

2015 DOE SSL Technology Development Workshop

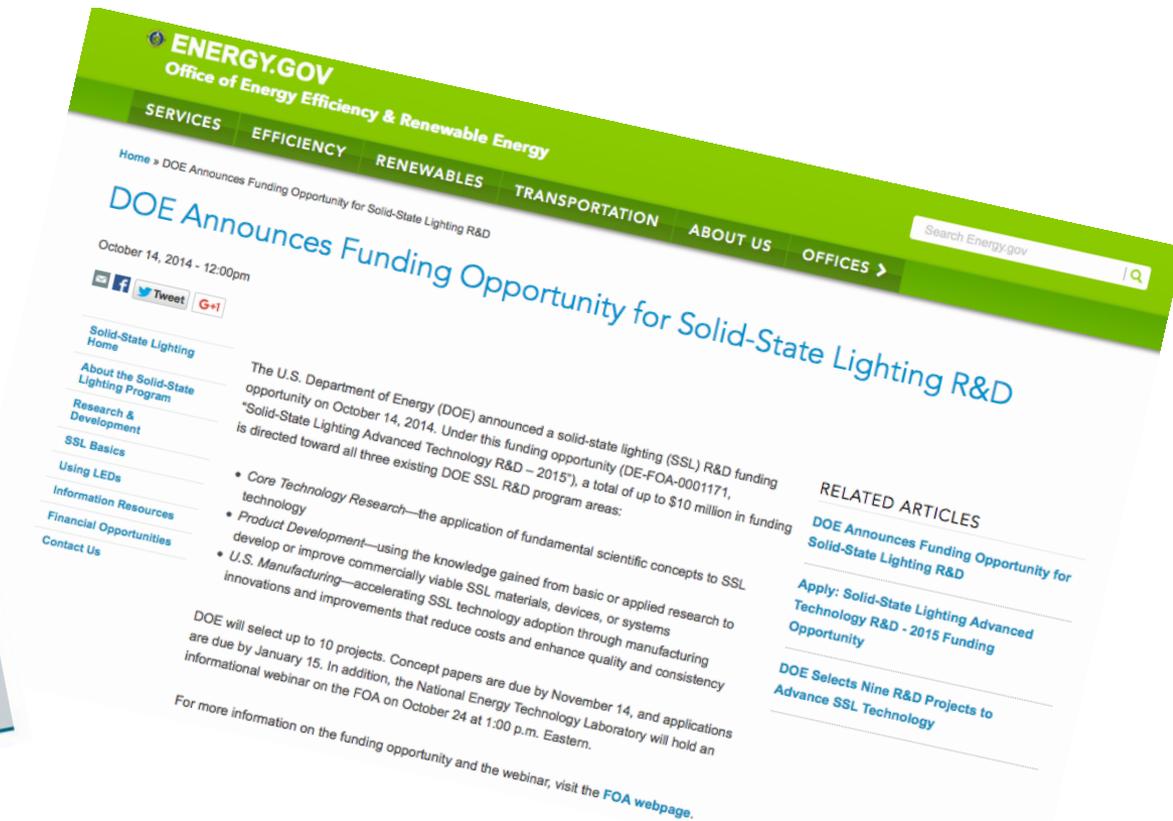
The Path to Higher Source, Package, and Product Efficacy

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Morgan Pattison, Ph.D., LC

SSLS, Inc.
Senior Technical Advisor
DOE SSL Program

R&D Plan and Funding Opportunity



<http://energy.gov/eere/ssl/downloads/solid-state-lighting-rd-plan>

<http://energy.gov/eere/ssl/articles/doe-announces-funding-opportunity-solid-state-lighting-rd-0>

Phosphor Converted LED Efficacy

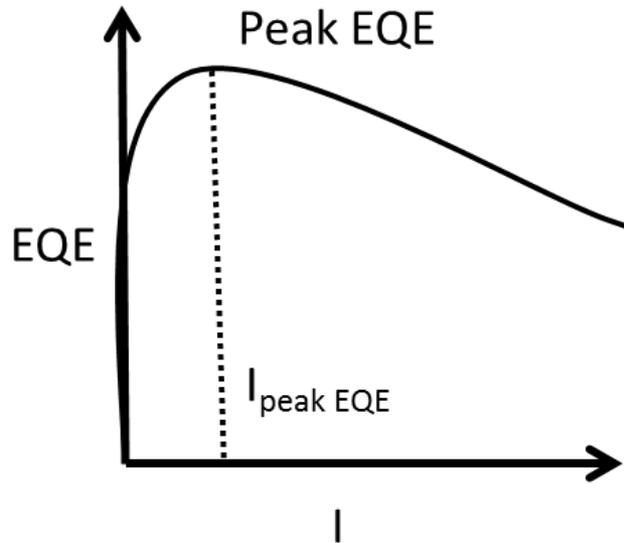
Metric		2015 Status	2020 Target
LER (lm/W)		331	387
Blue LED	Internal Quantum Efficiency	89%	95%
	Extraction Efficiency	85%	90%
	Electrical Efficiency	93%	95%
	Package Efficiency	85%	99%
	Power Conversion Efficiency	60%	80%
Green Phosphor	Quantum Efficiency	95%	99%
	Stokes Efficiency	84%	
	Conversion Efficiency	80%	83%
Red Phosphor	Quantum Efficiency	90%	95%
	Stokes Efficiency	74%	
	Conversion Efficiency	67%	71%
Overall Source Efficiency		43%	63%
PC-LED Efficacy (lm/W)		143	242

$$\eta_{LED} = (\eta_{IQE} \times \eta_{ext} \times \eta_{ele}) \times \eta_{package} \times A \eta_{phosphor}$$

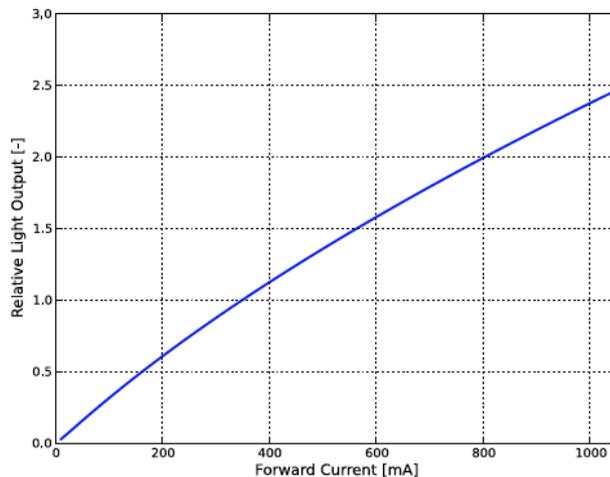
$$LPW = \eta_{LED} \times (LER)$$

<http://energy.gov/eere/ssl/downloads/solid-state-lighting-rd-plan>

Blue IQE- Droop

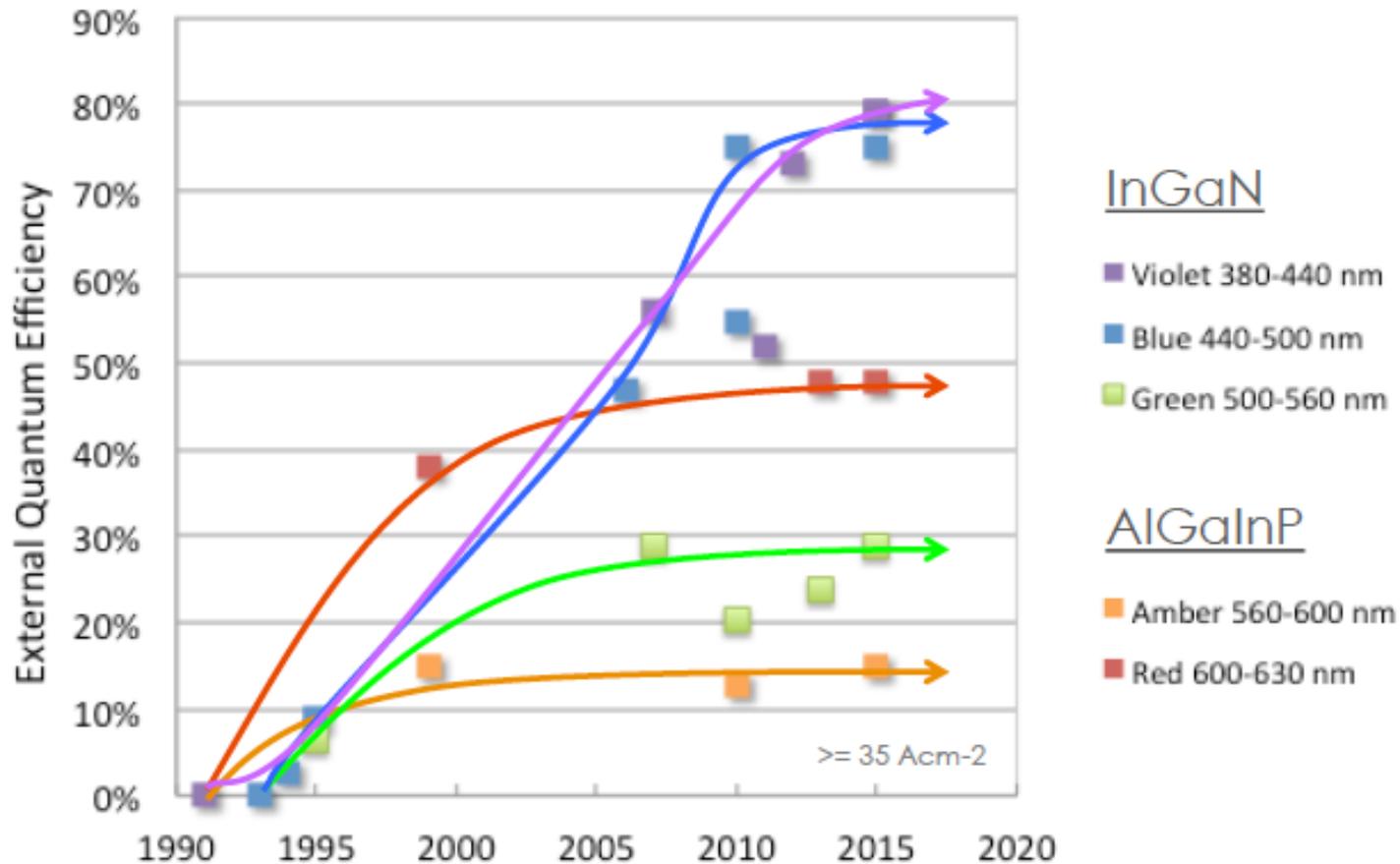


- Non-radiative Auger recombination process that limits efficiency at higher current density
- Droop limits how hard LEDs can be driven and Lm/\$



Luxeon Q Data Sheet

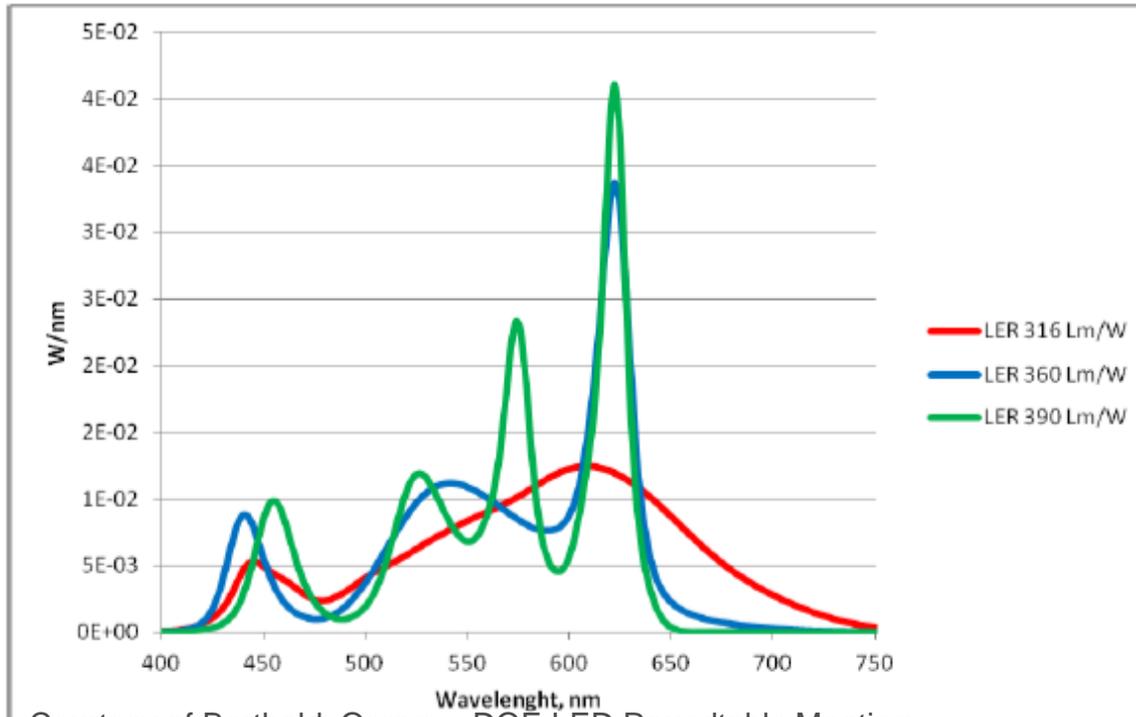
Green Gap



Courtesy of M. Krames, Arkesso

Spectral Efficiency and Spectral Tuning

Few examples of real LED spectra with higher LER (3000K, CRI ~ 80)



Courtesy of Berthold, Osram – DOE LED Roundtable Meeting

Current solutions
(2 phosphor system)
~ 310 – 330 Lm/W

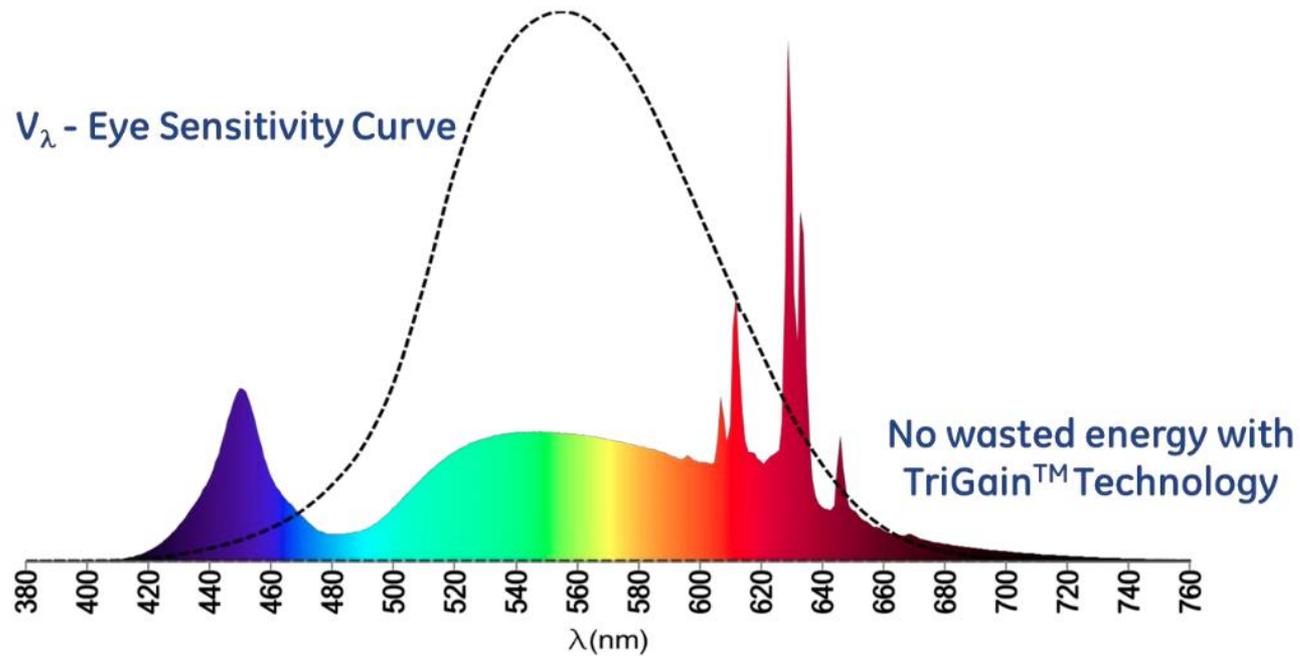
Combination of phosphor and InGaAlP chip
~ 350 – 370 Lm/W

Solution without phosphor
~ 380 – 390 Lm/W

$$LPW = \eta_{LED} \times (LER)$$

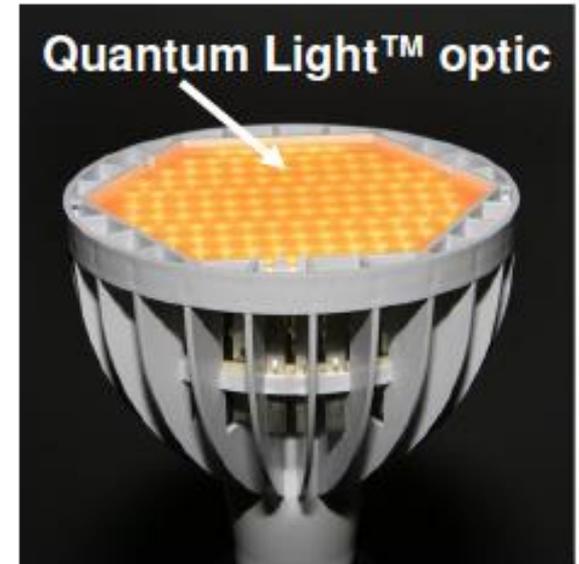
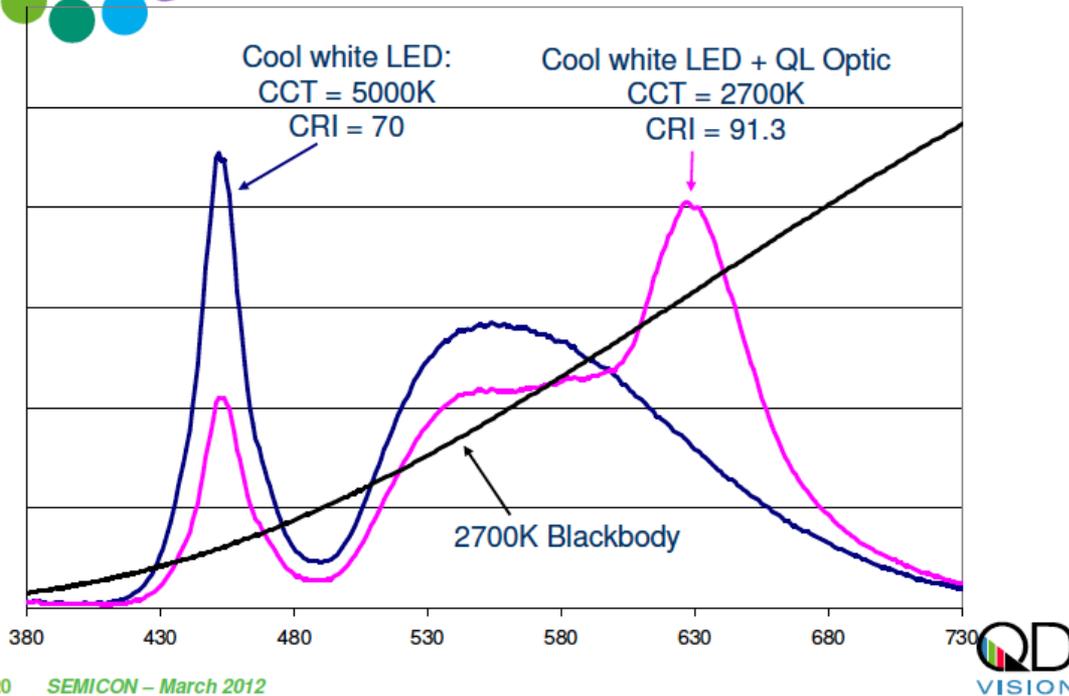
Narrow Red Phosphors

GE TriGain – PFS Phosphor



Quantum Dots

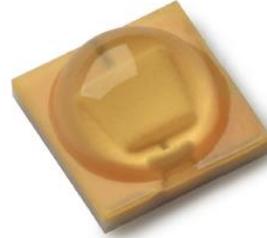
QDs Efficiently Convert the Blue Light to Red



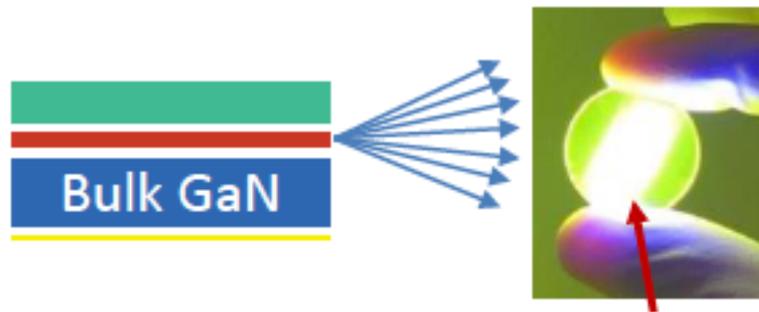
*Nexus R30 LED Array
2700K, 90+ CRI,
>60 LPW*

Additional Research Topics

- Encapsulation Materials
- Novel Emitter Architectures
 - Lasers
 - Tunnel junctions
 - Nano-rod LEDs
- Integration of LED package-power supply-optics
- Novel Luminaires



Laser



Coming Soon



RGB color mixed package efficacy

Metric		2015 Status	2020 Target
LER (lm/W)		397	
Blue LED	Power Conversion Efficiency ¹	60%	80%
Green LED	Power Conversion Efficiency	22%	35%
Red LED	Power Conversion Efficiency	44%	55%
Weighted Power Conversion Efficiency ²		34%	48%
CM-LED Efficacy (lm/W)		134	189

¹ See Table 5.3 for a detailed breakdown of efficiency channels.

² The weighted power conversion efficiency reflects the individual source power conversion efficiencies weighted by the proportion of each source in the final spectrum.