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NONDESTRUCTIVE BEAM PROFILE MONITOR USING MICROCHANNEL PLATE

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ABSTRACT

A microchannel plate (MCP) was applied to the charge collector of a nondestructive beam profile monitor, and the measurement of the beam profile of the KEK booster synchrotron was performed successfully during the acceleration period.

INTRODUCTION

For continuous measurement of the beam profile during acceleration, a nondestructive beam detector is necessarily required. One such detector was developed at ANL[1] . Nondestructive detection is acomplished by collecting the ions produced through ionization of the residual gas by the beam in the vacuum chamber. The similar detector was also constructed at KEK[2] . Since a metal strip was used as an ion collector for both detectors, any amplification of the ion current could not be expected. An attempt to amplify the ion current with a photomultiplier was done at RAL[3] . A microchannel plate[4] , which is composed of many fine glass tubes coated with an electron emissive material, is a compact and high-gain charge multiplier. We have replaced the metal collector with the microchannel plate and consequently achieved a high-gain detector. In this paper, we describe preliminary results of measurement of the beam profile in the KEK booster synchrotron with a nondestructive profile monitor using a microchannel plate.

MEASURING SYSTEM

A schematic of the nondestructive profile monitor (NDPM) is shown in Fig. 1. In order to observe horizontal and vertical beam profiles by rotating the NDPM angle of 90°, the aperture of this monitor is chosen to be square. Ions or electrons produced by interaction of the beam with residual gas drift along an electric field which is caused by a potential applied between the high-voltage plate and ground plate. According to the polarity of the field, ions or electrons are collected on the microchannel plate through a slit in the ground plate. Since the collection field is deformed by the beam potential, the observed beam profile is different from the actual one[5] . This problem will be discussed later.

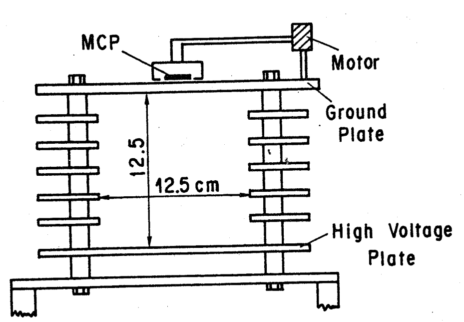

Fig. 1 Schematic of Nondestructive Profile Monitor

The MCP has a dimension of 25mm in diameter and 0.48mm in thickness. Incident ion current was collimated in 10mm longitudinally and 5mm transversely. The MCP is driven by a motor so that transverse distribution of the ion current is observed, i.e. the beam profile. The MCP read-out circuit is illustrated in Fig. 2. Here, charged particles come from left hand side and bombard the MCP, in which many electrons are bred and led to the anode by a bias potential V. Output gain was set to be about 2×10^4 by adjusting the bias voltage V. The NDPM was installed in the straight section of the KEK booster synchrotron and the signal was fed to an analog-to-digital converter(ADC) through the electronics system shown in Fig. 3. The beam profiles were measured successively with a sampling speed of 200μsec during the acceleration period.

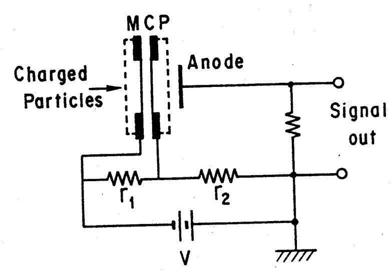

Fig. 2 Electric Circuit to get signal from MCP

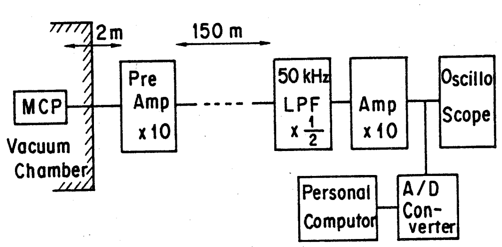

Fig. 3 Electronics System of Nondestructive Profile Monitor

RESULTS OF THE MEASUREMENT

Fig.4 and Fig.5 show signals observed by an oscilloscope when the MCP is placed at the farthest and nearest points from the beam, respectively. The sharp noise at the time of injection comes from an injection bump magnet, and the gently varying noise comes from the main bending magnet. Beam loss causes another sharp noise. As the farthest point is the place where charged particles induced by the proton beam do not reach the detector, subtracting Fig.4 from Fig.5 is the real signal of the beam. According to whether the polarity of the electric potential for the collection field is positive or negative, ions or electrons which are produced by circulating proton beam drift to the MCP, respectively.

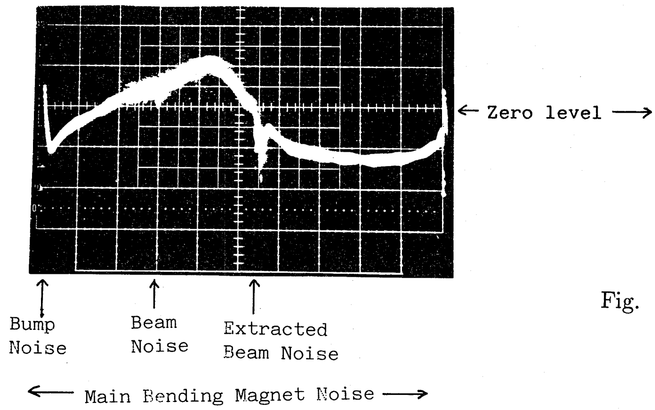

Fig. 4 Signal of MCP at farthest position (Noise) 5ms/div, 500mV/div

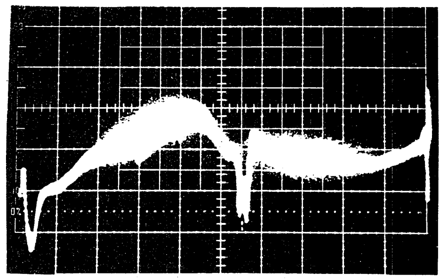

Fig. 5 Signal of MCP at nearest position (Noise and Real signal) 5ms/div, 500mV/div

The measured half widths at half height (HWHH) are shown in Fig.6. The open circle denotes the HWHH measured with a positive potential and the cross denotes one measured with a negative potential. The dashed line refers to the beam width obtained by the moving scraper method[6]. As the beam width measured with a positive potential is closer to the dashed line, the positive electric potential is adopted for the following measurement. When the positive potential is increased from 1 kV to 5 kV, the observed HWHH approaches the dashed line as shown in Fig.6. It is thought that an electric potential higher than 5 kV, which is the maximum value of our power supply, will make the electric field due to the circulating proton beam negligible. Although we could not get the absolute value of the beam size, the following measurement was done to check that the NDPM with 5 kV can measure such a relative motion as COD and variation of the beam size. In this case, the beam intensity is middle level (9×10^{11}ppp at extraction).

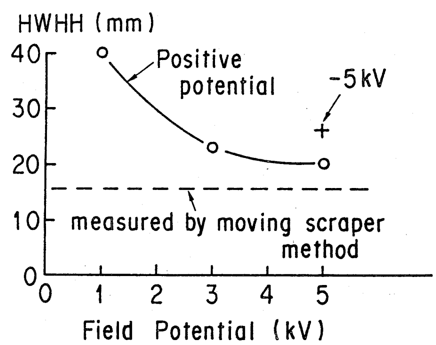

Fig. 6 Dependence of HWHH on the Field Potential by various measurements

The top and bottom figures of Fig.7 show the time variation of the COD measured by the ΔR and NDPM monitor, respectively. In this case, the COD is changed at about 12 msec by adding a bias voltage to the ΔR feedback.

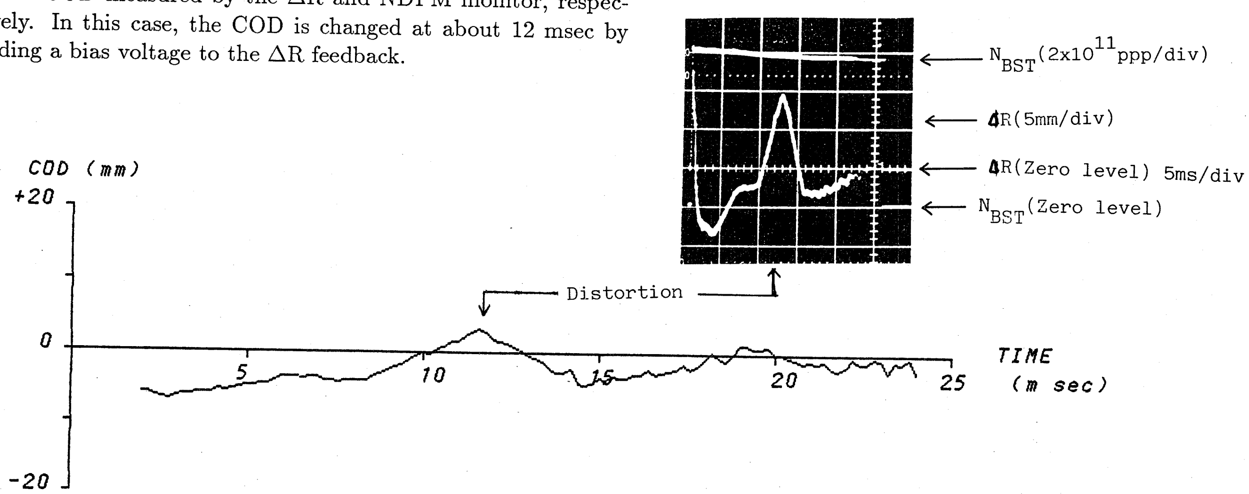

Fig. 7 Time variation of COD by the ΔR monitor and Non-destructive Profile Monitor

The top of Fig.8 shows the time variation of HWHH by NDPM and the moving scraper. Both figures show that the relative tendencies of the beam dynamics are in good agreement with each other. The bottom of Fig.8 shows the time variation of the beam profile from 2 msec after injection to 1 msec before extraction.

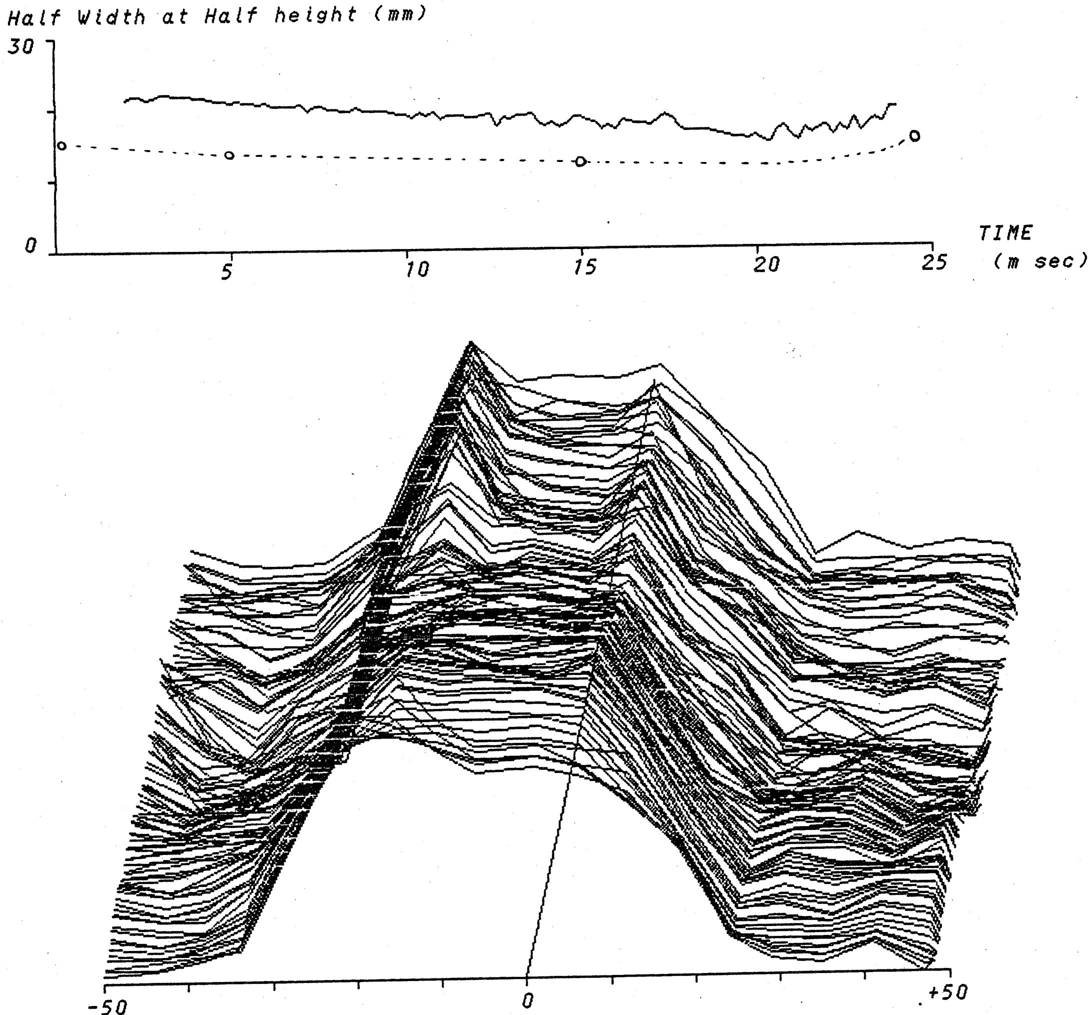

Fig. 8 Time dependence of HWHH and beam profile

CONCLUSION

By using MCP which has 10^4 amplification, the signal of charged particles induced by the circulating protons in the KEK Booster Synchrotron was obtained with good S/N ratio. In order to measure the beam profile by this system, collection of induced ions is better than electrons, although it is hard to explain this phenomena. The ion collecting field of 5 kV/12.5 cm, which is the maximum value of our power supply, is not enough to get the absolute value of beam profile. It is, however, useful to observe the relative beam dynamics such as the time variation of COD and beam size. For the improvement of this monitor, we are preparing to increase the ion collecting field to 30 kV/12.5cm. The absolute beam size observed under this field will be compared with one by the moving scraper method.

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