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LETTER TO THE EDITOR

The perturbing effect of a Langmuir probe near a magnetised double layer

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Abstract. A sequence of colour photographs of an emissive probe moving through a luminous anode double layer is presented. The double layer is seen 'following' the probe for as much as 10 cm. This effect may result in erroneous measurements of both the double-layer width and its position.

Recently, a number of experimental studies of double-layer formation have been performed, particularly in magnetised plasmas (see, for example, Torvén and Andersson 1979, Torvén and Lindberg 1980, Andersson 1981, Stenzel *et al* 1981, Jovanović *et al* 1982, Merlino *et al* 1984, Cartier and Merlino 1987). The potential profiles associated with these double layers are usually obtained from measurements of the floating potential of an emissive probe (Smith *et al* 1979) as the probe is moved through the double layer. In this Letter, we present visual observations of the effect that a Langmuir probe has when it is moved through a double layer.

The double layers are of the 'anode-type' and were produced in the device shown schematically in figure 1. An argon plasma is generated by a discharge drawn between a conical spiral filament and a grounded anode mesh in the source chamber. The plasma drifts into the main chamber where it is confined radially by an axial magnetic field of 3–4 kG. The neutral argon gas pressure is in the range of 10^{-4}–10^{-3} Torr. Typical plasma parameters in the main chamber were $n_e \simeq 10^9$–10^{11} cm^{-3}, T_e = 1–3 eV, and $T_i \approx 0.1\ T_e$. Further details are given in Alport *et al* (1986) and in Cartier and Merlino (1987). The double layers were produced in the diverging magnetic field region within the end chamber by applying a positive bias to the 11 cm diameter anode plate. When the plate bias voltage, V_p, is increased to sufficiently high values that the potential drop in the sheath exceeds approximately the argon gas ionisation potential (15.8 eV), the electrons accelerated through the sheath can become sufficiently energetic to ionise the background gas and produce a 'new' plasma within the

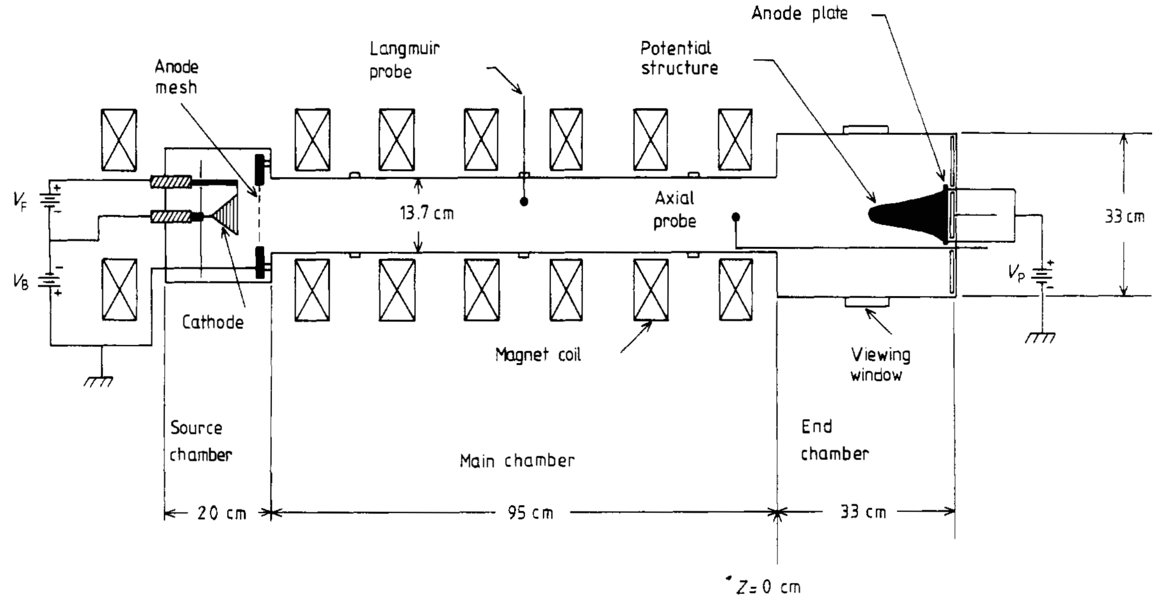

Figure 1. Schematic cross sectional view of the experimental arrangement used to generate double layers. The conical double-layer structure is depicted in the end chamber.

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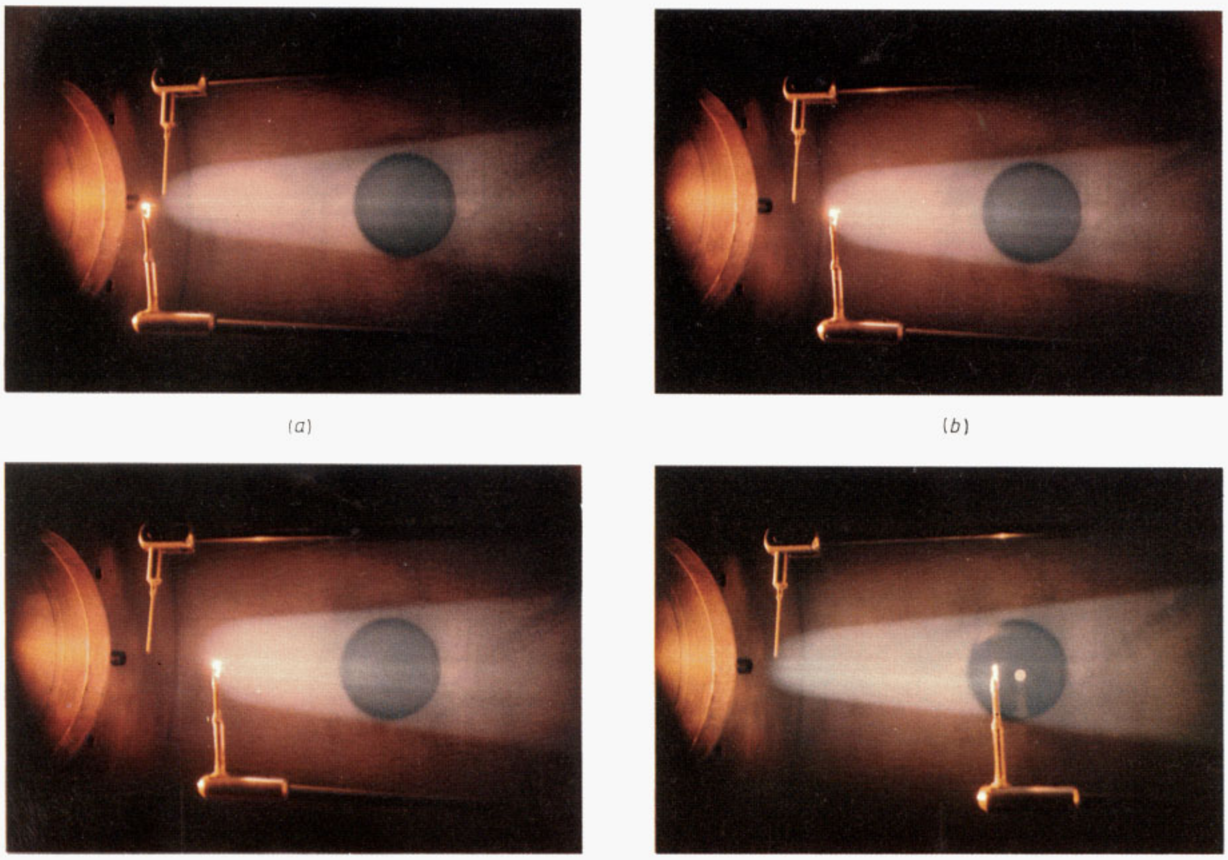

(a) (b) (c) (d)

Figure 2. Sequence of colour photographs showing the perturbation of a large obstacle (the emissive probe) as it is moved through the boundary of the light-emitting region. The upper probe marks the initial position of the apex of the light structure. The neutral pressure in this case was about 3×10^{-3} Torr.

sheath. If the rate of ionisation is high enough, the sheath detaches from the plate and develops into a strong, three-dimensional, magnetised double layer. In addition to ionisation, there is an increased rate of excitation of neutral argon atoms by the energised electrons. As a result, the onset of the double layer is accompanied by the appearance of a bluish conical-shaped structure extending outward from the plate toward the main chamber. This is shown schematically in figure 1. The boundary of the glowing structure lies just within the high-potential side of the double layer. This glow enabled us to observe directly the perturbing effect of probes on the formation of the double layers.

This effect is evident in the series of colour photographs shown in figure 2 (plate). These photographs show the light-emitting region which accompanies the formation of the double layer. The anode plate (not shown here) is to the right, as in figure 1. In this sequence of photographs, all external parameters were fixed and the axial position of the double layer is indicated by the upper, fixed Langmuir probe, while an emissive probe, of the type usually used for such measurements (2 mm diameter probe shaft), is moved from left (*a*) to right (*d*). The light structure can be seen 'following' the emissive probe for a distance of about 10 cm. At some point the double layer abruptly jumps back to its original position from the emissive probe location shown in (*d*). As a result of this effect, the measured double-layer potential profile may appear either wider or narrower than the true width and may appear to be located at the wrong axial position. This effect is greatest when the probe is moved through the apex of the conical structure, and is present even when the probe is neither emitting nor collecting current. It seems to be due to the physical obstruction by the probe on particles flowing through the double layer and the double layer's particular dependence on conditions just ahead of the apex.

For the type of double layers which we studied, the width of the double layer along the magnetic field and its axial position depended on the neutral gas pressure and the anode plate bias voltage. For a fixed neutral gas pressure, the double layers moved outward from the plate with increasing plate bias voltage. To diagnose these double layers properly, it was essential to eliminate the probe perturbation effects described above. In general, satisfactory measurements could only be made by using extremely small probes. For collecting probes we used a 0.8 mm tantalum disc supported by a 0.13 mm glass-insulated tungsten wire. The overall probe shaft diameter was 0.18 mm with a length of 1.7 cm. Similarly, an emissive probe was constructed using a 0.025 mm diameter tungsten filament spot-welded across two of these probe shafts with the spot welds insulated with Ceramacast. A typical example of the potential measurements obtained with this emissive probe is shown in figure 3 for various anode plate voltages between 40.5 V and 60.0 V, and at a fixed neutral gas pressure 1.2×10^{-3} Torr. During each of these scans of the potential, visual observations were made to check that the probe was not seriously per-

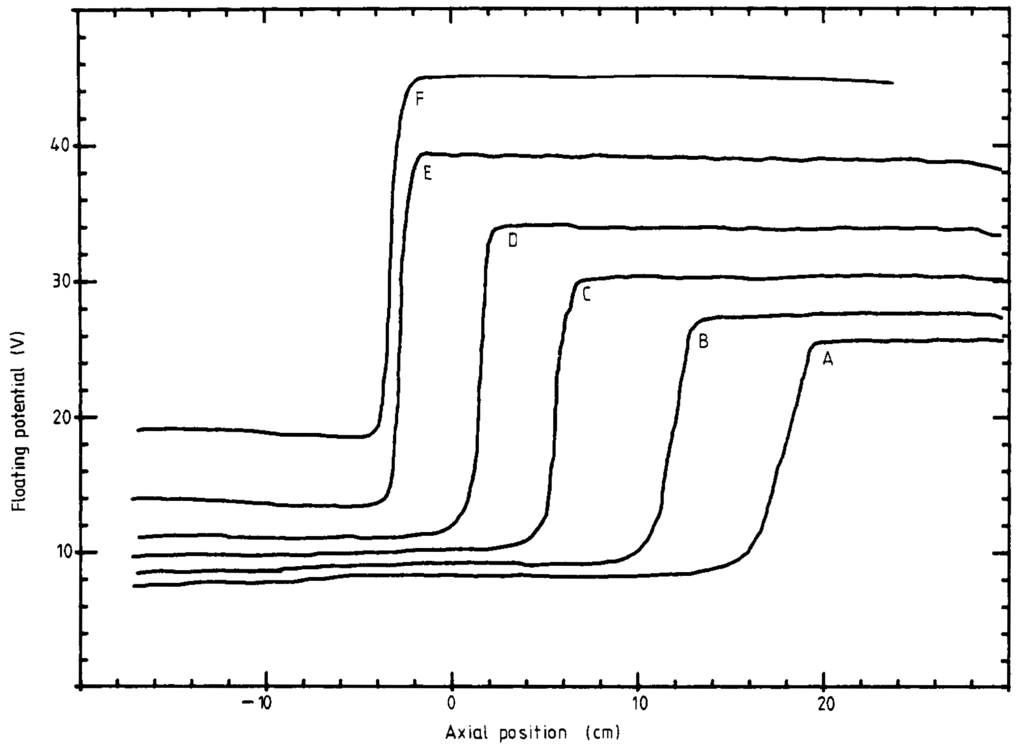

Figure 3. Double-layer axial potential profiles for various anode plate voltages obtained with the miniature emissive probe. A: 40.5 V; B: 43.0 V; C: 46.3 V; D: 50.0 V; E: 55.0 V; F: 60.0 V. $B_{max} = 3.7$ kG, $P = 1.2 \times 10^{-3}$ Torr, $Z_{plate} = 31.6$ cm.

turbing the double layers. Our observations point to a need for an independent check on double-layer potential measurements made with probes.

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