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Proceedings of Symposium on Ultrasonic Electronics, Vol. 32 (2011) pp. 201-202
8-10 November, 2011

2D or 3D Visualizations of Vibrations Measured with Optical Fiber Sensors

光ファイバセンサによる２D/3D 振動現象の可視化

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1. Introduction

A multi-channel optical vibration sensor with high space resolution was developed to measure and visualize two dimensional (2D) or three dimensional (3D) vibrations. It has the capability of simultaneous measurement of vibrations distributed over the small area of the object to detect transient propagations of the vibrations.

2. Method

2.1 Sensor unit

Fig. 1 shows a reflection type optical displacement sensor unit developed for the system. Its parts include a focusing lens, a lens holder and an optical-fiber bundle. This sensor unit measures the displacement of the object by detecting the variation of reflected photo-power. Optical design was carefully adjusted so that both the displacement dynamic range and space resolution meet our requirement. Followings are the characteristics of the sensor unit we developed.

- Space resolution (minimum gap between each sensor unit) of 4 mm.
- Working distance of about 4 mm.
- Displacement resolution of 10 nm.
- Displacement dynamic range is more than 90 dB.
- Frequency range of up to 80 kHz.

2.2 Calibration with the object

Since the optical characteristics depend very much on the surface of the objects, we developed the calibration capability with the surface of the object itself to realize the surface-independent measurement. **Fig. 2** shows an example of the system setting for the 2D measurement. The sensor head (arrayed sensor units) is mounted on the linear actuator and monitored with the laser displacement sensor.

During the calibration phase, the object is kept at a standstill, and only the sensor head moves by the linear actuator as shown in **Fig. 3** to obtain calibration data. Then, during the measurement, the sensor head stands still, while each sensor measures the vibration of the object as also shown in Fig. 3. Measured data are calibrated and linearized by the PC with the calibration data before the visualization. By following these process for each measurement, the surface-independent accurate measurement can be realized.

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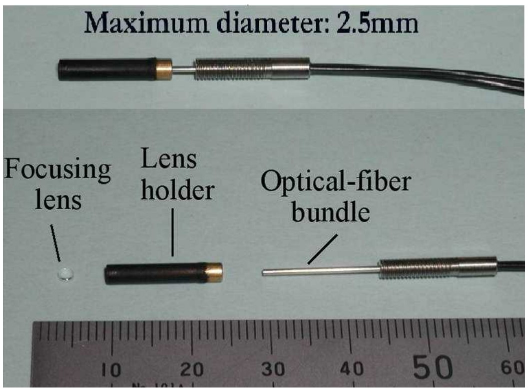

Fig. 1 Reflection type optical displacement sensor unit.

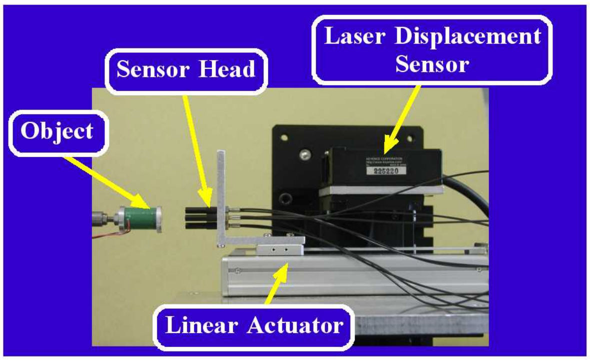

Fig. 2 An example of the system setting.

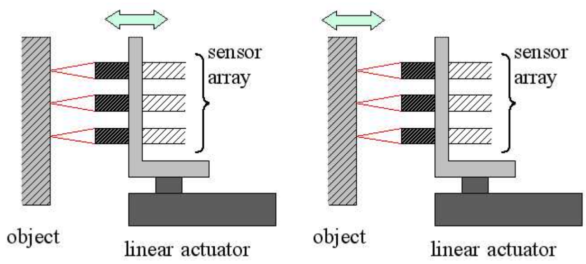

Fig. 3 Calibration with the surface of measuring object.

3. Results

Several vibrating objects were measured and their vibrations were visualized with the system we developed. Followings are examples of the result of measurements.

Fig. 4 shows an example of the 2D measurement setting for the vibration of the mechanical heart valve and some visualized images of the measured surface displayed in 3D animation style. With the help of 3D animation, detailed situation of the propagating vibration can be easily understood.

Fig. 5 shows an example of the 3D measurement setting and the measured data. Here, the object is the tip of the holding pipette used in the genetic recombination processes. A small cubic mirror is attached to the tip to reflect the light of sensor units adequately. Circular movement is activated at the tip of the holding pipette by the asymmetric actuators. In Fig. 5, a trace of the tip movement is plotted on a three-dimensional coordinate.

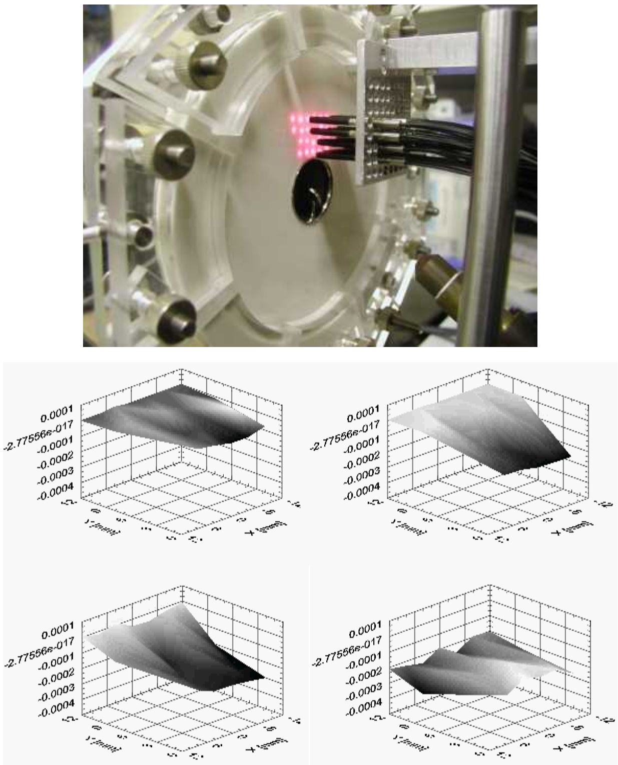

Fig. 4 An example of the 2D measurement of the vibration.
(Vibration of the mechanical heart valve.)

4. Discussion

Above-mentioned two measurements are just the examples, but they obviously indicate that the system we developed can visualize the vibrations under various kinds of situations. The system is effective especially for the study of trangent type vibrations due to its simultaneous measuring capability and its high space resolution. Currently, the frequency range of the system is up to 80 kHz. It mainly depends on the characteristics of the photo-detecting (transimpedance) circuits. There exists a kind of trade-off between its dynamic range of displacement measurement and its frequency range. Therefore, the frequency range can be easily expanded if such a wide dynamic range isn't needed.

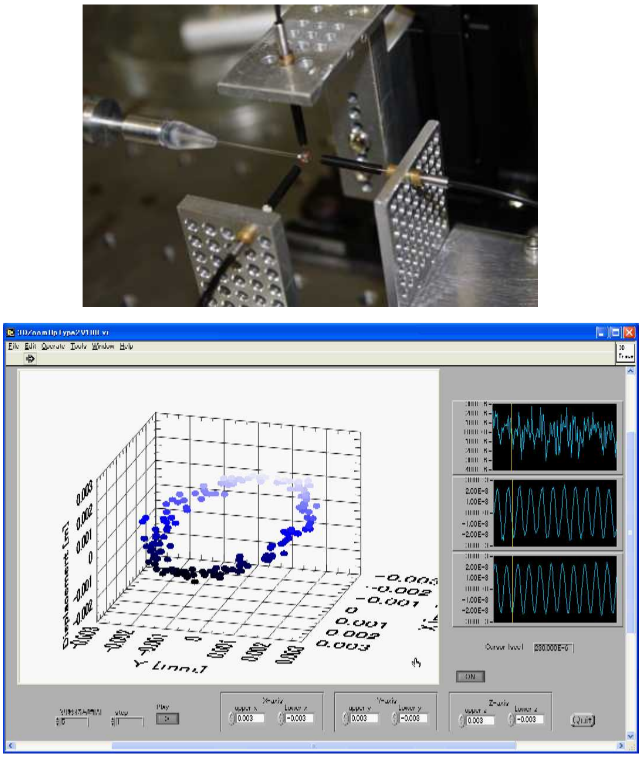

Fig. 5 An example of the 3D measurement of the vibration.
(Trace of the holding pipette tip vibrated with asymmetric actuators.)

5. Conclusion

We developed a multi-channel optical vibration sensor system, and showed that it is effective for the study of vibrations.

Acknowledgment
This work was partly supported by Grant-in-Aid for Scientific Research (C)(2)(14550427, 16560369).

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