The Fiber Grating Rain Gauge

Chan-Yu Kuo, Sih-Yuan Chen, Wen-Fung Liu
Department of electrical engineering
Feng Chia University
Taichung
ch20034512@gmail.com

Hung-Ying Chang
Ph.D. Program of Electrical and Communications Engineering
Feng Chia University
Taichung
hungying.chang@gmail.com

***Abstract*—In this paper we propose a novel rain gauge by using a fiber Bragg grating with the sensitively of 0.0294nm/mm for the measuring range from 0 to 140mm. The operation mechanism is based on the rain weight to load the thin film of rain gauge and then to stretch the grating to result in the grating wavelength shift.**

Keywords—rain gauge, fiber Bragg grating

I. Introduction

There are many different types of traditional rain gauges, such as the siphon type rain gauge, weighing rain gauge[1], and tipping bucket rain gauge[2~5], etc. For these traditional rain gauges, they are usually based on electronic types with the disadvantage of easy to be impacted by the water to cause the short circuit and then to result in measurement errors.

In this paper we propose a novel rain gauge based on a fiber Bragg grating with the function of weighing rain gauge. The operating mechanism is to use the rain weight to be converted into the height of rainfall by utilizing the fiber grating and the packaged design. The curve of rainfall can be recorded automatically. The advantage of fiber rain gauge is the light weight and small size, less susceptible to external interference, etc. The most important characteristic of the proposed fiber rain gauge is lower cost and high accuracy than the traditional rain gauges.

II. Basic Principles

The configuration of fiber grating rain gauge is to combine the silicone rubber thin film of the cross-section area of 50cm² with a fiber Bragg grating. The sensing basic principle is based on the Bragg wavelength shift owing to that the rain weight loads the thin film to cause the FBG to be stretched and then to create the grating wavelength to be shifted toward the longer wavelength. The configuration of sensing head is shown in Fig. 1. We use a 3D printer to manufacture a practical support structure to fix the fiber grating and the thin-film. Figure 1(b) shows a rain collected device which can collect up to 300 mm of rainfall in the hollow barrel. The weight of rainfall will pressure the silicone rubber thin-film to cause the grating wavelength shift. The conversion relationship between the grating wavelength and the testing rainfall is expressed as following equation:

$$H = (\lambda_B - \lambda_0)/S \quad (1)$$

where H means the depth of the conversion rainfall, λ_B is the measuring wavelength, λ_0 denotes the original grating wavelength, S is the sensitivity of the rain gauge.

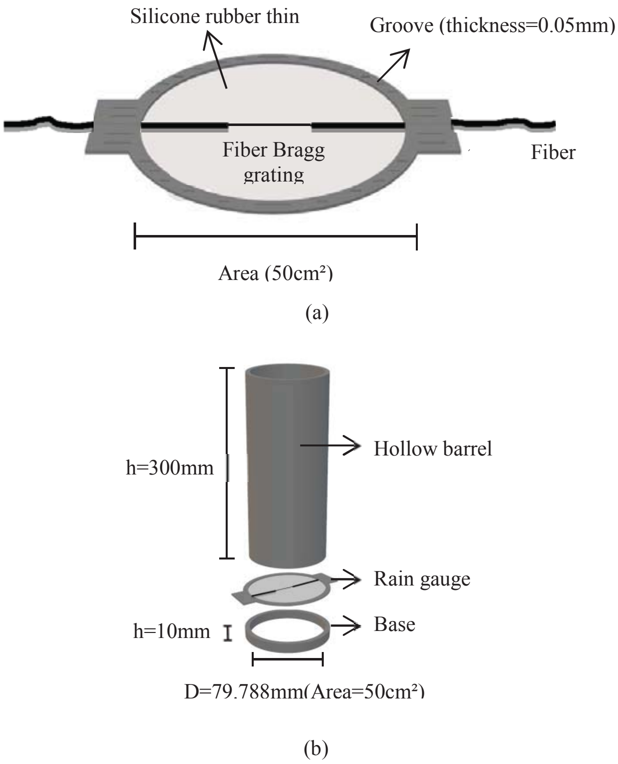

Fig. 1 (a) The fiber rain-gauge; (b) The configuration of fiber grating rain-gauge.

III. Experimental Set-up and Results

In this study, the shift of grating wavelength due to the weight of water is monitored by using the optical sensing instrumentation from the Micron Optics Corp. The experimental set-up is shown in Fig 2. The Bragg wavelength and the cumulative water depth will display on the laptop via the scanner immediately. The optical sensing instrumentation is not only able to measure the grating wavelength but also to transfer the data to rainfall by using the designed software.

978-1-5386-1445-7/18/$31.00 ©2018 IEEE

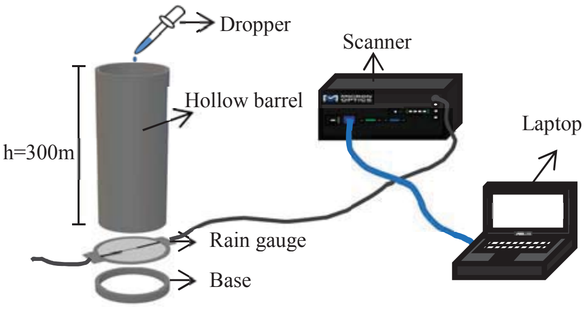

Fig. 2 The Experimental set-up of the rain gauge.

Figure 3 shows the curves of relationship for the grating wavelength shift versus the rainfall with different thicknesses of silicone rubber thin films. For using the original grating wavelength of 1547.50 nm, the experimental results show that the range of rainfall is from 0 mm to 140 mm. When the rainfall is changed, the axis stress of fiber Bragg grating is also varied. Therefore, the rainfall variation to cause the grating wavelength shift can be measured by the scanner and then transferred by the software. From the figure, the thinner silicone rubber, the higher sensitivity has. The sensitivities both of 0.03419nm/mm and 0.0294nm/mm are respectively obtained for 0.5mm thickness and for 1mm thickness. Figure 4 shows the relationship curve of the actual rainfall versus the converted rainfall. The converted rainfall is calculated from the grating wavelength shift by using equation (1). From Fig. 4 we can observe that there is a good linearity between actual rainfall and the theoretical predictable rainfall.

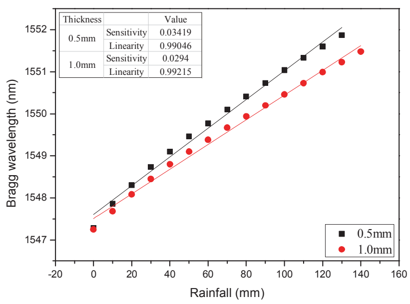

Fig. 3 the curves of relationship for the grating wavelength shift versus rainfall with different thickness silicone rubber thin films.

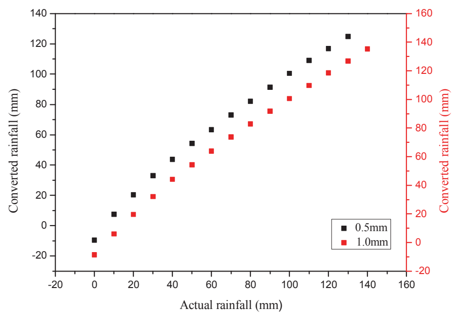

Fig. 4 the relationship of the actual rainfall versus the converted rainfall.

IV. Conclusion

In this paper, the rain-gauge is experimentally demonstrated with the measurement sensitivity of 0.03419nm/mm for 0.5mm thickness and the sensitivity of 0.0294nm/mm for 1mm thickness silicone diaphragm respectively. This fiber grating rain-gauge can provide a novel method with a nice sensing performance for measuring the rainfall for the daily or long time.

Acknowledgment

The authors would like to specifically thank the Ministry of Science and Technology, Taiwan, for sponsoring this research under Contract Nos. MOST 105-2622-E-035-015-CC3 and Most 106-2221-E-035-059.

References

[1] M. Colli, L.G. Lanza, P. La Barbera, “Performance of a weighing rain gauge under laboratory simulated time-varying reference rainfall rates,” Atmospheric Research, vol. 131, pp. 3-12, 2013.

[2] M. Stagnaro, M. Colli, L.G. Lanza, P.W. Chan, “Performance of post-processing algorithms for rainfall intensity using measurements from tipping-bucket rain gauges,” Atmospheric Measurement Techniques, vol. 9 (12), pp. 5699-5707, 2016.

[3] I.R. Calder, C.H.R. Kidd, “A note on the dynamic calibration of tipping-bucket gauges,” Journal of Hydrology, vol. 39, pp. 383-386, 1978.

[4] A. Molini, P. La Barbera, L.G. Lanza, L. Stagi, “Rainfall intermittency and the sampling error of tipping-bucket rain gauges,” Physics and Chemistry of the Earth, Part C: Solar, Terrestrial & Planetary Science, vol. 26, pp. 737-742, 2001.

[5] G.J.G. Upton, A.R. Rahimi, “On-line detection of errors in tipping-bucket raingauges,” Journal of Hydrology, vol. 278, pp. 197-212, 2003.