are rapidly expanding the field of microwave applications with possibilities which are far in excess of the capabilities of more conventional sources. Some of these potential applications arise from the ability of these devices to combine several microwave operations in one single device. This paper describes such a property which has hitherto not been reported, namely the ability of a Gunn oscillator to oscillate stably at several predetermined frequencies and to switch from one frequency to another with very little residual oscillation at frequencies other than the selected one. The switching is performed either by a pilot oscillator or oscillators which synchronize the Gunn oscillator at a lower power level and which can be removed after switching, or if there are only two stable frequencies present, by sending a positive or negative going pulse along the bias. Experimental results will be given together with a qualitative explanation of the mechanism.

Experiments. The Gunn samples used were planar devices with a contact of 75 μm^2 alloyed to the n-doped epitaxial layer of 10 μm on a n^+ substrate of GaAs of dimensions 300 $\mu m^2 \times 70$ μm. The samples were mounted in a varactor package (DO 19) with gold wire connections to the case. The samples were placed in a long waveguide cavity which resonates in $E_{10\ n}$ modes where n is around 30. The cavity has a transmission characteristic shown in Fig. 1a with 24 resonances from 8.05 GHz to 12.44 GHz. The frequency separation varies from 160 MHz to 200 MHz from 8 to 12 GHz and it is worth remarking that for TEM circuits this frequency spacing, which is the frequency separation between stable frequency states, is constant. A detail of the resonances is shown in Fig. 1b in which it is seen that each resonance is quite separate. A single resonance is shown in Fig. 2 where the horizontal scale is 4 MHz/cm. Fig. 2a shows the resonance at zero bias volt where the Q-factor is 600. When the bias is increased however to the threshold value the Q-factor increases to 1.200 (Fig. 2b) as the losses in the Gunn sample are reduced. At the onset of oscillation the sample oscillates at a high frequency and as the voltage is increased the frequency remains stationary and then jumps onto another resonance without passing through the intermediate frequencies (Fig. 3). This produces a staircase V/f curve from 12 GHz to 8 GHz as the voltage is increased from 10 to 14 volts. When the bias is reduced however, the oscillator jumps to a frequency at a lower voltage than that at which it left it, producing a hysteresis in the curves. It is apparent therefore that for a particular bias there are two stable frequencies possible. Two methods of switching from one frequency to another can be envisaged. Either one can send a positive pulse on the bias to switch to the lower frequency state, and a negative pulse to the higher state, or one can send a synchronizing signal at one or the other frequency. A block diagram of the measuring apparatus is shown in Fig. 4. Pulse switching is shown in Fig. 5 where the bias voltage is displayed in the lower half and the H.F. signal detected on the slope of a tuned detector is shown in the upper half. The pulse was 80 ns long with an amplitude of ± 0.75 V on a D.C. level of 11.54 V. The frequencies were 10.34 GHz and 10.52 GHz. Synchronizing switching is shown in Fig. 6. The two frequencies are shown on a spectrum analyser display after the pilot signal has been removed. The frequencies are 9.74 GHz and 9.90 GHz and the vertical scale is logarithmic with 10 dB/cm. The switching can also be achieved by a pilot where frequency is quite different from that of the oscillator. It is sufficient for there to be a phase interaction before synchronization for the oscillator to switch. In the experiment where the bias is increased (Fig. 3) there sometimes occurs an oscillation at several frequencies. When the oscillator is synchronized sufficiently for these to disappear however they reappear at a much reduced level when the pilot is removed. At each resonance in Fig. 3 the power and frequency variations with bias follow the same curve for the increasing and decreasing parts of the V/f curve (Fig. 7). The frequency scale has been very much enlarged and it is seen that the power curve follows closely the transmission resonance curve at threshold bias (Fig. 2b)

A second sample oscillated more powerfully and it was difficult to trace the V/f curve, as in Fig. 3, as it tended to stick at one frequency and then to skip several others when the bias was too far. For successive takes of this curve it would stick to different frequencies randomly. It was therefore impossible to switch this sample with pulses, but pilot switching was very successful. Fig. 8 shows four stable frequencies at 8.10, 8.55, 8.89 and 9.25 GHz with a fixed bias of 9.54 V. The horizontal dispersion is 200 MHz/cm and two harmonics of the same line are visible on each photograph. There is however only one frequency present. The vertical scale is logarithmic (10 dB/cm) and it is seen in the 3^{rd} photograph that there are residual oscillations at several other resonant frequencies at a level of -45 dB below the principal line. The power levels at the output were respectively 0.9, 1.57, 1.02 and 1.33 mW. A spectral line at one frequency (9.0 GHz) with a dispersion of 10 KH/cm and a vertical scale of 10 dB/cm is shown in Fig. 9a. The spectral width is 1 KHz at 3 dB. The noise properties are probably improved by putting the sample in a long cavity [1]. This characteristic of frequency memory was seen on all the Gunn samples that were tried and also by several samples who were mutually synchronized in the same cavity.

The same experiment was performed on an avalanche diode. For a fixed bias it did not oscillate at one frequency only, however, but over the whole spectrum. Fig. 9b shows a display with a horizontal scale of 200 MHz/cm which covers the whole of the X Band.

Outline of the mechanism. An analysis of an oscillator with two stable frequencies has recently been given by BRUYLAND [2] in which he explains the phenomenon by the non-linearities in the I/V characteristic. He also finds a condition in which the oscillator can function at several frequencies at the same time. The variation of the frequency with the bias can only be explained however by a variation in the impedance of the sample itself. This has been the subject of a number of theories [3] [4] which have not yet however led to a satisfactory model. An experimental approach by HOBSON has indicated approximately a linear increase of the capacity with bias [3] and he has also found a law of the form V.f = constant for Gunn oscillations in a cavity [5] which is very similar to the general shape of the curve indicated in Fig. 3. The required impedance match of the circuit to the Gunn sample can be found by taking into account the series resonance of the sample capacity, the series resistance and the inductance of the package and diode support.

Conclusion. The operation of a Gunn sample in a long cavity would appear to be interesting for applications in the fields of telecommunications where switching between channels is a common requirement, or in radar and phased-arrays. The use as a logic memory device would be interesting for the ease of the write and read functions but the heat dissipation of many samples would probably exclude its use. The wide frequency coverage might well lend itself to other applications.

The explanation is very brief and it is hoped to give a fuller account at a later date. A further insight into this mechanism however might well lead to a fuller understanding of the Gunn oscillator.

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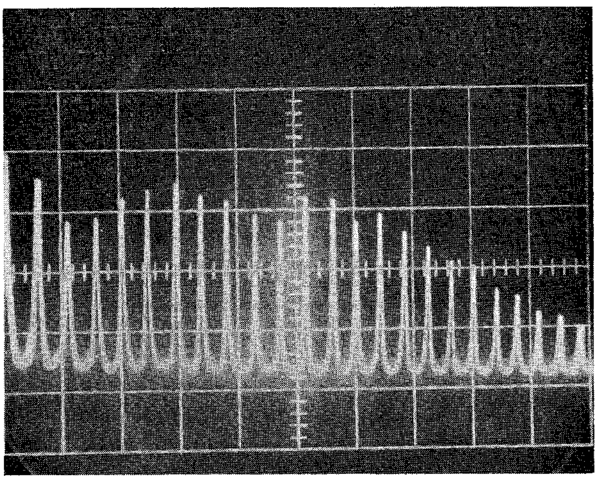
(a) 12.44 GHz to 8.04 GHz



(b) 10.26 GHz to 9.01 GHz

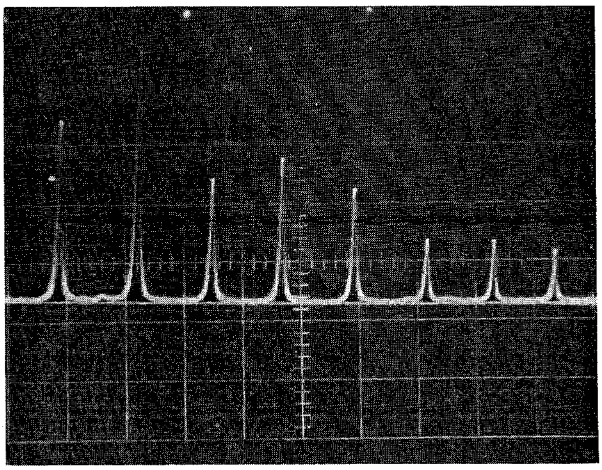
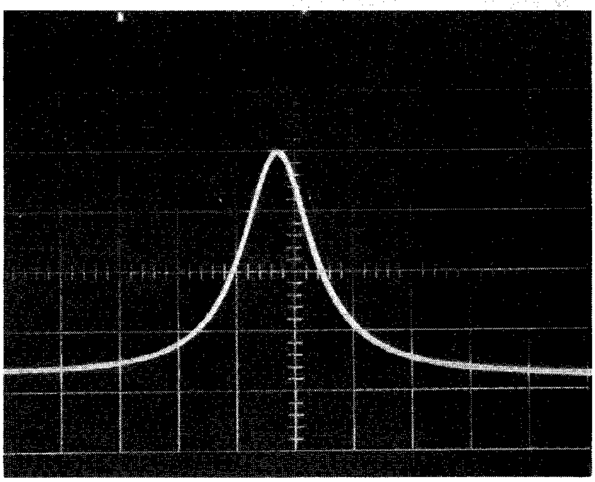
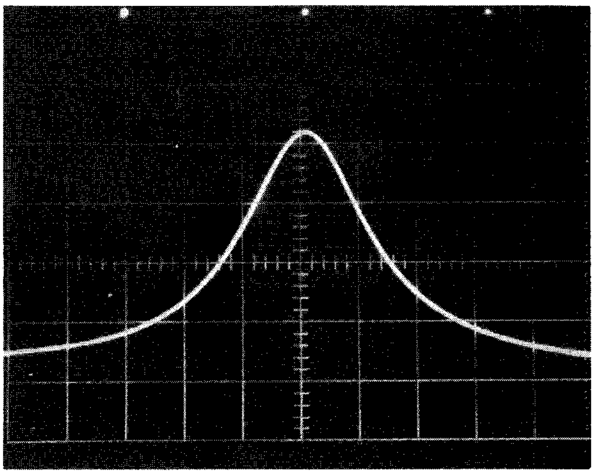


Figure 1. Transmission characteristic of the cavity.

(a) Vb = O



(b) Vb = threshold voltage



igure 2. Detail of the transmission characteristic at one resonan
for variable bias. Horizontal scale 4 MHz/cm.

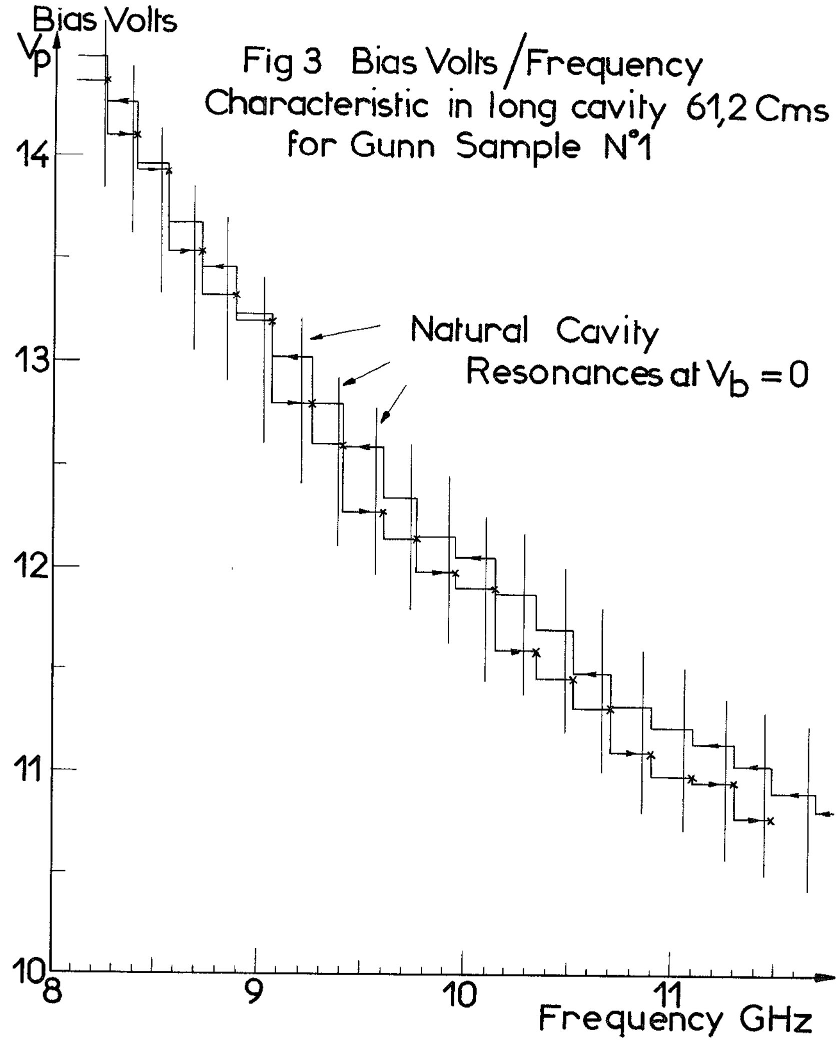
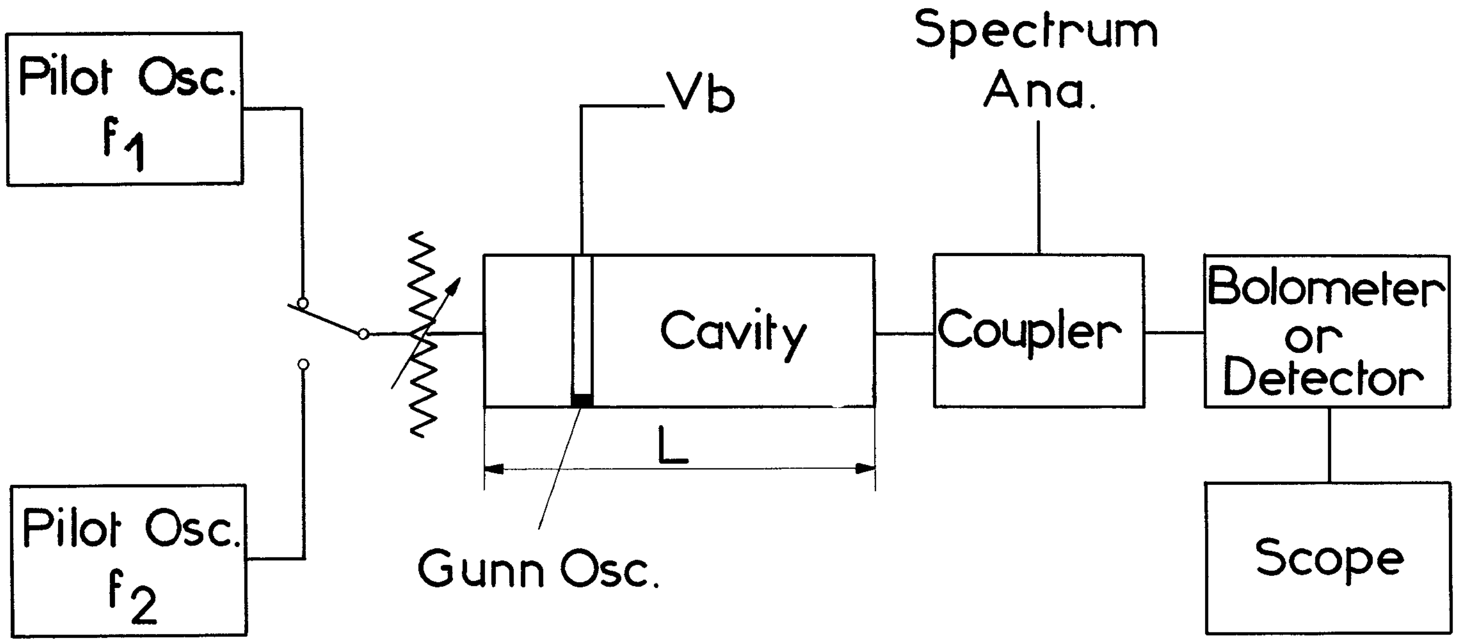


Fig 3 Bias Volts / Frequency Characteristic in long cavity 61,2 Cms for Gunn Sample N°1



BLOCK DIAGRAM
Fig 4

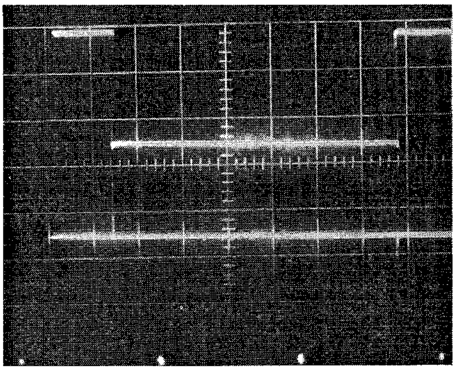


Figure 5. Pulse switching 1st sample.
Lower-Bias 11.45 V plus pulses ± 0.75 V, μs inverval,
80 ns width. Upper-frequency, f_1 = 10.52 GHz f_2 = 10.34 GHz

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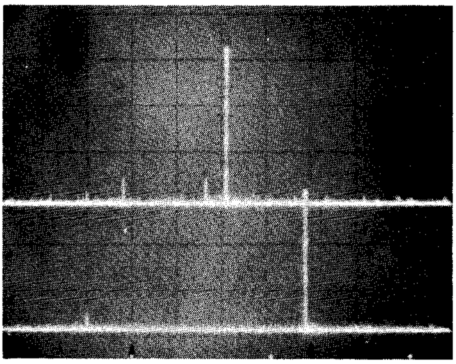
(a) f_1 to f_2



(b) f_2 to f_1

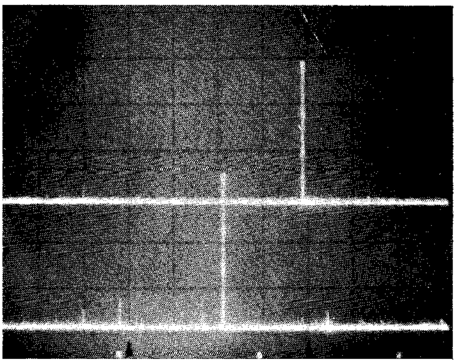
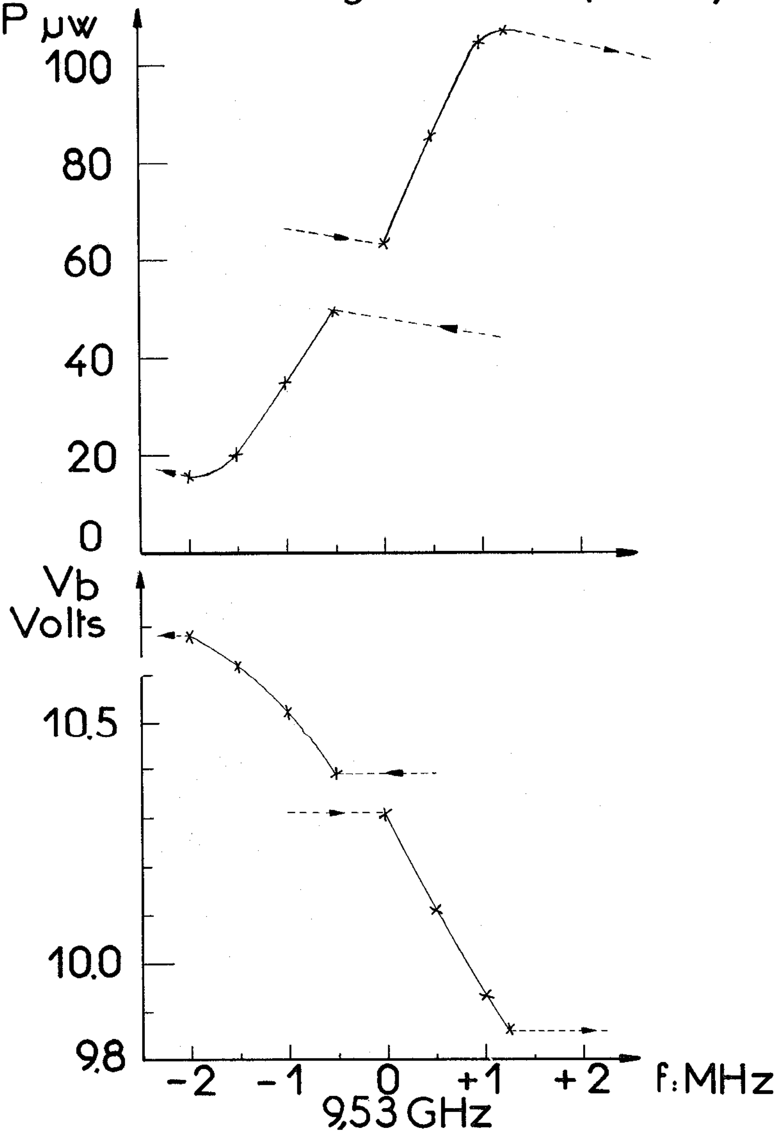


Figure 6. Pilot switching, 1^{st} sample, after removal of pilot. Horizontal scale 100 MHz/cm. Vertical scale 10 dB/cm.

Fig 7 A Single Resonance Characteristic of Power and Bias against Frequency



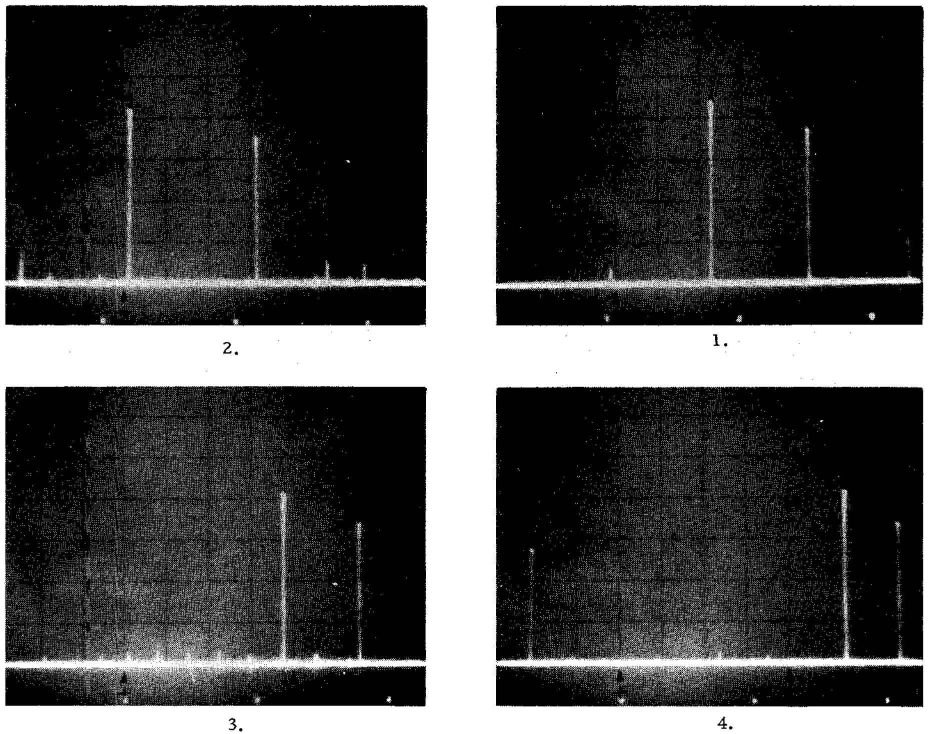


Figure 8. Frequency Memory 2nd sample. Pilot switching
Horizontal scale 200 MHz/cm. Vertical scale 10 dB/cm.

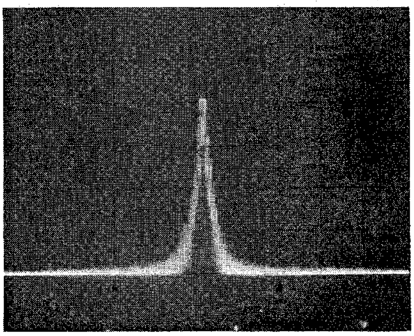


Figure 9 (a) Spectral width horizontal scale 10 KHz/cm
Verticle scale 10 dB/cm.

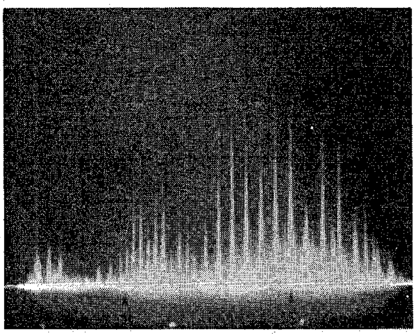


Figure 9 (b) Avalanche diode in the same cavity. Horizontal scale
200 MHz/cm, vertical scale linear.