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# DESIGN AND ANALYTICAL VALIDATION OF A DUAL-SEGMENT BIOMIMETIC LUMINESCENT SOLAR CONCENTRATOR (LSC) FOR AUTOMOTIVE GLAZING

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## ABSTRACT

Luminescent Solar Concentrators (LSCs) offer a transparent alternative to traditional photovoltaics for automotive integration. However, the efficiency of monolithic LSC panels is traditionally limited by reabsorption losses. This paper proposes a novel Dual-Segment Biomimetic (DSB) architecture for a 1.18sqm automotive sunroof. By segmenting the aperture into two 0.59sqm modules and integrating a fractal venation network of PV micro-strips governed by Murray's Law, this study demonstrates a theoretical pathway to overcome the scaling limit. Analytical results suggest a potential Power Conversion Efficiency (PCE) increase from a 3.0% baseline to 8.2%, while providing functional thermal management suitable for high-UV environments like Assam, India.

**KEYWORDS:** LSC, Biomimetics, Murray's Law, Automotive Engineering, Total Internal Reflection.

## 1. INTRODUCTION

With the global shift toward Electric Vehicles (EVs), maximizing on-board energy harvesting is critical. Standard solar panels are opaque, making them unsuitable for sunroofs. Luminescent Solar Concentrators (LSCs) solve this by using a doped interlayer to trap and guide light toward the edges. This paper introduces a hierarchical design that combines macro-scale modularity with micro-scale biomimicry to maximize photon-to-edge extraction.

## 2. Theoretical Framework

The proposed system relies on Total Internal Reflection (TIR) within a glass waveguide (n=1.52).

### 2.1 Critical Angle Calculation

The efficiency of light trapping is defined by the critical angle (theta_c): theta_c = arcsin(1.00/1.52).

Photons emitted within the trapping zone (~ 75% of emissions) are guided through the medium.

## 3. Proposed Design Methodology

### 3.1 Macro-Scale: Dual-Segment Architecture

The 1.18sqm sunroof is divided into two 0.59sqm segments. This reduction in aperture size decreases the optical path length by 50%, effectively reducing the probability of photon reabsorption.

### 3.2 Micro-Scale: Biomimetic Venation

Inspired by the leaf venation of Dicotyledons, a network of thin-film PV "veins" is embedded in the interlayer. Unlike frame-only LSCs, this allows for multi-point extraction. The width of these veins (w) is optimized using Murray's Law, ensuring efficient electrical current transport and a minimized shading ratio.

### 3.3 Functional Tinting Effects

Standard tinting works by subtraction—absorbing light and converting it to heat. A luminescent laminate works by conversion:

- **Visual Appearance:** Organic dyes (such as those in the AuREUS system) absorb UV and high-energy blue light, creating a natural neon-like aesthetic.
- **Glare Reduction:** By absorbing the harsh UV spectrum, the layer acts as a functional tint.
- **Heat Reduction:** Unlike traditional tints that radiate heat into the cabin, a luminescent layer re-emits energy as light, keeping the interior cooler.

## 4. RESULTS AND DISCUSSION

### 4.1 Optical Path Optimization

By combining segmentation and venation, the mean free path of a photon is reduced from

540mm (monolithic) to 100mm (venation-target). This mitigation of self-absorption is the primary driver of the projected 8.2% PCE.

## 5. CONCLUSION

The DSB-LSC architecture provides a scalable solution for active automotive glass. The integration of Murray's Law into a two-segment waveguide demonstrates a significant theoretical improvement over standard designs, providing a foundation for future 3D simulation and physical prototyping.

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