DISPLACEMENT MONITORS USING DIODE LASERS

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ABSTRACT

In low-emittance, high current accelerators, the magnet position should be monitored continuously to keep the magnet alignment as precise as several tens of microns. Two kinds of monitors are proposed; (1) a monitor of the relative displacement between two adjacent magnet support tables, and (2) a monitor of the displacement of a wire (that is a wire alignment system). Both monitors use laser diodes and PSDs (Position Sensitive Detectors). The first one monitors the relative displacement by measuring the position of the laser spot on the PSD. The resolution of the monitoring is expected to be about 1 µm. The second one detects the reflected laser light from the wire by two PSDs. The position of a thin wire (50 µm in diameter) can be monitored with a resolution of about 1 µm.

1. INTRODUCTION

An Accelerator Test Facility (ATF) [1] is under construction at KEK as a part of R&D efforts for linear colliders. It comprises a 1.54 GeV linac and a racetrack-shape damping ring. The main purpose of the damping ring is to realize a beam with very low emittance: the vertical and horizontal normalized emittances will be 5×10^{-8} m· rad and 3×10^{-6} m· rad, respectively. Precise alignment of magnets is required to achieve such low emittance. Simulations have shown that alignment tolerances of magnetic center are 60 µm in horizontal and 50 µm in vertical. and the tolerance for rotation around the beam line is 0.2 mrad. Real-time monitors are important to maintain such precise alignment. The FFTB of SLAC and the ESRF have real-time monitor systems. The FFTB uses a wire alignment system [2], and the ESRF uses the HLS (Hydrostatic Leveling System) [3]. Although both of them are excellent, the former is difficult to apply to arc sections, and the latter does not give the information on horizontal displacement. We propose two kinds of real-time monitors. Both of them use laser diodes and position sensitive detectors (PSDs). One is a displacement monitor which can be applied to the arc sections. The other is a wire alignment system simpler than that of the FFTB.

2. DISPLACEMENT MONITOR BETWEEN TABLES

Magnet movers are necessary for accelerators with tight tolerance since disturbance due to the ground motion and thermal expansion is no longer negligible. We will install five magnets for the arc sections (one combined-function bending magnet, two quadrupole magnets, and two sextupole magnets) on one table with three movers [4]. The relative displacements between these five magnets are negligible because their positions are close (less than 2.3 m) and the beam line is only 40 cm above the table surface. Then, we have to monitor and control only the position of the table. We will monitor the relative movement between adjacent tables since it is not easy to establish external references for the arc sections.

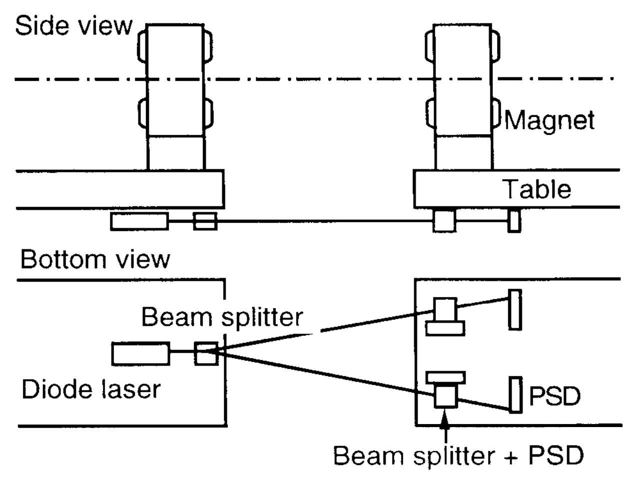

Fig. 1 Displacement monitor

Figure 1 shows the concept of this monitor. The monitor system is installed under the table plate to protect it against the radiation damage. The laser light from a diode laser is divided into two beams by a beam splitter. Two two-dimensional PSDs are used to determine each line of laser beam. We can obtain relative displacements in three directions ($\Delta x, \Delta y$, and Δz) and relative rotations (roll, pitch, and yaw) using 8 output signals from 4 PSDs. As the resolution of the system depends on the resolution of the PSD, we measured the resolution of the PSD itself [5]. The results of the measurement are shown in Fig. 2(a). The relative position of the PSD and the diode laser was changed by ±100 μm, and an output of PSD was recorded. The results show good linearity to the given displacement. The differences between the data and linear fit are plotted in Fig. 2(b). The standard deviation of this distribution is about 0.3 μm.

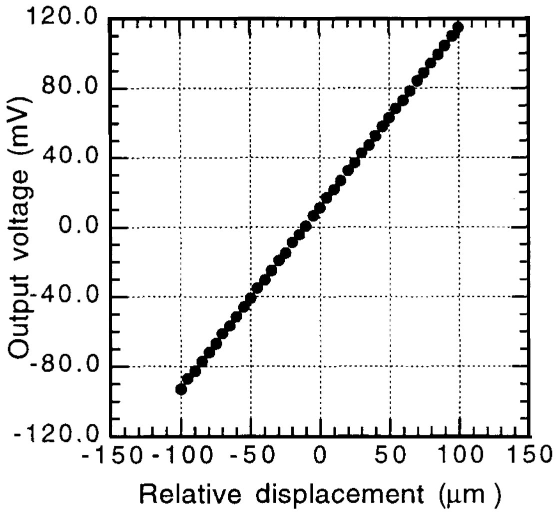

Fig. 2(a) Output of PSD

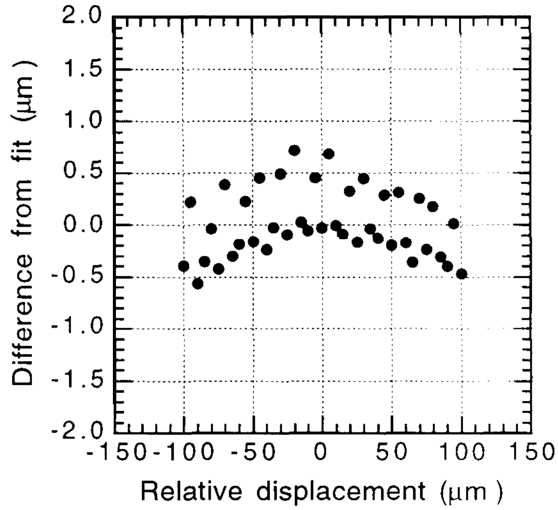

Fig. 2(b) Difference from fit

3. REFLECTION-TYPE WIRE POSITION SENSOR

The other monitor uses a thin wire as a reference. The movement of magnet relative to the wire is measured with a wire position sensor attached to the magnet. The idea is given in Fig. 3(a). The thin wire is illuminated by a laser diode, and the reflected light from the wire is detected by two one-dimensional PSDs. Then the wire position can be obtained using the following expressions:

$$x = \frac{l_1}{\sqrt{2}} \cdot \frac{l_2(s_1 + s_2)}{l_2^2 + s_1 s_2},$$

$$y = \frac{l_1}{\sqrt{2}} \cdot \frac{l_2(s_1 + s_2) - 2 s_1 s_2}{l_2^2 + s_1 s_2},$$

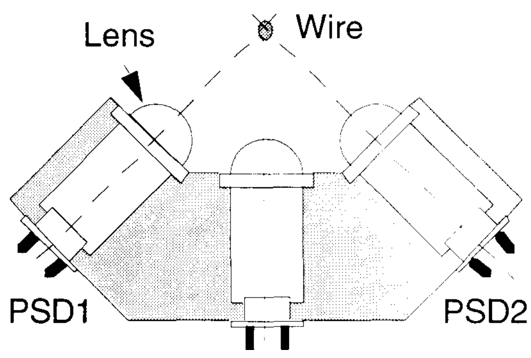

Fig. 3(a) Wire position sensor

where the definition of variables is given in Fig. 4.

A preliminary experiment was carried out with a diode laser and a gold-plated tungsten wire with a diameter of 50 μm (Fig. 3 (b)). First, we moved the wire in x-direction relative to the sensor by ±100 μm. We really moved the sensor block. The diode laser was not attached to the sensor block and was not moved. Therefore, the relative position between the wire and the laser was not changed. The calculated wire positions are plotted in Fig. 5(a) and (b). When we calculated the wire position, we made normalization so that the difference of the calculated x-values

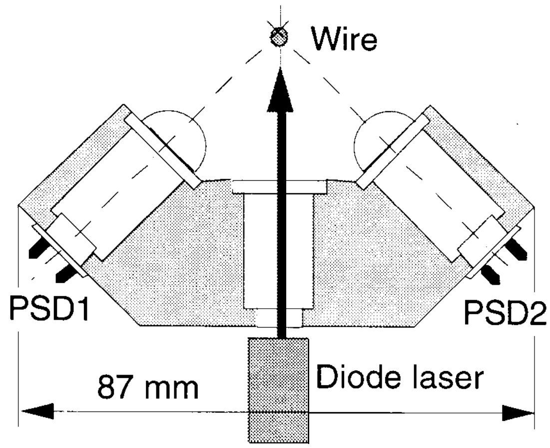

Fig. 3(b) Setup of preliminary experiment

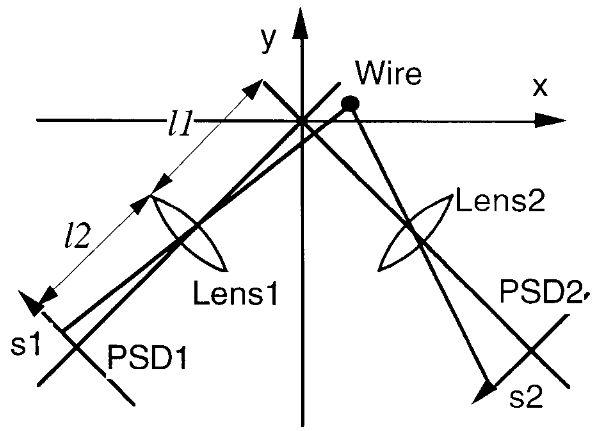

Fig. 4 Definition of variables

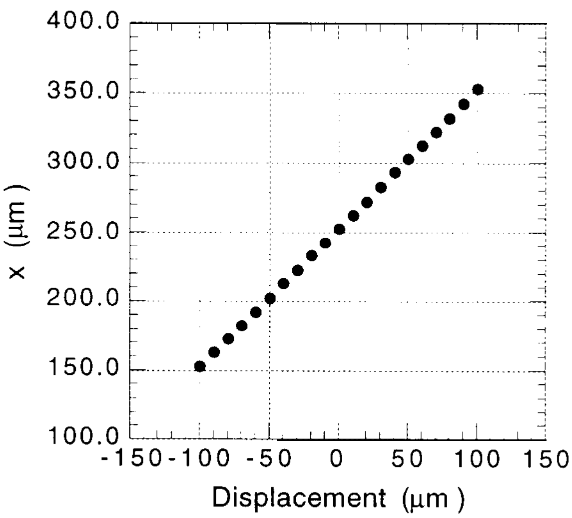

Fig. 5 (a) Calculated x-position

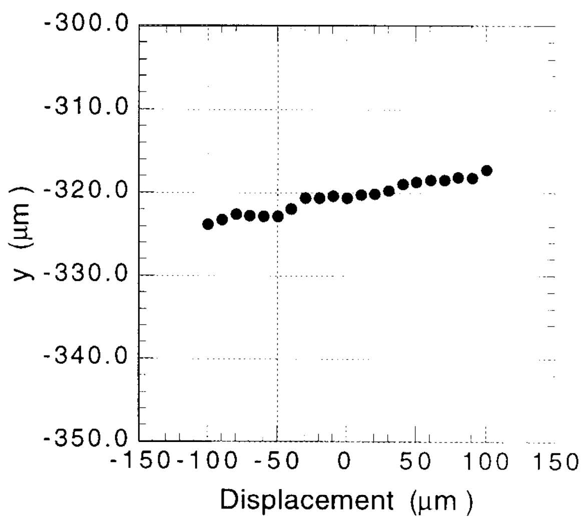

Fig. 5(b) Calculated y-position

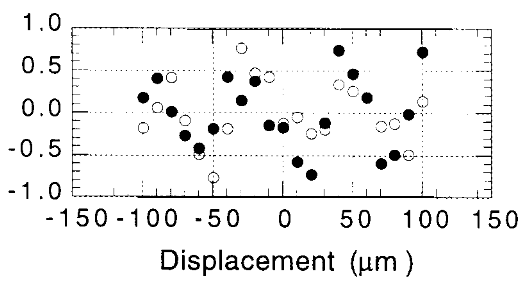

Fig. 5(c) Difference from fit
Solid circle : **Δx**
Open circle : **Δy**

at both ends became equal to 200 μm. This was done since we did not know the lengths l_1 and l_2 accurately enough. Both of x- and y-positions show good linearity to the given movements. Deviations from the linear fits are shown in Fig. 5(c). Next, the relative wire position was moved in y-direction. The results are shown in Fig. 6(a), (b), and (c). The normalization was applied to the y-values this time. The deviations distribute within ±2 μm in both cases (see Fig. 5(c) and Fig. 6(c)). The standard deviation of the distribution is slightly less than 1 μm even in the case of Fig. 6(c). Therefore, we can monitor the displacement of the wire with the resolution of about 1 μm. A disadvantage of this system is that it probably requires a thin wire to achieve good resolution and, therefore, cannot be applied to sections longer than a few meters.

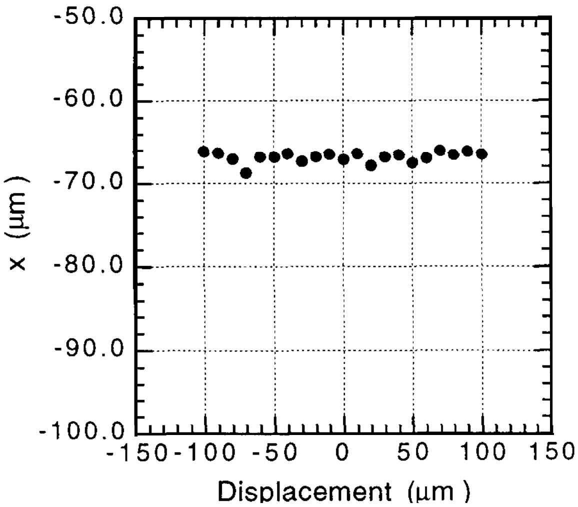

Fig. **6(a) Calculated x-position**

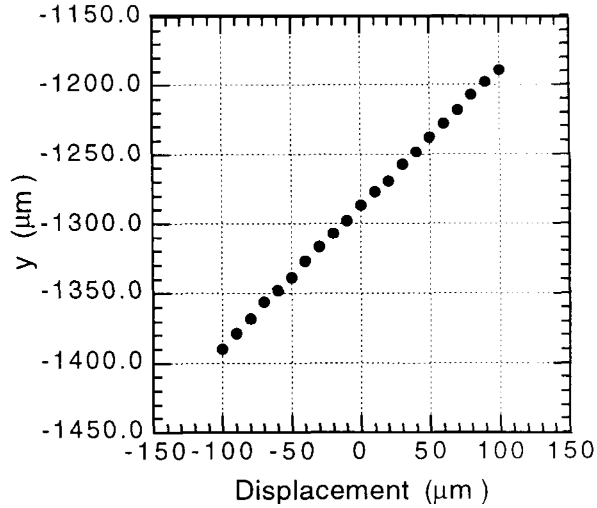

Fig. 6(b) Calculated y-position

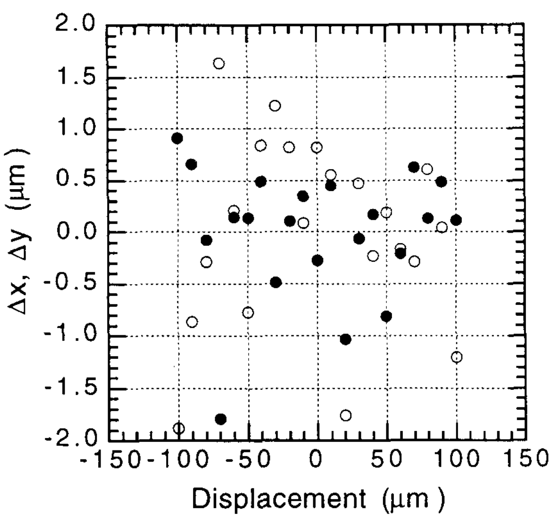

Fig. 6(c) Difference from fit
Solid circle : Δx
Open circle : Δy

4. SUMMARY

We intend to use the diode laser and PSDs to monitor the relative movement between magnet support tables of the ATF damping ring. The resolution of the PSD was tested at the first step of the development of the monitor. It is better than 1 µm.

The preliminary test of the reflection-type wire position sensor showed that the reflected light from the 50 µm gold-plated tungsten wire could be detected by one-dimensional PSDs [6]. It was also shown that the position resolution is better than 1 µm both in x- and y-directions.

The tests showed good results so far. However, we have to investigate the long-term stability of the diode laser and PSDs before installation of these monitors into the damping ring. The radiation damage has to be considered, too.

REFERENCES

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