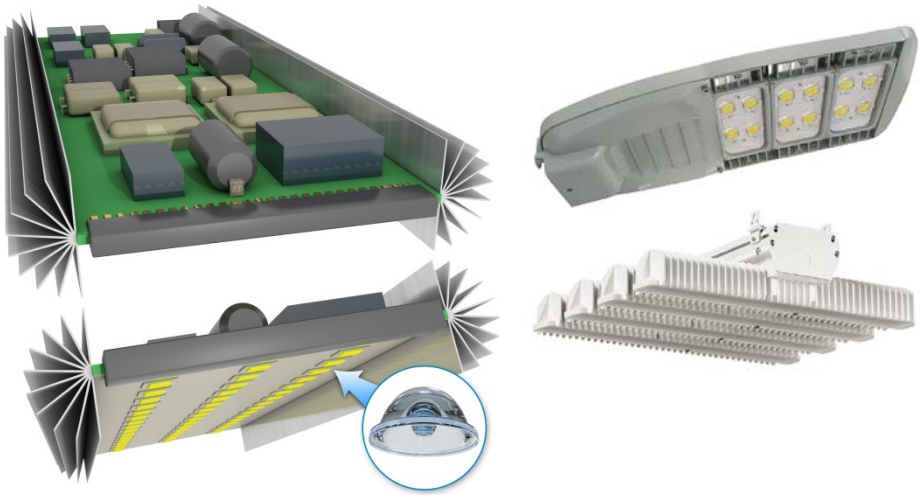
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Highly Integrated Modular LED Luminaire



GE Global Research

Ramanujam Ramabhadran

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Project Summary

Timeline:

Start date: August 15, 2016

Planned end date: June 30, 2018

Key Milestones

1. Milestone 1: Month 12, 96% efficient Driver Electronics Prototype with COTS magnetics
2. Milestone 2; Fully integrated light engine & electronics in a 16 klm luminaire at 200 lm/W

Budget:

Total Project $ to Date:

- DOE: $1,099,221
- Cost Share: $366,724

Total Project $:

- DOE: $1,177,064
- Cost Share: $392,335

Key Partners:

Stanford University
Current Powered by GE

Project Outcome:

As LEDs become more efficient, it is possible to achieve higher levels of integration, increase overall efficacy, and lower manufacturing cost in outdoor luminaires. Our goal in this project is to realize a very efficient outdoor luminaire that is low enough in manufacturing cost for assembly in the US.

Team

Ram Ramabhadran (PI)
Power electronics, LED Driver design
Experience in product development, manufacturing
Role: Driver design and overall project execution

Stanton Weaver
Packaging, assembly, thermal design
LED Efficacy and optics integration
Role: Optics and thermal design

Juan Rivas-Davila
Printed and compact magnetics design, power electronics design
Role: Transformer and inductor design for manufacturing

current powered by GE

Gary Steinberg
Systems Manager, Outdoor LED Lighting
Expert in overall system level assembly

Engineering Team from Current
Manufacturing and assembly expertise
Optics testing (NELA park, Hendersonville)

Challenge

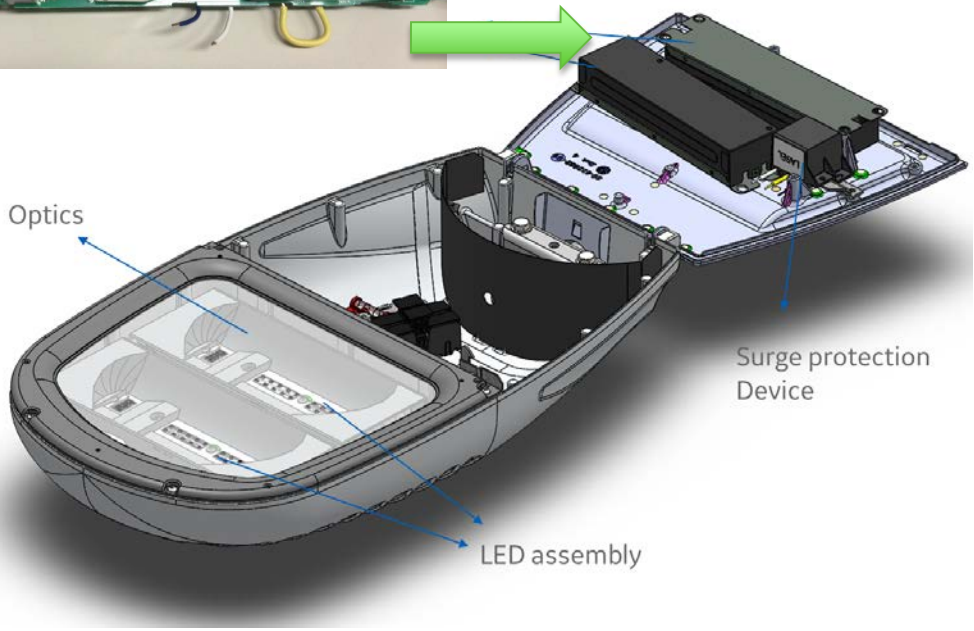
Problem Definition:

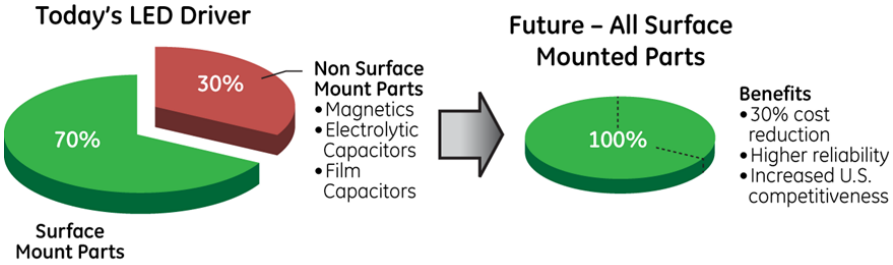
- Shift underway in outdoor lighting to LED, towns replacing fixtures to LED
- 21% in 2014, expected to reach 83% LED penetration in 2020
- **High efficacy is needed (200LPW) to realize quick return on investment**
- Outdoor fixtures larger, heavier, local manufacturing and shipping preferred
- **Need minimum 30% reduction in manufacturing cost**
- 10-15 year warranties are desired, driver reliability needs to be high

Benefits to be Realized

- *Design cost competitive with off-shore manufacturing (US manufacturable)*
- *50% decrease in design cycle time*
- *2X increase in light conversion efficacy with LED improvements*
- *Energy savings in outdoor market due to quicker LED adoption*
- *Adjacencies with electronics manufacturing in USA including semiconductors*

Approach





High Efficiency Driver and Optics

- Improve LED efficacy x Optics efficacy x Driver efficiency
- Focus on optics and driver
- Driver- SiC design achieving 95% efficiency, 40% less parts
- Optics- improved optical cavity with 8-10% higher efficacy

Integrated Low Cost Assembly

- SiC design enables 40% part reduction with lower cost
- Target full automated assembly
- Lighter smaller surface mount magnetics (30% faster)
- Integrated assembly lowers casting weight for shipping

Impact

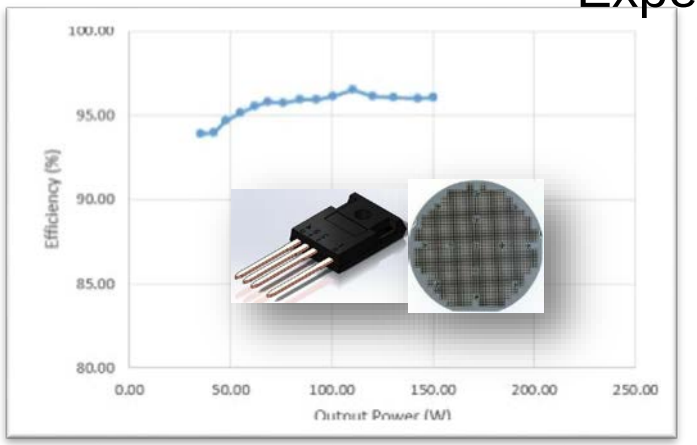
- **Driver and optics are in the 85% efficiency range today. To achieve DOE goals of 200 lm/W, these need to be improved substantially- focus of our work**

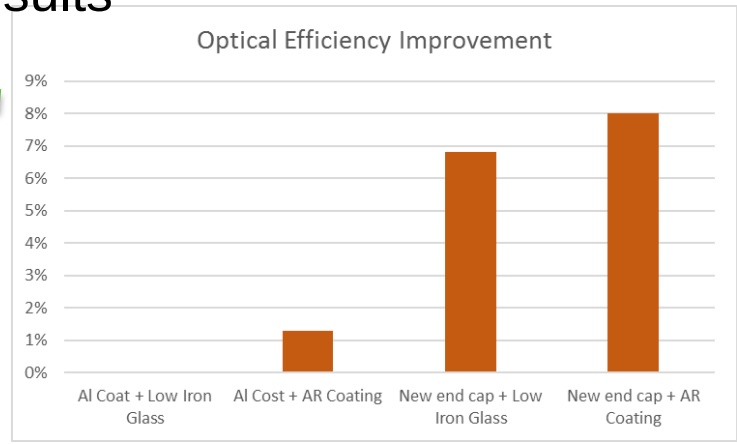
Parameter	State of the Art	GE Solution
LED efficacy (lm/W)	146	220 (DOE Projection)
Driver efficiency	86%	96%
Fixture/optical efficiency	87%	94%
Corrected overall efficiency	74%	90%
Luminaire efficacy (lm/W)	108	199 (GE Solution)

- **Impact of our work**
  - **Driver Efficiency**: 95% peak driver efficiency demonstrated
  - **Optics efficiency**: Improvement of 8% realized due to improved reflector design and coatings
  - **Low cost design**: US manufacturing capability demonstrated with >30% cost improvement

Progress

Experimental Results



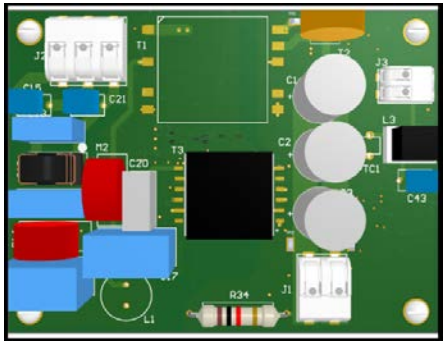


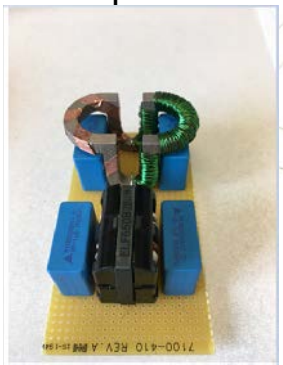
Driver

- ✓ Built integrated driver fixture
- ✓ GE SiC MOSFET
- ✓ Peak efficiency of 95% demonstrated

Optics

- ✓ AR coating+ modified reflector developed
- ✓ 8% higher optical efficiency tested at Current
- ✓ Improvement over mid 80s baseline efficiency





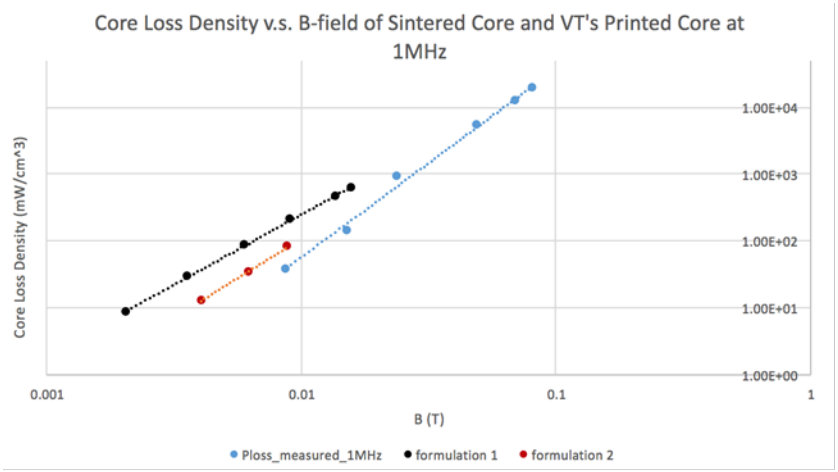
3D Printed Magnetic Cores
Compact and Lightweight Form Factors

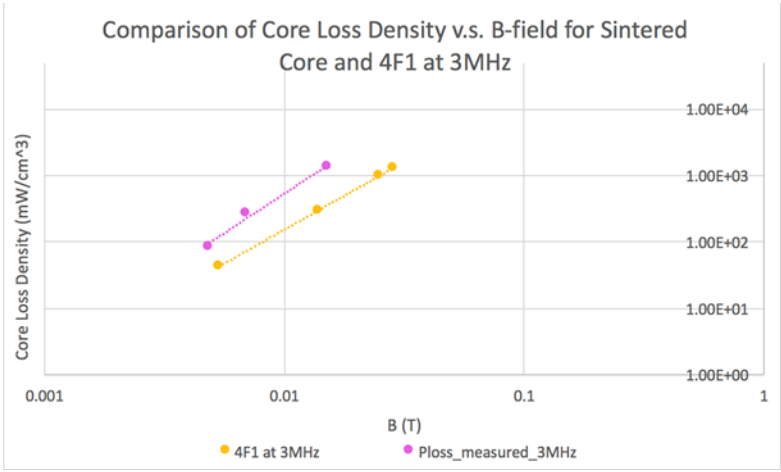
Manufacturing of Fixture

- All automated driver assembly
- 30% higher throughput
- 50% luminaire labor
- Comparable to offshore cost
- Fully SMD magnetics
- Developed process for printing cores

Magnetics Innovations Progress (Stanford)

- Magnetics are longest lead time item
- Developed inductor/transformer designs that can be automated
- 3D printed cores fabricated comparable to commercial cores
- Custom shapes with more compact footprint
- Easily enables automated assembly
- Transformer and inductor are manually placed today





Note: 4F1 material is measured at 100C, but our [illegible] are at a lower temperature (~50C)

3D printed core comparable to commercial core

Stakeholder Engagement

- **Project involved full collaboration with Current Powered by GE**
- **Phase 1 Review held at GE Factory at Hendersonville NC**
- **Testing of Optics done at NELA Park and Hendersonville NC**
- **Manufacturability input and cost from actual production inputs**
- **Integrated Fixture Proposal proposed for pre-NPI in April 2018**
- **Project Status**
  - Awaiting Stanford University partner to complete work on transformer
  - Two revisions of integrated driver developed
  - Costing workout held with manufacturing line at Hendersonville
  - Individual piece efficiency improvements demonstrated
  - Pending full integration of magnetic and driver into fixture

Remaining Project Work

- **Individual pieces (driver, optics, inductor core printing) have been demonstrated and achieve target efficiency or manufacturability**
- **Remaining Tasks**
  - Develop custom printed core with transformer (fully automated manufacturing)
  - Integrate driver in fixture and casting for full demonstration

Thank You

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REFERENCE SLIDES

Project Budget

Project Budget: 18 month, $1.569MM Program
Variances: No cost extension for completing magnetics work till June 30, '18
Cost to Date: DOE Funds $ 1,099,221, Cost Share $ 366,724
Additional Funding: Substantial engineering input, time, and testing facilities provided by Current, Powered by GE (formerly GE Lighting)

Budget History			
August 15, 2017 to Current		FY 2019 – Feb 14 2018 (planned)	
DOE	Cost-share	DOE	Cost-share
$ 1,099,221	$ 366,724	NA	NA

Project Plan and Schedule