

Project 10: Advanced Energy-Efficient  
LED Lighting for  
Residential and Commercial Applications

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# Acknowledgements



- California Energy Commission
  - PIER Program
- Architectural Energy Corporation
- Lightolier
- Mark Cherniack (New Buildings Institute)
- LRC staff and students



# Project Summary



- To develop an advanced, energy-efficient LED lighting system for residential and commercial buildings that:
  - reduces lighting energy use by 50% to 70% over traditional technologies
    - system luminous efficacy of 100 lm/W;
  - is cost effective to purchase, install, use and maintain
  - is compatible with building-based control systems (e.g., occupancy and daylight controls)
  - is capable of load-shedding



# Project Summary



- The end result of this project is a fully functional prototype.
  - Lightolier is the commercial partner in this project.



# Current Activities



- Market analysis report
  - Potential markets for this product have been identified.
    - Fastest growing market: recessed downlights.
    - Commercial applications sales are ~30% higher than for the residential market.
    - Specification grade luminaires sales are ~50% of total market.
    - Opportunity for a specification grade, highly efficient small aperture downlight (4"), producing at least 1000 lm to compete with compact fluorescent-based luminaires in size and light output, and with ceramic metal halide-based luminaires in life and cost.



# Initial Product Specifications



- Family of downlight, wall washer, and accent luminaires
- Target: 100 lm/W and 50,000 hours life at L<sub>70</sub>

**PHOTOMETRIC**

- 1000 lm
- CRI of 85 at 3000 K to 3500 K
- Three beam spreads (for different ceiling heights)
- 50-degree cutoff

**ELECTRICAL**

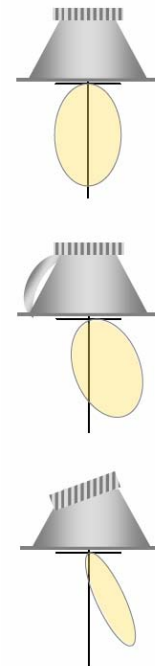
- Dimmable
- Compatible with occupancy, photosensor and load-shedding controls
- Capable of being used in emergency circuits or have its own battery backup

**MECHANICAL**

- 4-inch diameter
- Ideally less than 5-inch height, but not more than 6-inch height
- Non-IC rated

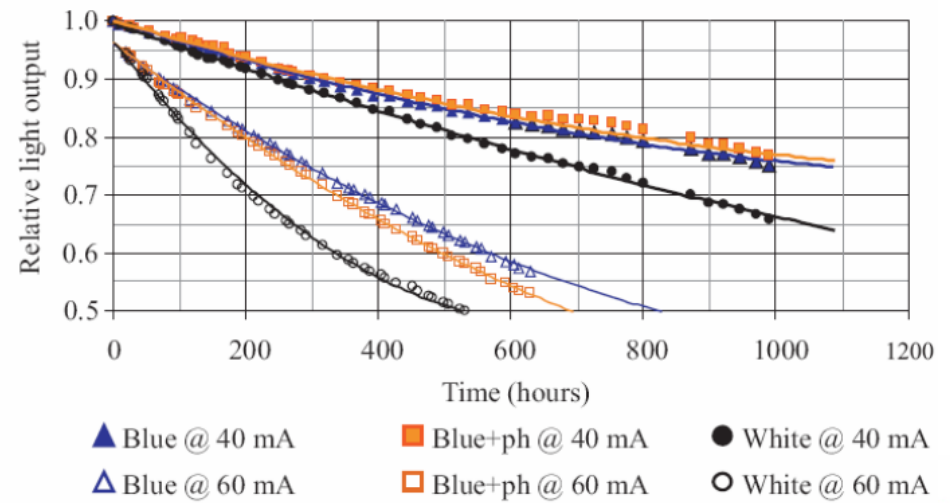
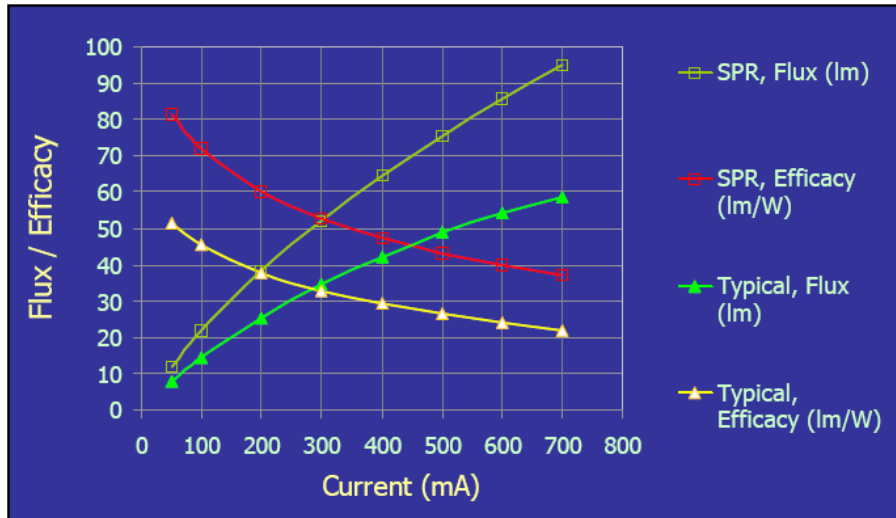
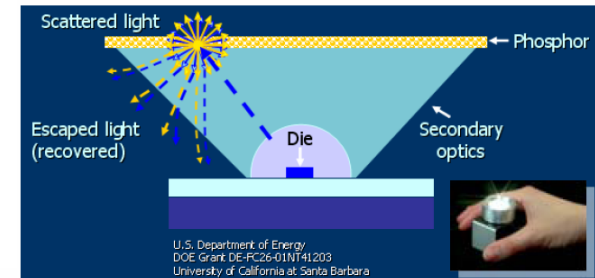
**ECONOMICAL**

- Target manufacturing cost (just materials) of \$50
- Target selling cost less than 20-watt metal halide comparable fixture



# Project Approach

- Project approach: SPE<sup>TM</sup> technology
  - Up to 60% improvement in light output and luminous efficacy over conventional LED technology
  - Longer useful life



Narendran, N., Y. Gu, J.P. Freyssinier-Nova, and Y. Zhu. 2005. Extracting phosphor-scattered photons to improve white LED efficiency. *phys. stat. sol. (a)* 202 (6): R60-R62.



# Current Activities



- Technical advances

- SPE improvement:

Ongoing



- First prototype: large-scale, off-the-shelf components
- Second prototype: small-scale, off-the-shelf components
- Third iteration: LED level SPE integration
- Goal of final iteration: 2-inch SPE-based module capable of producing in excess of 1000 lm at ~100 lm/W

# Technical Advancements



- Design process – Photometric criteria

- Optical modeling to design LED/SPE optics

- Optimized reflector design to maximize photon extraction
    - Converted ray-tracing models into CAD files to manufacture samples

- Phosphor analysis

- Analysis of phosphor density needed to achieve target chromaticity
    - Analysis of binding materials for phosphor
    - Analysis of methods for phosphor deposition on SPE optics
    - Optimization of curing process

<p><b>PHOTOMETRIC</b></p> <ul style="list-style-type: none"> <li>• 1000 lm</li> <li>• CRI of 85 at 3000 K to 3500 K</li> <li>• Three beam spreads (for different ceiling heights)</li> <li>• 50-degree cutoff</li> </ul>	<p><b>ELECTRICAL</b></p> <ul style="list-style-type: none"> <li>• Dimmable</li> <li>• Compatible with occupancy, photosensor and load-shedding controls</li> <li>• Capable of being used in emergency circuits or have its own battery backup</li> </ul>
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# Technical Advancements



- LED analysis
  - Characterization and selection of LEDs of appropriate peak wavelength and radiant power
  - Designed and manufactured custom PCB for LEDs
  
- Mechanical criteria
  - Heat sink analysis
    - Initial estimation of heat sinking requirements (LRC, Lightolier)
    - Initial housing and heat sink design in process (Lightolier)



# Technical Advancements



- **Economical criteria**
  - Manufacturing costs
    - Initial estimation of manufacturing costs based on target application
  
- **Electrical criteria**
  - To be addressed in the coming iteration process

# Technical Advancements

- Initial SPE-based prototype

- Performance

- ~200 lm to 1080 lm
    - 1.95 W to 15.87 W
    - 68 lm/W to 100 lm/W
    - 5300 K, 70 R<sub>a</sub> CRI

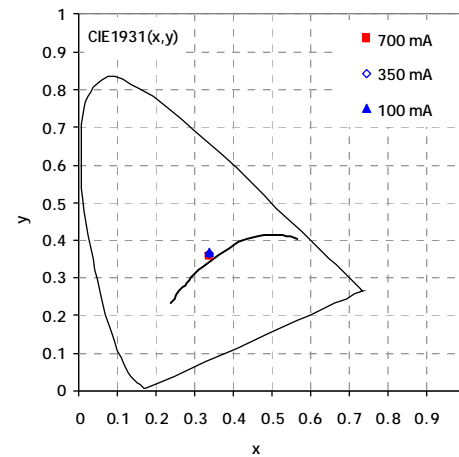


Table 1. Performance of the SPE-based LED module prototype.

Driven current	Luminous flux (lm)	efficacy (lm/W)	dc power
700 mA	1078	68	15.87 W
350 mA	623	83	7.50 W
100 mA	196	100	1.95 W

# Technical Advancements

- Second SPE-based prototype

- Performance

- ~255 lm to 390 lm
    - 5.57 W to 11.27 W
    - 34.7 lm/W to 45.8 lm/W
    - 5000 K, 70 R<sub>a</sub> CRI

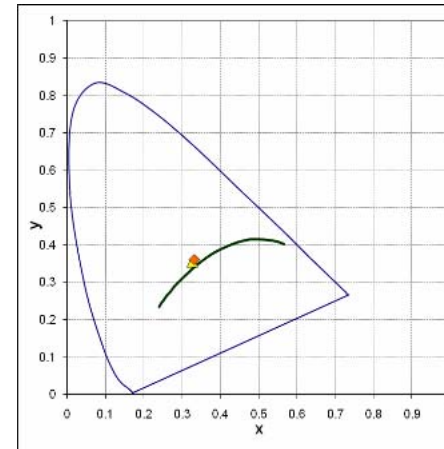


Table 2. Performance of the second SPE-based LED module prototype.

Driven current	Luminous flux (lm)	efficacy (lm/W)	dc power
700 mA	390	34.7	5.57 W
350 mA	255	45.8	11.27 W
-	-	-	-



# Next Steps



- Points to address in the next prototype iteration
  - Achieve 1000 lm
    - at 100 lm/W
    - LED module size within a 2-inch diameter
  - Color uniformity
  - Lower CCT
  - Better CRI
  - Address
    - heat sink and mechanical design (Lightolier)
    - electronic driver and control interface design to match Lightolier's existing control systems



# Market Barriers



- Market barriers will be determined once the final prototype performance and cost have been established.



Thank you

