Rapid Measurements of Two Dimensional Ion Beam Current Distribution for Pulsed Neutron Source

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Abstract

To monitor maximum current density and two-dimensional ion beam current distribution at the entrance of intense pulsed neutron source of INR the secondary electron monitor is considered. A new means is realized in this device. Two-dimensional primary beam current distribution is transformed into the corresponding distribution of secondary electrons. The electron distribution is transferred from the ion beam area, registered in discrete points and finally approximated. By means of the monitor one can detect with a high precision the current distribution practically within entire ion pipe during a time period that is not more than 10 ms.

I. INTRODUCTION

To prevent the termomechanical damage of first wall of the INR intense pulsed neutron source (INS) [1,2] as a result of proton beam action and to improve the using of this source a device for rapid monitoring of maximum proton beam current density jm and measuring of two-dimensional beam current density distribution j(x,y) at the entrance of INS is needed.

The j(x,y) measuring system must satisfy a number of stringent requirements in this case. Rms error of jm measurement must be not more than ± 5% of indication and its measurement time - 20 ms. Radius of measurement area must be not less than 60 mm when the ion pipe aperture is 160 mm. The device must ensure its calibration without disassembling and must disturb the beam negligibly.

Our studies have shown that the known devices for j(x,y) measurement [3,4,5] do not satisfy fully these requirements. However a secondary electron technique [6] has the best prospects. As for example the secondary electron monitor described in [7] has been already successfully tested.

II. PRINCIPLE OF OPERATION

Figure 1 shows a layout of such monitor which satisfies the requirements mentioned above. All sizes are given in mm.

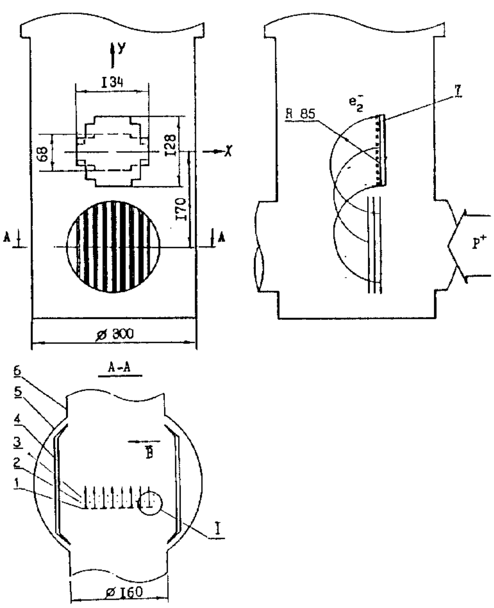

Fig.1. Layout of the beam monitor.

The monitor operation principle is the following. Electrons that have been produced as a result of interaction between the primary beam and thin striplike emitters (1), made of 0.01 mm tantalum foil, are accelerated on their path from the emitter with negative potential equal to -4 kV till the electrodes (3) under ground potential. The focusing of the electron flux in (x,z) plane was realized by installation of additional electrodes (2) with potential close to the emitter one. Then by semicircular focusing in uniform magnetic field the electrons are transferred from

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the ion beam space to the plane of 64-channel collector (7). The magnetic field is highly uniform in a region of the electrons motion and it is produced by specially shaped poles (4). In this figure the current collector (7) maximum sizes are displayed by: solid line - for occasion of beam monitoring at the entrance of the beam trap, dashed line - at INS. The lock and screen grids are placed before the collector (7).

Figures 2,3 explain the electrostatic focusing in primary convertor (PC) and mutual position of the electrodes: fig.2 shows distribution of electrons potential energy in the electric field of the electrodes and fig.3 - the electrons trajectories and equipotential lines of the same electric field.

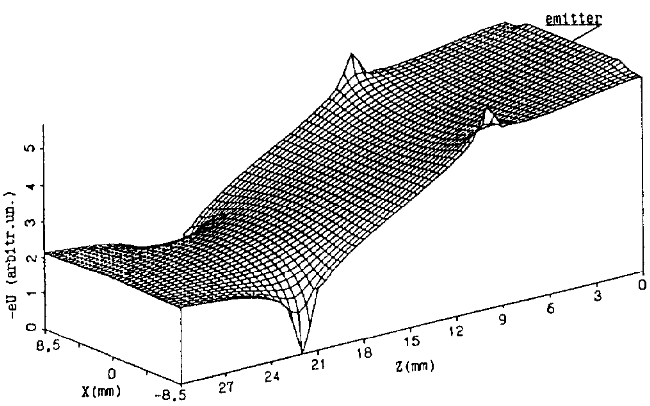

Fig.2. Distribution of electrons potential energy in electric field of PC.

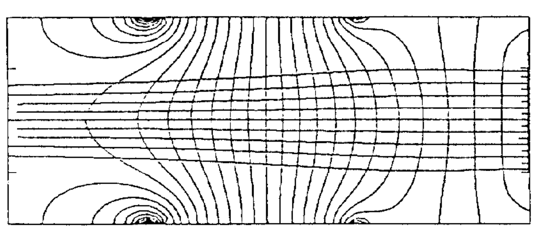

Fig.3. Electrons trajectories and equipotential lines of the electrodes field.

The distance between 15 mm wide emitters is 2 mm, the diameter of focusing electrodes and grids wires is equal to 0.1 mm . Leaving the emitter surface at the normal the electrons from 12 mm part are being focused into 0.2 mm wide strip at the distance of 26 cm downstream. The electrons from other parts produce background that has current density more than two orders less than corresponding magnitude of major current.

III. RESOLUTION OF THE MONITOR

The monitor resolution accounting real initial energy-angle secondary electron distribution have been defined by numerical simulation. In this case HWHM secondary electrons distribution along y coordinate in the collector plane is 0,5 mm and along x - 4 mm that are smaller by a factor of 5 as rms sizes of the ion beam. The electrons initial distribution along y was assumed to be delta-function and along x as uniform within emitter strip width. The monitor resolution is inversely proportional to electrons velocity i.e. by raising emitter potential it may be extremely improved.

Focusing high quality that have been obtained in rather simple system allows one to define by approximation method two-dimensional distribution j(x,y) with the demanded accuracy by use of its measurement in 64 discrete points. The two-dimensional Kotelnikov series technique was employed for approximation.

The PC electrostatic focusing system have been tested as model, a photo of which is shown in fig.4. A single strip thermoelectron current image width was less than 2 mm and this is in a good respect with calculations.

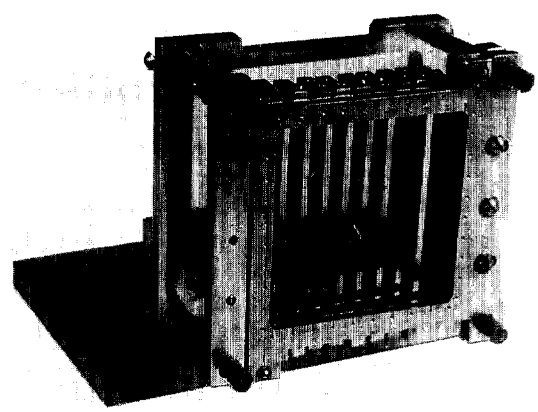

Fig.4. Photo of scale model PC.

To represent the results of two-dimensional ion beam current distribution measurements graphically both as isometric picture and lines of equal current density in the transverse plane the corresponding software has been developed. Fig.5 illustrates the efficiency of two-dimensional reconstruction algorithm employing Kotelnikov series: fig.5(1) shows the initial two-dimensional beam current density distribution, fig.5(2) - the computer simulation of 64-channel collector charges measurement. The error of the measurement was supposed to be a random variable in the range $\pm 3\%$ of indication. The distribution reconstructed by means of two-dimensional Kotelnikov series is displayed in fig.5(3).

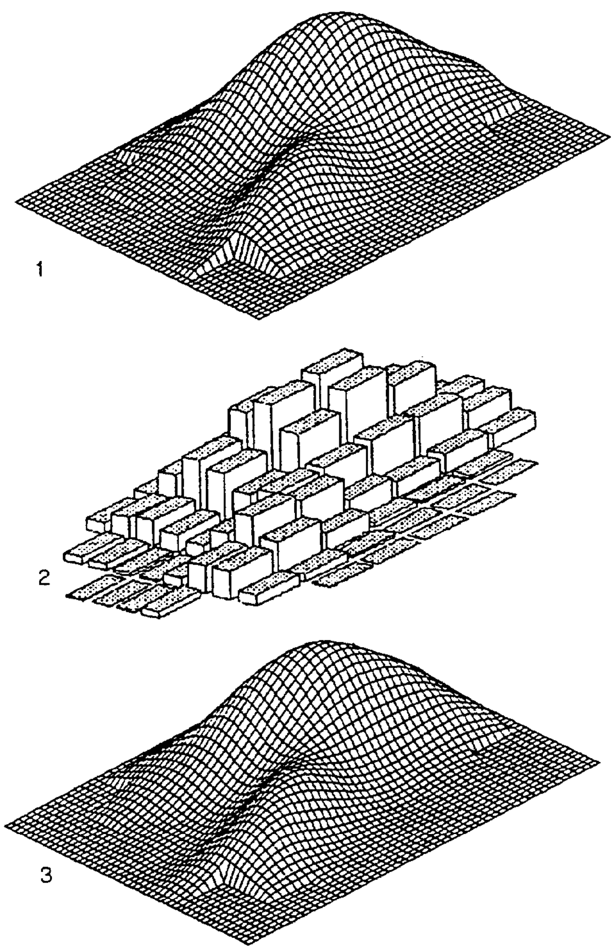

Fig.5. Results of simulation of j(x,y) measurement.

IV. CONCLUSION

Estimations and model tests show that the time period necessary for registration of two-dimensional distribution and determination of jm is less than 10 ms in our case. The convertor construction developed allows one to fulfill the detector operative calibration using the electrons of thermoemission.

Studies have shown that the monitor discussed can be successfully used with slight modification for monitoring of the same transverse size proton beam ŀ t with pulsed beam current up to 15 A.

V. ACKNOWLEDGMENTS

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VI. REFERENCES

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