II. MICROWAVE GASEOUS DISCHARGES

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A. HIGH-DENSITY MICROWAVE GASEOUS DISCHARGE

This program is being continued with a much thinner coaxial line as the probing element. Such a line does not disturb the plasma appreciably. In addition, a double probe of the type described by G. J. Schultz (1) was inserted in the bottle with its end 1.5 cm from the coaxial line for the purpose of measuring electron density at the position of the probe. It is assumed that the electron density at the coaxial line is related to that measured by the probe by a multiplicative factor that is independent of pressure. This assumption may have to be discarded when more precise measurements are needed. A bottle with a movable probe will be constructed for experimental verification.

Preliminary experimental results on the existing apparatus do not seem to verify the postulated theory (2). A plot was made (see Fig. II-1) of $\log(p\lambda)$ vs. $\log(n\lambda^2)$ at the minimum of the transmission curve when $\lambda = 33.3$ cm; p was varied from 1.5 to 0.08 mm Hg. This is the pressure range over which breakdown could be obtained with the present transmitter (approximately 60 watts output power at 3 Mc/sec); the discharge was uniform in appearance over the length of the bottle. The plot resulted in a straight line with a negative slope completely at variance with the theoretical curves plotted by Champion (2). It is again stressed that these are only preliminary results. The range over which $(p\lambda)$ and $(n\lambda^2)$ were varied was not large. It is planned to increase the range by using the S- or even X-band for probing frequencies and by increasing the power output of the 3 Mc/sec transmitter.
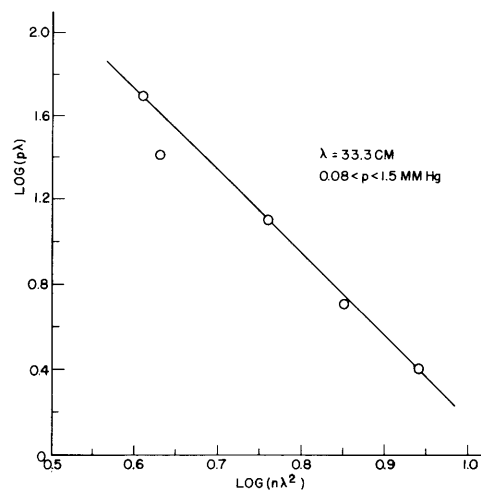

Fig. II-1

Plot of $\log(p\lambda)$ vs. $\log(n\lambda^2)$ at the minimum of transmission curve.

No explanation can now be offered for the results obtained. It would be very desirable to have an exact (or even approximate) solution to this problem, namely, to obtain, by the use of exact electromagnetic theory, a solution to the problem of transmission through a coaxial line in which a part of the outer conductor is a medium of complex conductivity, which is a function of position. Some progress has been made in this direction but not enough to be reported here.

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References

1. G. J. Schultz, Ph. D. Thesis, M. I. T., 1954.
2. K. S. W. Champion, Quarterly Progress Report, Research Laboratory of Electronics, M. I. T., April 15, 1954, p. 5.

B. PLASMA OSCILLATIONS

A tube for observing plasma oscillations has been constructed and put into operation. The spacing of the plasma-beam interaction region, contained between two circular electrodes, can be varied between 1.2 cm and 7 cm. Oscillations are observed by means of a probe that can be moved in and around the beam along its entire length. Electron densities can be measured with the same probe. The plasma through which the beam moves is maintained by a separate discharge. See Fig. II-2.
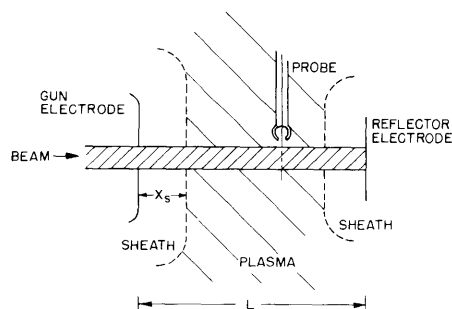

Fig. II-2

Schematic of plasma-beam interaction region.

The investigation, up to now, has concerned itself with the properties of the oscillations with respect to density, beam velocity and current, sheath voltage and spacing, and spacing between electrodes. Although one would like to have the plasma density completely independent of the beam, it is not possible. In fact, the beam can maintain its own plasma by ionizing the mercury vapor, and oscillations are frequently observed without having an independently supplied plasma. The plasma density surrounding the beam is thus largely dependent on the beam density.

It is certain that a sheath over the electrode through which the beam enters is necessary for producing oscillations, but it is not certain that it is also necessary to have a sheath over the reflector electrode. So far, oscillations have not been found when the reflector is set at anode potential so that there is no sheath. The position of the sheath edge has
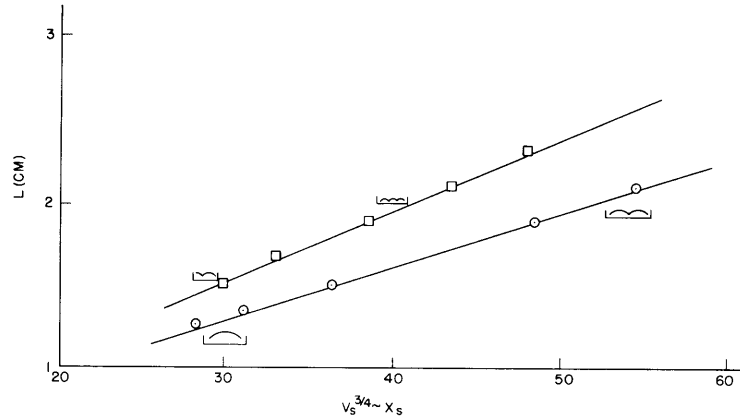
Fig. II-3

Electrode spacing as a function of sheath thickness.
Tube discharge current, 225 ma; accelerating voltage,
412 volts; gun current, 296 ma; frequency, 690 Mc/sec.

considerable effect on the mode of oscillation. A change of sheath voltage of less than
a volt, which changes the sheath edge position by an amount of the order of hundredths
of a millimeter, can cause a strong oscillation to disappear. The oscillation can be
brought back by changing the electrode spacing so that the separation of the sheath edges
is reproduced. See Fig. II-3. Oscillations are observed within the sheaths. This would
lead one to believe that the electrode surfaces serve as the boundary for the oscilla-
tions.

The standing-wave patterns for oscillations of a given frequency have been observed
as a function of the separation of the electrodes. It is found that as the spacing between
the electrodes increases the oscillation disappears and then reappears with an additional
loop in the standing-wave pattern. Since the wavelength does not change, the phase
velocity is independent of the spacing. This is illustrated in Fig. II-3.

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