

APS Energy Conf, Berkeley UCSB 2008

***Energy Efficient White LEDs
For Sustainable Solid-State Lighting***

Steve DenBaars

**Solid State Lighting and Display Center
Materials and ECE Departments
University of California, Santa Barbara**



Solid-State Lighting and Display Center

- One of the largest University Cleanrooms (13,000 ft²)

»



7 equipment bays

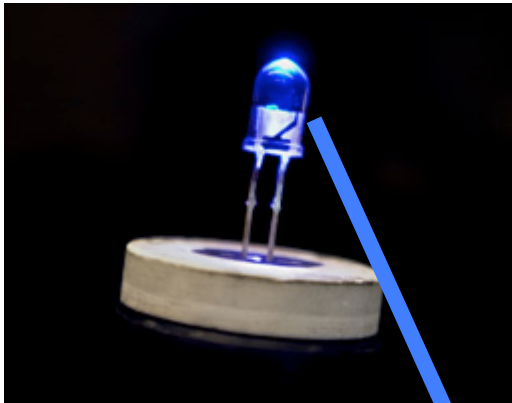
- World Class MOCVD/MBE Facilities
 - 6 MOCVD Systems, 7 MBE (3 Nitride)



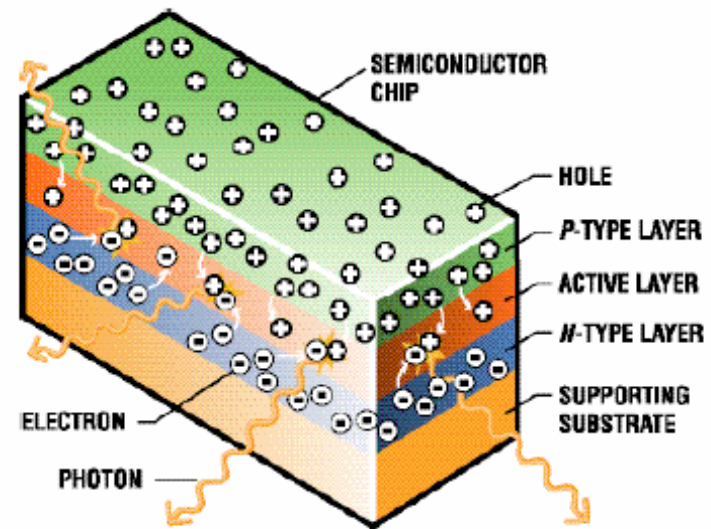
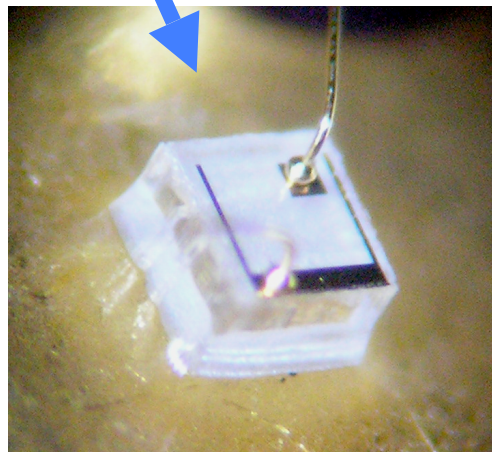
- Optical Test Facilities (LED and Laser)
- Materials Characterization (TEM, SEM, FIB, XPS, AFM, SIMS)
- Package and Lamp (LED and Laser) Assembly and Test

What is an LED?

L.E.D.= Light Emitting Diode (Runs on 3.2V DC Power)



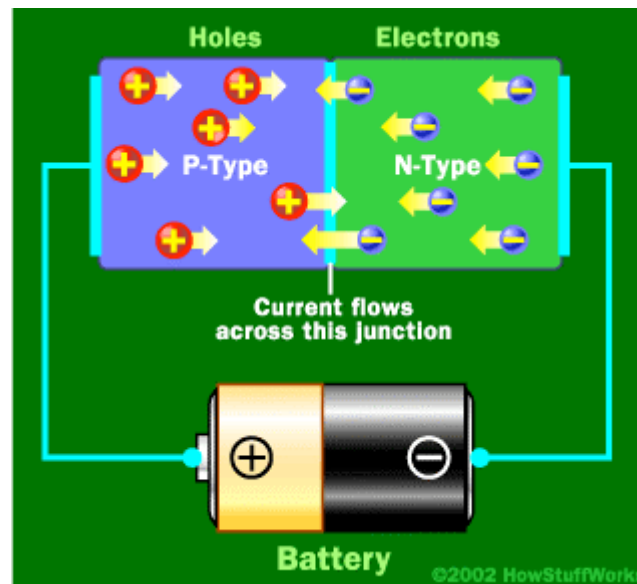
Blue LED



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

- Forward Bias p-n junction:
- Light is created by flowing current from battery

LEDs



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.

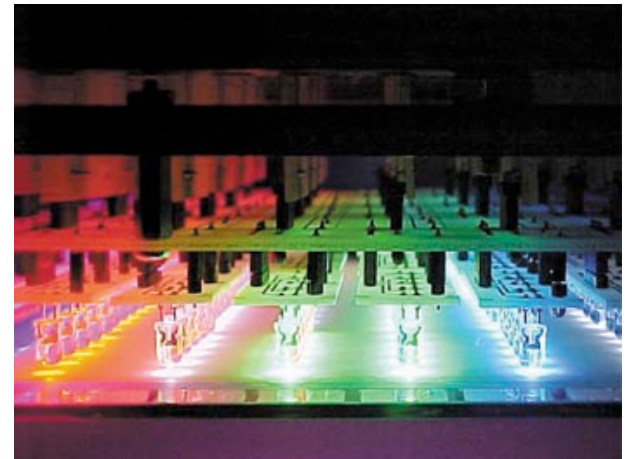
Size – typical package is only 5 mm in diameter.

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

Non-toxicity – no mercury.

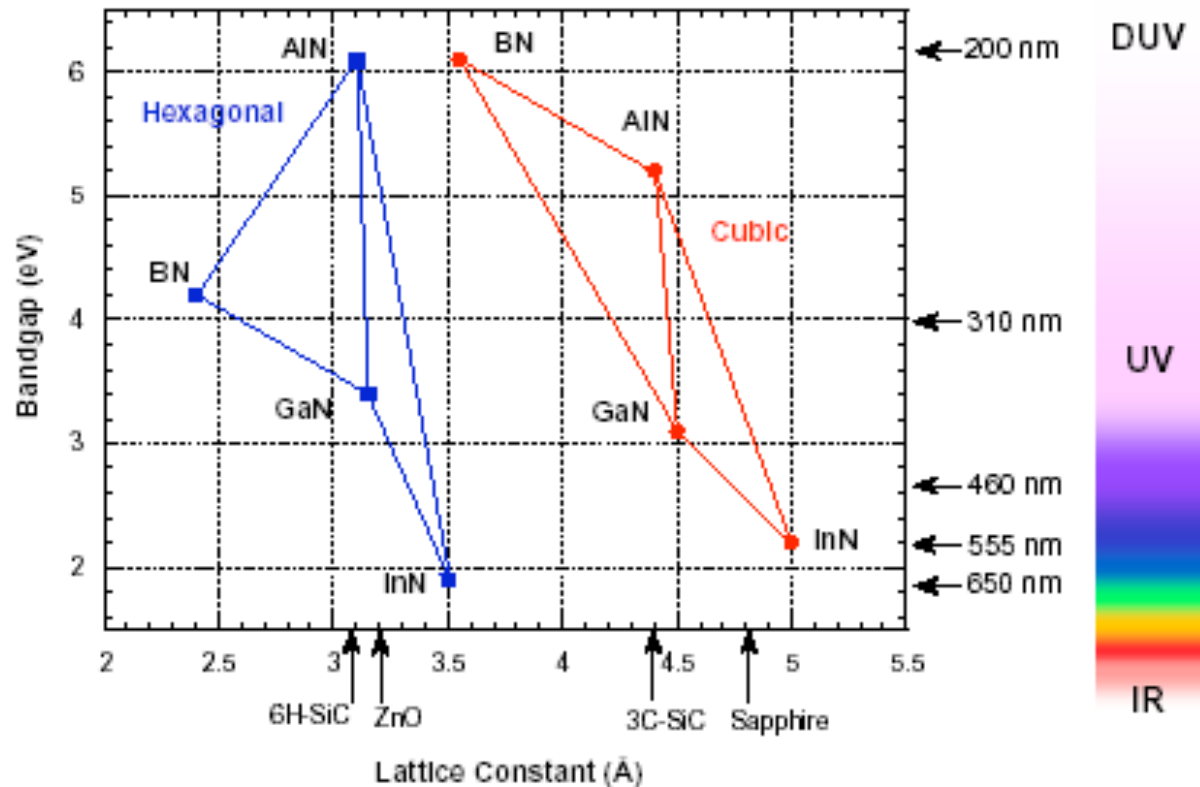
Versatility – available in a variety of colors; can be pulsed.

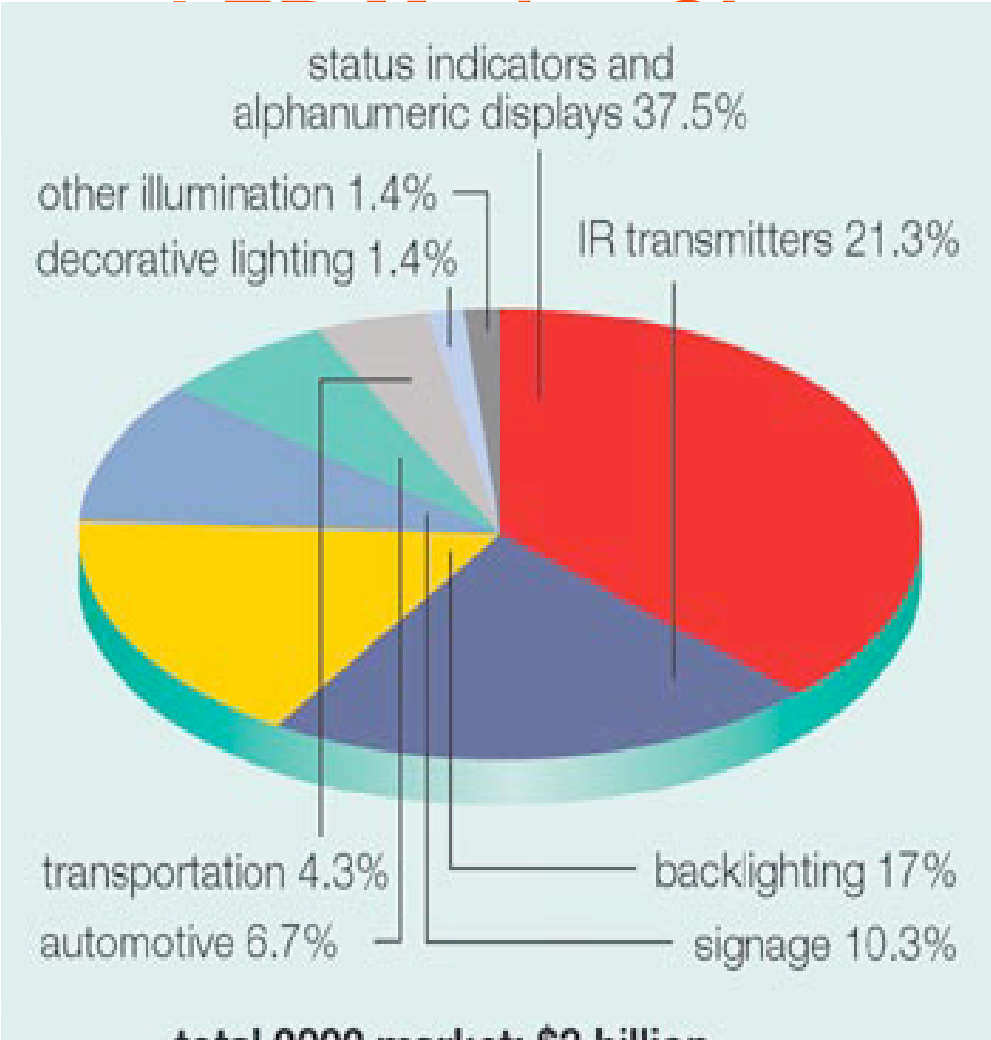
Cool – less heat radiation than HID or incandescent



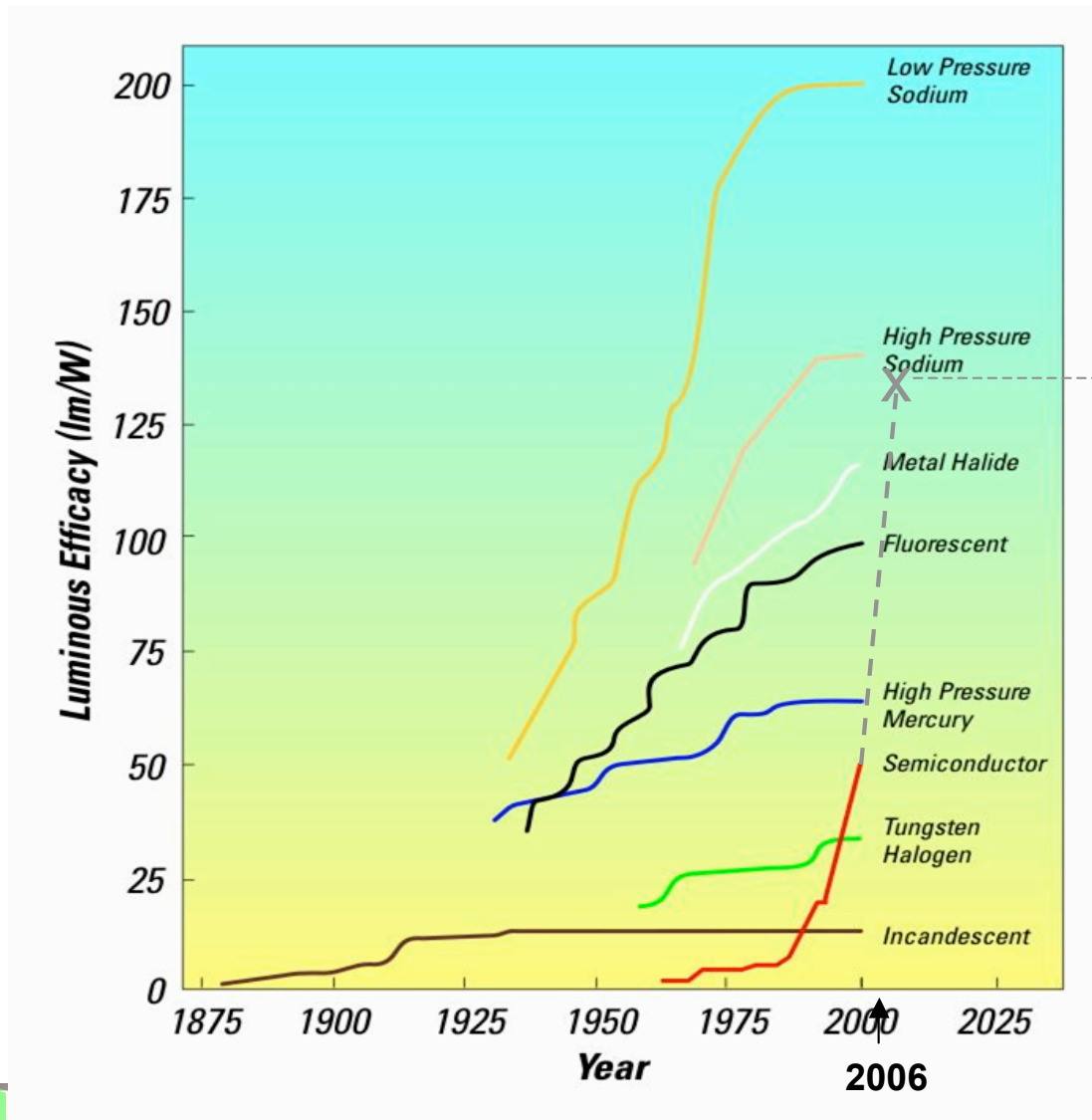
GaN Emits All Colors of Light

(Blue, Green, UV->White)

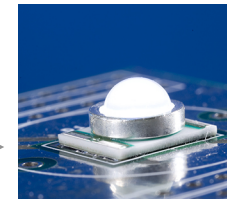




Luminous Efficacy of Various Light Sources









LED

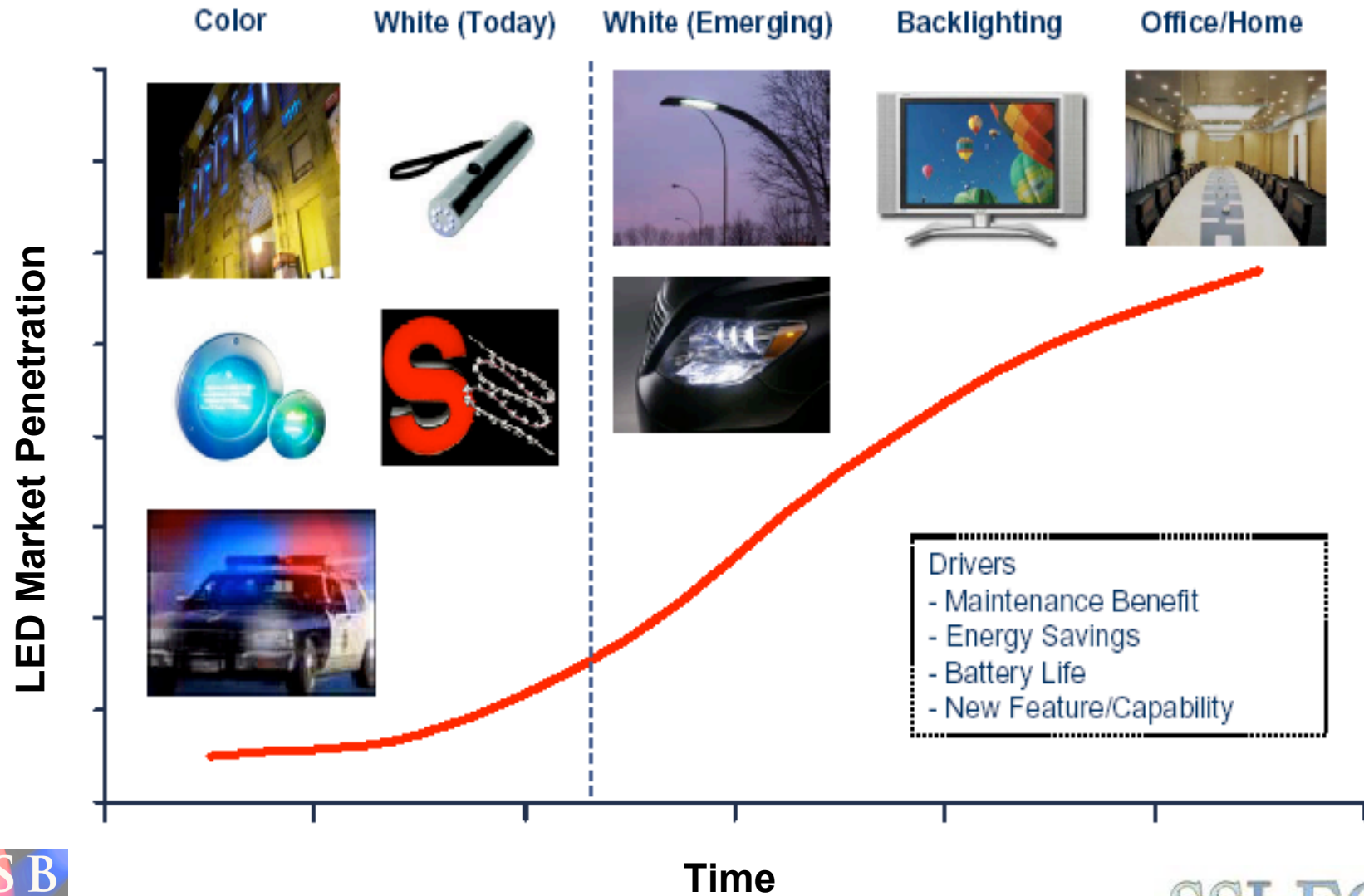


Current number for GaN white LED at UCSB is 116lm/W ucsb chip
143 lm/W partner chip

Lighting System Efficacy

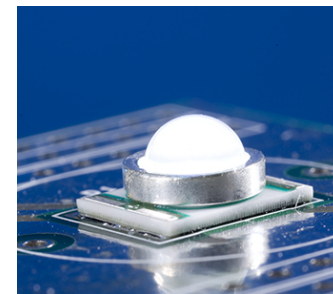
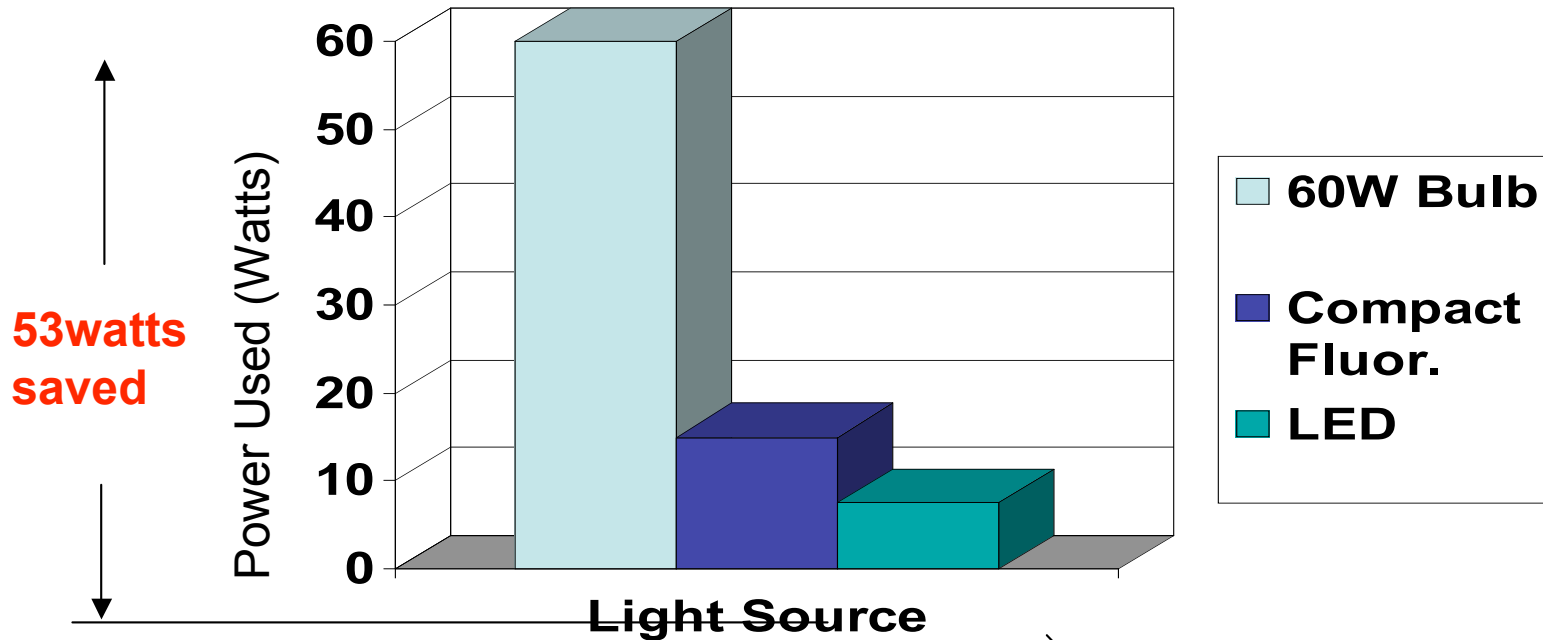
Luminaire Type		Lumens Per Watt	Fixture Efficiency	Usable Lumens Per Watt
Halogen Incandescent		17	45%	8
Compact Fluorescent		45	33%	15
150 W Cobra Head Type II Streetlight (HPS)		91	50%	46
400W HID w/Glass Housing (MH)		70	54%	38
XLamp LED Lighting Fixture		71	90%	64
T8 Fluorescent Tube		80	77%	62

LED Market Penetration



“The Promise” Energy Usage Comparison

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



Global Warming/Energy Savings Potential of LEDs



->Lighting Consumes 22% of all Electricity Produced

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

- Alleviate the need of 133 new power stations!*
- Eliminate 258 million metric tons of Carbon*



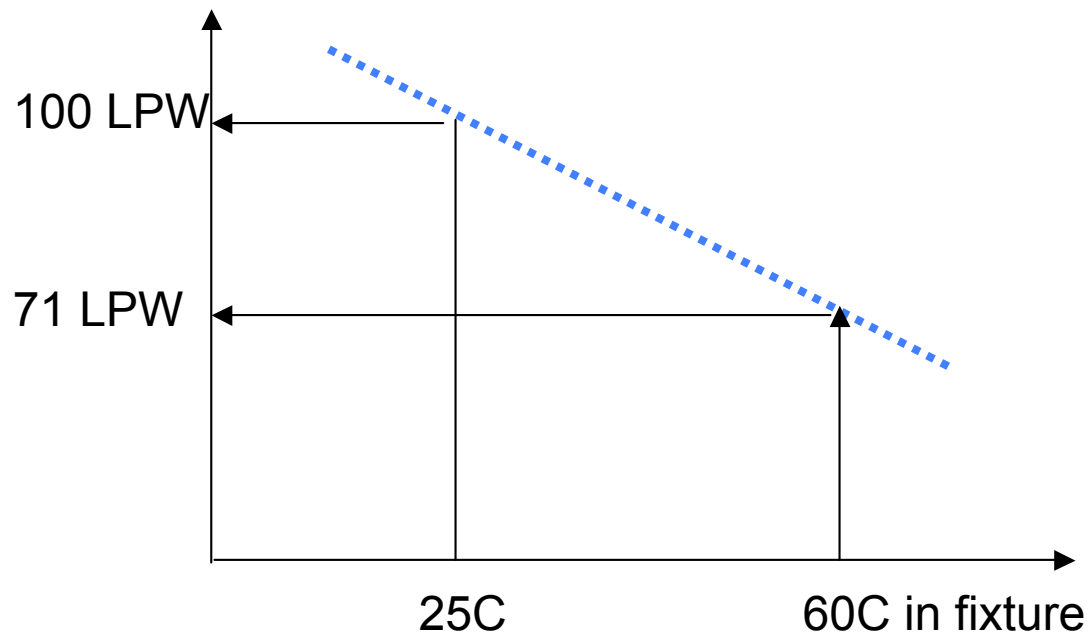
* “The Promise of Solid State Lighting” OIDA Report , 2001, http://www.netl.doe.gov/ssl/PDFs/oida_led-oled_rpt.pdf

**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



The Reality

- Commercial White LED “Bulb” 15-100 LPW
- Fixture Efficiency all over the map 10-80%
- Luminaire System Efficacy 15- 80 LPW
- HEAT is the Biggest Problem



LED “Lamp” Eff. vs. System Eff.

Company	LED	Fixture Eff.	System Efficacy
–	LED A 80 LPW	80%	64LPW
–	LED B 45LPW	50%	22.5LPW
–	LED C 50LPW	30%	15LPW
–	CFL 60LPW	50%	30LPW
–	Better wait for Energy Star Ratings		



Current LED Market \$2B/yr



**Cellphone
(Nokia)**



**Traffic signals
(Gelcore)**



**Large Displays
(NASDAQ)**



streetlights



**TVs (LED DLP™)
(samsung)**

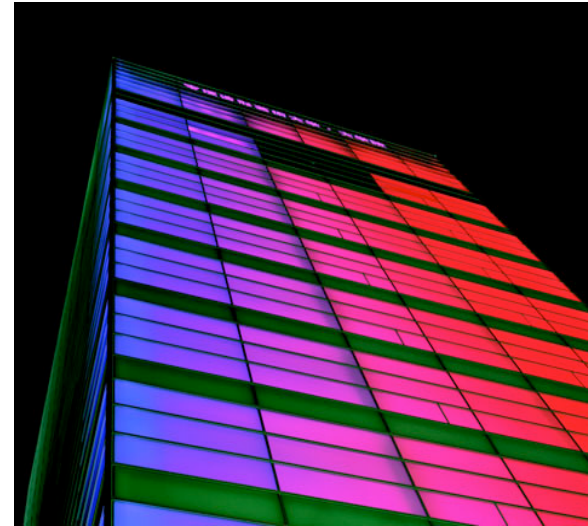


Automotive

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

AUTOMOBILE LED Headlights expected 2008 from Tokyo Motor Show



Nissan



Honda



Daimler Chrysler



Toyota

0.5-1% better fuel efficiency

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.**



Solar(Photovoltaics) + LED (Off-grid)

www.lutw.org



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

“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



Light Up The World Foundation



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

CONCLUSION

- R&D Level LED Single lamp efficacy (150lm/W) now exceeds CFL, but:
- Commercial based LED Lamp Fixtures are much lower 64LPW due to several factors that need further research and development in
 - Fixture Efficiency
 - Heat Sinking
 - Scale up to Mass production
- Stay Tuned.....