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All-optical photoacoustic fiber probe for endoscopic imaging

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1. Introduction

Photoacoustic imaging has developed extensively as a non-invasive and high spatial resolution imaging method for medical diagnosis. In the conventional photoacoustic imaging system, piezoelectric devices have been widely used for ultrasound detection. Although the transducer should be very small in size when implementing it to an endoscopic imaging probe, it is difficult to reduce the size while keeping the sensitivity high. To solve this problem, fiber optic probes equipped with a Fabry-Perot interferometer at the distal end of the fiber have been proposed. [1, 2]. However, this type of fiber-optic probe system usually requires a highly stable and narrow linewidth laser source. This makes it difficult to build a practical endoscopic-imaging system mainly due to the system cost.

In this report, we constructed a compact and low-cost photoacoustic imaging system based on the optical fiber probe using commercially-available optical components. We show basic characteristics of the fiber probe and results of preliminary test for photoacoustic imaging.

2. Principle Operation of Optical Probe

Figure 1 shows a schematic of the optical fiber probe system for ultrasound detection. This system consists of a 1550-nm distributed feedback (DFB) laser, an optical fiber circulator, and an InGaAs photo diode with a preamplifier. All of these components are available as equipment for optical communication system. The DFB laser operates in single mode with linewidth of 0.5 nm and the single-mode-fiber (SMF) based optical circulator shows isolation >40 dB with an insertion loss of around 0.8 dB. The InGaAs photo diode has a bandwidth of 30 kHz to 1 GHz. All the components are connected with SMF patch cables and thus, the system is compact and very stable in spite of the low cost.

As shown in Fig. 1, interference between the power reflected from the fiber/polymer interface P_1 and that reflected from the polymer's outer surface P_2 forms the reflected light power P_r. When ultrasound pressure is applied to the end of sensor probe, it induces change in the film thickness that causes phase modulation and then, it is detected as a change of P_r.

3. Photoacoustic Imaging

To perform photoacoustic imaging using the optical fiber probe, we prepared two types of blood vessel phantoms that are silicon tubes with inner diameters of 400 μm. One of the prepared tubes contains a black ink and another is with 15 % hemoglobin solution. These phantoms were placed 5 mm beneath the probe. The probe bound with a hollow optical fiber that is for excitation and it was scanned across the phantoms with 10 μm steps to obtain a B-mode image of the phantoms. Digital filtering and envelope demodulation were applied to raw detected signals to construct images. .

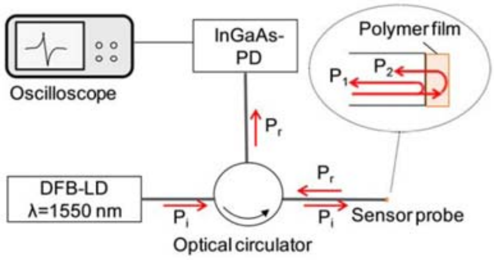

Fig. 1 Schematic of optical fiber probe system

Figure 2 shows a constructed image of blood vessel phantoms. The left picture is the entire constructed area where the two phantoms can be seen at depths of 5.2 mm from the imaging probe. The right shows an enlarged view of region surrounding the phantoms and one sees difference in brightness between the hemoglobin phantom in the right side and the black ink phantom in the left. This result shows capability of the fiber probe for detection of small variation with high intensity.

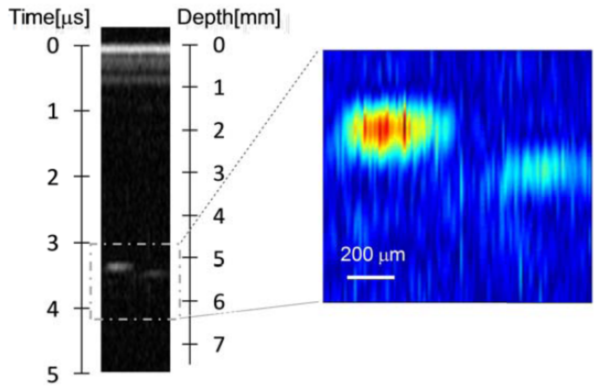

Fig.2 Bmode imaging of blood vessel phantom

References

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[2] S. Ashkenazi, Y. Hou, T. Buma and M. O'Donnell, Appl. Phys. Lett, **86** (2005) 134120.