



## ***“Current Status and Future Potential of Solid State Lighting”***

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## **SSLDC Faculty at UCSB**



**Shuji Nakamura**  
-Inventor GaN blue LED & laser



**Umesh Mishra**  
- Device fab



**James Speck**  
-MBE/TEM



**Steven DenBaars**  
-Epitaxial growth



**Evelyn Hu**  
-Nanostructures  
-Photonic X'tal



**Chris Vandewalle**  
-Elec. Theory



**Pierre Petroff**  
-QDots



**Fred Lange**  
-ZnO



**Tony Cheetham**  
-Phosphors

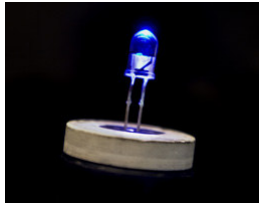


**Claude Weisbuch**  
-Photonic X'tal

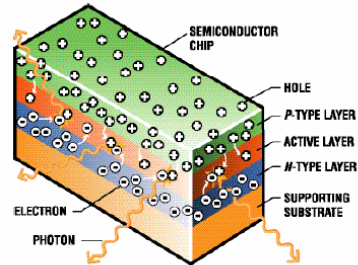
## What is an LED?



### L.E.D.= Light Emitting Diode



Blue LED



LED produces light by combining Positive and negative charges inside Gallium nitride crystal

## The Advantage of LED Lighting



**Long life** – lifetimes can exceed 100,000 hours as compared to 1,000 hrs for tungsten bulbs.

**Robustness** – no moving parts, no glass, no filaments.

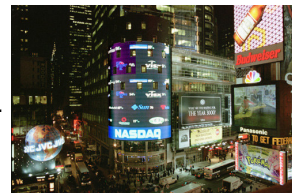
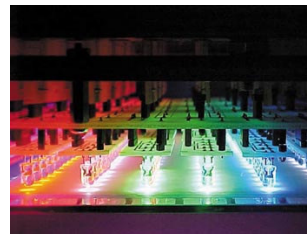
**Size** – typical package is only 5 mm in diameter.

**Energy efficiency** – 50- 90% less energy used translates into smaller power supply.

**Non-toxicity** – no mercury.

**Versatility** – available in a variety of colors; can be pulsed.

**Cool** – less heat radiation than HID or incandescent

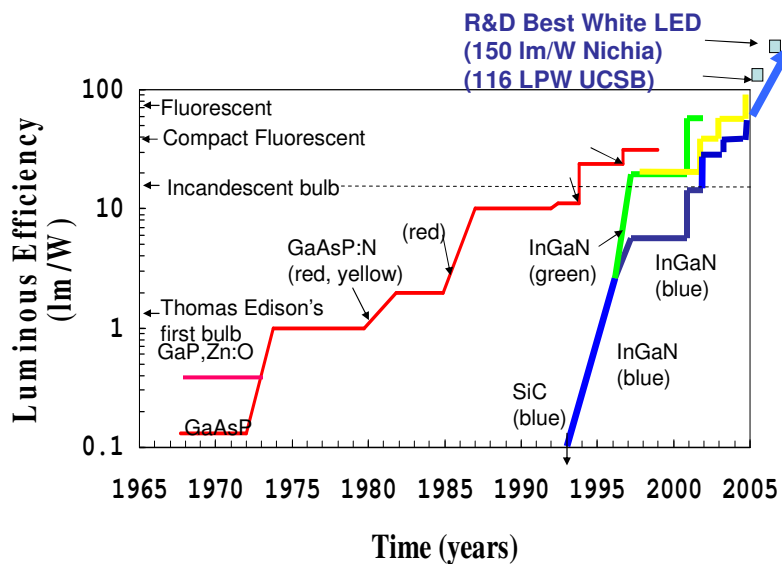


## R&D LED Efficacy Continues to Advance



- Dec 2005 Break-out session, Cree Inc. 70lm/W
- Sept 2006 Cree Inc announces 100lm/W
- December 2006, UCSB announces 116 lm/W
- January 2007, Nichia(Japan) announces 150 lm/W
- ->However, Mass Production Devices still Lag
  - Commercial White LED “Bulb” 50-80 LPW

## GaN LED Historical Development



## Current Status Solid-State Lighting Efficiency



	<u>GOAL(2015)</u>	<u>CURRENT*</u>
Electrical Efficiency	90%	80%
Internal Quantum Efficiency	90%	65%*
Extraction Efficiency	95%	60%*
White Conversion Efficiency	75%	55%
<b>TARGET</b> ( $K \cdot \eta_{total}$ )	200 lm/W**	117 lm/W

K = luminous efficacy of 6500K white 100% QE (335lm/watt)

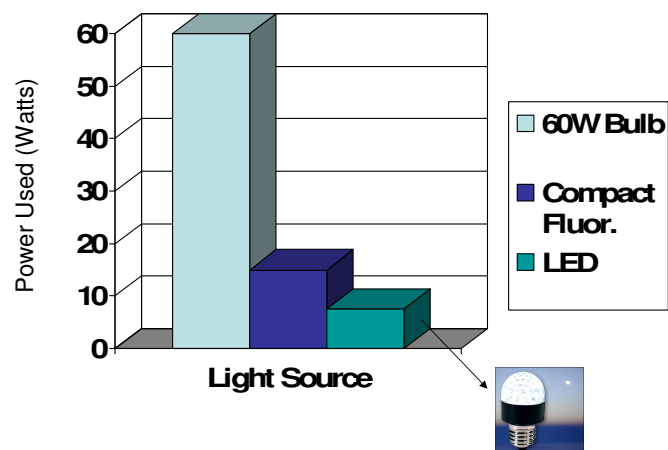
\* from EQE

\*\*theoretical estimate

## “The Promise” Energy Usage Comparison



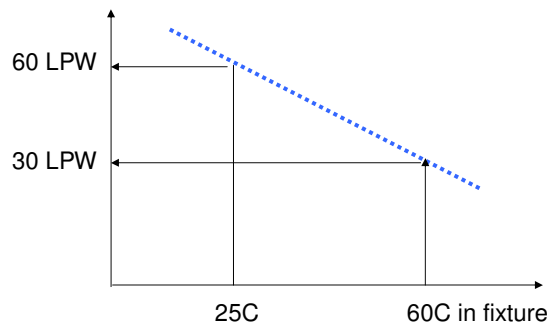
“Best” White LED and Compact Fluorescent vs. 60Watt Light Bulb Comparison



## The Reality



- Commercial White LED “Bulb” 50-80 LPW
- Fixture Efficiency all over the map 30-70%
- Luminaire System Efficacy 15- 40 LPW
- HEAT is the Biggest Problem



## LED “Lamp” Eff. vs. System Eff.



• Company	Lamp	Fixture Eff.	System Efficacy
– A	80 LPW	75%	56LPW
– B	45LPW	50%	22.5LPW
– C	50LPW	30%	15LPW
– CFL	60LPW	50%	30LPW
–	Better wait for Energy Star Ratings		



## DOE Energy Star Draft SSL



### Draft Solid State Lighting Requirements

(See [www.netl.doe.gov/ssl/](http://www.netl.doe.gov/ssl/))

- Downlight LED luminaire
  - Residential 29 LPW
  - Commercial 33 LPW
  - Minimum CRI 80
- Under cabinet task lighting
  - 29 LPW
  - Min CRI 80



## Current LED Market \$2B/yr



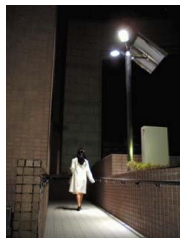
Cellphone  
(Nokia)



Traffic signals  
(Gelcore)



Large Displays  
(NASDAQ)



streetlights



TVs (LED DLP™)  
(samsung)

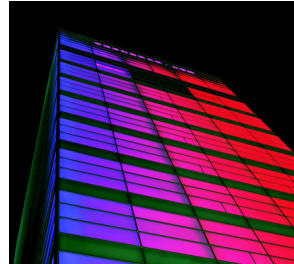


Automotive

## LEDs in Architectural Lighting



Installation Benjamin Franklin Bridge,  
PA, USA (Color Kinetics Inc.)



Lighting Systems by Color Kinetics Inc.  
Takarazuka University of Art and Design

## Car Headlights expected 2008 from Tokyo Motor Show



**Nissan**



**Honda**



**Daimler Chrysler**



**Toyota**

## Ultra-Mobile LED Enabled products



- Uses Blue, Green, Red LEDs



- CellPhone Camera Flash



(Osram Opto)

## LED Plant Growth



- **Blue and Green LEDs used to grow Wasabi at night,**
- **It is known that chlorophyll has the second distinct absorption peak in the vicinity of 450nm (blue light region) other than the first peak in the vicinity of 660nm (red light region) in its light absorption spectrum.**
- **The blue light is also indispensable to the morphologically healthy growth plant.**
- **On the other hand, the red light contributes to the plant photosynthesis.**



## Air/Water Purification



- Fruit and Vegetable Storage Life Extended 1 week
- Water Purification: UV LED to kill bacteria



(Credit: Hydro-Photon Inc.)

Mitsubishi Refrigerator MR-W55H,  
UV LED 375 nm, 590 nm

## Light Up The World Foundation



[www.lutw.org](http://www.lutw.org)



- Kerosene lighting and firewood are used by 1/3 of the world; they cause countless fires and are very inefficient (0.03 lm/watt).

- The average villager spends 10-25% of their annual income on kerosene.

- LED Lighting costs much less on an annual basis and payback period is just 6 months.

- LED Lighting /Solar Cell Off-Grid

[www.lutw.org](http://www.lutw.org)

***“In the few months we have had the White LED lamps the improvement in the children’s academic performance has been absolutely remarkable”***

**Headmaster, Mubarak Village, Pakistan June 2004**

## Global Warming/Energy Savings Potential of LEDs



Photo Courtesy of NASA, Supplied by Jeff Tsao of Sandia National Laboratories

If a 150 lm/Watt Solid State White LED “system” was developed, and employed, then in the United States alone:

- We would realize \$115 Billion cum. Savings in 2025\*
- Alleviate the need of 133 new power stations!\*
- Eliminate 258 million metric tons of Carbon\*
- Save 273TWh/year in energy\*\*

\* “The Promise of Solid State Lighting” OIDA Report , 2001, [http://www.netl.doe.gov/ssl/PDFs/oida\\_led-oled\\_rpt.pdf](http://www.netl.doe.gov/ssl/PDFs/oida_led-oled_rpt.pdf)

\*\*A. D. Little, “Energy Savings Potential of SSL” Report for Dept. of Energy, [http://www.eere.energy.gov/buildings/info/documents/pdfs/ssl\\_final\\_report3.pdf](http://www.eere.energy.gov/buildings/info/documents/pdfs/ssl_final_report3.pdf)

## CONCLUSION



- R&D Level LED Single lamp efficacy (150lm/W) now exceeds CFL, but:
- Commercial based LED Lamp Fixtures are much lower
- 15-56 LPW due to several factors that need further research and development in
  - Fixture Efficiency
  - Heat Sinking
  - Larger chip sizes
  - Scale up to Mass production
- Stay Tuned