Non-Invasive Medical Device for Health Monitoring


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Abstract

Cardiovascular health monitoring is crucial for early detection and management of circulatory conditions. Our project leverages photobiomodulation (PBM) technology to create an innovative tool for monitoring blood flow and oxygen circulation. By incorporating red LEDs, infrared sensors, and a battery, this non-invasive solution enhances cardiovascular health monitoring. PBM has been shown to improve cellular function, promote tissue repair, and reduce inflammation, making it highly valuable for medical institutions, rehabilitation centers, military applications, and sports teams. A key aspect of our design is a flexible, biocompatible casing made from thermoplastic polyurethane (TPU), ensuring both comfort and durability. The device also features real-time data transmission to external units, improving accessibility and usability. Our interdisciplinary team minimally collaborated with Electrical Engineering (EE) and Computer Science (CS) Capstone students to optimize design and functionality, utilizing CAD modeling, mathematical analysis, and prototyping. Spearheaded by Jesslynn Armstrong, President of Light Matter Solutions, LLC, our project represents a cutting-edge advancement in health technology. Expected outcomes include improved accessibility to cardiovascular monitoring, enhanced patient care, and a user-friendly, cost-effective solution. The implications of our device extend to proactive health management, facilitating early intervention and personalized treatment options.

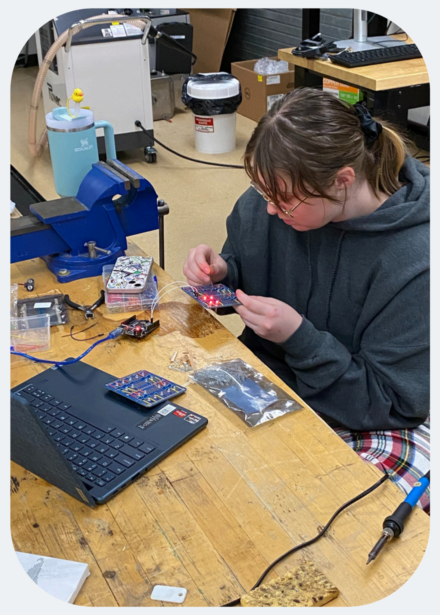
Methods

The device was developed through a structured process including material selection, fabrication, testing, and simulation. It uses red/infrared LEDs, sensors, and a rechargeable battery to apply PBM for cardiovascular monitoring and therapy.

Materials: TPU casing, lithium-ion battery, and 600–880 nm LEDs for deep tissue penetration. The casing was designed in SolidWorks and 3D printed.

Testing: Conducted via simulations (MATLAB/Excel) and physical prototypes. Simulations analyzed light absorption, oxygen saturation, and TPU cooling. Prototypes used breadboards; LED power and battery life were calculated digitally.

Results: The final PBM device combines flexible TPU with integrated LEDs, sensors, and a battery for therapeutic use.



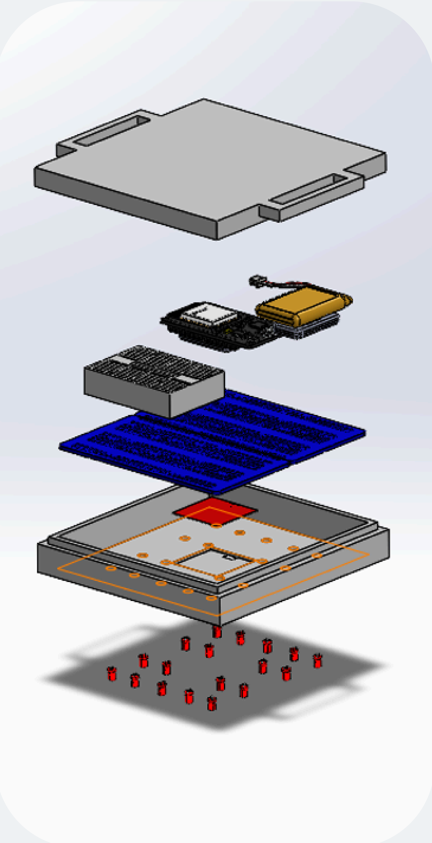
Requirements

1. **Design**: Non-invasive, skin-safe, lightweight, and durable for repeated use. All skin-contact materials must be medical-grade.
2. **Treatment**: Customizable sessions with a 20-minute default and auto shutoff.
3. **Power**: Rechargeable battery with at least 120 minutes of use per charge.
4. **Sanitation & Safety**: Easy to disinfect; must meet ISO 80601-2-61:2017 and IEC 60601-2-57:2023 standards.
5. **Monitoring**: Tracks SpO2 (±5% accuracy) and heart rate during therapy.
6. **Connectivity**: Bluetooth-enabled for real-time data transfer to an app; stores at least 30 sessions.

Conclusion

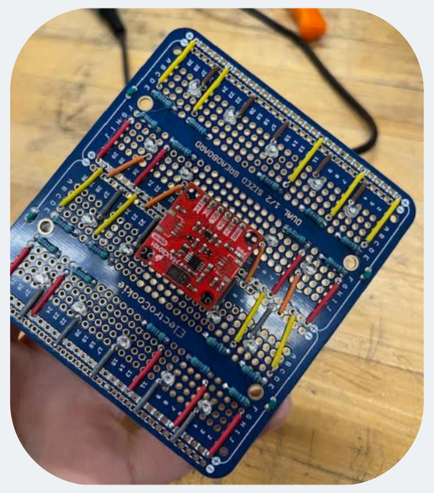
- Our project focuses on the design and development of the Light Dose Tensegrity Medical device — an innovative, non-invasive tool for monitoring blood flow and oxygen circulation that is essential for improving cardiovascular health.
- This device is important because it uses advanced photobiomodulation (PBM) technology to stimulate biological healing processes, reduce inflammation, and support tissue repair, offering practical applications in medical institutions, rehabilitation centers, military environments, and athletic programs.
- Our claim is that this device will not only enhance patient care but also provide real-time data transmission to medical professionals, combining portability, safety, and user comfort with state-of-the-art engineering.
- Some may argue that traditional invasive methods or pharmaceutical solutions are more effective; however, our research shows PBM therapy is supported by scientific studies, offers fewer side effects, and allows continuous, proactive health monitoring.

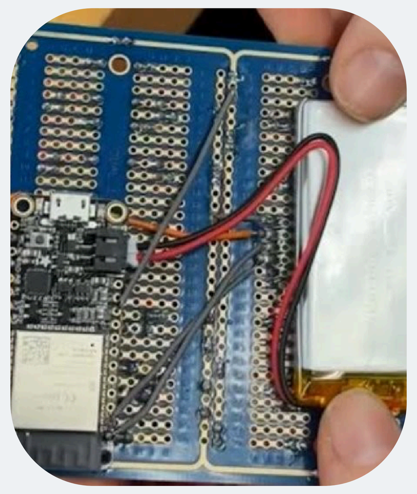
Results

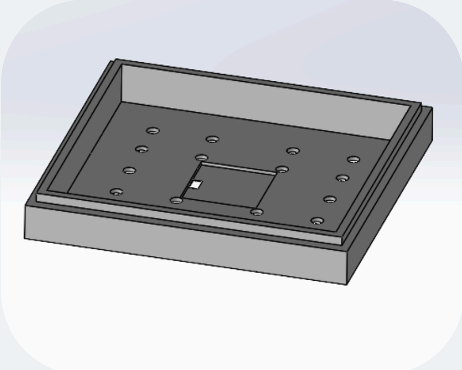


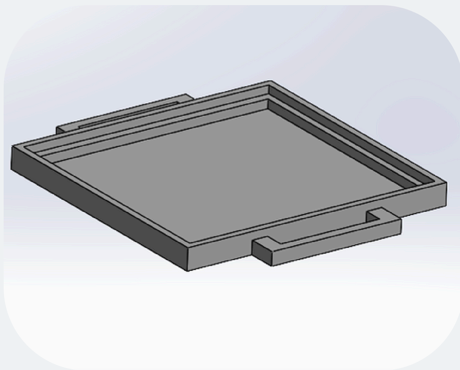
Our CAD design of the finished product is shown on the left. On the top and the bottom of the exploded view is our casing for the inner components. The top piece is the outer facing side (away from the body) and it consists of a handle on either side where straps are sewn on to hold the device to the body. The bottom printed piece (the one that will sit facing the body) consists of holes for each of the LEDs as well as a thin layer in the middle where the sensor will sit. Each piece has extruding/intruding pieces that allow the two to snap into place to hold all of the components together within. The blue breadboard shown in the exploded view holds each of the inner components together with solder Everything sits together in a way that optimizes readings from the sensor as well as allows the user experience the full effects of the LEDs.

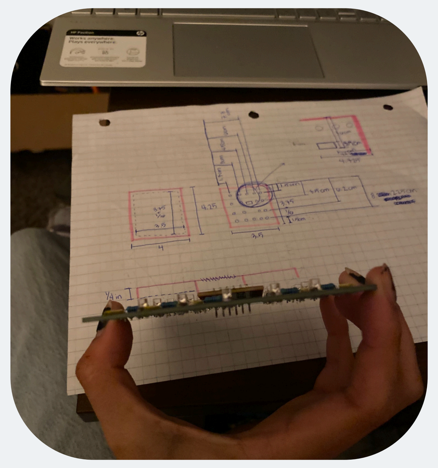
The inner components are shown in the images to the right. The inner breadboard consists of 18 red LEDs along the edges, a heart monitor sensor in the middle, a feather-board on the backside used for Bluetooth communication, as well as a lithium rechargeable battery on the backside to power the feather-board.

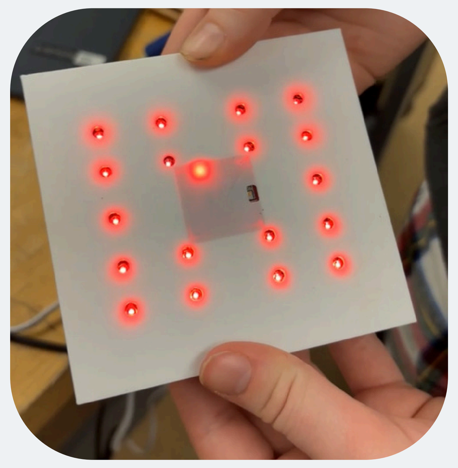






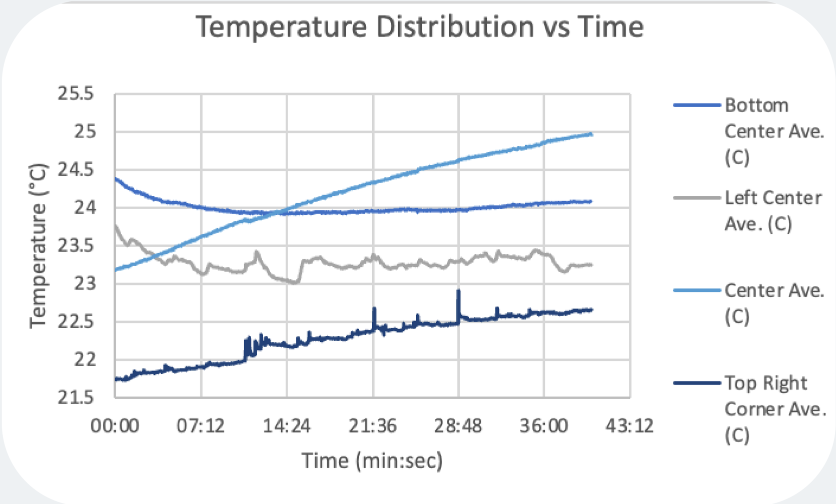




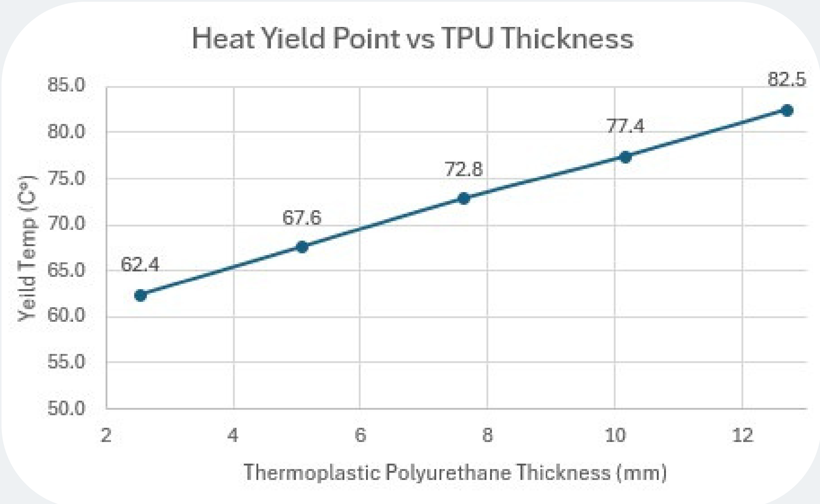


The final design of the photobiomodulation (PBM) device integrates medical-grade thermoplastic polyurethane (TPU) for flexibility and durability while housing essential electronic components such as red and infrared LEDs, sensors, and a battery.

Thermal testing conducted on a human tissue mimic indicates that the device consistently operates below 42 °C. The results suggest that the device can be safely used for durations exceeding 20 minutes without causing significant thermal damage to human tissue.



To evaluate the heat yield point of the TPU casing, samples of varying thicknesses were tested by gradually heating and observing when each began to deform. Thinner samples softened, while thicker samples withstood before visible deformation occurred. Results showed that increased thickness improves thermal resistance.



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[1] IEC 60601-2-57:2023, International Electrotechnical Commission, Standard for non-laser light source equipment used for therapeutic, diagnostic, monitoring, cosmetic, and aesthetic purposes. [2] ISO 80601-2-61:2017, International Organization for Standardization, Standard for safety and performance of photobiological medical devices. [3] T. Hwang et al., "Proposed Mechanisms of Photo-biomodulation or Low-Level Light Therapy," Lasers in Medical Science, vol. 34, no. 6, pp. 1195–1211, 2019. [4] R. G. Calderhead and E. Vasilyeva, "Low-Level Laser Therapy Effects on Vascular and Endothelial Function," Lasers in Surgery and Medicine, vol. 49, no. 5, pp. 505–515, 2017. [5] A. Slade, "Battery Design Guide for Portable Electronics," Power Electronics Journal, vol. 58, no. 4, pp. 47–58, 2021. [6] L. Smith et al., "Development of a LED light therapy device with power density control using a Fuzzy Logic Controller," Biomedical Signal Processing and Control, vol. 55, p. 101668, 2020.