# FAST ROTARY BEAM SCRAPER IN KEK PS BOOSTER

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## ABSTRACT

The beam scraper with a rotating rod to scrape the beam was constructed to vary the beam size in the booster synchrotron of KEK PS. It was successfully used for the investigation of the strength of intrinsic depolarizing resonance in the booster. Horizontal beam size, vertical beam size and closed orbit distortion were also measured during acceleration.

## INTRODUCTION

The beam scraper was installed in one of the straight sections S-5 in the booster synchrotron of KEK proton synchrotron to investigate depolarizing resonances which have to be crossed during acceleration[1]. One of two strong depolarizing resonances in the booster is intrinsic resonance due to vertical betatron oscillation. The strength of intrinsic depolarizing resonance is proportional to the amplitude of vertical betatron oscillation. Thus the information about the resonance strength can be obtained by varying vertical beam size using the beam scraper. In order to investigate the resonance strength, it is necessary that vertical beam size can be varied quickly at any energy during acceleration. The fast rotary beam scraper with a rotating rod was constructed for this purpose. The rod rotating synchronously with the acceleration cycle of the booster is inserted into the beam to scrape it. The beam can be scraped at any energy during acceleration by adjusting the rotation phase of the rod.

## DESIGN AND CONSTRUCTION

The rotating rod of the beam scraper crosses a part of the beam to decrease vertical beam size. Crossing timing of the rod across the beam is variable to scrape the beam at any energy during acceleration. The beam size is varied by adjusting the insertion of the rotating rod into the beam. Figure 1 shows the whole assembly of the beam scraper. The rotating rod (80 mm in length and 3 mm in diameter) made from aluminum is driven by a DC servomotor. The rotation axis of the rod is parallel to the beam orbit. The vertical rotation axis of the motor is converted to horizontal direction by a gear assembly in the vacuum chamber. The ferrofluidic vacuum rotary feedthrough is used for vacuum sealing and the gears are coated by molybdenum disulfide for lubrication.

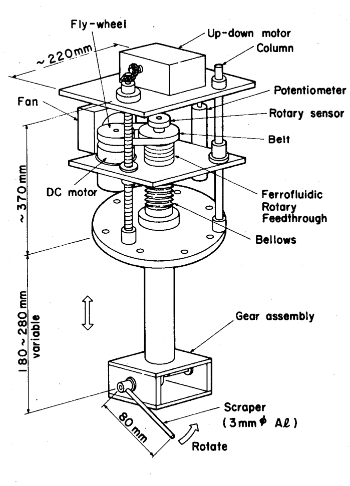


Fig. 1 The fast rotary beam scraper installed in the booster synchrotron.

The rotation of the rod is synchronized with acceleration cycle of the booster (20 Hz) by a phase locked loop (PLL) system. The block diagram of the PLL system is shown in Fig. 2. The servomotor is driven by the voltage which is proportional to the phase difference between the sinusoidal excitation current of the bending magnet and the rotation of the rod. The beam can be scraped at any timing during acceleration by adjusting the phase difference with the phase shifter. The time jutter of synchronization is about 20 μsec.

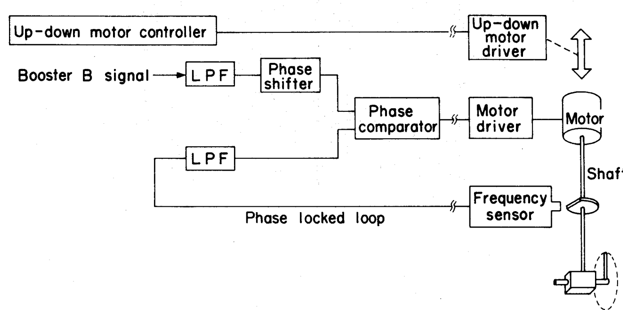


Fig. 2 Block diagram of PLL system for the servomotor control.

The particles which hit the rod are lost by multiple scattering and energy loss in the rod. The beam size blows up by multiple scattering. In order to scrape the beam without blow-up of the beam size, energy loss of the particle which hits the rod must be larger than the energy acceptance of the accelerating RF backet. Energy loss of the particle at 200 MeV by an ionization process in the rod is about 2 MeV which is larger than the energy acceptance of the RF backet of ± 0.5 MeV at the accelerating RF voltage of 8 KV. Thus it is expected that the particle which hits the rod is lost by one collision with the rod. Since the rotation of the rod is 20 Hz and its length is 80 mm, crossing time of the rod across the width of itself (3 mm) is 300 μsec which is much larger than the periods of beam revolution in the booster (0.625 - 0.167 μsec for 20 - 500 MeV) and of betatron oscillation. So the particles with the amplitude of betatron oscillation larger than the distance between the beam center and the top of the rod are lost completely by the collision with the rod[2].

For adjusting the vertical beam size the distance between the beam center and the rotation axis of the rotating rod is variable in vertical direction and its displacement is read by a potentiometer with the accuracy of about 0.1 mm. Vertical beam size was adjusted as follows. The vertical position of the rotating rod was adjusted to scrape the beam completely. In this case the top of the rod crosses the beam center. Then taking out the rod from the beam center by a displacement b, vertical beam size is given by 2b after beam scraping.

Figure 3 is an example of the beam intensity after scraping the beam with the beam scraper. Beam intensity after beam scraping becomes to be zero gradually as the top of the rotating rod approaches to the beam center. This causes the error in finding the beam center, so that we can adjust vertical beam size with the accuracy of about 0.5 mm. Vertical beam size can be measured in a similar manner.

Horizontal beam size can be also measured using

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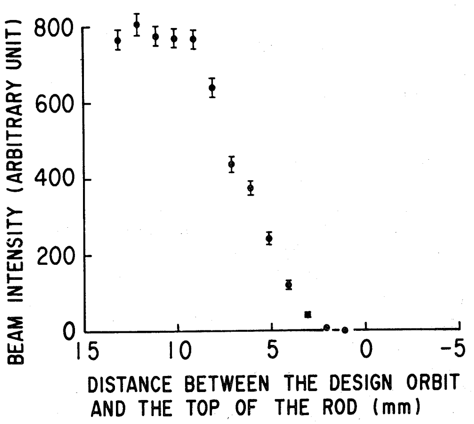


Fig. 3 Beam intensity after scraping the beam.

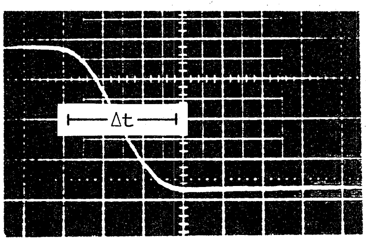


Fig. 4 Variation of beam intensity in the booster at transit of the scraper. Horizontal scale is 0.5 msec/div. The beam is scraped completely in Δt.

this beam scraper. Insertion of the beam scraper into the beam is adjusted to scrape the beam completely as shown in Fig. 4. In this figure the beam intensity goes to zero in about 1.5 msec. This time interval Δt gives the half beam size.

## SUMMARY AND RESULTS

Beam size was measured using this beam scraper. Figure 5 shows energy dependences of horizontal beam size and vertical beam size, respectively, on the beam energy during acceleration in the booster at the beam intensity of 1 - 2 × $10^{11}$ ppp. The curve drawn in this figure is the calculated vertical beam size with the assumption of the adiabatic damping and the vertical beam emittance of $\varepsilon_v$ = 13 π mm mr at 20 MeV. Adiabatic damping was clearly observed in the measurement of vertical beam size. In the measurement of horizontal beam size, adiabatic damping is not so clear because of the momentum spread of the beam. The vertical closed orbit distortion (COD) during acceleration was less than 2 mm at the scraper position as shown in Fig. 6.

Beam polarization of the polarized proton beam accelerated in the booster was measured at 500 MeV. Depolarization by intrinsic depolarizing resonance at about 260 MeV depends on the vertical beam size. Depolarization is expected to be small for large amplitude of vertical betatron oscillation since intrinsic resonance is so strong that almost complete spin-flip is expected in crossing this resonance. On the other hand depolarization is expected to be large for small amplitude of oscillation. Figure 7 shows the dependence of beam polarization on the vertical beam size. Positive polarization in this figure indicates that beam polarization filps twice by crossing two strong depolarizing resonances, imperfection resonance (at 108 MeV) and intrinsic one.

In summary, the fast rotary beam scraper was successfully used in the measurement of beam polarization of the polarized proton beam. It was also useful for the measurements of beam size and COD.

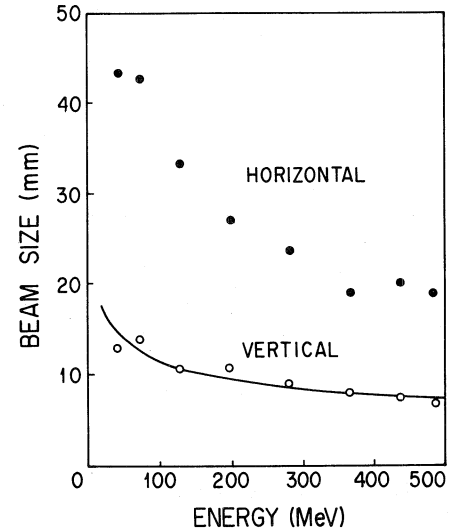


Fig. 5 Horizontal and vertical beam sizes during acceleration at the scraper position (straight section S-5).

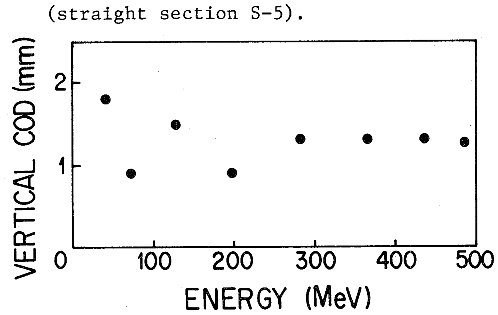


Fig. 6 Vertical closed orbit distortion during acceleration.

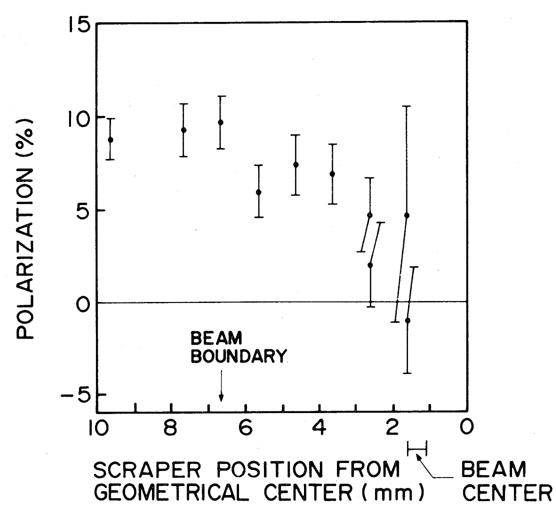


Fig. 7 Dependence of beam polarization of the polarized proton beam at 500 MeV on vertical beam size in the booster.

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2) H. Ishimaru et al., Proc. of the 2nd Symp. on Accelerator Science and Technology, Tokyo, 1978, p.119.