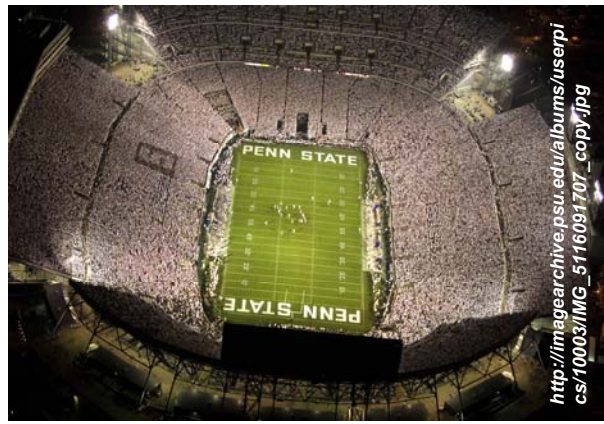


# Solid-State Lighting

Jeff Tsao · Physical, Chemical and Nano Sciences Center · Sandia National Laboratories



## Outline:

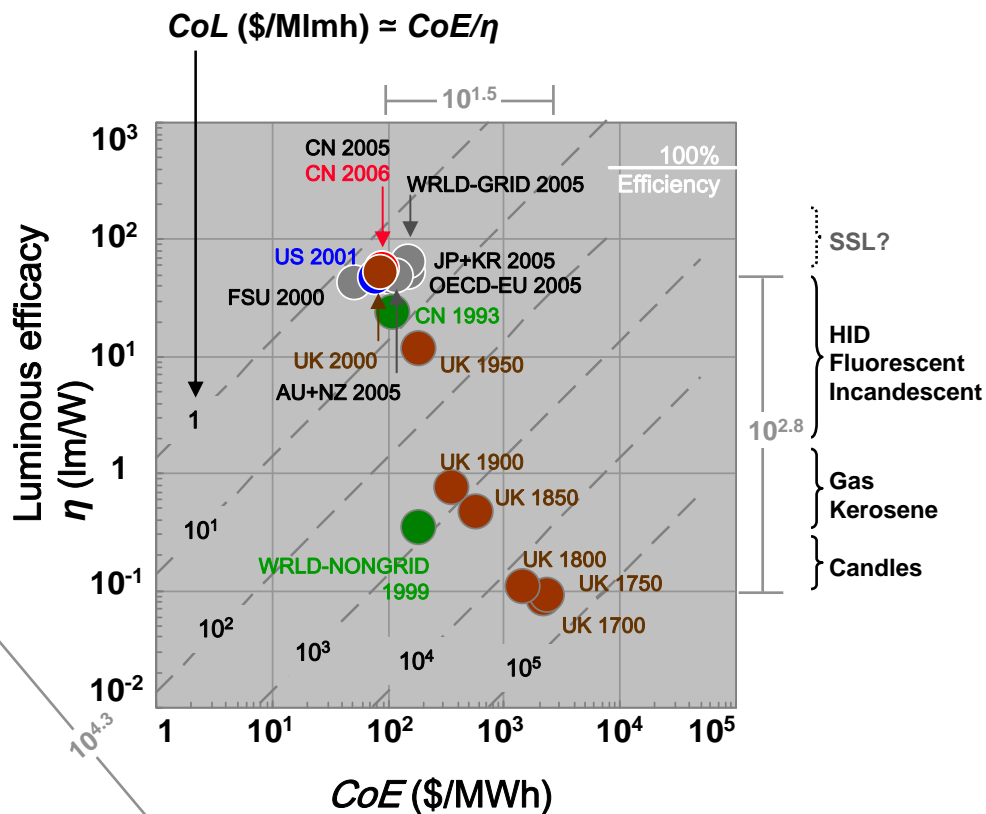
**1 Light  
Productivity  
Consumption**

**2 SSL Technology  
Past, Present, Future**

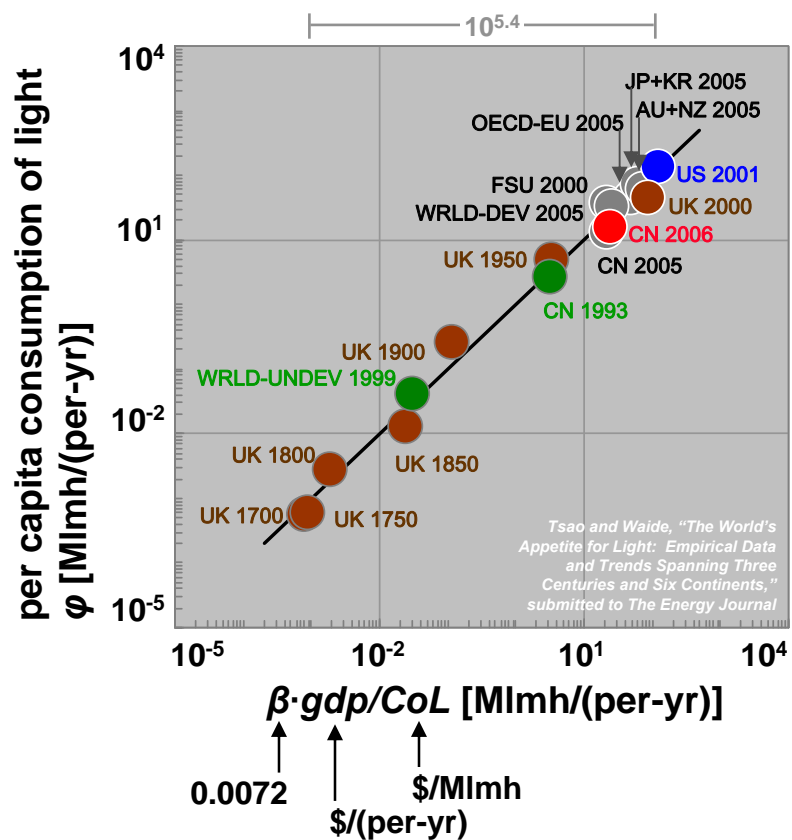
**3 SSL Science  
Past, Present, Future**

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Security Administration under Contract DE-AC04-94AL85000.

# Efficiency



# Consumption

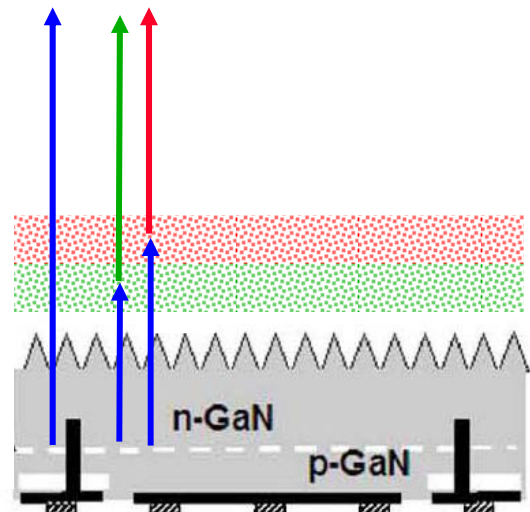


# Warm-White SSL State-of-the-Art: 12% Efficiency (46 lm/W)



*Spectral*     78%

<i>Blue Pump</i>	<u>32%</u>
<i>Electrical injection</i>	<u>75%</u>
<i>Internal radiative</i>	<u>75%</u>
<i>Droop maintenance</i>	<u>75%</u>
<i>Light extraction</i>	<u>75%</u>

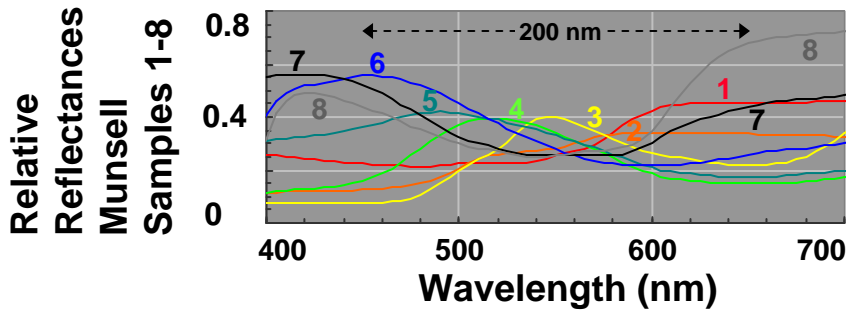
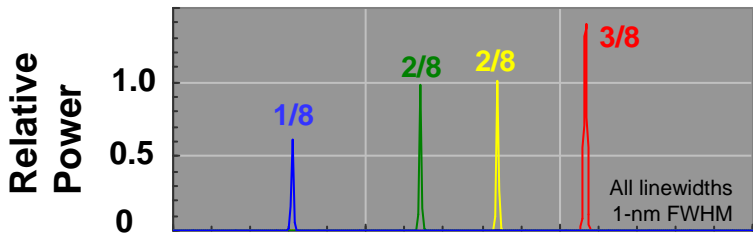
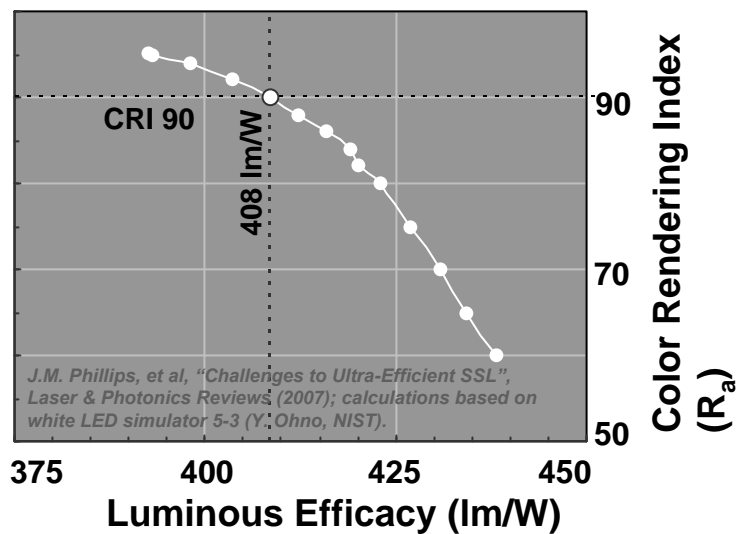
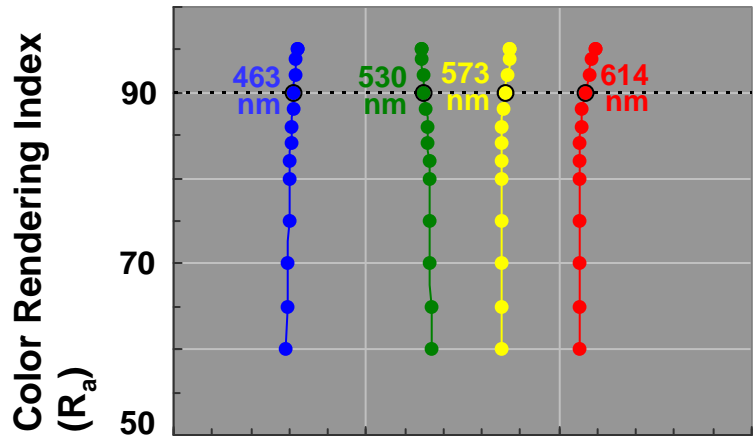
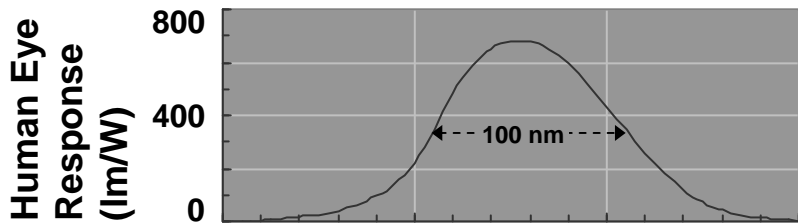


<i>Phosphor/Package</i>	<u>48%</u>
<i>Internal radiative</i>	<u>80%</u>
<i>Stokes deficit</i>	<u>75%</u>
<i>Scattering/absorption</i>	<u>75%</u>



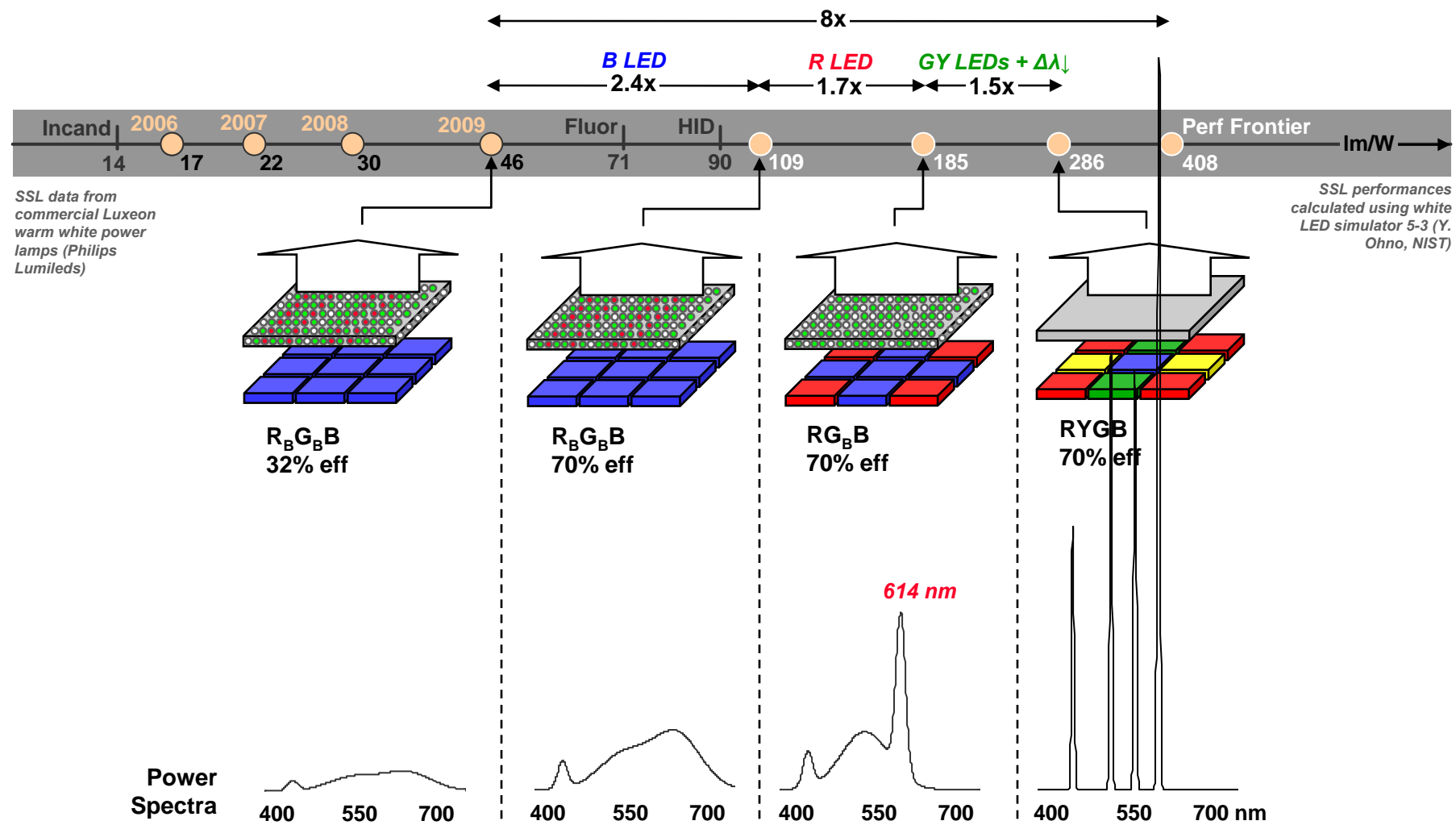
O. B. Shchekin, et al., "High performance thin-film flip-chip InGaN-GaN light-emitting diodes," *Appl. Phys. Lett.* 89, 071109 (2006)

# SSL Performance Frontier: 100% efficiency (408 lm/W)





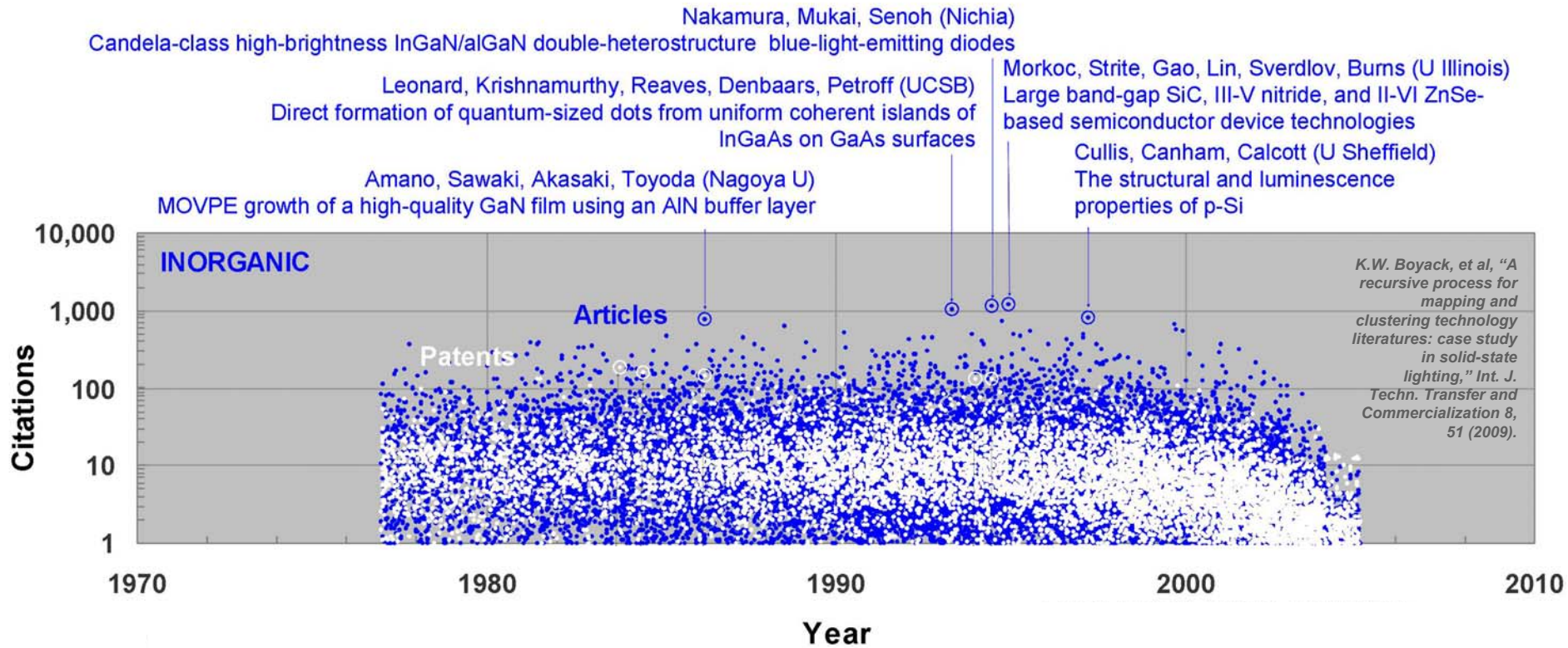
# SSL Progress Report: Luminous Efficacy





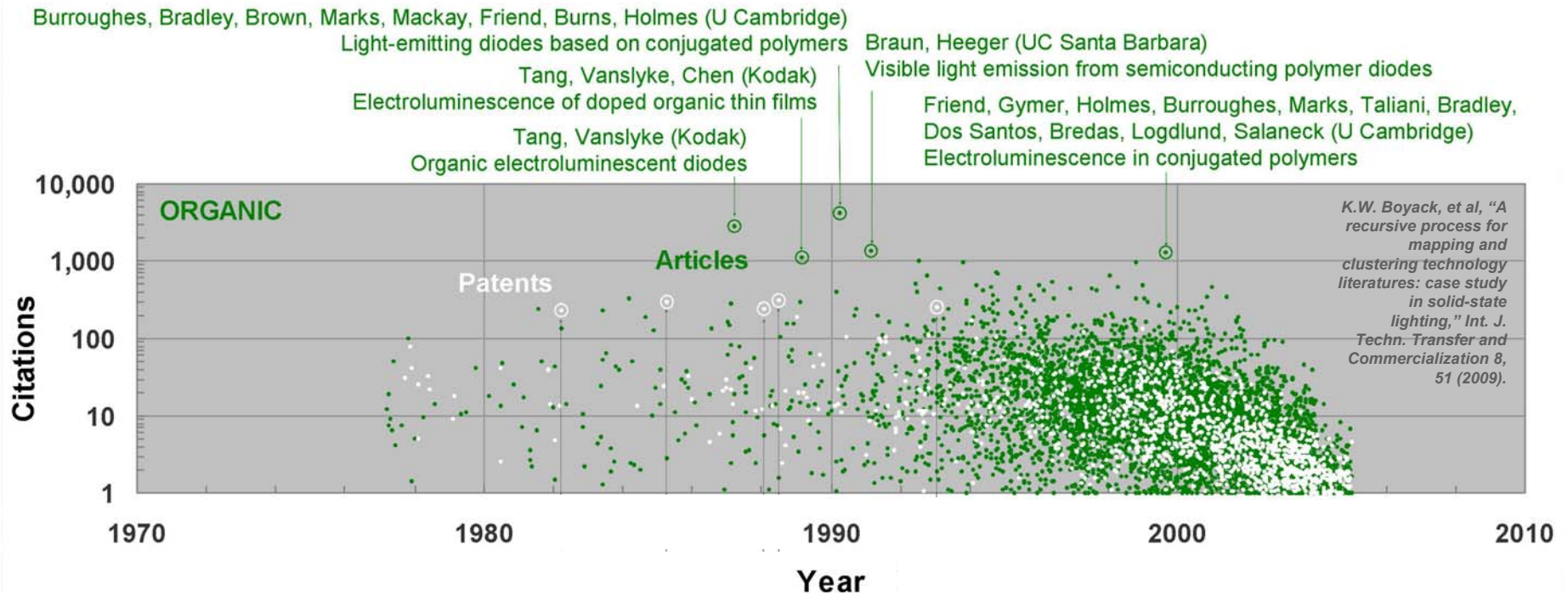
# SSL's S&T Foundations (Inorganic Materials)

Uncertainty · Patience · Persistence · Serendipity



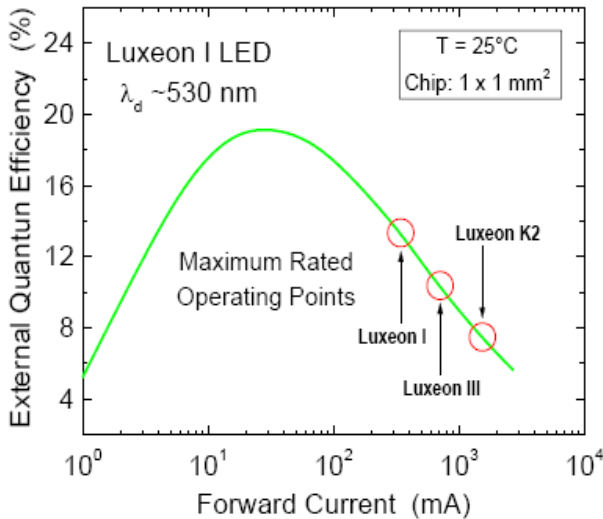
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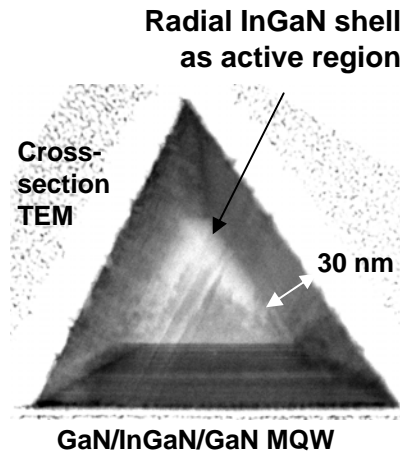
# Science Research Opportunities

## Wide-Bandgap Materials: Foundational Understanding and Beyond



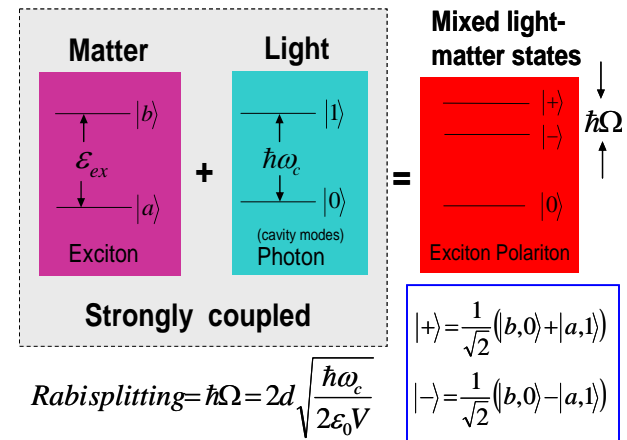
M. Krames, Lumileds Lighting, LLC, presentation at Basic Research Needs for Solid State Lighting Workshop, sponsored by U. S. Department of Energy, Office of Basic Energy Sciences, May 22-24, 2006, Washington, DC (2006).

## Beyond 2D: Luminescent Nanowires, Nanodots and Hybrid Structures



Courtesy of G. Wang (Sandia Natl Labs)

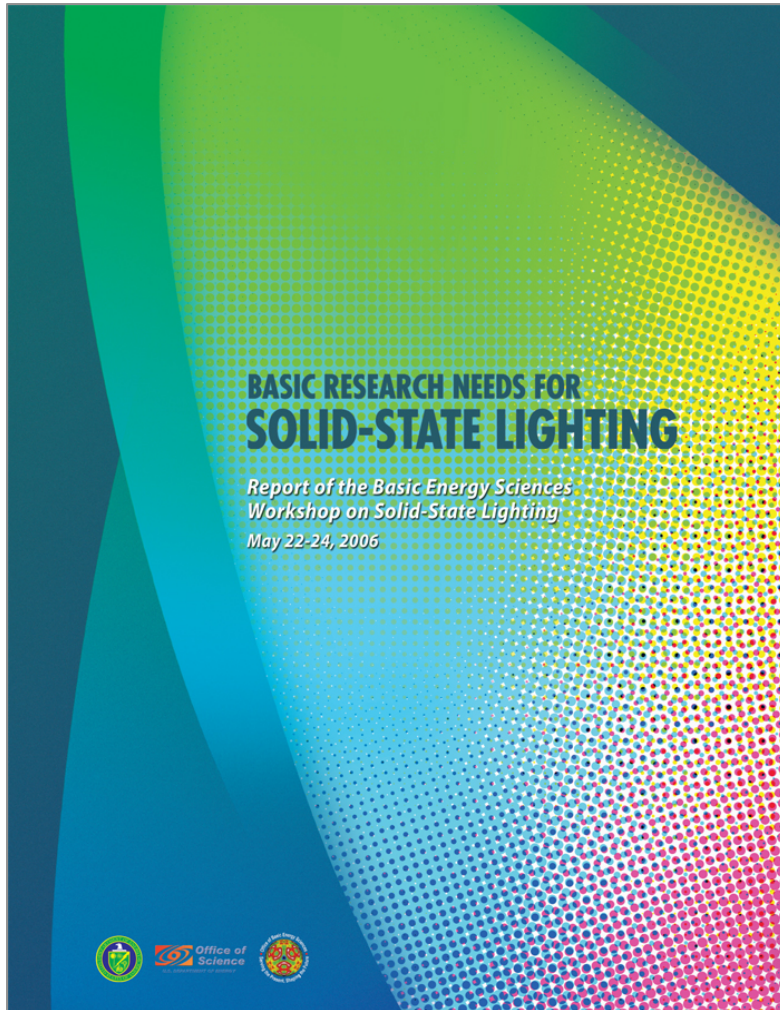
## Beyond Perturbations: Light and Matter in Subwavelength Photonic Structures



Courtesy of A. Fischer (Sandia Natl Labs)



# Basic Research Needs in Solid-State Lighting



- **Grand Challenges**
  - Rational Design of Solid-State Lighting Structures
  - Controlling Losses in the Light Emission Processes
- **Priority Research Directions**
  - Unconventional Light-Emitting Semiconductors
  - Photon Conversion Materials
  - Polar Materials and Heterostructures
  - Luminescence Efficiency of InGaN Structures
  - Managing and Exploiting Disorder in Organic Films
  - Understanding Purity and Degradation in OLEDs
  - Integrated Approach to OLED Design
- **Cross-Cutting Research Directions**
  - New Functionalities through Heterogeneous Nanostructures
  - Innovative Photon Management
  - Enhanced Light-Matter Interactions
  - Multiscale Modeling for Solid-State Lighting
  - Precision Nanoscale Characterization