THE FIRST RESULTS OF OPTICS MATCHING USING WIRE SCANNERS FOR THE KEKB BEAM TRANSPORT LINE

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Abstract

In the beam transport lines from the injector linac to KEKB rings, four wire scanners were installed for each of positron and electron line. The vibrations and no-linearities of the wire holders were suppressed to be small enough for beam size measurements. Optics matchings were made using the wire scanners. Better transmission from the linac to the rings was obtained. By detecting shower due to Bremsstrahlung near the detector, the beam sizes were successfully measured without any beam tunings dedicated for background.

1 INTRODUCTION

In the KEKB the electrons(positrons) accelerated in the linac up to 8GeV(3.5GeV) are transported to the main rings through beam transport(BT) lines whose length are about 500m. At the BT, electron and positron lines have a double-decked structure in the first part of tunnel of 350m long and fed into separated tunnel in the rest part. In order to maintain high luminosity, a well-controlled operation transport line is required for minimizing tuning time and a stable operation. A wire scanner(WS) for monitoring beam profiles non-destructively is useful for these purposes. Beam tests of a prototype for WS have been done at KEKB injection linac so far[1][2]. We produced improved wire scanners as an actual model; more compact, less expensive but with smaller wire vibrations. Especially we took care of the wire positioning which leads directly the systematic error. In order to study this effect two prototypes with cantilever supports had been produced. One had linear guides in vacuum which can suppress wire vibrations most effectively since the cantilever was very short. Another had linear guide outside the vacuum chamber. We measured the wire positioning for both of them[3]. As a result, both types were feasible but we adopted the type with one linear guide for its easier handling in maintenance and lower cost. We installed ten wire scanners in total to the BT lines, for all of which wire positionings had been measured before installation.

In the entrance of BT lines, at least three WS's are needed to determine beam emittance and Twiss parameters in the optics matching. For redundancy, we adopted four wire scanners are mounted in each line. By using a photomultiplier tube(PMT) with plastic scintillator, we detected shower occurred near the PMT due to Bremssstrahlung emitted from the wire crossing a beam. The PMT's were set at a wide angle(65°) to the beam lines. By this setting beam background from the upstream was effectively shut off and high S/N ratio was obtained without any dedicated beam tunings. In this paper, the first results of beam-size measurement and optics matching in the positron BT line are presented.

2 PRODUCTION OF WIRE SCANNERS

2.1 A structure of the wire scanner

The schematic view of the wire scanner is shown in Fig. 1. A thin thread of tungsten of 100μm in diameter is stretched between three pins on the wire holder so as to form three(X-,U- and Y-) wires perpendicular to the beam. The holder is attached on one side of long shaft, while another side of which is fixed, in a cantilever style, to a stainless block mounted on the Linear Guide. The block is moved with a pulse-motor through a screw shaft. The Linear Guide rails are tightly bolted on the thick base plate, which also support the total weight of the mover. The holder and its support shaft is in vacuum. The conversion ratio of rotation with pulse motor to linear motion is 4μm/pulse. The linear motion is monitored through a potentiometer with a resolution of 50μm. The vacuum chamber has a window of stainless steel of 50μm in thickness which allows low-energy knock-on electrons(δ-ray) to pass the window. We detected the δ-ray at the window and also high energy γ-rays at the downstream using a PMT(Hamamatsu/R329-02) with a $40 \times 50 \times 10$mm^3 plastic scintillator.

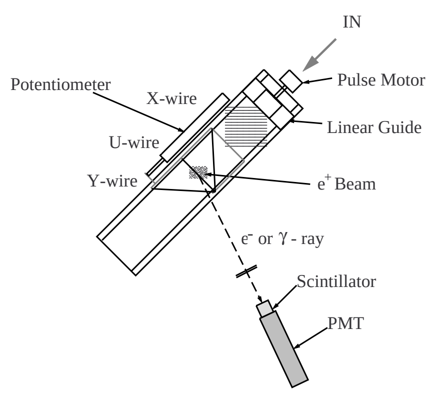

Figure 1: Schematic view of the wire scanner.

2.2 Measurement system of displacements of wire holder

Since we adopted a cantilever to support the wire holder, a vibration in the direction perpendicular to linear motion and to the beam was a serious concern. We have measured a static displacement (no-linearity) and also a vi-

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bration during linear motion. The layout of measuring system is shown in Fig. 2. A laser displacement-meter, KEYENCE/LC2430, was placed at the side of the wire holder. The LC2430 measures the distance from the surface reflecting the emitted laser light, using a built-in position-sensitive detector(PSD). The resolution is 0.02μm. As a reflector, we attached a block gauge with flatness of less than 0.1μm and with area of 30$\times$10mm^2 on the one side of the holder. We measured the displacements for all of ten WS's to be installed within the area of the block gauge. The linear motion was monitored with a magnescale. The measurement was done without a vacuum vessel. The pulse rate of the pulse motor was 1kHz. The results were: maximum amplitude of non-linear displacement was $\pm$8μm in peak-to-peak, maximum amplitude of vibration was $\pm$10μm in peak-to-peak. These are sufficiently small for the present beam size.

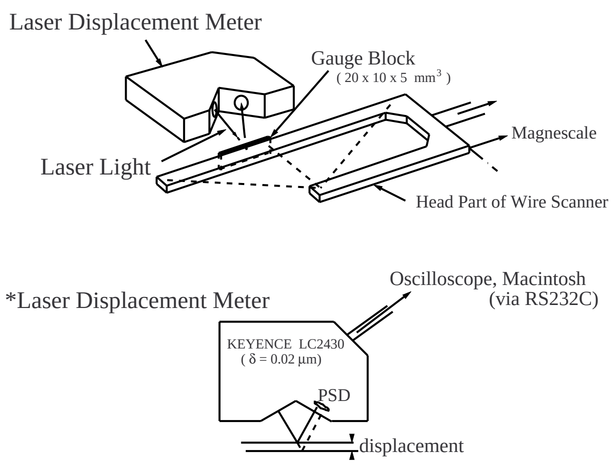

Figure 2: Schematic view of vibration measurement system.

3 OPTICS MATCHING

3.1 Arrangement of the wire scanners

The four wire scanners were placed at the downstream of quadrupole magnets for each of the positron and electron line. The arrangement of WS's in the positron line is shown in Fig 3. Two detectors(PMT's with plastic scintillators) were set for the four wire scanners: One PMT located near the C-wire detects high energy particles emitted from wires of "A" and "B", while another PMT near the D-wire detects particles emitted from wires of "C" and "D". For electron line, all detectors sit on in the same manner as "D" detector. The PMT was placed just downstream of the window with 65° in angle to the beam line. The detectors were surrounded by lead shield of 66mm in thickness in all direction, while to the upstream side the thickness was 166mm. The signal from PMT was put into the CAMAC ADC/2249W, LeCroy. The data were taken by a VME system via CAMAC serial highway.

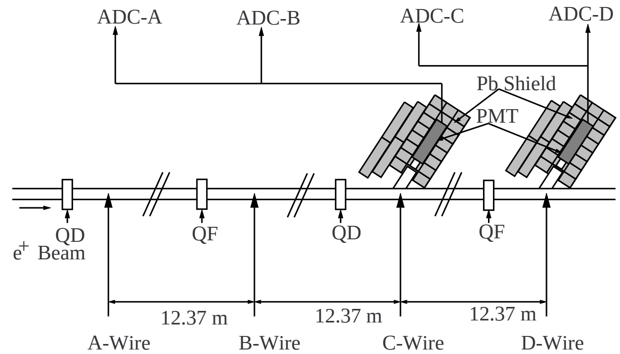

Figure 3: The arrangement of WS's in the positron line

3.2 Beam optics in the wire scanners

The four wire scanners were placed at a regular section of long straight, where the phase advance is $\pi/2$ for both of the horizontal and vertical planes. At the region, there is no dispersion in the design. A- and C-(B- and D-) wire scanners were placed at the downstream of the defocusing(focusing) quadrupole magnets. A matching of Twiss parameters to the linac was done by using all quadrupole magnets upstream the wire scanners, under the condition that the dispersion is to be closed and beta functions at some points not exceed some maximum values.

3.3 Measurement of beam sizes

The typical results of beam-size measurements are shown in Fig. 4 and 5 for electron(C-wire) and positron(A-wire) line,respectively. The horizontal axis is a position of wire holder along the scanning direction and the vertical axis is ADC count of the signal. We can clearly see three peaks corresponding to the Y, U and X wires crossing the beam. Each peak was fitted to an asymmetric Gaussian shape. The beam sizes of Y and X were obtained from peak with divided by $\sqrt{2}$. The typical S/N ratio was about 45 and 7.5 for electron and positron. For A, B, C wire scanners, we observed high S/N ratios almost independent on the beam condition. This is because the background from beam halo was almost completely shielded with the lead blocks of 166mm(30 radiation length). On the other hand, the signal from electromagnetic shower occurred at the beam pipe near the detector, which was generated by Bremsstrahlung γ-rays from the upstream wire. Although the detector sits at the wide angle(65°), huge amount of Bremsstrahlung γ-rays emitted in extremely small angle gives high S/N ratio. For D-wire scanner as shown in Fig 6, however, the PMT detects the small δ-ray as the signal, while the background comes from the shower produced in front of the detector by beam halo. We needed some dedicated beam tunings in order to decrease the background.

3.4 Matching

We have made optics matching at the positron line. The beam sizes at the four wire scanners were used to ob-

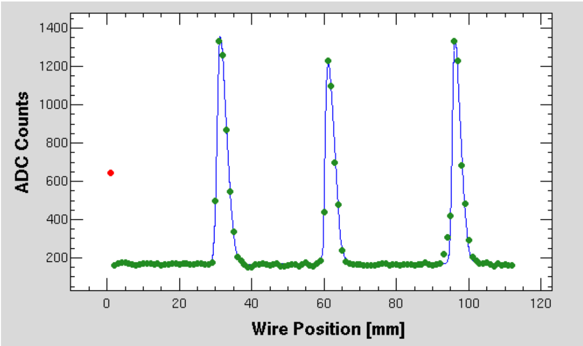

Figure 4: Typical transverse beam distributions(C-wire) in electron line. The left, middle and right peaks correspond to Y-, U- and X-wires, respectively.

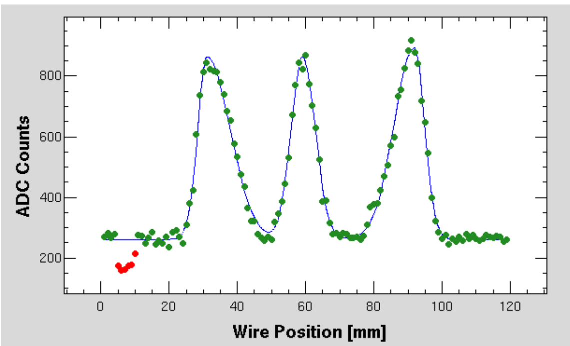

Figure 5: Typical transverse beam distributions(A-wire) in positron line.

tain Twiss parameters at the A-wire. In the phase space, we can draw two ellipses, one from measured parameters(S1) and another from design ones(S2). An additional ellipse(S3) can be drawn that it circumscribes the ellipse S1 and is similar to S2. Here Bmag means a ratio of an area of ellipse(S3) to that of ellipse(S2). It is given by[4]; $\mathrm{Bmag} = [\beta_2/\beta_1 + \beta_1/\beta_2 + \beta_1\beta_2(\alpha_1/\beta_1 - \alpha_2/\beta_2)^2]/2$. The subscripts 1 and 2 mean measured and design values, respectively. When measured twiss parameters are the same as design ones, Bmag becomes unit. The obtained emittances and Bmag's are summarized in Table 1. Although in the horizontal direction Bmag was not changed so much, in the vertical direction, it became smaller and the products of emittance and Bmag decreased after matching. This means that the transmission of the transport line becomes better.

4 CONCLUSION

We developed wire scanners for the BT line from the injector linac to KEKB rings. Since a cantilever support for a wire holder was adopted for easier maintenance and lower cost, we carefully designed them to suppress vibration and non-linear motion of the wire. Bench measurements showed that they were negligibly small for beam size measurements.

By using the wire scanners, the first trial for optics matching in the positron line has been successfully done.

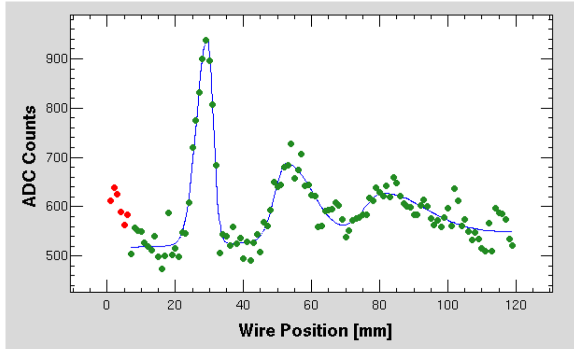

Figure 6: Transverse beam distributions of D-wire in positron line.

Table 1: The obtained emittances and Bmag's of positron line before and after matching.

	Before matching	After matching
ε_x [m]	1.09×10^{-6}	7.30×10^{-7}
Bmag_x	1.16	1.62
$\varepsilon_x \cdot \mathrm{Bmag}_x$ [m]	1.26×10^{-6}	1.18×10^{-6}
ε_y [m]	2.58×10^{-7}	2.33×10^{-7}
Bmag_y	6.54	2.04
$\varepsilon_y \cdot \mathrm{Bmag}_y$ [m]	1.69×10^{-6}	4.75×10^{-7}

Better transmission was obtained in the line. Emittances as well as Twiss parameters obtained in the optics matching process gave useful information for a tuning of the injector linac.

5 ACKNOWLEDGMENTS

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6 REFERENCES

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