DOI: 10.54254/2755-2721/2026.KA26173

Integrated Solar Energy Utilization and Conduction Filtration System—Medusozoa

Yang Tian[1*], Zimo Lu[1], Feiyan Long[1]

[1]*Beijing 101 Middle School, Beijing, China*

**Corresponding Author. Email: qingq0639@gmail.com*

Abstract. With rapid urbanization, many low-rise residential buildings and certain indoor spaces suffer from inadequate natural lighting, relying heavily on artificial illumination. This dependence leads to increased energy consumption and potential exposure to harmful ultraviolet radiation. Existing indoor lighting systems typically use fixed light sources with limited adjustment capabilities, resulting in inefficient use of natural light and lacking ultraviolet filtration, which poses both energy and health challenges. To address these issues, this study proposes the "Medusozoa" intelligent solar energy utilization system, which achieves indoor natural lighting through efficient light collection, intelligent sunlight tracking, ultraviolet filtration, and optical fiber conduction technologies. The system employs a light sensor, an Arduino microcontroller, and a servo motor to track the sun's angle in real time, maximizing sunlight collection. It filters out harmful ultraviolet light and efficiently channels the filtered light indoors through optical fibers, significantly enhancing energy efficiency while ensuring health and safety.

Keywords: Solar energy utilization, Ultraviolet filtration, Energy efficiency, Optical Fiber, Arduino

1. Introduction

In daily life, many low-rise residential units and classrooms often rely on artificial lighting during the daytime, which not only wastes energy but may also adversely affect health. For instance, prolonged exposure to ultraviolet radiation can lead to skin allergies or more serious conditions [1]. Moreover, certain indoor environments with improper lighting levels can cause discomfort for individuals sensitive to light. Some classmates have noted that dim lighting contributes to vision decline, while excessively bright artificial light irritates the eyes and causes discomfort [2].

The researchers found that up to 30% of surveyed individuals have experienced varying degrees of light-related discomfort. Furthermore, insufficient natural lighting leads to high energy consumption from artificial sources, representing a significant portion of total building energy use and posing challenges to sustainable development [3]. This highlighted the urgent need to enhance solar energy utilization while ensuring safety. However, existing policies and technologies have fallen short in addressing this issue [4], largely due to the lack of consideration for lighting requirements in architectural design standards and the high cost and complexity of current lighting technologies, which hinder widespread adoption [5].

DOI: 10.54254/2755-2721/2026.KA26173

From a broader perspective, this issue not only affects individual quality of life but also has profound impacts on sustainable development. Excessive energy consumption increases environmental pressure, while growing health problems burden the healthcare system [6]. To address these concerns, the research team developed an integrated device combining efficient light collection, ultraviolet filtration, and optical fiber conduction through an in-depth study of physical optics, ultraviolet reaction mechanisms, and mechanical control. And ultimately, designed the "Medusozoa" system, aiming to optimize solar energy utilization while effectively mitigating light pollution and health risks associated with ultraviolet exposure.

The study posits that current indoor lighting issues mainly arise from inadequate architectural lighting design—such as windows that are too small, improperly oriented, or obstructed—while natural light intensity is further influenced by weather and seasonal variations [7]. To address this, this paper proposes a solution focused on optimizing natural light utilization by efficiently collecting and channeling sunlight while filtering out ultraviolet light [8]. This approach reduces reliance on artificial lighting, thereby improving indoor lighting conditions and enhancing the efficiency of natural light resource use.

A compact device was developed to efficiently collect and conduct natural light using optical materials and simple mechanical structures [9]. The device incorporates ultraviolet filtration [10] to mitigate potential health risks from UV exposure while enhancing the efficiency of natural light utilization to meet diverse user needs. To validate the device's feasibility, the researchers combine optical simulations with practical experiments. Specifically, UV-sensitive materials are used to assess filtration effectiveness, while light intensity sensors [11] monitor indoor illumination levels to evaluate the device's light conduction efficiency and adjustment capabilities under varying environmental conditions.

2. Results and discussions

For this solar tracking device, A solution was adopted that combines light sensors with a servo system [12] to accurately track the sun's position and transmit sunlight indoors via optical fibers. This approach offers high light utilization efficiency, enabling automatic adjustments to maintain stable indoor lighting without manual intervention, and demonstrates strong adaptability to varying environmental conditions.

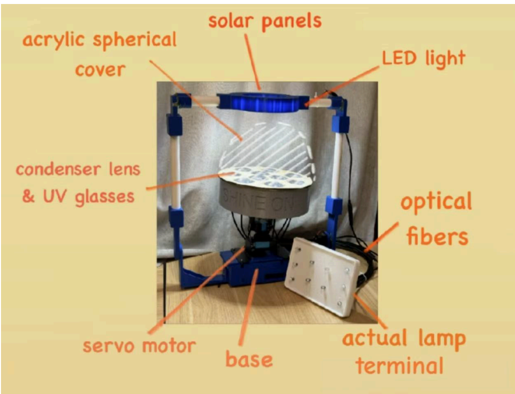

Figure 1. Structure of Medusozoa system

The structure of the Medusozoa system is demonstrated in Figure 1. Detailed design and assembly process are illustrated in the supporting information.

Solar panels: Provide energy, ensuring the device can operate independently during sufficient sunlight. Light sensors: Detect sunlight intensity and direction. Servo motor: Adjusts optical component angles based on sensor data to ensure continuous light tracking. Condenser lens and UV filter: Focus light and filter out UV rays, transmitting only useful light. Optical fibers: Transmit focused light indoors. LED supplemental lighting: Provides additional illumination when light is insufficient. Base: Supports the entire system, ensuring stable operation. Actual lighting terminal: Distributes light to various indoor areas for illumination.

To verify the system's functionality and accuracy, a series of experiments was designed targeting key modules, including UV filtration, sunlight tracking via light sensors, fiber optic conduction efficiency, and solar panel performance optimization.

2.1. UV filtration effectiveness test

Using UV lamps to simulate sunlight, UV filter's removal efficiency was evaluated by observing changes in security markings on paper money before and after filtration, verifying the filter's ability to prevent harmful UV damage. The results are listed in Table 1 and Figure 2, indicating that UV filter performs as expected, proving the device's feasibility in ensuring healthy light output.

Table 1. UV removal efficiency of UV filter

Light Source	UV Status (Present/Absent)	Filtration Effect (Marking Visibility)	Filter Used (Y/N)	Notes
UV Lamp (Direct)	Present	Visible	N	No filtration
UV Lamp (Filtered)	Absent	Invisible	Y	Good filtration
Natural Light	Absent	Invisible	N	No UV detected

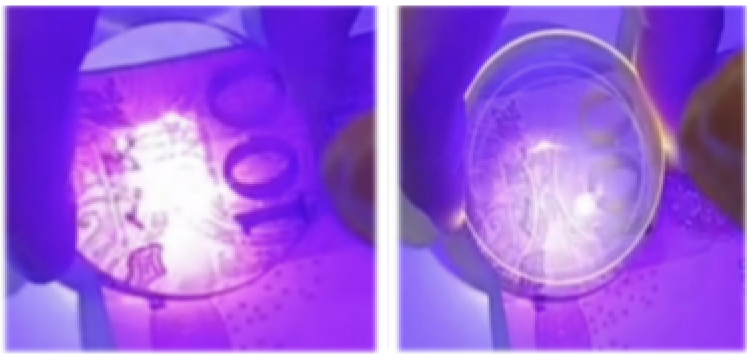

Figure 2. UV filtration test

2.2. Light sensor and servo functional test

To confirm the coordinated operation of light sensors and servos, the researchers conducted tests recording servo angle adjustments in response to light sensor output under varying light intensities, assessing the system's ability to maximize sunlight collection as external lighting changes. The results are summarized in Table 2, confirming light sensors and servos can effectively cooperate to achieve real-time optical component angle adjustment, proving system feasibility in sun-tracking functionality.

DOI: 10.54254/2755-2721/2026.KA26173

Table 2. Sun-tracking test data

Time (Hour)	Light Intensity (Photoresistor Reading, 0-1023)	Servo Angle (°)	Condenser Lens Adjustment (Y/N)	Notes
8:00	200	45	Y	Initial test, good performance
10:00	350	60	Y	Successful angle adjustment
12:00	800	90	Y	Direct sunlight, stable operation
14:00	600	75	Y	Weaker sunlight angle

2.3. Fiber optic conduction effectiveness test

Fiber optic transmission was tested by channeling light collected by condenser lenses through fibers and measuring output light intensity with sensors. This allowed calculation of fiber transmittance and performance analysis under different light source conditions. The results are listed in Table 3, demonstrating that fibers maintain high transmittance (>99%) with minimal loss for natural light, flashlights, and LEDs, proving their efficient light conduction capability meets system design requirements.

Table 3. Fiber conduction test data

Light Source	Input Light Intensity (Photoresistor Reading, 0-1023)	Output Light Intensity (Photoresistor Reading, 0-1023)	Transmitta nce (%)	Notes
Natural Light	512	514	99.8	High transmittance, low loss
Smartphone Flashlight	200	202	99.7	Successful conduction, negligible loss
LED	50	51	99.5	Stable performance

2.4. Solar panel efficiency optimization test

The system was tested under varying lighting conditions to assess solar panel efficiency, particularly focusing on energy storage and supplemental lighting capabilities during cloudy or low-light periods. This verified the system’s ability to dynamically adjust energy management based on ambient light intensity. The results are listed in Table 4. Testing under various conditions showed LED modules significantly improve indoor brightness when light is insufficient, especially during cloudy weather and dusk. While less critical in sunny conditions, supplemental lighting proves essential in low-light environments, verifying reliable energy storage and supplemental functionality across different conditions.

DOI: 10.54254/2755-2721/2026.KA26173

Table 4. LED supplemental lighting test data

Light Condition	LED Status (On/Off)	Light Sensor Reading (0-1023)	Ambient Brightness (Recommended Value, lux)	Notes
Cloudy	On	200	300	Significant brightness improvement with LEDs
Cloudy	Off	700	50	Low brightness without LEDs
Sunny	On	30	1200	Combined LED and natural light
Sunny	Off	25	1500	Sufficient natural light, LEDs unnecessary
Dusk	On	250	200	LEDs maintain stable brightness
Dusk	Off	900	20	Dark environment without LEDs

These experiments provide robust data to evaluate the performance and effectiveness of each functional module, ensuring the system's stability and reliability in practical applications. Future enhancements could focus on improving light sensor response speeds and boosting supplemental lighting effectiveness under extreme conditions.

3. Conclusion

The "Medusozoa" system integrates solar tracking, UV filtration, and high-efficiency fiber optic conduction to deliver natural indoor lighting while minimizing UV exposure. Key accomplishments include designing the full system framework, implementing Arduino-based tracking algorithms, and validating performance across light capture, filtration, and transmission. While current limitations involve size constraints and basic low-light control, future improvements aim to enhance adaptability, reduce weight, and refine supplemental lighting algorithms. With strong potential for commercial and environmental impact, Medusozoa offers energy savings, improved public health, and broader applications in homes, commercial spaces, greenhouses, and light-limited regions.

References

[1] Yu, S.-L.; Lee, S.-K. Ultraviolet Radiation: DNA Damage, Repair, and Human Disorders. Mol. Cell. Toxicol. 2017, 13 (1), 21–28. https: //doi.org/10.1007/s13273-017-0002-0.

[2] Effects of artificial light at night on human health: A literature review of observational and experimental studies applied to exposure assessment: Chronobiology International: Vol 32, No 9. https: //www.tandfonline.com/doi/abs/10.3109/07420528.2015.1073158 (accessed 2025-07-29).

[3] Pérez-Lombard, L.; Ortiz, J.; Pout, C. A Review on Buildings Energy Consumption Information. Energy Build. 2008, 40 (3), 394–398. https: //doi.org/10.1016/j.enbuild.2007.03.007.

[4] Bertoldi, P. Policies for Energy Conservation and Sufficiency: Review of Existing Policies and Recommendations for New and Effective Policies in OECD Countries. Energy Build. 2022, 264, 112075. https: //doi.org/10.1016/j.enbuild.2022.112075.

[5] Shabalov, M. Yu.; Zhukovskiy, Yu. L.; Buldysko, A. D.; Gil, B.; Starshaia, V. V. The Influence of Technological Changes in Energy Efficiency on the Infrastructure Deterioration in the Energy Sector. Energy Rep. 2021, 7, 2664–2680. https: //doi.org/10.1016/j.egyr.2021.05.001.

[6] The Energy Burden and Environmental Impact of Health Services - PMC. https: //pmc.ncbi.nlm.nih.gov/articles/PMC3519304/ (accessed 2025-07-29).

[7] Baeza Moyano, D.; San Juan Fernández, M.; González Lezcano, R. A. Towards a Sustainable Indoor Lighting Design: Effects of Artificial Light on the Emotional State of Adolescents in the Classroom. Sustainability 2020, 12 (10), 4263. https: //doi.org/10.3390/su12104263.

DOI: 10.54254/2755-2721/2026.KA26173

[8] Gupta, M.; Zala, P.; Gupta, S.; Varshney, S. Solar Concentration Based Indoor Daylighting System to Achieve Net Zero Sustainable Buildings. Energy Build. 2024, 321, 114662. https: //doi.org/10.1016/j.enbuild.2024.114662.

[9] Han, X.; Ding, L.; Tian, Z.; Song, Y.; Xiong, R.; Zhang, C.; Han, J.; Jiang, S. Potential New Material for Optical Fiber: Preparation and Characterization of Transparent Fiber Based on Natural Cellulosic Fiber and Epoxy. Int. J. Biol. Macromol. 2023, 224, 1236–1243. https: //doi.org/10.1016/j.ijbiomac.2022.10.209.

[10] UV Blocking Glass: Low Cost Filters for Visible Light Photocatalytic Assessment - Dunnill - 2014 - International Journal of Photoenergy - Wiley Online Library. https: //onlinelibrary.wiley.com/doi/full/10.1155/2014/407027 (accessed 2025-07-29).

[11] Bai, Y.-W.; Ku, Y.-T. Automatic Room Light Intensity Detection and Control Using a Microprocessor and Light Sensors. IEEE Trans. Consum. Electron. 2008, 54 (3), 1173–1176. https: //doi.org/10.1109/TCE.2008.4637603.

[12] Servo Motor Control System and Method of Auto-Detection of Types of Servo Motors | Scientific.Net. https: //www.scientific.net/AMM.496-500.1510 (accessed 2025-07-29).