SECONDARY ELECTRON MONITORS IN LINACS FOR INTENSE NEUTRON SOURCES

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Abstract

New secondary electron detectors for monitoring ion beam energy spectrum (BES), phase distribution of bunches (PDB) and two-dimensional beam current distribution (BCD) for the ion beams of intense neutron sources are considered. High energy secondary electrons forward scattered from residual gas in the case of the BES monitor and scattered from thin movable target at about 90° for the PDB one are used. To control beam current distribution two types of the BCD monitors using low energy secondary electron emission are presented.

Introduction

The secondary electron monitors have the best prospects for detailed study of beam dynamics in high power ion linac for intense neutron source applications [1,2,3], for precise beam matching and setting up the rf-parameters of its cavities. In this report two bunch phase distribution monitors using both low and high energy secondary electrons and also detector for monitoring ion beam energy spectrum are presented.

To control the ion beam shaping in front of the source, to prevent the thermomechanical damage of its first wall and also to control the ion beam propagation in systems including particles transverse coupling motion two types of the monitors for two-dimensional beam current distribution measurements are considered.

Beam cross section wire scanner

To control more precisely the ion beam propagation in transport systems, containing solenoids especially, secondary electron monitor for two-dimensional beam current distribution measurements has been proposed [4] and successfully tested. Fig. 1 shows layout of the monitor.

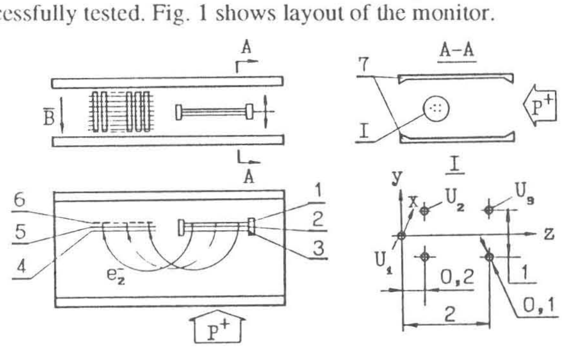

Fig. 1. Layout of beam cross section wire scanner.

The principle of the monitor operation consists in a recording of the density distribution of the low energy secondary electrons (emitted with energy less than 50 eV) along a wire-emitter (1) scanning the beam perpendicularly to its axis by step motor.

By applying high negative voltage (U_1 is about 1 kV) to the wire (1) the secondary electrons produced as a result of the primary beam-wire interaction are accelerated till the electrodes (3) under ground potential (U_3) and transferred in uniform magnetic field to the plane of multichannel collector (6) with the screen (4) and lock (5) grids in front of it. The highly uniform magnetic field in a region of electrons motion is produced by two specially shaped poles (7). To limit electrons motion in y direction a focusing electrodes (2) were installed. Their mutual position (in mm) is shown in fig. 1. For every position of the wire-emitter relative to the beam axis the secondary electron distribution is measured by the sequential registration of multichannel collector currents.

The monitor has been already successfully tested in the beam transfer line (0.75 MeV) of initial part of the INR linac (fig. 2). It is remotely controlled by a personal computer and CAMAC (fig. 3). The hardware also contains unit for the monitor calibration.

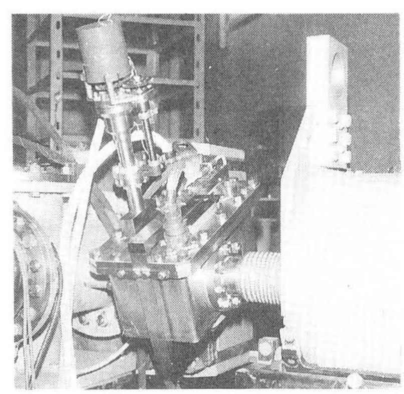

Fig. 2. Photo of the monitor mounted in the transfer line of the INR linac.

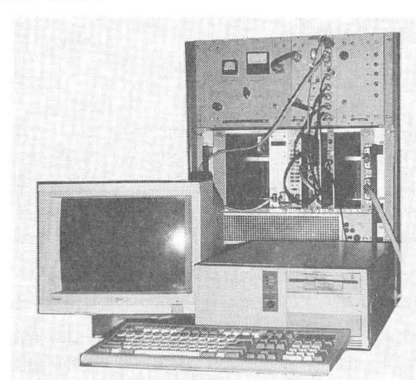

Fig. 3. Photo of the monitor hardware.

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 (fig. 4) the corresponding software has been designed.

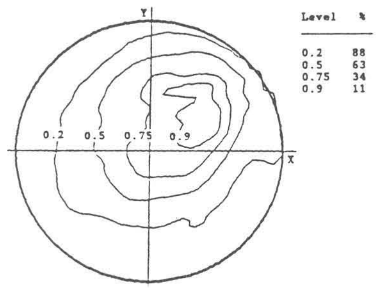

Fig. 4. Lines of equal beam current density and beam current in percent contained within the lines.

Spatial resolution along two orthogonal axes about 0.1 mm can be achieved. The device size along the beam is about 10 cm at the beam pipe aperture equaled to 4 cm. The major monitor parameters are independent of the beam energy.

Rapid monitoring of beam current distribution

For rapid monitoring of maximum proton beam current density j_m and measurement of two-dimensional beam current density distribution j(x,y) at the entrance of the INR intense neutron source the rapid monitor [5] has been created layout of which was shown in fig. 5. All sizes are presented in mm.

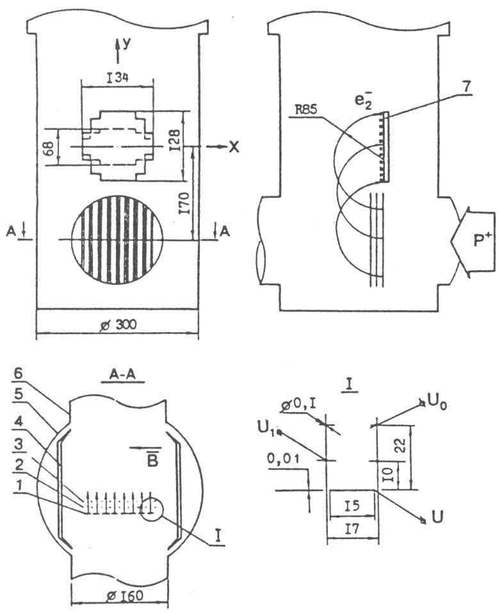

Fig. 5. Layout of rapid j(x,y) monitor.

The principle of the monitor operation is the following. Electrons that have been produced as a result of interaction between the primary beam and thin striplike emitters (1) made from 0.01 mm tantalum foil are accelerated from the emitters (1) with negative potential (U) equaled to -4 kV till the electrodes (3) under ground potential (U_0). The focusing of the electron flux in (x,z) plane was realized by installation of additional electrodes (2) with potential (U_1) close to the emitter one. 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). In this figure the current collector maximum sizes of 134×128 mm are shown. The lock and screen grids are placed in front of the collector (7). Fig. 6 explains action of the electrostatic focusing in primary converter of the monitor.

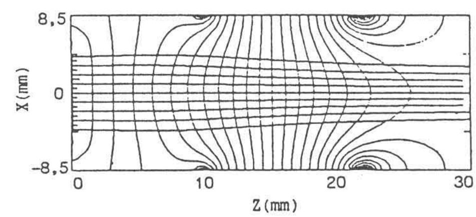

Fig. 6. Electrons trajectories and equipotential lines of the electrodes field.

The corresponding secondary electron two-dimensional current distribution is registered in discrete points (64 channels) and then approximated by two-dimensional Kotelnikov's series. Monitoring system records the beam current distribution with a high precision for a time less than 10 ms and determines excess of the beam current density above limiting magnitude for less than 1 ms. The device size along the beam is about 200 mm at the diameter of the beam pipe of 160 mm.

Bunch phase distribution monitors

At present the secondary electrons rf-detectors are the only beam diagnostic instruments for longitudinal profile measurement of short ion bunches with ion energy in a low or intermediate region. One of these detectors using low energy secondary electron emission is shown in fig. 7.

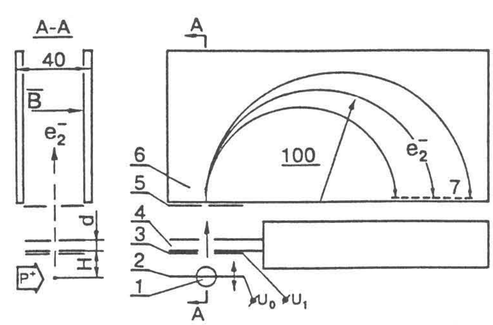

Fig. 7. Layout of bunch phase distribution monitor.

The principle of the monitor operation consists in the following. By applying high negative voltage (U_0) to the wire target (2) the secondary electrons produced as a result of the primary beam (1)-target (2) interaction are accelerated and formed as a narrow beam by means of collimator (3) at the entrance of rf-resonator (4) so that the axes of the electron and ion beams are orthogonal to each other. In the device the phase distribution of the high energy primary beam is isochronously transferred into the same distribution of the low energy secondary beam. Then this secondary distribution is coherently transformed into transverse one through rf-modulation in capacity gap of rf-resonator (4) and magnetic spectrometer (6) allowing direct presentation on a low frequency display. Recording the multichannel collector (7) output signal we get the bunch phase distribution averaged over the ensemble of the beam bunches for a measurement time.

The monitor phase resolution (DF) is basically determined by the secondary electron phase debunching on distance H and the resolution of rf-modulator with multichannel collector. Our studies showed that the monitor phase resolution taking d=5 mm, H=20 mm and U_0= -3...-5 kV, U_1=4...2 kV can be reach about 1° in the range of electrons entrance phase more 50° of 148,5 MHz at the rf-amplitudes in the capacity gap of 1...2 kV and R=100 mm. The monitor using the low energy secondary electrons with longitudinal rf-modulation has advantage over another types for research beams with high bunch density [6]. The use of a split-hole rf-resonator allows to reduce the monitor size along the ion beam up to several cm.

To eliminate thermoelectron current effect on the monitor operation the high energy secondary electrons are used. The monitor operating on these electrons is shown in fig.8.

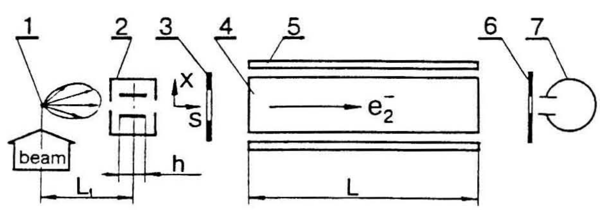

Fig.8. Layout of bunch phase monitor using delta-electrons.

It is known the secondary electrons as a result of the multiple scattering in the target (1) have broad energy-angle distribution. Therefore the energy spectrum width of the electrons flying through rf-deflector (2) in the isolated narrow angle in the vicinity of scattered angle of 90° is large enough too. In view of this the transverse rf-modulation is valid. Moreover, after the rf-deflector (2) the spectrometer (4,5) with crossed electric and magnetic fields is installed so that the planes of the beam analysis in phase and momentum are orthogonal to each other. The monitor resolution can reach 1 ps and its size along the ion beam is about 5 cm. The spectrometer length is about 30 cm at the electron energy of 4 keV.

Proton beam spectrometer

For monitoring proton beam spectrum of intense ion beam the spectrometer using forward scattered electrons is proposed. Delta-electrons (see fig. 9) scattered from residual gas in chamber (1) are isolated in narrow angle in the vicinity of scattered angle of 0° by means of the bend magnet M1 with semicircular electrons trajectories and collimator (3) and then analyzed by spectrometer (4) with multichannel collector (5) on its exit.

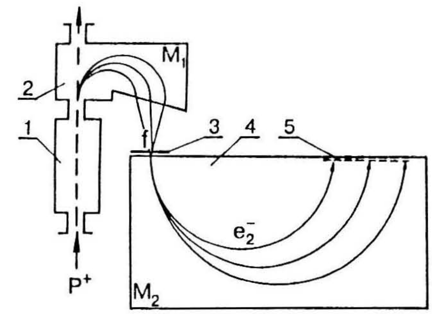

Fig. 9. Layout of proton beam spectrum monitor.

The fundamental trajectories in achromatic magnetic system (till the collimator 3) is shown in fig. 10.

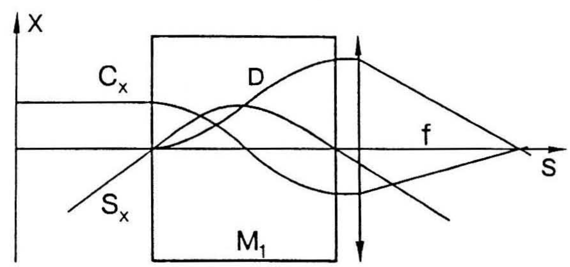

Fig. 10. Fundamental trajectories in magnet M1.

This ion beam spectrometer allows to define beam spectrum with resolution up to 0.1% using reconstruction technique. The monitor resolution function can be easily determined by scattering simulation with accounting of what the target electron is not rest.

Acknowledgment

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