ION SOURCE DEVELOPMENTS

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Part of the approach to obtain high preinjector beam intensities has been the investigation of two types of ion sources. Up until now, essentially the same amount of time has been devoted to experimentation with the duoplasmatron source and the rf source, to investigate the relative merits of each type. Before actually a conclusion was reached as to what type of source would be more favorable for the present application, the duoplasmatron source was installed in the preinjector. Up until now only very limited work has been done with this source on the 750 kv accelerating column. Two duoplasmatron sources are available. These were bought from HVEC. Some trouble was initially encountered with a short circuit of the magnetic flux path by means of a mild steel vacuum enclosure wall in the region of the intermediate electrode of this source. This has been corrected. Investigations of this ion source were carried out by A. Yokosawa, who studied, for example, the influence of the position of the cathode in the intermediate electrode chamber. It was found that this was not critical for source performance. More sensitive was the spacing between intermediate electrode and anode, the actual distance being now approximately 5 mm. The anode insert used is nickel, a copper-tungsten alloy was tried with essentially the same results. It was found that the diameter of the insert or the diameter of the non-magnetic section in the anode plate should be kept small in order to reduce "aberrations" in the beam. Also, shielding of the plasma near the aperture hole by means of a plasma cup was found to improve the performance of the ion source. The aperture hole is normally 0.030 inches or 0.020 inches with a cup diameter of approximately 0.150 inches. A small aperture hole is more favorable because then higher discharge currents can be employed, resulting in a higher proton percentage.

A typical phase space plot of the beam from this source, obtained with a 200 kv experimental accelerator section which was in essence a "Pierce" geometry system, is shown in Fig. 1. In this system a series of electrodes with small aperture holes enforcing a $z^{4/3}$ potential distribution is used.* This necessitates high gradients and consequently, the possibility of breakdown is increased. Nevertheless, this system has certain merits and it is intended to further investigate this in the future. Presently, the actual geometry used is that shown in Fig. 2, whereby an "einzel" lens focusing system is used similar to that used at the CERN preinjector. From field studies with the electrolytic tank and with a computer program indications were found of aberrations in the second section of the einzel lens. Especially with beams of the order of 75 ma the filling in this region could be approaching the actual diameter and the effects of the aberrations could become serious. Therefore, the diameters in this system were enlarged to accommodate higher beam intensities. Notwithstanding this, the aberrations were not completely eliminated.

In order to study the emittance of the source an experimental arrangement as given in Fig. 3 was used. The image pattern of a series of slits was observed on an aluminum target. The carbonization of vacuum grease was used to obtain a permanent image of which a typical example is shown in Fig. 4, with an exposure to the beam of the order of a few minutes.

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*E.R. Harrison AERE G/R 991 (1952)

It must be said that the use of vacuum grease is not recommended in this application because only recently it was found that the accelerator column had to be cleaned internally because of this.

A diagram, indicating how the phase space plot is determined from the image pattern is shown in Fig. 5, whereas in Fig. 6, some typical phase space plots are given. This was obtained with a section of the present focusing system going up to 200 kv only. Only preliminary results are available for beam emittance at 750 kv; these indicate a value of π.3 inch-mrad.

Some trouble still exists with cathode life of the duoplasmatron source. A tantalum filament has been used but with discharge currents of up to 15 amps, filament life is of the order of 5 to 10 hours. A matrix cathode was obtained from RCA and this is presently used in the source, showing already a substantially increased cathode life.

The rf type ion source has been investigated by M. E. Abdulaziz.* Starting from an rf source similar to that used at CERN a modified source was obtained, capable of output currents of 25% to 50% higher than that obtained with the standard version of this source. The ion distribution in the source cavity under equilibrium conditions of the discharge was studied and an equation of the density of the electrons and from this the density of the ions as a function of radius in a cylindrical source cavity was obtained. This is expressed in the form of a simple Bessel function as follows:

$$N_r = N_o \ J_o \left(r\sqrt{\frac{\gamma}{K}} \right)$$

where N_r is the density at the location r, N_o is the density at the axis of the cylindrical cavity, γ is the coefficient of the production of secondary electrons by collision with either gas molecules in the cavity or the surface

*M. E. Abdulaziz, IRE transactions of Nuclear Science, Vol. NS9, p.1

of the enclosure, and K is the diffusion rate of electrons to the sidewalls. From this it is obvious that the highest density exists on the axis and the logical approach is to try to extract a beam from this region. This was done; furthermore, the metal part of the extraction channel was better shielded from the discharge and also its length was shortened by about 25%. This improved performance as indicated before. Also the extraction voltage could be raised from 30 kv to 40 kv. The geometry finally arrived at is shown in Fig. 7, and in Fig. 8 some characteristics of the radial-extraction rf source are given, whereby plate power as indicated represents the rf power applied in the source cavity.

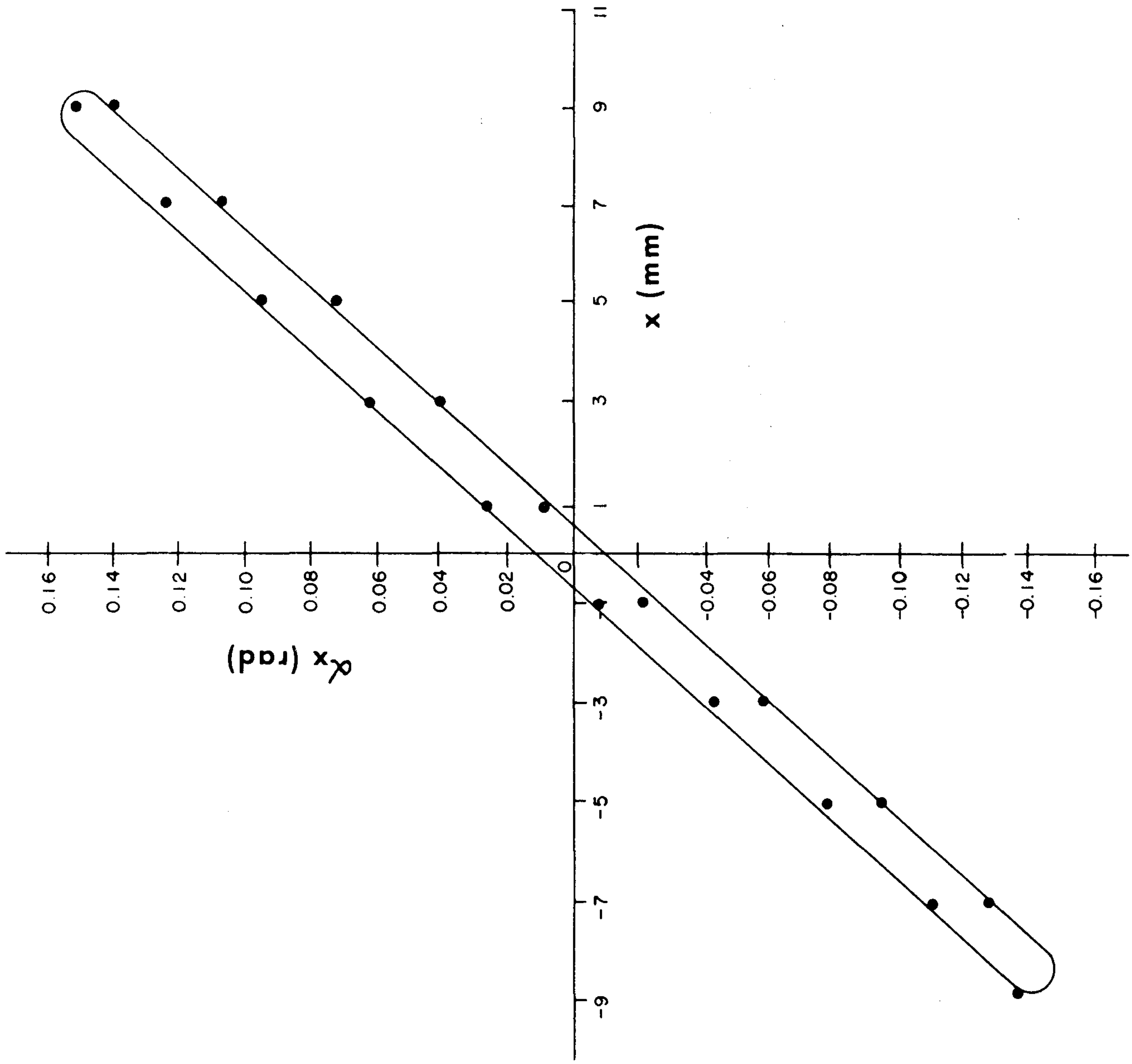

x (mm)
αx (rad)
11
9
7
5
3
1
-3
-5
-7
-9
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0
-0.04
-0.06
-0.08
-0.10
-0.12
-0.14
-0.16

Fig. 1

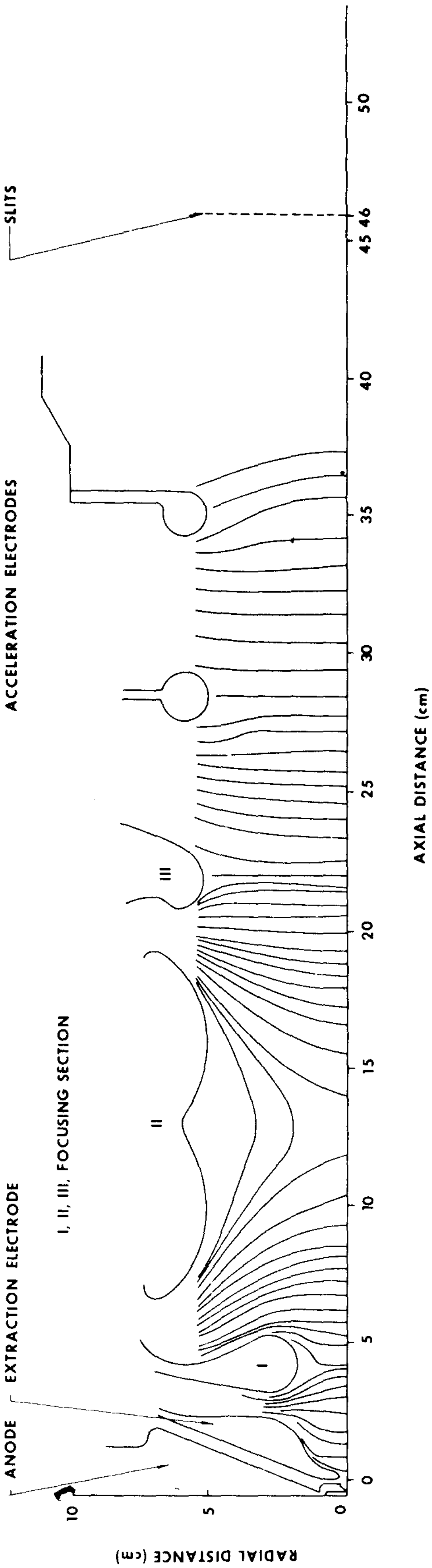

ANODE
EXTRACTION ELECTRODE
I, II, III, FOCUSING SECTION
I
II
III
ACCELERATION ELECTRODES
SLITS
AXIAL DISTANCE (cm)
RADIAL DISTANCE (cm)
0
5
10
15
20
25
30
35
40
45 46
50

Fig. 2

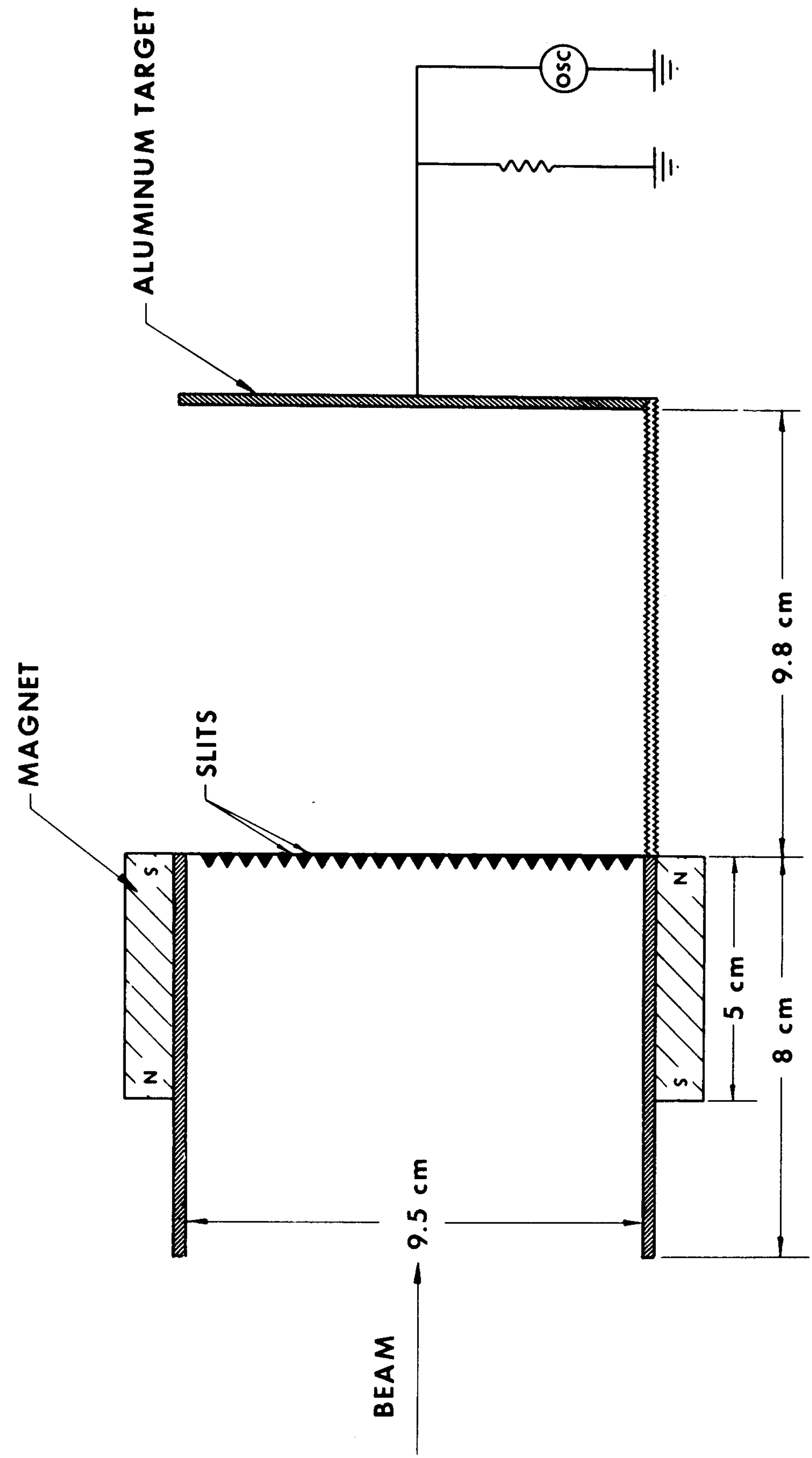

ALUMINUM TARGET
OSC
MAGNET
SLITS
S
N
N
S
9.8 cm
5 cm
8 cm
9.5 cm
BEAM

Fig. 3

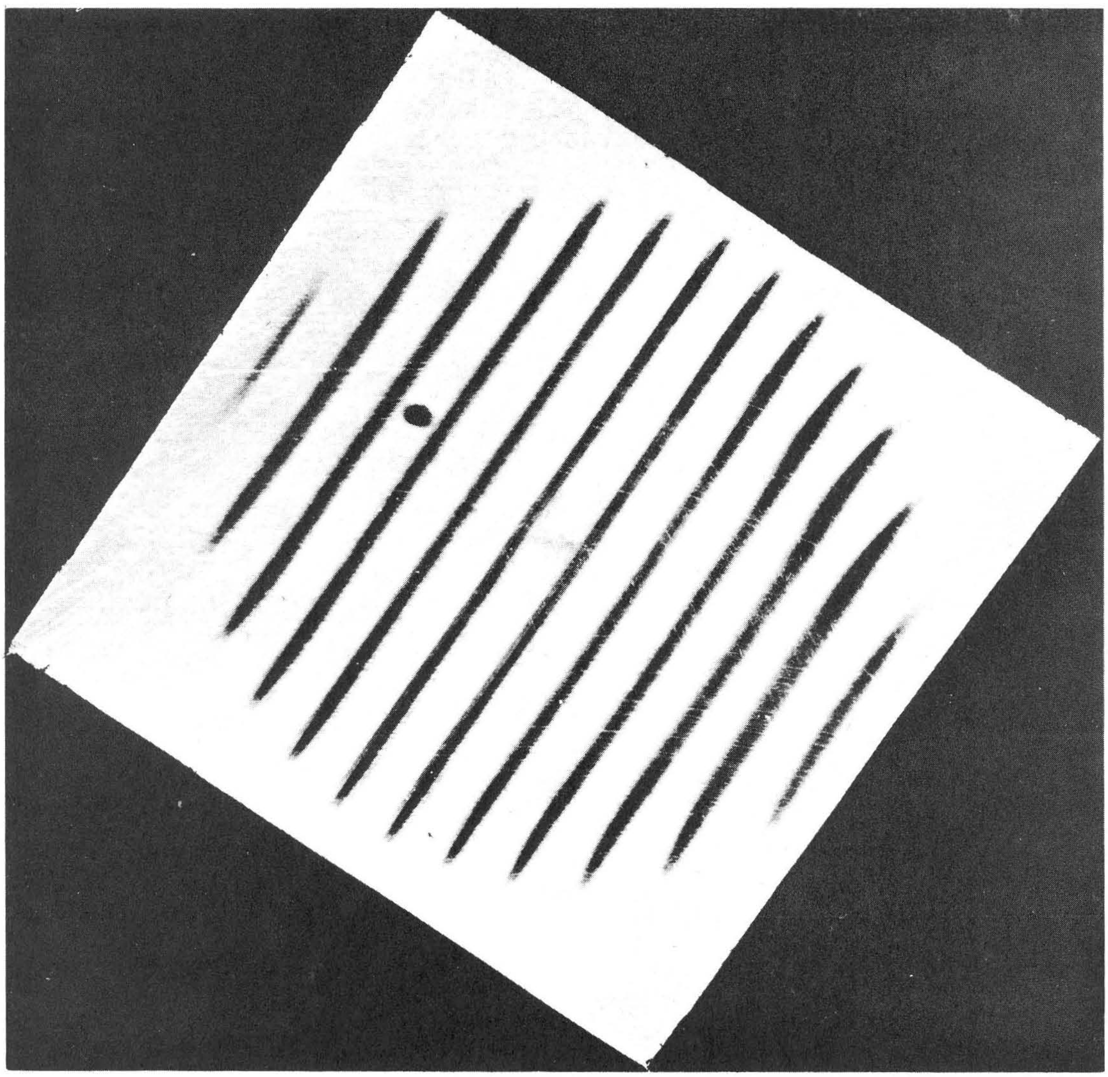


Fig. 4

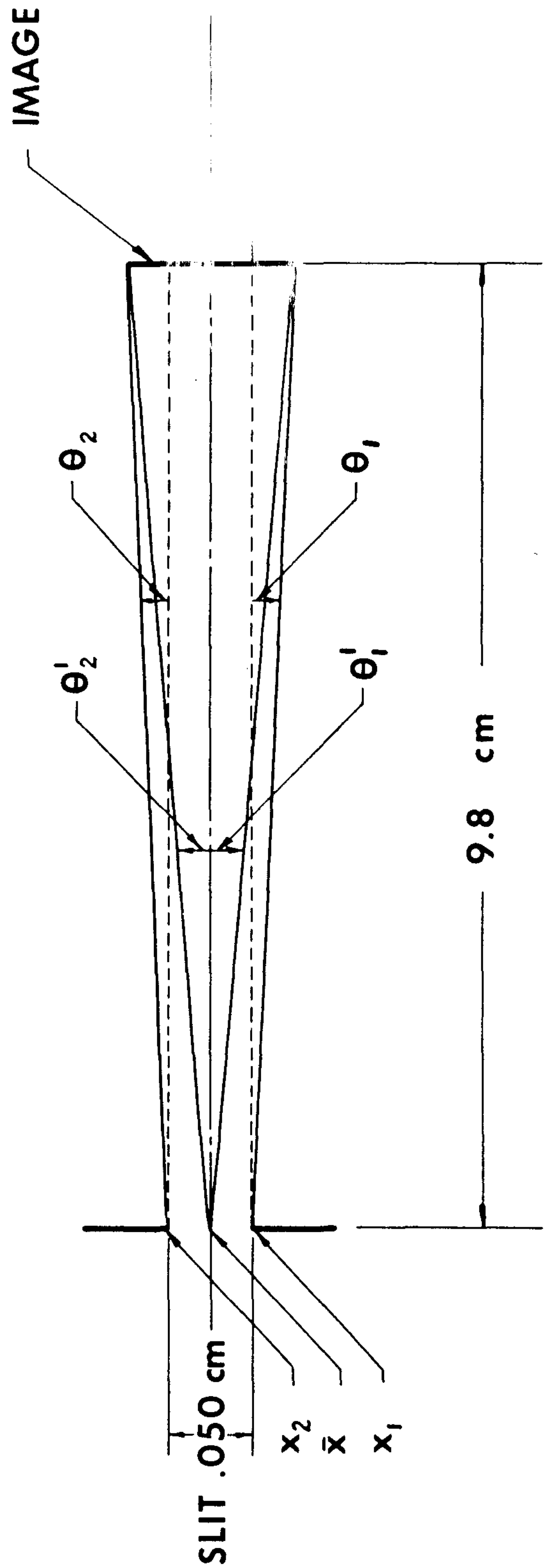
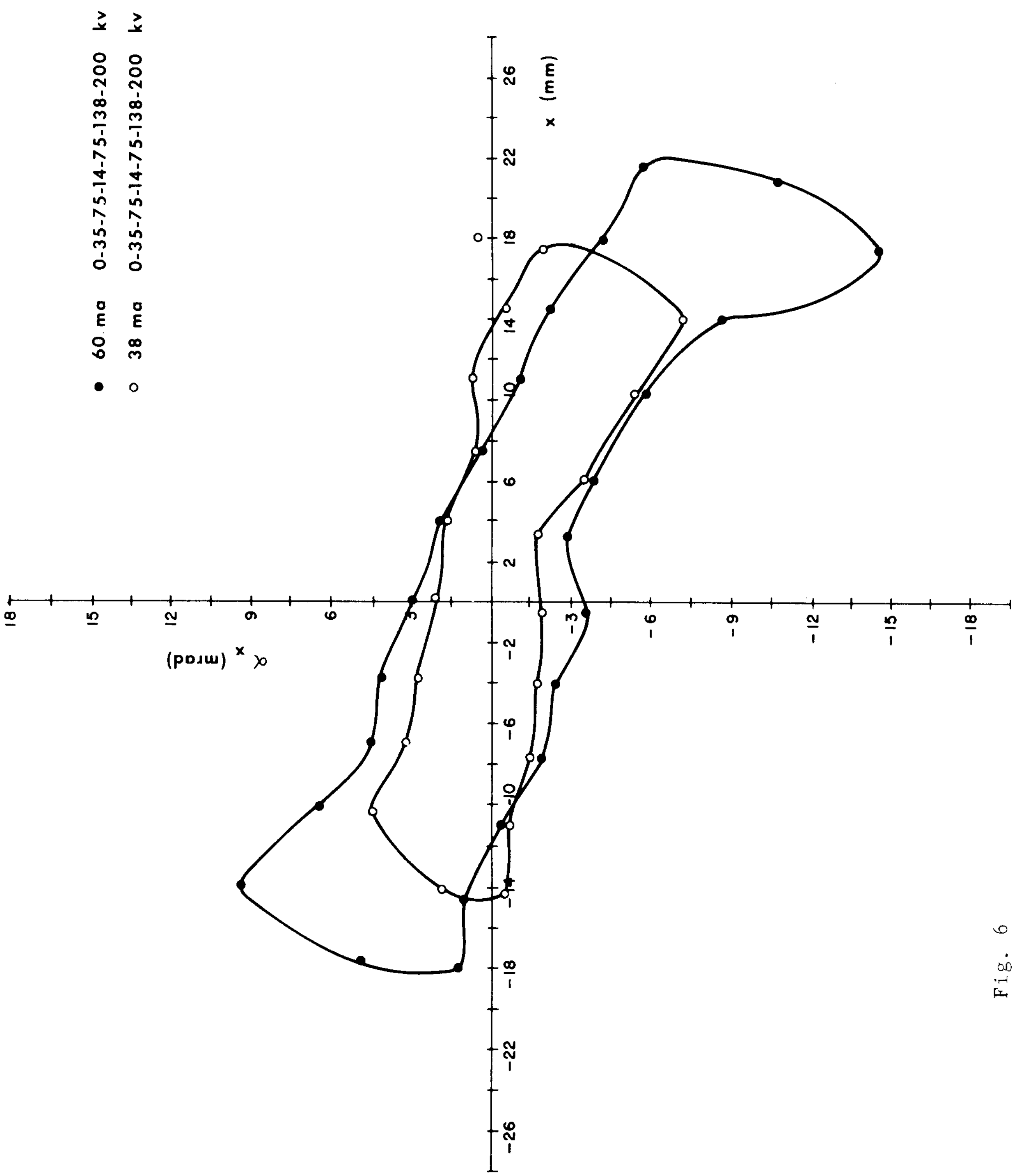


IMAGE
θ_2
θ_1
θ'_2
θ'_1
9.8 cm
SLIT .050 cm
x_2
$\bar{x}$
x_1

Fig. 5



• 60 ma 0-35-75-14-75-138-200 kv
○ 38 ma 0-35-75-14-75-138-200 kv
x (mm)
α_x (mrad)
18
15
12
9
6
3
-3
-6
-9
-12
-15
-18
26
22
18
14
10
6
2
-2
-6
-10
-14
-18
-22
-26

Fig. 6

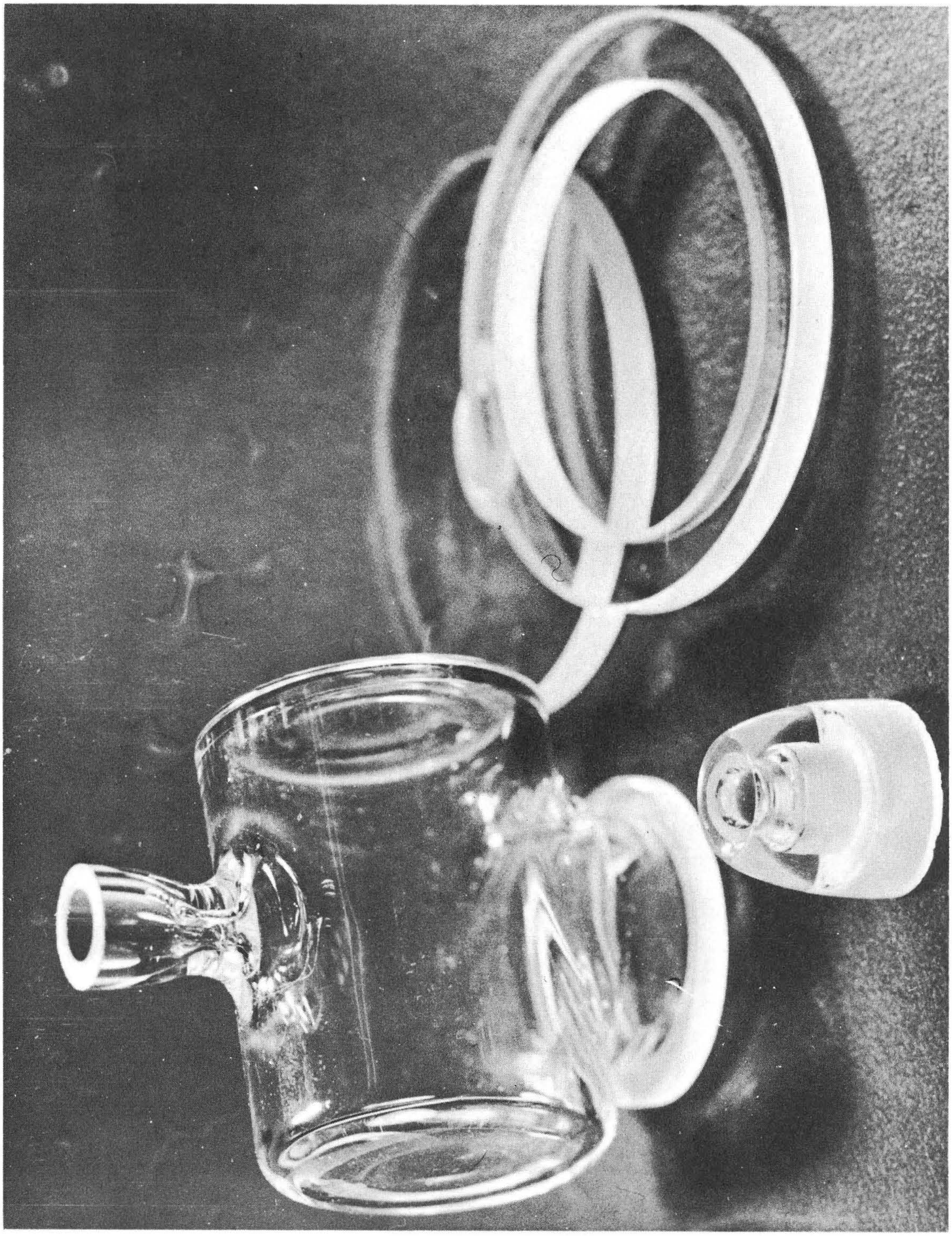


Fig. 7

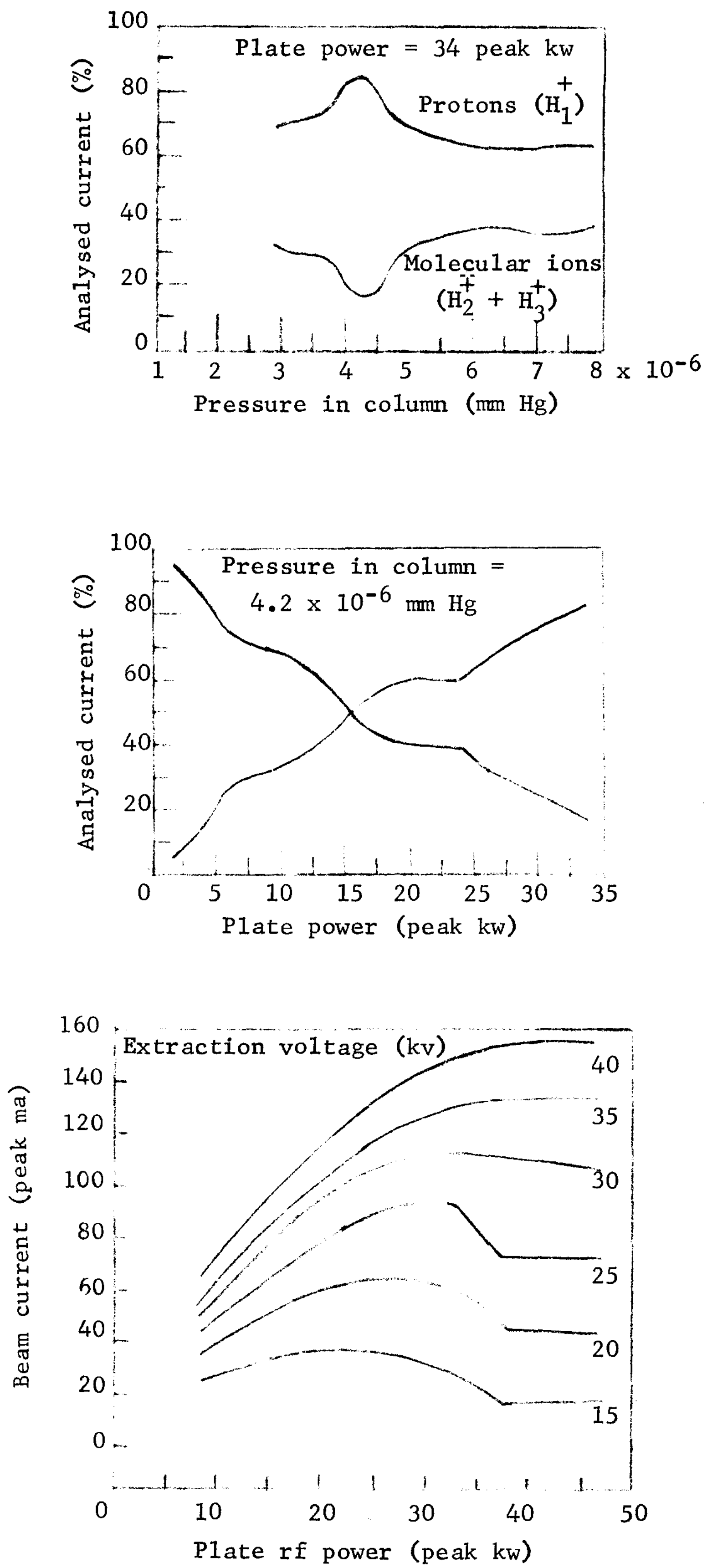


Plate power = 34 peak kw
Protons (H_1^+)
Molecular ions
$(H_2^+ + H_3^+)$
Analysed current (%)
100
80
60
40
20
0
1 2 3 4 5 6 7 8 x 10^{-6}
Pressure in column (mm Hg)
Pressure in column =
4.2 x 10^{-6} mm Hg
Analysed current (%)
100
80
60
40
20
0 5 10 15 20 25 30 35
Plate power (peak kw)
Extraction voltage (kv)
40
35
30
25
20
15
Beam current (peak ma)
160
140
120
100
80
60
40
20
0
0 10 20 30 40 50
Plate rf power (peak kw)

Fig. 8