S7-3 Hydraulic Pressure Measurement by Frequency-Shifted Feedback Laser and its Application to Tsunami Measurement

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1 Introduction

The frequency-shifted feedback (FSF) laser is a promising optical source for long distance, high resolution optical ranging[1,2].

The FSF laser cavity is closed via the first-order diffracted light of an intracavity acousto-optic modulator (AOM) and the FSF laser output generates chirped frequency comb. The chirped frequency comb is given by

$$\nu_i(t) = \gamma t - q/\tau_{RT}, \quad \gamma = \nu_{FS}/\tau_{RT} \qquad (1)$$

where τ_{RT} is a cavity round trip time, ν_{FS} denotes an intracavity frequency shift which is twice the AOM driving frequency and q is an integer of comb component.

When the laser output is split into two arms of the Michelson interferometer, the beat frequency is given by

$$\nu_{Bm} = 2\gamma z/c - m/\tau_{RT} \qquad (2)$$

where 2z is a path difference of the interferometer, and m is a beat order. The higher order beat frequencies are observed within the cavity free spectral range for any distance. Therefore, the long distance with high resolution optical ranging is possible with the FSF laser. We had demonstrated that the fiber length of 18.5 km is measured with a spatial resolution of 2 cm by using a 19832nd order beat frequency[3].

In this paper we propose and demonstrate a hydraulic pressure measurement by the FSF laser in combination with a fiber-optic sensor. The hydraulic pressure causes a change in the optical length of the fiber in the water. By a precise measurement of the fiber length with the FSF laser, the hydraulic pressure is measured in a frequency domain. We will also discuss an application to the tsunami measurement network system.

2 OFDR using FSF laser

The experimental setup of a hydraulic pressure gauge using a FSF laser is shown in Figure 1. The diode-pumped Nd:YVO_4 was used as a gain medium of the FSF laser. The AOM was driven at 80 MHz. The cavity FSR was 1265 MHz. The FSF laser output was split into two arms of the Michelson interferometer and the beat signal was detected at the optical detector by self-delayed heterodyne detection. In order to examine the variation of an optical fiber length by hydraulic pressure, a fiber-optic sensor is dipped in the water.

The fiber-optic hydraulic pressure sensor was a simple one. The optical fiber was a conventional single mode fiber for the optical communication. The length of the fiber was 1 km long, and it is rolled on the bobbin (height=130 mm, diameter=200 mm). For this length of the fiber, the beat frequency with an order of about 1590th was observed within the cavity free spectral range.

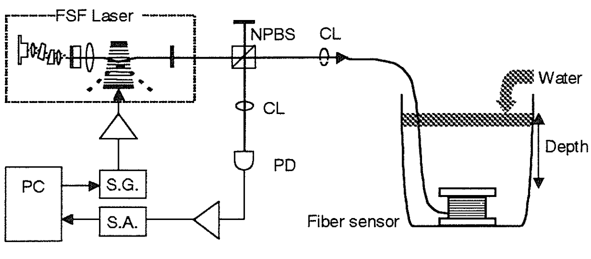

Figure 1 The experimental setup for measuring of the hydraulic pressure by the FSF Laser.

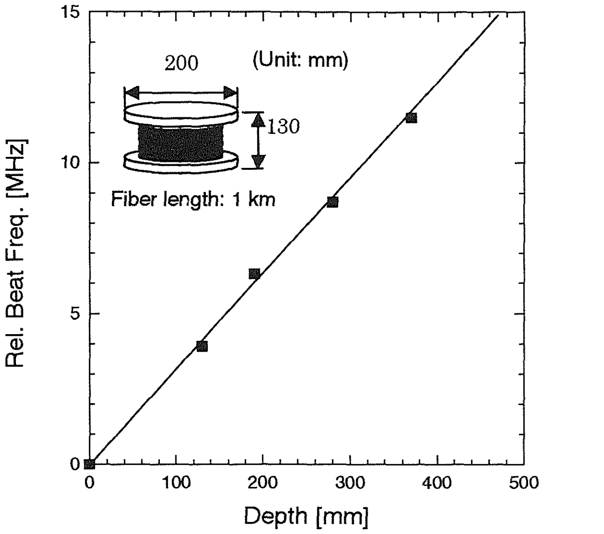

Figure 2 A varying beat frequency during depth changes and the inset shows the schematic of the fiber-optic sensor of the hydraulic pressure measurement.

Figure 2 shows a variation of the beat frequency to the depth change. The slope of the beat frequency to the depth was 31.3 MHz/m. Since the accuracy of the beat frequency measurement is 40 kHz, the accuracy of depth measurement by this system is 1.3 mm, and it corresponds to the hydraulic pressure of 1.3? 10^{-4} atm.

3 Application to Tsunami Measurement

An interesting application of this system is a tsunami measurement. Figure 3 shows a future plan of the tsunami measurement network system. A fiber-optic sensor array is placed on the seabed. When a tsunami runs across over the fiber-optic sensor array, the hydraulic pressure would cause a change in the fiber length, and it would be detected by the optical ranging system with the FSF laser on the land. The position of the sensors is identified by the beat order that is proportional to the distance from the land.

The advantages of the proposed system are following: (1) no power supply is required for the sensor, (2) real time, wide range tsunami detection is possible, and (3) compatibility with the optical communication network. Once the information of the tsunami is gathered with the system, one can predict the time of arrival and height of the tsunami by a numerical computation for the reliable and early warning of tsunami[4].

We hope it will be useful to integrate seismology and tsunami science in future.

4 Conclusion

We proposed and demonstrated an application of the FSF laser to a hydraulic pressure measurement in

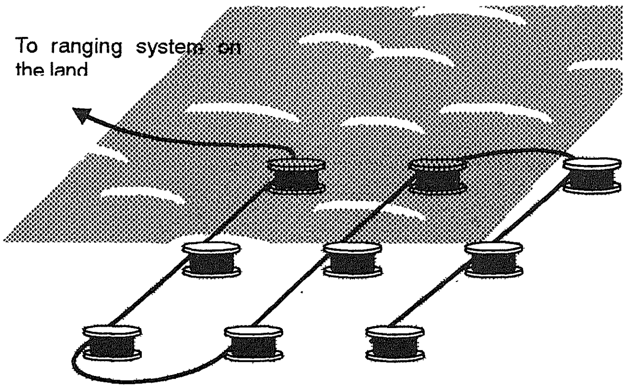

Figure 3 A future plan of the tsunami measurement network system.

combination with a fiber-optic sensor.

We are now developing the FSF laser with a gain medium of the Er:Yb:glass. Since the Er:Yb:glass FSF laser oscillates at 1.55 μm where the propagation loss of the optical fiber has its minimum, one can expand the range of the tsunami sensing. Another factor to be considered is a water temperature causes the fiber-length to fluctuate uselessly, and it is also our investigation.

5 Acknowledgement

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