SECONDARY ELECTRON MONITOR OF BEAM'S TWO-DIMENSIONAL TRANSVERSE CURRENT DENSITY DISTRIBUTION

A.M.Tron, P.B.Vasilev
Moscow Engineering Physics Institute
Kashirskoe sh. 31, 115409, Moscow, Russia

Abstract

A two-dimensional secondary electron monitor for Moscow Meson Facility linac beam is considered. The designed device realises a new method based on registration of secondary electron distribution along a single wire scanning a beam perpendiculary to its axis by step motor. Current resolution along two orthogonal axii about 0.1 mm may be achieved. The device size along the ion beam axis is approximately 10 cm at the beam pipe aperture equal to 4 cm. The monitor basic characteristics obtained from the computer and experimental investigations are presented.

1. INTRODUCTION

To insure small losses of the beam particles in the linac of Moscow Meson Facility (MMF) one needs in particular to check the two-dimensional current density distribution j(x,y) in the beam transverse cross section. A device designed for this purpose and named IDR must satisfy the next major requirements. The resolution of beam current components in the entire aperture region of 40 mm diameter must be not worse than 0,6 mm and device size along the accelerator axis must be about 0,1 m. A display time of the j(x,y) current density distribution measurement in the entire aperture is to be not more than several seconds. Together with small disturbance of the investigated beam the device must insure its checkup without disassembling of accelerator. The IDR major parameters must be independent of beam energy.

Our studies have shown that the known devices for j(x,y) measurement [1,2,3] don't satisfy these requirements. However a secondary electron technique [4] has the best prospects. In this paper a two-dimensional beam transverse current density distribution monitor (IDR) employing secondary electron technique is considered with respect to MMF beam studies in accelerator's 160 MeV section.

2. MONITOR OPERATION

The IDR monitor function is a recording of the density distribution of the low energy secondary electrons (emitted with energies less than 50 eV) along a wire scanning the beam perpendiculary to its axis.

Fig.1(a) shows the IDR photo; fig.2- a simplified layout that explains the monitor operation. Electrons that have been produced as a result of the interaction between the primary ion beam and electrode (1) are accelerated along their path from the emitter with a negative potential equal to 1..4 kV till the electrodes (3) under ground potential. Then by semicircular focusing in magnetic field the electrons are transfered from the ion beam space to the plane of the 60-channel current collector (6) with the screen (4) and cut off (5) grids before it. A magnetic field highly uniform in a region of electron motion is produced by two specially shaped poles(7). For every position of the emitter (1) relative to the beam axis the secondary electron distribution is being measured by the sequential registration of 60 collector currents. The converter containing wire electrodes (1-3) is driven by step motor.

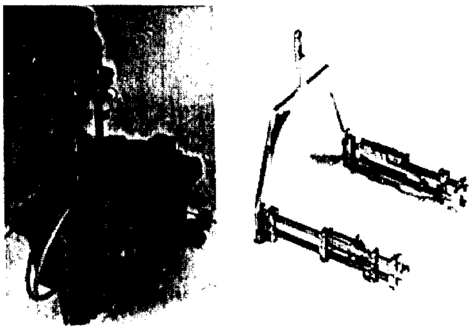

Fig.1. A photo of the IDR monitor (a) and a photo of the monitor primary converter(b).

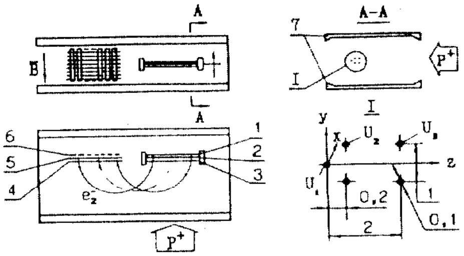

Fig.2. A layout of the IDR.

3. PRIMARY CONVERTER

A strict limit on the maximum monitor size along the accelerator axis and the uniformity of the magnetic field (not worse than 0,3%) in semicircular electrons trajectories region have led to a choice of the optimized magnetic poles shape and the minimal distance between the poles close to the beam pipe diameter. This purpose was realized by focusing of the electron flux in the (y,z) plane by installation of two additional electrodes (2). Electrodes mutual position is shown in fig.2; the electrodes material may be either carbon or tungsten or tantalum. A photo of the primary converter is given in fig.1(b). The geometry and potentials of the electrodes were initially determined by computer simulation. Then

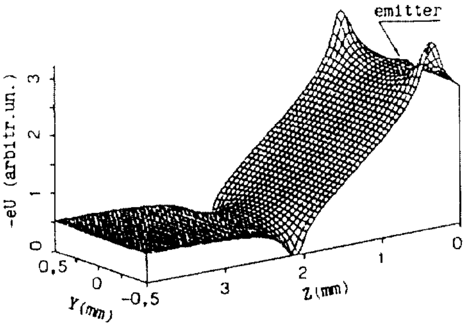

Fig.3. A distribution of electrons potential energy in electric field of the primary converter electrodes.

they were corrected in experiments with the thermoelectrons beam emitted from the emitter(1). Figs.3,4 shows the results of calculations: fig.3 - a distribution of electron potential energy in the electric field of electrodes, fig.4 - electrons trajectories and equipotential lines of the same electric field.

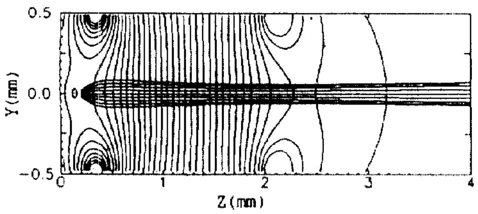

Fig.4. Trajectories of electrons and equipotential lines of the primary converter electrodes field.

4. RESOLUTION OF MONITOR

The monitor resolution was determined by the numerical integration of equations of electrons motion in a field being resultant of electrodes electric field, uniform magnetic field and ion bunches fields. Bunches have been supposed to be uniformly charged ellipsoids of revolution. Initial angle-velocity distribution of secondary electrons on the emitter was taken according to experimental data from [5,6].

Secondary electrons distribution along x coordinate in the collector plane when their initial distribution along x on emitter had been delta-function is shown in fig.5.

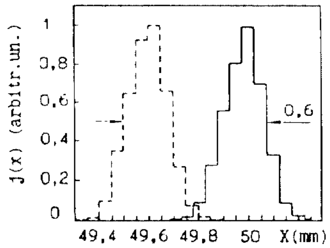

Fig.5. Secondary electrons distribution in the collector plane. Solid line - ion beam zero current; broken line - 50 mA current.

The distributions have been obtained for primary converter geometry described above, for electrons trajectories radius in the uniform magnetic field equal to 25 mm and their energy of 4 keV and for the next ion beam parameters : proton energy 160 MeV, beam radius 5 mm, bunch phase length 10 degrees at 0,2 GHz, pulse current 50 mA. The distributions full width on half maximum level is less than 0,6 mm and in the case of negligibly small beam influence this value is less than 0,2 mm. It must be pointed out that by rising the electrons energy one can make it up to 0,1 mm. In vertical plane (y,z) spatial resolution of beam current portions is determined by the emitter diameter. For the primary converter geometry consemed the secondary electrons that fly out from the emitter in the angle 30 degrees respectively to (x,z) plane comprises the distribution mentioned above. Electrons with another starting angles produce backgroung current with flux density by two orders of magnitude less than maximum value of the distribution.

5. BEAM HEATING OF EMITTER

The monitor emitter heating up to temperature when thermocurrent density can excess 1% of corresponding secondary electron current density restricts the device range of operation. To determine time dependence of the emitter maximum temperature when it is being pulse beam heated a one-dimensional unstationary heat transfer equation for thin rod including a radiant heat transfer term has been solved. Thermophysical coefficients for temperature profiles calculations have been taken from [7].

A target heating was supposed to be symmetrical about its centre and the problem mas solved for half the emitter. The beam current density distribution was taken Gaussian with its radius equal to doubled standard deviation of particles from beam axis. A heat power was supposed to be given of by beam particles at their permanent slow down in emitter.

Fig.6 shows tungsten and carbon emitter maximum temperature dependence on time at 160 MeV proton beam heating. Beam parameters: radius - 2.5 mm, pulse current and its duration - 0.05 A, 0,1 ms. Emitters' full lenght - 60 mm, their radii - 0,05 mm. Curves are given for three values of pulse repetition frequency.

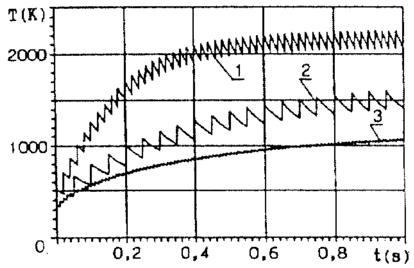

Fig.6. The temperature vs time dependences of the 160 MeV proton beam heated targets made of tungsten (curve 1,2) and carbon (3) for three pulse current repetition periods: 1 - 20 ms; 2 - 50 ms; 3 - 10 ms .
Pulse beam current 50 mA; beam radius 5 mm; target radius and length respectively 0,05 mm and 60 mm.

It follows from fig.6 than the carbon emitter monitor can be operated at maximum pulse repetition fq. (100 Hz) and for tungsten it must be not more than 20-30 Hz because emitter temperature should not be more than 2000 K.

By moving the emitter one can increase pulse repetition fq. for tungsten. Fig.7 shows the time dependences of maximum temperature of the same geometry tungsten emitter for beam radius 5 mm and

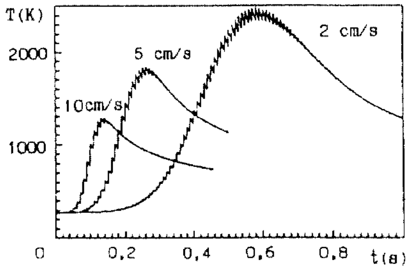

Fig.7. Maximum temperature time dependences of moving tungsten emitter for three velocity magnitudes.

maximum pulse repetition fq. 100 Hz. Addused magnitudes of the emitter translation velocity can be easily achieved by use of step motor.

6. CONCLUSION

The considered monitor for high energy section of MMF linac has passed bench test recently. It has shown that all components are operating satisfactory.

A system similar to those presented above will be mounted and tested in MMF linac 750 keV section in April-May and later in the same year in 160 MeV section. Possible positioning of a number of such monitors in accelerator channel major points to measure and check the beam two-dimensional distribution j(x,y) in all ion pipe aperture is under consideration.

ACKNOWLEDGMENTS

Authors feel their pleasant duty to express their gratitude to Prof. S.K.Esin for support of this research and to Dr. V.V.Shako for assistance in computer simulations.

REFERENCES

[1] J.R.Alonso, C.A.Tobias, W.T.Chu, "Computed tomographic reconstraction of beam profiles with a multiwire chamber", IEEE Trans. Nucl. Sci., vol.NS-26, pp.3077-3079, 1979.

[2] M.Iwasaki, Y,Akiba, R.Kadono, e.a., "Two-dimensional profile measurement of a pulsed meson beam by a computed tomography method", Nucl.Instr.Meth.Phys.Res., A221, pp.482-486, 1984.

[3] U.P.Komissarov, V.G.Mikhailov, V.A.Rezvov, e.a., 2-e Vsesousnoe soveschanie po uskorit. sar. chastits (Dubna, October 25-27, 1988), Dubna, R9-88-738, p.21, 1988.

[4] A.M.Tron, "Preobrasovatel emissionnogo izmeritelya dvumernogo raspredeleniya plotnosti toka po setcheniyu puchka zaryagennyh tchastitc", in the book: Metody raschota i experimentalnyie issledovanyia sistem lineynyh uskoritelei, Moscow, Energoatomisdat, pp.41-45, 1987.

[5] A.A.Schultz, M.A.Pomerantz, "Secondary electron emission produced by relativistic primary electrons", Phys. Rev., vol.130, No.6, pp.2135-2141, 1963.

[6] A.Koyama, "Contribution of directly excited electrons to the secondary electron emission from Al by high energy proton or -particle bombardment", Japan. J. Appl. Phys., vol.16, No.3, pp.431-440, 1977.

[7] Physico-khimichesskie svoistva elementov. Spravotchnik, Kiev, Naukova Dumka, 1965.