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Magnetoelectrostatic confinement with symmetric surface potentials

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A new plasma confinement principle, "magnetoelectrostatic confinement", has recently been developed as an alternative to the orthodox approaches to obtaining fusion energy (e.g., inertial and magnetic containment) Jones 1985. In magneto-electrostatic confinement unbalanced space charges (both ions and electrons) are injected into a conventional magnetic bottle (of the Stellarator type, Tokamak, etc.) and act as a system of magnetically insulated virtual anodes and cathodes. This set of magnetically anchored potential wells then serves to confine (and heat) the fusion plasma itself. Experiments suggest that this is superior to either the usual magnetic or inertial containment options.

In the experiments described in previous publications the plasma core was biased (either positively or negatively) with respect to ground (i.e., the walls of the vacuum chamber). Typical experimental results are shown in Figure 1 (taken from Jones, 1983 and 1987). The two curves V_p present the radial plasma potential profiles for typical magnetoelectrostatically confined discharges ; positive potentials have the advantage of inhibiting the penetration of impurity ions that are formed near the chamber walls. Frequently, however, magnetically confined plasmas may have an overall negative charge and magnetoelectrostatic confinement is also operative in that regime. In such systems refuelling pellets need only penetrate a short distance into the plasma ; the electrostatic fields (and possibly density and temperature gradient driven diffusion in a hollow plasma) will themselves drive the ionized fuel on into the plasma core.

In the present experiments the magnetoplasma core is uncharged and is surrounded by concentric layers of positive and negative space charge. These experiments were conducted in a low pressure hot filament magnetized arc in the "U-5" device, Figure 2. A variety of diagnostics are employed. The plasma density, n, and electron temperature, T, are measured by Langmuir probes. Ion distributions are measured by high resolution planar gridded retarding field electrostatic energy analyzers (Jones, 1978 and 1979). Continuous density profiles are obtained from ion saturation current records (or electron saturation current).

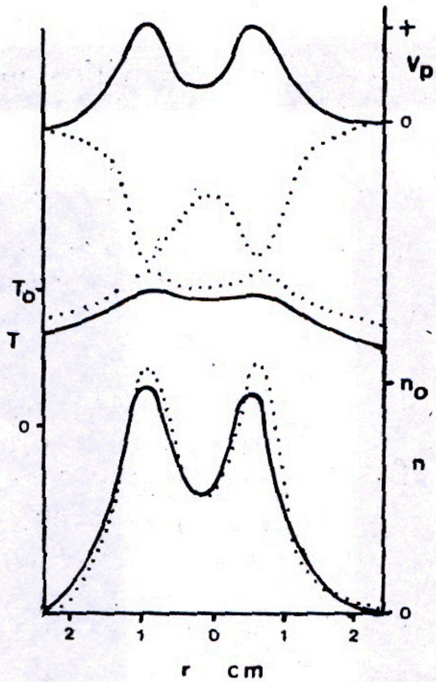

Figure 1. Solid Lines: Radial density, temperature, and plasma potential profiles of a magnetoelectrostatically confined positively charged plasma. Dotted Lines: Radial profiles for a negatively charged magnetoelectrostatically confined plasma.

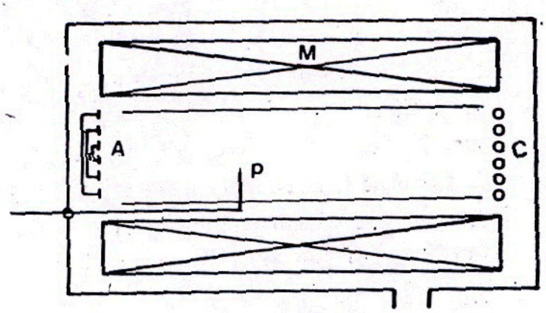

Figure 2: Low pressure arc discharge device having annular ring anode array A, annular filament array C, probe P, and solenoid magnets M.

Continuous electron temperature measurements are obtained using triple probe methods and plasma potentials are measured with hot emissive probes.

Various hollow plasma potential profiles are obtained by using annular cathodes and anodes (Jones, 1982 and 1983, also Kustom *et al* 1984 and Hooper *et al* 1984). Our procedure has been to compare gas discharges having different plasma potential profiles but nearly identical parameters (n, T, discharge power, magnetic fields, etc.). The present experiments are a direct extension of the work reported in Jones (1983 and 1987).

Typical experimental results are shown in Figure 3. In a conventional gas discharge without magnetoelectrostatic confinement (solid curves) the radial density

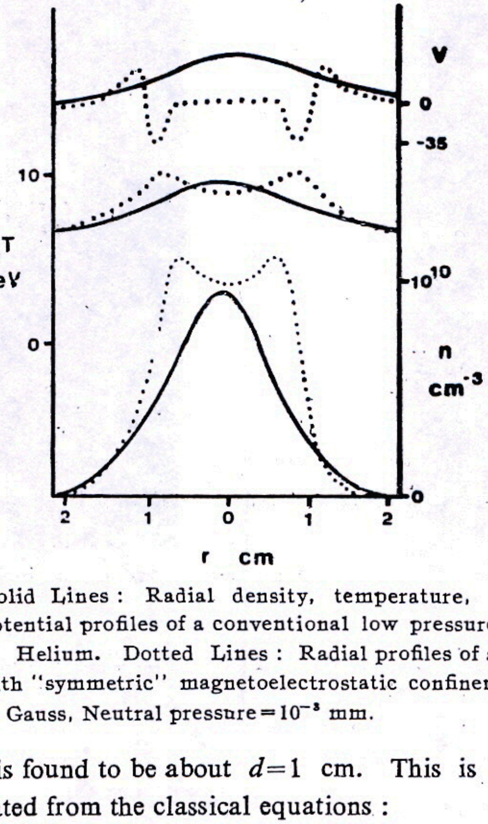

Figure 3. Solid Lines : Radial density, temperature, and plasma potential profiles of a conventional low pressure discharge in Helium. Dotted Lines : Radial profiles of a discharge with "symmetric" magnetoelectrostatic confinement. B= 50 Gauss, Neutral pressure$=10^{-3}$ mm.

gradient scale length is found to be about $d=1$ cm. This is in good agreement with the value calculated from the classical equations :

$$t=L/c_s \tag{1}$$

$$d=(2D_{\perp B}t)^{\frac{1}{2}}=(2r_{Le}^2\nu t)^{\frac{1}{2}} \tag{2}$$

where t is the end loss (axial) confinement time, L is the plasma column length (12 cm for the experiment of Figure 3), c_s is the ion acoustic speed, r_{Le} is the electron Larmor radius, and ν is the (dominant) electron-neutral collision frequency. t has been cross-checked experimentally by observing the decay of the ion satura tion current collected by a probe inserted in the discharge afterglow (Jones 1983).

The dotted curves of Figure 3 show the typical results with (symmetric potential) magnetoelectrostatic radial confinement. The average plasma parameters are nearly the same, only the radial plasma potential profile has been changed by biasing annular segments of the end wall (or, alternatively, by the injection of

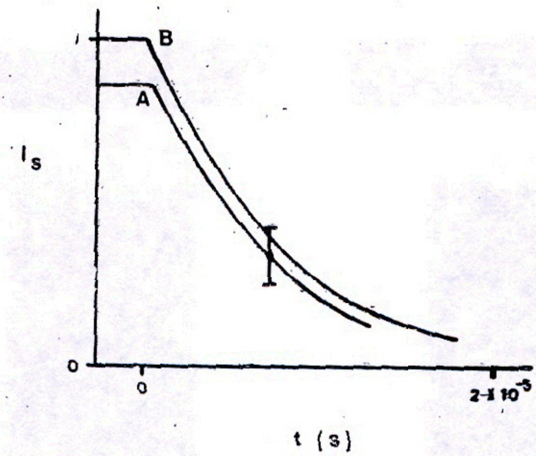

Figure 4. Ion saturation current collected in the discharge afterglow. Curve A: Conventional discharge with monotonically varying radial plasma potential profile. Curve B: With magnetoelectrostatic confinement.

annular electron beams). The axial confinement time remains roughly constant as verified in the afterglow, Figure 4. The radial density gradient scale length is, however, reduced to $d=\frac{1}{2}$ cm, indicating the existence of magnetoelectrostatic confinement in the "symmetric" or "balanced" potential regime.

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