NON-DESTRUCTIVE BEAM PROFILE MEASURING SYSTEM OBSERVING FLUORESCENCE GENERATED BY CIRCULATING BEAM

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The KEK-PS has two sets of non-destructive beam profile monitors (NDPM) in the booster and three sets in the main ring for horizontal and vertical plane, which observe those ions produced by circulating protons hitting the residual gas.[1] The measured beam sizes are always larger than those obtained by the BEAM SCOPE method.[2, 3] It results from the space charge of the circulating proton beam.

In order to eliminate this demerit, the idea of using a luminescence generated by the beam colliding with the residual gas has occurred. This idea, however, is only an idea without measuring [4, 5] or using test equipment to observe the beam at the beam transport line by a CCD camera.[6] It is very hard to observe the time variation of the beam profile (size) in a synchrotron because of the poor S/N ratio.

We inserted an optical shielding in the booster synchrotron ring (proton: 40-500 MeV) with a slit facing the beam. An optical fiber guide is fixed at the end of the slit, led out of the vacuum and connected to a photo-multiplier. A vertical beam profile is obtained by moving the slit vertically without being effected by the electric potential of the circulating beam. The most important factor concerning this method is how to eliminate noise caused by secondary particles generated due to beam loss.

I. EQUIPMENT

Figure 1 shows the measuring system at a straight section of the KEK-PS booster ring. Two slits, having a 0.5mm height, an 80mm width and a 250mm length and a rough surface coated with black plating, are arranged in the vacuum chamber with the symmetry positions to the horizontal beam center. The end of the slit is connected to an optical guide which has an end with the same shape as the slit, and a 1m length comprising of 0.5mm$^{\phi}$ acrylic fibers. Another end of the optical guide is combined with another optical guide. The combined part of the fiber guide is about 1m in length, and has an end with a 10mm$^{\phi}$ round shape, which is connected to an acrylic rod of 10mm$^{\phi}$ and 60mm length supported by a gauge port at a flange of the vacuum chamber. Another end of the acrylic rod at the atmosphere side is connected by an optical fiber guide of 10mm$^{\phi}$ and 1.5m length, the other end of which is connected to a photo-multiplier.[7] This optical guide system is called a "signal system" for the convenience of explanation.

The same system of the optical fiber guide (called a "blind system") is arranged closely near to the "signal system". The only having a different point concerning the "blind system" from that of the "signal system" is covering the top end having a rectangular shape with blinds in order to shield any luminescence generated by the beam.

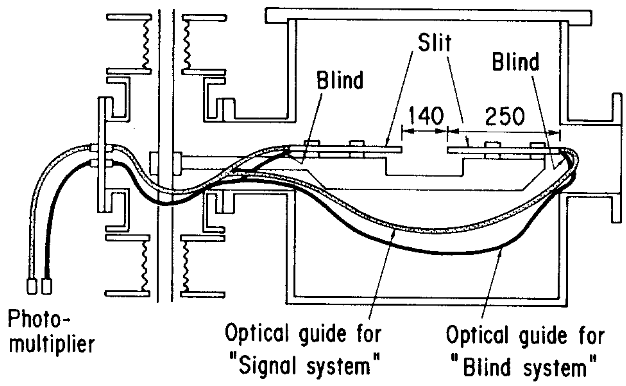

Figure 1: Measuring system to observe the luminescence generated by circulating beam

II. MEASURING

A . Aberration of the beam size

The two slits are set at the same vertical position and moved simultaneously so as to make the observing intensity be double. The largest vertical beam width (ΔY) measured by these slits, which causes an aberration of the beam size, is (see Figure 2)

$$\Delta Y = \frac{2d(a+\Delta x)}{L} + d \quad ,$$

where d is the slit height, L is the length of the slit, Δx and a are the horizontal distances between the slit end and the designed beam center, and between the designed beam center and the farthest beam position from the slit, respectively. By inserting the dimensions of our monitor (d=0.5mm, a=72.5mm, L=190mm, Δx=50mm) into above equation, the aberration of the beam size is found to be ΔY=1.3mm.

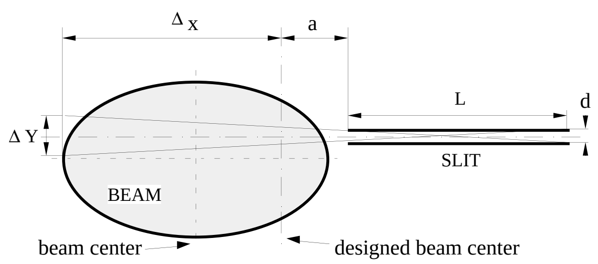

Figure 2: Aberration of the measured beam size due to the slit height

B. Noise and its elimination

The secondary particles generated due to beam loss at the vacuum wall penetrate the optical guide and produce Cherenkov light. The intensity of the light is much greater than the luminescence generated from collisions of the beam into the residual gas, and becomes severe noise. In order to eliminate this noise, the signal of the "blind system" is used. The quantities of Cherenkov light of the "signal system" and the "blind system" might be the same, because they are arranged close to each other. Therefore, the real signal is obtained by subtracting the signal of the "blind system" from that of the "signal system".

C. Block diagram of measuring system

As shown in Figure 3, the electric signals from the "signal system" and the "blind system" are amplified by a pre-amplifier (Z_{in}=10kΩ, A_{amp}=100 times) set near to the photo-multipliers, sent to the control room through a 50Ω coaxial cable, and connected to a subtracting circuit. The output signal of the subtracting circuit is observed by an oscillograph; a photograph is taken upon changing the vertical position of the slits.

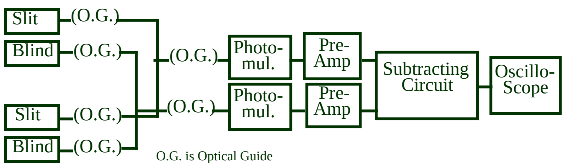

Figure 3: Block diagram of measuring system

D. Vacuum pressure and beam intensity

The S/N ratio is too poor to observe the beam profile under the normal vacuum pressure of $3*10^{-7}$ Torr at the location of this monitor. However, an observation becomes possible when the nearest ion pump is turned off and the pressure reaches $1.1*10^{-6}$ Torr one hour later, and under the almost largest intensity of $1.4*10^{12}$ ppp.

III. MEASURED RESULTS

A. Output signal figure

1. By moving the vertical position of the slits to the upper or lower limit, where no luminescence is injected into the slits, both signals from the pre-amplifiers of the "signal system" and the "blind system" are connected to channel 1 and channel 2 of an oscilloscope, respectively. Since it can be considered that the same intensity of Cherenkov light is generated in both systems under this condition, the two figures of the oscilloscope should agree with each other upon adjusting the bias voltages of the photo-multipliers (see Figure 4).

2. Both signals from the pre-amplifiers are connected to inputs of the subtracting circuit. Figures 5a and 5b show the averaging figures of 128 shots from the outputs of the subtracting circuit, where the slit position is at the upper limit and at the beam center, respectively. Since the S/N ratio is poor, the effect of noise still remains even at the slit position having the largest intensity of luminescence.

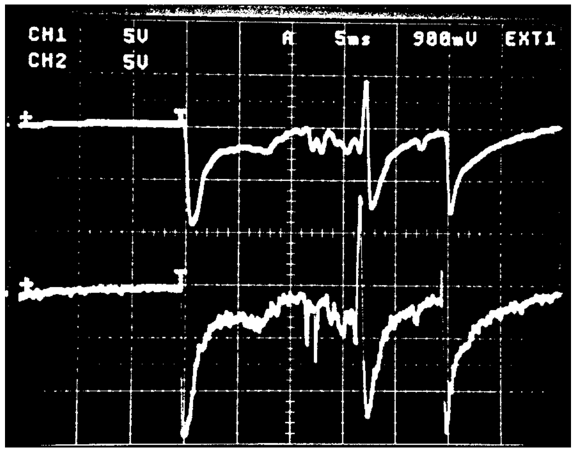

Figure 4: Upper and lower figure are the signals from the "blind system" and the "signal system", respectively, where the vertical position of the slit is set at the upper limit (X: 5ms/d, Y: 5V/d)

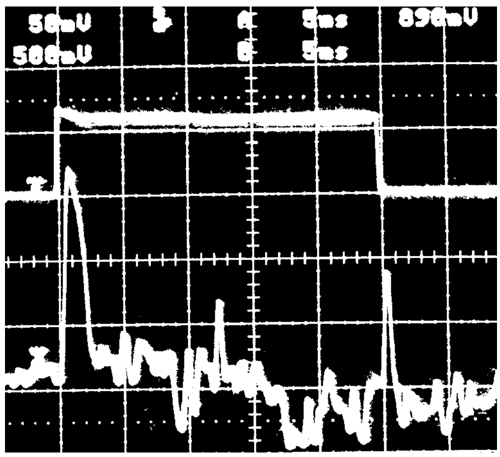

Figure 5a: Upper figure is slow beam intensity of booster, and lower figure is output signal of the subtracting circuit where the slit is set at the upper limit position (by averaging of 128 shots) (X; 5ms/d, Y: 0.5V/d)

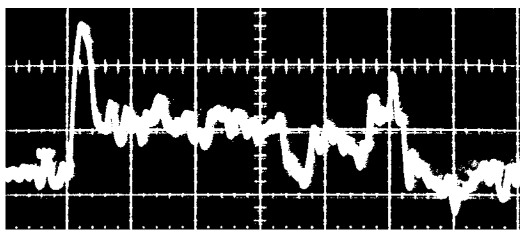

Figure 5b: In the case where the slit is set at the beam center position (by averaging of 128 shots)(Y: 0.5V/d)

B. Time variation of the beam profile

1. By moving the vertical position of slits from the upper limit to the lower limit in steps of 1mm, the output figures during the acceleration period (from 0 to 25ms) at every scraper position were taken by a photograph. By measuring and rearranging the values of the figures at times of 5, 10, 15, 20 and 25ms, beam profiles with the parameters of time are obtained, as shown in Figure 6. The time valuation of the full width of the beam profile at 50% height (FWHH) is taken from Figure 6, and plotted in Figure 7 (Photo NDPM).

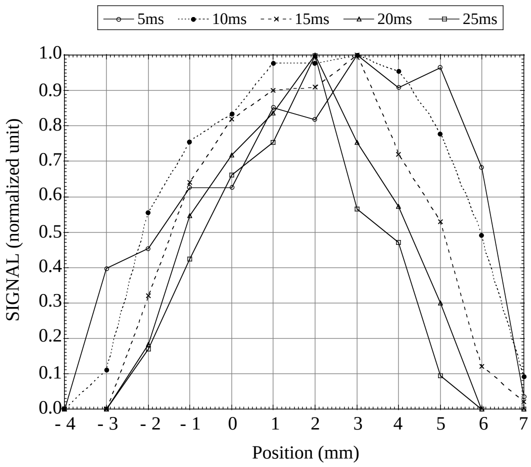

Figure 6: Beam profiles with the parameters of acceleration time from injection to extraction of the booster ring

2. The data measured by the ion collecting NDPM and BEAM SCOPE methods (the measuring system comprising two bump magnets, a scraper and a fast intensity monitor) and calculated adiabatic dumping curve are also plotted in Figure 7. Although the results measured by this monitor (Photo NDPM) and by the BEAM SCOPE are in good agreement with each other, those measured by Ion collecting NDPM are much larger than the others.

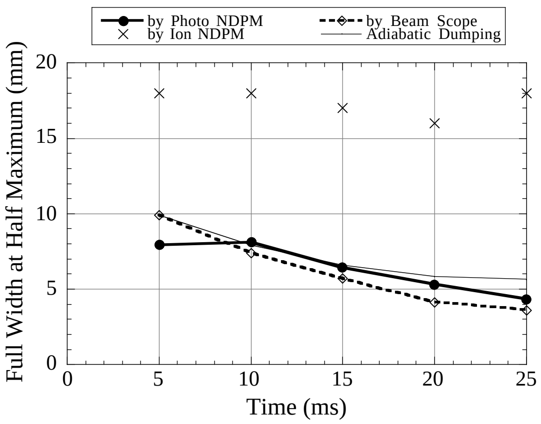

Figure 7: The time valuation of the full width of the beam profile at 50% height (FWHH)

IV. IMPROVEMENT

1. The S/N ratio is not good for taking clear observations. Since noise comes from the Cherenkov light generated by secondary particles penetrating the optical fiber, it can be eliminated by connecting a photo-multiplier to the slit directly without using any optical guides.

2. In this test measurement we adopted an old measuring technique, that is, taking photographs of the figures on an oscilloscope, and measuring the data with a scale. Data-taking, rearrangement and the outputs of the data will soon be automatically done by a computer.

V. REFERENCES

[1] T. Kawakubo, T. Ishida, E. Kadokura, Y. Ajima, T. Adachi, "Fast data acquisition system of a non-destructive profile monitor for a synchrotron beam by using micro channel plate with multi-anodes", Nucl. Instrum. Meth., A302 (1991) p397-405

[2] T. Kawakubo, E. Kadokura, T. Ishida, "On the reliability of measured results by non-destructive beam profile monitor", PAC93, Washington, USA, May (1993) p17-20

[3] T. Adachi, T. Kawakubo, M. Kihara, I. Yamane, C. Ohmori, "Beam profile measurement in the KEK PS booster using pulsed bump magnet and a movable scraper", EPAC94, London, UK, June (1994) p1655-1657

[4] Tazuo Shoji (Institute of Plasma Physics, Nagoya University), Private communication; He suggested the luminescence generated by the recombination of ion with electrons.

[5] Kay Wittenburg (DESY), Private communication, F. Hornstra, "A beam induced gas scintillation (BIGS) profile monitor for HERA", DESY, HERA, 89-04, Jan. (1989)

[6] D. P. Sandoval, et. al., "Video profile monitor diagnostic system for GTA", LA-UR-92-2727 (1992)

[7] Hamamatsu R5600U-01 (Spectral Response: 300-820nm, Material of Photo cathode: Multialkali, Current Amplification: $1*10^6$)