# Optical laser-generated electricity for powering tilt-meter sensor

**Nelfyenny[1], Dwi Bayuwati[1], Suryadi[1], Irwan Rawal Husdi[1], Imam Mulyanto[1], Aditya Dwi Prasetio[2], Dedi Irawan[3], Bambang Widiyatmoko[1], Andi Setiono[1]**
[1]Research Center for Photonics, National Research and Innovation Agency, Tangerang Selatan, Indonesia
[2]Research Center for Geological Disaster, National Research and Innovation Agency, Tangerang Selatan, Indonesia
[3]Faculty of Teacher Training and Education, Universitas Riau, Pekanbaru, Indonesia

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**ABSTRACT**

This research investigated the feasibility and efficacy of power over fiber (PoF) transmission systems for geotechnical monitoring applications, addressing challenges associated with traditional power transmission methods. Leveraging fiber optic technology, PoF systems offer advantages such as high reliability, minimal signal loss, and immunity to environmental factors. The study presents a detailed design and implementation of a PoF transmission system, integrating a high-power laser source (HPLS) and photovoltaic technology for efficient power transmission over extended distances. Results demonstrate impressive volt-ampere characteristics and conversion efficiencies, with the optimized system configuration achieving a peak power output of 682 mW. Furthermore, the study evaluated the performance of a surface inclinometer sensor powered by the PoF system, showcasing its effectiveness in monitoring soil movements with remarkable stability and consistent power supply. Future research directions include scalability studies, optimization of system efficiency, and field deployments to broaden the applicability of PoF technology in geotechnical monitoring, ultimately advancing disaster mitigation and infrastructure resilience efforts.



***Corresponding Author:***

Andi Setiono
Research Center for Photonics, National Research and Innovation Agency
KST BJ. Habibie, Tangerang Selatan, Indonesia
Email: andi033@brin.go.id

## 1. INTRODUCTION

Recent advancements in power over fiber (PoF) technology have revolutionized the field of remote monitoring systems, offering a viable alternative to traditional power transmission methods. PoF systems utilize fiber optic cables to transmit both data and power over long distances, providing high reliability and minimal signal loss. Compared to conventional power supply methods such as copper cables or batteries charged by photovoltaic devices, PoF offers several advantages. Firstly, PoF eliminates the need for frequent battery replacements or maintenance, reducing operational costs [1], [2] and ensuring continuous monitoring capabilities. Secondly, PoF systems are immune to electromagnetic interference [3], [4] and environmental factors, making them particularly suitable for harsh or remote environments where traditional power transmission methods may be impractical. Additionally, PoF technology enables power transmission to underwater sensors [5], expanding its applicability to marine monitoring systems such as tsunami detection networks. Relying on copper cables for power transmission in underwater environments may lead to increased expenses [6], [7]. Moreover, it is worth noting that PoF technology can also be utilized to supply power to microelectromechanical systems (MEMS) sensors for environmental monitoring applications [8],

[9], [10]. This extends its utility beyond geotechnical monitoring to various domains where remote power transmission is required. The design and implementation of PoF transmission systems emerge as a reliable and efficient alternative to power remote monitoring systems [11], [12]. By leveraging PoF technology, researchers can enhance the efficiency, reliability, and longevity of remote monitoring systems, ultimately advancing our ability to monitor and mitigate geological hazards effectively.

To provide a comprehensive understanding and context for the significance of PoF technology in remote monitoring systems, a wealth of research has been conducted in this area. Noteworthy studies include those by Matsuura [3], which explore the design and optimization of PoF systems for various applications. Additionally, works by Mei *et al.* [13] delve into the reliability and performance analysis of PoF systems in different environmental conditions. Furthermore, research by Perhirin *et al.* [14] investigates the integration of PoF technology in marine monitoring networks, highlighting its effectiveness in underwater power transmission. These studies, among others, underscore the multifaceted benefits and potential of PoF technology in revolutionizing remote monitoring systems across diverse domains.

Referring to our previous research in the context of developing a landslide monitoring system [15]–[17], a solar panel-based power supply serves as the primary electrical resource. However, this configuration faces challenges such as vulnerability to theft, particularly targeting the batteries, and maintenance complexities, posing significant obstacles. In this study, we implemented a PoF system using commercially available optical fibers commonly used for communication applications, which are generally more cost-effective. The implementation aimed to supply power to tiltmeter systems for monitoring slope inclination, further underscoring the versatility and practicality of PoF technology in diverse monitoring scenarios. The integration of PoF technology presents a promising avenue for enhancing the efficiency, reliability, and sustainability of remote monitoring systems. With ongoing advancements and research efforts, PoF technology holds immense potential to address the evolving needs of monitoring applications, contributing to improved disaster preparedness, infrastructure resilience, and environmental conservation efforts.

## 2. METHOD

### 2.1. Design of power over fiber transmission

The power over fiber transmission system in this research was designed to efficiently transmit power over extended distances by integrating various components, as illustrated in Figure 1. A pivotal component of this system was the high-power laser source (HPLS), which functions at a wavelength of 810.68 nm, boasting a maximum power output and operational current of 2.5 W and 3,300 mA, respectively. The system utilized a multi-mode fiber optic (FO) with a diameter of 62.5 µm and incorporates photovoltaic technology for light-to-electricity conversion, ensuring seamless power transmission. It is important to note that the photovoltaic device employed in this system, specifically the AFBR-POC206L from Broadcom Inc., is readily available on the market and comes equipped with fiber channel (FC) connectors, facilitating easy integration. The photovoltaic device AFBR-POC206L is a multi-junction compound semiconductor device that provides operating voltages in volts direct current (VDC) unit for typical 3 or 5 VDC applications. The optimal wavelength range for optical conversion is between 800 and 850 nm. It is designed with several thin photovoltaic semiconductor sub-cells interconnected with tunnel junctions, epitaxially grown on top of each other by the organic chemical vapor deposition method [18]. Additionally, it can achieve light conversion efficiency between 40% to 50%. However, efficiency may decrease with increasing fiber length [19].

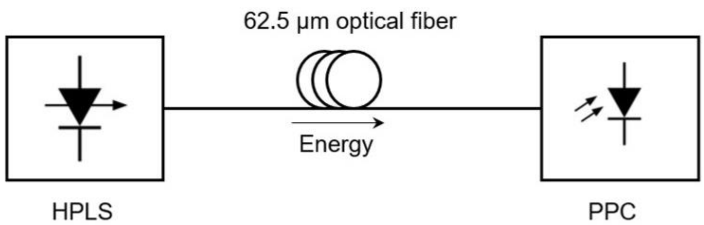



Figure 1. Schematic diagram of the PoF system

To evaluate its performance across lengths of fiber optic cables, experiments were conducted using fiber optic lengths of 200 m. The fiber length was achieved by connecting four 50 m segments of fiber optic cables through splicing. These segments were spliced together using fiber splicers to ensure a seamless and continuous transmission pathway. Optical power measurements after transmission through the 200 m fiber optic cable were conducted using a PM130D-Digital Power and Energy Console (Thorlabs). The characterization of the PoF system is detailed, with a focus on the volt-ampere characteristics (V-I) of the electrical output generated by the photovoltaic component when coupled with the HPLS. To achieve this, the electrical output produced was directed to a variable resistor set at 10k ohms. By adjusting the resistance value, the output voltage of the photovoltaic device and the corresponding current flow were measured. While characterizing the PoF system, the intensity of the laser source was manipulated by adjusting its current. The laser current was altered across multiple settings: 700, 1,000, 1,400, 1,800, 2,200, 2,500, and 2,900 mA. This variation enables the assessment of the system's performance under different laser intensity levels, providing valuable insights into its operational characteristics.

## 2.2. Tilt-meter design sensor

A three-axis accelerometer functioned as the sensor platform for the tilt-meter system, covering a measurement range ±180° (X-axis) and ±90° (Y-axis) with an impressive inclination accuracy of 0.2°. As schemed in Figure 2, the tilt sensor module seamlessly interfaced with the microcontroller system, utilizing the serial communication protocol for efficient data transfer. To power this system, we integrated a reliable 3.7 V, 5,000 mAh (18.5 Wh) battery along with a charging system for continuous operation. Additionally, the inclusion of a Wi-Fi embedded module allowed for versatile data transmission, seamlessly connecting to the data collector gateway system. This Wi-Fi application facilitated efficient data management. Delineated in Figure 2, the tilt-meter system's compact design and portability showcase the integration of the sensor module into a printed circuit board (PCB) board system. This configuration, known as the surface inclinometer sensor, enhances the precision of tilt measurements for various applications such as geotechnical studies or structural monitoring. The intricate specifications of the components comprising the inclinometer are meticulously detailed in Table 1, offering a comprehensive overview of their respective functionalities and performance attributes. The system's adaptability and robust design position it as a valuable tool for capturing accurate tilt data in diverse environmental conditions.

In addition to its technical capabilities, the tilt-meter system is designed with user-friendly features that simplify deployment and operation. The intuitive interface allows for easy calibration and setup, reducing the time and expertise required for installation. The system's firmware can be updated, ensuring that it remains up-to-date with the latest advancements and improvements. Furthermore, the robust housing of the sensor module provides protection against environmental factors such as dust and moisture, making it suitable for harsh outdoor conditions. This durability extends the lifespan of the device, offering a cost-effective solution for long-term monitoring projects. By combining high precision, ease of use, and rugged construction, the tilt-meter system stands out as a versatile and reliable instrument for professionals in the field.

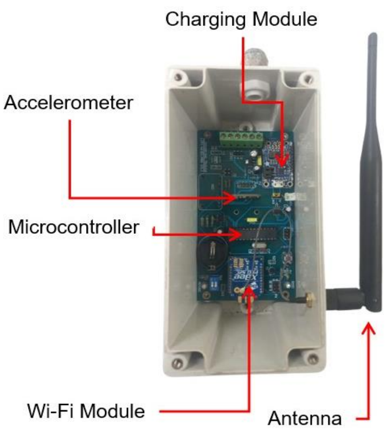



Figure 2. Tilt-meter sensor system

Table 1. Specification of tilt-meter

| Variable | Specification |
|---|---|
| Main controller | ATMega 328P |
| Sensor module | 3-axis-accelerometer |
| Data transceiver | Module XbeePro S2C |
| Charging module | Power Boost 1000C Adafruit |

## 3. RESULTS AND DISCUSSION

In this section, we delve into the integration of laser-based power systems with surface inclinometers, exploring both the technical intricacies and practical applications of this innovative fusion. The laser-based power budget serves as the backbone, facilitating the energy needs of essential components such as the surface inclinometer sensor module. This seamless integration not only enhances the efficiency of power distribution but also extends the functionality and reliability of landslide monitoring systems. Through meticulous analysis and real-world field measurements, we assess the effectiveness of this integrated approach, paving the way for enhanced understanding and management of geotechnical phenomena.

### 3.1. Laser-based power budge

The V-I characteristics of the employed photovoltaic, directly interfaced with the HPLS through the extended 200 m optical fiber, are presented in Figure 3(a). These graphical representations underscore the impressive maximal voltages achieved by the employed photovoltaic cells, reaching a peak of 6.98 V. Further analysis involved the meticulous computation of Volt-Watt curve characteristics, as illustrated in Figure 3(b) using values derived from Figure 3(a). It becomes evident that the operational zenith for optimal power transfer to the load materializes at an electrical power of approximately 682 mW. This optimized configuration results in a balanced interplay of voltage and current at 6.52 V and 104.6 mA, respectively. The investigation into the conversion efficiencies from optical to electrical power revealed significant findings, with the average efficiency of the photovoltaic AFBR-POC206L measuring approximately 40.35%. This power configuration was achieved through precise adjustments to the laser current, finely tuned at 2,900 mA, resulting in about 1.69 W optical power at a wavelength of 830 nm. Importantly, this setting represents a safe usage at ~87% of the specified maximum laser current, which is 3,300 mA, aiming to enhance the longevity and sustainability of the HPLS system. This strategic adjustment not only highlights the system's adaptability but also emphasizes its capacity for nuanced optimization, marking a significant milestone in the field of optical-to-electrical power conversion.

Expanding on these results, future research could delve into further optimizing the photovoltaic-HPLS interface to enhance conversion efficiencies even more. Additionally, exploring different configurations and materials for photovoltaic cells could lead to breakthroughs in improving overall system performance and sustainability. Overall, the findings presented in this section pave the way for advancements in optical-to-electrical power conversion technologies with promising applications in various fields, including powering monitoring system [20], [21], smart power management [22], [23], and internet of things [24], [25].

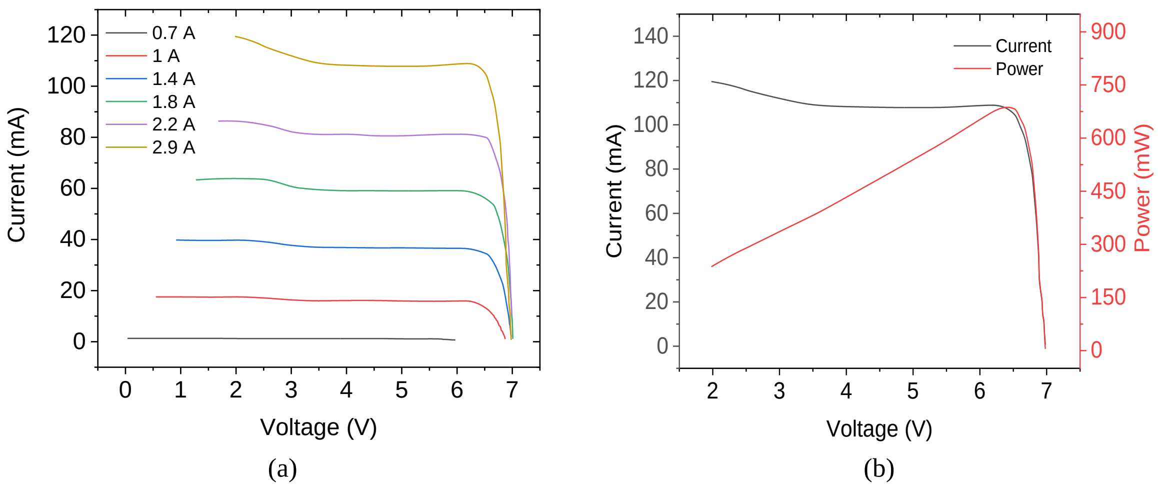



Figure 3. Photovoltaic performance (a) volt-ampere characteristics and (b) volt-watt curve analysis

### 3.2. Application of PoF system on a surface inclinometer

To evaluate the efficacy of the newly developed PoF system, the optimal power generated is harnessed to energize essential electrical components, particularly a surface inclinometer sensor, instrumental in meticulously monitoring rotational soil movements. The integration of the PoF system ensures that the inclinometer can operate efficiently in remote or challenging environments where conventional power delivery methods may be impractical. The PoF system successfully delivered a stable input voltage ($V_S$) of ~4.64 V to the surface inclinometer, ensuring reliable performance. As shown in Figure 4, the current supply

($I_S$) from the PoF system was measured at approximately 135 mA (full-square black line), which is adequate for both the operational needs and the charging requirements of the system. During the charging phase, the average charging current ($I_{CHG}$) was observed to be approximately 92.6 mA (open-square red line), while the load current ($I_L$) during active monitoring was around 38.4 mA. These values indicate a well-balanced power distribution that supports continuous operation and battery maintenance. The charging voltage curve demonstrates a smooth and steady rise in battery voltage over time. Starting at 3.67 V, the voltage (full-circle blue line) increases incrementally to 3.79 V after 250 minutes, reaching full charge at 3.92 V after being charged with a current of approximately 128.8 mA (open-square red line) under no electrical load. This gradual increase indicates that the PoF system provides a consistent and reliable charging current, avoiding any abrupt fluctuations that could potentially harm the battery or the connected components. The steady rise in voltage showcases the efficiency of the PoF system in maintaining a stable power supply. This is crucial for applications in geotechnical monitoring, where continuous and accurate data collection is essential.

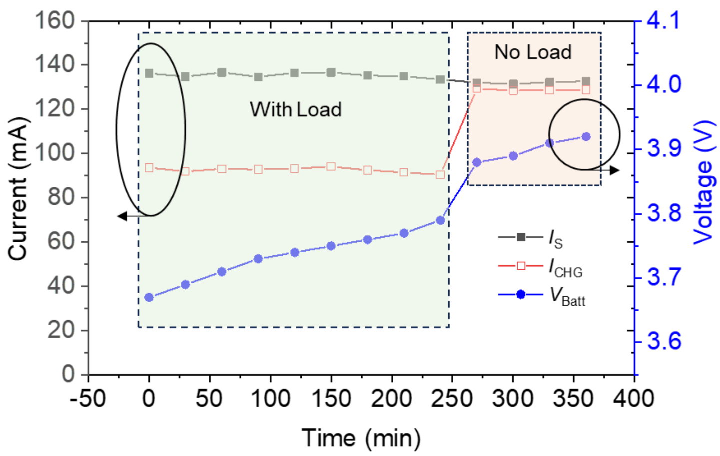
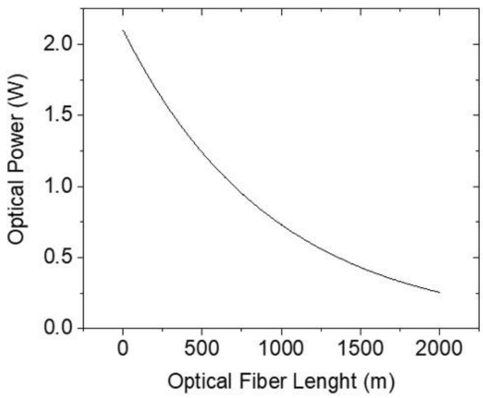


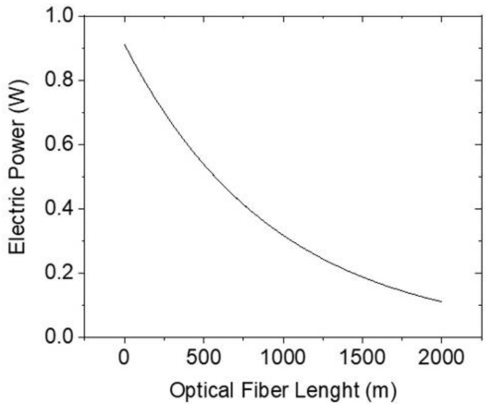

Figure 4. Charging performance of the PoF system demonstrates a steady increase in the battery voltage over time, with stable charging current

The consistent power delivery ensures that the surface inclinometer can reliably capture minute soil movements over extended periods, without interruption or loss of data integrity. Moreover, the stability of the voltage curve suggests that the PoF system is well-suited for long-term deployments in remote locations. The absence of significant voltage spikes or drops indicates a robust system design capable of operating under varying environmental conditions. This reliability enhances the overall effectiveness of the geotechnical monitoring system, providing confidence in the collected data's accuracy and consistency. The results confirm that the PoF system is highly effective in powering the surface inclinometer, offering a robust solution for geotechnical monitoring. The consistent voltage and current supply, coupled with efficient battery charging, highlight the system's potential for enhancing remote sensing applications. This innovative power delivery method opens new possibilities for deploying sensitive monitoring equipment in areas where traditional power sources are unavailable or unreliable, thereby expanding the scope and reliability of geotechnical investigations.

The measurements presented in this study were conducted for a maximum fiber length of 200 m. The formulation, $y=10^{\{(-000458x)\}}$ [18], can be utilized to determine the efficiency of optical energy transmission and its conversion to electric energy over longer distances. The calculations were performed for an input power of 2.1 W from the HPLS source, corresponding to a laser current setting of 2.9 A. Figure 5(a) illustrates that at a distance of 2,000 m, an optical power of 0.25 W can be achieved. In Figure 5(b), an estimation of the optical-to-electric energy conversion dependency is provided for optical fibers up to 2,000 m in length, with the estimation made for photovoltaic AFBR-POC206L. As depicted in the figure, at the maximum distance of 2,000 m, it is feasible to attain an electric power of 0.11 W when utilizing AFBR-POC206L. This underscores the potential for leveraging advanced photovoltaic technologies to sustainably harvest optical energy over considerable distances. In addition, these results hint at the scalability and adaptability of optical-to-electric energy conversion systems, paving the way for future exploration into extending the reach of such technologies for applications ranging from remote power generation to telecommunications infrastructure.




(a)




(b)

Figure 5. Power transfer and energy conversion efficiency with: (a) optical power at 2000 m and (b) optical-to-electric conversion: using photovoltaic AFBR-POC206L

## 4. CONCLUSION

In conclusion, our research yields significant results that demonstrate the practical viability and effectiveness of PoF transmission systems in geotechnical monitoring. Specifically, our experimentation showcases the remarkable performance of the PoF system in achieving high efficiency and reliability in power transmission over extended distances, as evidenced by the minimal signal loss and robust operation observed. Furthermore, the successful integration of PoF technology with tiltmeter systems highlights its potential to address critical challenges such as battery maintenance and vulnerability to theft, particularly in remote or challenging environments. The precise characterization of the PoF system's operational characteristics, coupled with field measurements confirming stable data acquisition with the surface inclinometer sensor module, underscores the tangible benefits and practical applications of PoF in enhancing ground motion monitoring. These specific findings offer promising avenues for further research and implementation, particularly in disaster mitigation efforts and infrastructure resilience enhancement.

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## REFERENCES

[1] J.-G. Werthen, S. Widjaja, T.-C. Wu, and J. Liu, "Power over fiber: a review of replacing copper by fiber in critical applications," *Optical Technologies for Arming, Safing, Fuzing, and Firing*, vol. 5871, 2005, doi: 10.1117/12.619753.
[2] E. Dimitriadou, L. Ghisa, V. Quintard, M. Guégan, and A. Pérennou, "Modeling of a 10-km optical link exploiting power-over-fiber for cabled submarine observatories," *Optical Engineering*, vol. 56, no. 11, Nov. 2017, doi: 10.1117/1.oe.56.11.116108.
[3] M. Matsuura, "Recent advancement in power-over-fiber technologies," *Photonics*, vol. 8, no. 8, Aug. 2021, doi: 10.3390/photonics8080335.
[4] C. Budelmann, "Opto-electronic sensor network powered over fiber for harsh industrial applications," *IEEE Transactions on Industrial Electronics*, vol. 65, no. 2, pp. 1070–1177, 2017, doi: 10.1109/TIE.2017.2733479.
[5] C. Diouf *et al.*, "Design, characterization, and test of a versatile single-mode power-over-fiber and communication system for seafloor observatories," *IEEE Journal of Oceanic Engineering*, vol. 45, no. 2, pp. 656–664, 2020, doi: 10.1109/JOE.2018.2876049.
[6] M. Dotoli, M. Gattagrisi, C. D. Pisani, and B. Turchiano, "Automatic changeover of unwinding coils in copper wires stranding machines: A case study," *IECON Proceedings (Industrial Electronics Conference)*, vol. 3, pp. 2491–2496, 2002, doi: 10.1109/IECON.2002.1185365.
[7] P. Phibbs, "Using submarine cables for climate monitoring and disaster warning Engineering feasibility study," *UNESCO*, pp. 1–42, 2012.
[8] A. Setiono *et al.*, "Performance of an electrothermal mems cantilever resonator with fano-resonance annoyance under cigarette smoke exposure," *Sensors*, vol. 21, no. 12, 2021, doi: 10.3390/s21124088.
[9] L. C. Souza, E. R. Neto, E. S. Lima, and A. C. S. Junior, "Optically-powered wireless sensor nodes towards industrial internet of things," *Sensors*, vol. 22, no. 1, Dec. 2022, doi: 10.3390/s22010057.
[10] J. D. Lopez-Cardona, C. Vazquez, D. S. Montero, and P. C. Lallana, "Remote optical powering using fiber optics in hazardous environments," *Journal of Lightwave Technology*, vol. 36, no. 3, pp. 748–754, 2018, doi: 10.1109/JLT.2017.2776399.
[11] J. B. Rosolem, "Power-over-fiber applications for telecommunications and for electric utilities," in *Optical Fiber and Wireless Communications*, InTech, 2017. doi: 10.5772/68088.
[12] C. Vazquez *et al.*, "Monitoring systems and remote powering for next generation broadband access networks," *International Conference on Transparent Optical Networks*, pp. 3–6, 2017, doi: 10.1109/ICTON.2017.8024920.
[13] Q. Mei, X. Gu, R. Shen, G. Li, Y. Li, and Y. Qin, "Meteorological monitoring system for transmission line tower based on power-

over-fiber," in *2023 6th International Conference on Energy, Electrical and Power Engineering, CEEPE 2023*, May 2023, pp. 37–41. doi: 10.1109/CEEPE58418.2023.10166295.
[14] S. Perhirin *et al.*, "A power-over-fiber system and its low consumption remote equipment for submarine applications," *OCEANS 2013 MTS/IEEE Bergen: The Challenges of the Northern Dimension*, pp. 2–7, 2013, doi: 10.1109/OCEANS-Bergen.2013.6608175.
[15] A. Setiono *et al.*, "Wire extensometer based on optical encoder for translational landslide measurement," *International Journal on Advanced Science, Engineering and Information Technology*, vol. 13, no. 1, pp. 17–23, 2023, doi: 10.18517/ijaseit.13.1.15636.
[16] D. Bayuwati *et al.*, "Testing of an opto-electric landslide sensor around a toll road-bridge," in *AIP Conference Proceedings*, 2022, vol. 2652. doi: 10.1063/5.0106543.
[17] M. I. Afandi, H. Adinanta, A. Setiono, Qomaruddin, and B. Widiyatmoko, "High resolution extensometer based on optical encoder for measurement of small landslide displacements," *Journal of Physics: Conference Series*, vol. 985, no. 1, 2018, doi: 10.1088/1742-6596/985/1/012007.
[18] P. Martinek and V. Prajzler, "Power over fiber using a large core fiber and laser operating at 976 nm with 10 W power," *Optical Fiber Technology*, vol. 80, Oct. 2023, doi: 10.1016/j.yofte.2023.103404.
[19] F. Audo, "Quasi-all-optical network extension for submarine cabled observatories," *Optical Engineering*, vol. 50, no. 4, Apr. 2011, doi: 10.1117/1.3560542.
[20] Y. Tanaka, T. Shioda, T. Kurokawa, J. Oka, K. Ueta, and T. Fukuoka, "Power line monitoring system using fiber optic power supply," *Optical Review*, vol. 16, no. 3, pp. 257–261, May 2009, doi: 10.1007/s10043-009-0048-x.
[21] A. Mekhtiyev *et al.*, "Power supply via fiber-optical conductor for sensors of mine working monitoring system," *Eastern-European Journal of Enterprise Technologies*, vol. 5, no. 5(125), pp. 15–23, Oct. 2023, doi: 10.15587/1729-4061.2023.289775.
[22] P. Wei, C. Zhao, H. Huang, S. Lu, C. Li, and H. Deng, "Power-over-fiber system with energy management scheme for electric power industry," *Optical Engineering*, vol. 58, no. 9, Sep. 2019, doi: 10.1117/1.oe.58.9.096104.
[23] E. P. Putra *et al.*, "Technology update on patent and development trend of power over fiber: a critical review and future prospects," *Journal of Photonics for Energy*, vol. 13, no. 1, Jan. 2023, doi: 10.1117/1.jpe.13.011001.
[24] A. I. A. Mohammed, P. J. Ker, H. J. Lee, M. Muhamad, A. W. M. Zuhdi, and M. M. A. Gamel, "Power over fiber for internet of things application," in *2020 IEEE 8th International Conference on Photonics, ICP 2020*, May 2020, pp. 101–102. doi: 10.1109/ICP46580.2020.9206501.
[25] J. D. Lopez-Cardona, D. Sanchez Montero, and C. Vazquez, "Smart remote nodes fed by power over fiber in internet of things applications," *IEEE Sensors Journal*, vol. 19, no. 17, pp. 7328–7334, Sep. 2019, doi: 10.1109/JSEN.2019.2915613.

## BIOGRAPHIES OF AUTHORS

**Nelfyenny** completed her Bachelor of Science degree in 2011 at the Department of Physics, Padjadjaran University in Sumedang, Indonesia, specializing in instrumentation physics with a thesis on imaging the surface of an object using an ultrasonic sensor. She furthered her academic journey by obtaining her Master of Science degree in experimental physics from Utrecht University in 2023, with her thesis focusing on optical analysis of ion dynamics in a battery. Presently, she serves as a researcher at the Research Center for Photonics under the National Research and Innovation Agency in Indonesia. Her research interests primarily lie in optical sensing, monitoring, and instrumentation within the optics field. She can be contacted at email: nelfyenny@brin.go.id.

**Dwi Bayuwati** received a BSc degree from the Bandung Institute of Technology (ITB), Indonesia, in 1984, majoring in solid state physics, and an M.Eng.Sc degree from the University of New South Wales, Australia, in 1991, majoring in optical communication. She is currently a senior researcher at the Research Center for Photonics, The National Research and Innovations Agency, Indonesia (BRIN/Badan Riset dan Inovasi Nasional). Her research interests include optical components, fiber optic sensors and optoelectronics. She can be contacted at email: dwib001@brin.go.id.

**Suryadi** is a researcher and member of the Optical Instrumentation Research Group (OPI), Research Center for Photonics. He is interested in research related to sensors and internet of things for disaster and environmental monitoring, Python-based programming, artificial intelligent applications and instrumentation for health applications. He can be contacted at email: sury023@brin.go.id.

**Irwan Rawal Husdi** is a researcher in the field of fiber optic sensors and is a member of the Optical Instrumentation Research Group. The current research topic is regarding the development of fiber Bragg grating (FBG) based hydrophones. Previously, he also had experience in development in the field of information and communication technology, including being involved in building a national CPNS registration portal that was integrated with the e-KTP data center, as well as testing free to air digital TV broadcasts in preparation for the migration from analog TV broadcasts to digital TV broadcasts. He can be contacted at email: irwa005@brin.go.id.

**Imam Mulyanto** received his Bachelor of Sciences degree in engineering physics from the National Jakarta University, Jakarta, Indonesia, in 2004. In 2017, he finished his master's study in electronics and communication from Institut Sains dan Teknologi Nasional with research topic focused on borehole fiber optic inclinometer. Currently, he works in Research Center for Photonics – National Research and Innovation Agency (BRIN) with research interests include fiber optic communication system and development of land movement sensors for electronic and optical based landslide detection. He can be contacted at email: imam005@brin.go.id.

**Aditya Dwi Prasetio** earned his bachelor's degree from Universitas Padjadjaran majoring engineering geology in 2011, with thesis related to earthquake source mechanism with geo-electricity and ground penetrating radar. He has a master's degree from Universitas Indonesia majoring in Geophysics in 2015. He currently works as a researcher at the Research Center for Geological Disaster, National Research and Innovation Agency of Indonesia-BRIN. His research related to earthquake moment tensor and currently focus on developing Python code to calculate coda wave attenuation. He can be contacted at email: adit015@brin.go.id.

**Dedi Irawan** is a lecturer at physics education, Department of Education of Mathematics and Natural Sciences, Universitas Riau, Pekanbaru, Indonesia. He works on basic and advanced photonics. He has published many articles and supervised master's degree and doctoral degree since 2015 in Universiti Teknologi Malaysia. Currently, research focuses on Fiber Bragg Grating sensor (FBG), Mach-zehnder Interferometer. Furthermore, he is also doing some research in optoelectronic and optical sensors utilizing FBG, MZI, and directional coupler for medical and agricultural application. He can be contacted at email: dedi.irawan@lecturer.unri.ac.id.

**Bambang Widiyatmoko** is a senior researcher in the field of optoelectronics who joined the Research Center for Photonics BRIN in Optical Instrumentation (OPI) research group. Research carried out includes disaster sensors, weight in motion (WIM) systems or non-stop vehicle weighing based on fiber optics, instruments for environmental monitoring and bio-photonics, especially the use of photon irradiation to control microbiological diseases in plants and accelerate plant growth. He can be contacted at email: bamb007@brin.go.id.

**Andi Setiono** received his Bachelor of Sciences degree in electronics and instrumentation from the Department of Physics, Gadjah Mada University (UGM), Yogyakarta, Indonesia, in 2009. In 2015, he finished his master's study in electronics and photonics from the Department of Electrical Engineering, University of Indonesia. He completed his doctoral study at the Institute of Semiconductor Technology (IHT), TU Braunschweig, Germany, in September 2021 through the IG-Nano Project (i.e., Indonesian-German Center for Nano and Quantum Technologies) supported by LENA and LIPI. Currently, he works in Research Center for Photonics – National Research and Innovation Agency (BRIN) with research interests include electronic systems for resonant silicon MEMS/NEMS sensors, and optical-based sensor technology. He can be contacted at email: andi033@brin.go.id.