

2010 DOE SOLID-STATE LIGHTING R&D WORKSHOP

Panel 1: The Limits of Efficacy

Does current packaging technology limit LED device efficacy?

Steve Paolini – CTO, Lunera Lighting Inc.

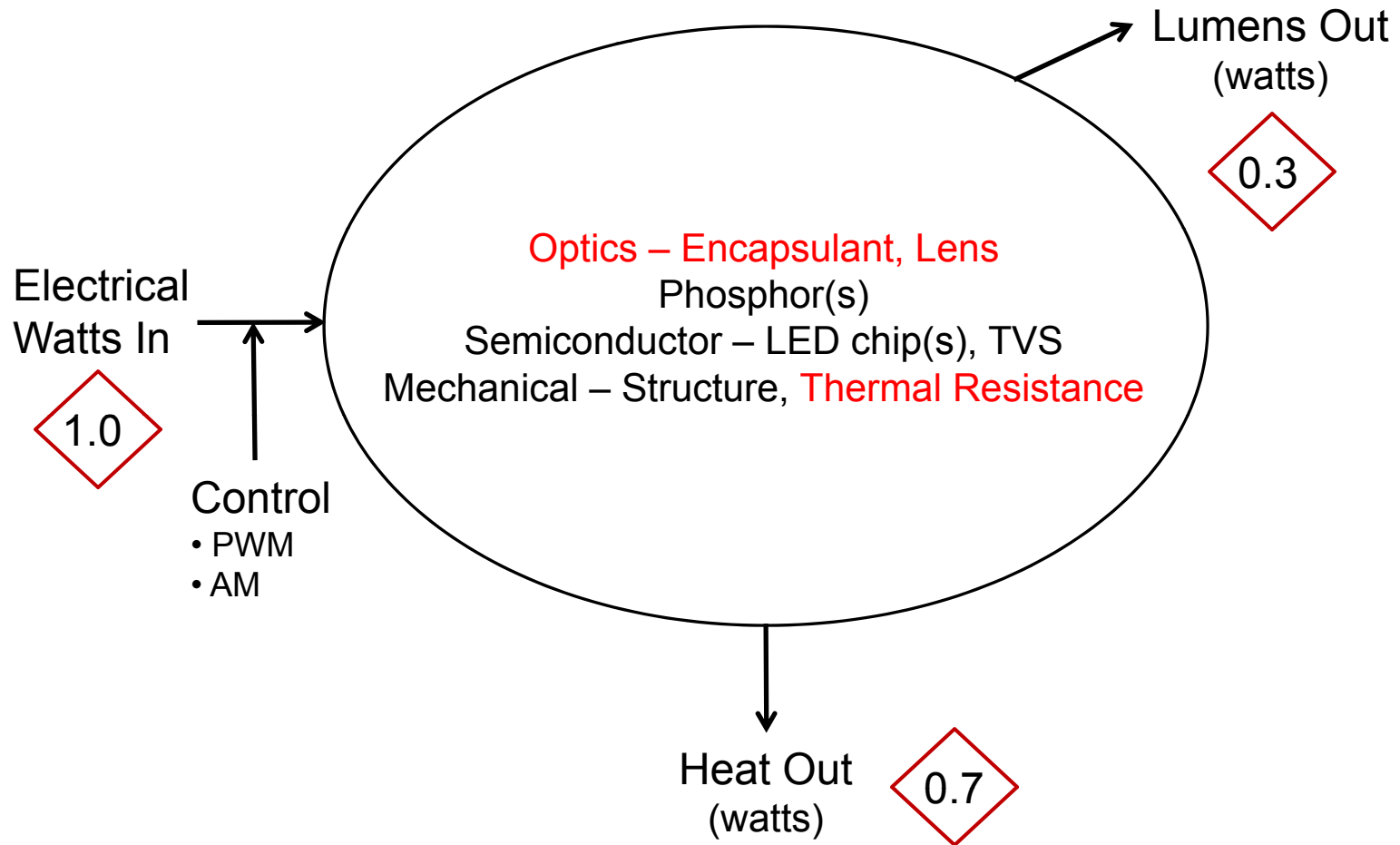


Life in a New Light™

Purpose of the package

- From the **luminaire perspective**
 - Least energy – electrical watts
 - Most light – lumens
 - Best light – desired CCT, high CRI, consistency
 - Least cost – initial price + operating costs
 - Long lifetime? – 3 years, twice as “good”
 - What is the B1, L90 spec?

LED Package



Package Traps Light

- Index of refraction mismatch traps light (TIR)
 - Simple chip in air, 15% gets out, **85% trapped**
 - Simple chip in 1.5 index silicone, 35% gets out
 - Exotic chip in silicone, 80% gets out
- Higher index encapsulant reduces TIR (more light)
 - TIR (Total internal reflection)
- Spherical “lens” reduces TIR
- **High index trade-off with exotic chip cost**

Package Traps Heat

- Thermal resistance stack-up
 - Junction to package
 - Package to PCB (MCPCB)
 - PCB to heat-sink
 - Heat-sink to ambient
- Array package bolts to heat-sink
- Chip on heat-sink

Phosphor

- Efficiency
- Thermal quenching
- Photo quenching
- Light quality
 - CCT
 - CRI (good R9, red is critical)
 - CQS (Color Quality Scale)
 - Consistency

Current - Voltage

- High voltage – low current
 - Use highest voltage code allows
 - Battery voltages steps (ex. 24, 48, 60, 120)
- High current – low voltage
 - Hurts efficiency down stream (I^2R , voltage conversion)

Big Chip – small chips

- Few big chips
 - Better for high light concentration (small étendue)
 - Extracting heat can be difficult (\$)
- Many smaller chips
 - Better when light is spread over large area
 - More packages can add cost (\$)
- Both can work well in many cases

Conclusions

- Does the package limit efficacy?
 - Today, yes. Fundamentally, only near the limit.
 - **Refractive index, thermal resistance**
- What about the chip, driver, optics, and thermal resistance?
 - Today, yes. Fundamentally, only near the limit.
- Work on the issues from the **luminaire perspective**
- Lighting controls can have large positive effect
 - Subject for another day

Steve Paolini

spaolini@lunera.com

<http://www.lunera.com/>



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