High-sensitive Remote Diagnostics of the Accelerated Particles' Beam Cross Section

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Abstract

The gauge for remote monitoring of the density distribution of accelerated particles' beam over cross section is based on the analysis spatial distribution of residual gas ionization products. With the transverse homogeneous electric field the released charges are transported through narrow slot behind which they are analyzed over energy with the electric field. Then they are registered by the open electron-optical converter with micro-channel-plate amplifier. The image of the beam distribution over cross section from the electron-optical converter screen is read out by TV-camera for representation on monitor. The detector was tested on cyclotrons at IAE (Moscow), INP (Kiev) and INP (Prague). The threshold sensitivity on the proton beam with the energy 30 MeV 10^{-8} A.

I. INTRODUCTION

The accelerated beam dimension and position monitoring in beam transport tract (BTT) is significant when performing precise nuclear experiments, as well as irradiating various targets, e.g. production if isotopes. For example, beam profile detectors used wide which registrated residual gas ionisation products in BTT [1,2].

The device was proposed in [3-7] for unconnected measurements of the accelerated beam transverse distribution in cross section (fig. 1).

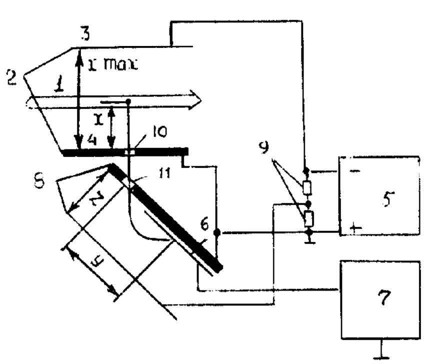

Fig. 1. The circuit of the beam cross section unconnected detector.
1 - investigated beam, 2-removing capacitor, 3,4-reflecting and removing electrodes, 5-permanent voltage course, 6-two-coordinate position sensitive detector, 7-registration circuit, 8-analysing capacitor, 9-resistive divider, 10-slot in removing electrode, 11-slot in the input plate of analysing capacitor.

The cross section detector includes removing and analyzing capacitors, current collector designed as electron-optical converter (EOC) with amplifier on microchannel plates (MCP) and corresponding power supplies. The guided beam ionizes BTT residual gas when passing the gap of removing capacitor. The ions released by the plane field are accelerated to the removing electrode with the shaping slot 1×50 mm in size and directed perpendicular to the BTT. Passing through the shaping slot the accelerated ions form the strip beam in which the spatial distribution of particles directed along the slot corresponds to the distribution of particles in the guided beam in this direction. Energy distribution of the removed ions corresponds to the investigated beam distribution over the other orthogonal coordinate. Electric field of analysing capacitor performs the analysis of this energy distribution. As a result, two-coordinate optical image of removed ions' distribution corresponding to the transverse cross section particle distribution in the guided accelerated particle beam, is formed on the EOC screen. Arrangement of analysing capacitor at an angle of 45° to the direction of removal and removing electrode plane provides linear correlation of the obtained image dimensions with the dimensions of the guided beam, and image dimension Y corresponding to the beam dimension X in the direction of removal are correlated by the dependence

$$Y = 2\cdot(E_u : E_a)\cdot X ,$$

where E_u and E_a are intensities of removing and analysing fields, respectively. The detection of the optical image of the beam transverse cross section is performed with the industrial TV camera.

II. DEVICE CONSTRUCTION

At present, the standardized device for the accelerated beam dimension and shift monitoring was developed at IAE cyclotron. The elements of construction of the beam cross section unconnected detector are placed in a standard diagnostic section with overall dimensions 230×230×230 mm and hole diameter for a flange 166 mm. The supply voltage is introduced through

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the flange on which the removing electrode and analysing capacitor with EOC are fixed. The detection of optical image of the beam cross section is performed with TV camera on the side of a flange on which the reflecting electrode of removing capacitor is fixed. Thus, some electrodes of removing capacitor are designed in the form of a grid with high transparence. The observation of EOC screen is carried out at angle of 45°. FOR the current location of beam dimensions on both coordinates equation $E_a = \sqrt{2}\cdot E_u$ was chosen between the intensities of removing and analysing fields, and $Y = \sqrt{2}\cdot X$.

A remove drive which provides installation of luminescent screen into the removing capacitor gap is fixed on one of the sides of the diagnostic section. The center of the luminescent screen is brought into coincidence with the line joining the TV lens center and EOC screen center. This allows to perform initial tuning of the beam using traditional diagnostics with the increased sensitivity, also to carry out comparative measurements to estimate serviceability of unconnected detector. Fig. 2 shows pictures of the beam transverse cross section of current interception luminescent screen and EOC screen. It can be seen that the images are identical.

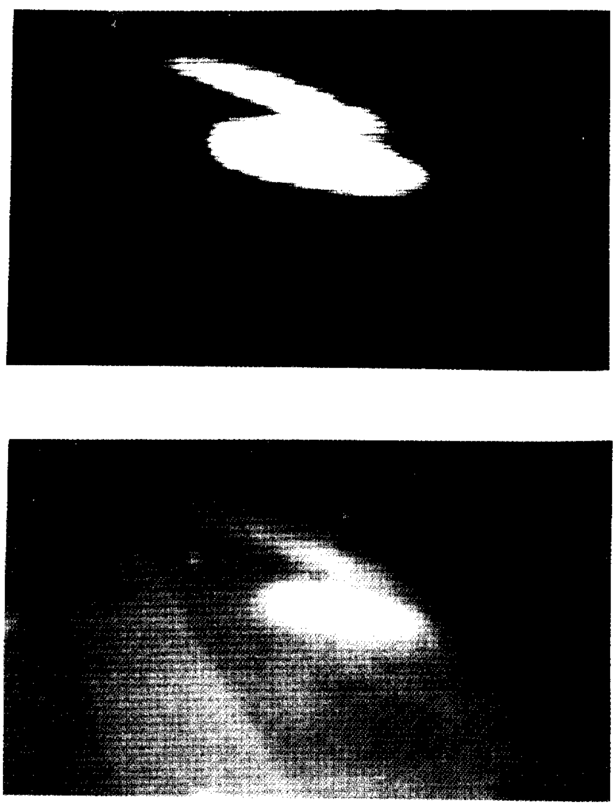

Fig. 2. Picture of the beam transverse cross section from the luminescent screen (a) and unconnected detector EOC screen (b).

Detector construction permits the beam intensity monitoring. It's enough to measure the screen EOC beam. But the sensitiveness of the device depends from the pressure in the BTT. For exclusing this dependence it is proposed to change MCP-multiplier amplification coefficient in accordance with pressure changing [5]. It may be reached as using some special functional converter for changing of MCP-amplification, as by the pressure changihg calculation when information is treated in computer.

The additional convenience for the user is produced by the unit of TV signal quasi-color presentation. The unit is based on rapidly stopped 8-stage ADC providing the upper step frequency up to 20 MHz. The 3 higher stages of ADC are used for modulation of 3 projectors of colored monitor. In this case the colored image of the beam cross section is formed on the monitor screen, and the shape of colored stripes of each color corresponds to the studied beam intensity distribution on the given comparison level. We also provided a device for separation of sync pulses from TV signal for current transmission of ADC codes into computer memory at digital processing of parameters of the guided beam cross section. An example of the computer data processing of the beam cross section is the beam diagnostics in a large scattering camera of IAE cyclotron. In this case by the signals from two separated beam cross section detectors we calculate position and angle of the current incidence on a physical target inaccessible for direct measurements (fig. 3). The section of the station for TV image digital processing was considered in [7].

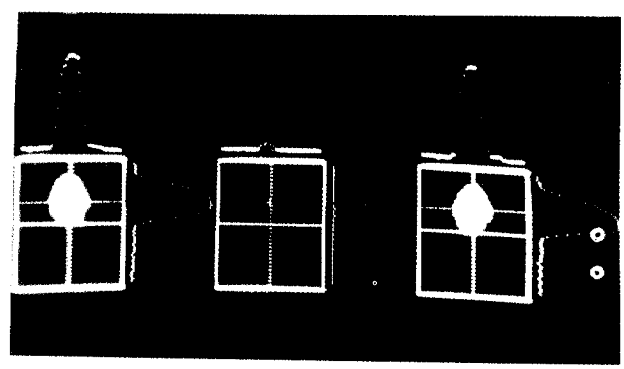

FIG. 3. Example of determination of the beam position on an image target.

III. MAIN PARAMETERS

Let us give for conclusion the summary table of the principle parameters of the beam cross section unconnected detector.

Dimensions of the controlled area 40×40 mm

Aperture	60 mm
Spatial visual resolution	1×1 mm
Spatial resolution after computer processing	0.1×0.1 mm
Sensitivity on 30 MeV proton beam	10^{-8} A
Effective pressure range in BTT	3×10^{-5} torr
Power supply voltage	10 kV
Consumption current	10 μA
Multiplier amplification coefficient of MCP	10^{8}
Amplification inhomogeneity over area	20 %
Time of image shaping	100 ns
Number of ADC stages	6
Step frequency	5 MHz
Number of color intensity gradation on a colored monitor	8

One must note that in case of necessity the dimensions of the controlled area can be easily increased up to 60×60 mm. The further increase of these dimensions is limited by the sizes of produced MCP.

IV. CONCLUSION

An explotation such detector at the cyclotron and tandem in Kurchatov Atomic Energy Institute, (Moscow), in Institute of Nuclear Phisic (Kiev), in Institute of Nuclear Phisic (Prague-Rgage), an experiments in Zentralinstitute fur Kernforschung (Dresden-Rossendorf) show that our detectors are very usefull devices for unconnected beam diagnostic at difference accelerators. The production of such detectors is prepared now as for flances apperture 166 mm, so for flances apperture 160 mmand 100 mm in accordance with standard ISO/DIS 1609.

V. REFERENCES

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