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A TEST FACILITY OF SUPER-ACCURATE ALIGNMENT SYSTEM FOR A LINEAR COLLIDER

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Abstract To develop an alignment system for Japan Linear Collider (JLC), a test facility consisting of a laser interferometer and piezo transducers has been constructed at KEK. The fundamental test using the sine wave disturbing vibration shows the distance between the interferometer head and the corner cube has been kept stable within an accuracy of 50 nm up to 20 Hz by the feedback technique, called active alignment method. The experiment with the random frequency disturbance suggests this system can be extended to the possible super-accurate alignment system.

INTRODUCTION

In the design study of JLC,[1] the beam size is calculated to be about 2 nm at the final focusing region, so the usual ground motion with the amplitude of the order of 100 nm becomes a serious problem for the alignment of final focusing magnets. While the high frequency components are easily reduced by the conventional damping method, the lower components below 10 Hz are quite difficult to suppress owing to a low specific frequency of a passive vibration-proof table. One thus needs tables or girders which are actively controlled to keep their relative positions stable against low frequency disturbances.

We have constructed a test facility to understand the girder control system using a laser interferometer and piezo transducers. In this report we will describe the facility components, the frequency dependence obtained by sine wave experiment and the test results using the white noise (random frequency noise) as the disturbing microtremor.

TEST FACILITY

Since the initial goal of the present test facility is to keep the distance stable as accurately as 50 nm at the maximum length of 1 m, the wave length of laser is required to be stable to 5×10^{-9}. We also use the facility in a vacuum vessel to avoid the effect of air turbulence. From these points of view, we chose the separate-function laser system, called L-IM-10 (He-Ne laser of Tokyo Seimitsu Co.,Ltd.), in which the interferometer head is connected by fiber cables to the laser generator and to the fringe counter. We can easily install the head in the vacuum space by using a feed flange for fiber cables without any beam alignment.

The piezo transducer should have low driving voltage to avoid possible discharge in the vacuum space, and to have good linearity to achieve fast response in the feedback system. The selected transducer is Model P-841.20 of Physik Instrumente Co., driving voltage of which is 100 V for the expansion of 30 μm. The transducer has a position sensor installed in the same casing. It is thereby possible to get as excellent linearity as 0.1 % of full scale.

The control stage made of stainless steel has a double structure, the upper and the lower stage with the same direction of moving axis. In order to measure the real motion of the stages, a capacitance microsensor with the accuracy of 2 nm for 1 μm displacement has been also installed into each stage. It was found by the actual measurement that the yawing angle is less than 0.2 sec, resonant frequency 250 Hz, response time 40 msec/μm and load capacity 20 kg. The resonant frequency is high enough in comparison with the operating frequency of less than 20 Hz. Details of the test facility are described elsewhere.[2]

TEST

The block diagram and the picture of test facility are shown in Fig.1 and 2, respectively.

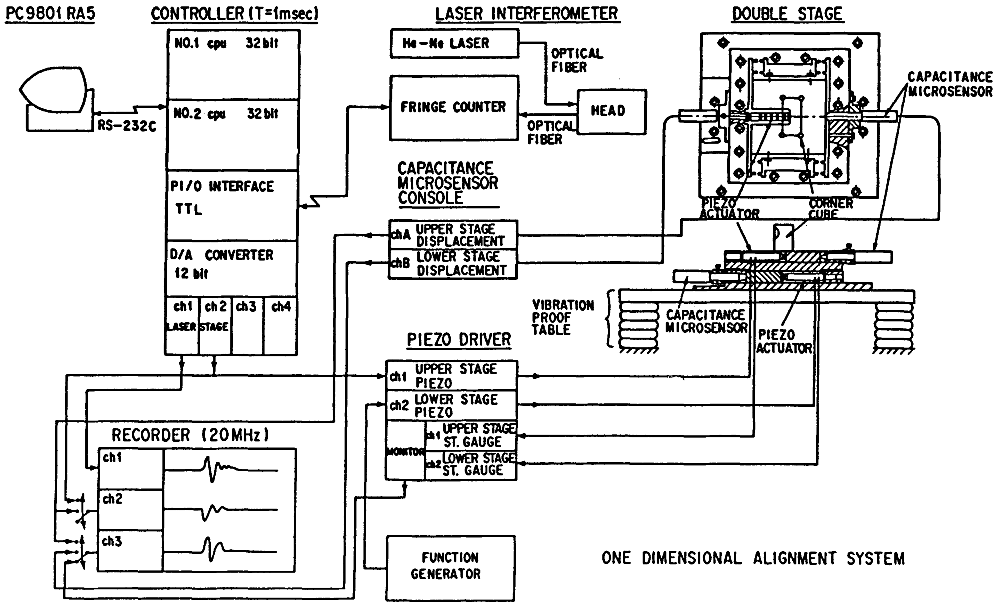

FIGURE 1 Block diagram of the test facility.

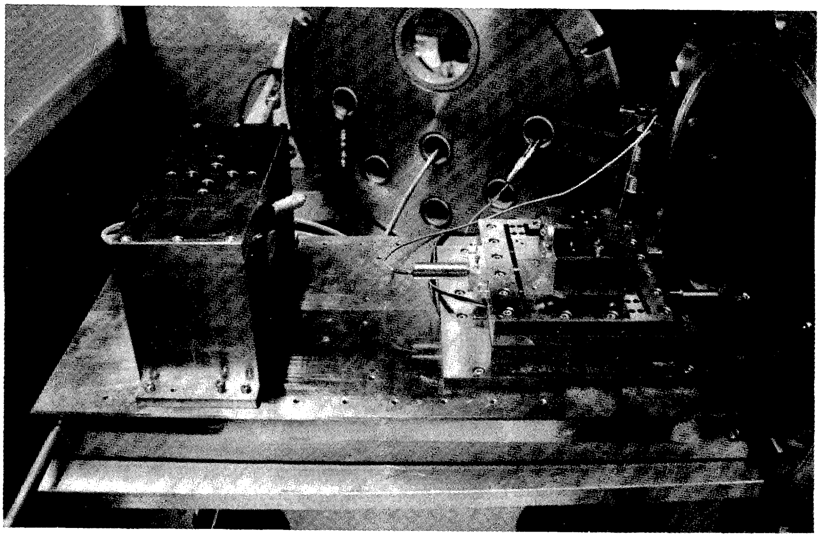

FIGURE 2 Picture of the test facility.

The corner cube is mounted on the upper stage and the interferometer head is located 28 cm from the corner cube as shown in Fig.2.
The vibration-proof table supports the whole components. The lower stage gives disturbing movements to the upper stage with an arbitrary wave form. The laser system measures the distance between the interferometer head and the corner cube with the sampling time of 1 msec. The CPU of the controller calculates the counteraction required to keep the corner cube stable, and then drives the piezo transducer of upper stage. Results of the test at 1 atm are shown in Table I for sine wave vibrations with amplitude of 500 nm.

TABLE I Vibrations after the position control against the disturbance of 500 nm amplitude.

Frequency (Hz)	Amplitude (nm)	Damping (dB)
0.1	19	-28
0.2	18	-29
0.5	19	-28
1	18	-29
2	25	-26
5	27	-25
10	30	-24
20	52	-20
30	77	-16
40	97	-14
50	190	-8.6

One can see that the damping of 20 dB or more is obtained up to 20 Hz. Especially for the vibration of less than 10 Hz, we can keep the stage stable within 30 nm. Figure 3 shows the typical damping feature observed on the oscilloscope, when a 10 Hz sine wave of 500 nm amplitude is added as disturbance.

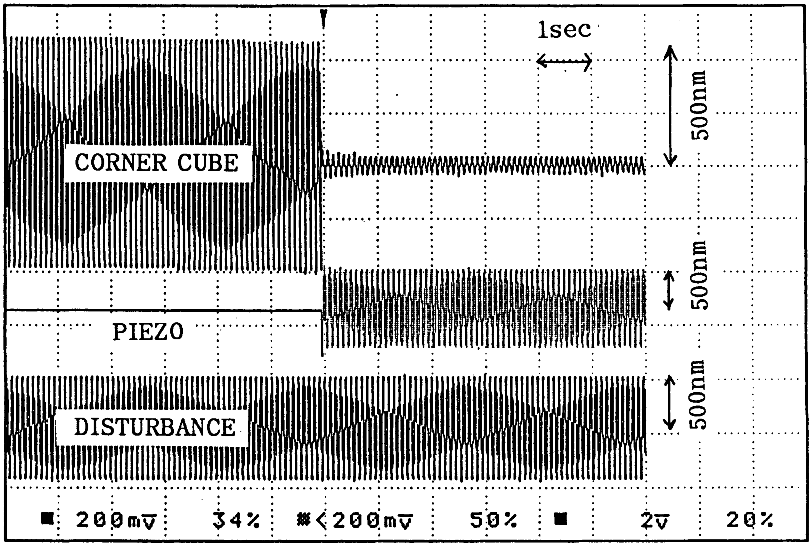

FIGURE 3 Typical damping seen on the oscilloscope against the disturbances of 10 Hz sine wave with 500 nm amplitude.

To investigate the response to the random frequency vibration, white noises with different cutoff frequencies are added as disturbances. Results are shown in Table II.

TABLE II Vibration damping against the white noise disturbances.

Cutoff Freq. (Hz)	Noise Amp. Max.P-P (nm)	Controlled Amp. Max.P-P (nm)	Damping (dB)
3	1380	50	-28.8
10	1920	100	-25.6
30	2220	300	-17.4
50	1980	630	-10.0

Figure 4 shows the typical display on the oscilloscope for the damping response against the white noise of 10 Hz cutoff frequency. The test in vacuum was performed without the capacitance microsensor, and we have obtained the same results.

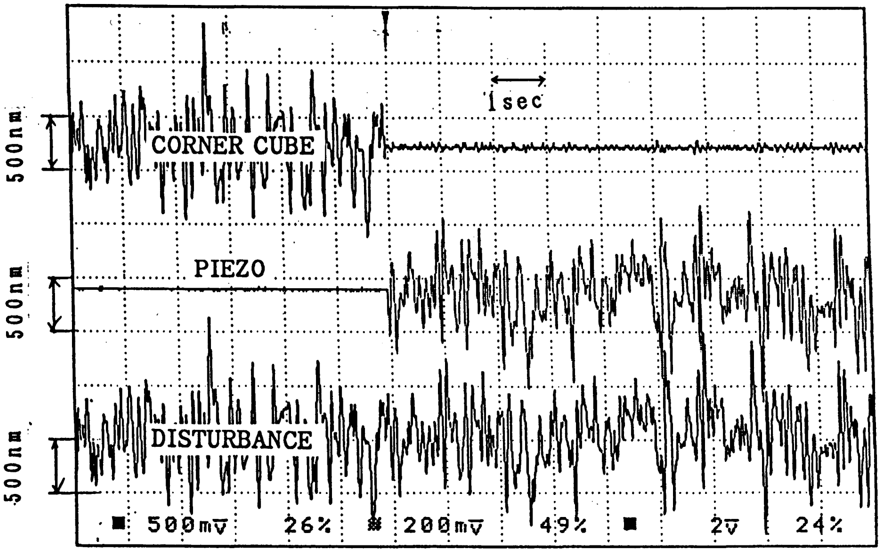

FIGURE 4 Typical display of the damping response against the white noise with 10 Hz cutoff frequency.

SUMMARY

The first test of the single axis active alignment was performed with a combination of laser interferometer and piezo transducer. Against sine wave vibration of 500 nm amplitude, the position has been controlled to better than 50 nm for frequencies up to 20 Hz. It has also been demonstrated that the damping is strong enough against the random frequency noise when the frequency components higher than 20 Hz are reduced by other methods.

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2. N.Ishihara et al, Presented at the First International Workshop on Accelerator Alignment,SLAC July 31 1989