A METHOD FOR MEASURING VIBRATIONS IN WIRE SCANNER BEAM PROFILE MONITORS

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Abstract

In the injector linac and the beam transport lines of the KEKB, a number of wire scanners will be installed for non-destructive beam profile measurements. A drive system, which utilizes a stepping motor and linear guides, will be used for them. Two prototypes have been evaluated in terms of vibrations at a wire-mount frame in a vacuum environment using a laser displacement meter. Vibrations observed for the two prototypes were found to be as small as $20\mu m$, which perfectly meets requirements from real beam operations.

1 INTRODUCTION

The KEKB accelerator is composed of 3 main components: an injector linac, beam transport(BT) lines and main rings. Electrons(positrons) are accelerated up to 8GeV(3.5GeV) by the linac about 500m long and guided to the main rings through the BT lines with the length of about 500m. Since the KEKB is a factory machine, a well-controlled operation of its injector is required for minimizing tuning time and a stable operation. From this viewpoint, beam diagnostic and monitoring tools will be essentially important. Of those tools, wire scanners (WS's) will be installed in some critical regions of the long linac and BT lines and used to measure transverse beam distributions non-destructively. In the machine tuning the wire scanners are used to determine beam emittances and Twiss parameters which are used in optics matching. In addition, they will be also used to watch beam condition during the stationary operation.

In the measurement with the wire scanners, a thin wire (typically several hundred microns in diameter) is moved across the beam transversely and γ-ray from Bremsstrahlung or secondary electrons, which are cased by an interaction between the beams and the wire materials, are observed by a detector. Since a thin wire is used, the measurement can be done almost non-destructively. On the other hand, we must be very careful with accurate positioning of wires. The positioning errors lead directly to systematic errors in results of measurements. The wire is driven by a pulse motor and linear guides. The positioning error can be divided into two categories. One is a static displacement mainly due to production errors of linear guides. The other is a mechanical vibration of holders in which the wires are stretched due to the wire-driving motion. In this report, we only consider the displacement and vibration perpendicular to the beam direction and to the wire-driving direction. Displacements or vibrations in other directions are negligibly small or not important.

2 TWO TYPES OF WIRE SCANNERS

We have been developed two different types of wire scanners as prototypes. Both are driven by a pulse motor with a maximum stroke of about 100mm. Type-A shown in Fig. 1A has two linear guides in vacuum which can suppress wire vibrations directly. On the other hand, Type-B in Fig. 1B has only one linear guide outside the vacuum chamber. For both types, a shaft about 200mm long supports the holder in which the wires are stretched. From the viewpoints of minimizing the wire vibrations, Type-A is better. However, Type-B has the advantages of a simpler structure and easier handling for maintenance: $i.e.$ the structure of Type A is more complicated in that the linear guides and ball bearings are in a vacuum and so replacement of the wire is somewhat troublesome. For both types, screw pitch is 2mm and the wire holders are driven by $4\mu m$ with one pulse of the pulse motors. In the present measurement, the position of the wire holder is measured by using Magnescale with the resolution of around $1\mu m$. Note that vibrations of the wires themselves can not be measured in the present method.

3 METHOD

We have employed a laser displacement meter(KEYENCE LC2430) for the wire position measurement. A schematic drawing of a system for the measurements is shown in Fig. 2. An object shaped like a flag was attached to the wire holder. The size of the flag is 40mm $\times$ 10mm with a shaft whose cross section is a square 5mm on a side. A block gauge with flatness of less than $50\mu m$ is pasted on the surface of the "flag". The displacement measurement is done by emitting a laser beam at the flag and detecting the position of a reflected beam with a built-in PSD. With this system, a resolution of measurements is about $0.02\mu m$. The measurement was also done in the condition that the chamber was evacuated to less than 10^{-5}mbar. For this purpose we installed an optical glass 5mm thick between the laser displacement meter and the flag. Although the optical glass 5mm in thickness makes an offset of about +1.8mm, it has nothing to do with results of the measurements.

The flag was installed at the wire holder as shown in Fig. 2. Since the head of the flag is stuck out of a vacuum chamber hole, we can drive the wire holder only by about 25mm-stroke with the flag attached. To enable the measurements in a wider range of the stroke, the flag is attached to three different points of the holder shown in the figure. This made it possible to measure the displacement in the range of about 50mm which is half of the full stroke.

We have done two different kinds of measurements; $i.e.$

a static transverse displacement dependent on the wire position and vibrations during wire-driving. Each measurement was done both in the air and vacuum conditions. In the measurement of the static displacement, we drove the wire in units of 0.7mm. We read a value on the laser displacement meter, which was an averaged value of 32768 data at each step after waiting for one second to ensure that the vibrations of the wire holder were damped. To see the reproducibility of measurements, we took data in the both forward and backward directions. In the vibration measurement, the flag was installed at the position nearest to the shaft head. At this position we expected the largest amplitude of vibrations of the three. As a measure of a size of the vibration, we took peak-to-peak displacements during continuous scans of the 25mm-stroke in the both forward and backward directions. In the measurement, analog signals from the laser displacement meter, which is not an average this time, were observed by using a digital oscilloscope. The pulse rate of the pulse motor was changed from 1kHz to 5kHz in units of 1kHz. At each step, measurements were repeated 5 times and we took an average.

4 RESULTS

Results are shown in Fig. 3 and Fig. 4. Fig. 3A and 4A show results for Type-A and Fig. 3B and 4B for Type-B. We only show results in the vacuum, since we did not observe any essential differences between the air and vacuum environments. The horizontal axis of Fig. 3 denotes the flag position (in units of mm) and the vertical axis shows the displacements. The figures in Fig. 3 contain data of three holder positions in both forward and backward directions. The linear parts of the data were subtracted from the figures, since these may come from a mis-alignment of the flag or others and has no essential importance. Sizes of static displacements in terms of the peak-to-peak values were about $10\mu m$ and $15\mu m$ for Type-A and Type-B, respectively. The displacement of Type-B shows a cyclic variation with a cycle of 2mm. This cyclic variation can be attributed to the pitch of a ball screw which converts the rotary motion of the motor to the linear motion. We can expect to suppress the cyclic variation by enhancing rigidness of a board which supports the linear guides.

The horizontal axis of Fig. 4 denotes pulse rates corresponding to the wire-driving-speed and the vertical axis shows the maximum (peak-to-peak) displacements during the continuous scans of the 25mm-stroke. Fig. 4A shows a data only in the forward direction. On the other hand, Fig. 4B contains results of the both directions.

As for the vibrations, all results of the maximum displacements for Type-A were less than $12\mu m$ except $21\mu m$ in the case of 4kHz. For Type-B, the maximum displacement is about $18\mu m$ also at 4kHz which is larger than the others in the range from 10 to $16\mu m$. We have to notice that the static displacements are included in the results of the vibration measurements. In the vibration measurements with continuous scans, the static displacements dependent

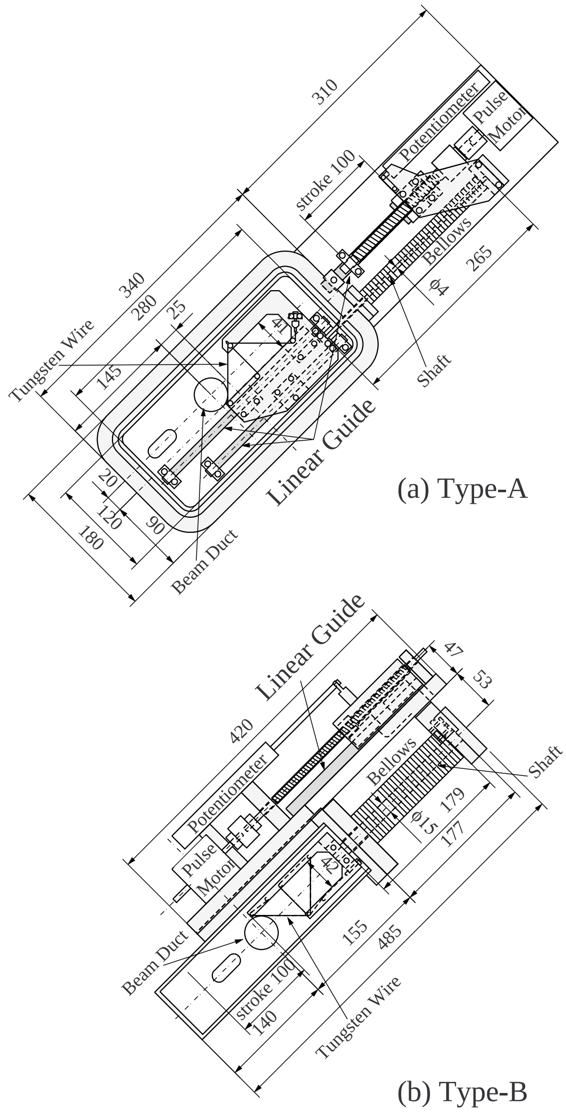


Figure 1: Schematic drawings of two wire scanners.

on the wire position were observed as vibrations. Besides these vibrations, we observed resonant peaks around 65Hz and 100 Hz. The 65Hz component is consistent with an eigenvalue of the proper vibrations for the shaft which is estimated to around 70Hz, although we have not yet understood the origin of the other component. The eigen frequency of the flag is about 500Hz and was not observed in the present measurement. The origin of the resonance around 4kHz is now under study.

With both types of prototypes, the oscillation amplitudes are less than $16\mu m$ except for around 4kHz. Since the horizontal and vertical wires make an angle of 45 degree to the wire-driving direction, effective displacements of the wires are these amplitudes divided by $\sqrt{2}$; $i.e.$ less than $11\mu m$. This value is well below a requirement from the machine operation for the linac and the BT lines. Type-A was installed in the Arc section of the linac after this vibration measurement. We made some preliminary beam test with

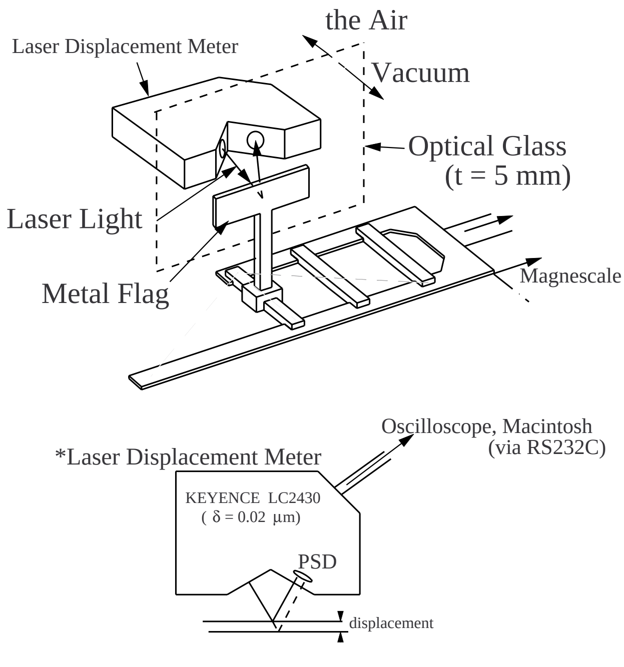


Figure 2: Schematic view of vibration measurement system.

this prototype system [1].

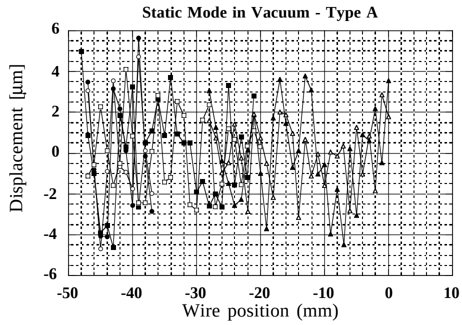
5 SUMMARY AND FUTURE PROSPECTS

We have developed two different kinds of wire scanners. For both prototypes, we measured wire vibrations during wire-driving motion in a vacuum environment. Measured vibration amplitudes were ten-odd microns except for the pulse rate of 4kHz. These are well below the requirement from the viewpoint of beam operations in the linac and the BT lines. There is still some room for improvement for Type-B. We can avoid the resonant pulse rate of 4kHz in the actual operation.

Since it turned out that both prototypes are feasible, we will adopt Type-B as an actual model. Type-B has the advantages of easier handling for maintenance and a low cost.

6 REFERENCES

[1] Y. Funakoshi et.al.:`BEAM TESTS OF A WIRE SCANNER FOR THE KEKB INJECTOR LINAC AND BEAM TRANSPORT LINE', in these proceedings.



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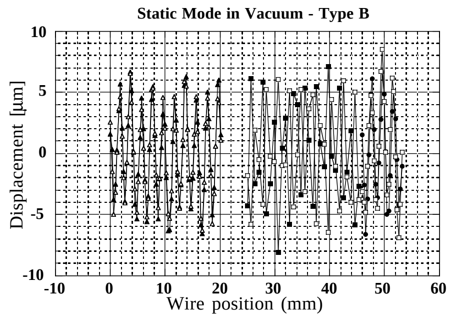

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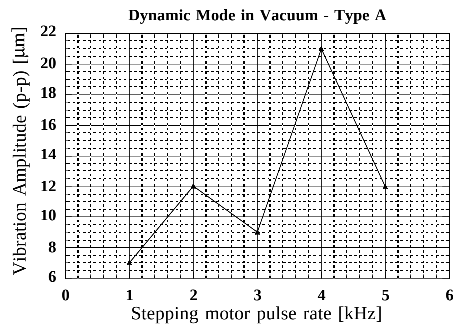
Figure 3: Results of static displacement measurements.



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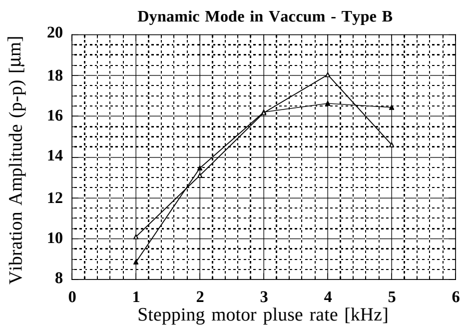

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Figure 4: Results of vibration measurements.