NANO-PROBE USING OPTICAL SENSING

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Abstract: Nano-Probe System is described in this paper. Recently industrial parts have been smaller in size of sub-micrometer order. Therefore it is needed to measure such small mechanical parts in high accuracy. For this purpose we have developed nano-CMM(Coordinate Measuring Machine), whose resolution is nano-meter order. We are now developing a probe attached to nano-CMM, which is named nanop-Probe. It must be small enough and be able to detect touch of an object with high sensitivity. As a principle of nano-Probe system, we have proposed Optical Sensing System, new system that can detect displace of a metal ball and carried out basic experiment. We are making prototype. Experiment that inspects availability of Optical Sensing System is done.

Keywords: Coordinate Measuring Machine, probe, three dimensional nanometer measurement

1 INTRODUCTION

Recently, industrial parts have been smaller in size of sub-micrometer order. Therefore, it is important to measure such small mechanical parts in high accuracy. For this purpose, we have developed nano-CMM[1][2][3], whose resolution is nano-meter order. The probe system attached to nano-CMM must be small enough and be able to detect touch of an object with high sensitivity. We call such a probe system as “nano-Probe System” and are developing it.

2 CONFIGULATION OF NANO-PROBE

Figure 1 shows principle of nano-Probe system that we have purposed. Laser beam is focused at the center of a metal ball through a stylus pipe. If the metal ball is moved by touching the object, the reflected lay moves too. We can detect displacement of a ball by measuring the reflected lay.

Figure 2 shows configuration of nano-Probe system. A laser beam through an optical fiber is made parallel by a collimator lens mounted at the end of the fiber. The laser beam is focused and goes in the hollow stylus. The reflected beam at the surface of a metal ball is focused at a QPD (Quadrant Photo Diode). Outputs of the QPD are sent to PC by an A/D converter and processed.

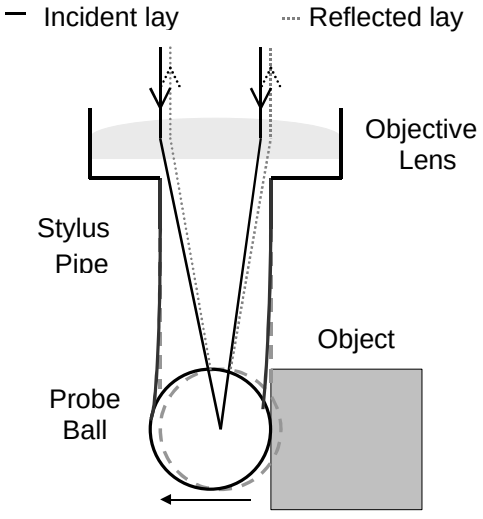


Figure 1. Principle of nano-Probe.

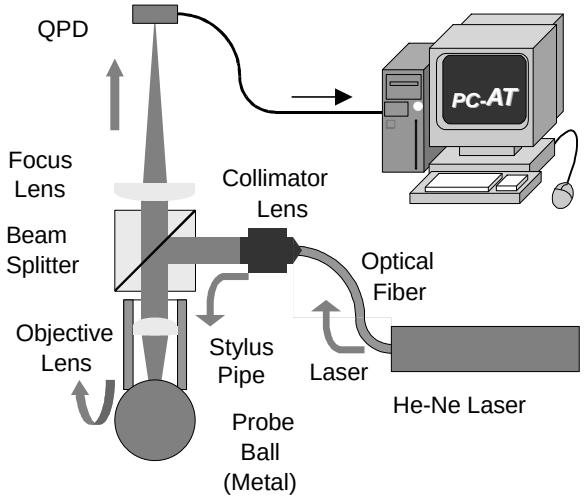
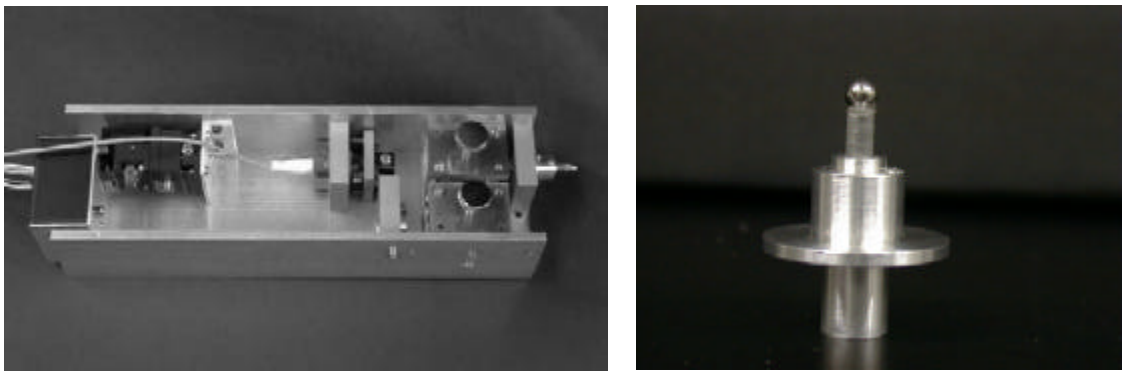


Figure 2. Configulation of nano-Probe.



(a) General view (b) Stylus part

Figure 3. Prototype nano-Probe.

Table 1. Specifications of prototype.

Item	specification
Length (Z-Axis)	200mm
Width × Depth	75mm×40mm
Mass	930g
Focal Length of Objective Lens	15mm
Focal Length of Focus Lens	150mm
Material of Probe Ball	Steel
Diameter of Probe Ball	5mm
Sphericity of Probe Ball	0.1μm
Material of Stylus	Acrylic Resin
Outer Diameter of Stylus	4mm
Inner Diameter of Stylus	3mm
Length of Stylus	10mm

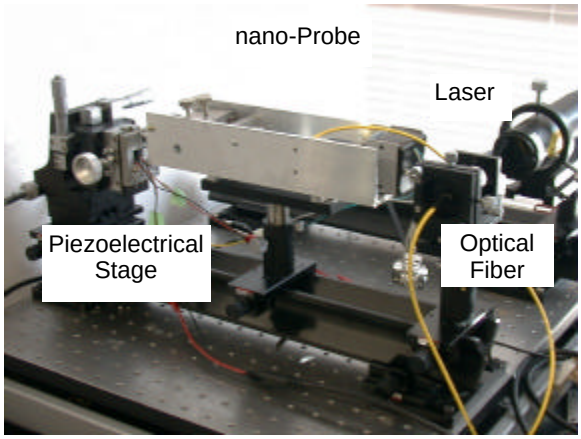


Figure 4. Experimental Setup

3 PROTOTYPE NANO-PROBE

Figure.3 shows prototype of nano-Probe. Table.1 describes its specifications. The stylus is made of acrylic pipe. This stylus is bent by elastic deformation and a probe ball is fixed at the end of the stylus. The laser-detecting unit including QPD and a circuit moves three-dimensionally by the translation stage. The circuit changes current from QPD into voltage and outputs to A/D converter in PC-AT. He-Ne laser is conducted by a single mode optical fiber. QPD is used to detect the displacement of the laser spot. The displacement is derived from output r_x and r_y, which are calculated by each outputs of diode as follows (Figure 4).

$$r_x = \frac{(p_1 + p_4) - (p_2 + p_3)}{p_1 + p_2 + p_3 + p_4}$$
$$r_y = \frac{(p_1 + p_2) - (p_3 + p_4)}{p_1 + p_2 + p_3 + p_4} \quad (1)$$

4 EXPERIMENT

We carried out experiments to estimate the accuracy of the prototype nano-Probe. Figure.6 shows experimental setup. We move a probe ball circularly by applying voltage to a piezoelectrical stage and record outputs of QPD. The diameter of probe ball's trajectory is 500nm.

Figure 6 shows output voltage from each diode of QPD. The difference of each diode's output is shown in figure 7. The total voltage is highly disturbed by fluctuation of He-Ne laser and each output is disturbed too. Figure 8 displays ratio of QPD's output which is divided by total voltage. The

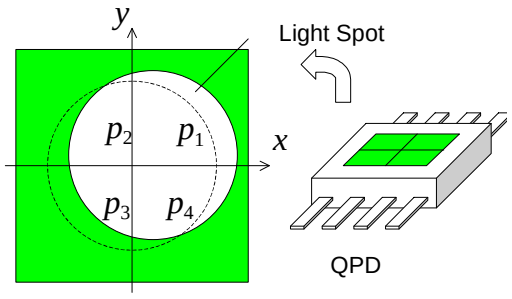


Figure 5. Detection of the displacement of a spot using QPD

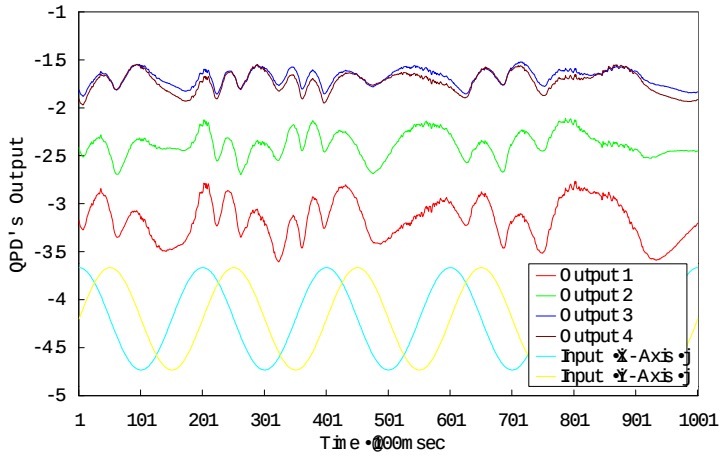


Figure 6. Outputs of QPD

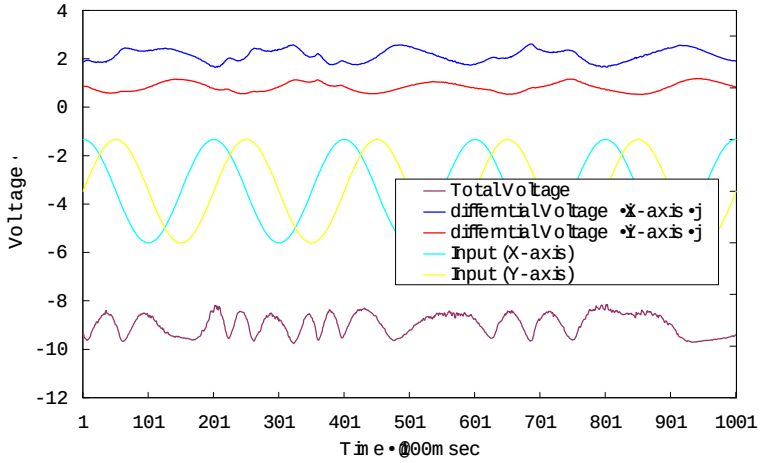


Figure 7. Differential Voltage and Total Voltage

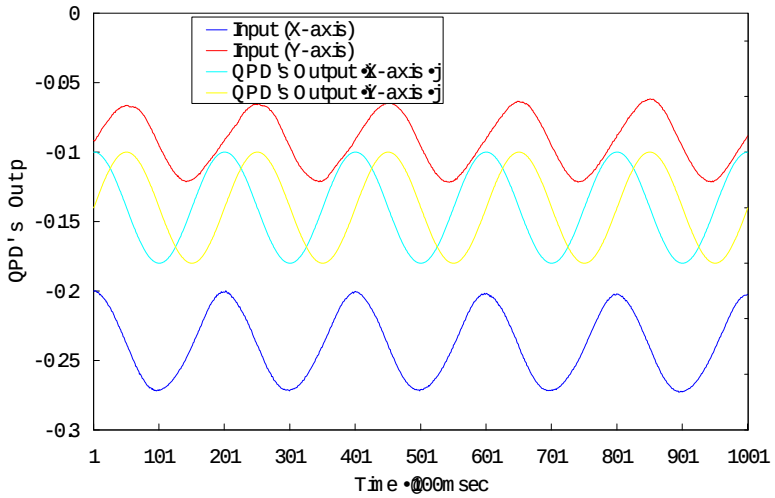


Figure 8. Ratio of QPD's output

ratio of diode's output has less noise and varies with the displacement of the probe ball. The ratio is shaped to sign curve corresponding to piezoelectrical stage.

The outputs of X-axis and Y-axis is shone in figure 9. The shape of graph is distorted and drifted. But repeatability is under 10nm even if including error by drifting.

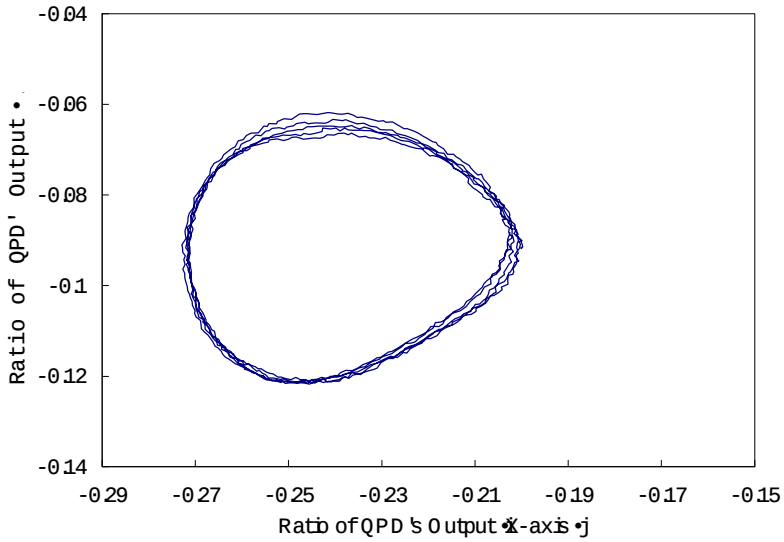


Figure 9. Lissajou's figure

5 CONSIDERATION

Prototype nano-Probe is capable of detecting displacement of the probe ball in nanometer-order and repeatability of which is under 10nm.

The distortion of plotted outputs of QPD is caused by angler error of piezoelectrical stage or the distortion of spot light. The drift of data is caused by the drift of scale or piezoelectrical stage.

It is considered that we can reduce repeatability by eliminating or compensating the influence of drift.

6 CONCLUSION

We have made the prototype nano-Probe and carried out basic experiment. The prototype can detect the displacement of the probe ball by order of nano-meter two dimensionally. We must eliminate or compensat the influence of drift.

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