PAPER • OPEN ACCESS

Non-contact Fiber Optic Displacement Sensor for Sugar Concentration Detection

To cite this article: Abdul Rahman Johari *et al* 2020 *J. Phys.: Conf. Ser.* **1484** 012006

Non-contact Fiber Optic Displacement Sensor for Sugar Concentration Detection

Abdul Rahman Johari[1], Ganesan Krishnan[1,2,3*], Hazri Bakhtiar[1,2], Husni Hani Jameela Sapingi[1,2] and Sulaiman Wadi Harun[3]
[1]Laser Center, Ibnu Sina Institute for Scientific and Industrial Research (ISI-SIR), Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia
[2] Department of Physics, Faculty of Science, Universiti Teknologi Malaysia, 81310 Johor Bahru, Johor, Malaysia.
[3]Department of Electrical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

Email: k.ganesan@utm.my

Abstract. A non-contact fiber optic displacement sensor was used for sugar concentration sensing. A concentric fiber optic bundle and sucrose solutions were used as the fiber probe and sugar samples respectively. Concentration of samples used were in the range of 9% to 33% weight percentages. The fiber probe was displaced above the sample surfaces and displacement curves were recorded. There were two peaks were observed in the displacement curve for each sample. The distance between peaks increases linearly as concentration increases and it was used to evaluate the sensing performance. In term of the performance, the sensitivity and linearity obtained were 0.08295 mm/% and 96% respectively.

1. Introduction

Fiber optic sensors are becoming popular due to its compactness and immunity to electromagnetic waves [1]. Sugar concentration detection is an important measurement in food and beverage sector. Many researches had been done to detect sugar concentration in samples using chemicals [2] and electromagnetic waves [3]. Various types of fiber optic sugar sensors had been demonstrated in previous researches, namely using multimode fiber (MMF) [4], fiber Bragg grating [5] and fiber optic displacement sensor (FODS) [6] [7]. The FODS is a compact and simple system compared with other fiber sensors. However, there is possibility of sample contamination due to immersion of fiber probe in the sample. This problem was solved by introduction of mirrorless FODS (MFODS) that will not contaminant the samples due to its non-contact nature. [8] MFODS uses the principle of reflection of light at flat air-liquid interface to determine the reflective index of liquid. When a liquid is confined in a tube, the air-liquid interface forms a meniscus as a result of surface tension. The contact angle of the meniscus formed is a function of impurity in the liquid [9].

In this paper, the concentration of sugar in water detected via MFODS by utilizing the change in the meniscus's contact angle with concentration of sugar solutions.

2. Methodology

Figure 1 shows the experimental setup used in this work. A He-Ne laser was used as the light source. The output wavelength of laser was 633 nm with 10 mW output power. Concentric fiber optic bundle was used for this experiment. The laser beam was coupled into transmitting fiber of the fiber bundle. Then, the light exited the transmitting fiber from the other end and reflected on the meniscus of air-sample interface. The reflected light was collected by the receiving fiber and it was detected by a photodetector which was placed at the other end of receiving fiber. The photodetector was connected to Tektronix TDS 3052C oscilloscope to display the voltage which corresponds to the amount of light received. The fiber bundle probe was mounted to a steeper motor. The sugar solutions were prepared by mixing sucrose powder with water and the weight percentage of the samples used were in the range of 9% to 33 %. As for the procedure, initially, the laser was warmed up for 15 minutes to stabilize the laser output. The sample was placed under the probe and the probe was adjusted till it was just above the air-sample interface. The speed of the stepper motor is set to 1.04 mm/s. Then, the probe was scanned upward by activating the stepper motor and the voltage data was recorded.

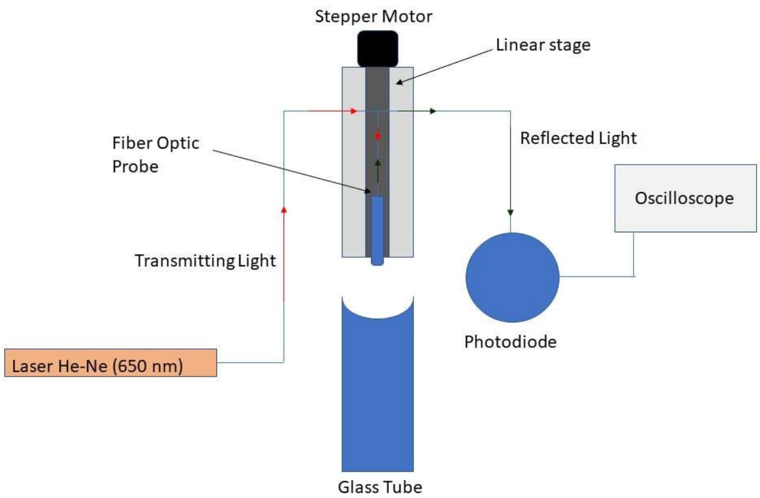

Figure 1. Mirrorless fiber optic displacement sensor setup.

3. Result and discussion

Figure 2 shows the voltage against displacement graph for the sucrose solution concentration with 9% concentration. From the graph, it can be seen there are two prominent peaks in the displacement data. During the first peak, a maximum overlapping between the receiving fiber cores and reflected light was obtained. The second peak happen due to focusing effect of the concave meniscus surface. The displacement curve obtained in Figure 2 agrees well with Yang et al. [1] results except there is no zero voltage point that divides the second peak in our result. This might be due to geometry of receiving fibers used were different in both of the works.

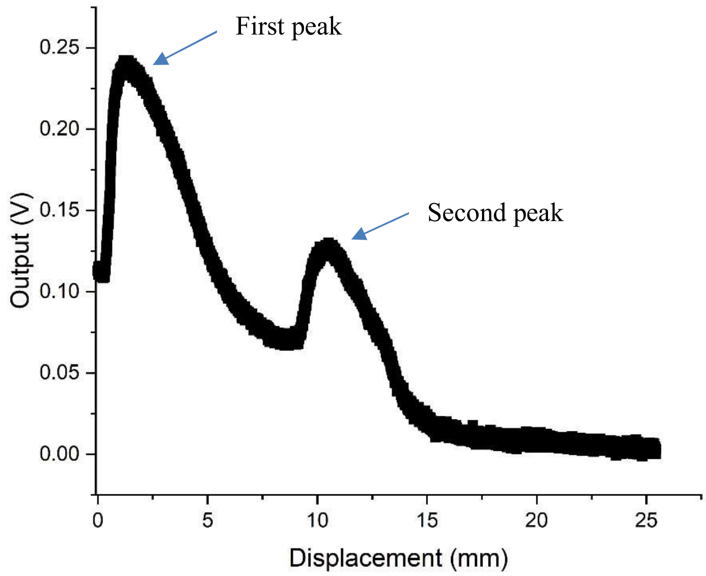

Figure 2. Displacement data for 9 % sucrose solution.

Figure 3 shows the displacement curves of sucrose solutions with various concentrations. As the general features, all the curves have the first and the second peaks in it. Upon close extermination of the Figure 3, the distance between the first and second peaks varies as the concentration of sucrose changes. The distance between first peak and second peak was extracted and it is shown in Figure 4.

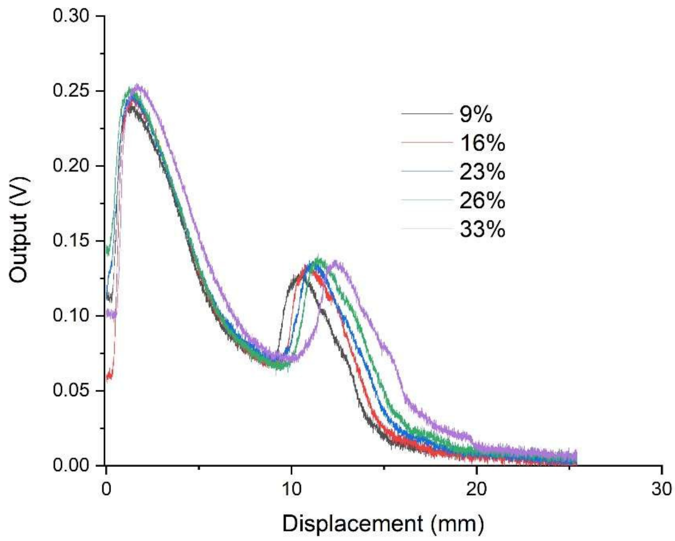

Figure 3. Displacement Curve of FODS with different concentration.

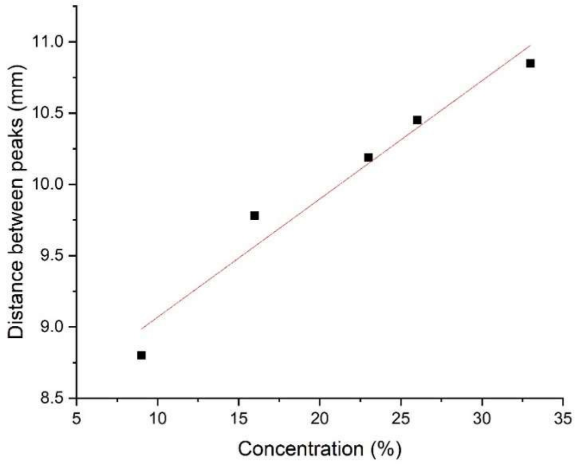

Figure 4. Relationship between distance of peaks and concentration.

From figure 4, the performance of sensor as the sugar concentration detector was obtained. The sensitivity and linearity of this graph is 0.08295 mm/% and 96% respectively. The resolution of sensor is calculated as 1.21 % and it is a better resolution compared with the previous study, which was 2.5 % [7].

4. Conclusion

The sugar sensor demonstrated in this work achieved sensitivity of 0.08295 mm/% and its linearity was more than 90%. Apart from the good sensing performance, the non-contact nature of sensor will ensure that the samples will not be contaminated during the measurement. Therefore, this sensor can be used in the food and beverage industrial to determine the sugar content in the samples.

Acknowledgement

Authors would like to acknowledge the financial support under UTM-TDR fund with research grant vote number of 06G83. Thanks to Research Management Centre of UTM for the grant management and Ministry of Education Malaysia for the postdoctoral scholarship given to one of the author.

References

[1] Yang HZ, Lim KS, Harun SW, Dimyati K and Ahmad H 2010 *Sensors Actuators, A Phys.*, **162(1)** 8–12
[2] Baker GA, Desikan R, and Thundat T 2008 *Anal. Chem.* **80(13)** 4860–4865
[3] Lee DK *et al.* 2015 *Sci. Rep.* **5** 1–7
[4] Qian S, Liang Y, Ma J, Zhang Y, Zhao J, and Peng W 2015 *Sensors Actuators, B Chem.*, **220** 1217–1223
[5] Chen X, Zhou K, Zhang L and Bennion I 2005 *IEEE Photonics Technol. Lett.*, **17(4)** 864–866
[6] Bidin N, Zainuddin NH, Islam S, Abdullah M, Marsin FM and Yasin M 2016 *IEEE Sens. J.*, **16(2)** 299–305
[7] Yasin M, Samian and Aini FN 2016 *Optoelectron. Adv. Mater. Rapid Commun.*, **10(5–6)** 347–350,
[8] Krishnan G, Bidin N, Abdullah M, Ahmad MFS, Bakar MAA and Yasin M 2016 *Sensors Actuators, A Phys.*, **247** 227–233
[9] Mysels KJ and Florence AT 1973 *J. Colloid Interface Sci.*, **43(3)** 577–582