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Non-destructive Beam Profile Monitor at HIMAC

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Abstract

Non-destructive profile monitors (NDPM), based on micro-channel plate (MCP), have been developed and installed in both the synchrotron ring and high-energy beam transport (HEBT) line at HIMAC. Beam test using these monitors have been carried out since April of 1995 to investigate a change of vertical beam size in synchrotron and a possibility of observing beam with high energy by one pass. In this paper the measurement system is mainly reported, and the preliminary results are also briefly presented.

1. INTRODUCTION

NDPM based on MCP has been studied and developed at many accelerator facilities [1～3], because of a powerful method for non-destructive beam diagnostics. The NDPM utilizes residual gas ionization. The ion-electron pairs created by the impact of high energy charged particles on residual gas are accelerated in a uniform electric field, and ions or electrons bombard the surface of MCP. Electrons emitted by the bombardment are multiplied in MCP when a bias voltage is supplied between both ends of MCP. The multiplied electrons in MCP are collected to multi-anode strips or resistive anode using charge division method. One-dimensional beam profile is obtained as electric signal through a read out circuit.

NDPMs at HIMAC have been studied and installed for following purposes. (1) To investigate a change of vertical beam size of circulation beam during acceleration and extraction at synchrotron, because the measured vertical emittance of the extracted beam is not consistent with the calculated value based on the adiabatic dumping. (2) To monitor the beam profile non-destructively at HEBT during irradiation treatment of tumor. Therefore, two NDPMs have been designed, and installed to the synchrotron ring and HEBT, respectively.

The paper reports the design considerations of the NDPM and the preliminary testing results.

2. DESIGN CONSIDERATION

The NDPM consists of an accelerating electrode of ions or electrons created by a beam, a cascade-MCP with 32ch multi-anode strips and a read out circuit.

2.1 Estimation of output signal level

The expected signal amplitude obtained from a monitor was roughly estimated using the well-known Bethe-Bloch formula. The number of ion-pairs, that can be produced along the unit length of a 290MeV/n carbon beam, is first estimated. In this case, 5.7pairs/cm/Torr is obtained for the beam revolution frequency of 1.5MHz in the average vacuum pressure of $1x10^{-9}$Torr in the ring. Taking these values into account, since the gain of a cascade-MCP and the beam intensity are assumed to be 10^7 and 10^8pps, respectively, the estimated output current per channel is 44nA. In NDPM at HEBT, the output current is estimated at 2.9pA/ch under the conditions of $1x10^{-7}$Torr of the vacuum pressure and 10^7 of MCP's gain.

The estimation suggests that measurement in HEBT needs cascade-MCP to obtain large gain, and possibly worse vacuum condition, in the ring , lower gain is enough for assumed intensity. Nevertheless, cascade-MCP was adopted also for the ring to cover the request for weaker beam.

2.2 Structure of NDPM

Fig. 1 shows a photograph of the NDPM at HIMAC. The NDPM has 7 electrodes, which are arranged to realize a uniform electric-field to accelerate ions or electrons created by a beam. The field was calculated by using the code Poisson as shown in fig. 2. The maximum voltage is ±25kV. The effective area that beam can pass through is $180x75mm^2$ for measuring a vertical profile in synchrotron, and $100x100mm^2$ for a horizontal beam profile in HEBT. The electrode at the opposite end of the field cage to MCP is made of mesh, in order to use UV-rays for gain calibration of each anode. In both cases, the size of MCP is $55x8mm^2$ (Hamamasu Photonics F4772-01), and the interval between neighboring anode-electrodes is 1.7mm. The output of the MCP was operated at 0.5kV negative to the anode strips which are at the grand level.

In the case of ring, the electric field of the NDPM may distort a closed orbit by about 8mm during the injection. In order to correct this disturbance, an additional electrode is installed at just downstream of the NDPM. This correction electrode has a similar structure to the monitor, and is fed high voltage with the inverse polarity by same power supply as the NDPM. In the case of HEBT, however, the correction electrode is not used because an orbit distortion is negligible due to one pass high energy beam.

In order to keep high vacuum in the ring, the NDPM was baked at 200℃ for 24hr before installation to the ring, and the resistor of 20MΩ to divide the high voltage to each electrode are equipped outside of the vacuum chamber to remove out-gas sources.

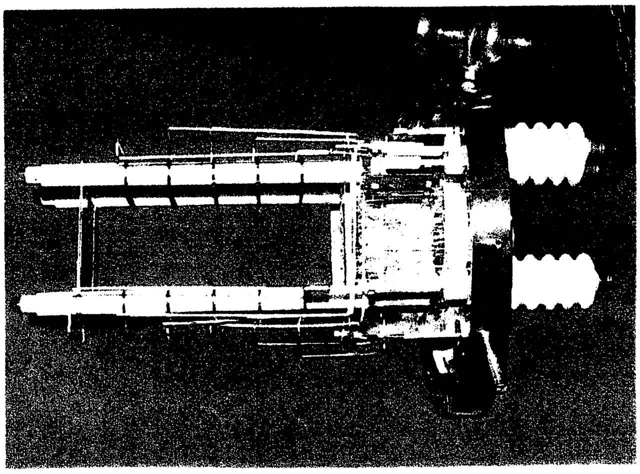


Fig. 1 Photo of the NDPM at HIMAC synchrotron.

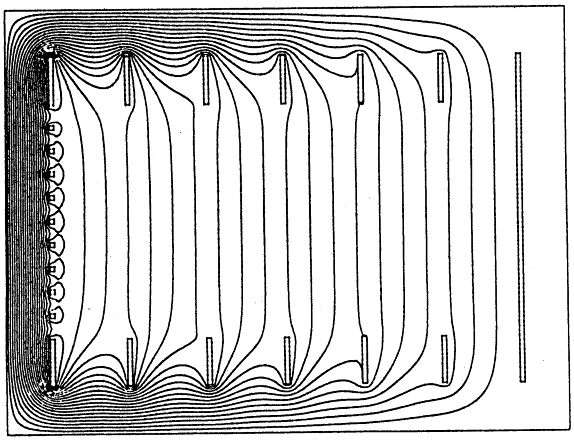


Fig.2 Equipotential line calculated by Poisson code. At the left is the mesh electrode and MCP position is at the right end.

2.3 Read-out circuit and control system

Fig. 3 shows a schematic block diagram for the read out circuit and control system. In the case of ring, the charge from the anode strip is converted to a voltage with the conversion ratio of 1V/nA, then it is digitized after a 32ch analog-multiplexer. The digitized signal is thirdly stored in a memory. The signal acquisition is repeated in this way for 1.4s at the minimum interval of 10ms. The stored data is transferred to the control computer in the central control room, and finally displayed on a CRT. The local control system is connected to the control computer through GPIB. The operation of the NDPM is normally carried out at the central control room. In the case of HEBT, generated current signal in the NDPM is integrated in the existing read out circuit with exchanging a capacitor from 10000pF to 500pF, which is used for multi-wire proportional counter type monitor[4]

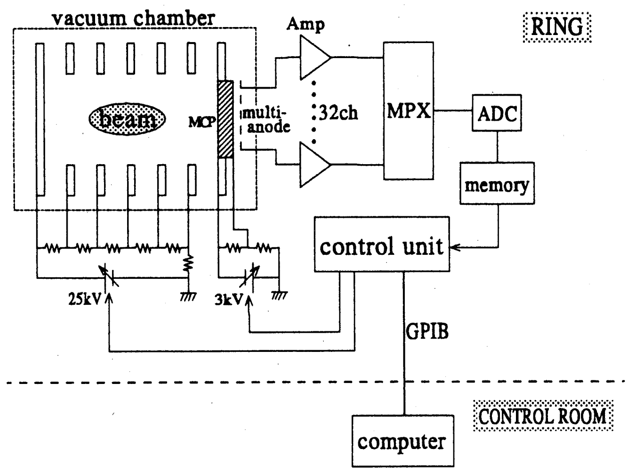
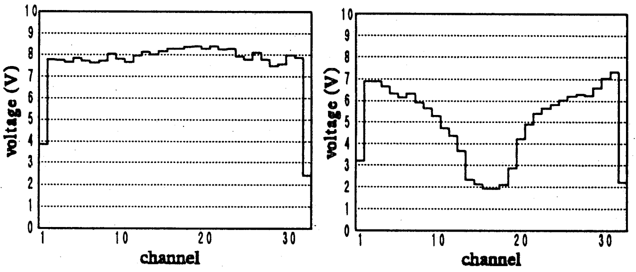


Fig. 3 Block diagram of read-out circuit and control system.

3. PRELIMINARY TEST

3.1 Calibration

UV-rays were irradiated to investigate uniformity in the gain characteristics of MCP. Results of both before beam test and after 300hr beam exposition are shown in fig. 4. As can be seen in fig. 4(a), the uniformity of gain was within ±5% at NDPM in the ring before beam test. In the case of ring, however, since the created electron intensity is somewhat high due to high revolution frequency, the gain seems to become small gradually . It is thus necessary to compensate the gain deterioration. At present, the fluctuation of the gain in each channel is measured by using UV-rays, and it is compensated in the level of software, resulting in a flat response on a CRT. In HEBT, since the created electron intensity is usually small due to one pass beam, such gain deterioration has not been observed yet.



(a) (b)

Fig. 4 Gain characteristics of anode channels of NDPM in the ring. (a)before beam test. (b)after 300hr use.

3.2 Profile measurement

As shown in fig. 5, the beam profiles can be observed in both cases of ring and HEBT under the conditions summarized on Table 1. In the case of ring, signal levels were decreased as increasing a beam energy, because of reduction of energy loss.

When a correction electrode was not used in the ring, a decrease by 20~30% in the beam intensity was seen due to the kick by the accelerating electric field of the NDPM. Such a decrease was compensated by using the correction field. In HEBT, when the supplied voltage to the accelerating electrode is higher than 20kV, an increase in the noise can be found. As long as the vacuum pressure is better than 10^{-7}Torr, this noise remain very small, however the beam profile was not satisfactorily observed.

Table 1. Testing conditions.

	synchrotron	HEBT
beam	C^{6+}	Ne^{10+}
vacuum	1×10^{-9}Torr	3×10^{-7}Torr
energy	6~350MeV/u	400MeV/u
intensity	5×10^{8}pps	1×10^{8}pps
MCP gain	5×10^{4}	10^{7}
field voltage	~17kV	~20kV

4. SUMMARY

The NDPMs at HIMAC have been designed and tested. As a preliminary result, they measured the expected beam profile in both the cases of ring and HEBT. Both in the ring and HEBT, the measured output was consistent with the estimation. In HEBT, however, the beam profile was not satisfactorily observed when the vacuum is better than 10^{-7}Torr and the beam intensity lower than 10^{7}pps.

5. ACKNOWLEDGEMENTS

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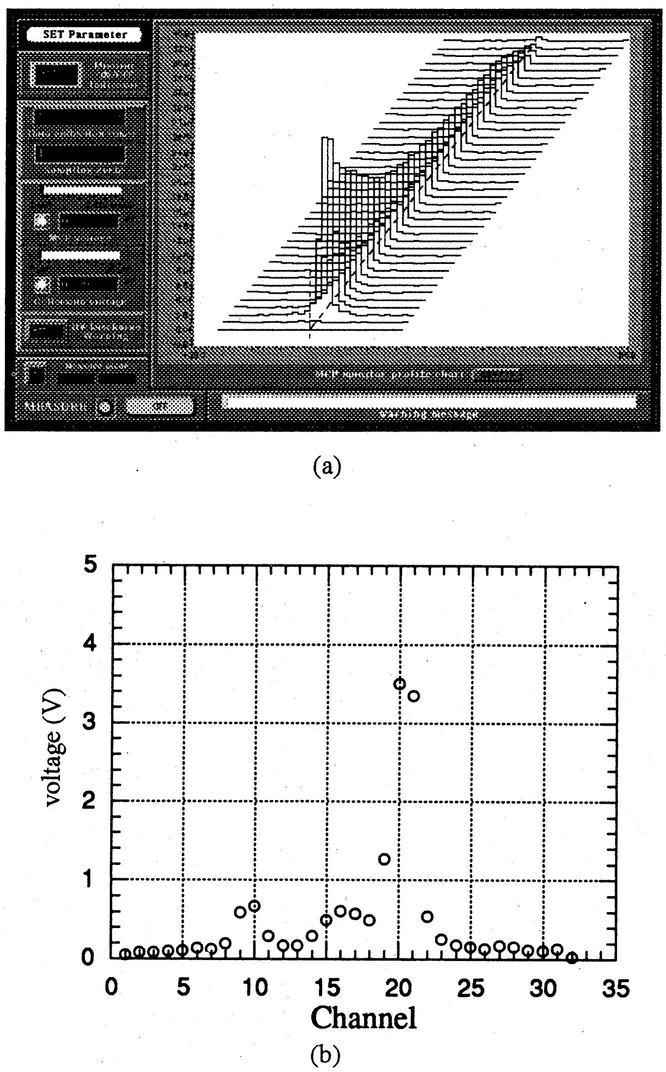

(a)

(b)

Fig. 5 Measured beam profile. (a)synchrotron.(from injection to the end of extraction, the interval of 30ms), (b)HEBT

6. REFERENCES

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