Quantum Dots for White LED Application

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Outline

- The SSL promise
- Challenges in high colour quality white LEDs
- Quantum Dot
- Breaking color – efficiency trade off


OSRAM
SYLVANIA


Lumentra


GO
GO Lighting Technologies Inc.


BRO
Breault
Research


Lighting Analysts
illumination engineering software


SSLnet


labsphere
A HALMA COMPANY


RUUD
LIGHTING
Ruud Lighting Canada
beta
LED


OPA
Ontario Power Authority


Ontario Centres of
Excellence


TORONTO Atmospheric Fund

Lighting Industry : Facts

$70 billion

-35%

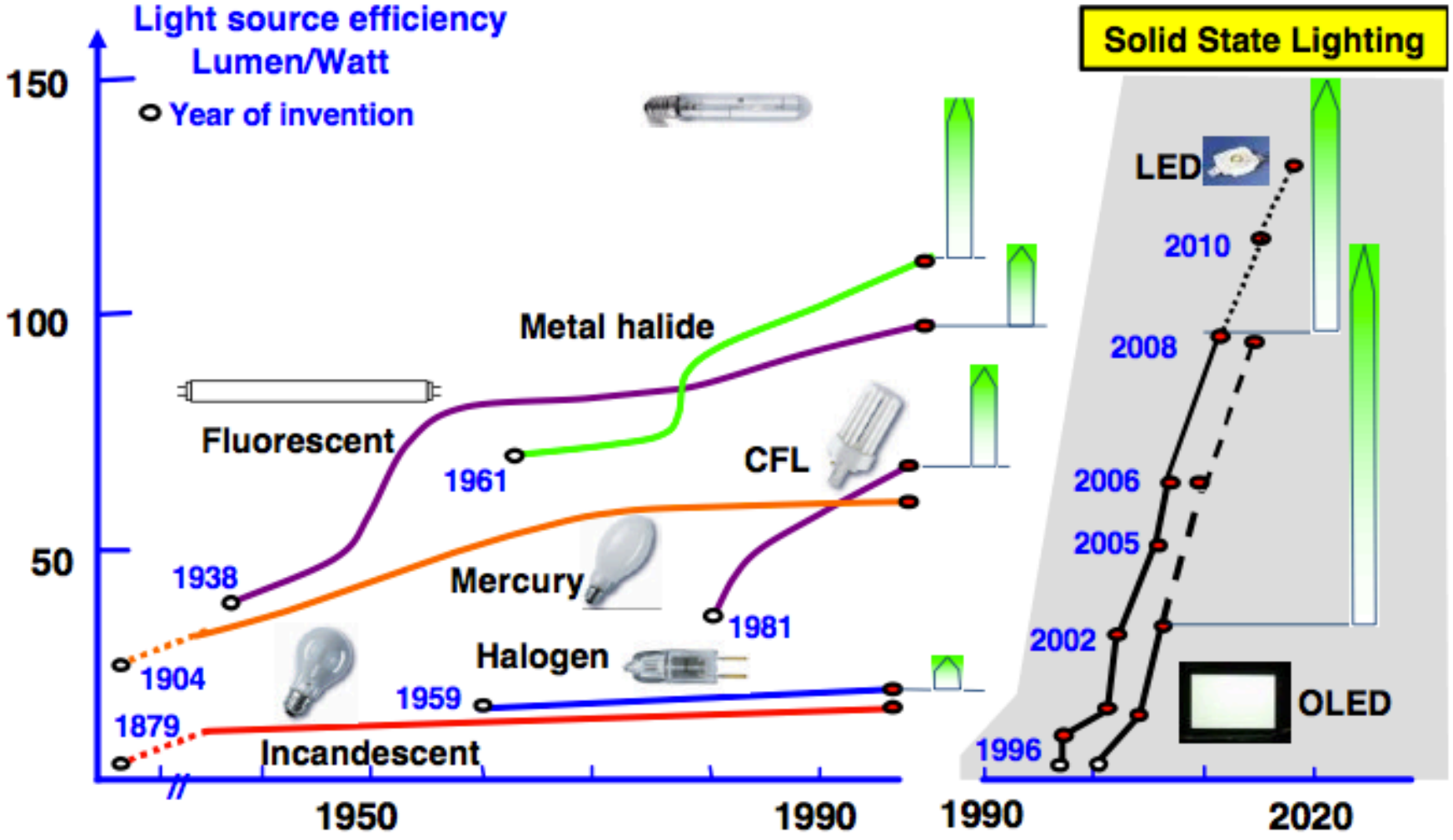
by 2030

22%

of all electricity use

Source: Optoelectronics Industry Development Association

SSL vs Legacy Technologies



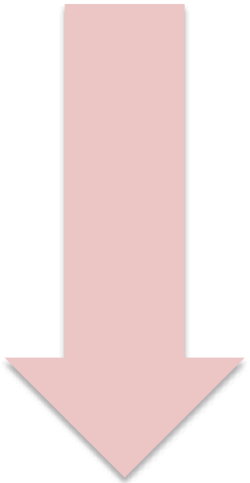
Courtesy: OSRAM Opto Semiconductors

LED advantages

- Promise of high efficacy in excess of 200 lm/W
  - 80-130 lm/W today
  - best in other technologies is only 150 lm/W
- Pulsed (PWM) LEDs offer further savings
- Directional : every photon counts, 75-80% coefficient of utilization
- Long life L_{70} = 50,000 hrs
- Accurate colour control, high Colour Rendering Index (CRI)
- Intelligent lighting; adaptive controls
- Combined with solar cells – off-grid lighting
  - Promising for developing economies – think cell phones

Lighting Market

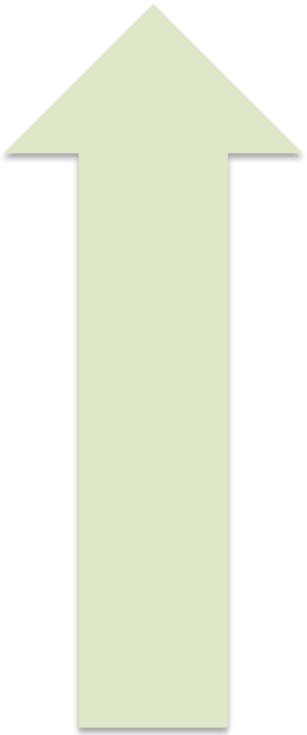
Overall lighting market



-15%

2009

+24%

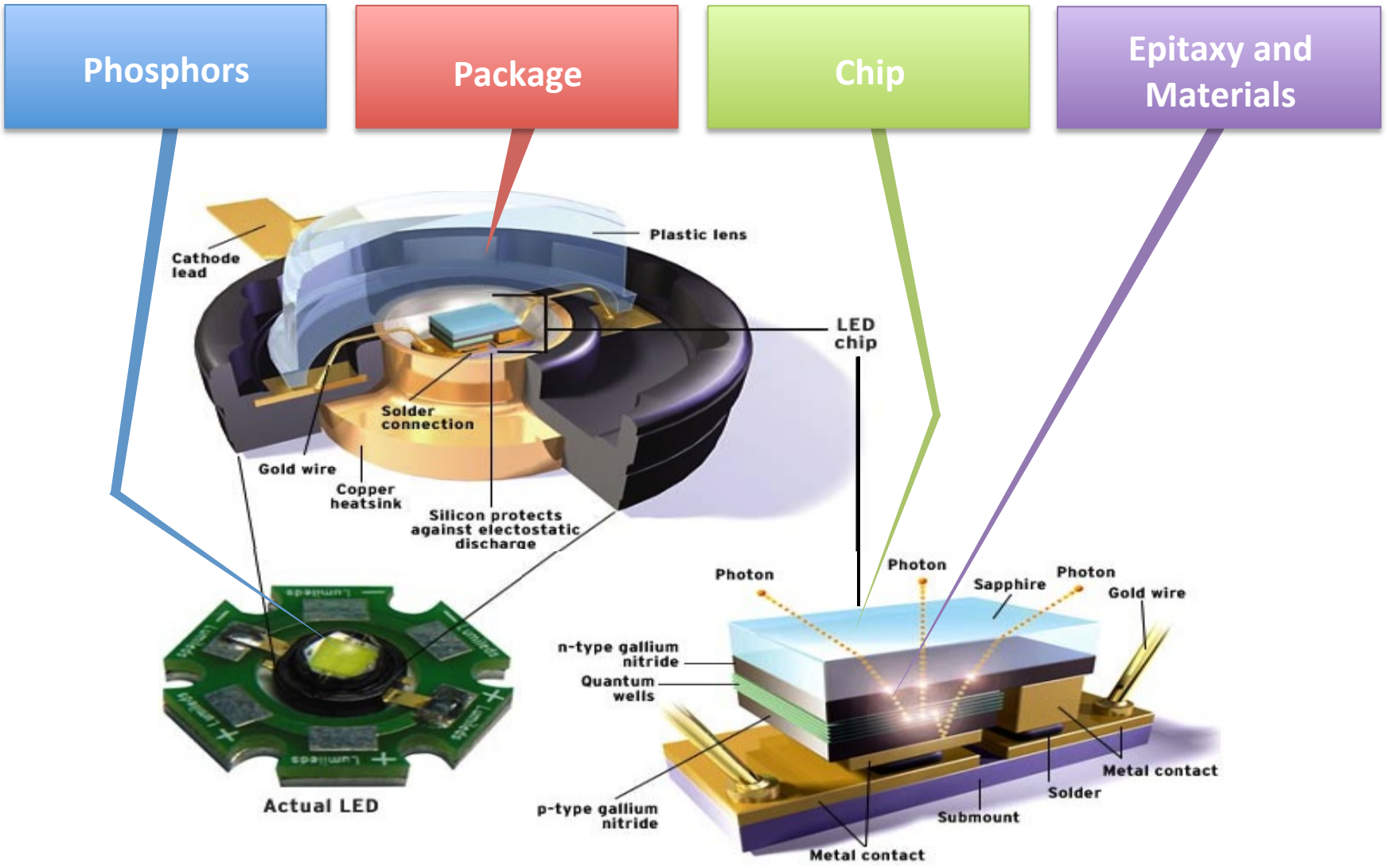


LED lighting market

Need for high colour quality

- We evolved under sunlight
- Our biorhythm is controlled by sunlight
- Modern urban dweller spends entire day under artificial light
- Sunlight – epitome of colour quality
- "Fast food of light"
- Core Sunlighting – the organic alternative
- SSL promise

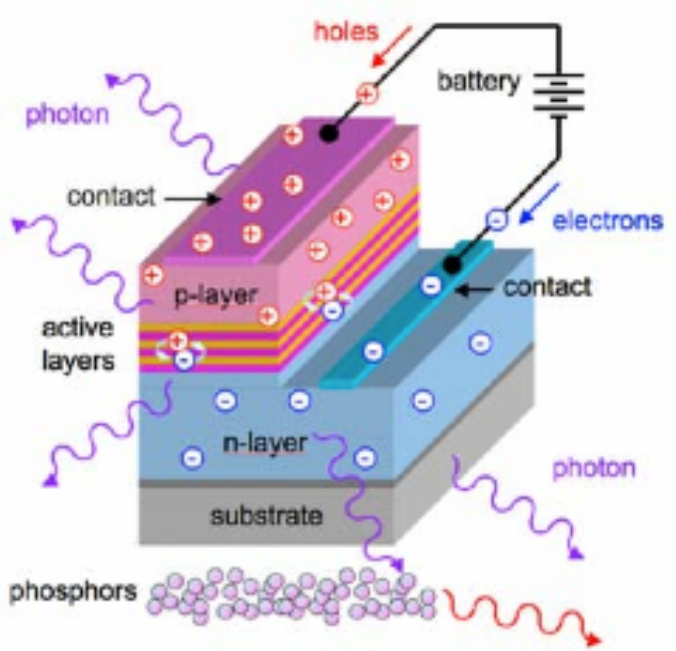
The four elements of high-power LED



Courtesy: Philips Lumileds

Epitaxy and Materials

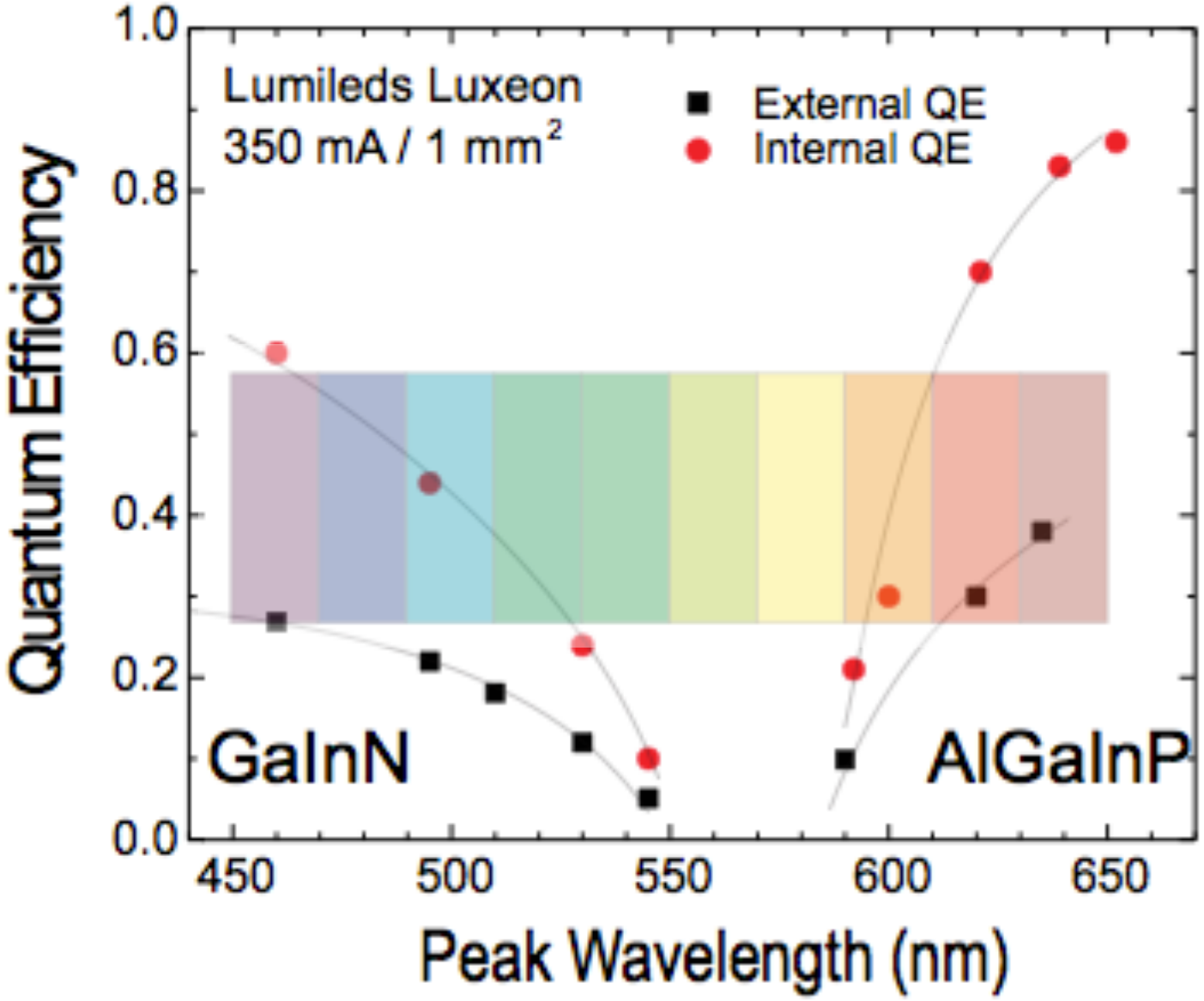
- AlGaInP
  - developed since 90s
  - Yellow, Orange, Red
  - External quantum efficiency – 55% around 650 nm
- InGaN
  - developed since 90s
  - Blue, Green
  - External Quantum Efficiency – 56% in blue



Current white LEDs are InGaN blue with YAG based phosphors

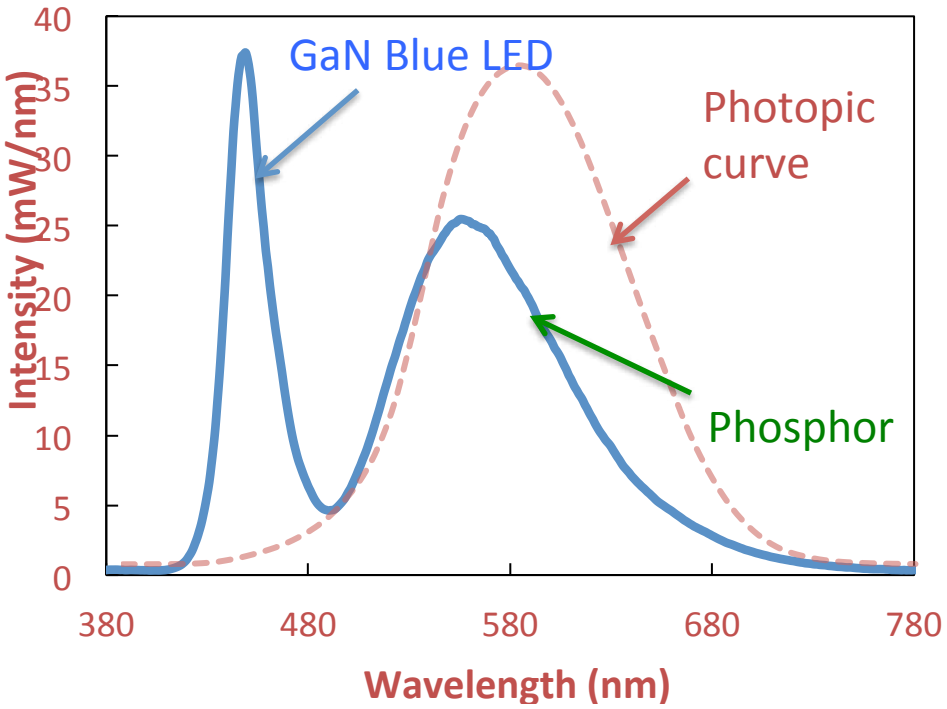
Alternate approach involves RGB LEDs

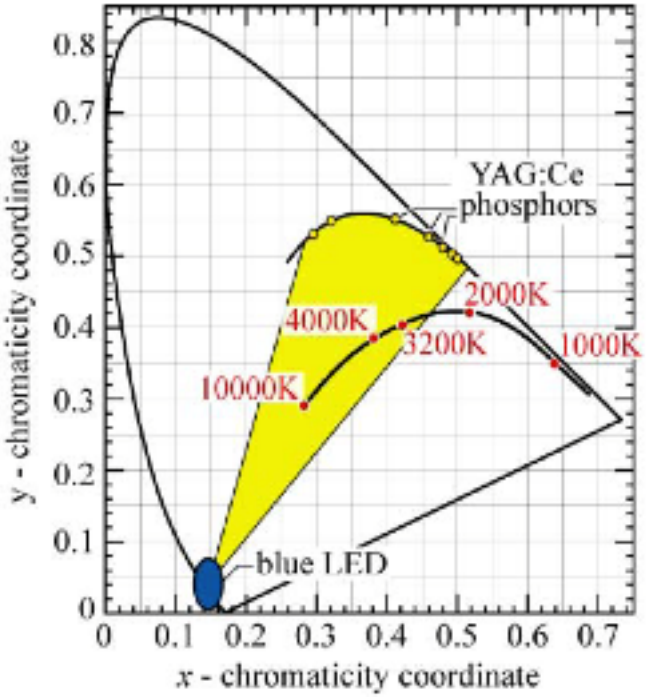
The Green Gap



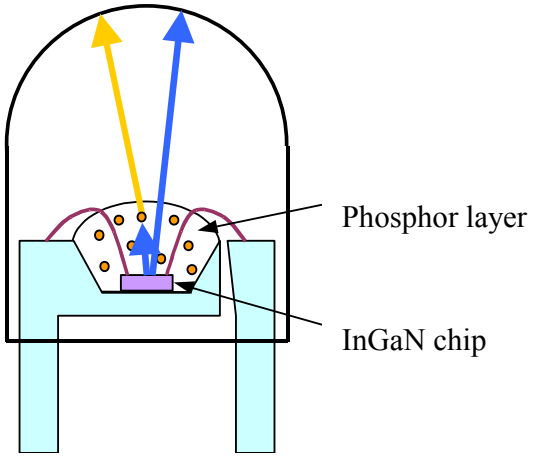
M. R. Krames et al. J. Display Technology, **3** (2007), p160

Blue LED and Phosphor





High colour temperatures; CCT ~4000K
Poor colour rendering; CRI ~ 80

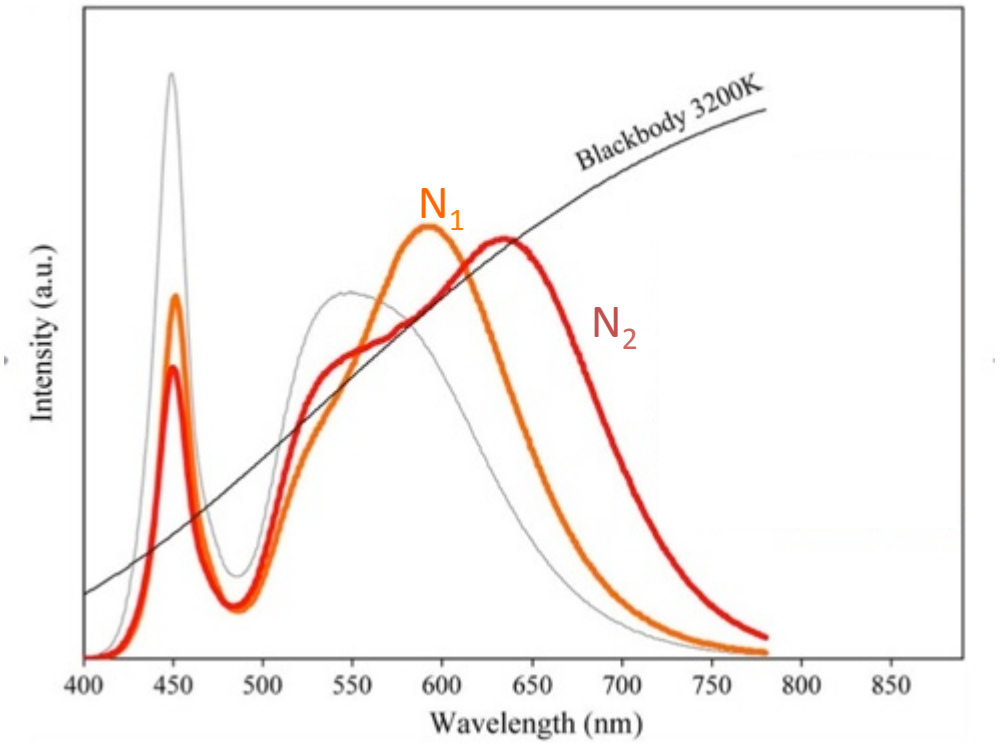


Multi phosphor approach

- $SrGa_2S_4:Eu^{2+}$ + $SrS:Eu^{2+}$
- CCT = 3700 K
- CRI = 89

Dissimilar materials
Different thermal properties

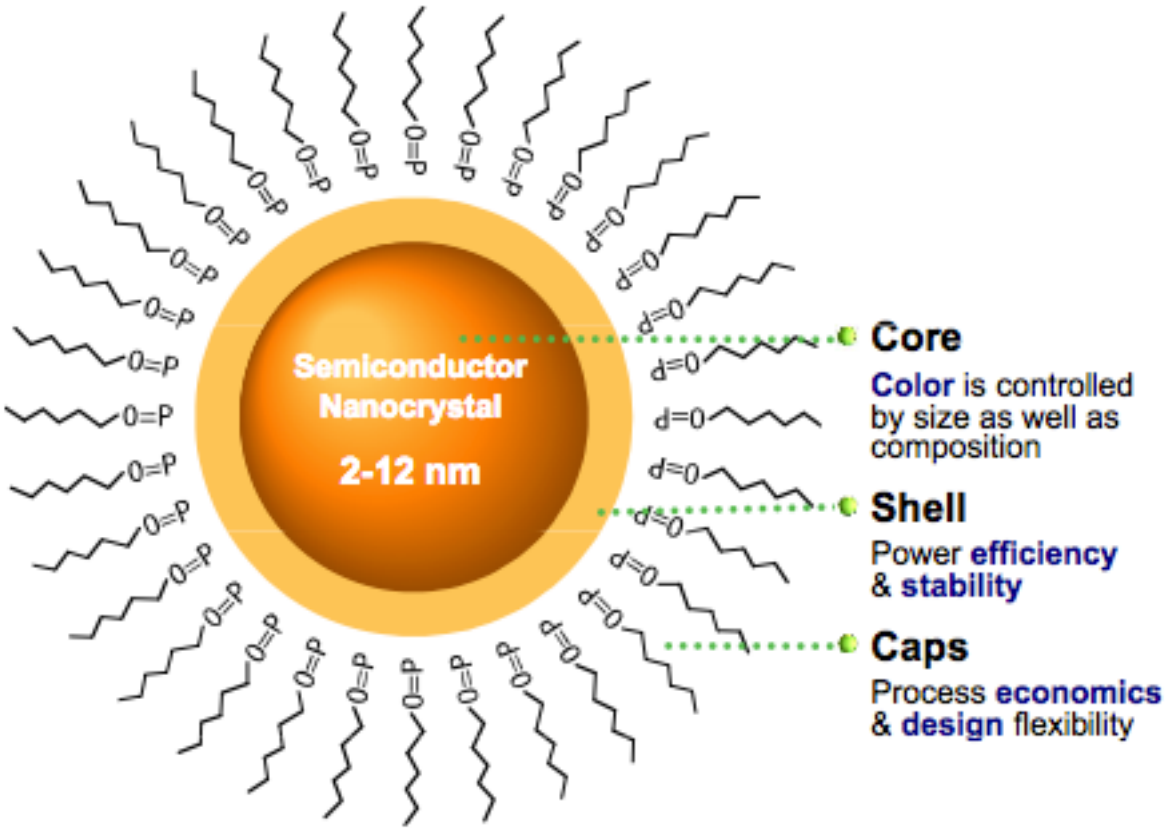
-> shrinkage and cracking
-> blue light leakage



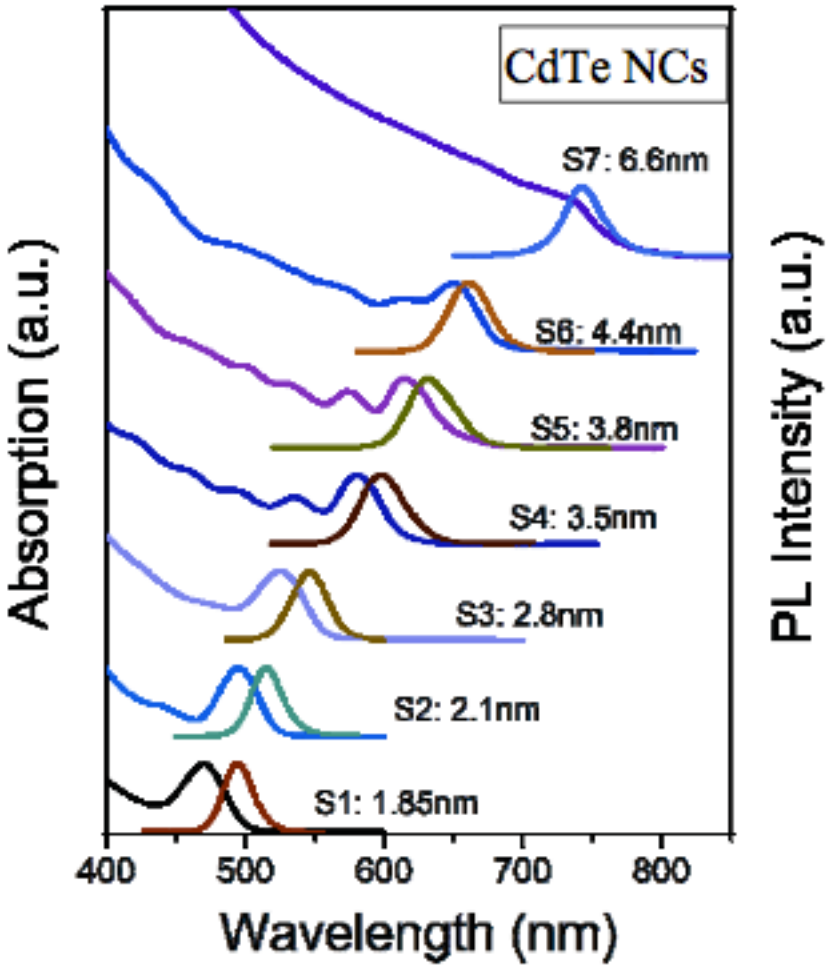
R.Mueller-Mach and G.O.Meuller, *Proc. SPIE* **3938**, 30, 2000

Quantum Dot Phosphors

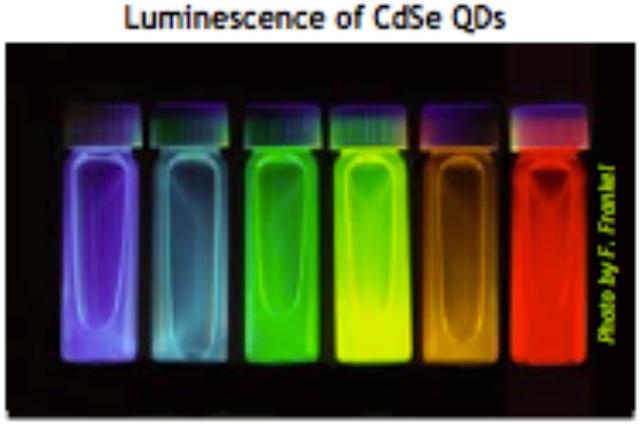
Semiconductor nanoparticles with core-shell structure



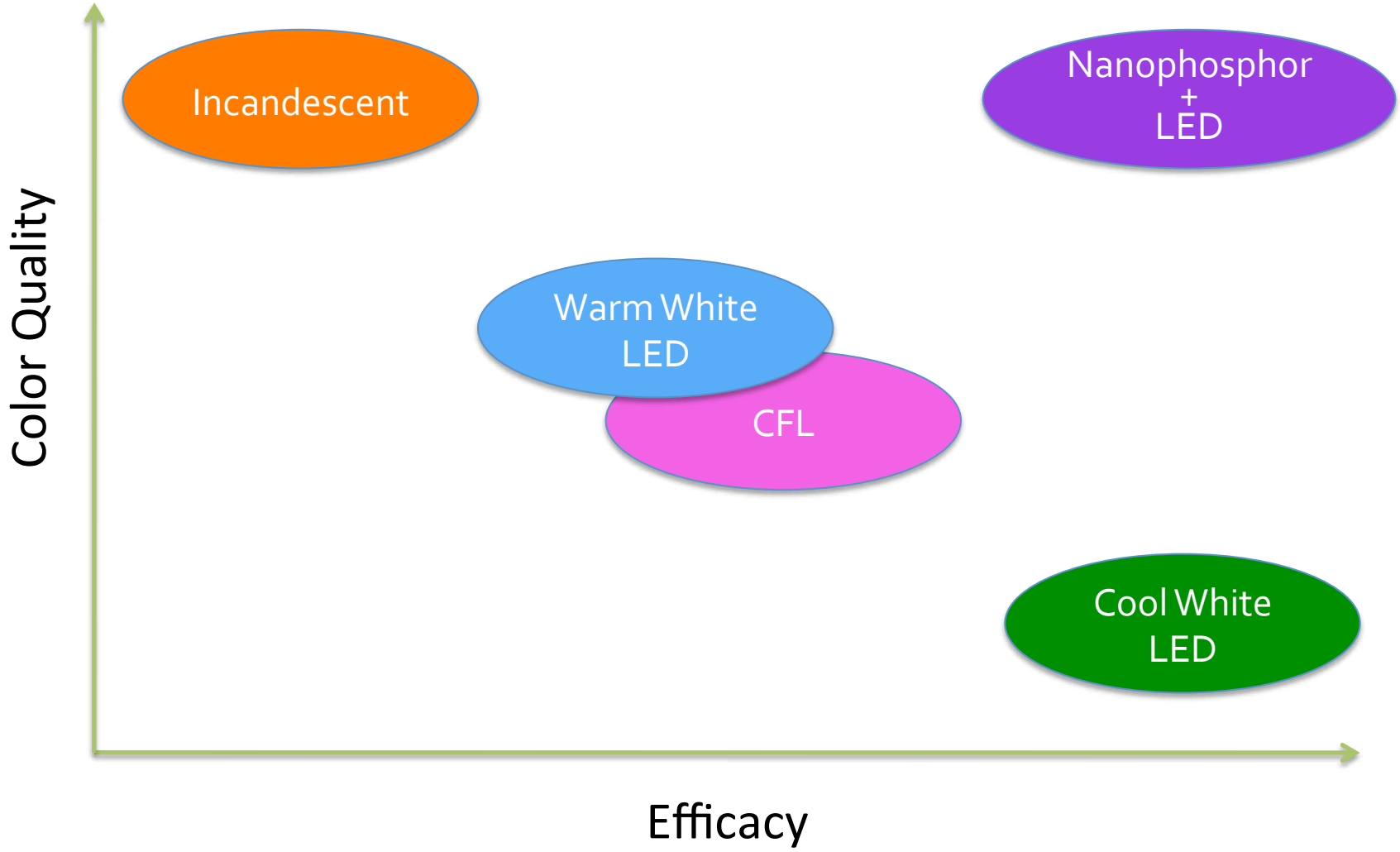
Luminescence Spectra of QDots



Semiconductor Quantum dots



Efficacy with Color Quality



Quantum Dot - Advantages

- Engineered Properties
- Light emission across entire visible spectrum
- Narrow emission – precisely tunable
- High efficiency
- Solution process
- Easy deposition on films

- High CRI
- Warm white
- Higher lamp efficiency
- Simple manufacturing
- Low cost

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Stability of nanoparticles – biggest concern

- We start with negatively charged polymers dispersed in water
- Collapsing polymer traps precurosrs.
- Polymer is crosslinked with UV light
- Platform method – almost anything in periodic table
- Possible to dope – precise control of properties
- Multi-emission quantum dots – direct white light generation

Lumentra

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- Tunable, excellent color control
- Good particle size control > controlling scattering
- 'One-pot synthesis'
- No dissimilar thermal properties > no shrinking, cracking, leakage
- No spatial inhomogeneity
- Promise of long term stability

Lumentra

Acknowledgement

Lumentra

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Institute for Optical Sciences

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