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NON-DESTRUCTIVE FAST DATA TAKING SYSTEM OF BEAM PROFILE AND MOMENTUM SPREAD IN KEK-PS

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Abstract

A mountain view of beam profiles in a synchrotron ring can be taken without any beam destruction by collecting charged particles produced by the circulating beam hitting residual gas in the ring to a sensor. When a rectangular Micro Channel Plate with multi-anodes or lined-up electron multipliers is used as the sensor, the profiles can be measured within one acceleration period, even if the beam intensity is very low and the ring is kept in a high vacuum. We describe this non-destructive profile monitor (NDPM) as well as the momentum spread measurement system by a combination of two sets of NDPM.

1. INTRODUCTION

It is very convenient for beam studies and machine operation to measure the beam profile in a synchrotron ring without causing any damage to the circulating beam. The principal of the non-destructive beam profile monitor (NDPM) is to measure the position dependence of the positive ion current produced by the circulating proton beam in a synchrotron ring. Since the current signal is very low, we usually use an element to amplify the signal, such as a micro-channel plate (MCP) or an electron multiplier (EM). We had installed two sets of NDPM by using a large rectangular area MCP with 32 anodes[1], one of which measures the horizontal beam profile in the Booster ring and another in the Main ring. For setting NDPM at a ring position with a large beam size, using an assembly of many EMs as a sensor, is better than using a MCP, from the view point of long life against radiation and a high saturating signal current[2]. A combination of two NDPMs (one of which is made of EMs and set at the place with a large dispersion function; the another is made of MCP and set at a location with a small dispersion function) is used for measurements of the momentum spread*. We introduce this measurement result in the Main ring.

The VME computer system takes data from those sensors via an A/D converter, rearranges them and displays a "mountain view" of the transversal beam profiles as well as the time dependence of the beam (center, size, momentum spread) within one acceleration period.

2. NON-DESTRUCTIVE PROFILE MONITOR SYSTEM AND DATA-TAKING METHOD

A.Mechanism and electric circuit

A circulating beam in a synchrotron strikes residual molecules in the vacuum ring while producing positive ions and electron pairs with some probability. When a positive collecting voltage is supplied to an electrode (as shown in Figure 1), positive ions move from the bottom to the top along the collecting field. If a large-area rectangular MCP with multi-anodes or lined-up EMs are placed at the end of the field, they can measure the number of ions which are produced in proportion to the beam intensity along the vertical collecting field. In our case, the MCP is a tandem-type and has an effective area of 81mm×31mm; 32 anodes (each anode has a width of 1.5mm, a length of 29mm and a pitch of 2.5mm) are placed closed to the output side of the surface of the MCP. An EM-type NDPM has 30 lined-up EMs, in which every EM has an aperture with a width of 5.2mm and a length of 30mm. Every anode of the MCP or EM has an independent electric circuit (shown in Figure 2).

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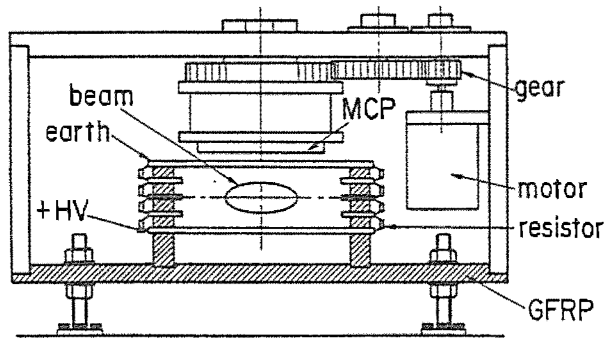

Figure 1. Fundamental plan of a horizontal NDPM with multi-anodes.

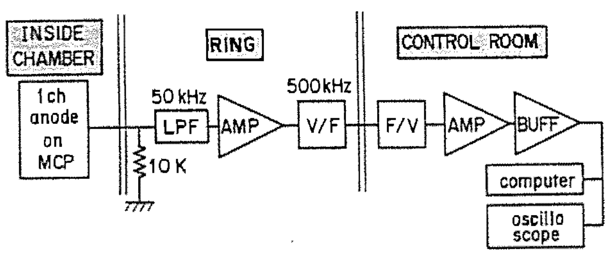

Figure 2. Block diagram of the electric circuit connecting every anode on an MCP or EM.

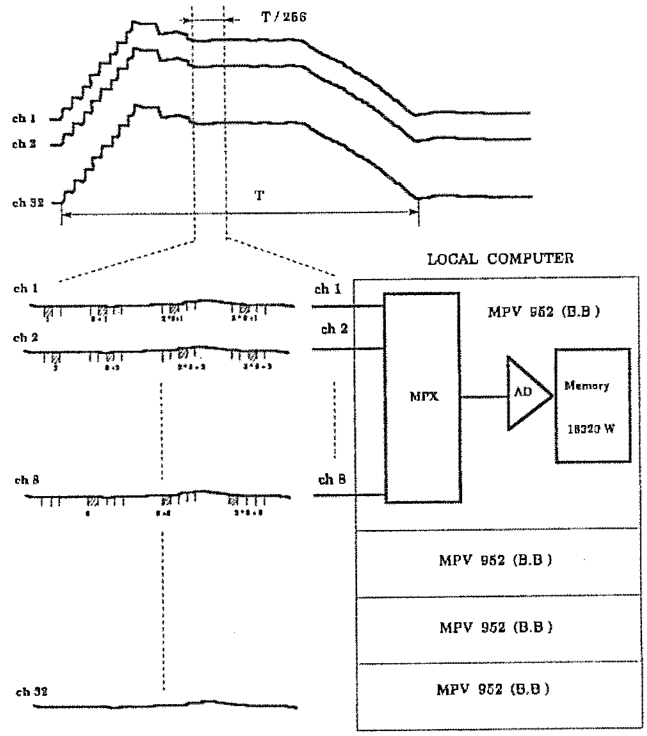

Figure 3. Multiplexer and A/D converter system to take signals from 32 anodes.

B. Data taking

Every anode's output signal from beam injection to extraction is memorized by a VME local computer via an A/D converter. The A/D converter has a data-sampling period which can be changed from 3μsec to 255μsec, and eight input terminals. As shown in Figure 3, (in the case of the minimum data-sampling period) the signal from one anode is chosen by a multiplexer for 3μsec with every 24μsec(=3μsec$\times$8ch). Therefore, our NDPM system (which has 32 anodes) requires four A/D converters and the minimum data taking period for one anode is 24μsec. As the data-transfer time from the local computer to the center one is not fast, we set the maximum data-taking number from one anode to 256. When the measuring time range is long, such as the Main ring acceleration period (about 3 sec), we increase the sampling time from the minimum value (=3μsec) and take 256 data by averaging over several data for an increasing S/N ratio.

C. Calibration

In this system the most important point concerns the calibration of the entire gain, which includes the MCP, pri-amp, voltage-to-frequency converter (VFC), frequency-to-voltage converter (FVC), main-amp and analog-to-digital converter (ADC). For observations of the beam profile, the direction of the anode stripes on the MCP is set so as to be parallel to the beam direction, as is shown in the left-hand figure of Figure 4 (Measuring position). For the calibration, however, the direction of the stripes is changed by a pulse motor and set perpendicularly to the beam direction, as shown in the right-hand figure of Figure 4 (Calibrating position). In this position, each anode can be considered to receive the same quantity of ions produced by the circulating beam, and the anode signal should be similar to each other. Therefore, the calibration constants are set by these figure heights.

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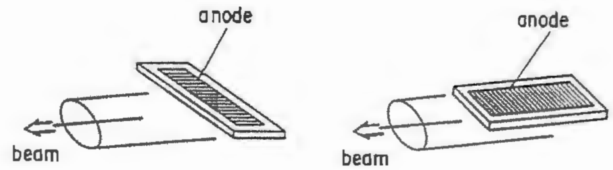

Figure 4. Orientation of the anode strip lines of a MCP.
Left figure: Measuring position (the anode strip are parallel to the beam).
Right figure: Calibrating position (the anode strip are perpendicular to the beam).

D. Rearrangement

The VME computer system takes the time dependence of the current from every anode via an A/D converter in the "measuring position", divides the data by the above-mentioned calibration constants and rearranges them to a "mountain view" of the transversal beam profile within one acceleration period, as shown in Figure 5.

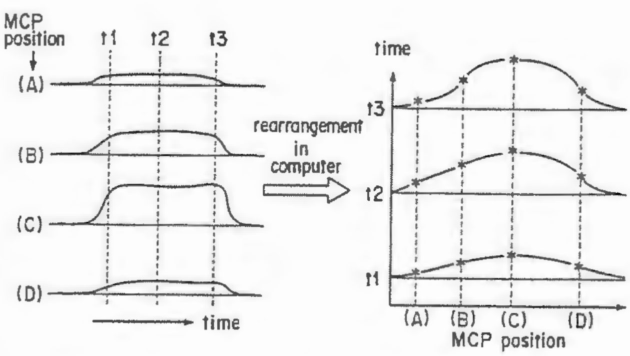

Figure 5. Typical current signal from multi-anodes and a "mountain view" of the beam profile rearranged by a computer.

3. MEASUREMENT RESULT

A. "Mountain view" and time dependence of the beam profile center

The computer outputs by rearranging the data at the place, where the dispersion function is small, of the Main ring. The time dependence of the center of the horizontal beam profile (shown in Figure 7) is in good agreement with the output signal of the ΔR monitor (shown in Figure 8).

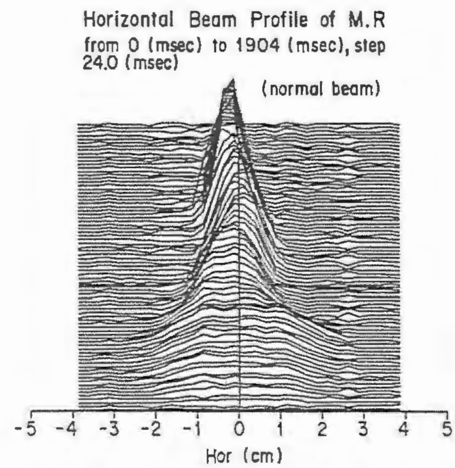

Figure 6. "mountain view" of horizontal beam profile in the Main ring.

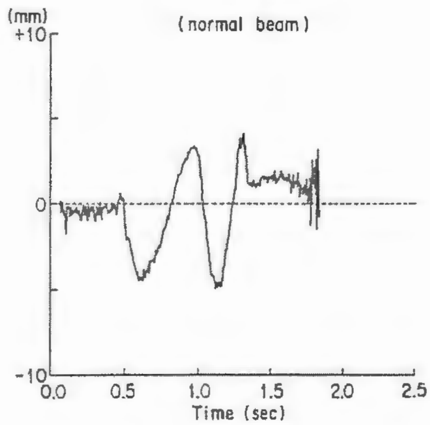

Figure 7. Time dependence of the center of the horizontal beam profile calculated by a computer.

Figure 8. Output Signal of the ΔR monitor at the same position of NDPM (X:200ms/d, Y:2mm/d).

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B. Momentum spread of circulating beam

(This measurement idea was suggested by Prof.S.Hiramatsu and Dr.N.Kumagai.)

Assuming that the intrinsic beam profile and momentum distribution have Gausian shapes, the total half beam width (x) is

$$x = (\beta\varepsilon + (\eta\frac{\Delta P}{P})^2)^{1/2}, \qquad (1)$$

where β is the Twiss parameter, ε the beam emittance, η the dispersion function, and ΔP the momentum spread. If two NDPMs are installed at a location with the same Twiss parameters (β), but having a different dispersion function (η_1, η_2), the momentum spread is deduced from the above-mentioned equation to

$$\frac{\Delta P}{P} = (\frac{x_1^2 - x_2^2}{\eta_1^2 - \eta_2^2})^{1/2}, \qquad (2)$$

where x_1 and x_2 are the half beam width at the position with η_1 and η_2, respectively.

The time dependence of a half beam width at 20% height of a beam profile measured by MCP (at small η) is shown in the Figure 9, and the output of EM (at large η) is shown in the Figure 10. The time dependence of the momentum spread in the Main ring is calculated from those two figures and is shown in Figure 11, which shows a sharp peak at the transition time (~0.8s).

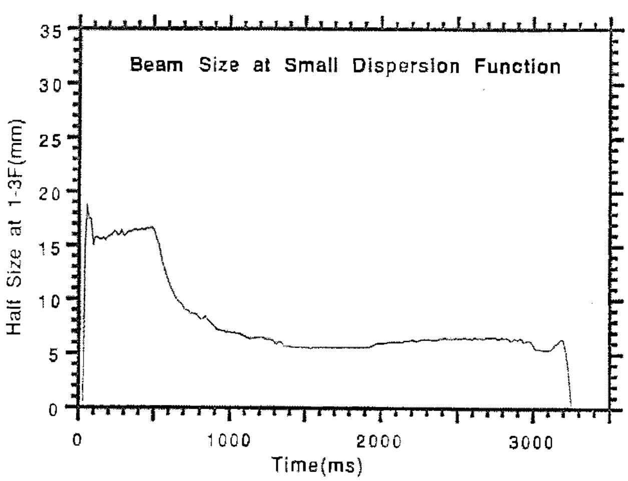

Figure 9. Time dependence of a half beam width at 20% height in the Main ring at small η.

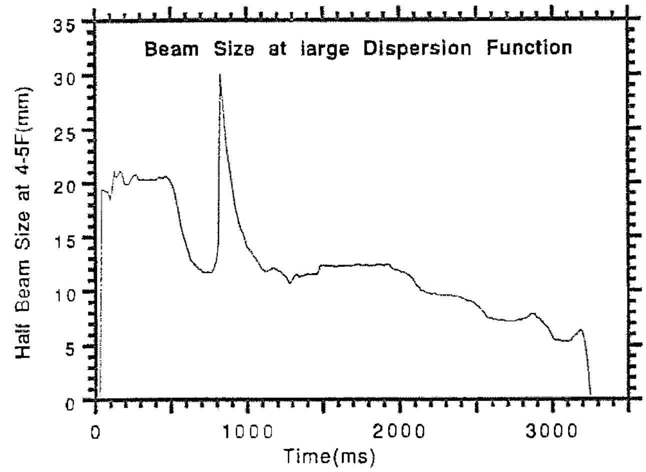

Figure 10. Time dependence of a half beam width at 20% height in the Main ring at large η.

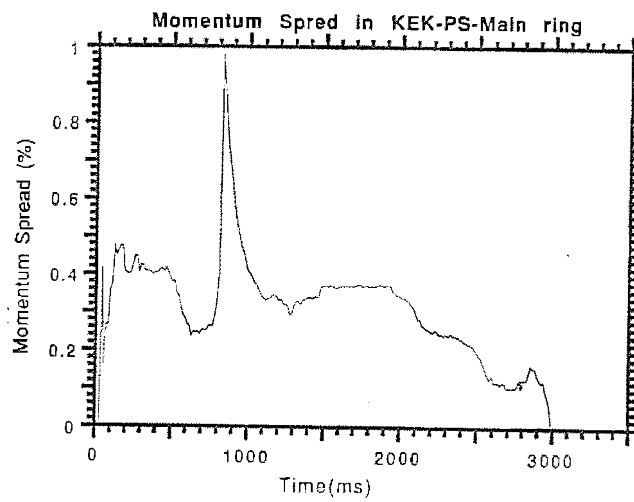

Figure 11. Time dependence of the momentum spread in the Main ring.

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