Setting New Benchmarks for LED Efficacy and Brightness

DOE Solid State Lighting Workshop
Atlanta, January 29-31, 2008

CREE
LED Light

DOE Solid State Lighting Projects

Project Name	Small Area Array-Based LED Luminaire	LED Chips and Packaging for 120 LPW SSL Component
Objectives	• Demonstrate a high efficiency array-based LED luminaire testbed • 1000 lumens total light output • Manage thermal issues using passive cooling	• Develop a novel 120 LPW SSL lamp component that emits at a color temperature of 4,100 K • Low cost module suitable for commercial SSL luminaires
Duration	1/05 - 1/08	10/07 – 10/09
P. I.	Thomas Yuan	James Ibbetson

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Projects Team

Team Member	Location	Projects Staffing	Project Roles
Cree Santa Barbara Technology Center	**Goleta, CA**	**Scientists, engineers and technicians (full time staff) at Cree SBTC** **Specific individuals working on project as needed**	**Chip fabrication & Design** **Package design & fabrication** **Thermal, mechanical and optical array design** **Prototype builds and testing**

- **Additional support from Cree, Inc. in Durham, NC**
  - **Cree Lighting (high volume LED lamp builds, LED product applications)**
  - **Cree Opto (GaN/SiC materials, specialty fabrication & characterization tools)**

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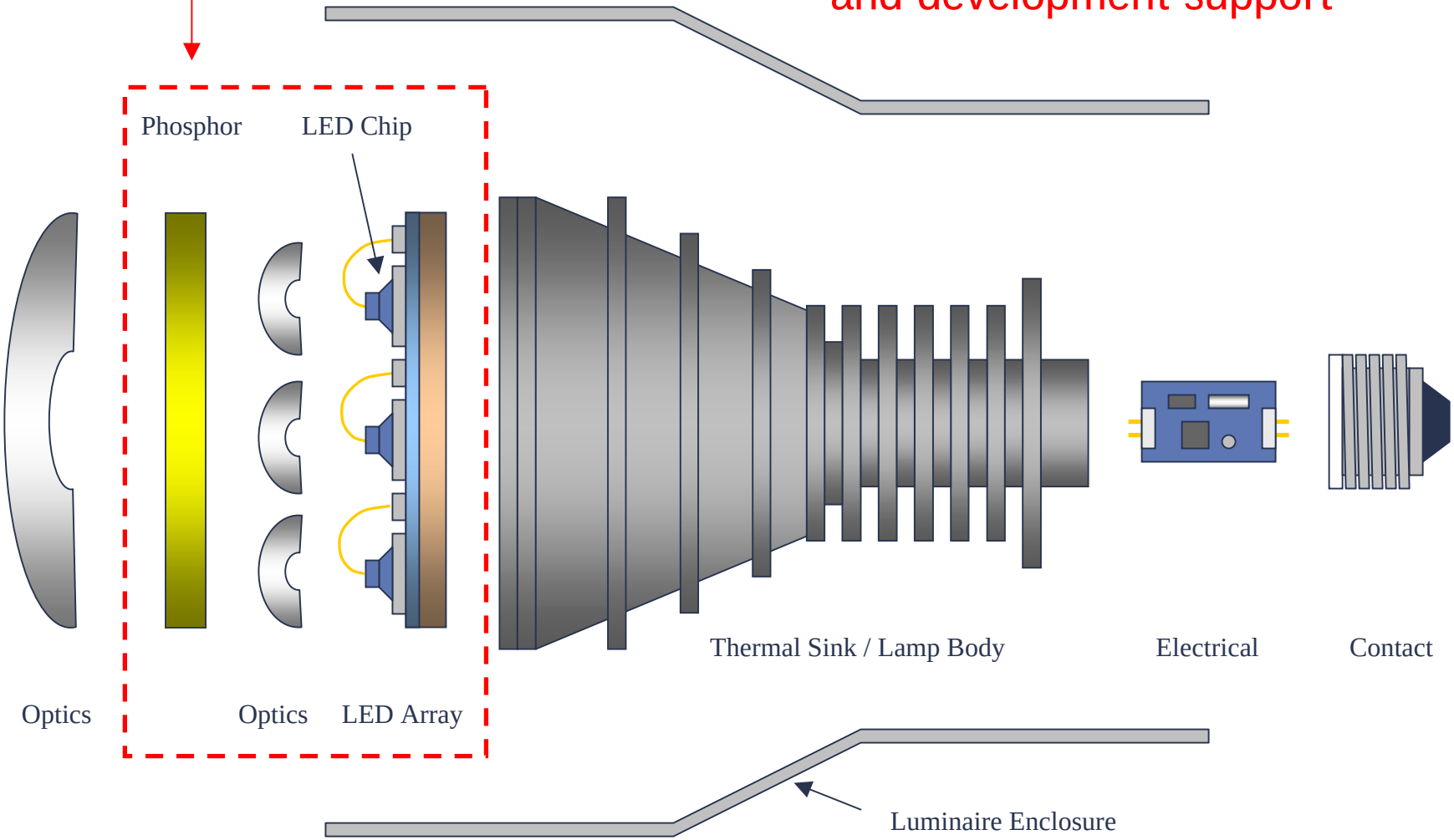
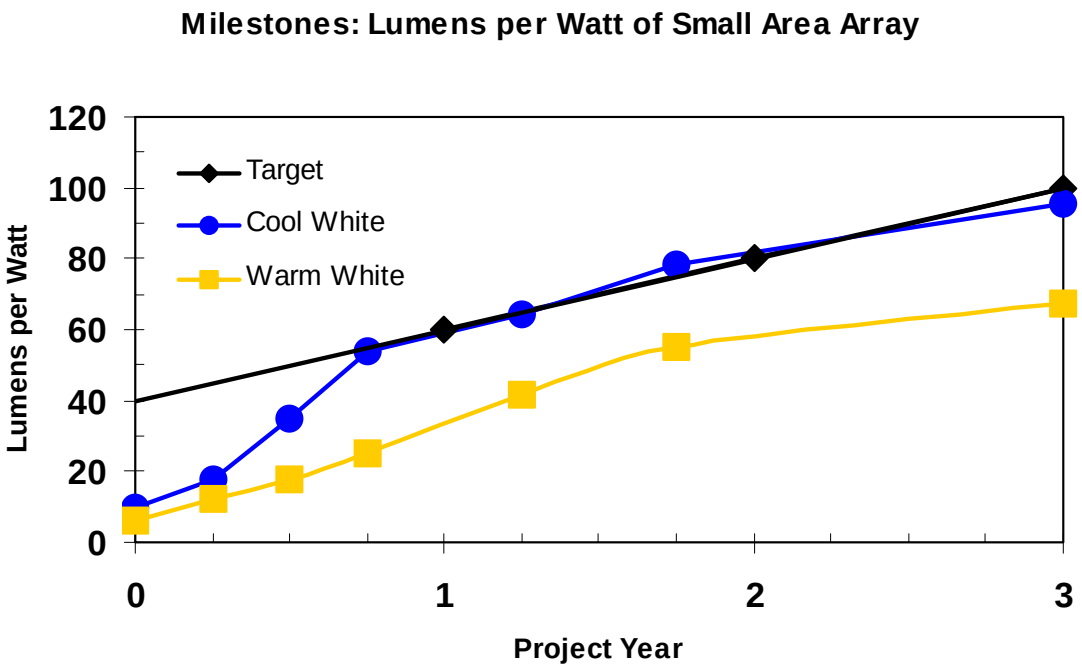
Luminaire Project Elements

Cree's business is the "filament"

Luminaire testbed for applications and development support



Luminaire Project – LED Array Performance



Year 3	Current	Voltage	Chromaticity		Lumens	CCT	Efficacy	Color rendering
	(mA)	(V)	x	y	(Lum)	(K)	(Lum/W)	(CRI)
Cool White Array	350	24	0.325	0.354	800	5850	95.3	79.3
Warm White Array	350	22	0.449	0.406	529	2825	67.3	80.5

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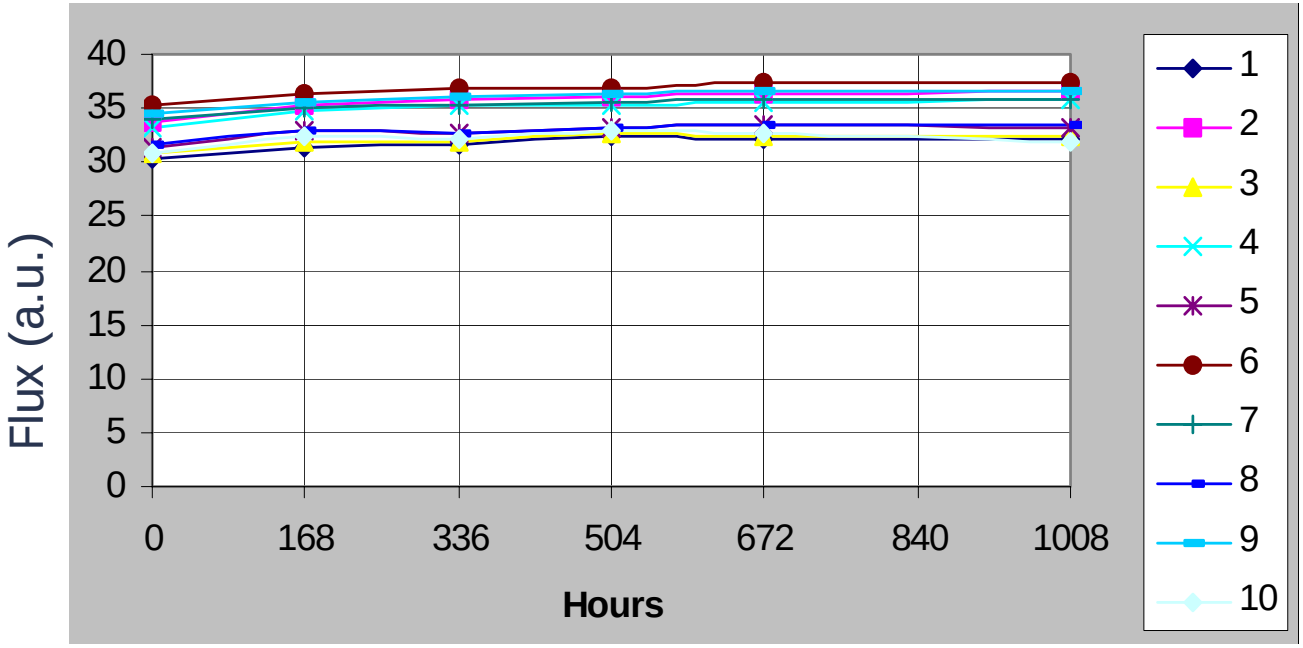
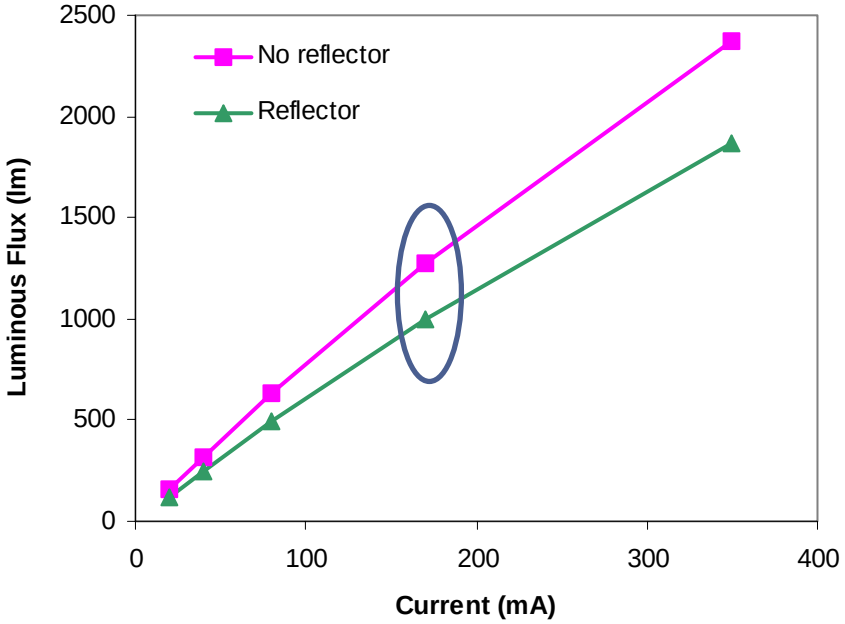
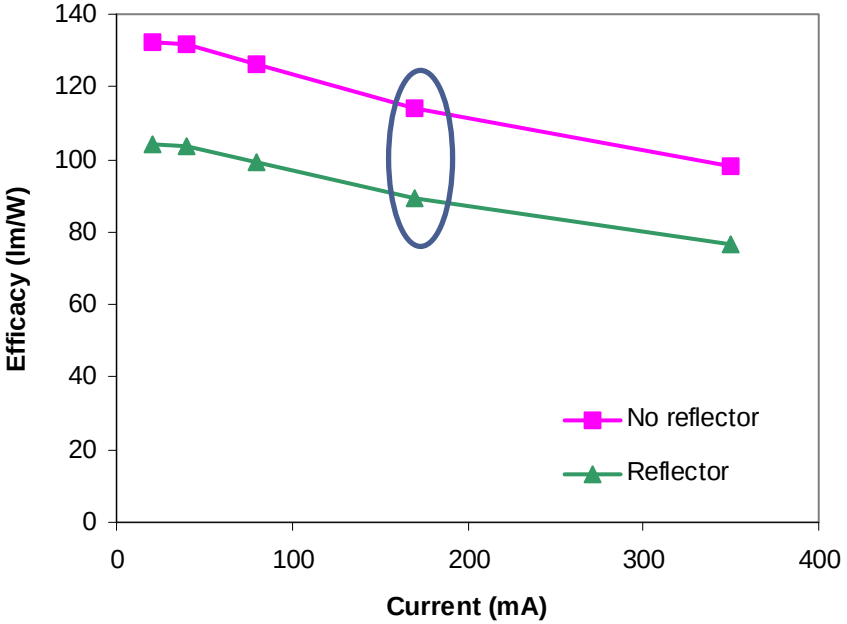
Luminaire Project – LED Array Flux Maintenance

- Using new die attach processes and alternative materials in array elements, luminous flux was maintained through 1000 hours of testing under stressed operating conditions (85°C/85% RH ambient)



Cool White Luminaire Testbed (6,000 K CCT)





- **Luminaire testbed with reflector outputs 1000 lumens with an efficacy of 89 lm/W**
- **Without the reflector the flux is 27% higher: 1275 lumens with an efficacy of 114 lm/W**

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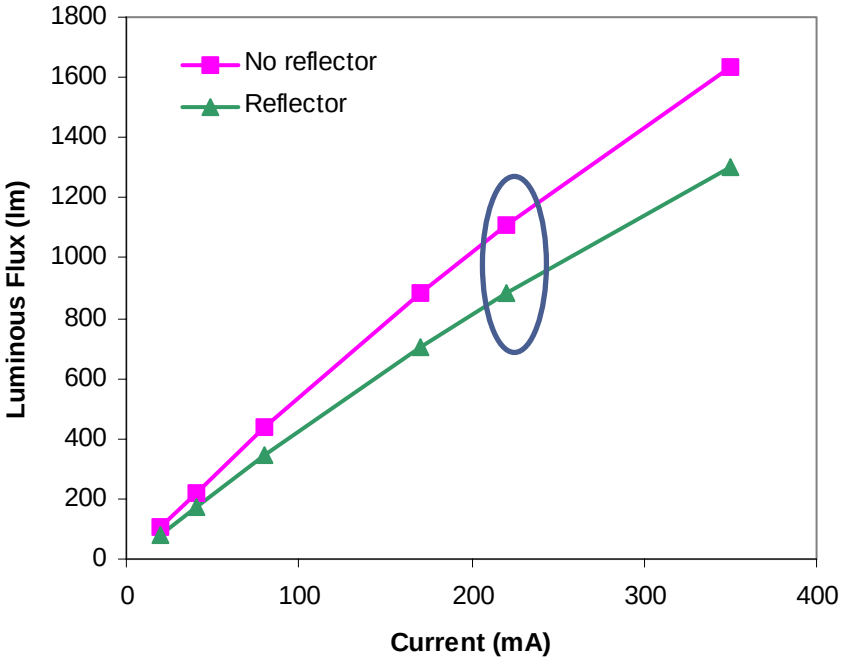
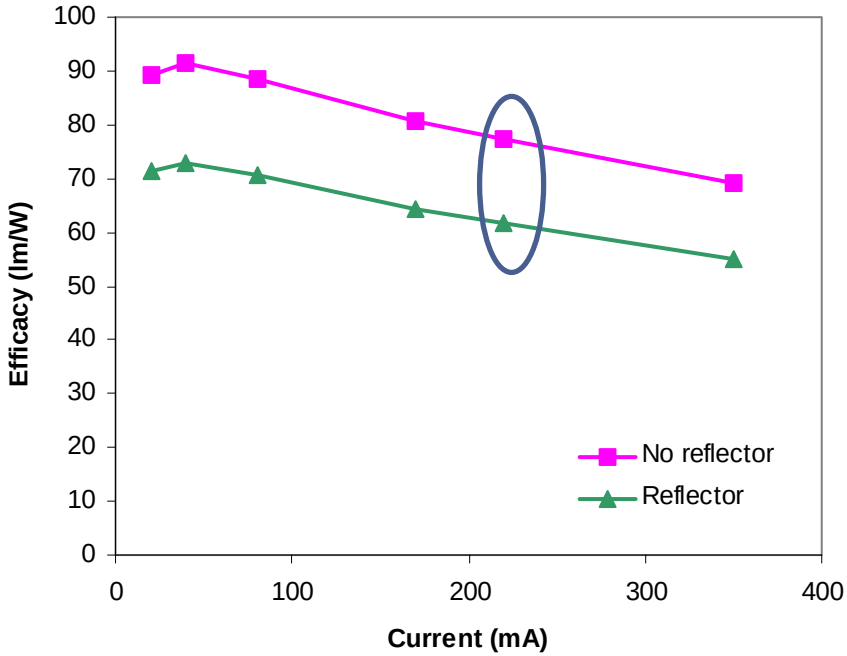
Warm White Luminaire Testbed (2,800 K CCT)





- **Luminaire testbed with reflector provides 925 lumens with an efficacy of 61 lm/W**
- **Without the reflector the flux is 25% higher: 1160 lumens with an efficacy of 76.5 lm/W**

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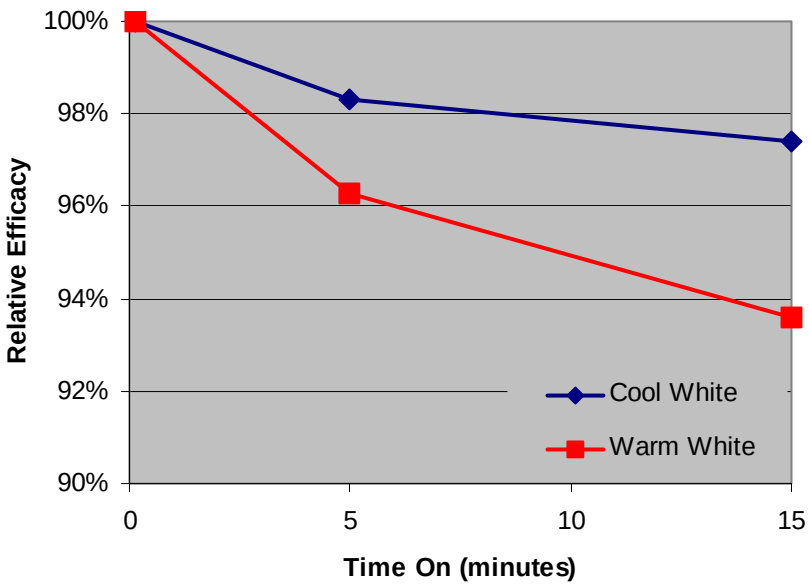
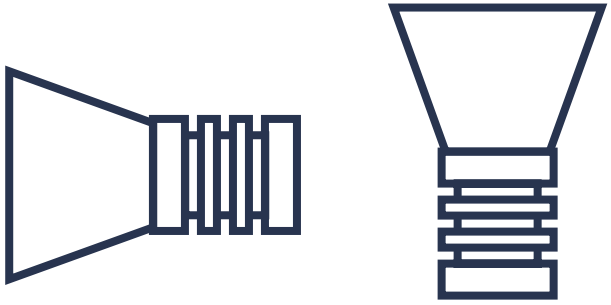
Luminaire Thermal Effects



Luminaire	Cool White	Warm White
Input Power	11.0 W	14.8 W
% Flux after 15 min.	96.4	92.6
% Efficacy after 15 min.	97.4	93.6
Heat Sink T. (steady state)	53 °C	65 °C

- **Junction-to-ambient thermal resistance of 3.4 - 3.8 °C/W**
- **Heat sink-to-ambient resistance is ~3 °C/W (~10% geometry effect)**



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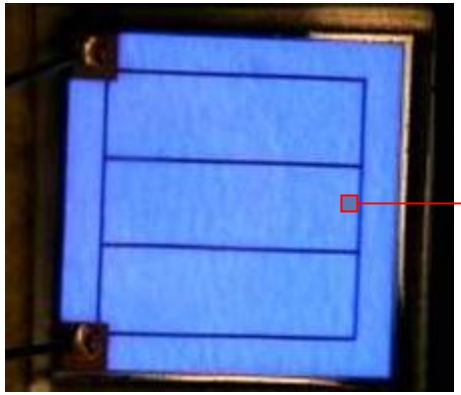
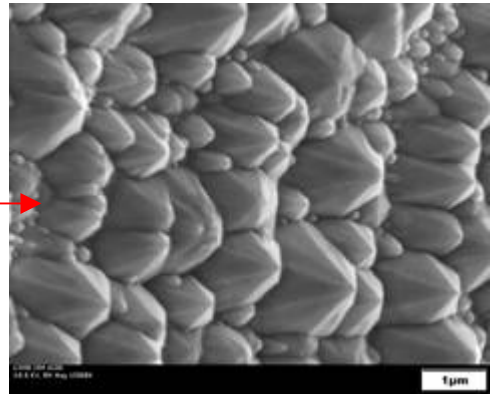
Component Project – Baseline Technology 10/07

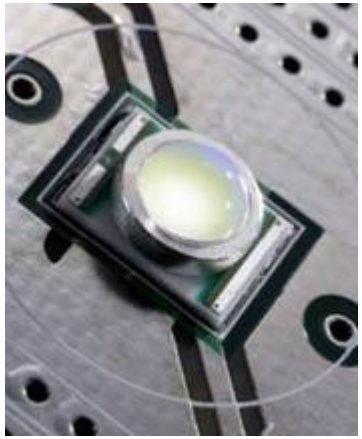
EZBright™ LED Chip





- Surface Features
  - Improve light extraction
  - Efficiency scales with chip size
  - Enable lambertian radiation
- Wafer level submount technology
  - Allows for silver epoxy or eutectic die attach
- Low Vf

XLamp® 7090 XR-E



**Cree's brightest product bin @ 350mA*

Product	CCT Range (K)	Min. Flux* (Lm)
Cool white	5,000 - 10,000	107
Neutral white	3,700 - 5,000	87.4
Warm white	2,600 – 3,700	73.9

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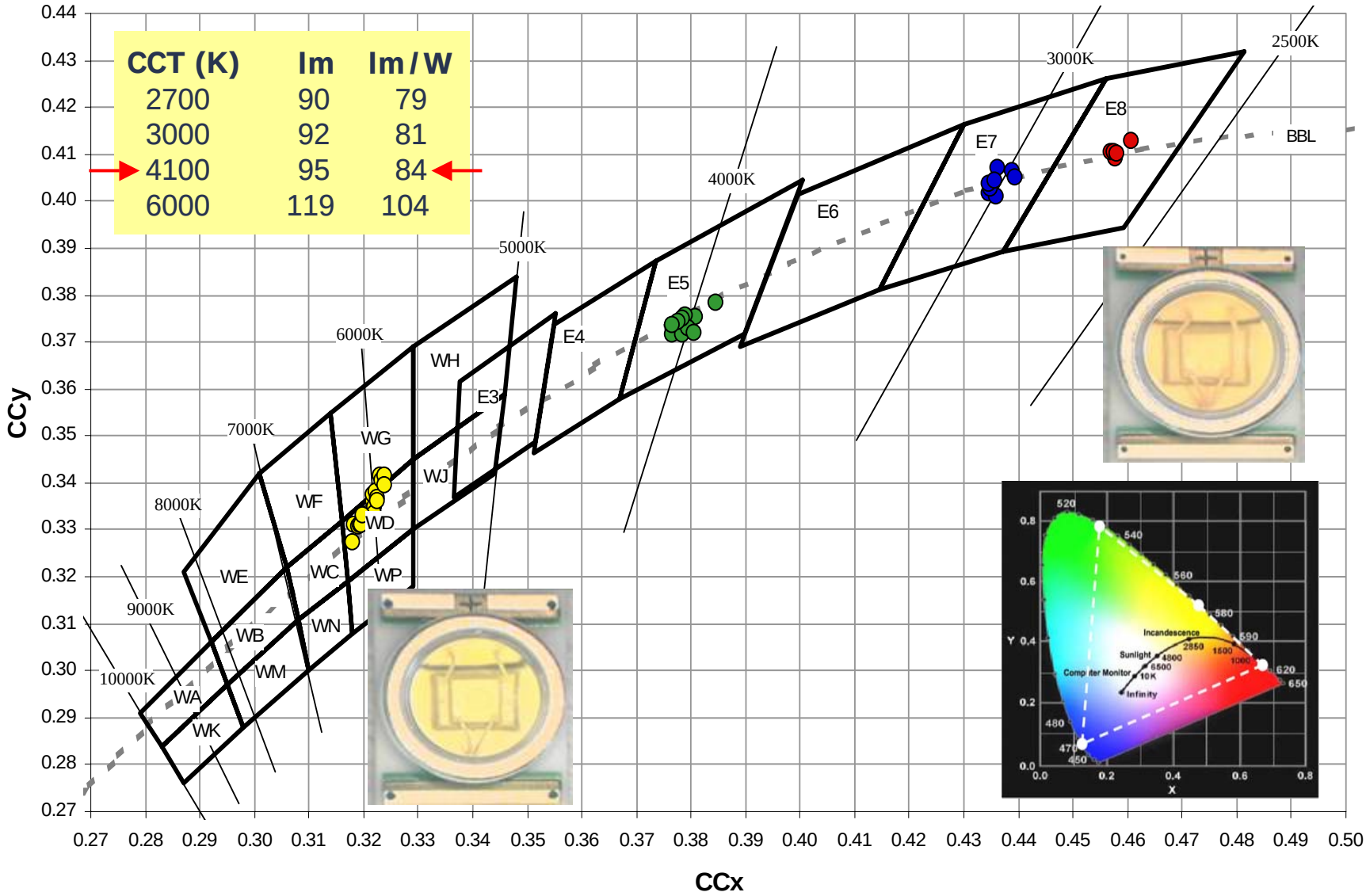
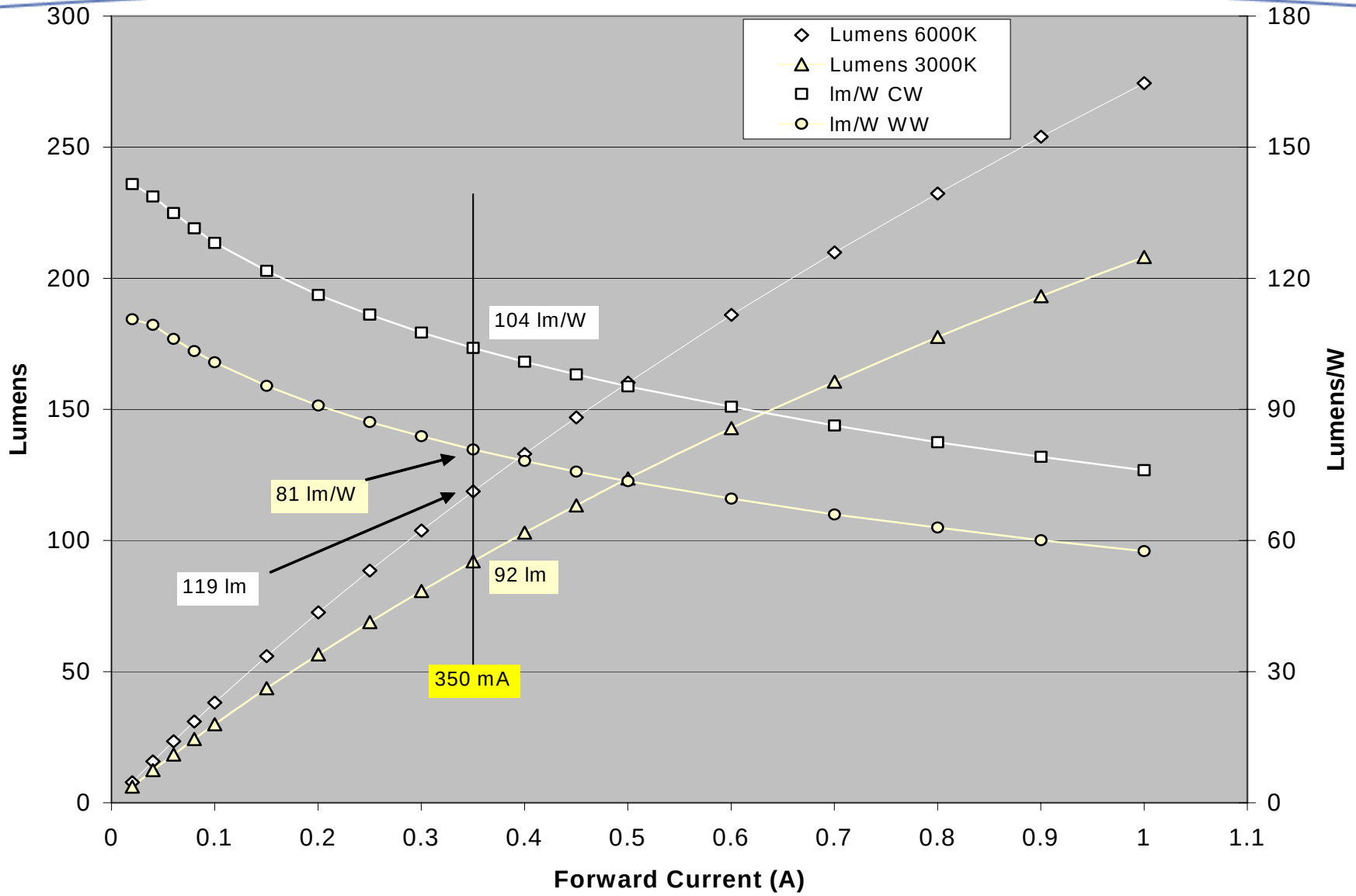
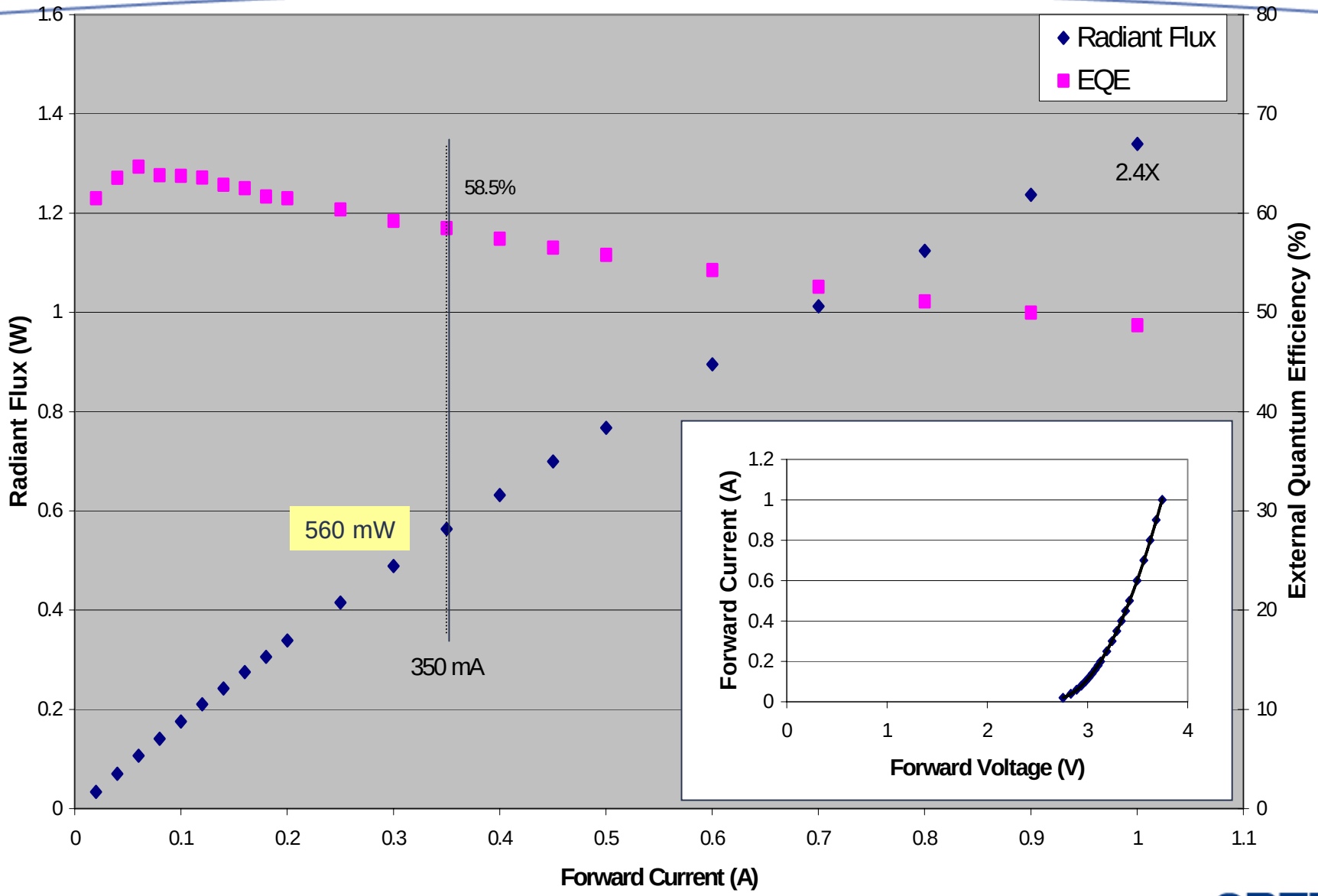
Gen 2 Performance Q4/07



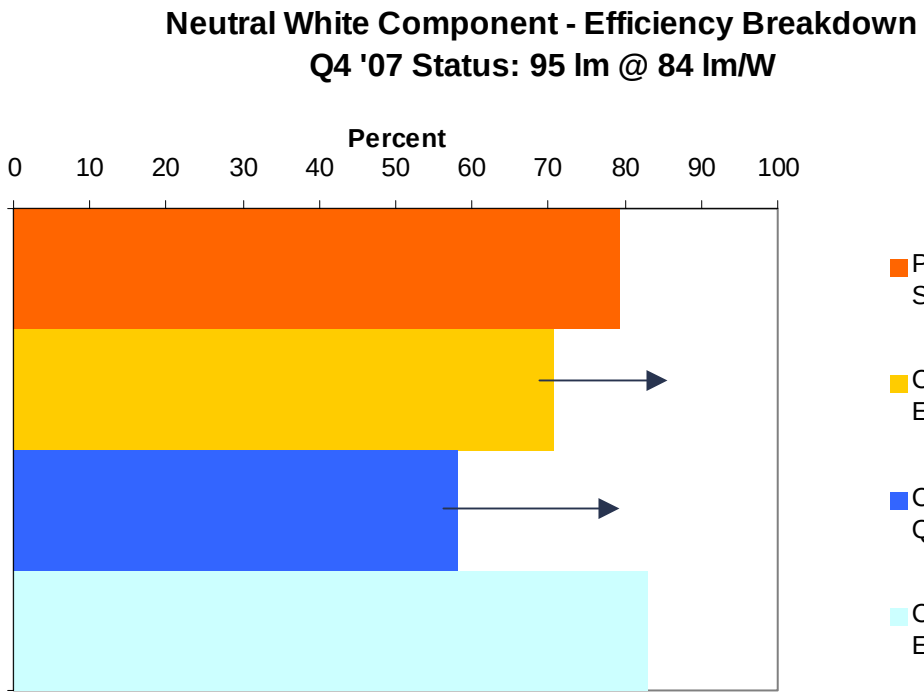
Gen 2 Best – Cool and Warm White



Gen 2 Best – Blue



Getting to 120 lm/W at 4,100 K CCT



Room Temp., 350 mA

Down-conversion efficiency is ~ 56 %

Chip 'wall plug' efficiency is ~ 48 % (460 nm, 3.25 V)

- **SSL Component project targets areas of current main losses:**
  - **Chip light extraction efficiency, IQE (peak, 'droop')**
  - **Down-conversion efficiency excluding Stokes loss**
- **Incremental gains anticipated in other areas**
- **Overall, targeting ~40 % gain in efficacy at 350 mA**

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Summary

- High efficacy luminaire testbeds demonstrated on DOE project
  - 1000 lumens at 89 lm/W cool white
  - 925 lumens at 61 lm/W warm white
  - 3% to 7% less in steady state operation (thermal)
  - 100% flux maintenance after 1000 h at 85°C/85% r.h.
- 'Lighting Class' white LEDs available now, based on XLamp® 7090 XR-E package and EZBright™ chip technology
- 120 lm/W ('neutral' white) at the component level is in sight

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