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MEASUREMENTS ON THE SOURCE PROPERTIES OF A HOLLOW CATHODE

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ABSTRACT. The ion production rate of a hollow cathode in a magnetized arc has been measured. At low magnetic fields supersonic ion drifts have been observed. The ionized fraction of the gas flow decreases with increasing flow and the ion flux saturates at high flow rates.

INTRODUCTION. The strongly ionized plasma of a magnetized hollow cathode arc can be used for the production of particle beams [1, 2]. In such applications the longitudinal (along the B field) drift velocity of the ions w_{zi} is of major importance [3]. Besides the axial momentum balance in the external plasma column, the particle production inside the cathode is a factor of interest for sources [4]. We have measured the longitudinal drift velocity of the ions at the exit of the cathode. Together with the gas flow, the electron density and the characteristic width of the plasma column, the total ion production of the cathode is established just behind the cathode. We have calculated the ionized fraction of the gas flow that leaves the cathode ionized. The ion production rate saturates at high gas flows.

EXPERIMENTAL ARRANGEMENTS. The drift velocities are measured in Argon by Fabry Perot interferometry on the Doppler shift of the 6684 Å ion spectral line (fig.1).

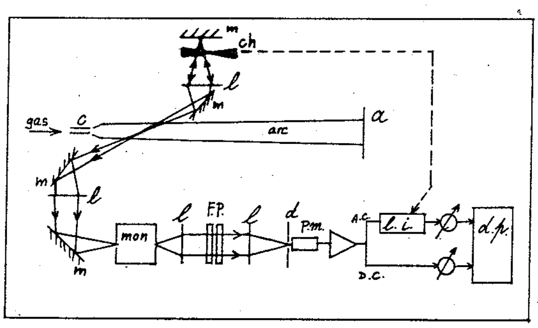

fig.1 Experimental arrangement for ion drift velocity measurements. c = cathode, a = anode, ch= chopper, l = lens, m = mirror, mon = monochromator, F.P. = Fabry Perot interferometer, d = pinhole diaphragm, p.m. = photo multiplier, l.i. = lock in amplifier, d.p. = digital processing.

A red shift in the direct light beam corresponds with an equal blue shift in the chopped beam. Thus an absolute wavelength shift is obtained. The Fabry Perot interferometer, pressure scanned and temperature stabilized, is also used for ion temperature (T_i) measurements. The local emissivity ε of the plasma continuum radiation is obtained from Abel inversion and gives, after calibration with Thomson scattering, the electron density n_e ($\varepsilon \sim n_e^2$) which is assumed to be equal to the singly ionized density n_i. All data have been collected and handled with a PDP 11 LSI computer.

RESULTS. For the results indicated in fig.2 we have applied a magnetic field B = .2 T, an anode current I_a = 50 A, an arc length of 1.3 m and a Tantalum cylindrical cathode of 6 and 8 mm inner and outer diameter respectively. The distance z from the cathode is 3 cm. We plot the ion production rate against the gas flow rate.

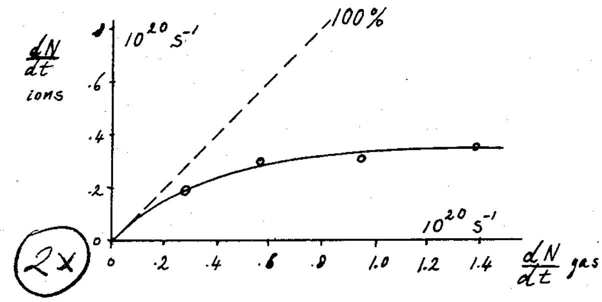

fig.2 The produced ion flow rate as a function of the gas flow into the cathode.

We note that at low ϕ almost full ionization is obtained but that at higher ϕ a saturation sets in. The ion production rate $\frac{d}{dt} N_i$ amounts to about 5 % of the total charge flux $\frac{I_a}{e}$ through the cathode (e = elementary charge). The axial ion drift w_{zi} and the ion thermal velocity $v_{ti} = (2kT_i/m_i)^{\frac{1}{2}}$ depend strongly on B, as is demonstrated in fig.3. Here the conditions are I_a = 50 A, z = 1 cm, ϕ = 6 atm cc/s. The corresponding n_e is nearly constant (fig.4).

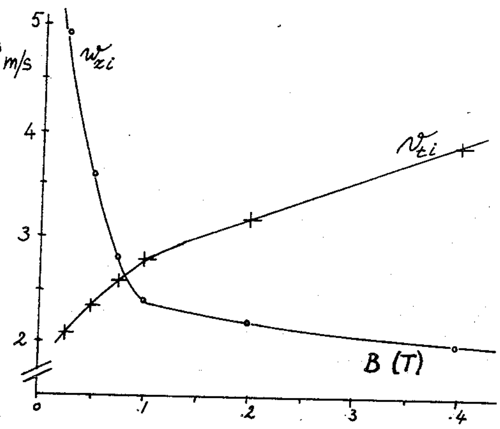

fig.3 The ion axial drift velocity w_{zi} and thermal velocity v_{ti} as a function of the B field.

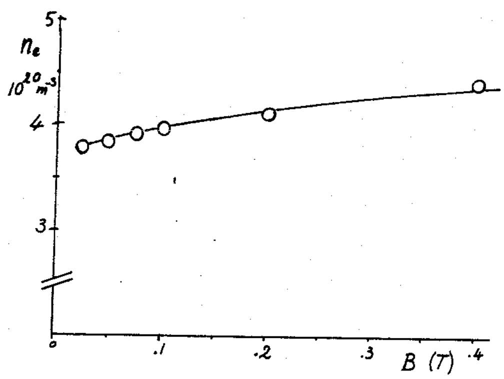

fig.4 The electron density n_e as a function of the B field.

We note that at low B fields the ion drift w_{zi} is supersonic, which is of particular interest in applications of a hollow cathode as a particle source. The cause thereof must be found in the axial momentum balance : in order to yield the required current of 50 A, the plasma pressure inside the cathode must be high enough (we have measured a gas pressure in the supply pipe of the cathode of 14 ($\pm$ 1) torr in the whole range of B between .025 and .4 T). At low B the plasma pressure in the external column $n_e k(T_e + T_i)$ drops so that axial momentum conservation requires a high inertia contribution $m_i(n_i + n_a)w_{zi}^2$.

References

[1] P.G. Theuws, Ph.D. Thesis Eindhoven University of Technology, 1981.

[2] A. Hershcovitch & A. Prelec, Rev.Sci.Instrum. 52 (1981) 1459.

[3] J.M. Vogels, J.C. de Haas, B. Willems, T. Trommelen & D.C. Schram, Intern. Conf. on Plasma Phys., Göteborg 1982, contrib. papers pg. 11.

[4] J.L. Delcroix & A.R. Trindade, in Advances in Electronics and Electron Physics 35 (1974) 87, Academic Press 1974.