A Silicon γ -Ray Spectrometer

CURRENT pulses produced by the passage of an ionizing particle through a semi-insulator have been reported in the literature¹. Since most of these materials are, as yet, not available in commercial quantities, we decided to investigate the use of high-resistivity silicon, available as 5,000 ohm cm. *p* type. We estimated that current pulses of about 10^6 ion pairs might be detectable, particularly if the specimen volume is restricted, and the working temperature is lowered to that of liquid air.

Ohmic contacts are made to the specimen by alloying into a boron-diffused surface layer with gold-gallium wire. A number of devices have been prepared most of which detect radiation. The variation of performance between detectors indicates that the processing is not yet under complete control. However, the following performances have been recorded. Gamma-rays from cobalt-60 have produced pulses up to a maximum of 2 mV., for which the signal to noise ratio is greater than 50 at liquid air temperatures, offering the possibility of high-resolution spectroscopy. Other specimens have detected 1-MeV. γ -radiation and 4-MeV. alpha-rays at room temperature, with a signal to noise ratio suitable for monitoring purposes. The current pulses have duration of a few μ sec. There is a certain amount of indirect evidence that the thermal cycling programme inherent in the boron diffusion process is modifying the carrier life-time and the compensation of the material²⁻⁴. This possibility, together with the effect of surface states, is being investigated as essential for production of reproducible devices.

We wish to thank Mr. J. A. Raines for his advice on the diffusion techniques, and Mr. T. James for assistance in fabricating the counters. Permission to publish this communication has been granted by the Admiralty.

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ENGINEERING

Operation of the Backward-Wave Oscillator

WE have recently made some measurements of the voltage distribution along the slow-wave circuit of our 'travelling-wave-tube analogue', operated as a backward-wave oscillator, which are of interest in helping to decide between the various theoretical models which have been proposed to describe backward-wave oscillator operation.

The travelling-wave-tube analogue was described in detail in a recent paper¹, and is based on the lumped circuit travelling-wave tube first described by Matthews². Briefly it consists of a series of drift tubes inside a vacuum envelope interconnected with a series of inductance coils which are outside the vacuum envelope (Fig. 1). The coil-drift tube system simulates an LC delay line the parameters of which can be adjusted to represent those of a normal, practical slow-wave structure. The advantage of the system is that the slow-wave structure properties can be varied, by changing the coils, without breaking the vacuum as would be necessary in the case of a conventional tube. The structure is matched at the opposite end from the gun by means of a high-frequency carbon resistor of appropriate value, while signal is fed on to, or coupled off from, the gun end (according to whether operation is in the forward or backward mode) via a simple T-section network.

Whether the system operates as a forward-wave amplifier, or a backward-wave amplifier or backward-wave oscillator, depends on the electron gun voltage, that is, on choosing the electron velocity so that the electron beam travels in synchronism with the appropriate harmonic. With the particular delay line used, backward-wave operation was obtained for gun voltages ranging between about 200 and 700 volts corresponding to currents of the order of a few milliamperes. No additional attenuation was added to the slow-wave structure—the intrinsic attenuation being sufficient to inhibit operation in spurious modes. The start-oscillation current was found to be about 1.7 mA. and the oscillation frequency about 300 Mc./s., while the coupling impedance of the first backward mode was about 200 ohms, corresponding to an effective *C* value (Pierce's travelling-wave tube gain parameter) of about 0.06 at start-oscillation.

The voltage along the slow-wave structure was measured by means of a coaxial diode probe mounted on a sliding carriage inside the focusing solenoid, enabling it to be connected to each section in turn. Curves of the voltage distribution obtained are shown in Fig. 2. While the mean trend of the points from collector to gun end is exponential, the falling off of voltage in the half-section at the gun end, the minimum occurring in the region of section 3 and the maximum in the neighbourhood of section 7, are all significant and accord very well with the results of the non-linear theory published by Rowe³. Comparison of these curves with those of Rowe show a striking similarity, allowing for the fact that our measurements could only be made at discrete points along the structure.

It is quite clear that at least a 3-mode theory is necessary to explain the operation and that a 2-mode theory of the type discussed by Gould⁴, although it indicates the right value of starting current, does not predict the correct voltage distribution on the line. It is also important to consider non-linear terms in the

Fig. 1. The lumped circuit backward-wave oscillator analogue