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Characteristics of fiber Bragg grating due to temperature changes in honey solution

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ABSTRACT

The high sensitivity and low power consumption of fiber Bragg grating (FBG), has been widely applied in optical technology to measure temperature and strain. Currently, the need for detection by the industrial sector is increasingly being developed, one of which is the detection of characteristics in honey solutions. The use of FBG as a detector has a great opportunity to see the unique characteristics of the honey solution. Therefore, this problem needs to be followed up by analyzing the effect of honey temperature on the FBG output power, changes in Bragg wavelength, and the rate of temperature change. The research method was carried out by placing FBG in a heated honey solution, then measuring the temperature between 30°C – 60°C with an increase of 5°C. The FBG used consists of a wavelength of 1550 nm and 1310 nm which is fed with 1 mW of input power. The results showed that the highest output power of FBG against honey solution B was in the range of 213.60 – 214.58 μW. Changes in Bragg wavelength were quite significant for the increase in temperature of honey solution with a difference of 0.58 – 0.76 nm.

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1. INTRODUCTION

Fiber Bragg gratings (FBG) have attracted much attention in optical sensing for the measurement of strain, temperature, and refractive index [1-3]. The advantages of FBG are its small size, high sensitivity, and resistance to electromagnetic interference [4, 5]. FBG is a transmission medium that has a grid as an optical filter or reflector that works based on the resonance effect of the grid. The FBG grid makes the light at certain wavelengths reflected and at others transmitted [6-8].

The characteristics of FBG are generally carried out by giving the effect of temperature changes on the FBG directly using a heated bulb or plate [9, 10]. Research on the characteristics of the FBG has been carried out and the output power of the FBG decreases with increasing temperature [11, 12]. In addition, a given temperature change also affects the Bragg wavelength [13-15].

In this study, the characteristics of FBG are carried out by giving the effect of temperature changes by organic matter or fluids, namely honey. Measurements were made at a temperature range of 30°C – 60°C for every 5°C change with variations in wavelengths of 1550 and 1310 nm. Laser diode as input with -5 dBm power and optical power meter as output. Furthermore, the effect of honey temperature on FBG was measured. The optical power obtained is then calculated and analyzed to detect the relationship between the variation of honey temperature and the optical output power of the FBG, the change in Bragg wavelength, and the rate of change in the temperature of the honey.

2. THEORY

FBG is a type of optical fiber that relies on electromagnetic wavelengths propagating in its core. The spectrum determined by FBG depends on the lattice period and the effective refractive index of the fiber core. Bragg wavelength relationship (λ_B) with lattice period (Λ) and its effective refractive index (n_{eff}) [16] defined Equation (1) as follows:

$$\lambda_B = 2n_{eff}\Lambda \tag{1}$$

Bragg wavelengths are affected by strain and temperature. Changes in temperature affect the refractive index of the core and the lattice period of the FBG causing a change in the Bragg wavelength [17]. Bragg wavelength shift ($\Delta\lambda_B$) for temperature changes (ΔT) can be defined in Equation (2) below:

$$\Delta\lambda_B = \lambda_B(\alpha + \xi)\Delta T \tag{2}$$

where, α is the optical fiber expansion coefficient (for silica ~0.55 × 10^{-6} °C^{-1}) and ξ is the thermo-optical coefficient (~8.6 × 10^{-6} °C^{-1}) [18].

The wavelength shift can be determined by calculating the difference between the output power displayed by the OPM when given a change in temperature and the reference output power [14] which is expressed in Equation (3) as follows:

$$\Delta P_0 = 18.7\exp\left[-0{,}111(\Delta\lambda_{B,0})^2\right] - 18.7\exp\left[-0{,}111(\Delta\lambda_{B,1})\right]^2 \tag{3}$$

where, $\Delta\lambda_{B,0}$ is the Bragg wavelength at the reference state and $\Delta\lambda_{B,1}$ is the Bragg wavelength at a given temperature variation [19].

OPM measures the average output power of the FBG in dBm. The mathematical relationship between reading power in OPM in watts and a reference power of 1 milliwatt [20] is expressed in Equation (4):

$$P\,(dBm) = 10\,\log\frac{P_0}{P_{ref}} \tag{4}$$

3. MATERIALS AND METHOD

This research was conducted with optical experiments on the characteristics of FBG on changes in honey temperature. The research steps are shown in Figure 1.

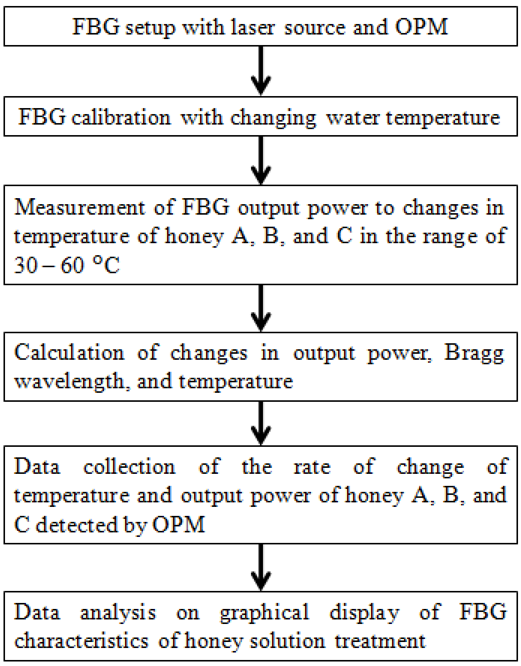

Figure 1. Research flowchart.

The research started by preparing FBG with laser source and OPM. The output power and reference temperature are measured before starting the measurement process. Furthermore, FBG calibration is carried out by increasing and decreasing the water temperature to obtain optical output power. The temperature range measured is 30°C – 60°C at every 5°C change. Then measured the effect of changes in honey temperature on FBG as shown in Figure 2.

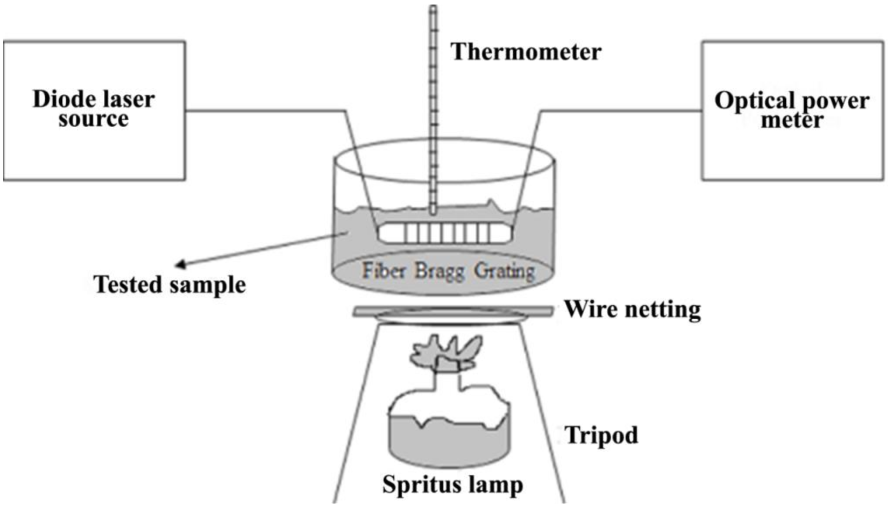

Figure 2. Measurement of FBG output power to honey temperature changes.

Data processing using Microsoft Excel to get the Bragg wavelength changes that occur. The materials and tools used in this study were FBG, mineral water, packaged honey (A, B, and C), diode laser, optical power meter, thermometer, spirit lamp, and glass beaker.

4. RESULTS AND DISCUSSION

Before conducting the research, the FBG was first calibrated to conform to the standard. Figure 3 shows the results of the 1550 nm measurement, the data is denser than 1310 nm which means the 1310 nm measurement is more sensitive than 1550 nm [11]. This is caused by the attenuation factor and power loss on the FBG [21]. The output power of the FBG when the temperature rises and falls with 1550 nm has a range of 207.58 – 208.64 μW and 1310 nm has a range of 210.70 – 211.84 μW. Calibrations at the same wavelength have different measurement results when the temperature changes. This is because the water used for the calibration process is mineral water (impure water).

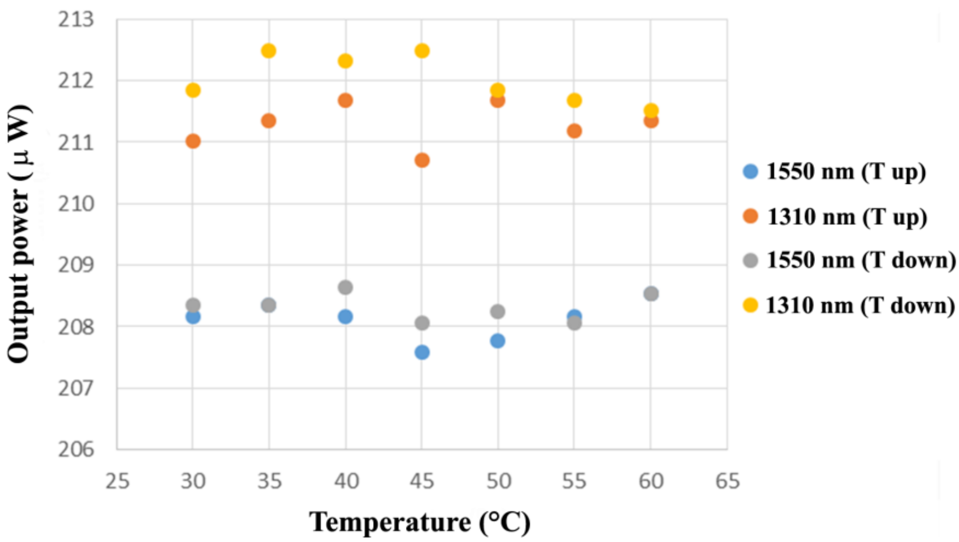

Figure 3. FBG output power to temperature changes with a wavelength of 1550 and 1310 nm.

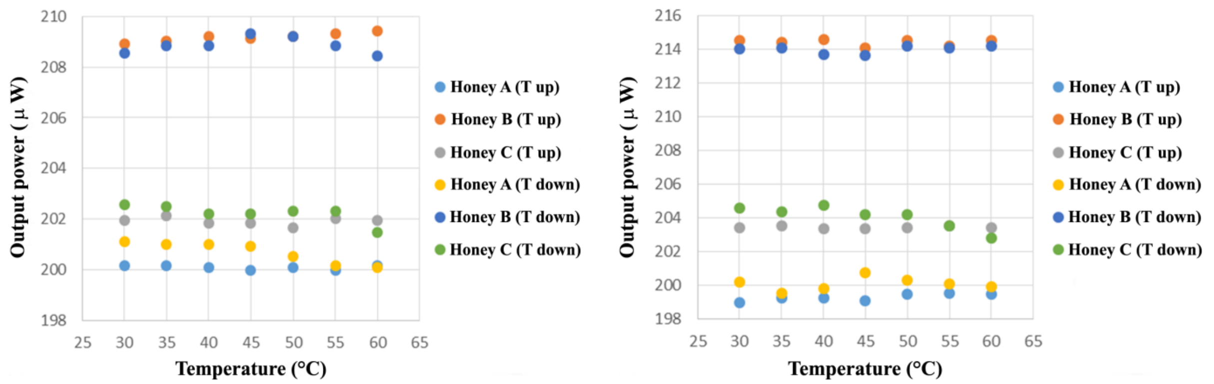

Figure 4. The characteristics of the FBG output power and temperature for the three types of honey with a wavelength of 1550 nm (left) and 1310 nm (right).

Figure 4 show that the output power of the FBG is lower when the honey temperature is increased. The arrangement of FBG and honey particles when the temperature rises stretch which causes the FBG light guide to be imperfect because the light is diffracted so that the detected power loss is greater and the FBG output power is getting smaller [22, 23]. The measurement results of 1550 nm and 1310 nm indicate that honey A, B, and C have different output power. This is due to differences in the density of honey. The higher the density of honey, the more absorption is carried out by the substances contained in honey [24].

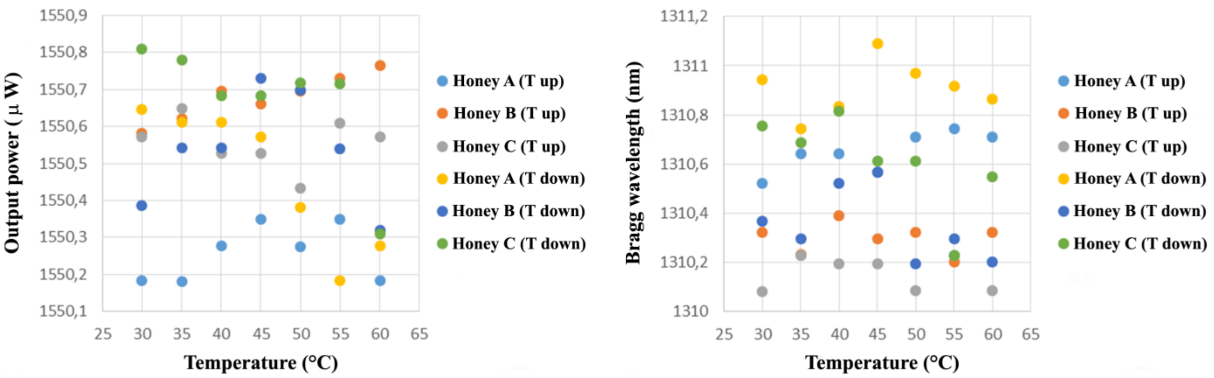

Figure 5. Changes in the Bragg wavelength in three types of honey with respect to temperature with a wavelength of 1550 nm (left) and 1310 nm (right).

Figure 5 show the change in the Bragg wavelength at a certain temperature. Changes in the Bragg wavelength are affected by the value of the refractive index of the FBG. The higher the density of honey, the greater the refractive index. Changes in the refractive index will change the effective refractive index so that the Bragg wavelength will change. The Bragg wavelength will shift to a lower wavelength when the refractive index of honey increases [25]. Changes in the Bragg wavelength in this study fluctuated. This is due to the uneven distribution of heat on the FBG and the effect of honey composition.

5. CONCLUSION

Research has analyzed the correlation of FBG characteristics to changes in honey temperature. The output power of the FBG is inversely proportional to the given temperature. This is influenced by the arrangement of particles, density, and light absorption. Changes in the Bragg wavelength have shifts and fluctuations that are influenced by heat distribution and honey composition. The rate of change of temperature has different measurement results for each particular temperature which is influenced by the area being heat-treated, the length of the medium being heated, and the difference in heat between the two mediums.

REFERENCES

[1] Liu, J., Zhu, L., He, W., & Dong, M. (2020). Temperature-sensing characteristics of polarization-maintaining fiber Bragg grating inscribed directly by 800-nm femtosecond laser pulses. *Optical Fiber Technology*, **56**, 102186.

[2] Sahota, J. K., Gupta, N., & Dhawan, D. (2020). Fiber Bragg grating sensors for monitoring of physical parameters: A comprehensive review. *Optical Engineering*, **59**(6), 060901.

[3] Bhaskar, C. V. N., Pal, S., & Pattnaik, P. K. (2021). Recent advancements in fiber Bragg gratings based temperature and strain measurement. *Results in Optics*, **5**, 100130.

[4] Sun, L., Hao, H., Zhang, B., Ren, X., & Li, J. (2016). Strain transfer analysis of embedded fiber Bragg grating strain sensor. *Journal of Testing and Evaluation*, **44**(6), 2312–2320.

[5] Ramadhan, K., Saktioto, Syahputra, R. F., Soerbakti, Y., Fauzan, M. (2020). Dispersi multi-layer pada inti serat optik moda tunggal. *Seminar Nasional Fisika Universitas Riau V (SNFUR-5)*, **5**(1), 1–5.

[6] Huang, F., Chen, T., Si, J., Pham, X., & Hou, X. (2019). Fiber laser based on a fiber Bragg grating and its application in high-temperature sensing. *Optics Communications*, **452**, 233–237.

[7] Afriastuti, S., Gemawati, S., & Syamsudhuha, S. (2021). On (f, g)-Derivation in BCH-Algebra. *Science, Technology and Communication Journal*, **1**(3), 89–94.

[8] Siswanti, T. F., Gemawati, S., & Syamsudhuha, S. (2021). t-Derivations in BP-Algebras. *Science, Technology and Communication Journal*, **1**(3), 97–103.

[9] Mieloszyk, M., Andrearczyk, A., Majewska, K., Jurek, M., & Ostachowicz, W. (2020). Polymeric structure with embedded fiber Bragg grating sensor manufactured using multi-jet printing method. *Measurement*, **166**, 108229.

[10] Sun, M. Y., Shi, B., Zhang, D., Liu, J., Guo, J. Y., Wei, G. Q., & Cheng, W. (2020). Study on calibration model of soil water content based on actively heated fiber-optic FBG method in the in-situ test. *Measurement*, **165**, 108176.

[11] Prajitno, G. & Yunifar, R. I. (2015). Analisis pengaruh perubahan suhu dan perubahan panjang kupasan cladding serta coating terhadap rugi daya yang dihasilkan oleh fiber optik multimode silika tipe G-651. *Jurnal Sains dan Seni ITS*, **4**(2), 15595.

[12] Ghorat, M., Gharehpetian, G. B., Latifi, H., Hejazi, M. A., & Bagheri, M. (2019). High-resolution FBG-based fiber-optic sensor with temperature compensation for PD monitoring. *Sensors*, *19*(23), 5285.

[13] Hu, T., Zhao, Y., & Song, A. N. (2016). Fiber optic SPR sensor for refractive index and temperature measurement based on MMF-FBG-MMF structure. *Sensors and Actuators B: Chemical*, **237**, 521–525.

[14] Laffont, G., Cotillard, R., Roussel, N., Desmarchelier, R., & Rougeault, S. (2018). Temperature resistant fiber Bragg gratings for on-line and structural health monitoring of the next-generation of nuclear reactors. *Sensors*, **18**(6), 1791.

[15] Yustina, Y., Wulandari, S., & Priawan, O. (2021). Observation of growth rate of catfish (Pangasius sp.) Against mixed feed fermentation of mustard and cabbage waste flour. *Science, Technology and Communication Journal*, **2**(1), 26–31.

[16] Reddy, P. S., Sai Prasad, R. L. N., Srimannarayana, K., Sai Shankar, M., & Sen Gupta, D. (2010). A novel method for high temperature measurements using fiber Bragg grating sensor. *Opt. Appl*, **40**(3), 685–692.

[17] Zhan, Y., Xue, S., Yang, Q., Xiang, S., He, H., & Zhu, R. (2008). A novel fiber Bragg grating high-temperature sensor. *Optik*, **119**(11), 535–539.

[18] Qian, Y., Zhao, Y., Wu, Q. L., & Yang, Y. (2018). Review of salinity measurement technology based on optical fiber sensor. *Sensors and Actuators B: Chemical*, **260**, 86–105.

[19] Zhang, L., Wu, G., Li, H., & Chen, S. (2020). Synchronous identification of damage and vehicle load on simply supported bridges based on long-gauge fiber Bragg grating sensors. *Journal of Performance of Constructed Facilities*, **34**(1), 04019097.

[20] Zhang, B., & Kahrizi, M. (2007). High-temperature resistance fiber Bragg grating temperature sensor fabrication. *IEEE Sensors Journal*, **7**(4), 586–591.

[21] Yurchenko, A. V., Gorlov, N. I., Alkina, A. D., Mekhtiev, A. D., & Kovtun, A. A. (2016). Research of the additional losses occurring in optical fiber at its multiple bends in the range

waves 1310nm, 1550nm and 1625nm long. *Journal of Physics: Conference Series*, **671**(1), 012001.

[22] Annisa, R., Hidayah, H., Hartono, H., & Supriyadi, S. (2019). Light Bulb Substitute Lens for Measuring Liquid Bias Index. *International Journal of Active Learning*, **4**(1), 40–44.

[23] Du, Y., Han, Q., Hu, H., Sang, M., Zhao, X., Song, X., Wang, H., & Liu, T. (2019). High-sensitivity refractive index and temperature sensor based on cascading FBGs and droplet-like fiber interferometer. *Sensors and Actuators A: Physical*, **299**, 111631.

[24] Mokhtar, W. M., Pang, N. H. M. K., & Halim, R. M. (2021). Gold nanoparticles coated FBG sensor based on localized SPR for adulterated honey classification. *Nano Hybrids and Composites*, **31**, 45–54.

[25] Halid, N. S. T., Daud, S., Rohizad, S. N. A., Multar, E., & Yusoff, A. R. M. (2020). Surrounding refractive index and liquid based sensors using fibre bragg grating. *Journal of Physics: Conference Series*, **1484**(1), 012009.