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Development of an optical vibration sensor unit for underwater use.

水中用光学式振動センサユニットの試作

Jun Hasegawa† (Takushoku Univ.)
長谷川 淳† (拓殖大学 工)

1. Introduction

A multi-channel optical vibration sensor system has been developed.[1-3] It has the capability of simultaneous measurement of vibrations distributed over the small area of the object as shown in **Fig. 1** and visualizing them. Although, the system was effective for the study of vibrations, it could be worked only in the air. Therefore, I planed to develop an optical vibration sensor unit for underwater use to measure the vibrations of the underwater objects.

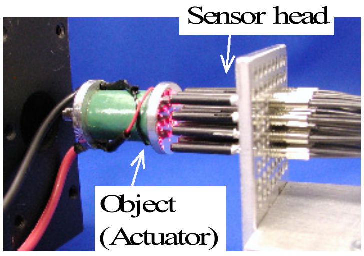

Fig. 1 Previously developed multi-channel optical vibration sensor system in the air.

2. Development of the sensor unit

The sensor unit for underwater use was developed on the basis of the previous system, which adopted a reflection type optical-fiber displacement sensor unit. There were two technical difficulties to be overcome:

1. Since the refractive index of the water is greater than that of the air, the optical design of the sensor unit had to be redesigned.
2. Waterproofing is mandatory.

Fig. 2 shows the cross-sectional view of the newly designed optical vibration sensor unit for underwater use. This sensor unit measures the displacement of the object by detecting the variation of reflected photo-power. An optical-fiber bundle is used for both emitting and sensing photo-power. Two focusing plano-convex lenses are placed so that their convex face each other to solve the first problem. All parts are fixed with curing adhesive to realize waterproofing.

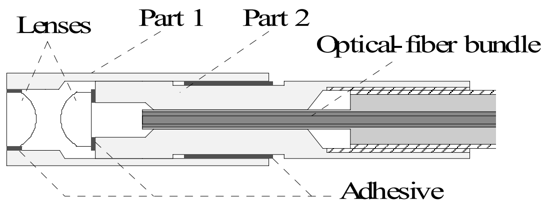

Fig. 2 Cross-sectional view of the optical vibration sensor unit for underwater use.

An transimpedance amplifier shown in **Fig. 3** is used to detect the photo-power. It seems that the circuit becomes the 1st-order lowpass filter, but it is with the frequency characteristics of the 2nd-order lowpass filter because the cutoff frequency of the feedback loop and the band-width of the op-amp are so close. Theoretical value of cut-off frequency is 958kHz, while that of the previous system is 80kHz.

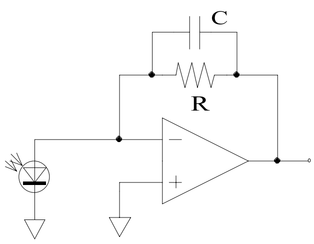

Fig. 3 Circuit diagram of the transimpedance amplifier.

Fig. 4 shows the optical vibration sensor system developed for underwater use.

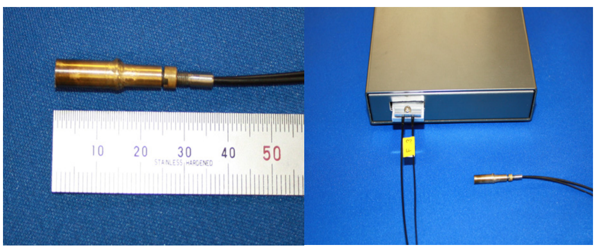

Fig. 4 Newly developed optical vibration sensor system for underwater use.

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e-mail: jhase@es.takushoku-u.ac.jp

3. Results

Fig. 5 shows the underwater displacement -output characteristics of the sensor unit. Its maximum sensitivity and working area are almost the same as those of the previous system.

Frequency characteristics of the system was measured and compared with that of the theoretical value as shown in **Fig. 6**. It seems that the bandwidth of the measured value is slightly wider than that of the theoretical value. However, it could be the allowable limit of error because the typical values of the device were used for the calculation of the theoretical value.

The results of other various measurements including the noise evaluation showed that the characteristics of the system developed are almost the same as those of the previous system except for the frequency bandwidth and outer diameter of the sensor unit. The bandwidth spread to 900kHz from 80kHz, while the diameters of the sensor increased to 5mm from 2.5mm.

Vibrating surface of a ultrasonic cleaner was measured for the test of the system. **Fig. 7** shows the settings of the measurement. An example of measured vibration is shown in **Fig. 8**. The vibration with the frequency equal to the driving frequency of the ultrasonic cleaner (42kHz) can be observed clearly.

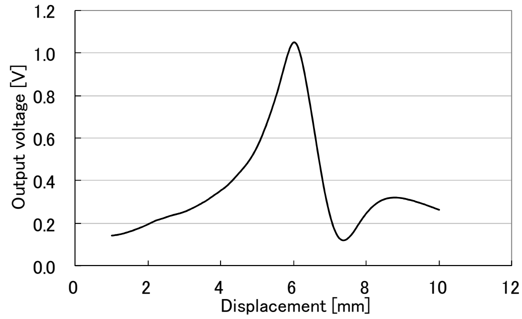

Fig. 5 Displacement-output characteristics of the sensor unit.

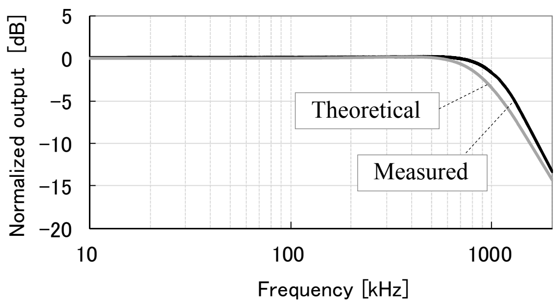

Fig. 6 Normalized frequency characteristics of the system.

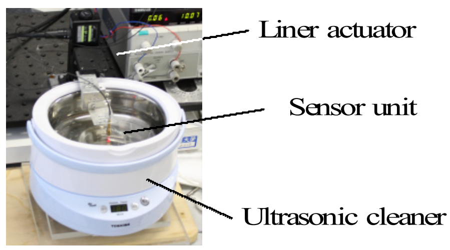

Fig. 7 Settings for the measurement of the vibrating surface of the ultrasonic cleaner.

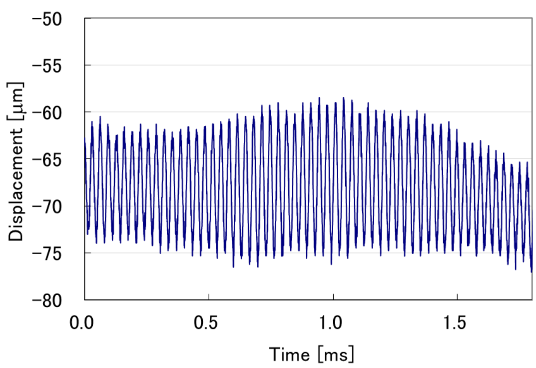

Fig. 8 Measured vibration of the surface of the ultrasonic cleaner.

4. Conclusion

An optical vibration sensor unit for underwater use was developed to realize the visualizations of underwater vibrations. Hereafter, realization of simultaneous sampling with the multi-channel sensor system and visualization of underwater vibrating object should be done.

Acknowledgment
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