## A New Microwave Harmonic Generator*

IF my estimate[1] of up to $10^7$ amp./cm.$^2$ for the emission current density of free cathode 'spots' on a clean mercury surface is accepted, the mercury arc may be regarded as an indestructible point-contact rectifier with interesting microwave properties. At high rates of growth of current (that is, in excess of $6 \times 10^7$ amp./sec.) the cathode emission appears to be unable to follow the rising current by its normal method of increasing size[1] and presumably (at microwave frequencies) must either change its emission density or become unstable, or both. In either case a 'non-linear' current-voltage relationship is still to be expected.

Instability of short mercury arcs at microwave frequencies has already been reported[2], and following a suggestion by Prof. B. Bleaney, this communication describes the use of such arcs for the purpose of harmonic generation from a relatively high-powered microwave input.

Fig. 1 shows in diagrammatic form the essentials of the harmonic generator. Microwave power at 2·5 Gc./s. (from a continuous-wave magnetron of up to 100 watts output) is used to maintain a very short mercury arc between a mercury pool 'cathode' and tungsten wire 'anode'. The harmonics generated are collected by the smaller wave-guide shown, coupling to which is assisted by the adjustable tuning plunger placed inside the discharge tube. The tube is filled with argon to a pressure of at least one atmosphere, an even higher pressure being desirable. By using such a gas pressure it is possible to maintain a great density of ionization in the 'positive column' plasma of the arc, so that harmonics generated in the very small region of cathode-fall can be communicated to the anode wire. By tilting the discharge tube the arc may be adjusted to minimum length, the shortest possible arc being the most efficient.

With an estimated input power of a few watts at 2·5 Gc./s., an output in excess of one milliwatt was obtained at 10 Gc./s.; also a strong signal at 30 Gc./s. was detected by a spectrum analyser placed close to the arc tube. The anode wire for these experiments was 0·5 mm. in diameter and length of arc was about 0·1 mm. An ammeter connected from anode to cathode indicated a rectified current of 100–600 m. amp., the electrons flowing from the mercury to the tungsten wire 'anode'.

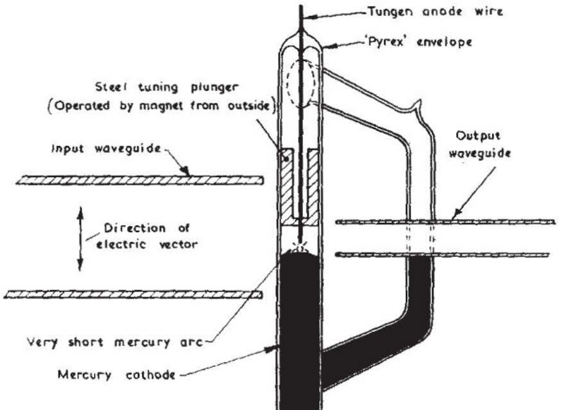

Fig. 1. Arc harmonic generator

If a 4–8 volt battery is connected externally so as to assist this electron flow, the microwave driving power may be reduced. If, in addition, the anode wire is made thin enough (for example, 0·1 mm. diameter) to become red-hot under the action of the discharge, a very short arc indeed may be obtained in the dimple formed by insertion of the anode below the normal free mercury surface, a cushion of mercury vapour preventing all but occasional short-circuiting of the arc. This 'dimple-arc' mode of operation can be the most efficient of all, but care has to be taken to avoid melting the rather fine anode wire necessary for low shunt capacity.

For the input frequency described, the quality and efficiency of the arc harmonic generator seem entirely comparable with the 'non-linear' semi-conducting crystal type, but the arc has one considerable additional virtue: there is no upper limit to the input power that can be used, for the arc cathode spot cannot be damaged. Work is continuing with the view of extending the use of the generator into the millimetre-wave region.

This work has been carried out as part of the research programme of the National Physical Laboratory and is published by permission of the Director of the Laboratory.

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[1] Froome, K. D., *Proc. Phys. Soc.*, B, **62**, 805 (1949).

[2] Froome, K. D., *Nature*, **179**, 267 (1957).

## A Spectrum of Turbulence at Very High Reynolds Number

THE downstream component of the turbulent velocity has been recorded in a sea-water channel with a Reynolds number, based on the depth, of $4 \times 10^7$. The measurements were made near the southern end of Discovery Passage (50° 00′ N., 125° 12·5′ W.) with a tidal current of 100 cm./sec. flowing northward at the point of observation. At this point the channel is about one mile wide and the water has been flowing with a depth of about sixty metres for a little over a mile, having entered the passage from the wide and deep basin of Georgia Strait.

The turbulent velocity was measured with a hot film anemometer, the form of the probe being a platinum film of thickness $4 \times 10^{-6}$ cm., plated around the tip of a glass cone which pointed into the stream. The maximum dimension of the film is about 1 mm. and it has a resistance of five ohms. An a.-c. bridge was used with a carrier frequency of 7·5 kc./s. The probe was mounted on the nose of a heavy body towed at a depth of 25 feet from the stern of a ship steaming against the current so as to maintain a fixed position.

A thirty-minute sample of the turbulence signal has been analysed with narrow band filters. Fig. 1 shows the high frequency end of the energy spectrum and the dissipation spectrum, each multiplied by the wave-number $k$ so that the area under the curves represents the energy and dissipation on the semi-logarithmic plot. Fig. 2 is a logarithmic plot of the energy spectrum.

The points at the extreme values of $k$ are not very reliable. For $k < 0{\cdot}02$ cm.$^{-1}$, the motion of the towed