

Comparison of sensitivity and thermal response of chirped fiber Bragg gratings at various degrees of bending

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ABSTRACT

The development of optical fiber sensors based on fiber Bragg grating (FBG) has driven the need for a deeper understanding of sensor characteristics under mechanical deformation conditions. This study is motivated by the limited investigations specifically examining the simultaneous interaction between bending and thermal response in chirped FBG. This research aims to analyze the effect of bending degree on the sensitivity and thermal response of chirped fiber Bragg grating (CFBG), to observe Bragg wavelength (λ_B) shifts and transmission power variations, and to determine the optimal bending configuration. Measurements were conducted using a dual laser source at wavelengths of 1310 nm and 1550 nm, with bending angle variations of 0°, 10°, 20°, 30°, and 40°, across a temperature range of 35°C to 49°C representing human physiological conditions. Results demonstrate that bending degree exerts a substantially more dominant influence on transmission power than temperature variation, with inter-angle power differences exceeding 12 dB. Bending angles of 20° and 30° consistently yielded the highest transmission power, with sensitivity values reaching 1555.72% and 1527.37% respectively at 1550 nm. The 1310 nm wavelength exhibited slightly higher sensitivity, whereas the 1550 nm demonstrated better thermal response stability. This research contributes to establishing optimal operating conditions for CFBG sensors in wearable health monitoring applications requiring high sensitivity and reliable thermal stability.

Keywords: Bending; Bragg wavelength; chirped fiber Bragg grating; sensitivity; thermal response

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INTRODUCTION

Fiber Bragg grating (FBG) sensors are widely used for temperature, strain, and deformation measurements because of their compact size, immunity to electromagnetic interference, and multiplexing capability [1]. These advantages also support wearable applications for physiological and motion monitoring [2]. Chirped fiber Bragg gratings (CFBGs) extend these capabilities through a spatially varying grating period, producing a broad reflection band responsive to temperature and strain distributions [3].

Bending and temperature can both influence sensor output, making their combined effects important for reliable measurements. Hong et al. [4] demonstrated FBG-based wearable rings for joint motion monitoring, while Han et al. [5] distinguished bending and temperature effects using a sampled CFBG mounted on a cantilever

beam. These studies highlight the influence of sensor configuration and interrogation method on the measured response.

This study examines CFBG optical power responses at bending angles of 0°, 10°, 20°, 30°, and 40°, using 1310 and 1550 nm illumination over 35°C – 49°C. Relative power changes and temperature-dependent responses are compared to identify configurations offering pronounced optical responses and comparatively stable output for potential sensing applications.

LITERATURE REVIEW

Hill and Meltz [6] described the fundamental principles, fabrication methods, and optical properties of fiber Bragg gratings. Their work provides the basis for understanding how the grating structure determines wavelength-selective reflection and supports sensing applications.

Erdogan [7] analyzed the spectral characteristics of uniform, apodized, and chirped gratings. This framework explains how grating design influences reflection and transmission spectra and provides a theoretical basis for interpreting the optical response of CFBGs under changing experimental conditions.

Pereira et al. [8] demonstrated an interrogation method using ultra-short FBGs as optical edge filters, incorporating temperature compensation. Their study illustrates how a wavelength-dependent filtering arrangement can support power-based interrogation. This distinction is relevant to the present study, which compares optical power responses under bending and temperature variations rather than directly measuring spectral shifts.

RESEARCH METHODS

Experimental Setup

The experiment used a CFBG, a dual-wavelength laser source at 1310 nm and 1550 nm, an optical power meter (OPM), a digital thermometer, and a protractor. The CFBG was connected between the source and OPM to measure transmitted power (see Figure 1).

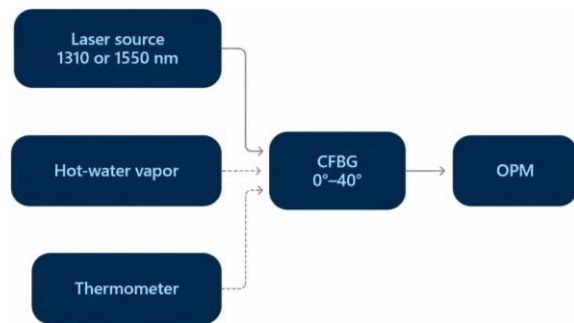


Figure 1. Transmission-based CFBG setup for bending and thermal measurements.

The sensing region was secured at bending angles of 0°, 10°, 20°, 30°, and 40° and positioned above hot water without contacting the liquid. Temperature near the sensing region and transmitted power were recorded during cooling from approximately 49°C to 35°C. Measurements covered both wavelengths and all bending configurations, with 0° serving as the reference.

Power readings were converted from dBm into milliwatts, calculated using the Equation (1):

$$P_{mW} = 10^{\frac{P_{dBm}}{10}} \quad (1)$$

Relative power change was calculated using the Equation (2):

$$R_p = \frac{P_\theta - P_0}{P_0} \times 100\% \quad (2)$$

where P_θ and P_0 denote bent- and straight-fiber power at matching wavelengths and temperatures. Power-temperature curves were compared in Excel and OriginLab to assess bending effects.

RESULTS AND DISCUSSION

Optical Power Response to Bending

Figure 2 (1550 nm) and Figure 3 (1310 nm) show a nonmonotonic relationship between bending angle and transmitted power, with the highest outputs generally occurring at 20° and 30°. Near 35°C, power increased from -29.38 to -17.19 dBm at 1550 nm and from -30.44 to -17.98 dBm at 1310 nm between 0° and 20°. At 40°, outputs decreased to -27.54 and -28.17 dBm, respectively.

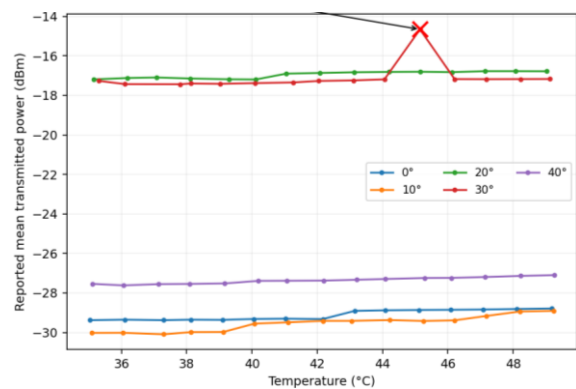


Figure 2. CFBG transmitted-power characteristics of power versus temperature at 1550 nm.

Curvature-induced radiation loss can reduce transmission [9] but cannot fully explain the increase at intermediate angles. Mounting, local strain, coupling, and source-grating spectral alignment may also influence the response.

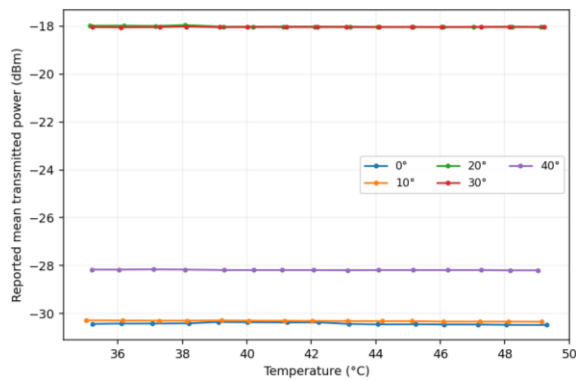


Figure 3. CFBG transmitted-power characteristics of power versus temperature at 1310 nm.

Temperature-Dependent Power Response

At 1550 nm, power generally increased with temperature, although steps and isolated deviations require further examination. At 1310 nm, power spans ranged from 0.030 to 0.125 dB, indicating smaller temperature-dependent variations than at 1550 nm (see Figure 4).

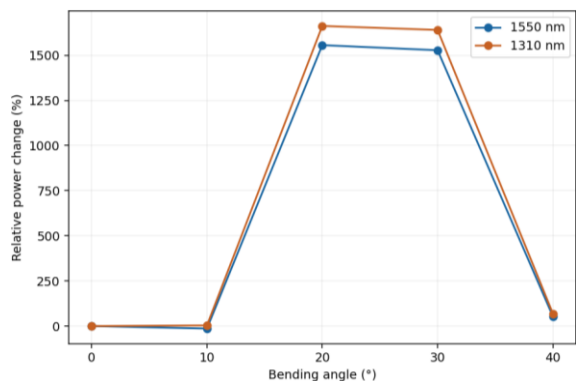


Figure 4. CFBG transmitted-power characteristics of relative power change near 35°C.

CFBG thermal response depends on grating design and temperature distribution [10]. Non-uniform vapor exposure may influence results. Small power variations do not establish accuracy or repeatability; calibration must consider the complete system [11].

Relative Power Change

Figure 5 shows relative power changes near 35°C. At 20° and 30°, these reached approximately 1556% and 1527% at 1550 nm, compared with 1662% and 1640% at 1310 nm. These percentages describe changes relative to the straight-

fiber reference, rather than sensitivity per unit angle or temperature. The larger percentages at 1310 nm partly reflect its lower reference power.

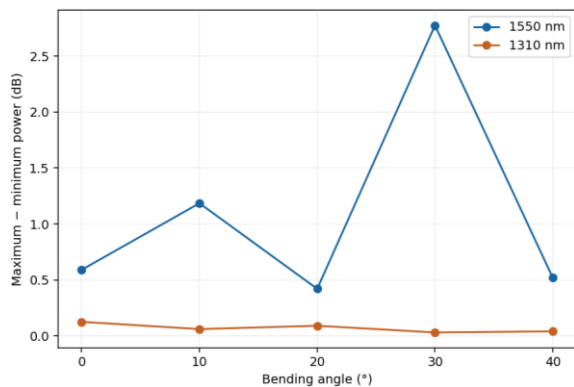


Figure 5. CFBG transmitted-power characteristics of power span across tested temperatures.

Measurement Limitations and Configuration Assessment

The -14.66 dBm entry at 1550 nm, 30°, and 45.15°C requires verification before fitting or optimization. Because the specified grating resonance is near 1550 nm, the 1310 nm results represent fiber-assembly transmission unless a corresponding resonance is confirmed. Calculated wavelength shifts must also be distinguished from measured spectra.

Overall, 20° – 30° produced the highest reported power, while 1310 nm exhibited smaller temperature-dependent variations. Establishing an optimum requires verified data, controlled bending geometry, repeated measurements, and uncertainty evaluation [11]. Wearable performance remains to be validated.

CONCLUSION

The CFBG assembly showed a nonmonotonic bending response, with the highest transmitted power at 20° – 30°. Near 35°C, the 20° configuration increased power by 12.19 dB at 1550 nm and 12.46 dB at 1310 nm relative to the straight configuration. The 1310 nm measurements exhibited smaller temperature-dependent variations. Data verification, repeated testing, and uncertainty evaluation are needed before determining an optimum or validating wearable applications.

AUTHOR CONTRIBUTIONS

Titis Oktiva Sari: Investigation, analysis, visualization, drafting. Saktioto Saktioto: Conceptualization, methodology, supervision, review editing. Rakhmawati Farma: Validation, review editing. Rahmondia Nanda Setiadi: Methodology, analysis. Tengku Emrinaldi: Resources, validation. Defrianto Defrianto: Supervision, review editing. All authors approved the manuscript.

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DECLARATION OF AI USE

The authors declare that no AI tools were used to prepare this manuscript.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

All supporting data are included in this article. No additional datasets are available.

ETHICAL APPROVAL

Ethical approval was unnecessary, as no humans or animals were involved.

REFERENCES

- [1] Kersey, A. D., Davis, M. A., & Friebele, E. J. (1997). Fiber grating sensors. *J. Light. Technol.*, **15**(8), 1442. DOI: [10.1109/50.618377](https://doi.org/10.1109/50.618377)
- [2] Song, X., Fan, Y., & Tang, X. (2025). FBG-based wearable sensors and devices in the healthcare field: A review. *Opt. Laser Technol.*, **181**, 111920. DOI: [10.1016/j.optlastec.2024.111920](https://doi.org/10.1016/j.optlastec.2024.111920)
- [3] Tosi, D. (2018). Review of chirped fiber Bragg grating (CFBG) fiber-optic sensors and their applications. *Sensors*, **18**(7). DOI: [10.3390/s18072147](https://doi.org/10.3390/s18072147)
- [4] Hong, C.-Y., Abro, Z. A., & Lakho, R. A. (2021). An FBG-based smart wearable ring fabricated using FDM for monitoring body joint motion. *J. Ind. Text.*, **50**. DOI: [10.1177/1528083719870204](https://doi.org/10.1177/1528083719870204)
- [5] Han, Y.-G., Dong, X., Lee, J. H., & Lee, S. B. (2006). Simultaneous measurement of bending and temperature based on a single sampled chirped fiber Bragg grating embedded on a flexible cantilever beam. *Opt. Lett.*, **31**(19), 2839-2841. DOI: [10.1364/OL.31.002839](https://doi.org/10.1364/OL.31.002839)
- [6] Hill, K. O., & Meltz, G. (1997). Fiber Bragg grating technology fundamentals and overview. *J. Light. Technol.*, **15**(8). DOI: [10.1109/50.618320](https://doi.org/10.1109/50.618320)
- [7] Erdogan, T. (1997). Fiber grating spectra. *J. Light. Technol.*, **15**(8). DOI: [10.1109/50.618322](https://doi.org/10.1109/50.618322)
- [8] Pereira, L., Min, R., Woyessa, G., Bang, O., Marques, C., Varum, H., & Antunes, P. (2023). Interrogation method with temperature compensation using ultra-short fiber Bragg gratings in silica and polymer optical fibers as edge filters. *Sensors*, **23**(1), 23. DOI: [10.3390/s23010023](https://doi.org/10.3390/s23010023)
- [9] Marcuse, D. (1976). Curvature loss formula for optical fibers. *J. Opt. Soc. Am.*, **66**(3), 216. DOI: [10.1364/JOSA.66.000216](https://doi.org/10.1364/JOSA.66.000216)
- [10] Palumbo, G., Tosi, D., Iadicicco, A., & Campopiano, S. (2018). Analysis and design of chirped fiber Bragg grating for temperature sensing for possible biomedical applications. *IEEE Photonics J.*, **10**(3), 7103015. DOI: [10.1109/JPHOT.2018.2829623](https://doi.org/10.1109/JPHOT.2018.2829623)
- [11] Vallan, A., Bellone, A., Perrone, G., Sento, M., & Carullo, A. (2025). Calibration and uncertainty evaluation of fiber Bragg grating temperature sensors. *IMEKO TC2 PhotoMet 2025*, Modena, Italy. DOI: [10.21014/tc2-2025.005](https://doi.org/10.21014/tc2-2025.005)