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ION BEAM DEFLECTION IN EXTRACTION ELECTRODES

by

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ABSTRACT

Experimental data for a single aperture accel-decel electrode system showing the relationship between the angular deflection of a beam and the transverse shift of the extraction aperture is presented. We derive a simple theory which gives good agreement with the experimental data and may be used to predict beam deflection for other extractor geometries.

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first gap. The dimensions of the switch are shown in Figure 1. The [illegible] (aperture and accelerator gap) is equal to 0.[illegible]

The [illegible] deflection [illegible]

[illegible]

[illegible]

[illegible]

Theoretical model

[illegible] and [illegible] of the [illegible] simpler approach is [illegible] optical models of beam optics(8,10) derived from electron gun [illegible] calculations.(11)

The equivalent optical system of the extraction electrodes is shown in Figure 1a. The convergent rays from the curved emitting boundary are turned into a nearly parallel beam as they go through the electrode lens formed by the aperture of the extraction electrodes. The focal length of this lens can be calculated using the formulas given by Davisson and Calbick(12)

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first gap. The dimensions of the system are shown in figure 2. The aspect ratio (aperture radius/extractor gap) is equal to 0.5.

The width of the beam and its deflection were determined using a scanning probe at 44.5 cm from the plane of the extraction electrode. Data obtained for the variation of $\Delta\theta$ with Δx are shown in figure 4. The data lie on a straight line with a slope $\frac{\Delta\theta}{\Delta x}$ equal to 5.4°/mm.

Theoretical model

Theoretical estimates of the effect of aperture displacement have been derived from the computational models of the beam optics of the extraction electrode system(6) and from calculated distortion of the electric field(9). A simpler approach is to use the analytical models of beam optics(8,10) derived from electron gun optics calculations(11).

The equivalent optical system to the extraction electrodes is shown in figure 3a. The convergent rays from the curved emitting boundary are formed into a nearly parallel beam of rays by the divergent lens existing in the aperture of the extraction electrode. The focal length of this lens can be calculated using the formulae given by Davisson and Calbick(12)

i.e.

$$f = \frac{4V}{E_1 - E_2} \quad \text{(circular aperture)}$$

and

$$f = \frac{2V}{E_1 - E_2} \quad \text{(slit aperture)} .$$

To a first order, E_2, the electric field in the region after the extraction electrode is zero, and E_1 the electric field in the extraction gap has a value of $\frac{4}{3}\frac{V}{d}$ for space change limited flow. (V is the extraction voltage and d the extraction gap). Consequently, to this order, f equals 3d for a circular aperture and $\frac{3}{2}$ d for a slit aperture(8, 10).

More accurate estimates should allow for E_2 being non-zero in an accel-decel electrode system and for an increase in electric field in the gap due to convergence of the ion beam[10, 11, 13].

The effect of translation of the extraction aperture may be estimated from this model as the effect of translation of the divergent lens normal to the optical axis (fig. 3b). Clearly

$$\Delta\theta = \frac{\Delta x}{f} \quad .$$

i.e.

$$\Delta\theta \doteq \frac{\Delta x}{3d} \quad \text{for circular apertures}$$

$$\doteq \frac{2\Delta x}{3d} \quad \text{for slit apertures} \quad .$$

The difficulty in applying these formulae arises from uncertainty in the location of the principal plane of the lens. Assuming it to be at the face of the extraction electrode nearest the source we estimate d to equal d_1 plus D_1 in fig. 2 which leads to an estimate of $\frac{\Delta\theta}{\Delta x}$ of 4.2 degrees/mm.

The discrepancy between this value and the experimental value of 5.4 degrees/mm can be explained simply by supposing that the princ-iple plane of the lens is closer to the source.

Comparison with Other Data

Measurements of angular deflection of beams due to aperture dis-placement have also been reported by the Berkeley[14] and Oak Ridge[15] groups for slit and circular apertures and for different gap spacings. Comparison of the data presented by Stewart[15] with the model we propose may be obscured by the uncertainty in location of the lens.

This effect does not appear to be dominant in Stewart's data for circular apertures for which he measured a value of $\frac{\Delta\theta}{\Delta x}$ equal to $\frac{18.4}{d}$ degrees/mm (d in mm) compared with the theoretical value of $\frac{19.1}{d}$ degrees/mm. However the data for slit apertures can only be evaluated by plotting $\left(\frac{\Delta\theta}{\Delta x}\right)^{-1}$ versus d (figure 5). One sees that there is a non zero intercept, indicating that the principal plane of the lens is not co-incident with the front face of the extraction electrode. The slope of the curve is 0.031 degree^{-1} compared with the theoretical value of 0.026 degree^{-1}.

Thus one sees that this simple model gives good agreement with experimental data and may be used to predict beam deflection for other extractor geometries provided that care is taken in designating the position of the principal plane of the divergent lens.

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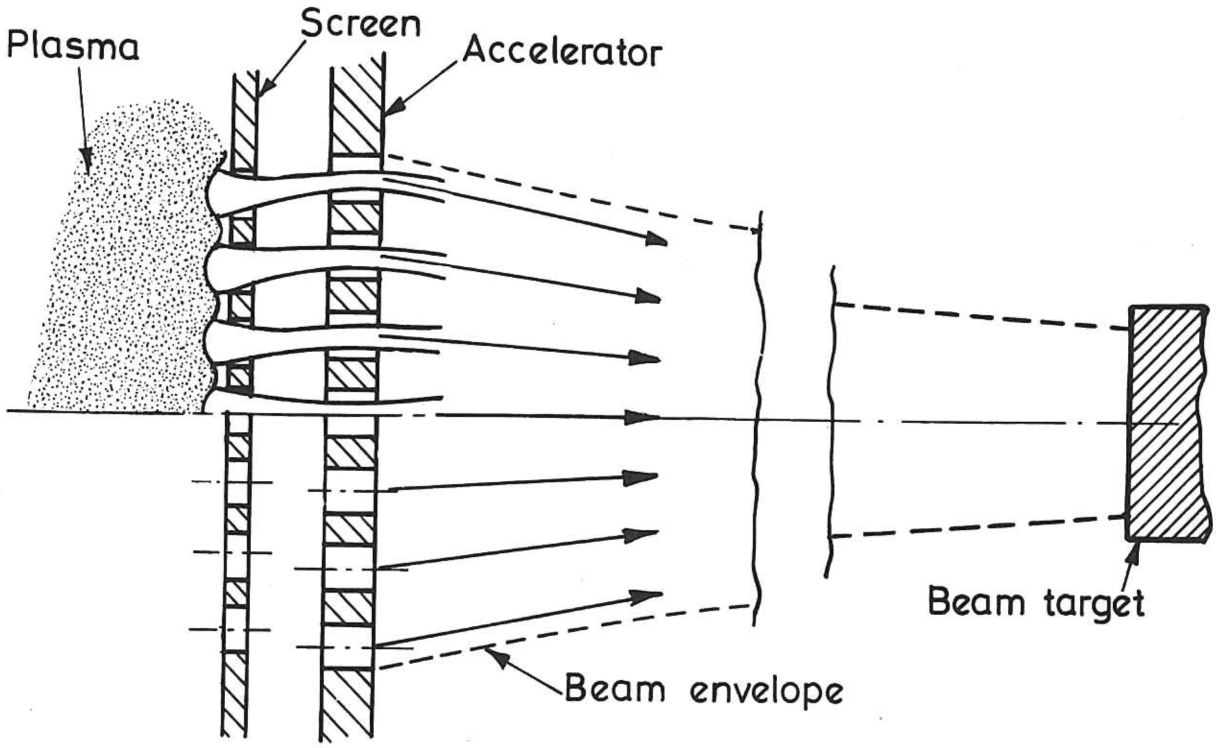

Fig.1 Convergent beam trajectories produced by displaced apertures. (After Poeschel and King Ref.6)

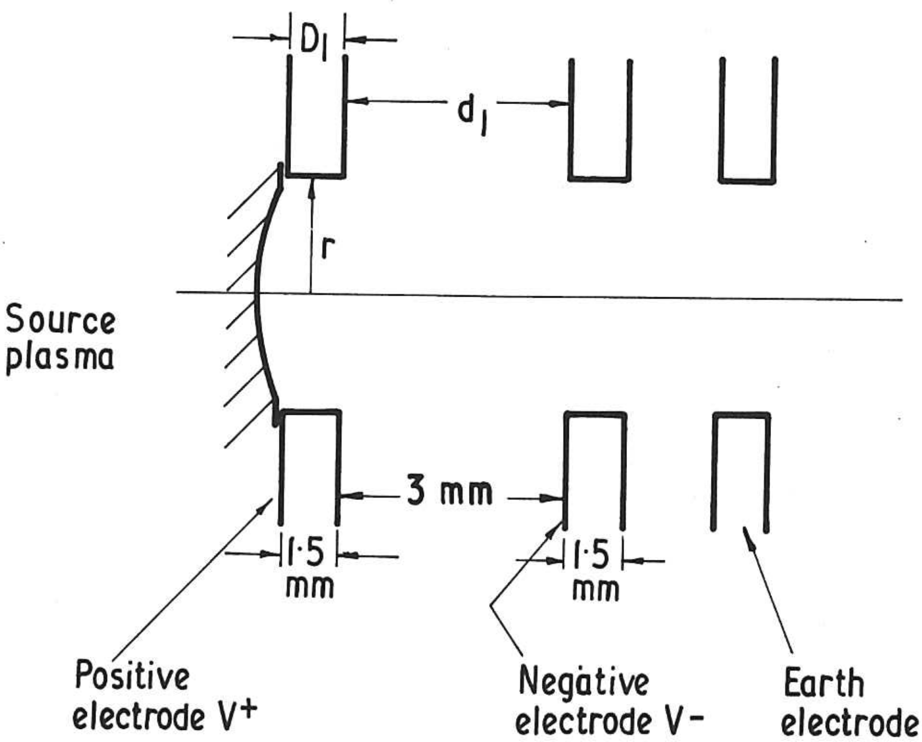

Fig.2 The single aperture electrode structure.

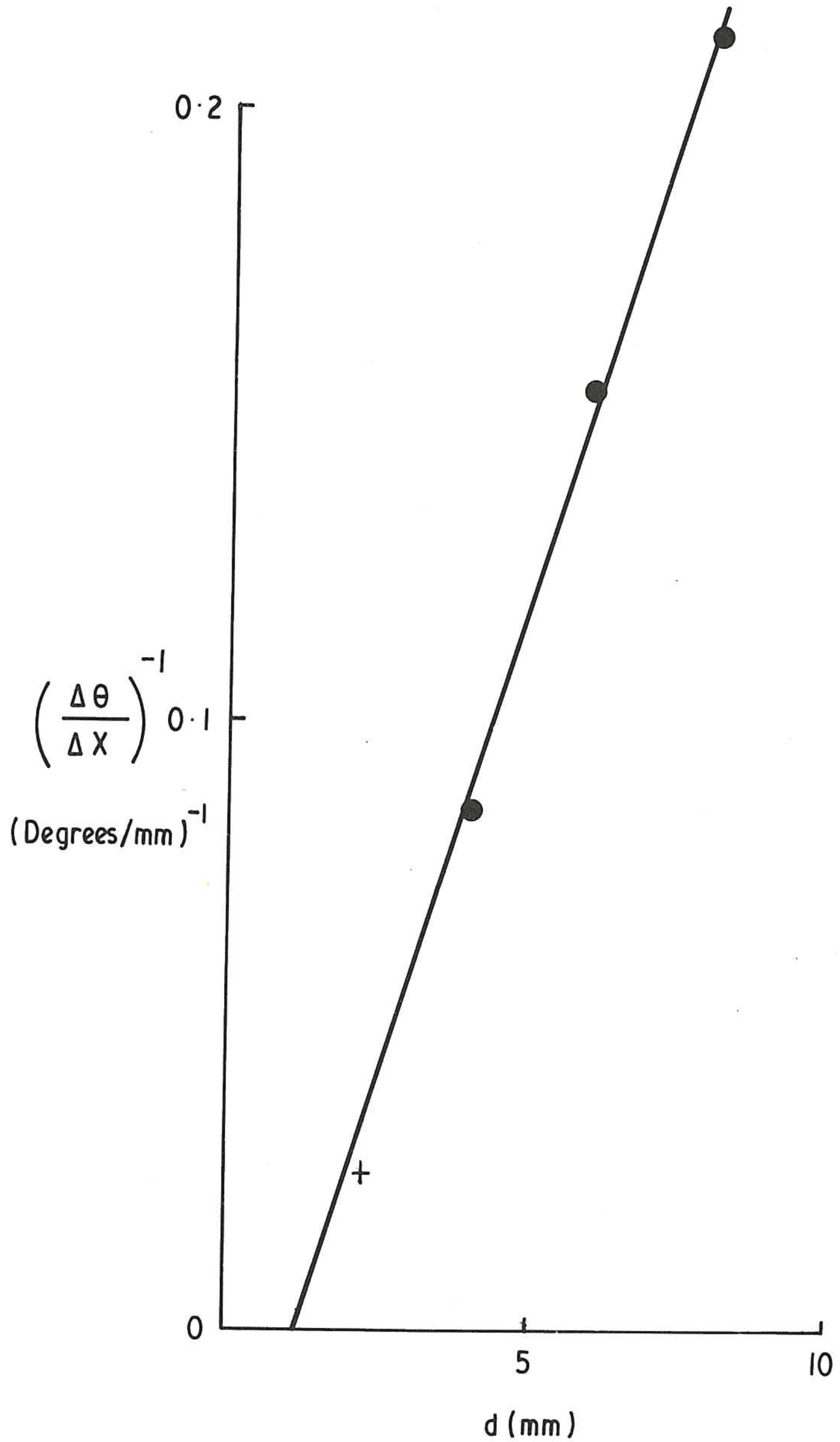

Fig. 5 Data on angular displacement for slits. ● Oak Ridge Ref.15. + Berkeley Ref.14.

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