MPS/LIN - Note 71-5
6.5.1971. ED/fm

THE INFLUENCE OF EXTRACTION CONDITIONS OF THE ION SOURCE ON THE PHASE DENSITY DISTRIBUTION IN INTENSE ION BEAMS

M.A. Abroyan, V.S. Kuznetsov, N.P. Kuznetsova, R.P. Fidelskaya

TRANSLATION by E. Dziura

State Atomic Energy Committee of the USSR

Scientific Research Institute of Electro-Physical Equipment
imeni D.V. Efremov

THE INFLUENCE OF EXTRACTION CONDITIONS OF THE ION SOURCE ON THE PHASE DENSITY DISTRIBUTION IN INTENSE ION BEAMS

M.A. Abroyan, V.S. Kuznetsov, N.P. Kuznetsova, R.P. Fidelskaya

Leningrad 1970

Translated at CERN by E. Dziura,
Visitor from the Institute of Nuclear Research, Swierk, Poland.

Abstract

Phase density distribution for the beam section close to a source was found by measured distribution of phase density for some more distance beam section with the help of numerical solution of equation system for a self-consistent field. Ion beams obtained from a duoplasmatron were studied at different operation regimes of the source, i.e. at variation of extraction conditions.

The calculated distribution of phase density near the source makes it possible to judge about the shape of the plasma boundary, dimensions of the radiating surface and their variation with variation of extraction conditions. The results on the beam velocity structure near the source of different extraction conditions are given.

The phase space volume* of an ion beam is mainly defined by the conditions of extraction from the source. To solve the task of increasing the phase density of high intensity beams, first of all one has to determine the relation between beam phase density distribution and conditions of extraction from the source plasma. The redistribution of the phase density and the changes of phase volume configuration occuring in real beams (1) do not allow for the unambiguous interpretation of the influence of conditions of extraction when the measurement of phase density distribution is carried out at a distant beam point (section). The measurement of phase distribution close to the plasma surface is extremely difficult if at all possible for the time being.

In our work the phase density distribution was measured at some distance from the duoplasmatron source (2) region of the beam and then the phase density distribution f, the configuration of transverse phase volume, and the current density distribution close to the plasma surface, were calculated numerically. Calculations were performed by the numerical solution of a set of self-consistent field equations for the function f. This method is described in (1, 3, 4).

A modification of the known four slit method (5) was adapted to carry out the measurements of transverse phase volume.

Three groups of experiments were examined, each with different conditions of extraction. Working parameters of the ion source for these cases are given in Table.

---

* The distinction drawn by the authors between an unbounded phase space or co-ordinate system, and a bounded volume in phase space, or "phase space volume" abbreviated to phase volume, is preserved in the translation. "Phase volume density" is also abbreviated by the authors to phase density and likewise "phase volume projection " (emittance) to phase projection (Trans.)

Nr. of experiment		Beam current I (A)	Magnetic field B (T)	Discharge current I_d (A)	Extraction voltage U (kV)	Beam brightness B $(A/m^2.rad^2)x\ 10^8$
1	I	1.5	0,33	55	60	4,8
2	I	2,0	0,33	92	60	6,1
3	I	2,4	0,33	200	60	8,4
1	II	1,1	0,85	55	30	3,7
2	II	1,2	0,85	55	40	5,3
3	II	1,3	0,85	55	50	5,8
1	III	1,2	0,33	92	30	5,1
2	III	1,8	0,52	92	30	7,6
3	III	1,6	0,85	92	30	9,7

The results of measurements and calculations of phase density distribution and other parameters of the beam for the first group of experiments (cf. Table) are illustrated in Fig. 1. In this group, plasma density and shape of emitting surface were altered by a change of discharge current in the source.

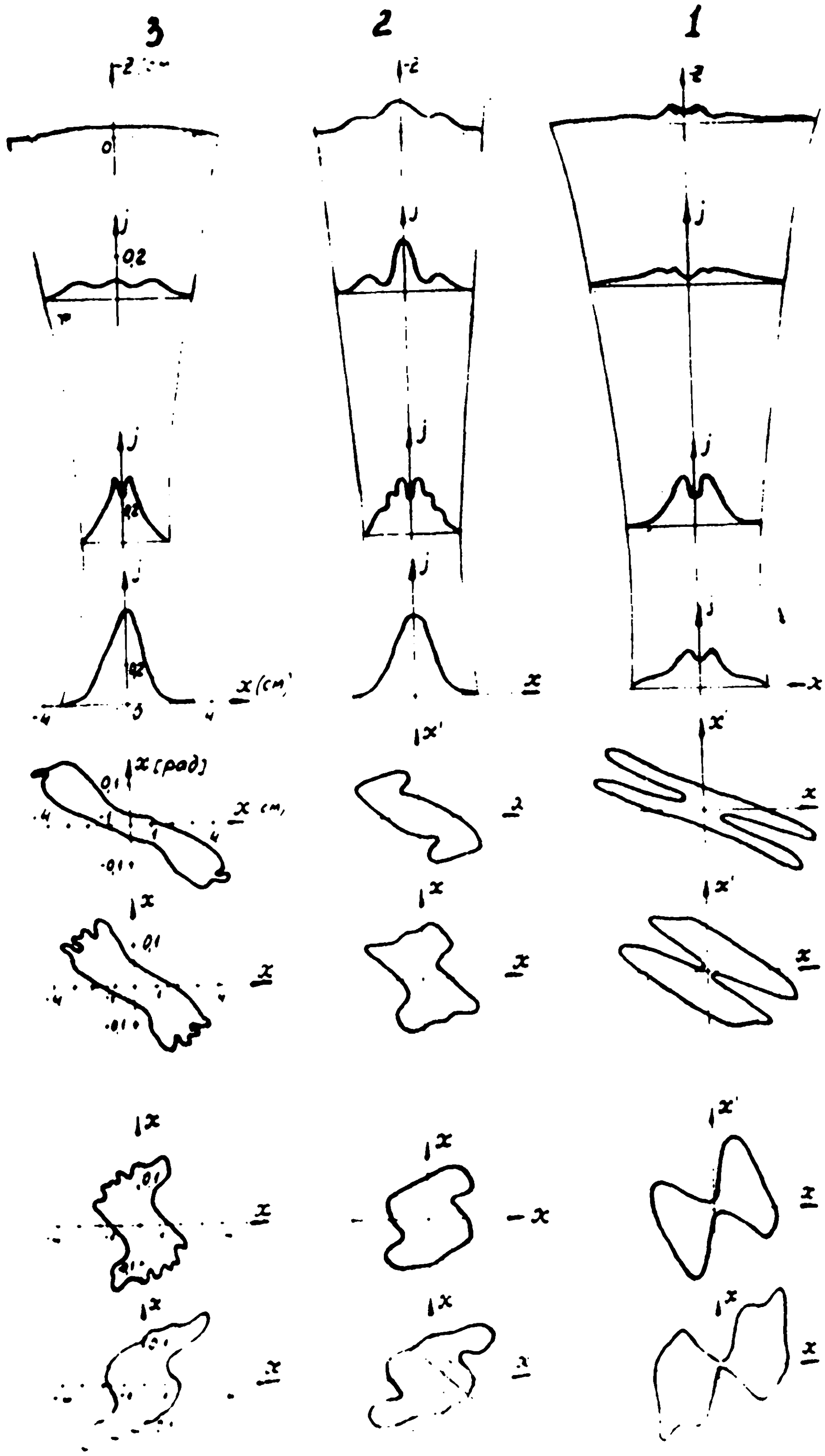


Fig. 1 Beam envelopes, current density distributions and phase volume projections at different values of source discharge current. Projections are given for the particles with zero angular velocity.

The current density distributions and projections of transverse phase volume at various points along the beam are shown; beam envelopes are also illustrated in this figure. Calculated envelopes are in agreement with the visual observations and with evaluations of beam dimensions at the source from the images on the film.

The transverse phase volume configuration and current density distribution uniquely determine the shape of the plasma surface. A qualitative picture of the emitting surfaces for analyzed cases is shown in Fig. 2. For comparison, there are also illustrated some simple geometries of plasma surface usually taken for quantitative treatment of extraction from the plasma.

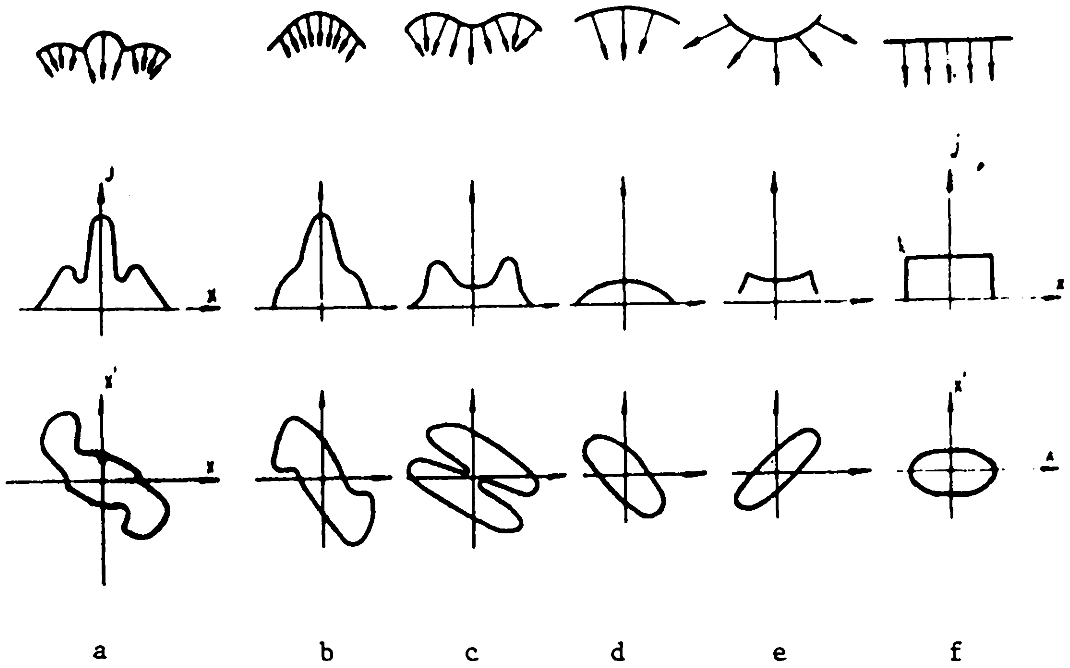


Fig. 2 Shape of plasma surface, beam current density distributions and phase volume projections at various working conditions.

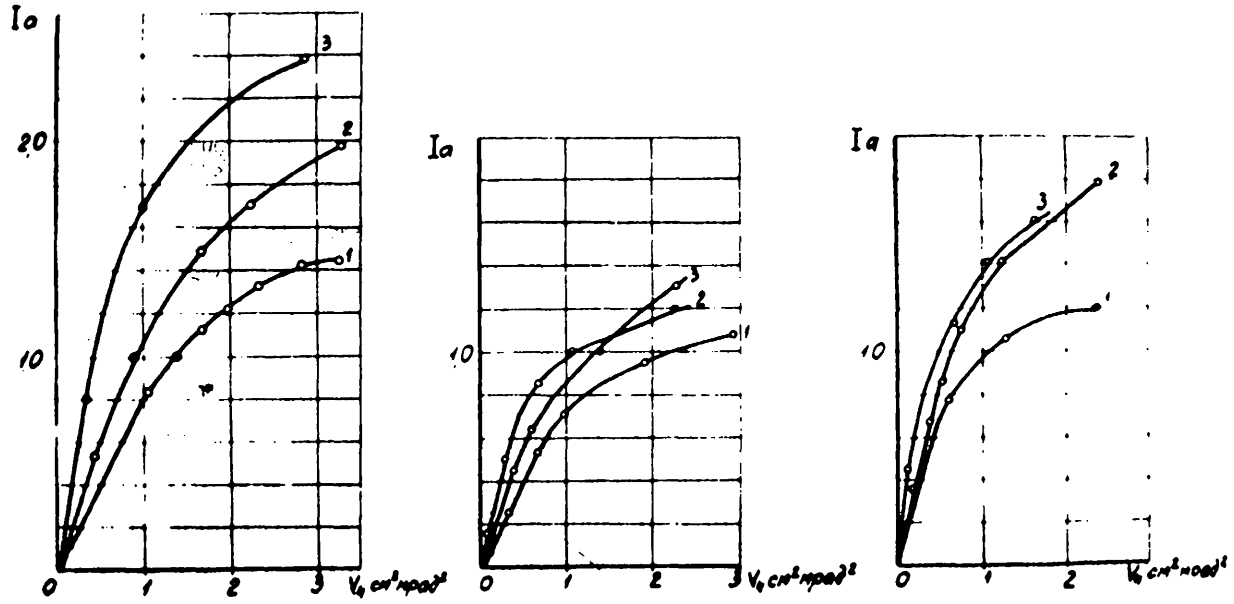
As Fig. 2 shows, the real surface of the plasma is a complicated one with the varying radius of curvature; the curvature of the surface can have different signs. In these circumstances the extracted current has a complicated multi-velocity structure.

An H-like configuration of phase projection (case "c" in Fig. 2) corresponds to a plasma surface, the curvature of which decreases from the edges to the centre (sign of curvature may change), and to the saddle-shaped current density distribution of the beam.

Zigzag-like configuration of the phase projection (case "b" in Fig. 2) corresponds to the plasma surface with the curvature increasing from the edges to the centre and to the bell-shaped current density distribution. More complicated configurations may exist (case "a" in Fig. 2).

Presented results (cf. Fig. 1) show that the phase density distribution and configuration of transverse phase projection, change considerably with the distance from the source. The dependence of the beam current I on the 4-dimensional phase volume appears to be the invariant of that motion. This dependence defines also the brightness of the beam, that is the current density within the phase volume, the most important characteristic of the stream of charged particles. The dependence I vs (V_4) for all investigated cases is shown in Fig. 3. The case "a" corresponds to different values of discharge current with the remaining parameters constant. In this case both the plasma density and plasma surface shape are affected. The growth of the brightness with the increasing discharge current is due to increase of plasma density. But, as stated before, in this case the deterioration of the phase volume projection caused by the distortion of the plasma surface leads to the increase of effective phase volume of the beam.

Case "b" corresponds to the variation of extraction voltage where only the shape of plasma surface is affected. Therefore, at high values of extraction voltage when the distortion of emitting surface become high, the brightness of the beam falls.



a b c

Fig. 3 I vs (V_4) dependence : a - discharge current being varied; b - extraction voltage being varied; c - magnetic field in the source being varied.

Case "c" corresponds to the variation of magnetic field. The increase of the brightness in this case is less pronounced than in the case "a" because there is no magnetic field in the extraction region.

REFERENCES

(1) Kuznetsov,V.S., Kuznetsova N.P., Fidelskaya R.P., Solnyshkov A.I, Abroyan M.A.
Investigation of phase density redistribution in real beams of charged particles by means of numerical calculations.
Report, National Conference on Charged Particles Accelerators, M., 9-16 October 1968.

(2) Abroyan M.A., Komarov V.L.
In "Electrofizitheshaya apparatura" wyp I, M., Atomizdat, 1963, page 119.

(3) Kuznetsov V.S.
"Zhur. Tekhn. Fiziki", 37, 5, 932 (1967).

(4) Kuznetsov V.S., Fidelshaya R.P.
"Zhur Tekhn. Fiziki", 38, 10, 1756, (1968).

(5) Ivanov N.F., Sivkov J.P., Solnyshkov A.I.
In Electrofizitheskaya apparatura" wyp 4., M.,Atomizdat 1966, p. 3.

Distribution (open)

Linac Scientific Staff
P. Lapostolle
K.H. Reich
F. Sacherer