Beam-Plasma Interaction

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Measurements have been made of plasma electron concentration and oscillation intensity through some inhomogeneous low-pressure hot-cathode discharges traversed by electron beams. A strong tendency has been found for oscillations to grow in amplitude when a beam moves down a plasma concentration gradient, and to die out when a beam moves up a gradient.

ALTHOUGH it has been known for many years[1] that excitation of plasma electron oscillations is an important step in randomization of momentum of electron beams in a low-pressure plasma, it has proved singularly difficult to determine the exact conditions for their production. Recently, Spitzer[2] has proposed that similar processes may also occur in pinched discharges. Considerable interest therefore attaches to a suggestion by Allis[3] that the concentration *gradient* of plasma electrons is a controlling factor, theory indicating that oscillations are most likely to grow in amplitude if propagated down a concentration gradient. Allis pointed out that the growth condition was probably satisfied near the hot cathode of some discharges we have studied,[4] where oscillations are known to occur.

We have now made simultaneous Langmuir probe analyses and oscillation measurements in 15 further discharges of this kind. The plasma was in mercury vapor; pressures were about 1 micron, voltages 15–30 v, and currents 20–40 ma, drawn from a plane oxide cathode 8 mm in diameter. About half the discharges were of "meniscus" type,[4] with a quiescent plasma for a few mm in front of the cathode; the other half were of a type with oscillations through the whole inter-electrode space.[5] Some 50 gradients of plasma electron concentration occurred in these discharges; for at least 85% of these, Allis' criterion was found to hold. The frequencies of the oscillations were close to those calculated from the concentrations at the principal maxima of plasma electron concentration.

These results must be taken with some reserve until more is known definitely about the current-voltage characteristics of Langmuir probes exposed to oscillating plasmas and beams, and about how oscillations are picked up by probes. The general shape of the electron concentration contours found by single probes was, however, reproduced by the ion currents drawn by both single and double probes, while the agreement between measured and calculated frequencies also gives an indication that the results may be reliable.

In any event, Allis' proposal has at least indicated a method of attack on this difficult problem, and gives a pointer as to how the ionization balance equations for quiescent plasmas have to be modified when oscillations occur. It may also partly explain why oscillations are relatively easily excited when a primary beam is reflected along its original path, since either the direct or the reflected beam will necessarily traverse any concentration gradient in the correct sense for excitation.

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[1] I. Langmuir and L. Tonks, Phys. Rev. **33**, 195 (1929).
[2] L. Spitzer, Nature **181**, 221 (1958).
[3] W. P. Allis, paper presented at the 1957, Boulder, Colorado, meeting of the Union Radio-Scientifique Internationale (unpublished).
[4] See Allen, Bailey, and Emeleus, Brit. J. Appl. Phys. **6**, 320 (1955).
[5] K. G. Emeleus and D. W. Mahaffey, J. Elec. 4, 301 (1958).