A 100 mA ION BEAM WITH A LARGE BRIGHTNESS

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Introduction

We pointed out at the International Particle Accelerator Conference of Frascati, in 1965, that it is possible to get an ion beam with a large brightness provided some focusing rules are observed.

Figure number 1 summarizes these rules.

Under these conditions the beam emittance at the ion source exit is found to be small and is not disturbed later by the focusing and accelerating systems.

Furthermore particle trajectories from the ion source to the entrance of, say, a linac, can be entirely computed.

It is therefore possible to design a focusing and accelerating system from the knowledge of the initial source beam conditions which are determined by experiments in Laboratory.

While in 1965 the extracted beam intensity was limited to 42 mA, we have recently been able to get 100 mA out of a 350 keV preaccelerator used as a model for the construction of the 750 keV preinjector of the Saturne new injection line.

We shall describe this 350 keV setup and give our latest results.

Description of the Setup

The ion source -

The source is a classical duoplasmatron with a 10 mm diameter and 30 mm long plasma expansion cup in which the magnetic field is reduced by a soft iron shielding; see figure number 2.

Beam extraction system -

The shapes of the extraction electrode and of the first electrode of the lens shown on figure 3 provides a Pierce-like potential repartition.

The calculated voltage on the extraction probe was 45 kV, it was however necessary to raise the voltage up to 55 kV to get an 80 mA beam, and up to 73 kV for a 100 mA beam.

Focusing lenses and acceleration tube -

The focusing lens, directly after the extraction electrode, is determined when one knows the potential distribution along the axis $V = f(z)$.

The particles trajectories computation, including space charge, can then be carried on with a computer, admitting the correctness of the divergence theorem in the lens area where the beam travels (1/3 only of the diameter is occupied by the beam).

We tried several $V = f(z)$ functions in order to get a cross-over point 50 cm at least after the end of the acceleration tube.

If an electric field of 15 kV/cm, which is a sensible value, is chosen for the acceleration tube, it is found necessary that:

- 1°) Pierce geometry should be used up to at least a 45 keV beam energy,
- 2°) particles should be accelerated at least up to 150 keV before focusing.

The lenses geometry has been designed such that nowhere the electric field is greater than 100 kV/cm.

Figure number 4 shows the selected potential distribution, and figure number 5 represents the focusing and accelerating electrodes shape.

Experimentation

Voltage formation -

Voltages on the preaccelerator have been raised up to their maximum values (150 kV on the lens and 350 kV on the tube) within 48 hours.

After atmospheric pressure readmittance it takes about 5 hours to be back to maximum voltages.

If vacuum has been maintained good, it takes only a few minutes to get a correct beam.

Results -

The beam intensity is measured with a polarized target. Impulsions of 60 mA, 170 μs pulse length, and 100 mA, 40 μs pulse length, have been obtained.

Emittances are measured with a system of holes and quartz, images of the holes on the quartz are photographed. By variating the exposure time, it is possible to know the density distribution in an elementary pencil beam.

86 per cent of the protons are contained in a normalized emittance of 2.6×10^{-6} m.rad.

Figure number 6 summarizes the results, and gives the values of the main parameters.

Discussion

The total acceleration voltage was 357 kV, the lens was tuned at 157 kV and 10 kV, while calculations indicated 150 and 19 kV.

The extraction voltage was 75 kV instead of 45 kV calculated.

These differences are somewhat important specially for the 10 kV lens compared to the theoretical 19 kV.

The normalized beam brightness is

$B = \frac{16}{\pi^2} \frac{I}{E^2} = 23.1 \times 10^9$ A.m^{-2}. rad^{-2}. This figure is by a factor 3.8 smaller than our previous results, since we had a 88.10^9 A.m^{-2}.rad^{-2} brightness for a 44 mA beam, the plasma expansion cup diameter was then 7 mm.

In order to explain these disagreements we have measured the beam density at the source output, using an electronic measurement device rather than photographic techniques. (†)

Directly on the extraction probe is displayed a set of 0.2 mm diameter holes.

A wire is moved behind the probe, and the current in the wire is measured. We found that the density rapidly decreases when moving from the plasma cup axis.

Figure 7 gives a typical density distribution.

The plasma is therefore not uniformly expanded. The density distribution is very sensitive to slight modifications of the expansion space. Experiments are continued to precise this point.

(†) The last work is now carried on by Mr. Bex.

Bibliography

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(3) Theory and Design of Electron Beam - Pierce, D. Van Nostrand, Inc., New York 1954, Chap. IX, p. 174.

(4) Theoretical and experimental study of ions focusing in order to improve the beam brightness by suppressing aberration causes. J. Faure - 1965.

(5) Ion beam brightness conservation - study of a non brightness disturbing lens. P. Bernard - 1966.

DISCUSSION

A. J. FAURE, SACLAY

ALLISON, LRL: Did you do any plasma density plots against magnetic field in your cup, or do you just have the one set of data?

FAURE: We do not have any density plot against magnetic field, but we have very recent results showing that the plasma density can be improved. By a modification of the shielding of the walls with a pyrex sheet, for example, we could flatten the density and increase the brightness by a factor 1.8.

VOSICKI, CERN: What was the hydrogen pressure in your source for these results?

FAURE: It is, so far as we can calculate it, about 10^{-1} Torr.

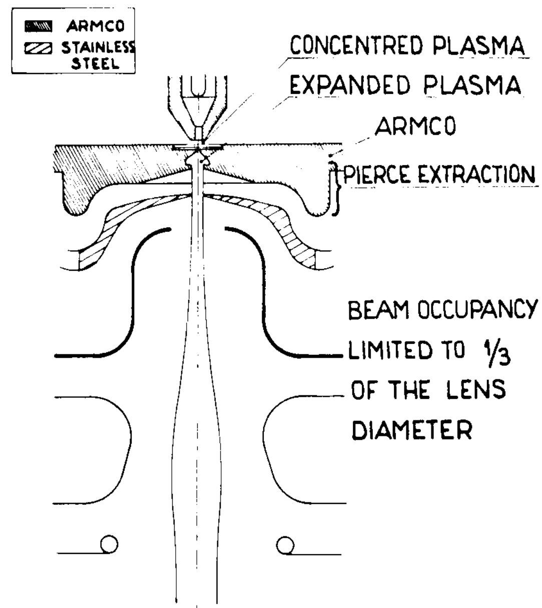

Fig. 1. Criteria for aberration-free beam.

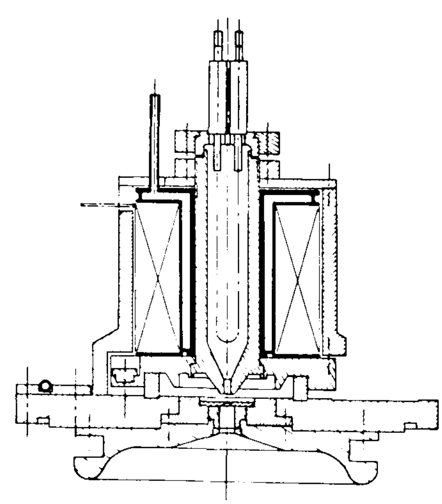

Fig. 2. The Von Ardenne ion source.

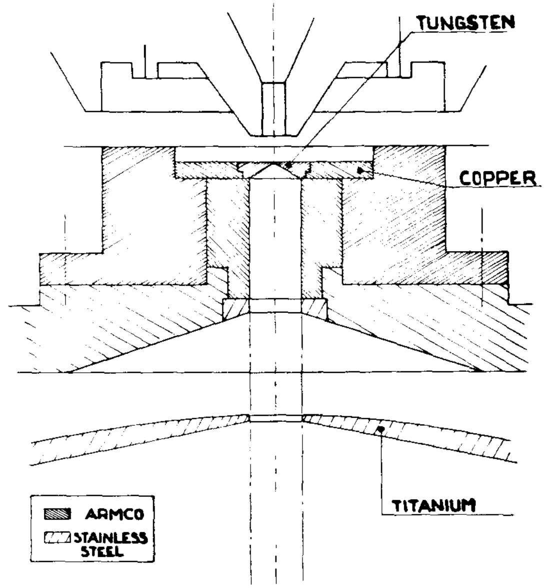

Fig. 3. The extraction probe.

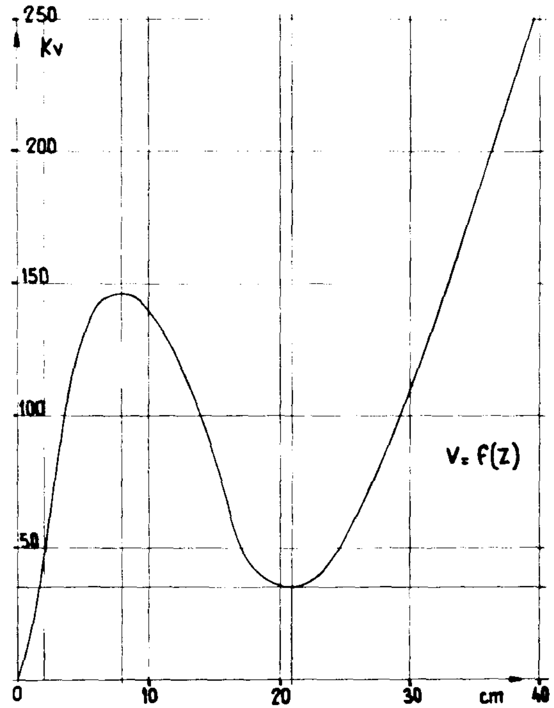

Fig. 4. Potential distribution along the lens axis.

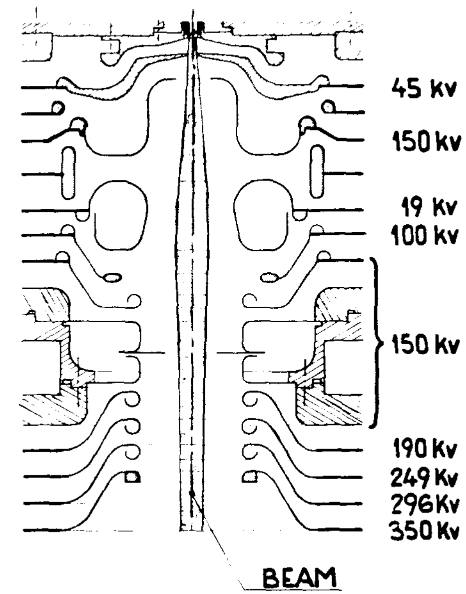

Fig. 5. The focusing lens.

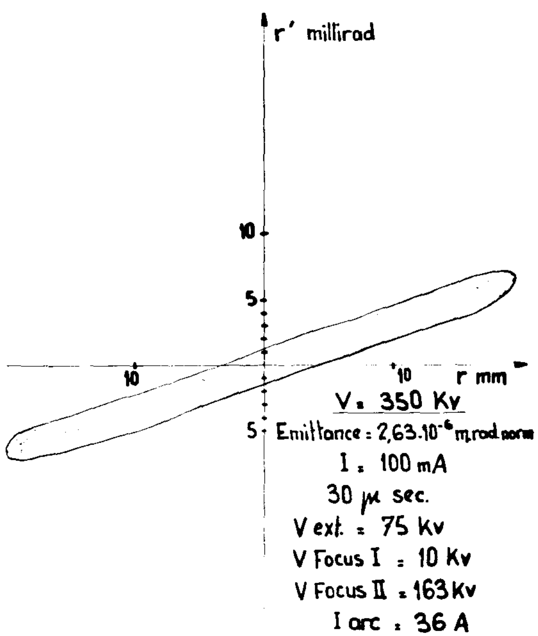

Fig. 6. Experimental results.

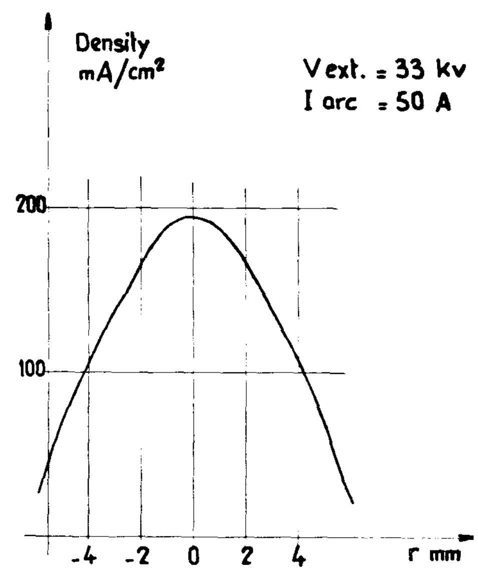

Fig. 7. Density distribution at ion source exit.