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7.1 Beam monitoring system for intense neutron source

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Abstract

Monitoring system realizing novel principle of operation and allowing to register a two-dimensional beam current distribution within entire aperture (100...200 mm) of ion pipe for a time in nanosecond range has been designed and accomplished for beam control of the INR intense neutron source, for preventing thermo-mechanical damage of its first wall. Key unit of the system is monitor of two-dimensional beam current distribution, elements of which are high resistant to heating by the beam and to radiation off the source. The description of the system and monitor are presented. Implementation of the system for the future sources with more high intensities are discussed.

1. Introduction

Beam monitoring system, considered in the paper, is required for safe and effective operation of intense neutron source. For the effective operation it is necessary to form an appropriate two - dimensional beam current distribution at the entrance of the source. For the safety we must control, continuously and rapidly, the maximum of the beam current density within a large aperture, for example, within the area of the 100-200 mm diameter. The latter requirement deals, first of all, with preventing thermo - mechanical damage of the first wall of the source.

Hence, at given beam energy the two - dimensional beam current distribution is the only beam characteristic that should take for this monitoring.

Phenomenon, based on which the monitor could be built, and the monitoring system, on the whole, have to satisfy the following main requirements.

Coefficient of conversion of the beam current density into a corresponding current at the entrance of an appropriate module of hardware has to be constant within both entire area of this monitoring and entire operation range of the beam current density.

This property has to hold at any beam energy, beam charge effect, etc. and others possible terms of primary converter operation including its heating by the beam and high level of radiation.

The conversion has to be rapid: the time-interval between the moment of the beam-converter interaction and the moment of corresponding electron signal entry into the hardware has to be about 0.1 microsecond and less.

The error of the beam current density determination at its maximum has to be about 5 %.

The elements of the monitor have to be high resistant to the heating and radiation.

Our studies have shown that the mentioned above requirements can be satisfied totally with the monitor, the principle of operation of which is based on secondary electron emission. The monitor has been proposed by the author of the paper in 1992, and in a year the main principle of its operation has been proved experimentally in another device, installed in the proton linear accelerator at INR, that was published in the paper [1] in 1994.

In this paper the monitoring system for the INR source is considered as an example, the main principle of its creation can be applied to the future intense source, designed at many Laboratories at present [2,3,4,5,6].

Taking into account the mentioned above requirements it should be noted at once the following. To decrease the influence of intense radiation of the source the monitor for the INR source has been installed in small solid angle of the radiation flux, at the distance of 5 m from the source. To decrease the radiation contribution into the measured beam current distribution the input of each integrator, in the realized monitor system, is opened during the beam pulse only. For getting appropriate accuracy the measured distribution is normalized on the magnitude of signal from the beam current monitor. For transferring the distribution on to the surface of the source the beam position monitor has been installed additionally.

Hence, in our case the considered monitoring system consists of the beam position and current monitors followed by the two - dimensional beam current distribution monitor at the distance of 25 m. The former monitors have been installed after the last optic lenses. These monitors are rather routine technique, and in the paper the later monitor, realizing new principle of operation, will be considered.

In the case of the INR source the project beam parameters taken for consideration are: pulsed current 50 mA, pulse duration 100 μs, proton energy 600 MeV, frequency of pulse repetition 100 Hz, rms radius of the beam in horizontal plane 20...30 mm, the rms radius in vertical plane 10...15 mm.

2. Two - Dimensional Beam Current Distribution Monitor

For rapid monitoring of maximum proton beam current density j_m and measurement of two-dimensional beam current distribution j(x,y) at the entrance of the INR intense neutron source the rapid monitor has been proposed [1] and accomplished, schematic drawing of which is shown in Fig.1, where all sizes are presented in mm .

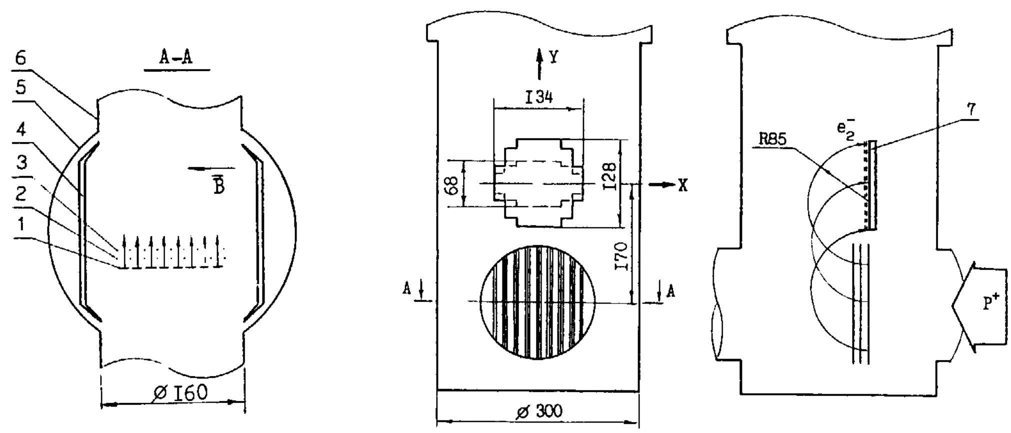

Figure 1. Schematic drawing of rapid monitor.

The principle of the monitor operation consists in the following. Electrons that have been produced in a result of interaction between the proton beam and thin strips of the monitor emitter (position 1 in Fig.1), made from the 10 μm –foil of tantalum, are accelerated from the emitter (1), being at negative potential of 4...10 kV, till the electrodes (3) at 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. Action of this focusing is made clear by Fig. 2, where distribution of the electrons potential energy in electrostatic field of these electrodes (a) and the electrons trajectories with equipotencial lines of the electrodes field (b) are plotted.

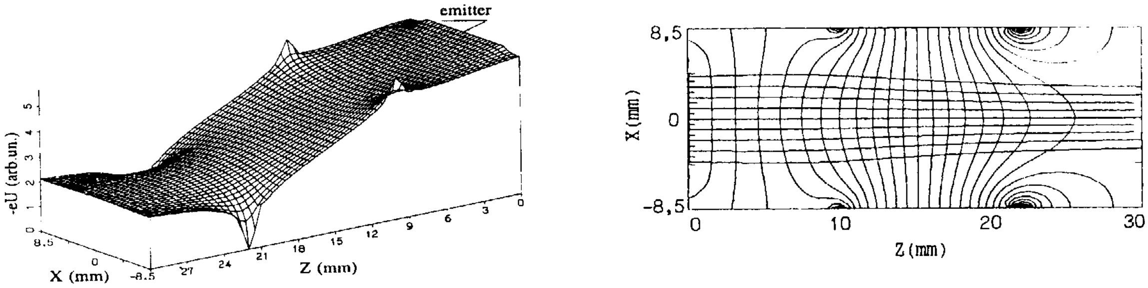

Figure 2. Distribution of electrons potential energy in electrostatic field of the electrodes (a) and electrons trajectories with equipotential lines of the electrodes field (b).

The distance between the foil emitter of the 15 mm-width is 2 mm, the diameter of focusing electrodes is equaled to 0.1 mm. Figure 2 b makes clear mutual position of the electrodes.

Using semicircular focusing in uniform magnetic field the electrons are transferred from the ion beam space to the plane of 64-channel collector (7). The uniform magnetic field is produced by specially shaped poles (4), that in detail are shown in Fig. 3.

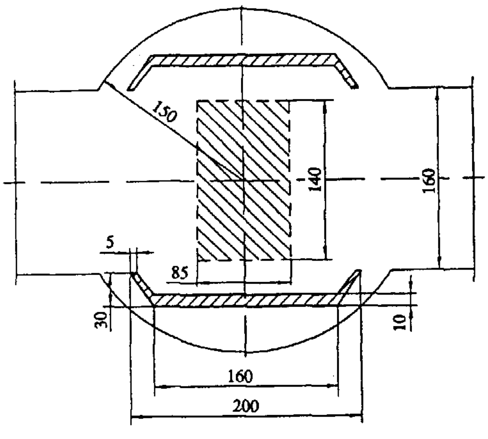

Figure 3. Geometry of magnetic poles.

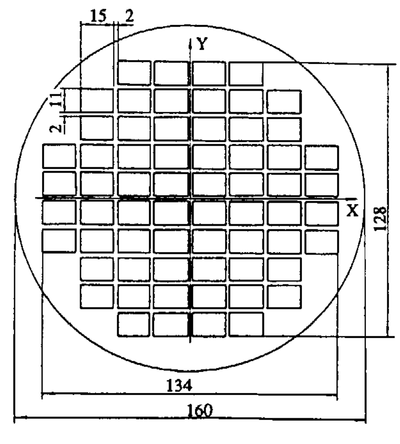

Figure 4. Collector geometry.

In Figure 1 the maximum sizes of the secondary electron collector of 134 ×128 mm and 134× 68 mm are shown, the latter is for the neutron source. More in detail the geometry of the collector is plotted in Fig. 4. The lock and screen grids are placed in front of the collector (7). The corresponding two-dimensional secondary electron current distribution is registered in discrete points and then approximated by two-dimensional series.

The monitor size along the accelerator beam is 200 mm at the diameter of the beam pipe of 160 mm.

3. Spatial resolution

The monitor spatial resolution has been determined by numerical simulation of secondary electrons trajectories taking into account their real initial energy-angle distribution [7]. These initial distributions and their histograms at randomly generation for these calculations are plotted in Fig. 5

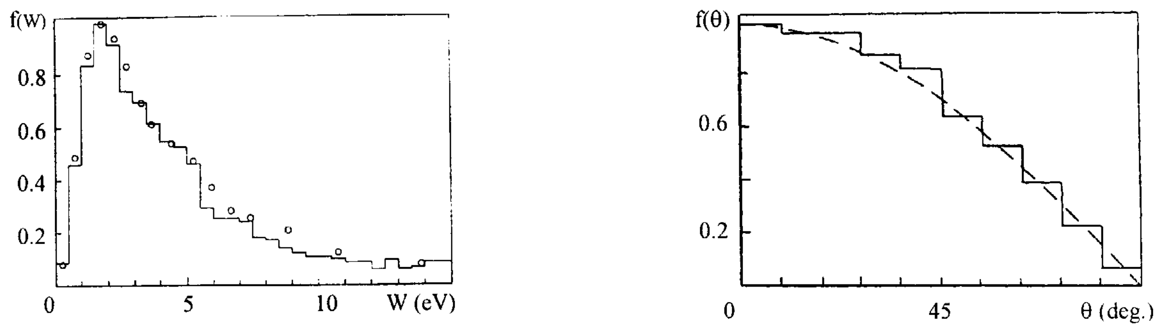

Figure 5. Initial secondary electron energy (a) and angular (b) distributions.

The initial distribution of the electrons along the y-axis was assumed to be the delta-function and along the x- axis - the uniform within the emitter strip width of 15 mm.

Results of these calculations are presented in the histograms in Fig. 6. HWHM of the secondary electron distributions in the plane of the collector along the y - and x - axes are 0.5 mm and 6 mm, respectively.

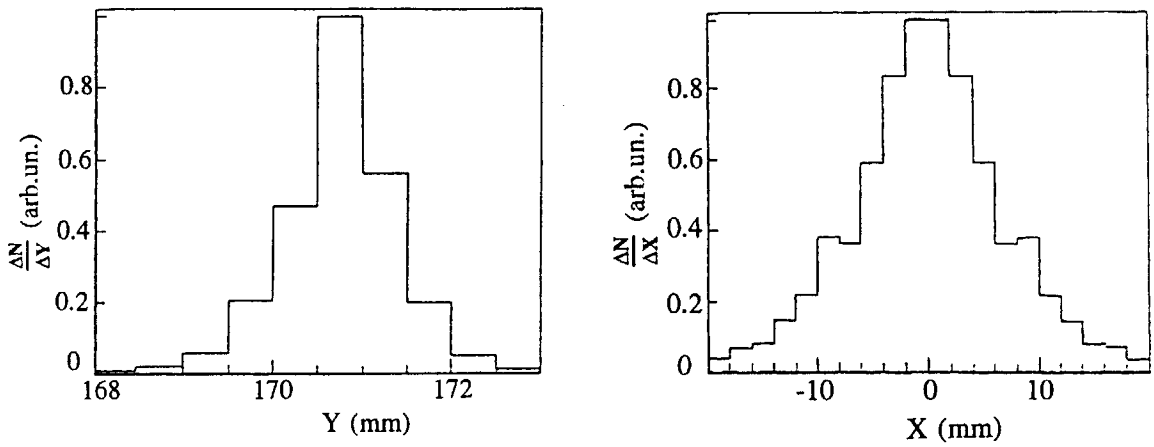

Figure 6. Monitor's apparatus functions along the y- and x- axes, respectively.

Our studies have shown that the considered monitor can be successfully used, with slight modification, for the monitoring the same beam distribution, but with pulsed beam current up to 15 A.

4. Hardware and software

Hardware of the monitor consists of CAMAC modules, the modules rack-mounted in the control room and the commutator of analog signals that is placed at a distance of 3 m from the monitor. The rack-mounted modules are: the module for the monitor calibration, high and low voltage power supply.

The calibration module serves for heating the calibration wire, placed at the centre of the primary converter near the foil emitters, and also for controlling the heating current and the thermocurrent from the wire. Varying the accelerating voltage of the emitters one can bring the thermocurrent image and the centre of the multichannel collector together.

CAMAC modules are: output and input registers, controller, analog to digital converter, digital to analog converter, - all of them produced by the industry, and control module that synchronizes operation of all modules with the commutator.

In the control module the rapid comparison of the beam current density maximum with the threshold is performed in the form of analog signal. We note, the same procedure is performed in the form of digital signal in the controller at the same time. At the emergency, when the maximum of the beam current density exceeds the threshold, the corresponding signal is gone to the ion source of accelerator.

Software sets three regimes of the monitor operation: regime of recording the bias of zero voltage of the integrators, regime of recording the two-dimensional distribution with appropriate analysis of signals and regime of the calibration. One of the pictures from the display at the regime of recording the beam current distribution is demonstrated below in Figure 7.

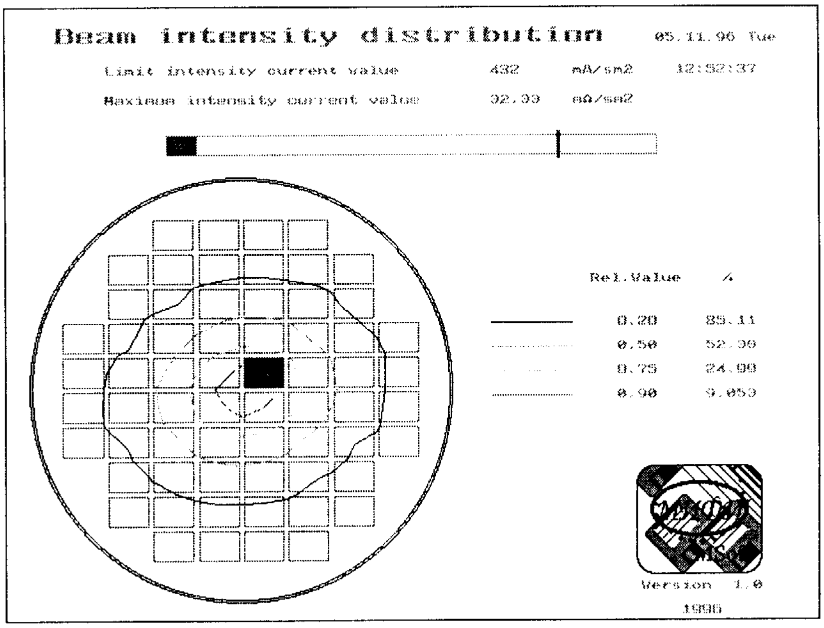

Figure 7. View of the display screen in the operation regime.

5. Conclusion

The two-dimensional beam current distribution monitor system, realizing new principle of measurement, has been accomplished, tested and is ready for commissioning in the transfer line of the INR neutron source that will be performed after production of the monitor vacuum chamber and its installation in the line by the INR.

The monitor, considered in the paper, allows carrying out direct, rapid and with high accuracy measurement of the two-dimensional beam current distribution within large area of the monitoring.

Workability of this new principle of monitor operation has been already proved in another device, where the single channel of the primary converter has been realized and this channel is moved in magnetic field across the beam section [1]. This device, installed in the INR linac, have been operating without disassembling for repair since 1992.

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