Chirped Amplitude-Modulated Phase-Shift Method Based Overall Non-Mechanical 1-D Spectrally Scanned LiDAR

Zheyuan Zhang[1], Chao Zhang[2], Takuma Shirahata[1], Shinji Yamashita[1], Sze Y. Set[1]

[1] University of Tokyo, Research Center for Advanced Science and Technology, [2] Shimane University
E-mail: zhang@cntp.t.u-tokyo.ac.jp

1. Introduction

Dispersion-tuning swept lasers (DTSL) is an actively mode-locked non-mechanical wavelength-swept laser that can provide a fast wavelength sweeping rate (in the order of hundreds of kHz) and a broad wavelength range (~100nm). It is promising to serve as the light source for swept-source optical coherent tomography (SS-OCT), but has not been used for LiDAR because of its relatively short coherence length and chirped repetition rate. In this research, we propose a novel approach that allows the phase-shift measurement of chirped amplitude-modulated signals: the chirped amplitude-modulated phase-shift (CAMPS) method. With this method, we can make use of the advantages of DTSL and realize an overall non-mechanical spectrally scanned LiDAR system.

2. Experimental Setup

The experimental setup of the proposed system is shown in Fig.1. A chirped electrical signal of 720-726 MHz with a sweep rate of 10 kHz is used to mode-lock the DTSL through an intensity modulator. Each output wavelength of DTSL corresponds to a certain modulation frequency. A dispersive grating is used to diffract the light from the DTSL to a different direction according to the wavelength. When the wavelength sweep range is set to 40 nm, a scanning angle of ~3.5° can be achieved. The scanning range can be expanded by using a broadband optical amplifier.

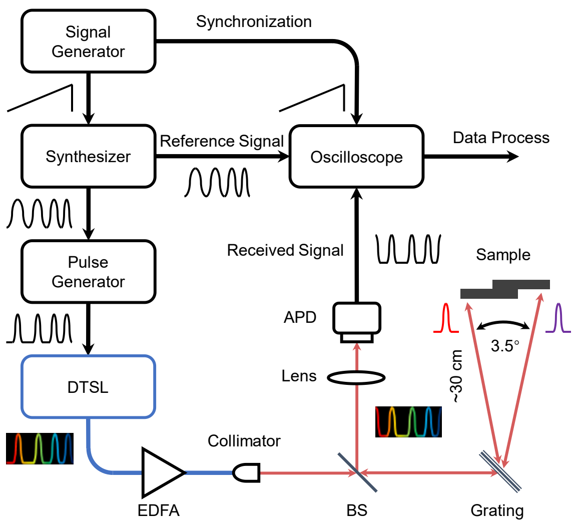

Fig.1 Experimental setup of the proposed system.

The experimental result shows that the axial resolution of one single scan performed by the proposed system is ~1 mm. An axial ranging RMS error of ~200 μm can be expected when the systematic error is compensated.

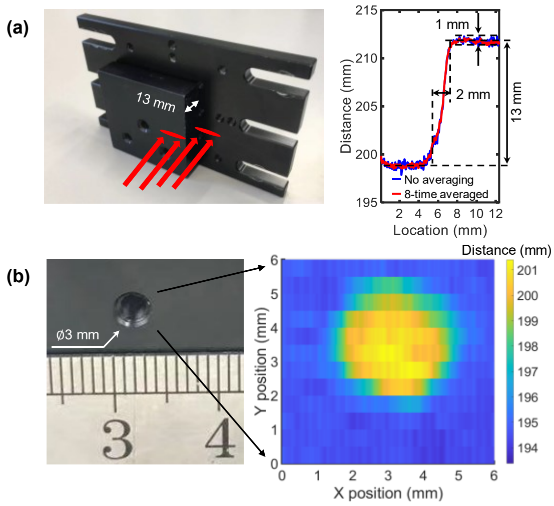

Fig.2 Result of (a) a line scan on a 13 mm step and (b) a manual 2-D scan on a screw hole with 3 mm diameter.

3. Conclusions

We successfully demonstrate an inertial-free LiDAR system based on the novel CAMPS technique without using any mechanical parts in the whole system. This is the first time the DTSL is employed in LiDAR applications, and the first time an overall non-mechanical spectrally scanned LiDAR system is proposed. As a proof of concept, an axial ranging RMS error of ~200 μm at a scanning speed of 10 kHz with the compensation of the systematic error, which corresponds to a phase resolution of 0.35°. With a 32-time waveform averaging, it can be improved to 35 μm (0.063°). The CAMPS technique is also potential for the ranging disambiguation. Making use of the changing frequency of DTSL, the tradeoff between ambiguity-free distance range can be broken, while ensuring high reliability and stability.

Acknowledgements

This work is supported by Japan Society for the Promotion of Science (JSPS) Grant-in-Aid for Scientific Research (S) Grant Number 18H05238 and Scientific Research (B) 19H02149.

References

[1] S. Yamashita. IEEE J. Sel. Top. Quantum Electron. 24.3 (2018) 1–9.
[2] Y. Zhai, et al. OFS (2018) ThE48.