Novel Phosphors for Luminescence Conversion

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UCSB Materials Lab, Summer 2004

Project Funding: Solid State Lighting
Device and Display Center

Phosphor Applications

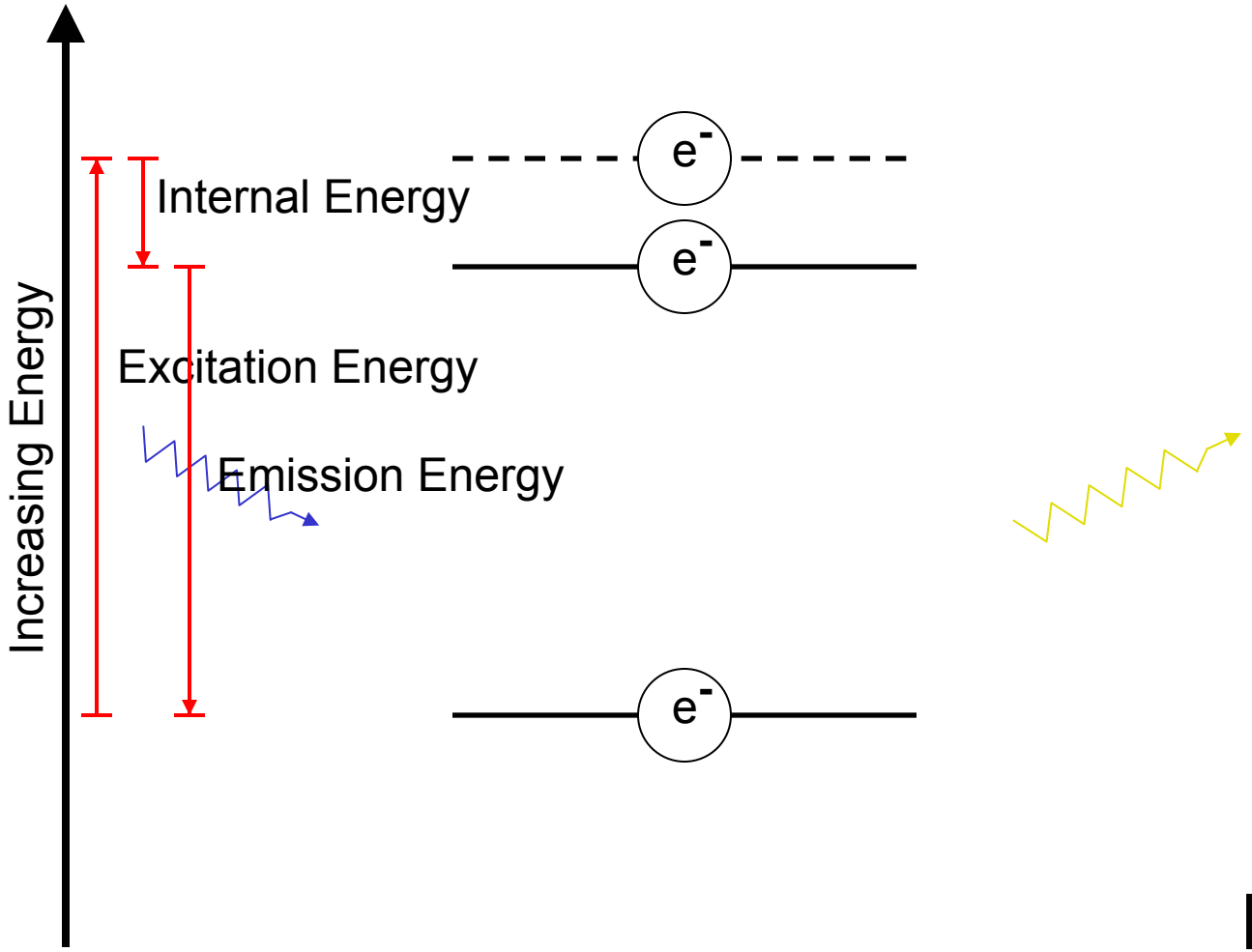
- Luminescence Conversion
  - Fluorescent Lighting
  - Solid State White LEDs
- Photon / Electron Detection
  - TV Screens
  - CERN's L3 Experiment

Project Overview

- Objective:
  - Synthesize novel phosphors for luminescence down-conversion (from Blue/UV to yellow).

- Motivation:
  - Improve efficiency & lifetime of solid state lighting.

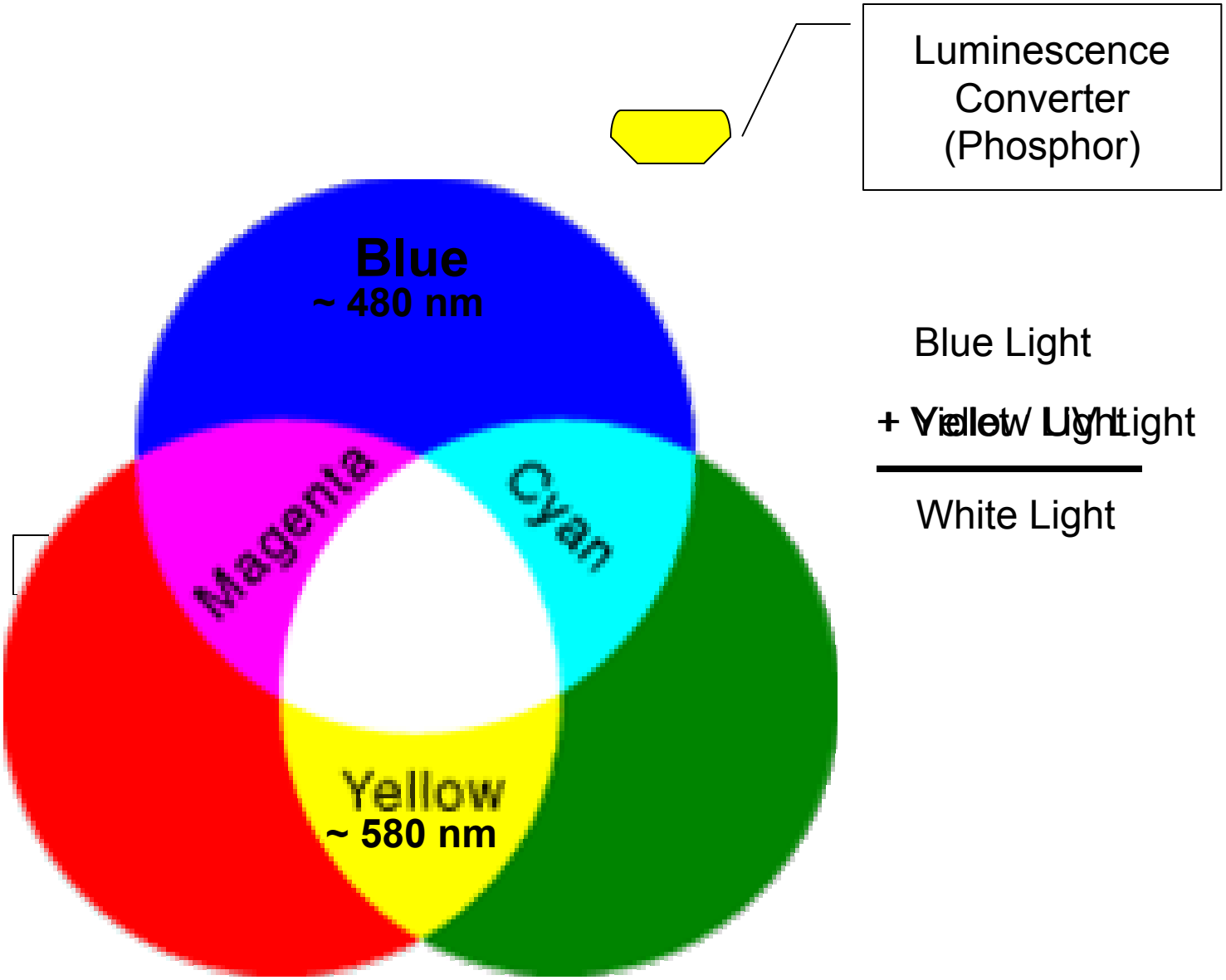
Luminescent Down-Conversion



$E\lambda=hc$

Excitation / Relaxation Energy Diagram

Luminescence Conversion White LED



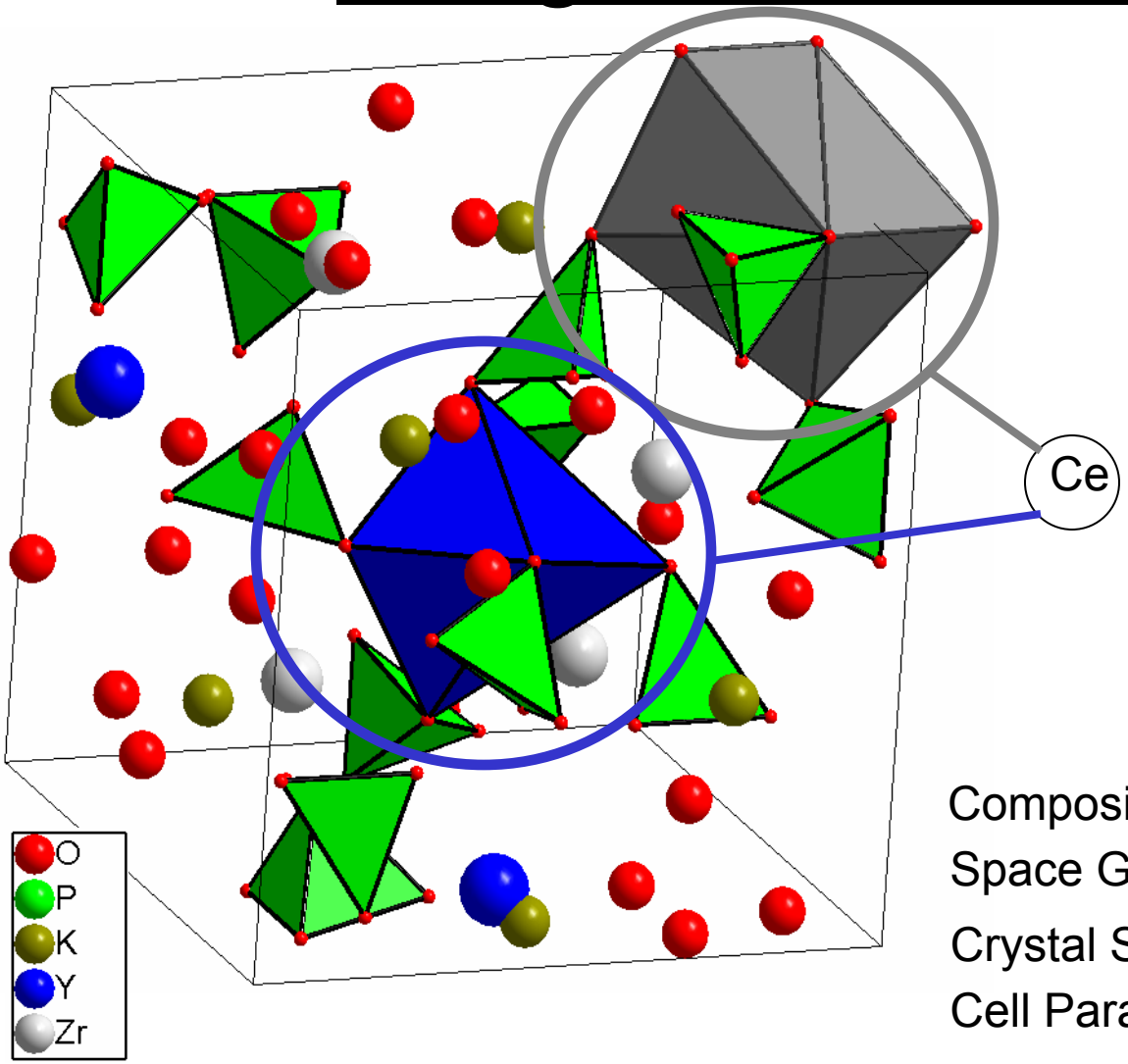
Adapted from: http://science.howstuffworks.com/light6.htm

Adapted from: Schlotter, Schmidt, and Schneider, *Luminescence conversion of blue light emitting diodes,* Appl. Phys. A 64, 417-418 (1997)

Research Methods

- Approach:
  - Design new applicable phosphor materials.
    - Alter existing PL materials.
    - Create entirely new phosphors.
  - Synthesis
    - Sol-Gel
    - Solid State
  - Characterization
    - XRD
    - PL

Langbeinite Structure



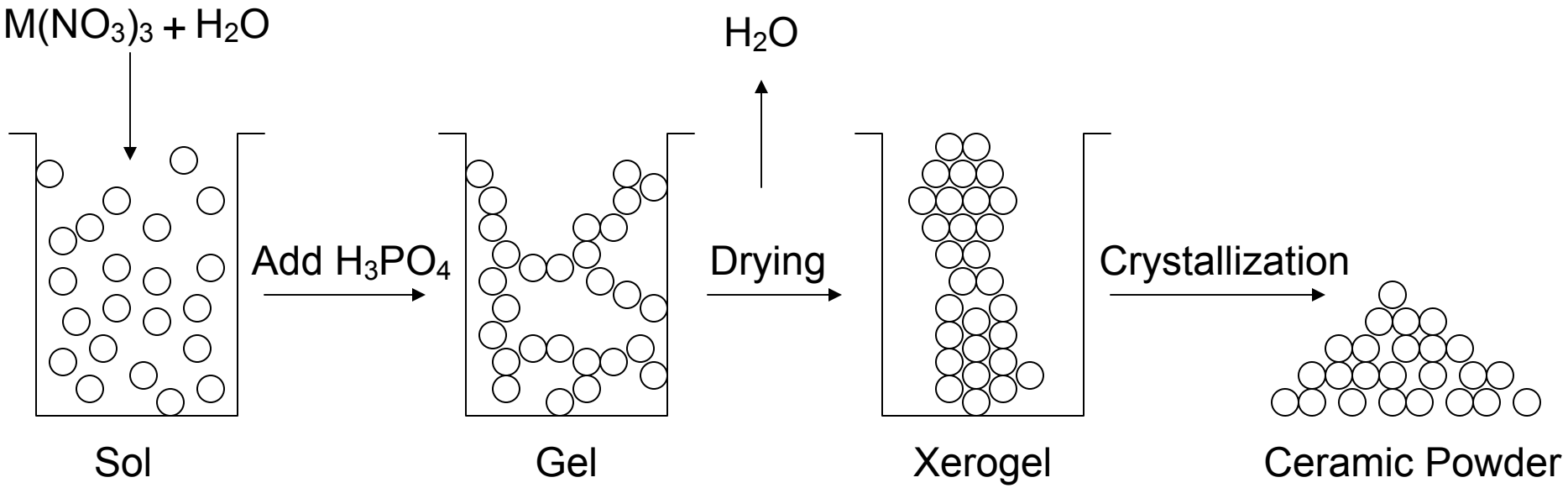
Composition: $K_2YZr(PO_4)_3$

Space Group: $P2_13$

Crystal System: Cubic

Cell Parameters: 10.3345(8) ($x10^{-10}$ m)

(Why) Sol-Gel Synthesis

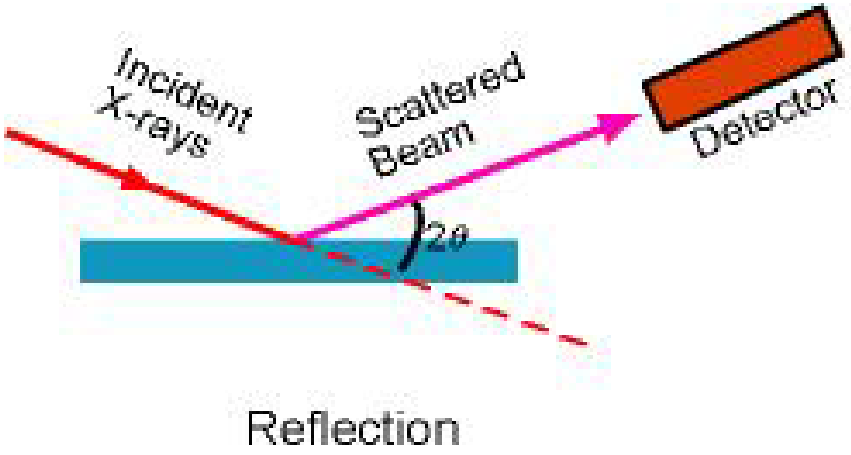


$M(NO_3)_3 + H_3PO_4 \longrightarrow MPO_4 + 3H_2O$

Mill, Heat to 700°C

Adapted from: Brinker and Scherer, Sol Gel Science, Academic Press (1990)

Powder X-Ray Diffraction

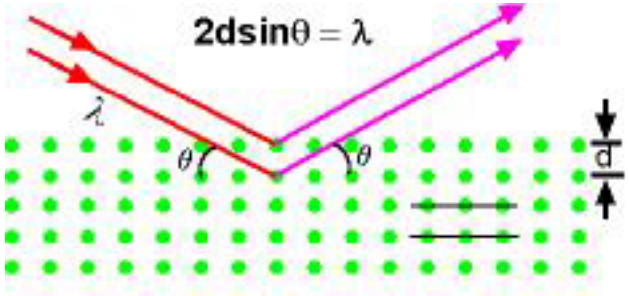


Reflection

http://www.mrl.ucsb.edu/mrl/centralfacilities/xray/xray-basics/Xray-basics.html#x1

Scale:

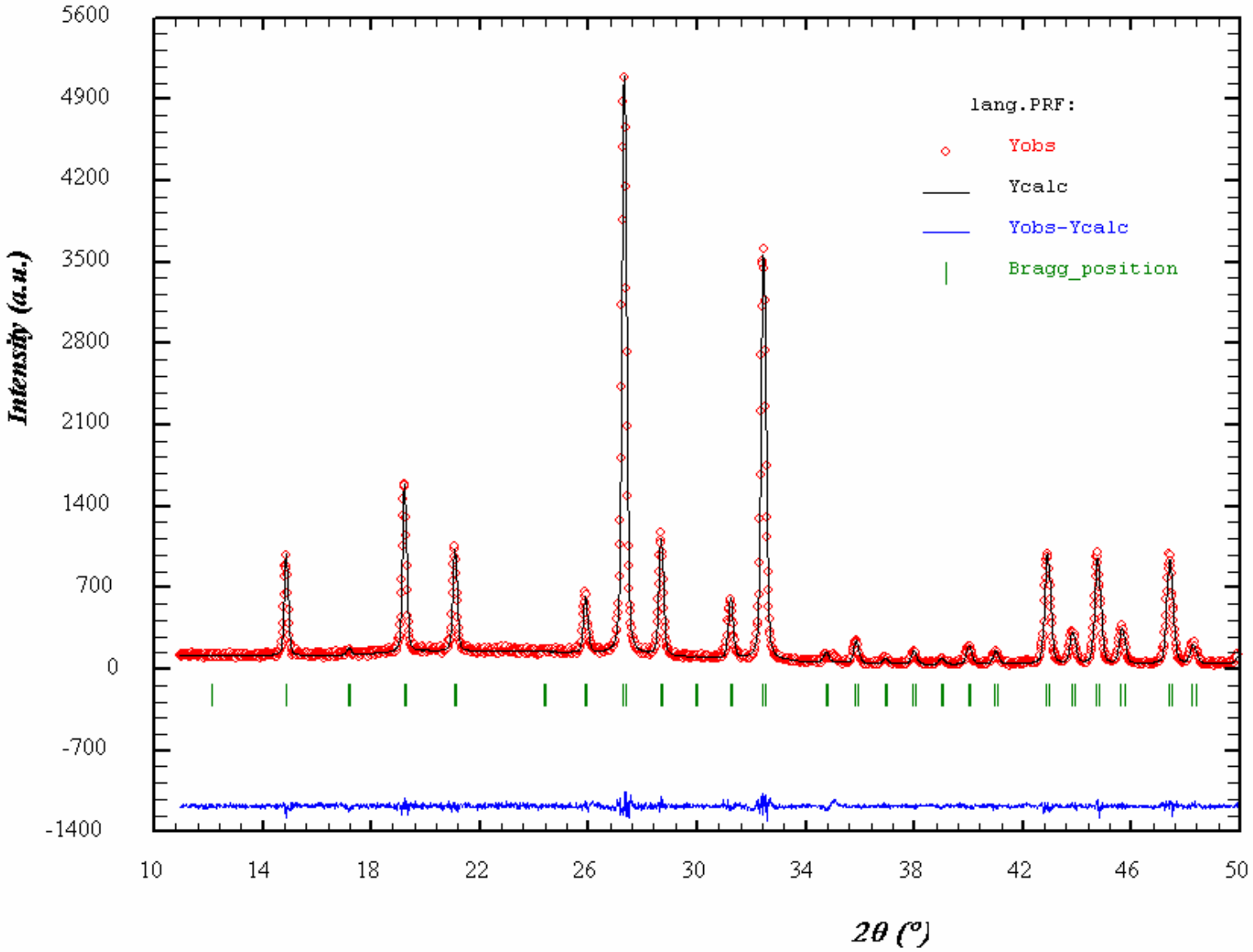
$\lambda_{Cu} = 1.54$ Å



Bragg's Law

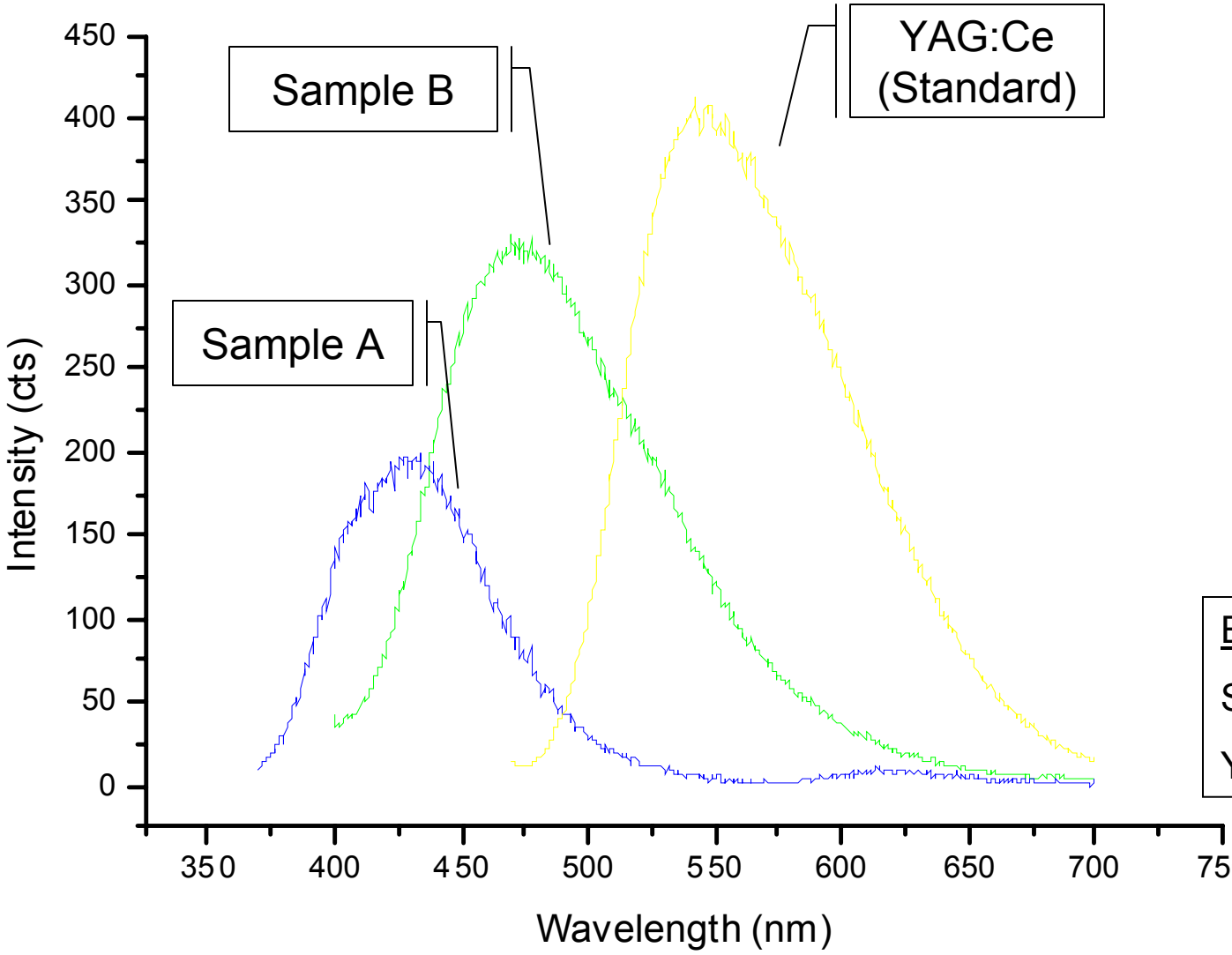
http://www.mrl.ucsb.edu/mrl/centralfacilities/xray/xray-basics/Xray-basics.html#x1

Langbeinite: $K_2YZr(PO_4)_3$, 2% Ce Doped



Sintag X2 Theta-Theta Diffractometer

Luminescence Spectrometer



Excitation:

Samples A&B – 380nm

YAG:Ce – 460nm

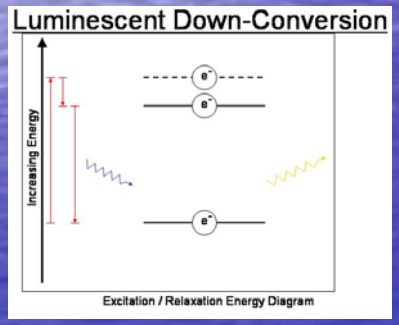
Future Research

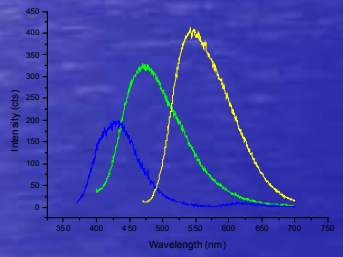
- High efficiency solid state lighting.
- Improved synthesis methods.
- Materials integration.

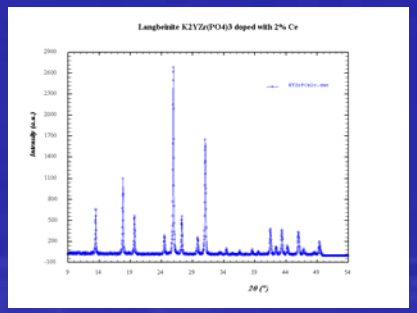
Acknowledgements

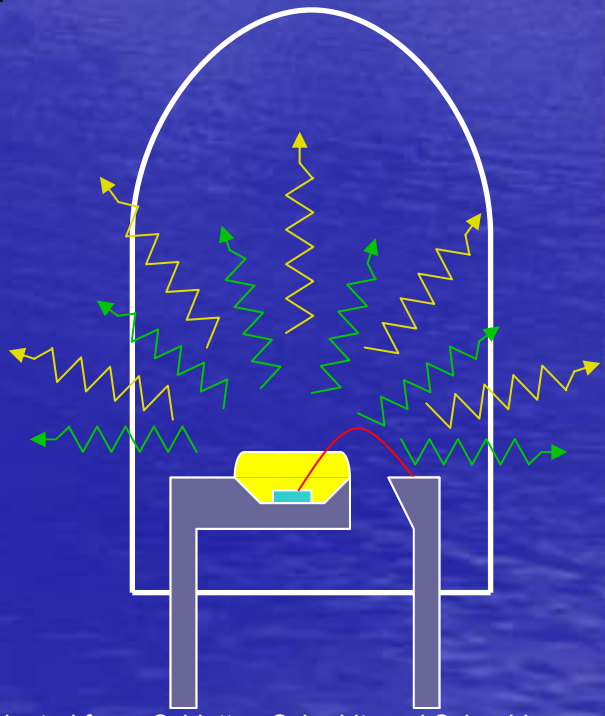
http://science.howstuffworks.com/light6.htm

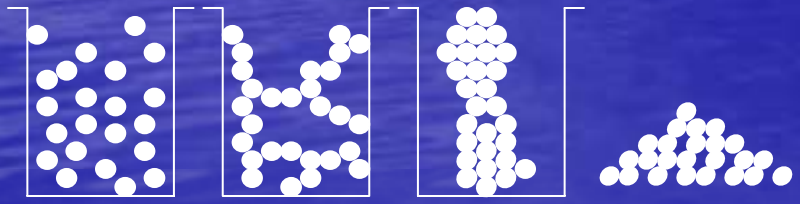
- MRL: Cheetham Group, Joe Doyle
- INSET: Trevor Hirst, Nick Arnold, Mike Northen
- SBCC: Dr. Young, Don Ion











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Relative Efficiencies / Lifetimes:

100 W Incandescent Bulb (~800 h):

17 lu / W

Fluorescent Tubes (~10,000 h):

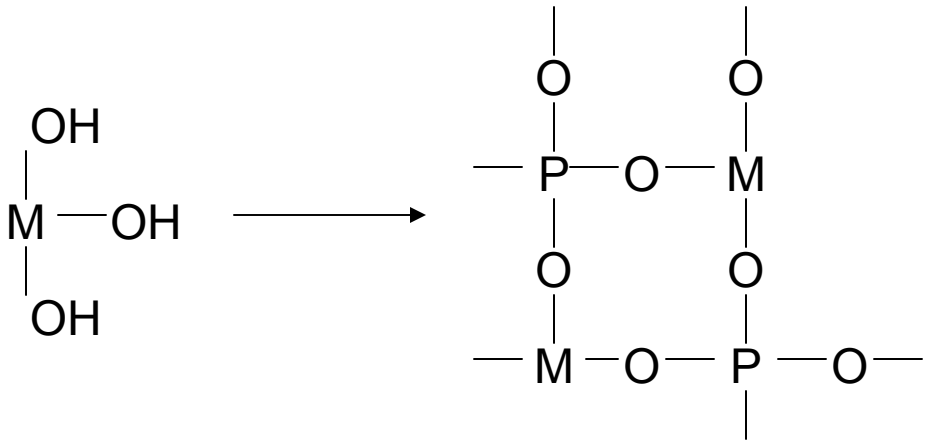
50-70 lu / W

White LUCO LED (~100,000 h):

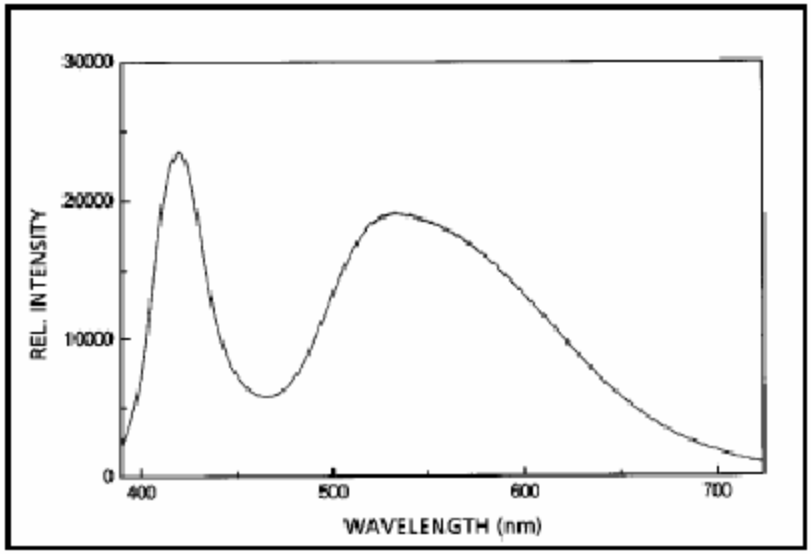
40-50 lu / W (Nichia)

65-74 lu / W (Cree)

Sol-Gel



White LED Spectra



Haaheim, ***A History of Solid State White Lighting***, UCSB (2002)