Research for Improvement of Resolution of Distance Sensor Using Fluctuation of Laser Terminal Voltage due to Self Coupling Effect

Tatsuya Ohba, Norio Tsuda, Jun Yamada
Dept. of Electrical and Electronics Engineering
Aichi Institute of Technology, AIT
Toyota, Japan
E-mail: v18706vv@aitech.ac.jp

Abstract— **When acquire signal due to the self-coupling effect from the terminal voltage of the laser, the signal-to-noise ratio gets worse. Because it is difficult to detect the signal, so it was impossible to measure the distance with a resolution of 1 cm or less. In this study, we proposed a new noise reduction method, that could carry out measurement for a resolution of 1 cm or less, which has not been done before. From the experimental results, we reported the factors that cause the errors in the distance sensor employing a self-coupling effect.**

Keywords-Self coupling effect; distance sensor; terminal voltage; Vertical Cavity Surface Emitting LASER.

I. INTRODUCTION

Generally, the light intensity of a Laser Diode (LD) slightly fluctuates when part of the light scattered on the target surface interferes with the laser light on its active layer. Self-coupled laser sensors make use of this variation for distance [1], [2], micro displacement [3], [4], velocity measurement [5], [6] and so on. Aside from fluctuations of light intensity, self-coupling effect also causes fluctuations of the terminal voltage [7], which can be used, instead of the photodiode (PD), to develop a compact and inexpensive photodetector free sensor can be realized. Conventional, researches on laser distance sensors utilizing laser terminal voltage fluctuations caused by self-coupling effect, found out their wide range of applications, such as for position control of robot arms, collision avoidance, shape measurement, etc.

A self-coupled laser distance sensor detects a signal called Mode Hop Pulse (MHP). The MHP changes proportionally with distance, and this property allows distance measurement to be done. MHP will be explained fully in section II.

The theoretical resolution of distance measuring equipment using MHP is determined by laser and circuit characteristics; in current researches, this is 0.44 mm, allowing a measurement accuracy at intervals of only 1cm. In this paper, we measured the accuracy at an interval of less than 1 cm. The measurement principle is shown in Section III, and the measurement results are shown in Section IV. The conclusion is described in section Ⅴ.

II. DISTANCE MEASUREMENT PRINCIPLE

In this section, we will briefly summarize the principles of the self-coupling effect, as it has been fully explained in the previous studies [8]. In the same longitudinal mode, the oscillation wavelength of a LD varies proportionally with the applied voltage. Moreover, when half the wavelength and the set of integer n are equal to the measurement distance, the fluctuation of the applied voltage due to the self-coupling effect is maximized. If a triangular wave modulation is applied to the LD, then a periodic fluctuation occurs, as shown in Figure 1. From the same figure, the dotted line shows the applied triangular wave voltage waveform, while the solid line indicates the resonance condition satisfied at equal intervals, thus, resulting to a step wise pulse that is superimposed on the applied voltage. The periodic voltage fluctuation due to the self-coupling effect is called MHP.

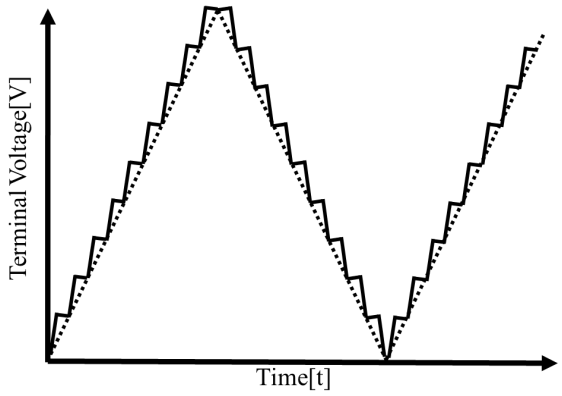

Figure 1. Schematic of the MHP.

The average frequency of all MHPs generated during one period of the modulated signal varies in proportion with the distance. Moreover, their frequencies are all equal when the total speed difference between the sensor and the object (Figure 1). The distance resolution of the self-coupled laser distance sensor is the length that the MHP changes by one, and the measurable distance is determined by the coherence length of the LD. Conventionally, the fast Fourier transform (FFT) is used to acquire the MHP frequency output of considerable white Gaussian noise (WGN), from the laser terminal voltage.

 ISBN: 978-1-61208-691-0

III. MEASUREMENT SYSTEM

Figure 2 shows a schematic of the distance measurement system.

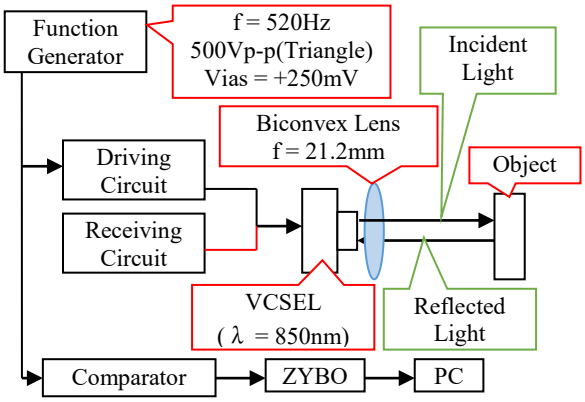

Figure. 2 Block diagram of distance measurement system.

The Vertical Cavity Surface Emitting LASER (VCSEL) is a ULM850-B2-PL-S46FZP (ULM850), having a 850 nm wavelength, a 2 mW light intensity output, a single beam mode, and a circular polarization. The laser driver applies a 520 Hz triangular wave with a 1.8 mA p-p triangular current. The ULM850 modulation efficiency is 0.46 nm/mA. The receiver is designed as a multistage band pass filter (BPF) with 2500 times amplification, and upper and lower cut-off frequency limits of 2 MHz and 100 kHz, respectively. The laser beam is adjusted to yield a collimated beam and the target object is a white paper. The comparator digitalizes the laser terminal voltage because the system-on-chip (SoC) device used only supports digital signals.

The MHP frequency is measured using an SoC device named ZYBO. In the FFT using ZYBO, the sampling frequency is 3.2 MHz, four FFT processed spectral data were averaged to reduce noise.

IV. MEASUREMENT RESULT

Figure 3 shows the results of the distance measurement. Because the resolution of the time FFT is about 1.5 mm, the measurement interval was set to 3 mm.

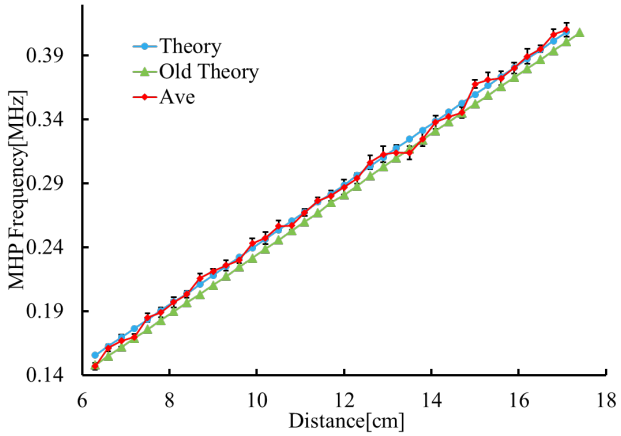

Figure.3. Result of distance measurement.

The measurement distance was in the range 6.3 to 16.4 cm. Ave is an experimental value obtained by averaging the results obtained from repeating the measurements 20 times in each distance. The optical path length becomes longer than the actual due to the refractive index of the lens. The theoretical value corrected by considering the influence of the lens is Theory, and the theoretical value not considered is Old Theory. From the comparison of the respective data, the theoretical values before correction did not match with the experimental values; however, the corrected theoretical values agreed with the experimental values.

V. CONCLUSION

When the laser output light interferes with the returning light, the terminal voltage of LD slightly fluctuates. On the other hand, when the triangular wave modulation is applied to the applied voltage, the voltage frequency fluctuates due to the self-coupling effect generated during one cycle of the modulation signal, which varies in proportion to the distance. Therefore, by measuring the distance signal (MHP) from the fluctuation of the terminal voltage of the LD, the distance can be measured without PD. The measurement conducted for this study was for a resolution of 1 cm or less, which has not been verified so far. The results revealed that it is necessary to measure by taking into consideration the influence of the refractive index of the lens in the measurement of 1 cm or less.

REFERENCES

[1] Yah Leng Lim, K.Bertling, et.al,"Displacement and distance measurement using the change in junction voltage across a laser diode due to the self-mixing effect , Proc.SPIE Vol.6038 60381O (2006).

[2] Gregory Mourat, Noel Servagent,Thierry M.Bosch,"Distance measurement using the self-mixing efect in a three-electrode distributed Bragg reflector laser diode", Opt. Eng. 39(03), pp.738-743 (2000).

[3] T. Gharbi, A. Courtevill and A. Chebbour,"Backscatter-modulated laser diode for low-frequency small-amplitude vibration measurement", Appl. Opt. 36, pp.8233-8237 (1997).

[4] G. Giuliani, S. Donati, and L. Monti,"Self-mixing laser diode vibrometer with wide dynamic range", Proc. SPIE Vol. 4827, pp.353-362 (2002)

[5] P. J. Groot, G. M. Gallatin, and S. H. Macomber,"Ranging and velocimetry signal generation in a backscatter-modulated laser diode", Appl. Opt. 21, No. 21, pp.4475-4480 (1988)

[6] L. Krehut, J. Hast, E. Alarousu, and R. Myllyla,"Low cost velocity sensor based on the self-mixing effect in a laser diode", Opto-Electronics Rev. 11, No. 4, pp.313-319 (2003)

[7] J. Hashizume, S. Shinada, F. Koyama, K. Iga,"Reflection Induced Voltage Change of Surface Emitting Laser for Optical Probing", Opt. Rev. 9 p. 186 (2002)

[8] Takeshi Yoshimatsu, Norio Tsuda, Jun Yamada,"Signal Processing for Distance Measurement Using Laser Voltage Fluction Due to Self-Coupling Effect", SandM, Vol.29,No. 9 pp.1315-1324 (2017)

 ISBN: 978-1-61208-691-0