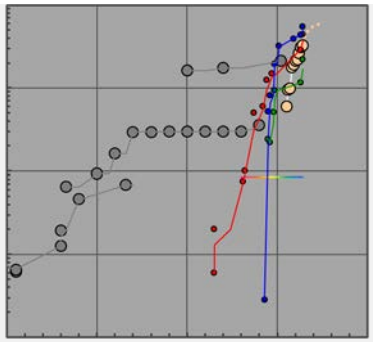
Exceptional service in the national interest

SAND2017-12137C


The New World of Engineered SSL

Past & Present, but mostly Future (5 SSL Grand Challenges)

Jeff Tsao

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SAND2017-10809 C

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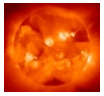
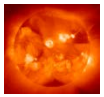
Evolutionary importance of visible light

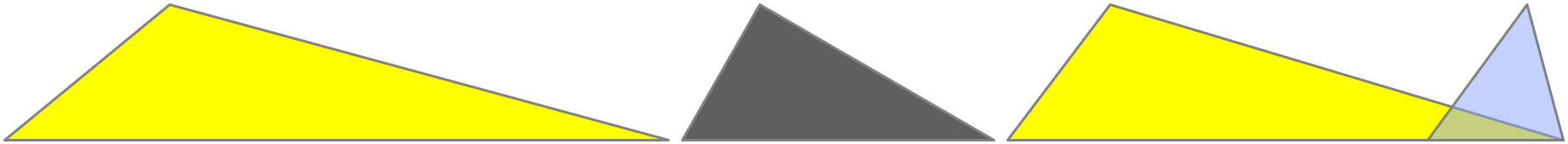


Full-disk view of the X-ray Sun and was produced by the Yohkoh solar observatory in 1991.
http://en.wikipedia.org/wiki/File:Yohkohimage.gif

Full moon view from Earth in Belgium, courtesy of Luc Viatour.
http://en.wikipedia.org/wiki/File:Full_Moon_Luc_Viatour.jpg



BridgeluxHelieon Solid-State Lamp.
http://www.bridgelux.com/products/helieon.html



Asaphus species (Trilobite) picture taken by DanielCD.
http://en.wikipedia.org/wiki/File:Asaphus_species_trilobite.jpg

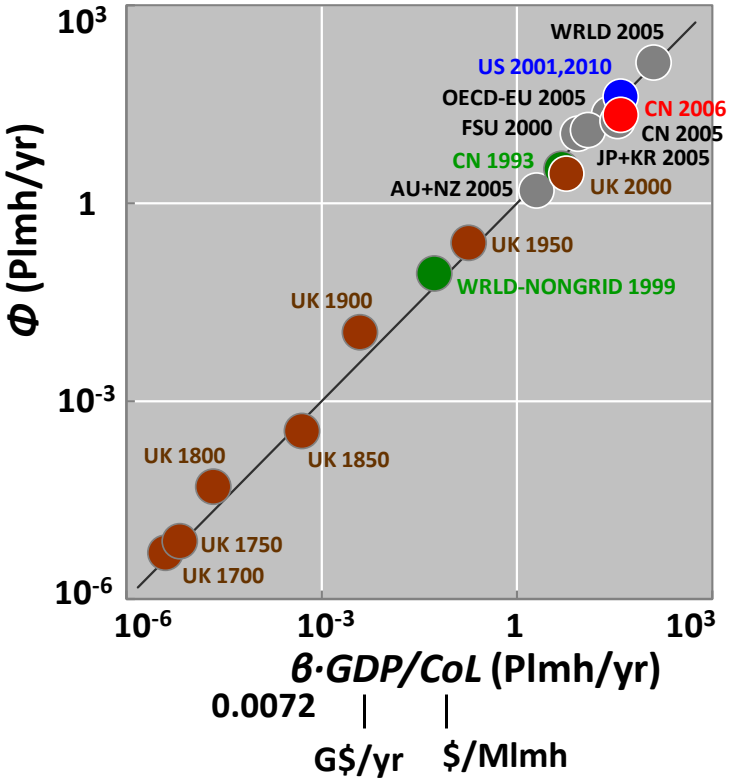
Red Lory (Eos bornea) upper body preening feathers.
http://en.wikipedia.org/wiki/File:Red_Lory_%28Eos_bornea%29-6.jpg

Gray wolf, canis lupus, courtesy of Chris Muiden.
http://en.wikipedia.org/wiki/File:Canis_lupus_265b.jpg

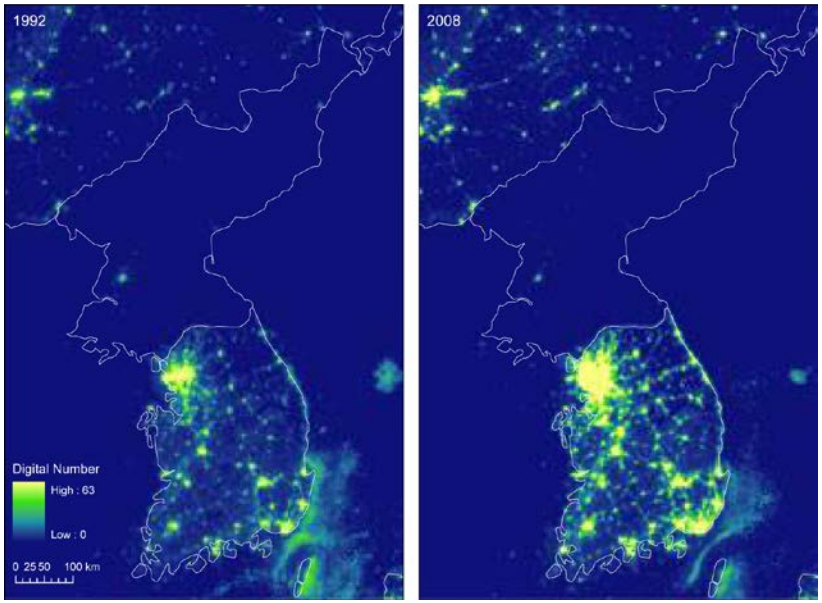
Olive baboon in Kenya; courtesy of Ryan Harvey;
http://en.wikipedia.org/wiki/File:Male_Olive_Baboon_2.jpg

A baby wearing many items of winter clothing: headband, cap, fur-lined coat, shawl and sweater. Courtesy of Andrew Vargas, Clovis, United States.
http://en.wikipedia.org/wiki/File:Well-clothed_baby.jpg

Economic importance of visible *artificial* light



J.Y. Tsao and P. Waide, "The World's Appetite for Light: Empirical Data and Trends Spanning Three Centuries and Six Continents," LEUKOS **6**, 259-281 (2010).



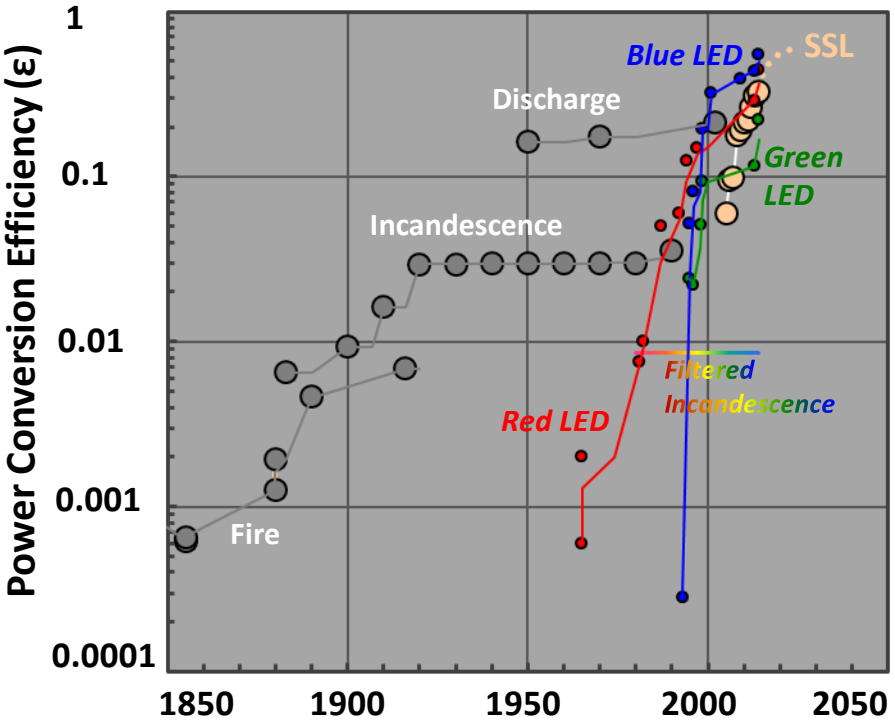
1992 2008

Korean Peninsula

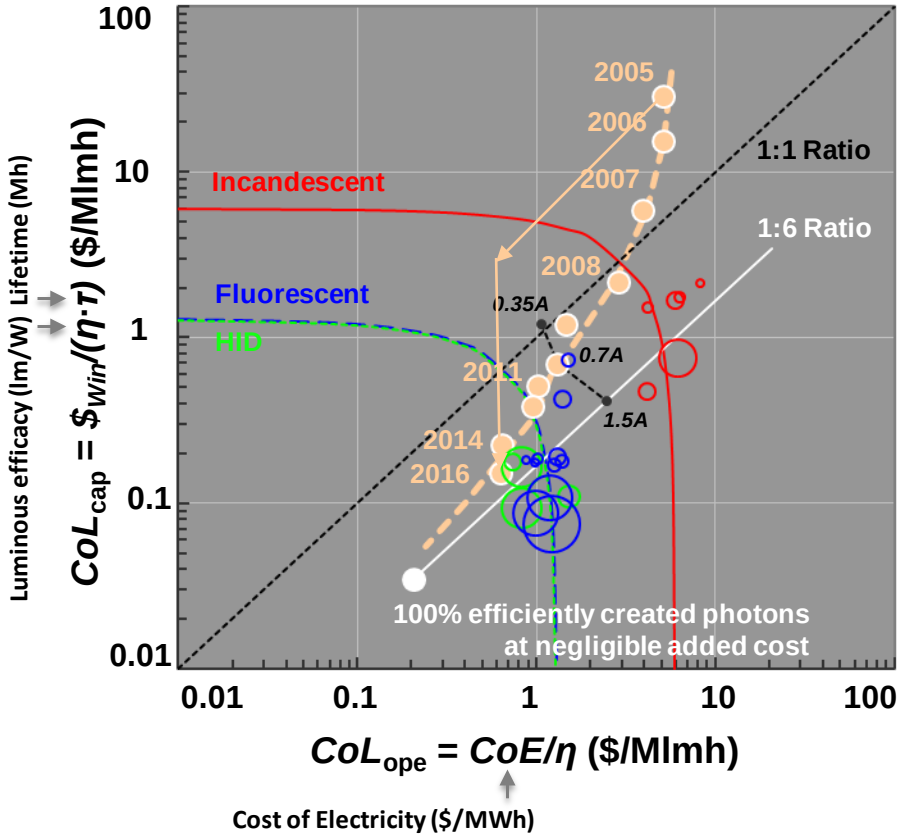
J.V. Henderson, A. Storeygard, and D.N. Weil, "Measuring Economic Growth from Outer Space," Amer. Economic review **102**, 994-1028 (2012).

Coming importance of solid-state lighting

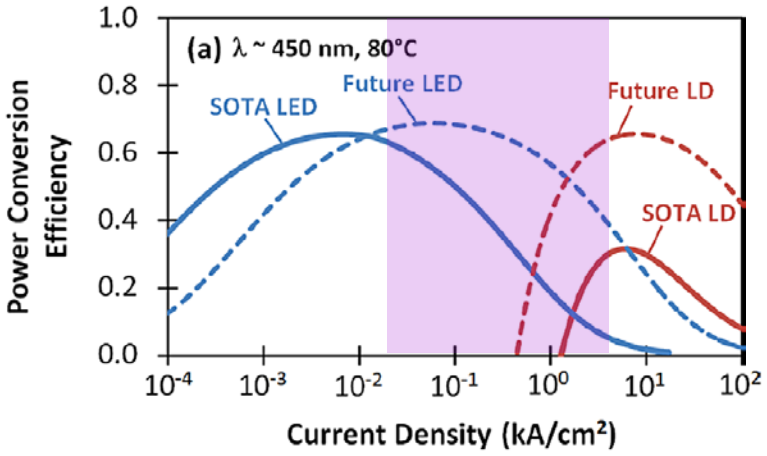
White & blue photons are now delivered by commercial devices at 30 & 60% efficiency, with 50% & 80% on the horizon



And the cost of the devices that produce those photons is becoming negligible

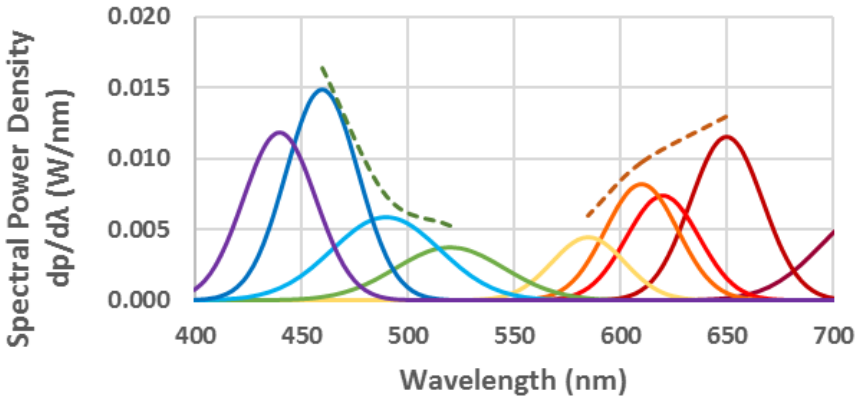


SSL GC 1: Valley of Droop



Courtesy, Jon Wierer, Lehigh University

SSL GC 2: RYG Gap



After 2017 DOE SSL R&D Plan

SSL GC 3: Expanded Functionality

Sony's *Multifunctional Light*

Actuation
- Color-Tunable and On/Off/Dim Light
- Speaker

Communications
- Wi-Fi

Sensors
- Temperature, Humidity, Presence
- Microphone

To Come?
- Local Intelligence and Alexa-like Interactivity
- Cameras
- Structured Light and 3D Mapping
- Chemical/Biochemical Sensing

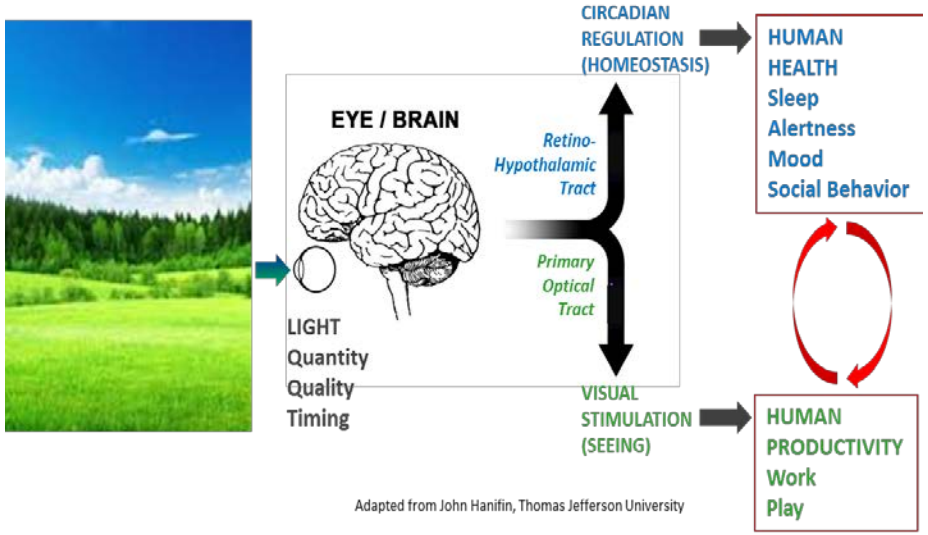
Augmented Reality and Illumination/Display Convergence

From Corning's "A Day in the Life"

After Extreme Tech (April, 2016) https://www.extremetech.com/extreme/193402-what-is-night-vision-how-does-it-work-and-do-i-really-need-it-in-my-next-car

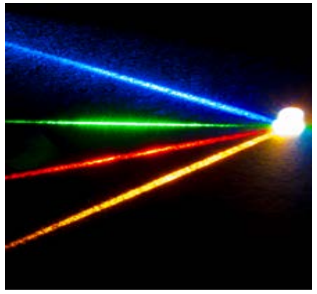
SSL GC 4: New Applications

Human Health



Indoor Farming

Co-Evolution



Plant Biology
Genetic Engineering
Breeding &
Artificial Selection

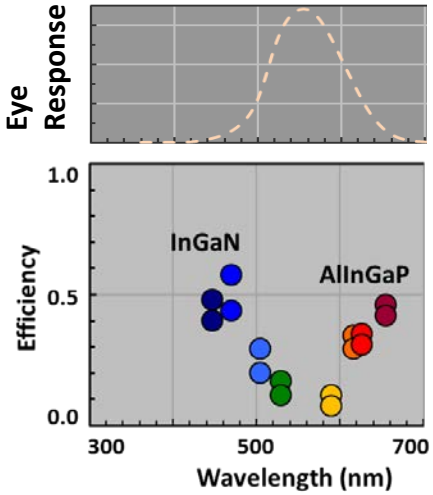
Plant Environment
Non-directional
- *Temperature*
- *Chemistry*

Directional
- *Gravity*
- *Photons*
  (Fuel & Signaler!)

SSL GC 5: Reconceptualizing Lighting Efficacy

$$\eta_{Source} \cdot \varepsilon_{Space+Time+\lambda} \cdot \eta_{Use} = \eta_{Lighting}$$

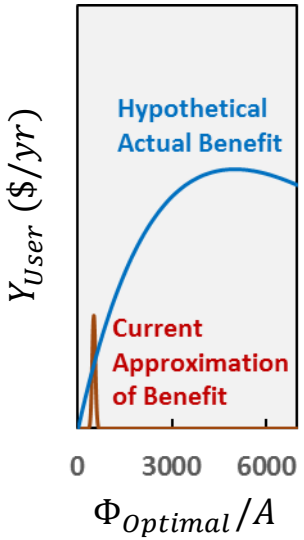
$$\frac{\Phi_{Actual}}{P_{Elec}}$$



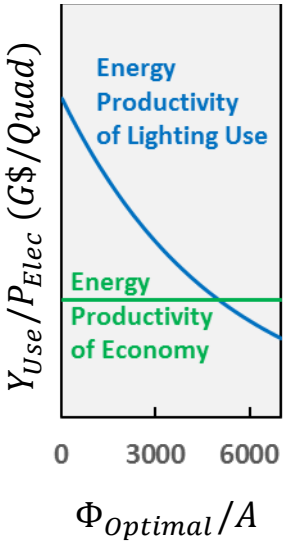
$$\frac{\Phi_{Optimal}\big|_{Y_{Use}}}{\Phi_{Actual}}$$

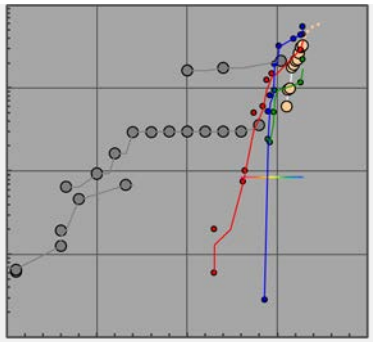
$$\Phi_{Optimal} = \iiint \frac{\partial^3 \Phi_{Optimal}}{\partial\lambda\partial A\partial t} d\lambda dA dt$$

$$\frac{Y_{Use}}{\Phi_{Optimal}\big|_{Y_{Use}}}$$



$$\frac{Y_{Use}}{P_{Elec}}$$




Solid-State Lighting Grand Challenges for the Future

1. *Valley of Droop*
2. *Red-Yellow-Green Gap*
3. *Expanded Functionality*
4. *New Applications (Human Health, Indoor Farming)*
5. *Reconceptualizing Lighting Efficacy*