MONITORING OF LOW INTENSITY ION BEAMS AT FLNR ACCELERATOR COMPLEX

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Abstract

Detectors are developed to diagnose ion beams inside the accelerator, during beam transportation, and to control beam in the user area. The intensity of beam in the range from several ions per second up to pnA, the energy, the density distribution and the grade of the beam are monitored by the detectors. Depending on the operating conditions the ionization chambers, the proportional counters, the scintillation detectors and lamellar sensors with dual screen are used. The main criteria for the detector design are the reliability in long time operation under radiation, in magnetic fields and in rapidly changing vacuum conditions, and the possibility of quick repair or replacement. The diagnostic detectors are located in the channels to study the radiation resistance of electronics, and in the channel for the biological research.

INTRODUCTION

Beams of accelerated ions of low intensity are required for applied research, e.g., research of radiation resistance of electronics [1] or in biology. The intensity of these beams is less at three or more orders of magnitude than those used at the FLNR accelerator complex traditionally. There is a need to create a new set of diagnostic tools with greater sensitivity. A new set based on the detectors that are traditionally used in physical experiments. When choosing the detectors the conditions in which they will operate are taken into account. For example, detectors placed inside the cyclotron are exposed to a strong magnetic field, high radio frequency field and x-radiation. The detectors operate in high vacuum, which must not be spoiled. It is not always possible to remove the detector from the vacuum chamber. It can only be moved to the periphery, if the cyclotron works on the traditional beams. The detector should be reliable and resistant to radiation.

MEASUREMENT OF BEAM CURRENT INSIDE THE CYCLOTRON

Two different detectors operating in the current mode are designed and tested to work inside the cyclotron. First one is the detector based on secondary emission; the second one is the air filled ionization chamber with a thin metallic entrance window. Currents produced by these detectors are measured by means of amplifiers, the minimum value of the input current which is 1 pA.

The detector based on secondary emission consists of three lamellae, one of which is located in the center perpendicularly to the beam axis, the other two above and below, respectively. The width of each lamella is 8 mm, the thickness is 1 mm, and the distance between the centers of the lamellae is 11 mm. Each lamella is surrounded by a screen. The screen is open only from the side of the ion beam. Voltage +9 V from a battery is fed to the screen. The emission electrons arising from the bombardment of ion beam are collected by the screen. This screen is surrounded by second screen which is grounded. Dual screening reduces noise level to less than 1 pA. Current from each of the lamella is measured.

The described detector allows measuring the ion current only in arbitrary units. The output of the secondary electron emission depends on the type of ion, its energy and is proportional to the differential energy loss in the material of the lamella. The experiment on the calibration of the detector by the external beam of argon with energy of 32 MeV/nucleon shows that the detector can be used on the beam intensities higher than10^4 ions/s.

In the same calibration experiment it was shown that a detector with ionization chamber can be used on the beam intensities by three orders of magnitude lower. Special measures are adopted to prevent x-ray radiation from dees on the readings of the detector. Current from ionization chamber is measured on collector, in front of which there are two identical electrodes. The voltage on these two electrodes is supplied with the opposite polarity. Currents in the chamber compensate each other in the absence of the beam. The beam is passed only through space between the collector and one of the opposite electrodes. In spite of the high sensitivity, the camera has some disadvantages. One of them is the presence of the entrance window, which limits the application of the detector for measuring the intensity of ions having a small path length. Another disadvantage is the presence of gas in the volume of the ionization chamber inside a cyclotron that can create an emergency situation.

THE DETECTOR TO MEASURE THE BEAM CURRENT AFTER THE EXIT FROM THE CYCLOTRON

Gas-filled detector is mounted directly after the beam extraction from a cyclotron. The working gas of the detector is air. The input window of the detector with a diameter of 60 mm is closed by a foil of stainless steel with a thickness of 6 μm. The detector can operate in two modes: proportional counter and ionization chamber. The detector is a set of interleaved grids, the anodes and cathodes. The anodes are coiled from a wire thickness of 20 μm, and the cathodes from wire thickness of 100 μm. Voltage 1800-2100 V is supplied to the counter. Its efficiency is nearly 100% for all ions. Similar proportional counter filled with air is described in [2].

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The detector in the mode of a proportional counters suits for measuring the beam intensity in the range from single up to10^5 ions/s. The detector is switched into the mode of ionization chamber at higher beam intensity. The transition from mode to mode is caused by reducing the voltage to 300 V. Ionization chamber current depends not only on the beam intensity but also on the species and energy of the ion beam. The measured current can be correlated with the intensity of the ion beam in the overlapping range of the ionization chamber and proportional counter. The detector in the mode of ionization chamber can measure the beam intensity in the range from 10^2 to10^8 ions/s. The described detector helps in the extraction of a beam even at low intensity within a cyclotron. With their help, can be controlled the acceleration and extraction of ions, when the traditional ECR sources produce ions with a low yield. The possibility appears to expand the variety of beams and energies.

DETECTORS TO MEASURE THE BEAM PROFILE DURING TRANSPORTATION OF THE BEAM TO USER AREA

Multi-channel secondary emission detectors are used for the diagnosis during transport of beams to user area. Detectors are of two kinds: with 13 and 25 lamellae. The first is to monitor the transverse distribution of the beam in a region with a diameter of 80 mm, the second - in square 80 x 80 mm. The detectors are made on the same principle as the detector with three lamellas, described above, that is, have dual screening. The currents from all of the lamellae are measured by multichannel current amplifier. A fragment of the detector is presented on Fig.1, which shows the location of one of the lamellae and of the screens. Multi-channel detectors are an alternative to phosphors and can be used for a beam with flux density above 10^4 ions/s cm^2. The readings of the detectors are linearly proportional to the current of the incident beam, in contrast to the phosphors.

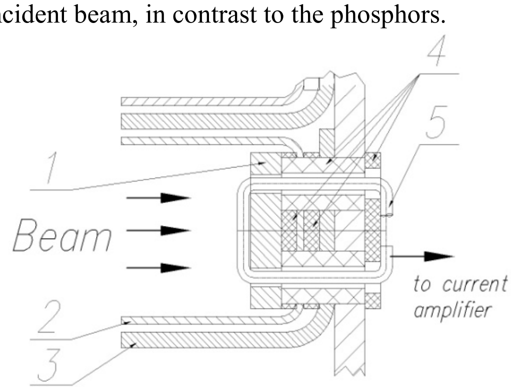

Figure 1: Location of the lamellae and of the screens. 1- lamella, 2 - the first screen, 3- the second screen, 4 – isolators made from Al2O3 , 5 - copper wire

DETECTORS TO MEASURE THE ENERGY OF ION BEAM DURING THE TRANSPORTATION TO THE USER AREA

Energy beam is measured on the straight section of the beam transport line. Time-of-flight method is used to measure energy. The time of flight is determined by registering the induced one and the same beam microbunch signals from two scintillation detectors separated by path length. Microbunches are a natural time structure of ion beams accelerated in the circular accelerator. Detectors with a substantially smaller size compared with the scanning beam cross section are used. They are mounted on the periphery of the scanning ion beam in such a way that they don't overshadow each other and the device under test. Method allows working with beams of low intensity. More detail concerning the method are described in [3]. The created detectors based on organic scintillators and photosensory modules of the firm "HAMAMATSU".

The diagnostic system has a function of identifying the ion. For its implementation the system uses a detector with a thick CsI scintillator which is inserted into the beam. The total energy of the studied ion is measured using this detector. The total energy and time-of-flight can definitely identify the ion. This feature is rarely used.

DETECTORS TO MEASURE BEAM PARAMETERS AT THE TARGET OF THE USER

Control of the irradiation of the user objects is carried out using the detectors of the two appointments. The intensity and homogeneity of the beam at the object is controlled by one set of detectors. The given beam intensity and exposure time is controlled with the help of other set installed on the periphery of the object. Detectors based on organic scintillators and photosensory modules of the firm "HAMAMATSU" use on beams for studies of radiation resistance of electronics. The registration efficiency is 100%. The detectors operate in the counting mode [3]. Due to low radiation hardness of the organic scintillators the possibility of fast them replacement is provided.

The homogeneity of the distribution and the intensity of the beam at the object are controlled in advance. The readings of detectors in the target region correlate with the readings of the detectors located at the periphery. The detectors controlling the uniformity of the beam are removed out and control is carried out by detectors at the periphery. Nine detectors are now used to control the homogeneity of the beam. There is a need to increase their number.

The ion beam at the channel for biological studies is controlled by five ionization chambers, Fig. 2 [4]. The cameras are thin and the beam passes through them. The biological object is positioned immediately behind the central camera. The other four cameras are used to control the homogeneity of the irradiation field.

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Central camera is calibrated in units of absorbed dose rate. Ionization chamber can measure the dose rate in the range from 10^{-3} to10^{2} Gy/s.

All service for detectors, signal processing and presentation of the results are carried out by electronic components conforming by the standard "Euromechanics". Communication with a computer located on the remote accelerator, goes via Ethernet.

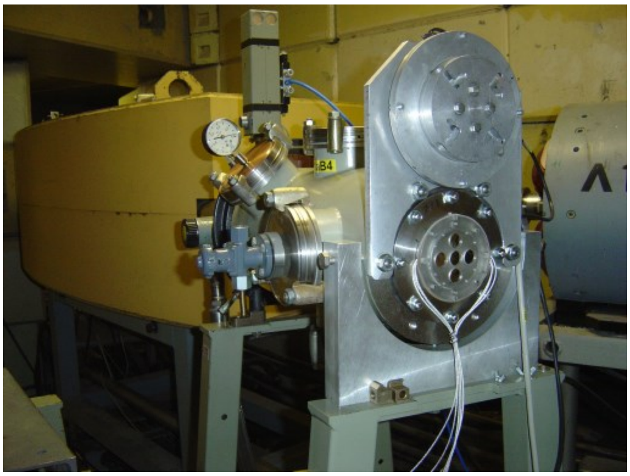

Figure 2: Five-channel ionization chamber for monitoring the irradiation of biological objects

CONCLUSIONS

A new set of diagnostic tools with increased sensitivity is created for applied research. A new set based on the detectors used traditionally in physical experiments. Detectors are developed to diagnose ion beams inside the accelerator, during beam transportation, and to control beam in the user area. The beam intensity in the range from several ions per second up to pnA, the energy, the density distribution and the grade of the beam are monitored. Depending on the operating conditions the ionization chambers, the proportional counters, the scintillation detectors and lamellar sensors with dual screen are used. The main criteria for the detector design are the reliability in long time operation under radiation and the possibility of quick repair or replacement. The diagnostic detectors are located in the channels to study the radiation resistance of electronics, and in the channel for the biological research.

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