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MICROLASER DISPLACEMENTMETER

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Abstract: An extremely small optical displacement sensor using a laser diode integrated with a microlens and based on the composite cavity principle was constructed. The microlaser displacementmeter has been developed using this optical sensor. The measuring resolution of the displacement is less than 0.01 µm and it can detect very low velocities of less than 5 µm/s. The optical sensor is very small, 800 µm × 900 µm. The microlaser displacementmeter shows good linearity between relative displacement and output signal.
Keywords: Optical micro system, Microlaser, Displacementmeter

1 INTRODUCTION

Laser displacement meter and Doppler velocimeter have been widely used to measure the displacement and velocity of many kinds of materials, such as steel, paper, and liquid. However, conventional laser devices are large and expensive. When many measuring points are needed, many fiber cables have to be handled between the probe and the equipment. Integrated optical circuits solved these problems.[1-2] These optical devices are hybrids and the laser diodes and photodiodes are attached separately. Therefore, the difficulty of aligning each of parts remained problems. We, therefore, developed an integrated microlaser sensor. The sensor is constructed of laser diode, photodiode, microlens and waveguide. They are fabricated on the same GaAs substrate and ,therefore, there is no need to align the optical parts.

This paper describes an extremely small optical displacement sensor and the very small motion and vibration can be measured using the sensor.

2 STRUCTURE OF SENSOR

2.1 Structure

The structure of the integrated sensor is shown in Fig. 1. A laser diode (λ=850 nm), a photodiode and waveguide (fluorinated polyimide) are fabricated monolithically on a GaAs substrate. The laser beams are emitted from the ends of the laser diode and two beams are reflected by the left and right sides of the waveguide. The beams are emitted from the ends of the waveguide and are applied to the measuring object. The external object moves in the vertical direction and in the horizontal direction.

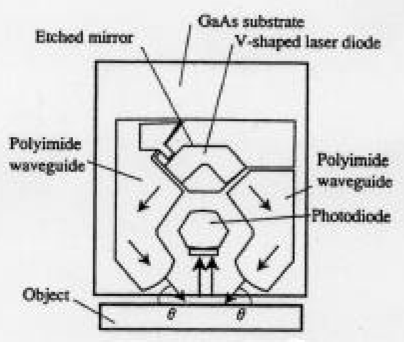

Figure 1. Structure of microlaser sensor

The fabrication process of the sensor consists of three steps: laser diode and photodiode formation, waveguide formation and die and wire bonding.

2.2 Fabrication process

The fabrication process of the sensor is shown in Fig. 2. The laser diode and the photodiode are fabricated on a GaAs substrate. The gradient-refractive-index film for the microlens is deposited on the photodiode by ion sputtering and the deposited film is etched by reactive-ion beam. A polyimide waveguide is fabricated by coating and baking. The waveguide is etched by RIE.

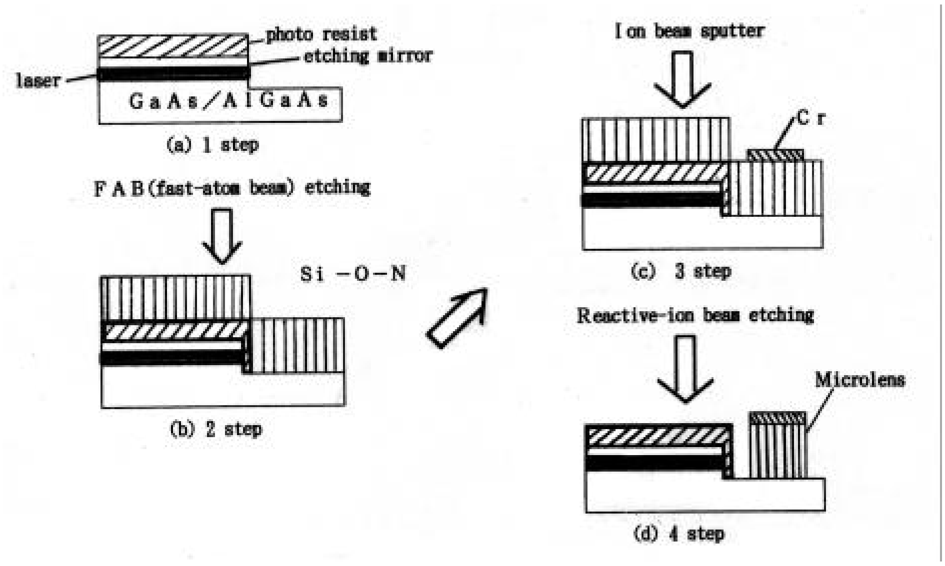

Figure 2. Fabrication process of microlaser sensor

3 EXPERIMENTAL SETUP

Experimental setup is shown in Fig. 3. The metal which reflects the laser beam is attached to a moving object. The object is moved by a piezoelectric actuator. The actual displacement of the moving object is measured with a laser interferometer displacement sensor and the resolution of the sensor is 0.01 μm. An example of the output signal from the photodiode is shown in Fig. 4.

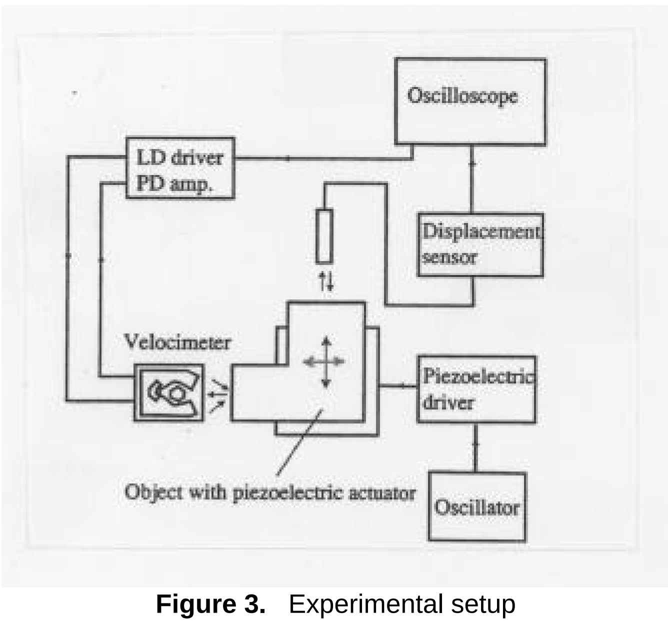

Figure 3. Experimental setup

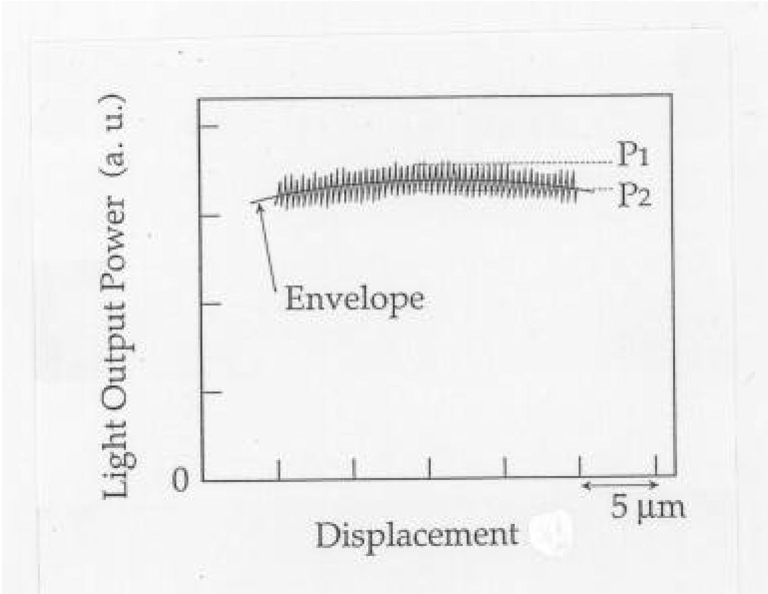

Figure 4. Signal from PD

The output signal of the photodiode is a sine wave and the two pitches of the sine wave is corresponding to four times of the half wave length of laser diode (LD). The signal pitches are changed by the distance between the LD and the measuring object.

4 EXPERIMENTAL RESULTS

4.1 Measurement of static displacement

Fig. 5 shows measured relationship between the light output power and the displacement of the object in the horizontal direction. The light output power is modulated to a sine-like wave by the displacement of the object with a period of 0.4 μm.

4.2 Measurement of dynamic displacement and vibration

The relationship between the output power of the photodiode and the displacement of the measured object is shown schematically in Figure 6. The output waves which are corresponding to 1-2, 1-3, 1-4, 1-5 and 1-6, are shown in Fig. 7 respectively. The dynamic displacement and vibration can be measured using these relationships.

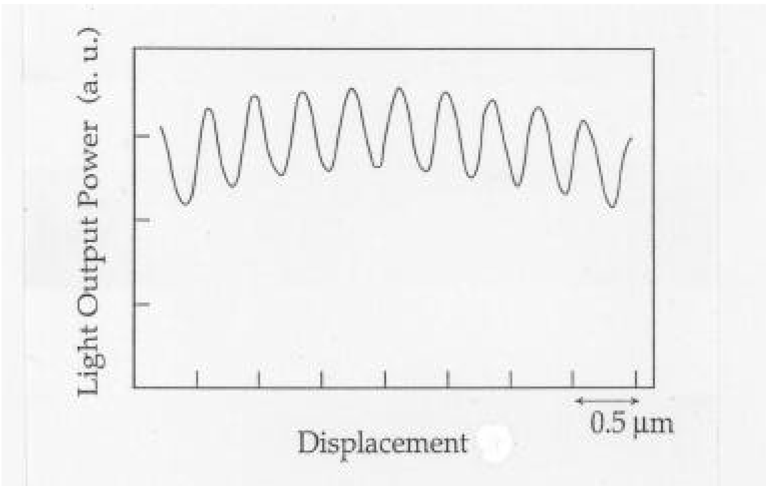

Figure 5. Output power from photodiode

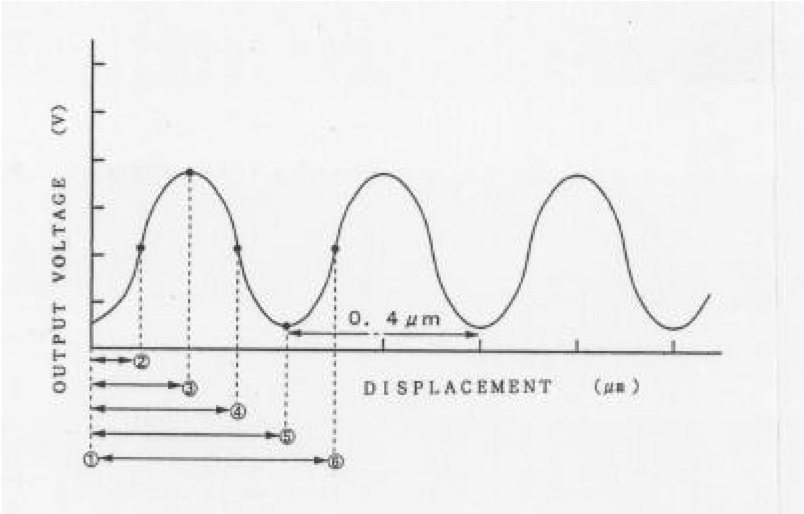

Figure 6. Schematic of output wave of photodiod

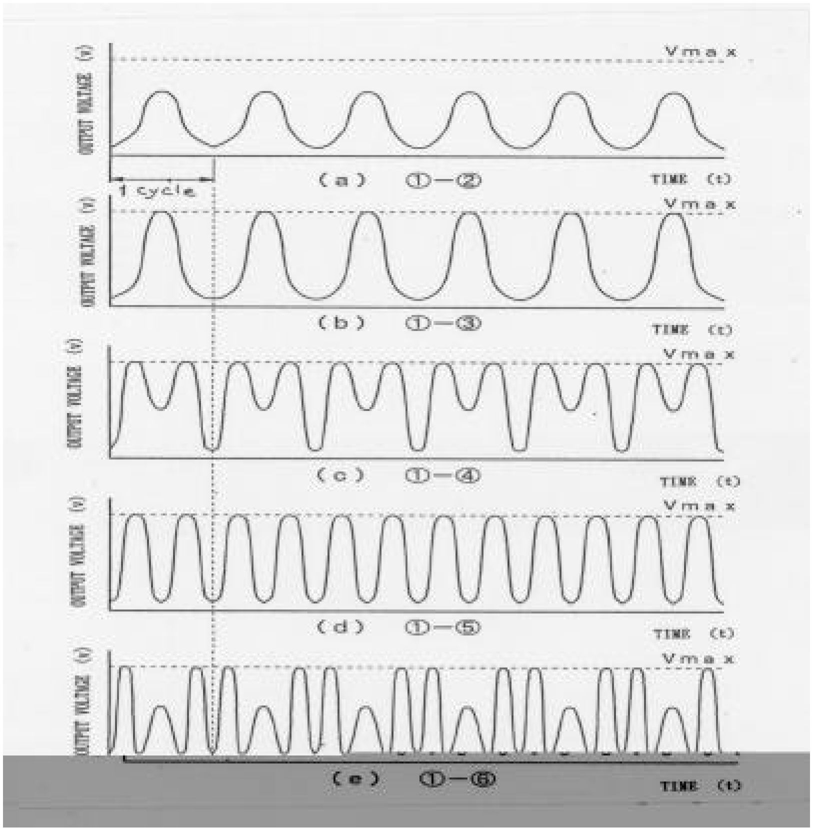

Figure 7. Examples of output waves

4.3 Dynamic characteristic of a piezoelectric driver

The frequency characteristic of the piezoelectric element is measured using the microlaser displacementmeter. The measured result is shown in Fig. 8. The input driven frequencies to the piezoelectric driver are changed from 0 Hz to 5000 Hz. The sub-micrometer order dynamic displacement can be measured by the microlaser displacementmeter. Moreover, nanometer order displacement will be measured using this sensor.

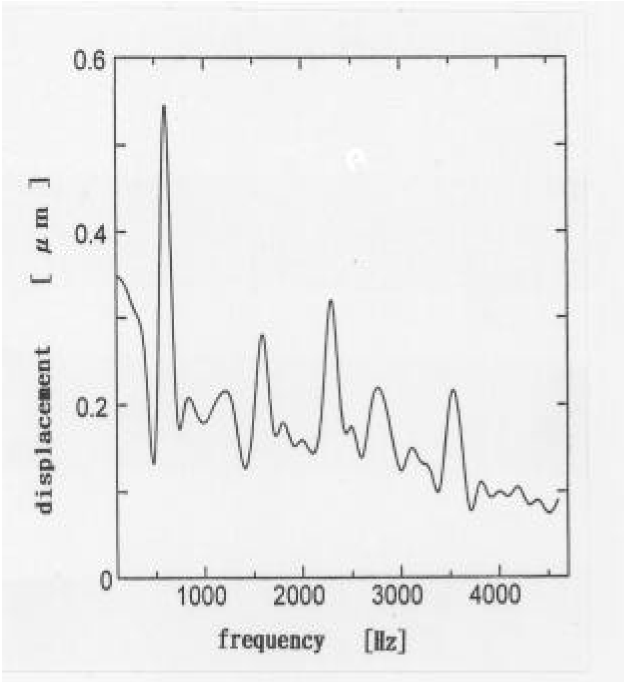

Figure 8. Frequency characteristic of piezoelectric element

5 CONCLUSIONS

An extremely small integrated laser displacement sensor was fabricated. The fabrication process and the evaluation of the displacementmeter were presented. The measured results satisfied the requirements of conventional laser displacement sensor. The proposed microlaser sensor can detect displacement less than 0.01 μm and if this sensor is applied to measuring moving speed of objective, it can detect relative speeds as low as 5 μm/s. The proposed sensor will be shown to be applicable to a wide variety of measuring techniques.

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