Scalable Light Module for Low-Cost, High-Efficiency LED Luminaires

#DE-EE0006264 Project Overview

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Wide-Area Luminaires

• Wide-area luminaires such as troffers vary in form factor and performance, with application requirements often dictating design choices

• Each requires specific light engine & secondary optics designs based on system geometry & output requirements
Project Elements and Technology

• Develop a scalable, versatile Light Module architecture that can enable:
  ▪ High optical, thermal efficiency
  ▪ Reduced LED count
  ▪ Fewer mechanical piece parts
  ▪ Simplified integration and assembly

Low $/k\text{lm}$

Compact LEDs
- High Efficacy and CRI
- Low Normalized Cost ($/k\text{lm}$)
- Desirable Emission vs. Angle
- Small Optical Source Size

High-Efficiency Light Module
- High Optical Efficiency
- Low BOM
- Low Profile, Low Weight
- High Luminance & Color Uniformity

Broad-Area Luminaires
- Low Cost ($/k\text{lm}$)
- High Efficacy and CRI
- Rapid Assembly
- Compact, High-efficiency Driver
**Project Elements and Technology (cont.)**

**Development Focus**

- **Smart Optics**
- **Compact LEDs**
- **Light Module**
- **Electrical Interconnection**
- **Simple Mechanical Assembly**
- **Low-Profile, Wide-Area Luminaires**
  - 6"x48", 12"x48", 24"x24", 24"x48", etc.
- **Demonstration Luminaire**

**CHALLENGES**

- Compact, high-efficacy AND high-CRI LED
- LED intensity, color vs. emission angle
- Light spreading, extraction, diffusion
- Targeting > 90% net optical efficiency
- Very low (< 1 cm) overall thickness
- Manufacturable fabrication processes
- Low bill of materials, assembly costs
- Low-profile electrical interconnections
- Very compact > 90% efficient driver
- Minimized handling & number of steps
- Simple, rapid assembly
- Mechanical stability with minimal BOM
Project Objectives

- High efficacy warm-white LEDs with high (90+) CRI
- Cost-effective, high optical efficiency, scalable Light Module
- Compact, high-efficiency (90+% ) electrical driver
- Electrical and mechanical subsystems w/ low BOM, assembly $
Task 2: Compact High-CRI LED Development

- Simultaneously achieve high efficacy and high CRI
- Integrated TrueWhite® (blue/ yellow + red chips) LEDs

Example: XM-L color

Subtasks:

2.1 Establish optimal LED chip size, number, configuration
2.2 Develop selective phosphor application
2.3 Explore package substrate materials
2.4 Determine reliability of prototype LED packages
Task 3: Light Module Design, Testing

- Design, fabricate, and test a cost-effective, low-profile optical system that efficiently distributes light over large areas

Point source

Area Source

- Subtasks:
  3.1 Design Light Module optics elements
  3.2 Model intensity and color mixing capabilities of waveguide/extractor elements
  3.3 Achieve high optical efficiency with fully optimized prototype LEDs
Task 4: Light Module Manufacturing Development

• Develop and test methods for cost-effective, reproducible, & scalable manufacturing of Light Module optical components

• Collaborate with Cree production groups and vendors to verify practicality, cost of proposed mfg. methods

• Subtasks:
  4.1 Mfg. processes for optimized Light Module subsystems
  4.2 Define critical feature dimensions and tolerances
Task 5: Luminaire Electrical and Mechanical Dev.

• Holistic design of electrical and mechanical sub-systems to contribute to low system BOM
• Minimize or eliminate thermal elements
• Designs compatible with low-profile, lightweight geometries and simple/rapid assembly

• Subtasks:

5.1 Develop low-cost electrical interconnection scheme for low-profile luminaires
5.2 Design and build compact and efficient electrical driver
5.3 Design and build lightweight mechanical structure for low-profile, broad-area luminaires
Task 6: Demo Luminaire with Light Module Integration

• Demo luminaire will exhibit the design, cost, and performance advantages of the Light Module concept
  ▪ 3000K CCT, > 90 CRI
  ▪ Efficacy > 116 lm/ W
  ▪ Driver: >90% efficiency, compact size
  ▪ End user price: ahead of DOE projection ($/ klm)

• Subtasks:
  6.1 Assemble and test 2’ x 4’ demonstration luminaire based on Light Module concept
  6.2 Final estimation of assembled luminaire costs and end-user price