The Science behind LEDs

IES San Francisco - Emerging Professionals

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Contents

- LED history and source for further reading
- Summary of process of making LEDs
- In depth on practicalities

LED history - over 50 years

SORAA
Simply Perfect Light™

1962 — First LED (red) N. Holonyak, Jr.

1969 — First GaN (polycrystalline) P. Maruska

1986 — GaN on sapphire (monocrystalline) I. Akasaki

1993 — First Blue LEDs / LDs S. Nakamura

1999 — Watt-class White LEDs

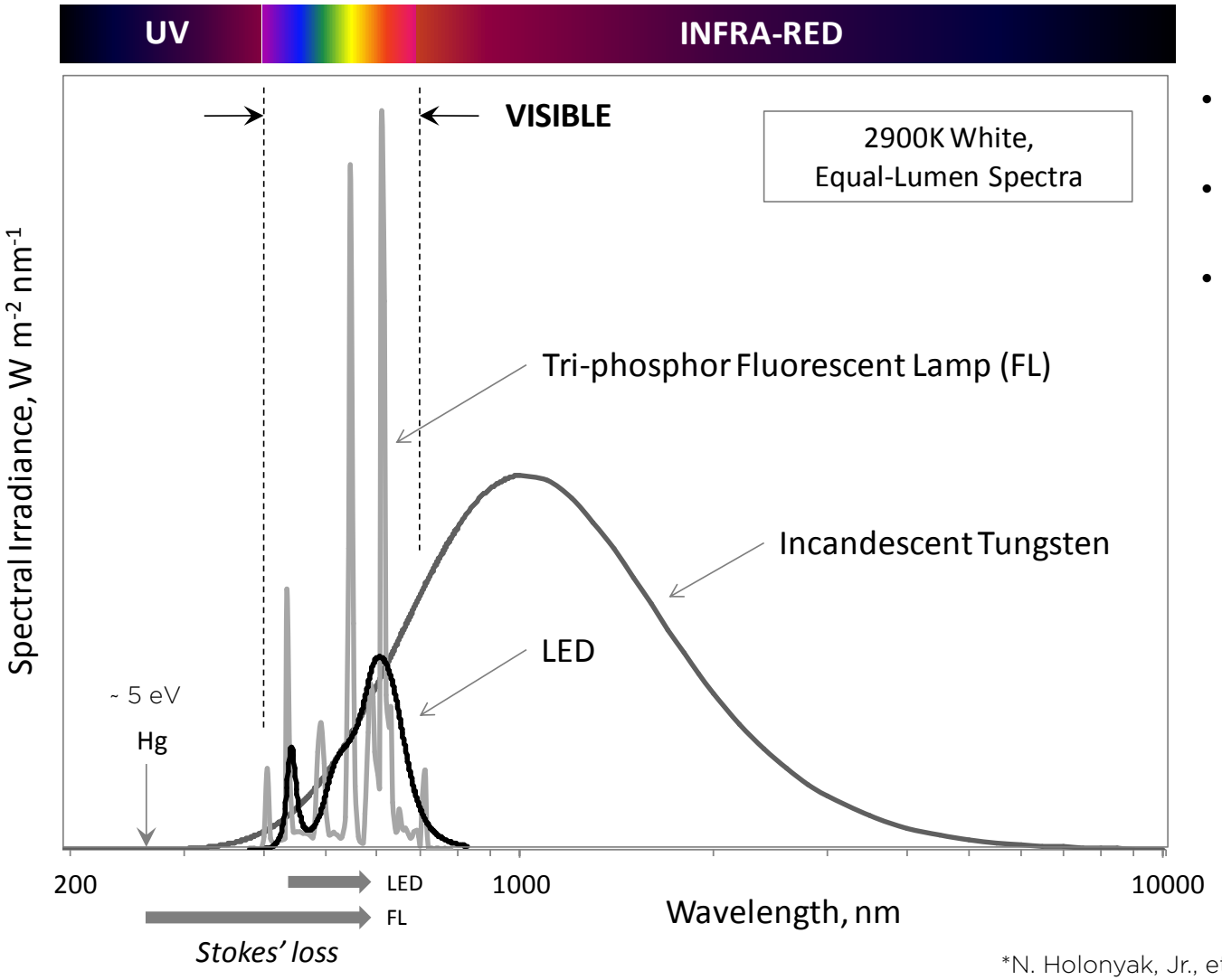
2006 — Bulk-GaN based LEDs / LDs UCSB

2008 — Soraa Founded

2012 — First GaN-on-GaN™ Lighting Product

2014 — Soraa founder awarded Nobel Prize in Physics

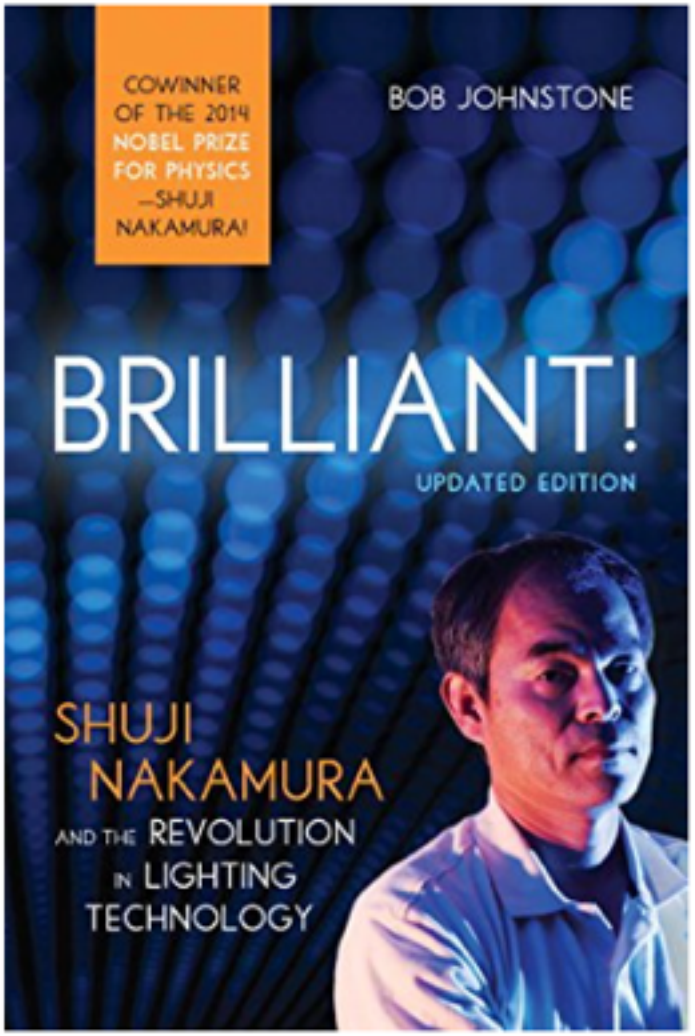
LEDs fundamentally more energy efficient



- Incandescents
  95% heat
- Fluorescents
  Max. efficiency ~ 50%
- LEDs
  "ultimate lamp"*

*N. Holonyak, Jr., et al., *Am. J. Phys.* 68, 864 (2000)

Good LED reading



http://www.nobelprize.org/nobel_prizes/physics/laureates/2014/

Process of making LEDs

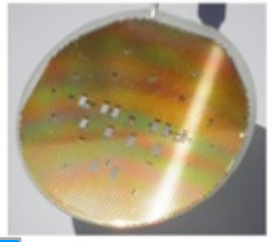
LED substrate

Gasses, Materials

LED Epitaxy

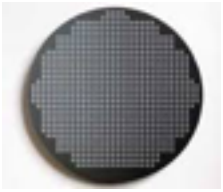
MOCVD

Metals



Wafer Fabrication

Thinning
Etching
Masking
Photo Lithography
Metal Evaporation



Singulation

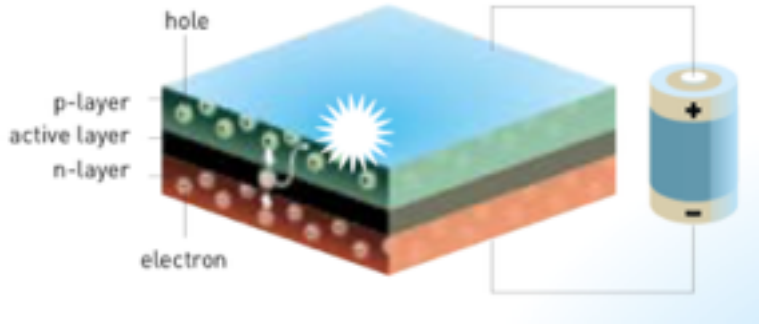
Cutting
Testing
Sorting

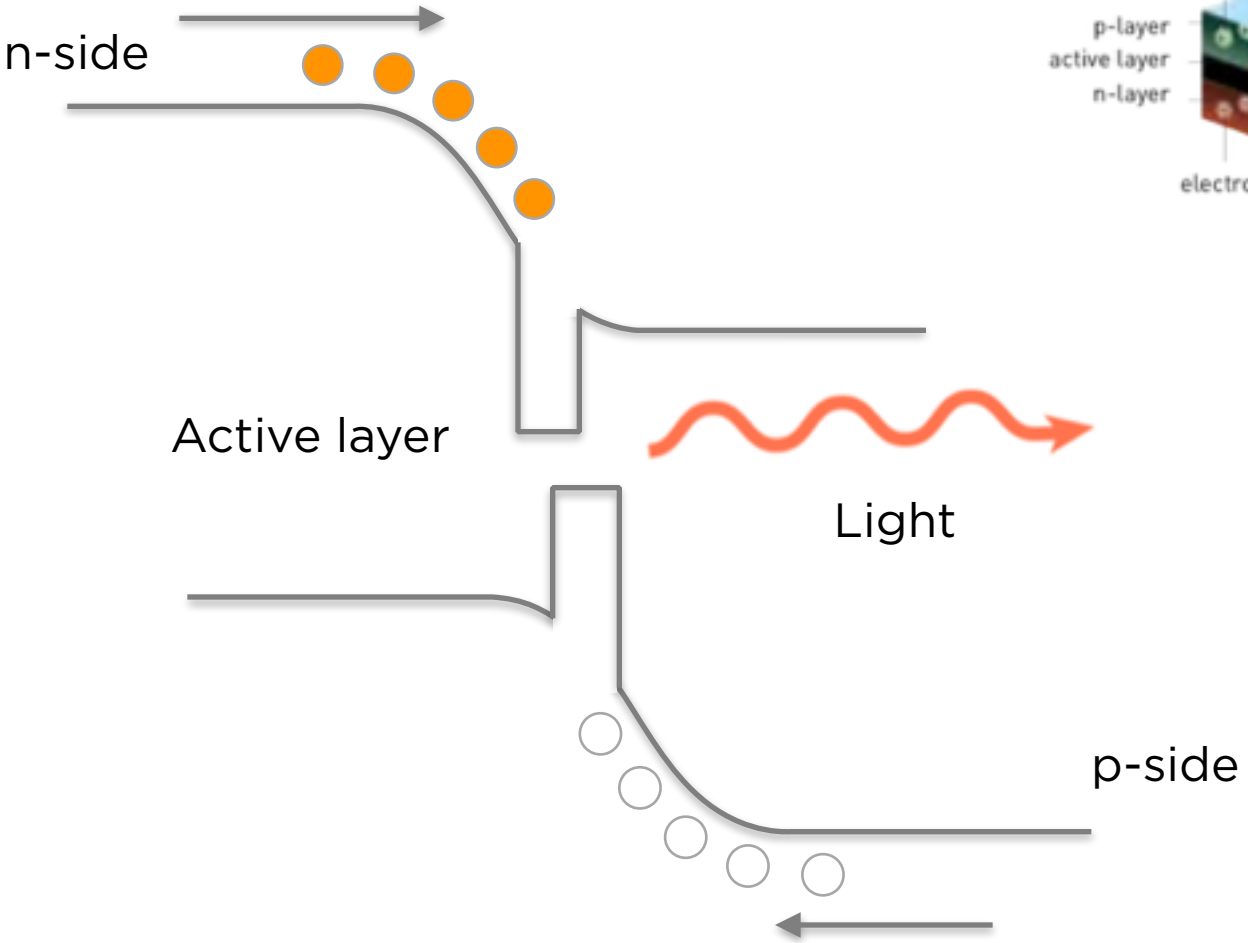
LED Base
Phosphors

LED Package Assembly

Die attach
Phosphor dispense
Test

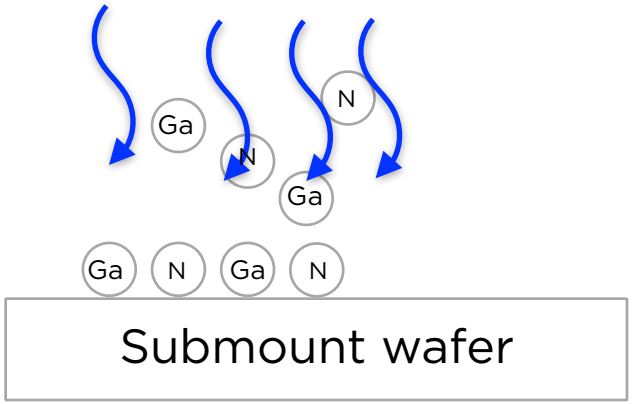
Roller coaster at the heart of the LED





LED Epitaxy - the heart of the LED

- Equipment: MOCVD
- LED materials
  - Gallium
  - Nitride
    - In, Al
- LED wafer sub-mount material
  - Sapphire
  - Silicon Carbide
  - Silicon
  - GaN



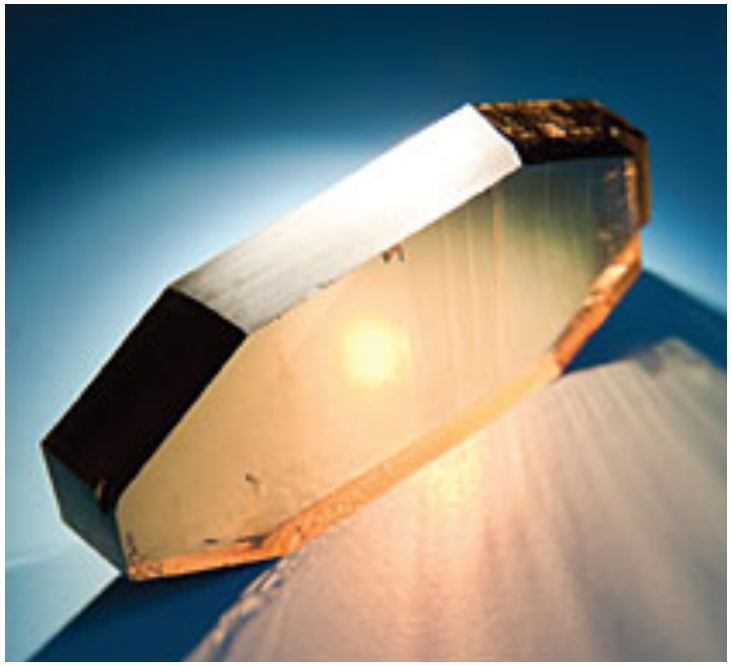
MOCVD

- Very tight process tolerances!

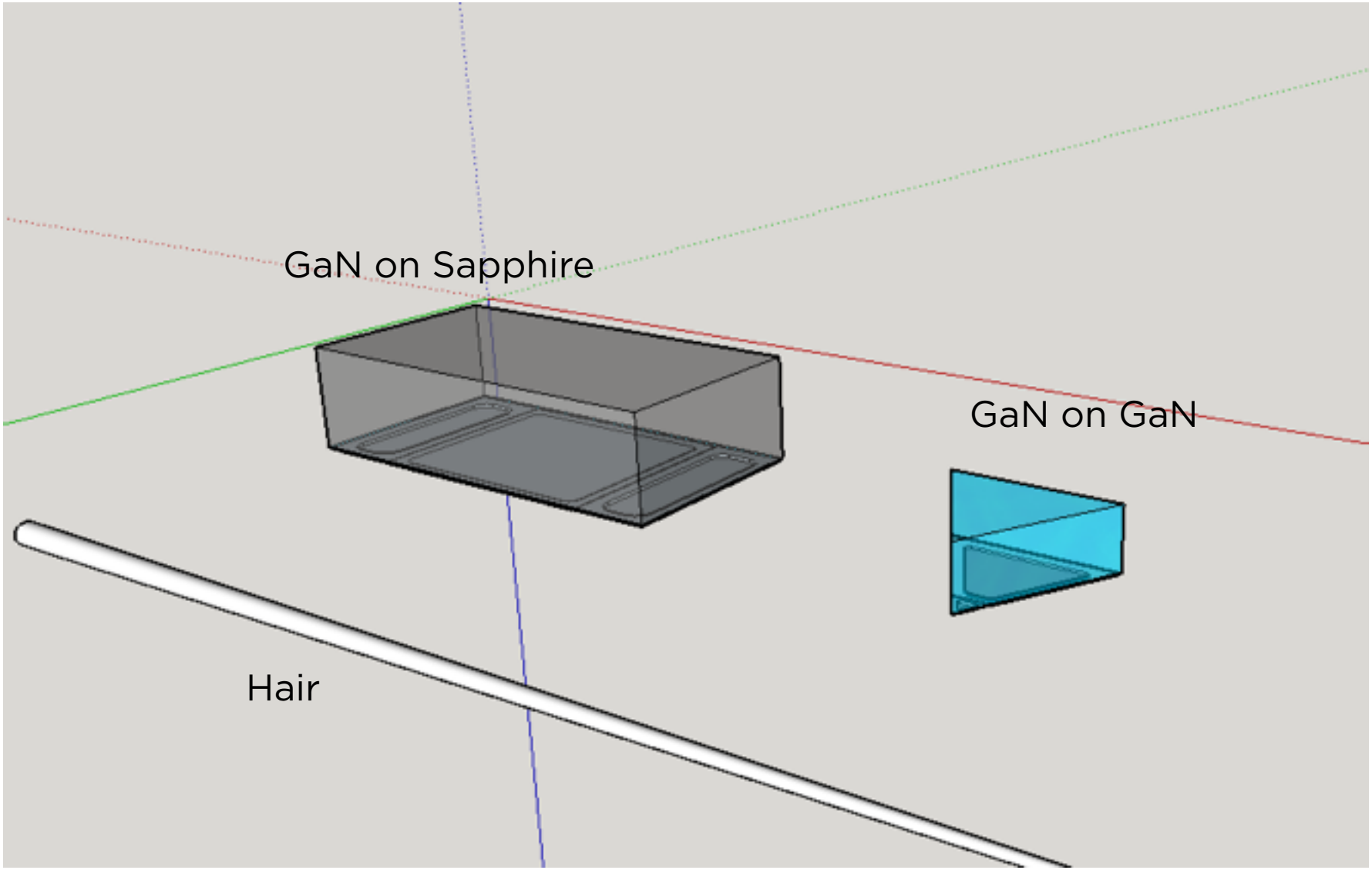
Gallium Nitride - unique material system

- Transparant
- Thermally conductive
- Electrically conductive
- Robust - strong

- Can produce light

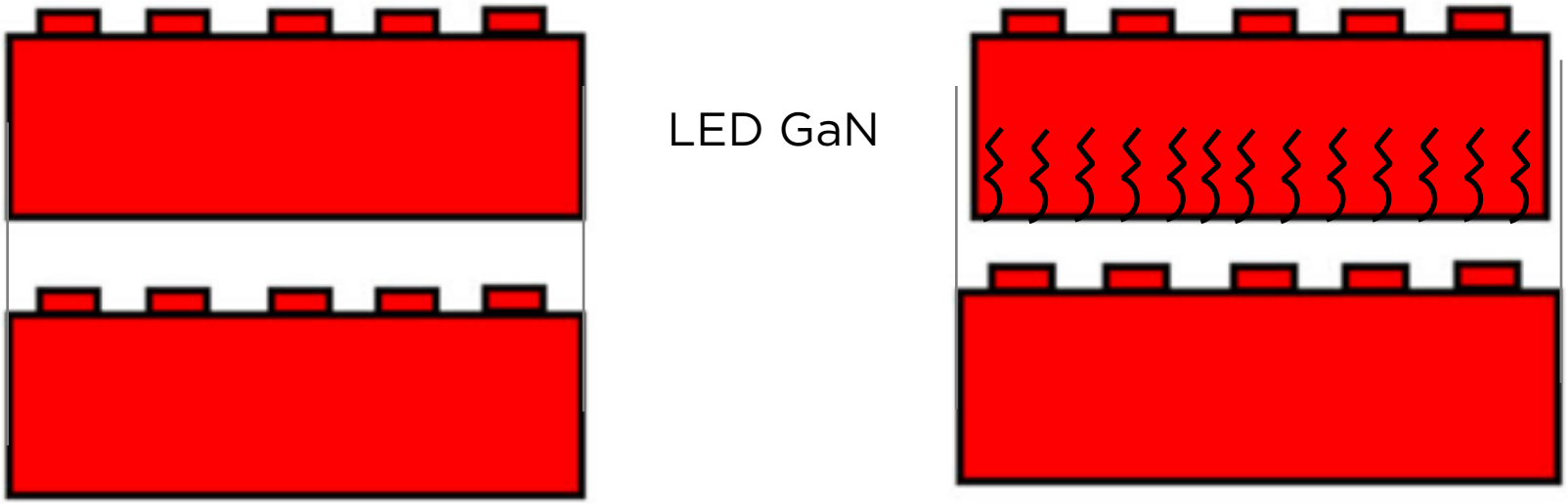


Die examples



Dislocations

- Occur when substrate material and deposition material are not perfectly matched



No dislocations with GaN substrate

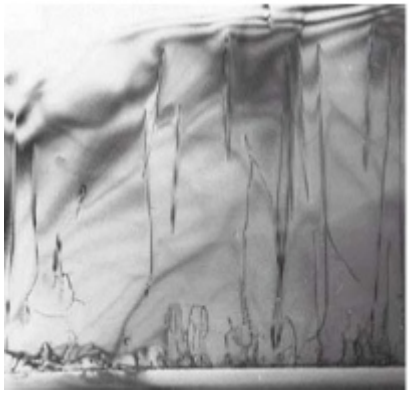
GaN on Sapphire
Hetero-epitaxy

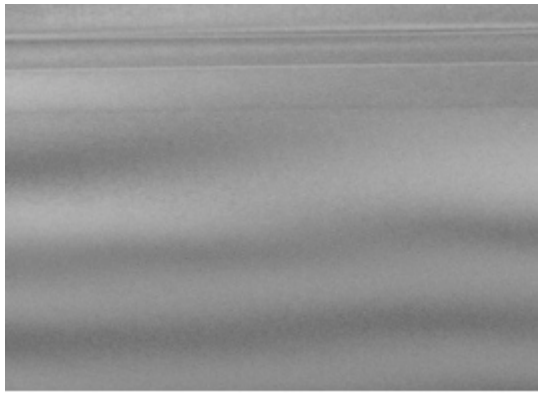
GaN on GaN
Homo-epitaxy

GaN Epitaxy

Buffer layer

Sapphire
Sub mount





GaN Epitaxy

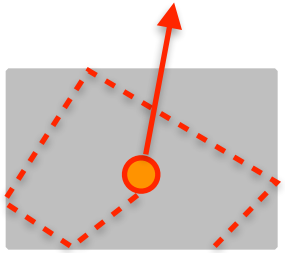
GaN
Sub mount

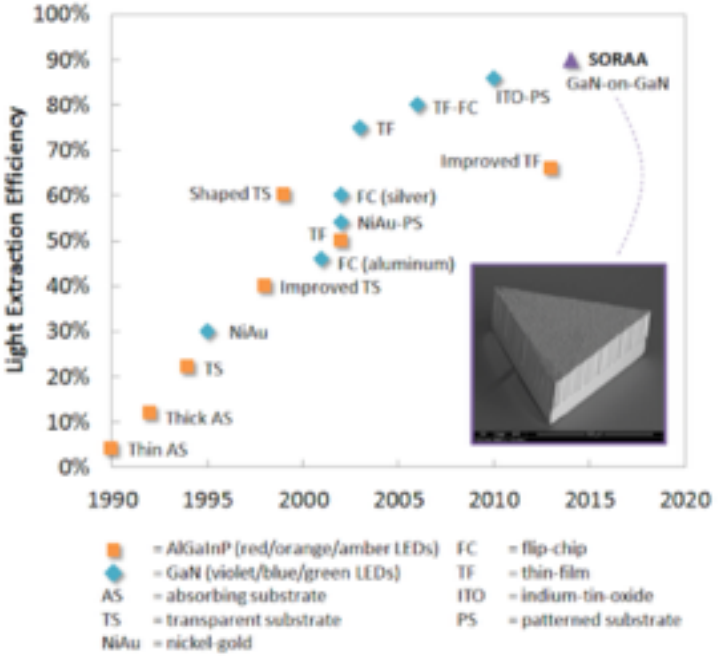
1,000x fewer dislocations

Triangular shape best for light extraction

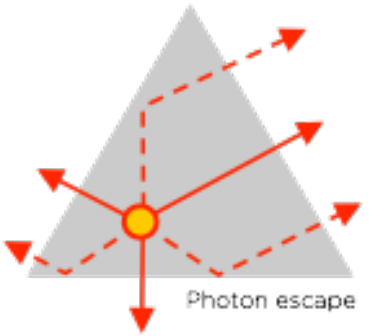
Light needs sharp angle of incidence to escape die

Rectangular Die



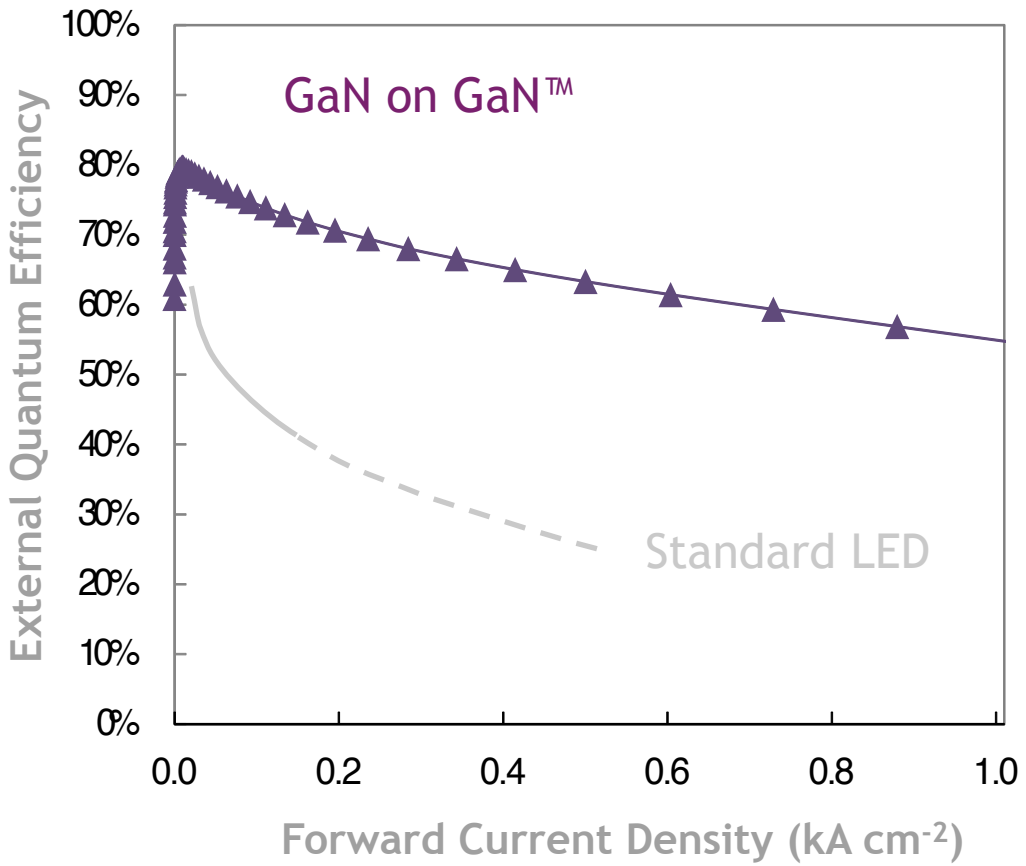


Triangular Die

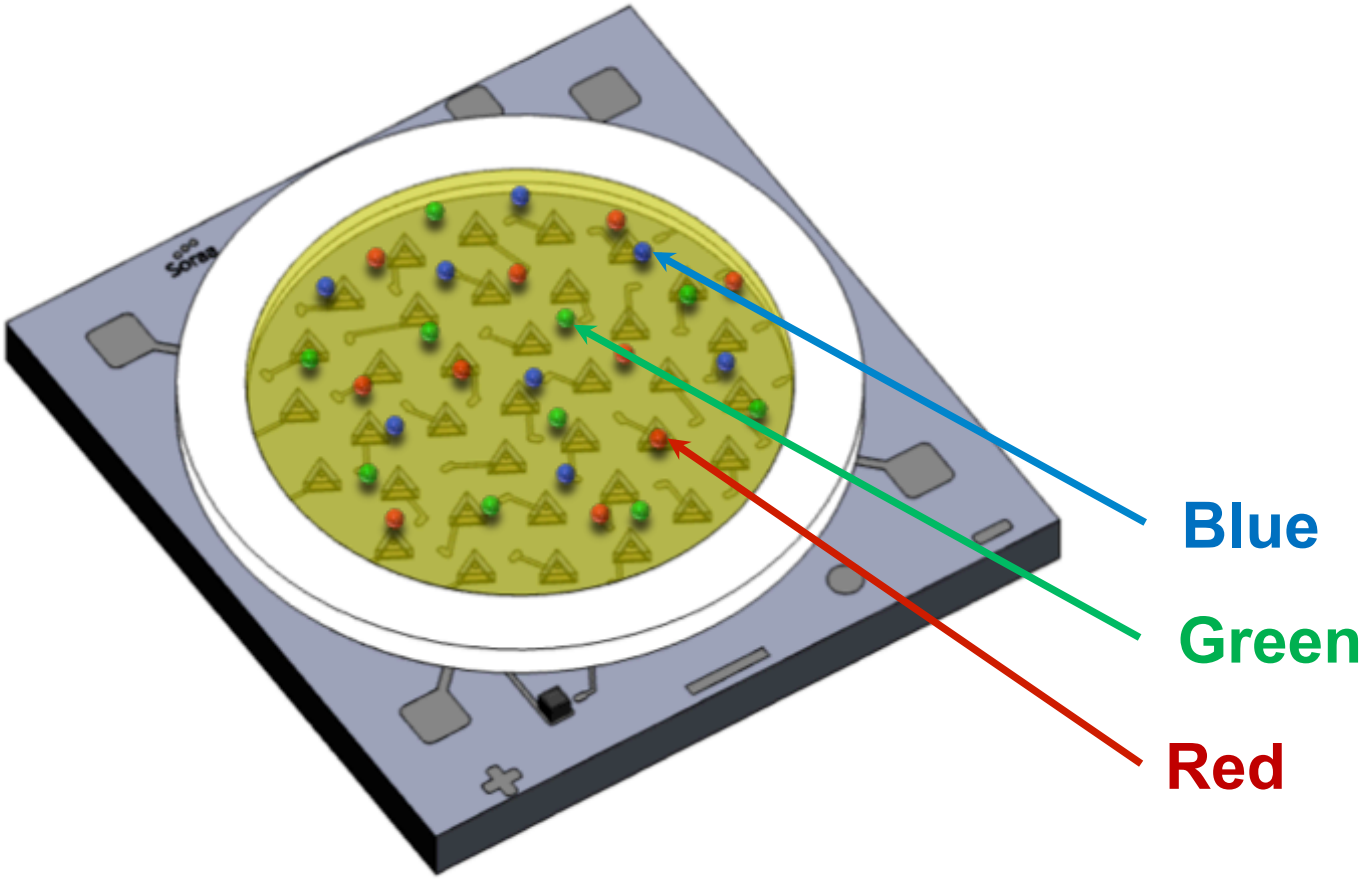


Droop

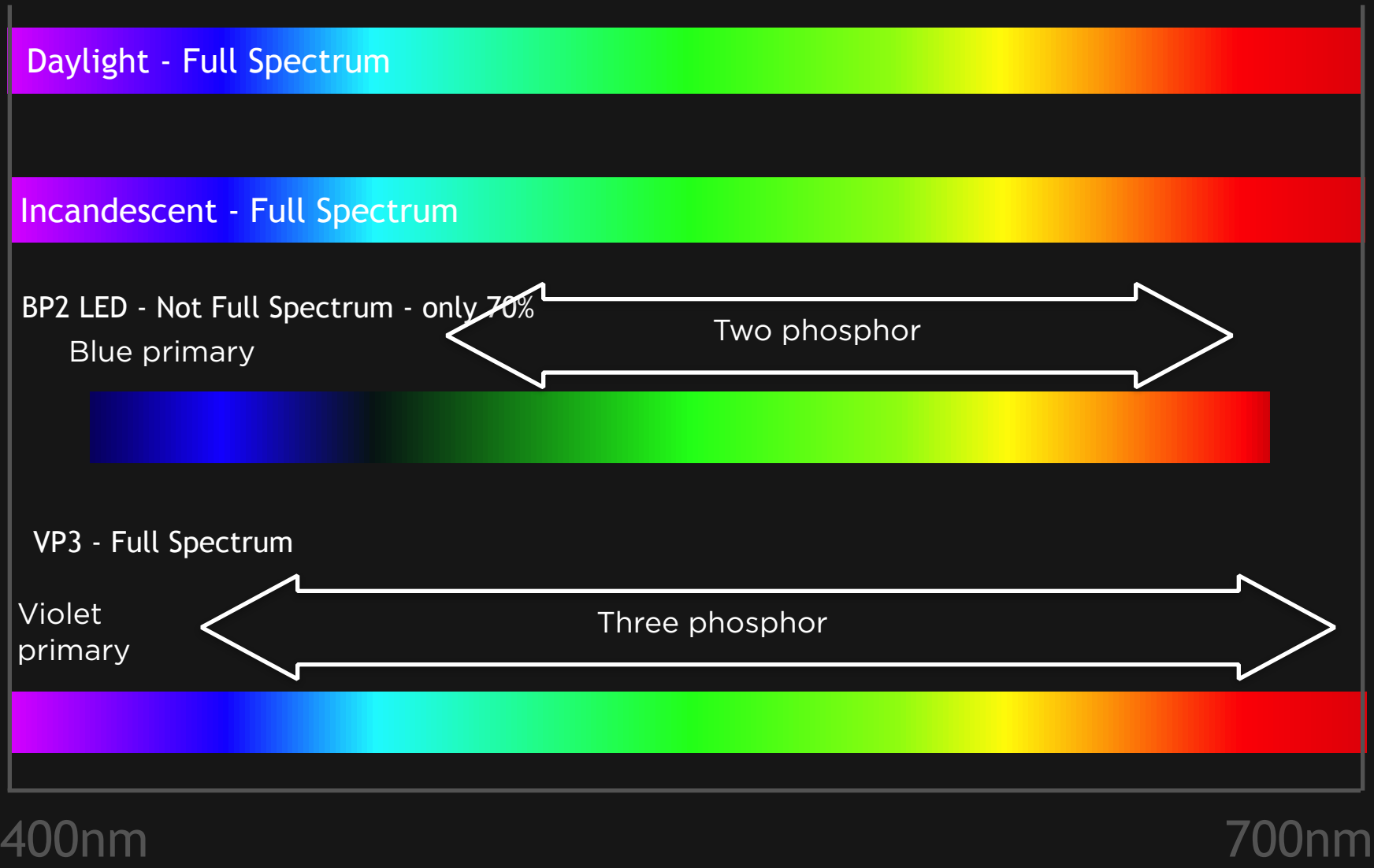
- Lower efficiency when driving more current densities
- GaN on GaN highly efficient at higher currents
- Higher light density - good for narrow beams and directional lighting



Creating white light

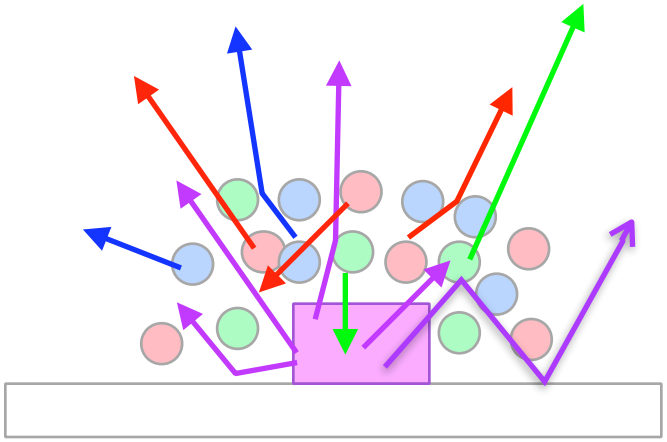


Spectral Distribution -
Full Spectrum Sources vs.
Non-Full Spectrum Sources

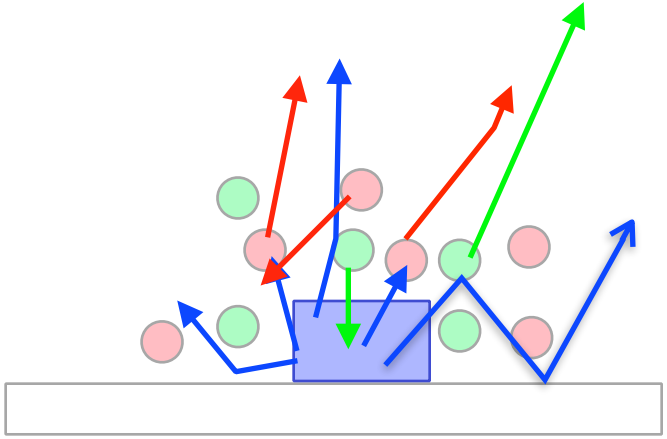


Color Conversion

- Light on its way out
  - Converted to different color when hits a phosphor particle
  - Light can be absorbed by a phosphor particle
  - Can also bounce off a phosphor particle
  - Light is shooting through the phosphor layer in basically all directions
  - We want it to be reflected out - never be absorbed



VP3



BP2

Thank you!