END-SEMESTER REPORT

DEVELOPMENT ENGINEERING PROJECT (CP301)

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Supervised by

Dr. Harpreet Singh

Submitted to

Dr. Harpreet Singh, Dr. Ravi Kant

Submitted by

Name	**Entry Number**
Abhinav Kumar	2021MEB1260
Akshat Chouhan	2021MEB1265
Vipul Pundge	2021MEB1311
Soumyadip Mondal	2021MEB1327
Zaheer Mohd. Abass	2021MEB1339

Department of Mechanical Engineering

Indian Institute of Technology, Ropar

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Table of Contents

1. *Title of the Project:*

Daylight System Using Optical Fibers

2. *Aim:*

The main aim is to design and fabricate a daylight system which utilizes sunlight to provide illumination to gloomy indoor places, without the aid of electricity.

3. *Introduction:*

Daylighting technologies have emerged as pivotal components in the pursuit of energy efficiency within green buildings. Harnessing the natural brilliance of daylight not only enhances visual comfort and productivity but also offers a distinct advantage in reducing reliance on conventional energy sources. Unlike traditional solar energy applications such as thermal power generation or photovoltaics, daylighting represents a unique approach to solar utilization, focusing on optimizing natural light for interior illumination.

By employing sophisticated optic-mechanical electric systems, daylighting technology efficiently captures and channels sunlight into interior spaces via high-concentration fiber optics. This innovative approach effectively separates and filters out infrared and ultraviolet radiation, ensuring that the transmitted light remains cool, natural, and gentle on the eyes. The resulting illumination surpasses the qualities of artificial lighting, providing a serene and inviting ambiance that enhances indoor environmental quality.

One of the notable advantages of daylighting systems is their ability to penetrate deeper into buildings without compromising spatial layout or exacerbating heat gain issues commonly associated with conventional strategies. As these technologies mature and become more economically viable, they hold immense potential for significant energy savings and improved indoor environments across various applications.

While fixed daylighting systems are prevalent, our project endeavors to pioneer a portable prototype, characterized by its compactness and ease of handling. Portable daylighting systems offer unparalleled flexibility, allowing for easy assembly and disassembly as needed. This versatility ensures adaptability across diverse environments and underscores the practicality of daylighting technology in meeting evolving architectural and environmental needs.

Fig.1 Expected result from our system [8.1]

A lot of rural areas in India suffer from lack of electricity or power outage. Our system aims to provide a low-cost solution which can be implemented in these conditions leading to availability of indoor lighting where it is not available today.
Even in areas where electricity is readily-available, our system can help reduces the use of power, thus contributing to environmental sustainability.
This inspired us to choose this daylighting system as our topic for the development project and explore economical and cost-effective solution for the same.

4. *Background and Literature Review:*

In recent years, there have been numerous efforts to harvest solar power in pursuit of sustainable and renewable energy. This has led to emergence to various technologies that harvest solar energy in one form or another. Among the many innovative solutions, daylight harvesting systems have emerged as a promising approach to optimize light utilization withing indoor spaces.

Harnessing sunlight not also significantly reduce the reliance on artificial lighting but also reduces the load on eyes, thereby enhancing visual comfort.

Traditional daylight collecting systems frequently encounter obstacles such unequal light distribution, reliance on outside variables like the weather, and challenges accessing deep interiors of buildings. The use of optical fibers into daylight harvesting devices has drawn notice as a ground-breaking development in response to these difficulties. Optical fibers provide an innovative way around the drawbacks of traditional technologies to direct natural light deep into structures.
The core principle of daylight harvesting using optical fibers involves capturing sunlight at the building's exterior and guiding it through high-quality optical fibers to deliver uniform and controlled illumination throughout the indoor spaces. This technology holds significant potential for a wide range of applications.

Daylight systems have attracted a number of researchers "researching" about various designs which could be utilized for applications such as residential, commercial, and industrial buildings, as well as educational institutions. We explore some of these works and their insights.

The study in [8.1] proposed a sophisticated daylight system using a highly concentrating Fresnel Lens. It also presents a design for a solar tracking system that helps keep the array of lenses always facing toward the sun. The design presented in this paper is very cumbersome and requires sources of electricity, which is a factor that our design tries to avoid.

In [8.2], the design proposed is a sleeker version of the one above. It uses a mirror in the solar collector component instead of a highly-focusing Fresnel lens. This system also uses an integrated sun-tracking system and proposed two different designs for it. The first uses a photocell to measure the intensity of incoming light. It modulates the tracking motors to point the collector in the direction of maximum light intensity. In contrast, the second strategy utilizes electronic micro-controllers to calculate the celestial bearing of the sun relative to the earth and align the collector accordingly. Both of these strategies are viable for a system seeking to use a solar tracker.

The study in [8.3] talks about use of light tubes in daylight systems. It lists various configurations of light tubes such as single light tube, double light tubes, or two separate light tubes. The work analyses the differences in setup required for each of them and compares their performance in common office buildings. It concludes that a single light-tube design is better than the other two aforementioned designs.

The author in [8.4] explores the concept of "photo plumbing" and compares four different designs to analyze their effectiveness in the Indian climate. These designs were called "HIMAWARI", "Parans sp3", "Hybrid Solar Lighting" and "Solux" daylighting systems. After the study, both "Parans sp3" and "Hybrid Solar Lighting" systems performed better than the other two, and concepts from those systems helped us in making a better design for our system.

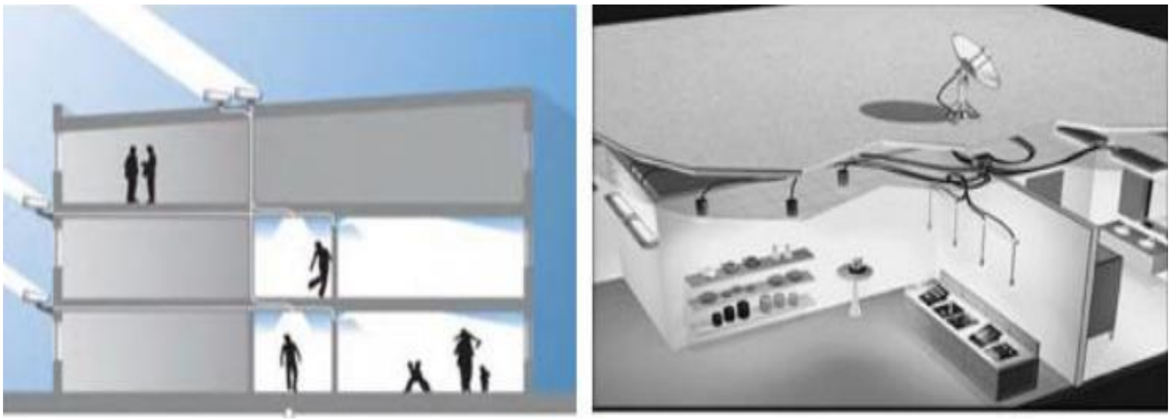


Fig.2 Schematic Representation of Day lighting [8.4]

The reference [8.5] is a collection of various case studies about the benefit of daylighting system in schools. The case studies describe schools that were approved by school boards and administrators to incorporate the benefits of daylighting into their learning environments. It suggests that incorporating natural daylight into school environments can have positive effects on both student health and academic outcomes. The authors argue that such improvements are achievable at a reasonable cost for educational institutions.

[8.6] is one of the works we found that also does not incorporate a tracking component. This design makes use of both optical fibres and light pipe technology to overcome their respective limitations. The study claims, through both their theoretical analysis and field test, that their system has the same reception feature as the traditional optical fiber system with a tracking device and that its graph of the illuminance roughly follows the fluctuation of the curve of the solar irradiance.

The work in [8.7] goes in detail about the vertical pipes and their use in illuminating the central parts of buildings not reached by sunlight. This study provides a comprehensive design for using light pipes to distribute light at different floors of the building. The reported about an increase in illumination of about a factor of seven for lower level of building for low elevations of sun with the use of a sun-tracker.

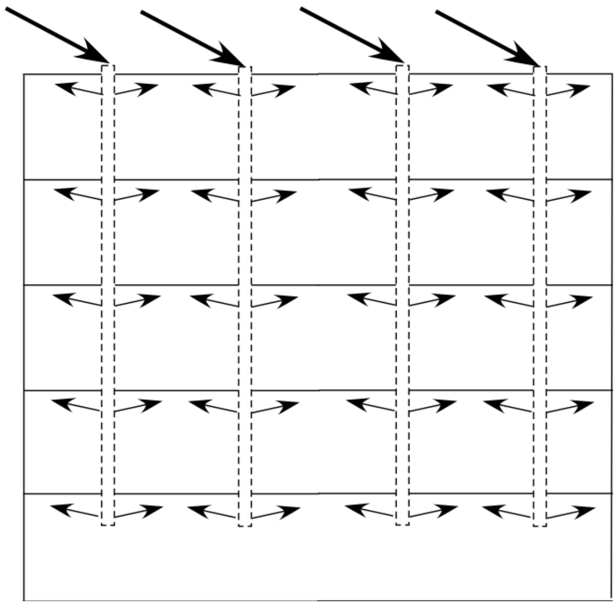


Fig.3 Basic design of daylighting system using natural light to a five-level building[8.7]

All of these studies have explored different aspects of daylighting systems and have helped us to know about various design considerations while making a daylight system. We have learned about the limitations of these designs and also their features which seem to have been outside the scope of our project.

- ***Objective***

  With our learnings from these studies, our objective is to devise a robust and compact daylight system with minimum cost. While most of these solutions have been researches, we aim to make a system is ready to be used in day-to-day life conditions and is cost-effective, environmentally friendly, and easy to deploy and maintain.

5. *Project Journey:*

In this project, we aim to design and fabricate a daylight system that utilizes sunlight to provide illumination to indoor spaces without relying on electricity. Our objective is to create a robust, cost-effective, and environmentally friendly solution that can be easily deployed and maintained.

- ***Design Phase:***

During the initial design phase, we conceptualized the daylight system. Our focus was on achieving maximum efficiency while minimizing costs. First, we designed a prototype for a special daylighting device. We've looked into how daylighting works and tried to find affordable and creative ways to make our design stand out. We used a computer program called SolidWorks to simulate our design and make sure it works well.

We considered the following two designs, ultimately selecting the most efficient, cost-effective, and feasible option.

First Design:

In this design, a concave mirror will be used to collect and focus sunlight. The incident sunlight is directed toward the mirror, which reflects and converges precisely at the focus. The concave mirror is positioned such that its focal point coincides with the entrance of the optical fiber bundle where a lens is attached. The optical fibers then transmit the focused sunlight to the interior of the building.

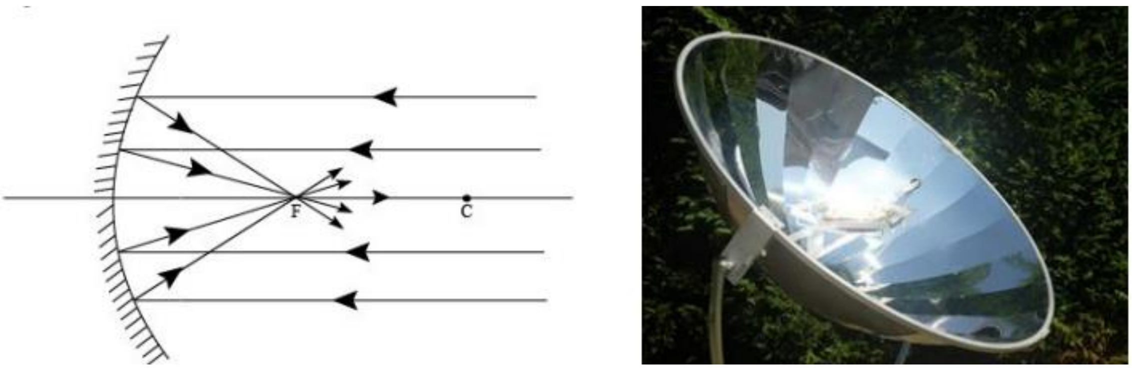


Fig.4 Sunlight Collection using Concave Mirror

Advantages of this design:

- Cost effectiveness: The use of a concave mirror as the primary sunlight collector keeps the system cost low. In rural areas, where financial resources may be limited, an economical solution like this can have a significant impact.
- Reduced Complexity: Complexity can be a barrier to adoption, especially in areas with limited technical expertise. The concave mirror design minimizes complexity by relying on a single optical component.

Disadvantages of this design:

- Large Mirror Requirement: To achieve efficient light convergence, a sufficiently large concave mirror is necessary. The larger the mirror's surface area, the better it can collect and focus sunlight onto the optical fibers.
- Space Constraints: Finding suitable locations for large mirrors within buildings can be challenging, especially in compact spaces.
- Heat Generation: Concentrating sunlight on a small area (such as the optical fiber entrance) can lead to localized heating. When sunlight converges at the mirror's focus, the intensity of light increases significantly. This can raise the temperature at the fiber entrance. Excessive heat can damage the optical fibers over time.
- Reduced Efficiency: Elevated temperatures may affect the overall efficiency of the system. The following solid-works model was made for this design.

The heat generation factor was considered a major drawback which ultimately led us to not pursue this design choice.

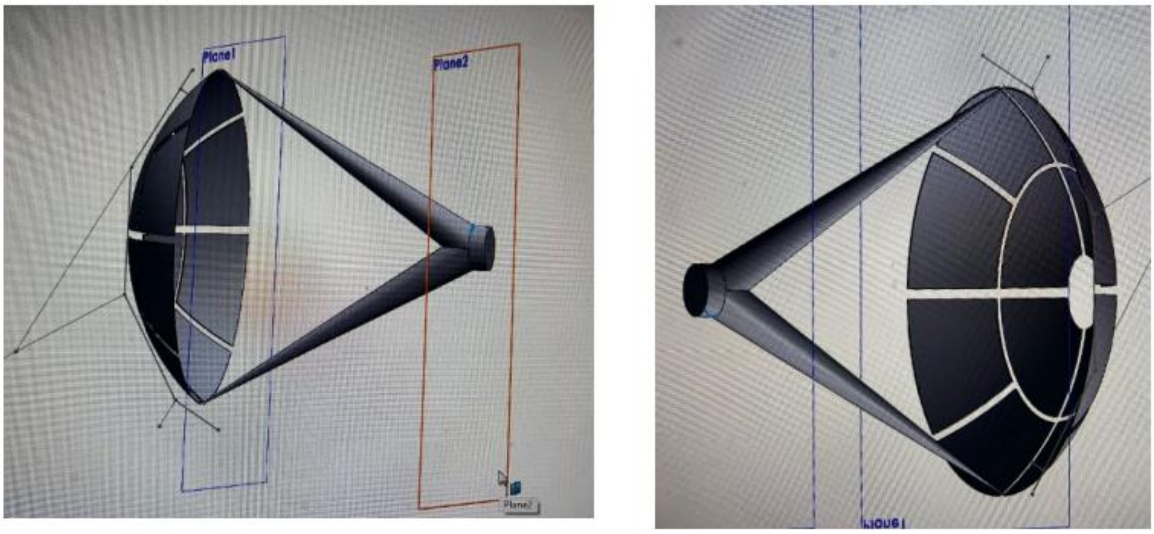


Fig.5 SolidWorks model of the design using mirror

Design 2:

In this design, Sunlight is collected by the Fresnel lens on the roof. The lens focuses the sunlight onto a specific point. The concentrated light is then directed into optical fibers. Optical fibers transmit the light to different areas within the building. Collimated light (parallel rays) ensures efficient transmission through the fibers. Interior lenses further distribute the light, providing uniform illumination.

Advantages of this design

- High Intensity Illumination: Fresnel lenses generate exceptionally high intensity, providing a potent source of light within our system.
- Efficient Solar Energy Concentration: These lenses effectively concentrate sunlight onto optical fibers, significantly enhancing energy density. This feature makes them particularly well-suited for various solar energy applications.

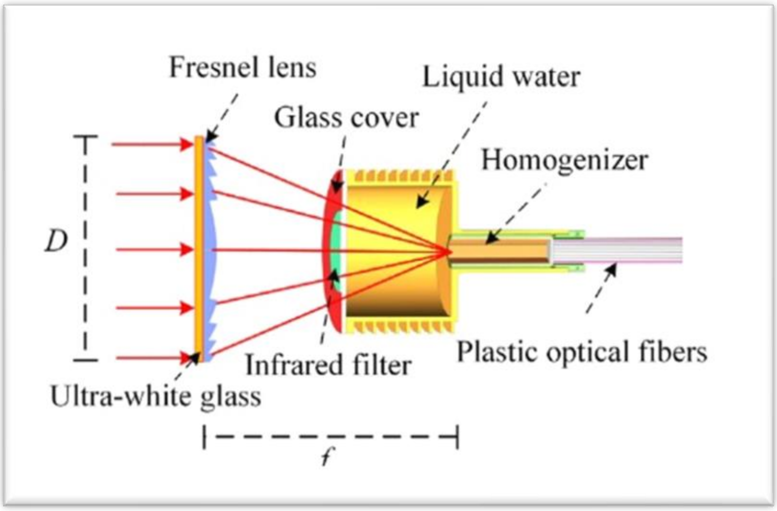


Fig.6 Schematic of the sunlight concentration and transmission via Fresnel lens [8.1]

Drawbacks of this design:

- Cost Considerations: Despite their effectiveness, Fresnel lenses can be prohibitively expensive compared to alternative models. Minimizing costs is paramount for our project's success, prompting the exploration of more economical options.
- Maintenance Demands: Optical fibers utilizing Fresnel lenses necessitate regular maintenance to uphold optimal performance. Factors such as dust accumulation, scratches, or other contaminants can degrade functionality over time, highlighting the need for diligent upkeep.
- Limited Focusing Area: While proficient at concentrating light, Fresnel lenses confine this focus to relatively small areas. This limitation poses challenges for projects requiring expansive coverage, necessitating the exploration of alternative solutions like heliostats for larger spaces.
- Heat Generation Concerns: The heating effect associated with Fresnel lenses can pose challenges within our system, potentially leading to overheating issues. Addressing this concern is crucial to ensure the longevity and reliability of our system

All of the aforementioned limitations posed a major challenge to us, thus leading to rejection of this design choice.

Design 3:

As we didn't receive our main design requirements within budget in first two designs, we opted for a different approach.

The third design makes use of a number of small plano-convex lenses, arranged in an array-like pattern where each lens has its own small light transmission system. These small systems independently transmit sunlight which is then added up on the receiver end. These lenses are essential for optimizing how the light spreads, making our daylighting device efficient. We carefully considered things like focal length and material properties before deciding on the kind of lenses to use.

This new design offers a comprehensive solution that integrates efficiency, innovation, portability, cost-effectiveness, and environmental sustainability. It stands out as a compelling option for illuminating indoor spaces using sunlight.

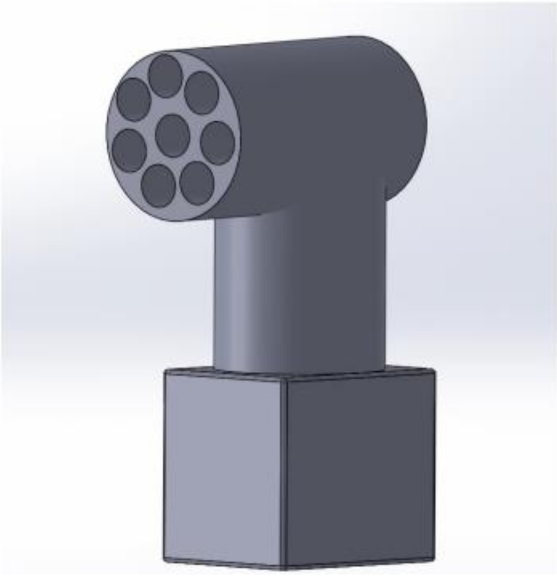


Fig.7 SolidWorks Model of third design approach

Advantages of the third design approach:

- Minimizing Heat Generation: The utilization of smaller plano-convex lenses helps minimize heat generation light transmission. As the size of each lens is small, heat generation due to a single lens is very small and due to sparse arrangement and no interaction between lenses, this small amount of heat does not add up and gets dissipated on its own. Hence, this solution helps us mitigate the drawback of heat generation which was a major problem in both the previous designs.
- Compactness and Ease of Handling: The portable prototype is designed to be compact and lightweight, making it easy to transport and handle. Components are optimized for size and weight, allowing for convenient storage and transportation to different locations as needed. Ease of handling ensures that the system can be set up and dismantled quickly and without requiring specialized tools or expertise.

- Assembly and Disassembly: The system is designed for easy assembly and disassembly, with modular components that can be quickly interconnected. Clear instructions and intuitive design make it accessible to users with varying levels of technical expertise, reducing the need for specialized installation teams. Rapid deployment and removal minimize disruption to existing structures and activities, making the system ideal for temporary installations or events.
- Cost-effectiveness was a key factor considered throughout the design phase. This involves evaluating the cost implications of various design choices, materials, and manufacturing processes. By prioritizing cost-effectiveness, the project aimed to develop a solution that provides maximum value for the resources invested, ensuring that it remains accessible and affordable for potential users.

- ### *Work Done after Mid-Semester*

Cutting of Optical Fibers: We meticulously cut the optical fibers to the appropriate length required for our daylight system. The length was determined based on factors such as the distance between the light collecting unit (acrylic cylinders and PVC pipes) and the desired indoor illumination points. Ensuring uniform lengths for all optical fibers was crucial to maintain consistent light transmission efficiency.

Fig.8 Optical fibers used for transmission of light

Acrylic Cylinders: We began by cutting 10 sets of acrylic cylinders. These cylinders were specifically designed with holes to allow optical fibers to pass through them. The purpose of these acrylic cylinders is to securely hold the optical fibers in place while allowing light converged through the plano convex lens to enter the optical fibers.

Fig.9 Acrylic Holders for collection of optical fibers

PVC pipes: We prepared 10 sets of PVC pipes. These pipes serve as the outer casing for our light collecting unit. To enhance light collection efficiency, we attached plano-convex lenses to the open end of each PVC pipe. These lenses converge sunlight onto the optical fibers.

Fig.10 PVC pipes are used for fixing the lenses

Lens Preparation: After attaching the plano-convex lens to each PVC pipe, we took an additional step to ensure optimal light transmission. We thoroughly cleaned the lens surface using a specialized lens cleaning fluid solution. This solution effectively removes any dust, fingerprints, or other contaminants that might hinder the lens's performance. A clean lens is essential for maintaining the efficiency of our daylight system, as any impurities can scatter or absorb sunlight.

Fig.11 Plano-convex lens used to concentrate sunlight

Acrylic Cylinders and PVC Pipes Integration: We carefully inserted the acrylic cylinders into the PVC pipes, ensuring a snug fit. At the open end of each PVC pipe, we positioned plano-convex lenses. These lenses are crucial for focusing sunlight onto the optical fibers. The lenses concentrate sunlight, directing it toward the acrylic cylinders.

Collecting Unit: The collector unit consists of the acrylic cylinders, PVC pipes, and lenses. It collects sunlight and funnels it into the optical fibers. The uniform lengths of the fibers help maintain consistent light transmission efficiency.

Fig.12 The setup of the collector head

Final assembly:

Enclosed box: The final assembly includes an enclosed box. This box serves as the central unit where all components come together.

Collector Unit Attachment: The collector unit (which includes the acrylic cylinders, PVC pipes, and lenses) is attached to the exterior of the enclosed box.
Optical Fiber Entry: A pipe connects the collector unit to the interior of the box. Through this pipe, the optical fibers enter the box.

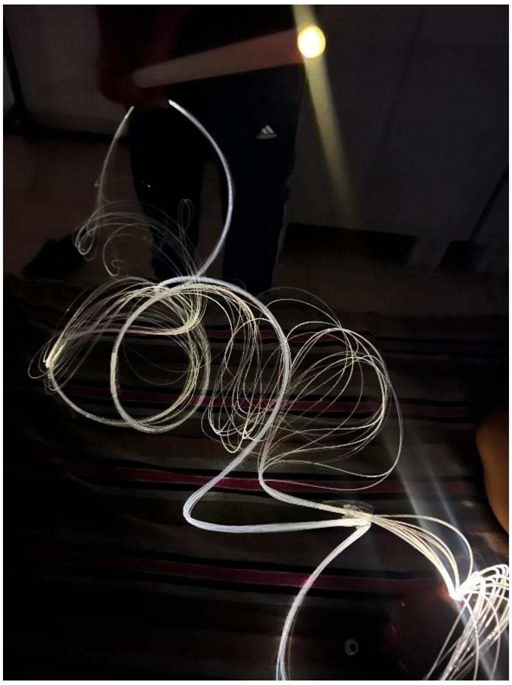
Working Principles:

- **Sunlight Collection**:
  - When sunlight falls on the collector unit, the plano-convex lenses converge the light onto the optical fibers at the collector end.
  - The collector unit, positioned outside the box, captures sunlight.
  - The plano-convex lenses focus the sunlight onto the optical fibers.
- **Optical Fiber Transmission**:
  - The optical fibers, guided by the pipe, enter the dark box.
  - The fibers transmit the focused sunlight from the collector into the box.
- **Illumination**:
  - As the sunlight travels through the optical fiber cable, it reaches the interior of the dark box.
  - The previously enclosed dark space is now illuminates due to the transmitted sunlight.
  - This illumination provides a natural and eco-friendly light source without the need for electricity.

Fig.13 The final setup

Light Transmission: The optical fibers play a crucial role in transmitting sunlight. As light enters the acrylic cylinders, it gets guided through the fibers. The fibers are designed to minimize losses, ensuring efficient transmission of natural light. At the other end of the optical fibers, we can direct the light to specific areas within the indoor space, providing illumination where needed.

The following images show the transmission of light through the optical fibers



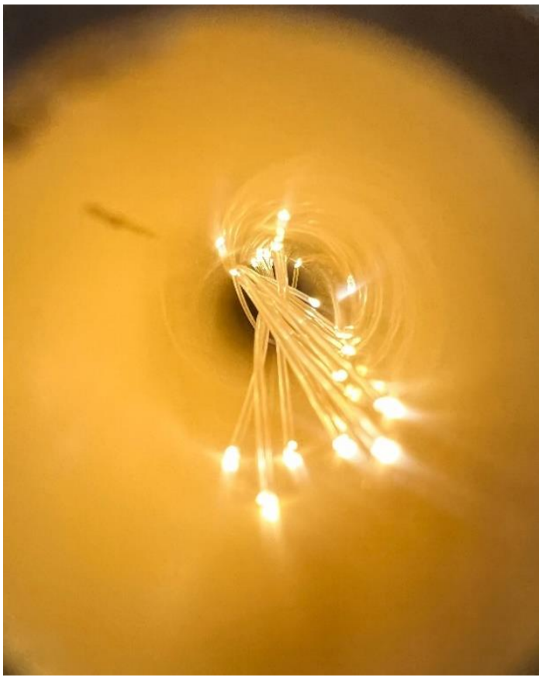


Fig.14 & 15 Testing of the optical fibers for light transmission

Fig.16 Optical fibres transmitting light

6. *Future Possibilities:*

A daylight system using optical fibers is a fascinating project. Some future possibilities for this innovative technology:

1. Improved Efficiency and Uniform Illumination:

- Researchers have been working on enhancing the efficiency of fiber-optic daylighting systems. One critical aspect is achieving uniform illumination throughout the interior space. Currently, there's a need to illuminate the optical fiber bundle with uniform light flux.
- A proposed method involves using a parabolic concentrator to collect sunlight, which is then focused toward a collimating lens. This lens distributes the light evenly over each optical fiber in the bundle. An optics diffusing structure at the end of the fiber bundle further spreads the light within the interior
- Future advancements could focus on optimizing the design of these components to achieve even better uniformity and efficiency.

2. Integration with Smart Building Systems:
    - Imagine integrating daylighting systems with smart building controls. Sensors could detect ambient light levels and adjust the fiber-optic system accordingly. For instance, during sunny days, the system could automatically dim or redirect sunlight to minimize glare.
    - Smart algorithms could dynamically balance natural light and artificial lighting to maintain optimal illumination levels while minimizing energy consumption.

3. Hybrid Systems with Artificial Lighting:
    - Combining fiber-optic daylighting with energy-efficient LED or OLED lighting could provide a versatile solution. During nighttime or cloudy days, the artificial lighting component could seamlessly take over.
    - Researchers could explore how to seamlessly transition between natural and artificial light sources, ensuring consistent illumination regardless of external conditions.

4. Urban Applications and Light Redistribution:
    - Urban environments often lack sufficient natural light due to high-rise buildings and narrow streets. Fiber-optic daylighting could be used to channel sunlight into these spaces, reducing the need for electric lighting.
    - Additionally, redistributing excess sunlight from sunlit areas to darker corners of a building could enhance overall comfort and reduce energy consumption.

5. Integration with Building Materials and Architectural Elements:
    - Imagine building materials (such as walls, ceilings, or floors) that incorporate optical fibers. These materials could transmit sunlight throughout the building, creating a harmonious blend of natural and artificial light.
    - Architects and designers could explore innovative ways to seamlessly integrate daylighting systems into the aesthetics of buildings.

6. Cost Reduction and Mass Adoption:

- As technology matures, cost-effective manufacturing processes and materials could make fiber-optic daylighting more accessible.
- Research and development efforts should focus on scalability, affordability, and ease of installation to encourage widespread adoption.

Solar Tracking system:

The primary objective of a solar tracking system is to ensure that solar panels or mirrors are always oriented perpendicular to the sun's rays. This maximizes the amount of solar energy captured. The system achieves this by continuously adjusting the orientation of the solar panels as the sun moves across the sky. The system is self-sufficient and does not use external source of power, apart from solar energy.

Working Steps:

- **Initial Positioning**: At sunrise, the system starts with the panels facing east (towards the rising sun). The light sensors detect sunlight and trigger the motors to adjust the panel angles.
- **Continuous Monitoring**: Throughout the day, the system continuously monitors the sun's position. If the sun moves, the light sensors detect the change and signal the motors.
- **Motor Adjustment**: The motors slowly rotate the frame to align the panels with the sun. They follow the sun's path, adjusting the panel angles to keep them perpendicular to the incoming sunlight.
- **Autonomous Operation**: The system operates autonomously without human intervention. It ensures that the panels face the sun optimally, maximizing energy production.
- **Shading Prevention**: If the sun is partially blocked (e.g., by clouds or nearby structures), the motors adjust the panels to prevent shading. This prevents overheating and ensures consistent energy output.

7. *Conclusion:*

In our project of "The Daylight System Using Optical Fibers", we tried to find a transformative solution poised to address the crucial challenge of indoor lighting accessibility, particularly in regions grappling with electricity shortages. With a central aim of harnessing sunlight in a manner that is not only efficient but also cost-effective, portable, and user-friendly, our system stands out as compared to other daylight optical systems. The project recognizing the intrinsic value of natural light in enhancing visual comfort and productivity within indoor spaces.

By leveraging optical fibers, acrylic cylinders, PVC pipes, and plano-convex lenses, we have engineered a system that efficiently collects and channels sunlight, providing a natural and gentle source of illumination. Our emphasis on cost-effectiveness, ease of deployment, and environmental sustainability underscores our commitment to making this technology accessible and impactful, particularly in underserved communities and regions facing energy challenges.

The potential applications of our portable daylighting system extend beyond rural areas with unreliable electricity grids; it can also complement existing power sources in urban settings, reducing dependency on conventional lighting methods and contributing to overall energy conservation efforts. As we move forward, further refinement and optimization of our prototype will be crucial to ensure scalability and widespread adoption. Continued research and development efforts on the daylight optical fiber system will focus on enhancing efficiency, durability, and affordability, making the daylight system a viable and attractive solution for diverse architectural and environmental contexts.

In essence, our project represents a significant step towards realizing a more sustainable and illuminated future, where access to clean and reliable lighting is not a luxury but a fundamental right for all. Through innovation, and a commitment to positive change, we are confident that our daylighting system will make a meaningful difference in improving indoor environments and advancing the global transition towards renewable energy solutions.

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