Construction of the Optical Delay Line for the Optical Coherence Tomography

Kitsakorn Locharoenrat and I-Jen Hsu

***Abstract*—We have constructed the compact optical delay line for the axial scanning of time-domain optical coherence tomography. The delay line contains the retro-reflector, and the inclined reflection mirror, as well as the scanning mirror. This delay line is performed by the low-coherence reflectometer with a scanning speed of 400 Hz. The dimension of the delay line is 2 cm × 2 cm. We have achieved the scanning range of about 3 mm within the scanning mirror's vibration angle of approximately 10 °.**

***Index Terms*—Imaging technique, interferometer, optical delay line, reflectometer.**

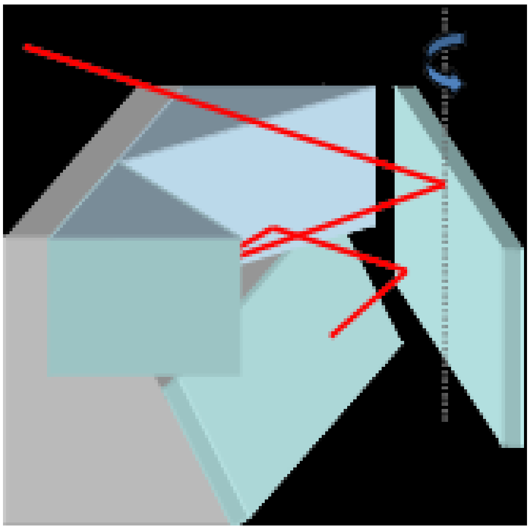
I. Introduction

Many optical imaging techniques, for instance phase-shifting interferometry [1]-[6] and low-coherence reflectometry [7]-[12] require the effective optical delay lines offering a phase variation of optical signal through discretely or continuously optical path length. Originally, many designs of the delay lines have been proposed either for large scanning range or for high frequency. For example, the piezoelectric transducer performs a rapid scanning, but the travelling range is restricted in micrometer scale. The stepper motor stage and linearly motorized translation stage performs long-range scanning, however, the translation speed is limited in the scale of centimeter per second. So far, different designs of the delay lines have been developed to increase both scanning rate and scanning range [13]-[23], however, most of these configurations are not easy to fabricate into small components.

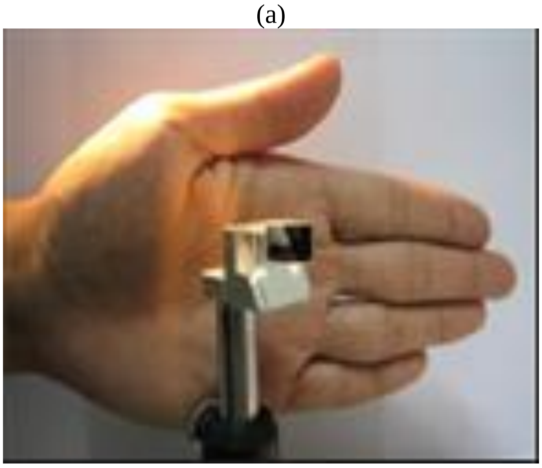
In this article, we construct the compact optical delay line for the axial scanning of time-domain optical coherence tomography that is very easy for fabrication. Another benefit of our delay line is that the scanning range is large in the millimeter range when the vibration angle of the scanning mirror is about 10 ° with the high scanning rate of 400 Hz.

II. Material Fabrication

In Fig. 1 we show the compact optical delay line for free-space optical coherence tomography configuration, including the retro-reflector, the inclined reflection mirror and the scanning mirror. The retro-reflector is constructed by using the right-angled prisms pair mounted onto the aluminum jig. The reflection mirror is tilt at 60 ° normal to the surface of the scanning mirror and it is located below the prism pair under the same aluminum jig. The gap between the retro-reflector and the scanning mirror at its normal surface is 5 mm. The total dimension of our delay line is about 2 cm × 2 cm.



(a)



(b)

Fig. 1. Conceptual design (a) and photograph (b) of the compact optical delay line for the optical coherence tomography including the retro-reflector integrated by the inclined reflection mirror. The red line represents the light propagation in the delay line system indicating the direction of the light from/to the delay line is in collinear conditions during scanning.

III. Experiment

The experimental setup of the compact optical delay line in the typical free-space optical coherence tomography

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configuration is described as in [24]. Briefly, the He-Ne laser is used as the light source and it is also performed to calibrate the nonlinearity of the optical delay line with respect to the tilted angle of the scanning mirror. The tilted angle is set between 0 °and 10 °. First, the light is incident at 30 °normal to the scanning mirror's surface. After light reflection in ordering at the scanning mirror and the retro-reflector, the light is incident at the scanning mirror once again. The light is then incident at the inclined reflection mirror so that the reflected light is firmly collinear with the incident one. This can avoid the walk off problem causing variation in intensity of optical signal during scanning. It is noted that the galvoscanner is driven by a function generator to generate continuously waveform. This waveform is served as a trigger to synchronize the acquisition of the interference signal. The scanning rate of the delay line is determined by the galvoscanner's scanning rate at 400 Hz.

IV. Results and Discussion

In Fig. 2 we show the experimental results of the optical path difference as a function of the tilted angle of the scanning mirror in order to demonstrate the performance of our optical delay line. These experimental results are estimated at positions of the maximum interference signals. It is found that within the maximum tilted angle of the scanning mirror of approximately 10 °, we obtain the imaging depth represented by the optical path difference at about 3 mm.

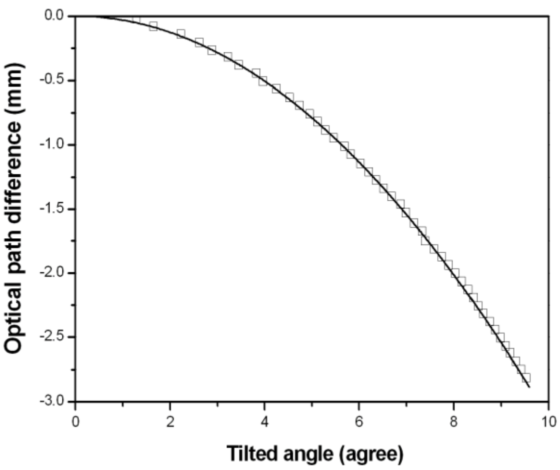

Fig. 2. Optical path difference as a function of the tiled angle of the scanning mirror.

V. Conclusion

We have constructed the optical coherence tomography system with the optical delay line consisting of the reflective components for large scanning range with high frequency. In the delay line, the retro-reflector together with the inclined reflection mirror is assembled onto the aluminum jig. The dimension our delay line is 2 cm × 2 cm. When the vibration angle of the scanning mirror is about 10 °at a scanning rate of 400 Hz, we have achieved the imaging depth of the optical coherence tomography system at approximately 3 mm. Our optical delay line has advantages that it is very compact and easy to fabricate.

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