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# Low-power Digital Fiber Optic Sensing Network with Microprocessor-controlled Sensor Terminals

**Chanty Rotha, Takeshi Nishimura, Yosuke Tanaka, Tatsutoshi Shioda, and Takashi Kurokawa**
Graduate School of Engineering, Tokyo University of Agriculture and Technology
2-24-16 Naka-cho, Koganei-shi, Tokyo 184-8588, Japan
Phone/FAX: +81-42-388-7405, E-mail: tyosuke@cc.tuat.ac.jp

**Abstract:** We propose a low-power digital fiber optic sensing network where microprocessors control varieties of sensors. Low-power modulators such as liquid crystal ones produce the digital optical signal. This low-power system is driven by laser light.

## 1. Introduction

Sensing networks have attracted much attention in many fields, beginning from such a small-scale system as home security system to such large-scale systems as electrical power plants, chemical plants, bridges, and road transportation systems. The signal of the sensing networks generally consists of wireless, metallic cable, or optical fiber transmission. However, the conventional systems have several problems. The metallic cable network suffers from electro magnetic interference and consumes high power, which limits the long distance signal transmission. The wireless systems cannot be used in the underground and hospitals. Besides, the wireless systems have a maintenance problem because the power is supplied only from batteries. The analogue fiber sensor where the fiber functions as a sensing head lacks in flexibility. It is difficult for this type to measure several physical or chemical parameters at the same time. Furthermore, it takes high cost when using special fibers such as fiber Bragg gratings. In the digital fiber sensor where the fiber is used as a transmission line, each sensor terminal has a laser diode. This terminal takes high cost and consumes high power.

In this paper, we propose a novel low-power digital fiber optic sensing network. This system uses sensor terminals in which microprocessors control sensors. We can measure a wide variety of physical or chemical parameters by choosing appropriate sensors. The digital optical signal is produced with low power optical modulator such as liquid crystal ones. Since the power consumption of the sensor terminals are very little, the driving power of the whole system is provided through O/E conversion of the laser power [1].

## 2.Principle

Figure 1 illustrates a schematic diagram of the fiber optic sensing network we propose. The signal light is provided from a laser diode installed in the monitoring side; it is propagated through optical fibers to sensing sides. The sensing side consists of a sensor terminal with several sensors. The sensor terminal is composed of a microprocessor, A/D converters, Photovoltaic (PV) cell, and an optical modulator. This configuration allows us to measure a wide variety of physical or chemical parameters just by replacing the sensors. This is also attractive from the viewpoint of reducing the fabrication cost of the sensor module. The analog signals from the sensors are converted into digital signals by the A/D converters. The microprocessor processes the digital signal and adds header signal for discriminating and avoiding collision of the signal from each sensor terminal. Then the obtained signal is converted into optical signal with an optical modulator. Though the optical modulator does not have to be very fast, it should be driven with low power. This requirement is satisfied by a liquid crystal optical modulator [2],[3] or MEMS modulator. Using these devices, the total power consumption per one sensor terminal becomes approximately 100 μW, which is only 0.5 % of the conventional systems.

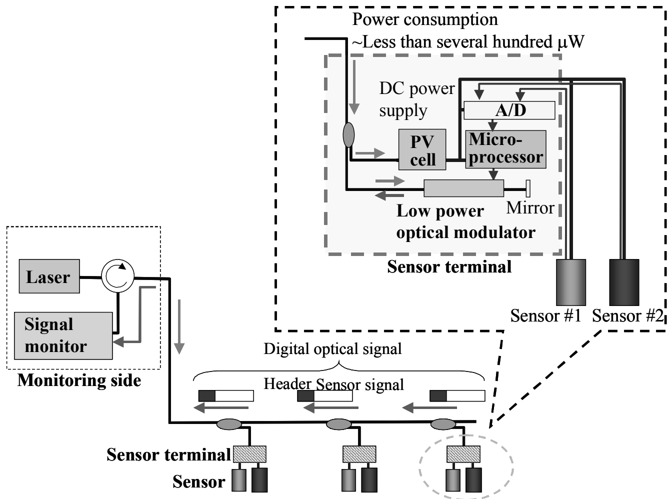


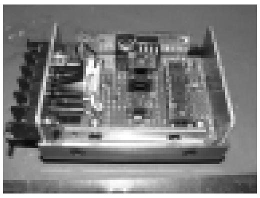

**Fig. 1. Schematic of low-power fiber optic sensing network.**

The driving power of the proposed system is provided through O/E conversion of the laser power in the PV cell [4]. Since the power conversion efficiency of a PV cell for laser light is as high as 20 to 40 %, hundreds of sensors can be operated with several ten mW of the laser power. Recently, such high-power laser diodes with several hundreds mW to several W is commercially available, which have been mainly fabricated for Raman amplifiers.

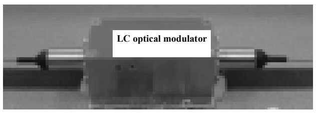
This sensing system with fiber optic powering is especially useful for remote sensing in the places where DC electrical power supply is difficult. For example, we can apply this system for monitoring strain of a large bridge, a chemical plant dealing with explosive material, and electrical power plant radiating strong electro-magnetic noise.

### 3. Basic experiment of sensing system using fiber optic powering

As a basic study of the proposed sensing system, we constructed a remote temperature sensor. Figure 2 (a) shows the fabricated processing unit of a sensor terminal. A microprocessor with 192 kHz clock frequency controls a digital temperature sensor and a liquid crystal optical modulator (LCOM). The photograph of the LCOM is shown in Fig.2 (b), which has fiber pigtails on both sides of the 5cm long body. The LCOM can produce the digital optical signal with kilobits per second.



(a)




(b)

**Fig. 2. (a) Microprocessor-controlled processing unit and (b) Liquid crystal optical modulator.**

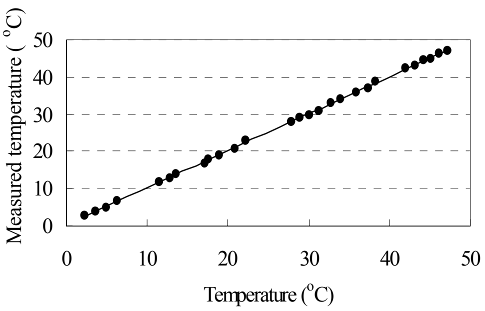



**Fig.3 Temperature measured with sensor terminal at the end of 5-km-long fiber.**

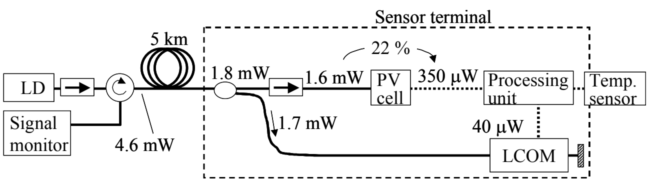



**Fig. 4. Power consumption of the sensing system**

The extinction ratio of the LCOM was -26 dB at 25 and 50° C and -20 dB at 0°C for the laser light operating at 1.55 µm. These values were high enough to ensure digital signal transmission in the temperature range 0 to 50°C. Using these components, we measured the temperature at the end of 5km-long single-mode fiber. The wavelength of a laser used in this system was 1.55 µm. As shown in Fig.3, the temperature was measured with an accuracy of $\pm 0.5$ °C, where the reference temperature was measured with an independent temperature sensor with an accuracy of $\pm 0.1$°C. Figure 4 shows the power consumption in this system. One sensor terminal was driven with laser power less than 5mW. Since the transmission speed of the signal is as slow as kbps, we can also use multi-mode fibers for shorter transmission length around 1 km. In this case, it is possible to transmit power higher than several W [1].

### 4. Summary and conclusion

We have proposed a low-power digital fiber optic sensing network. Each sensing module in the network is controlled by a microprocessor. That makes a flexible and low-cost system where a variety of sensing can be realized just by replacing the sensor devices without changing the whole sensing module. The digital optical signal is generated with low power by using a LC optical modulator that is also controlled by the microprocessor. The total power consumption in the whole system is low enough to be driven with a laser power. As a basic experiment, we have fabricated a temperature sensor system. The power consumption of the whole system was 350 µW. This implies that hundreds of sensors can be driven with a several hundred mW LD. This sensing system is promising and attractive for a wide variety of sensing application beginning from such a small-scale system as home security system to such large-scale systems as electrical power plants, chemical plants, bridges, and road transportation systems.

### Acknowledgement

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### References

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