Preliminary Results On Luminaire Designs For Hybrid Solar Lighting Systems

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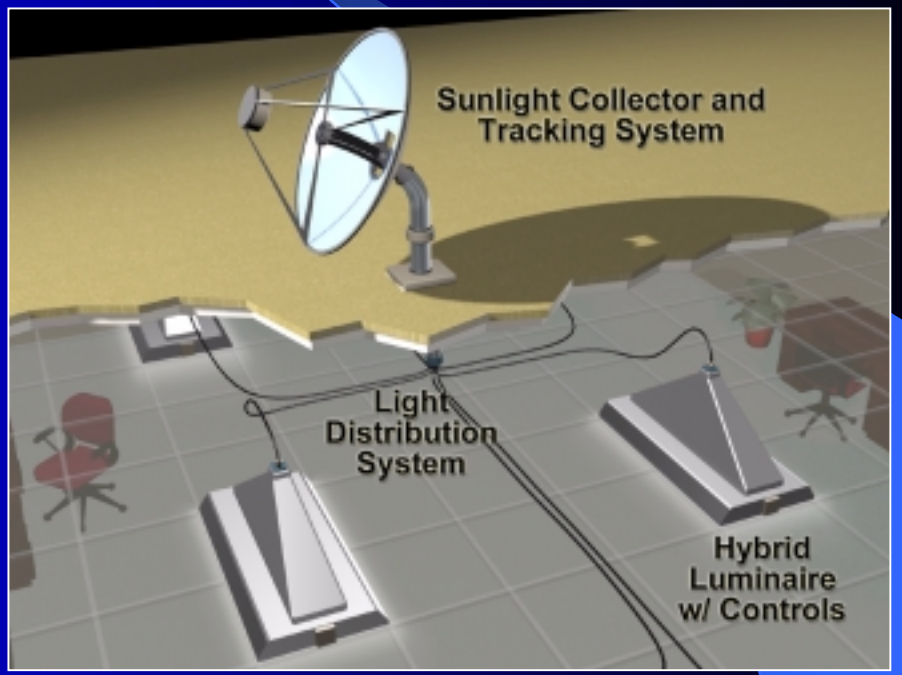
The Hybrid Lighting Project

- Reduces energy usage through the collection and redistribution of sunlight.
- Requires the seamless integration of fiber optic lighting and electric lighting.

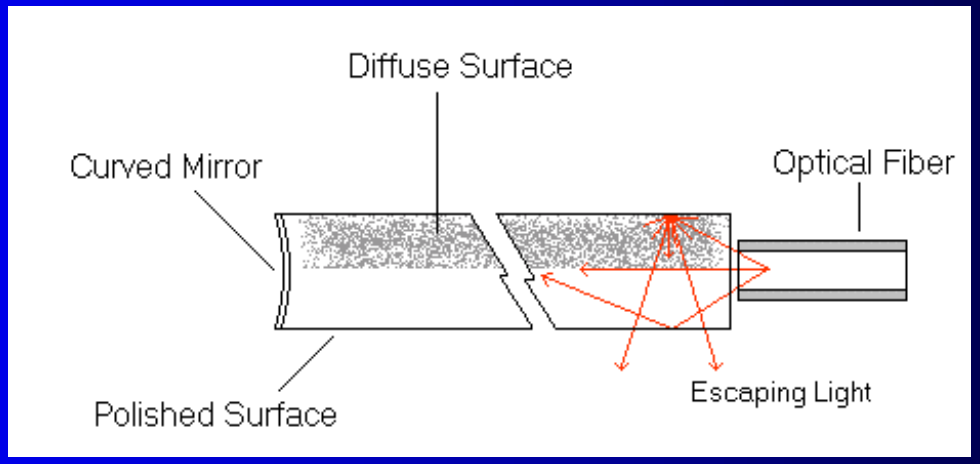


Requirements of a Hybrid Luminaire

- Incorporates both solar and electric illuminants
- Maintains a constant total output intensity
- Exhibits high optical efficiency for both solar and electric illuminants
- Compensates for color differences between solar and electric illuminants
- Maintains a static spatial intensity distribution
- Is easily integrated and installed
- Reasonable cost

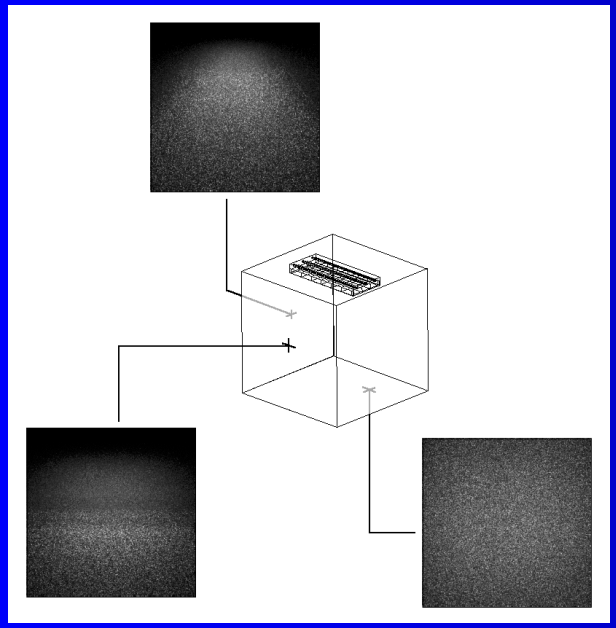
Design #1: Cylindrical Diffuser Approach

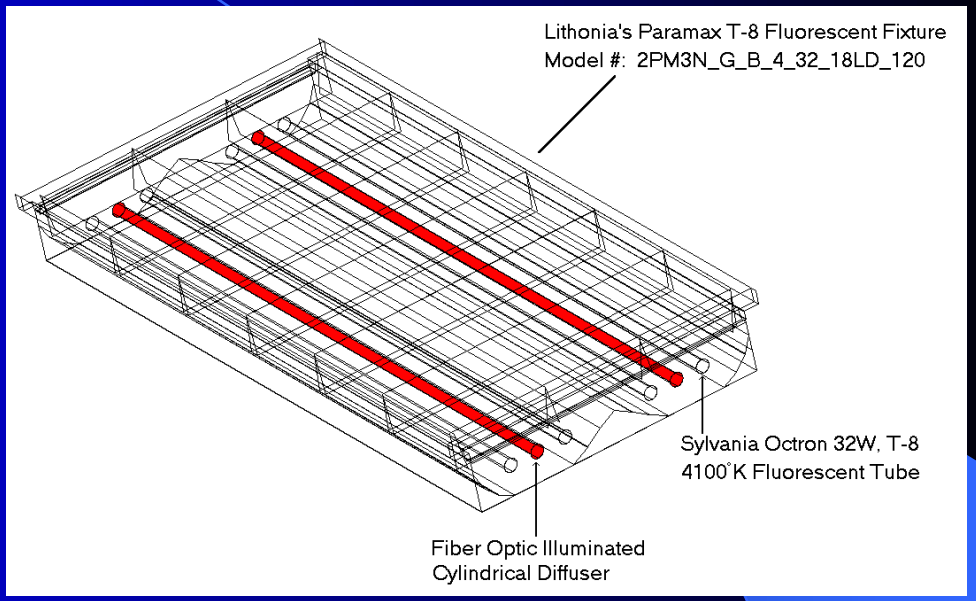
- 1.0 meter long, plastic core with air cladding, cylindrical waveguide design
- Designed for illumination by end-coupled large core optical fiber (NA = 0.65, core diameter = 12 mm)
- Bottom hemisphere is polished, top hemisphere exhibits surface roughness creating method for light to escape waveguide
- Curved mirror reduces undesirable emitted intensity gradient



Design #1: Modeling and Simulation

- Lithonia's Paramax® fixture selected for retrofitting.
- Original fixture's spatial intensity distribution was modeled using ZEMAX ray tracing software. (50+ NSC Surface Model)





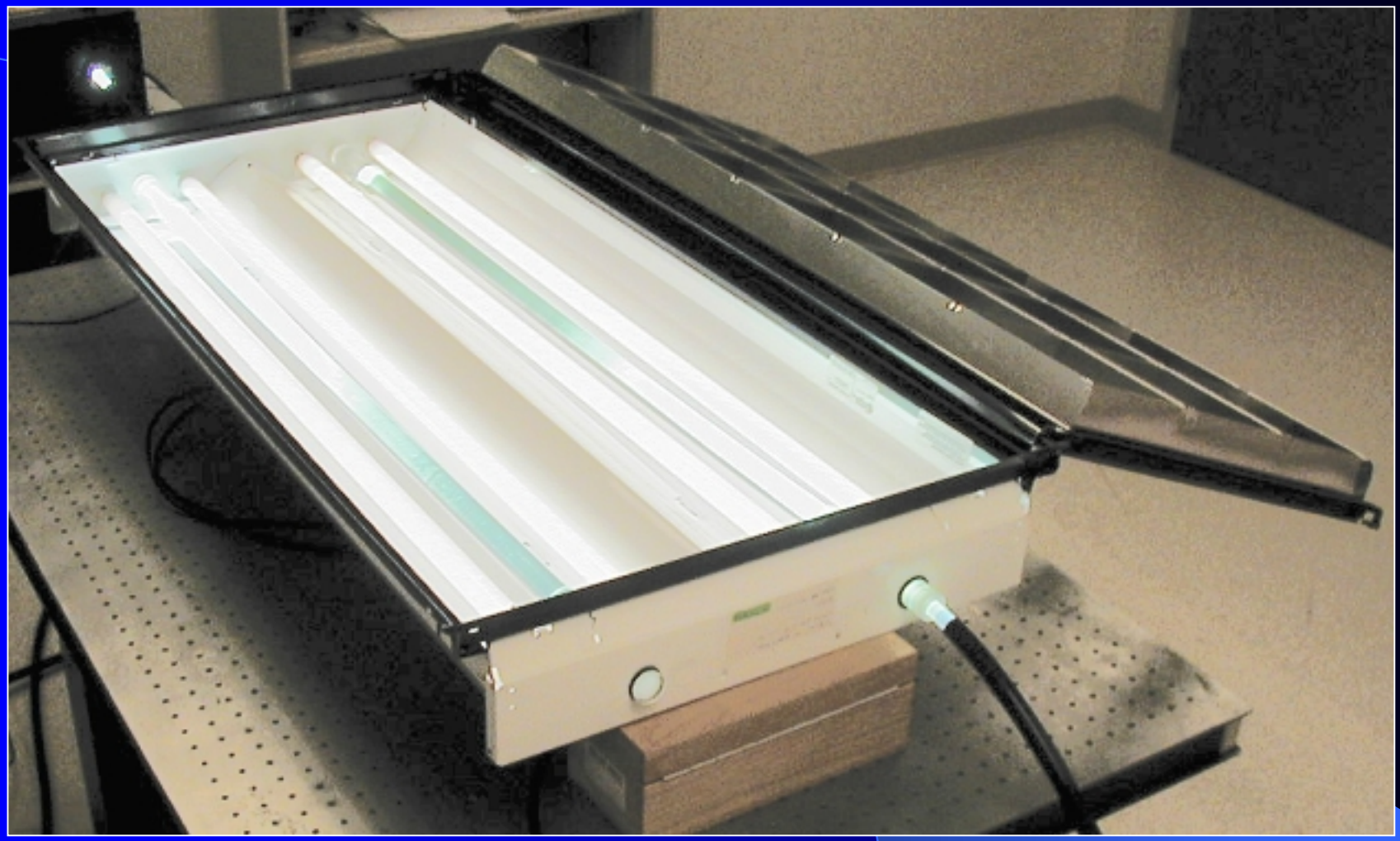
- Potential hybrid luminaire designs were modeled and optimized to mimic spatial intensity distribution of electric lamps.

Design #1: Construction Details

- 1.0 meter long, 2.54 cm. diameter, cast acrylic rod
- Top surface sandblasted to produce uniform scatter
- One end polished flat, the other curved (R = 4 cm).
- Top surface and curved end dip coated with silver reflective paint

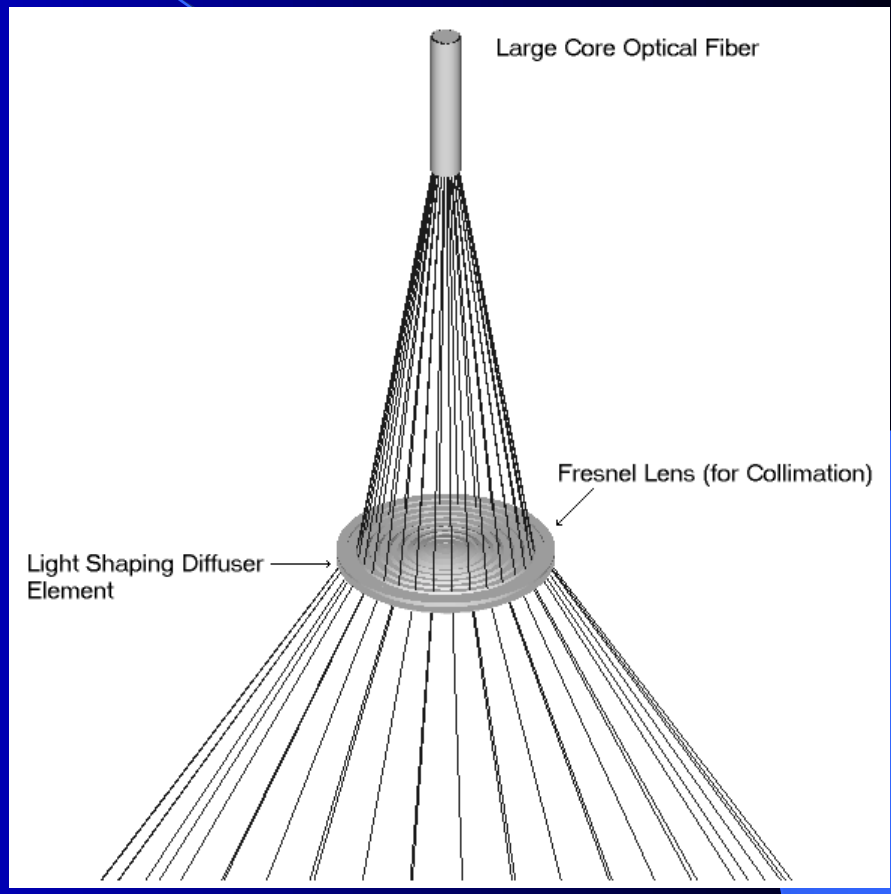
- Surface scatter of top hemisphere exceeds modeled scatter parameters
- Resulted in unwanted intensity gradient along illuminant length

Finished Hybrid Luminaire Design #1

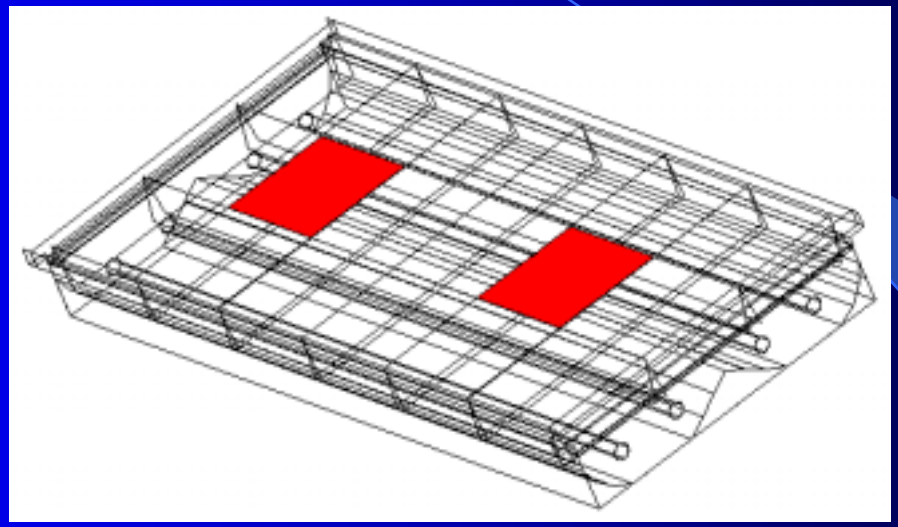


Design #2: Structured Diffuser Approach

- High-efficiency “light shaping” diffuser element used to forward-scatter 90% of incident light from optical fiber
- Diffuser element creates ***controllable*** elliptical intensity distribution
- Divergence angles of 160° (full-angle) are possible
- Diffuser reduces fiber optic “footprint”



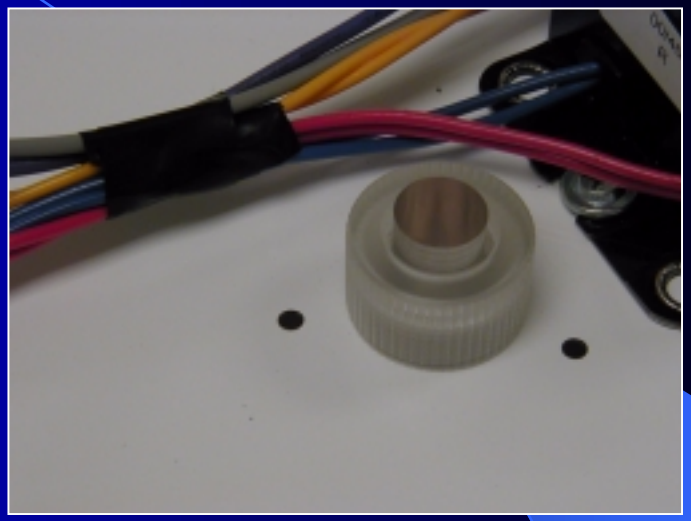
Design #2: Modeling and Simulation

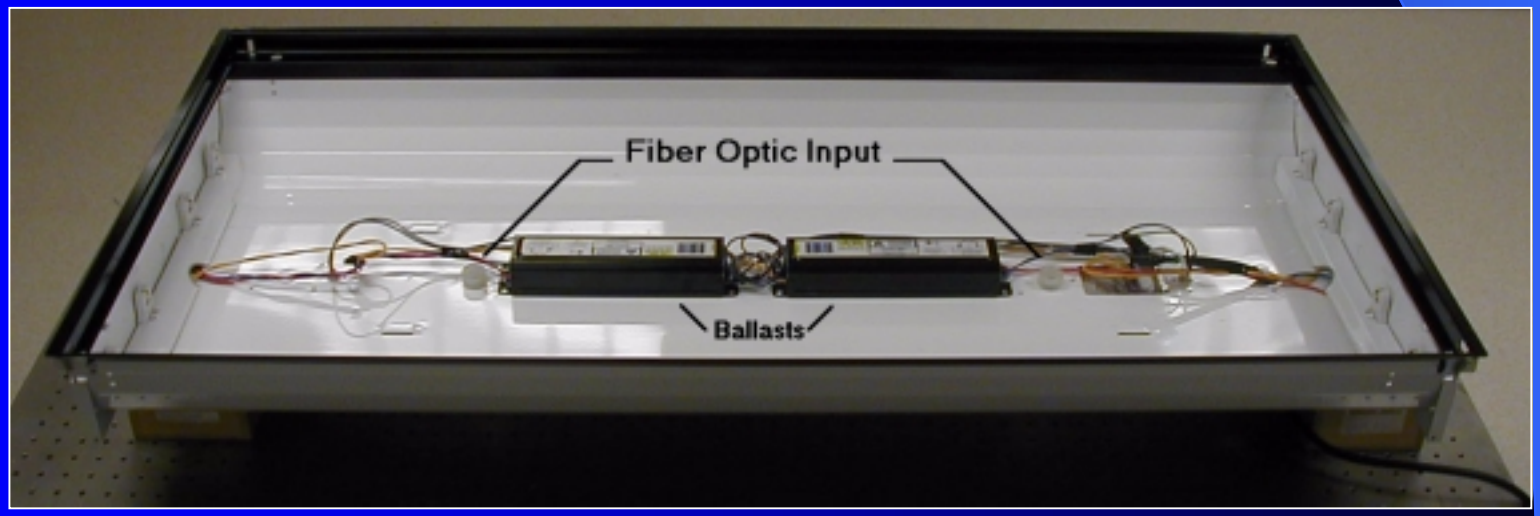


- Two “Light Shaping” diffuser elements were modeled in a Lithonia Paramax® fixture with 18-cell Baffle
- Diffusers modeled as x-y Guassian sources
- Design optimized for 6 ft. illumination distance
- Slight intensity distribution differences at high angles

Design #2: Construction Details

- Fiber optic ports installed in top of fixture
- Baffle housing modified to include aperture for fiber optic-emitted light





Finished Hybrid Luminaire Design #2

Advantages and Disadvantages

Design #1: Cylindrical Diffuser

Advantages

- Cylindrical diffuser closely mimics intensity distribution of electric lamps and is very forgiving of manufacturing errors
- Cast-able design ($)
- Intensity normalization is independent of other fiber optic sources
- Compact/self-contained design

Disadvantages

- Difficult to accurately predict/model scattering properties
- Tight manufacturing tolerances required for high optical efficiency

Design #2: Structured Diffuser

Advantages

- High optical efficiency
- Low-cost molded plastic components
- Easily modeled

Disadvantages

- Differences in the spatial intensity distribution of fiber optic and electric illuminants is dependent upon distance from fixture
- Fiber optic sources must be equivalent in output intensity to permit intensity normalization using electric lamps
- Two stage design requires mounting in troffer and louvers.

Future Research Efforts

- Measure changes in spatial intensity distribution experienced by both hybrid luminaire designs using the ORNL “Illumination Cell”
- Measure optical efficiency of cylindrical and structured diffusers
- Develop suitable electrical feedback control system for fiber optic and electric illuminants
- Measure color differences between solar and electric illuminants