Novel Ultra-High Power LEDs Raising the Bar for UV Curing

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Hg Lamps versus LEDs: It's about the power

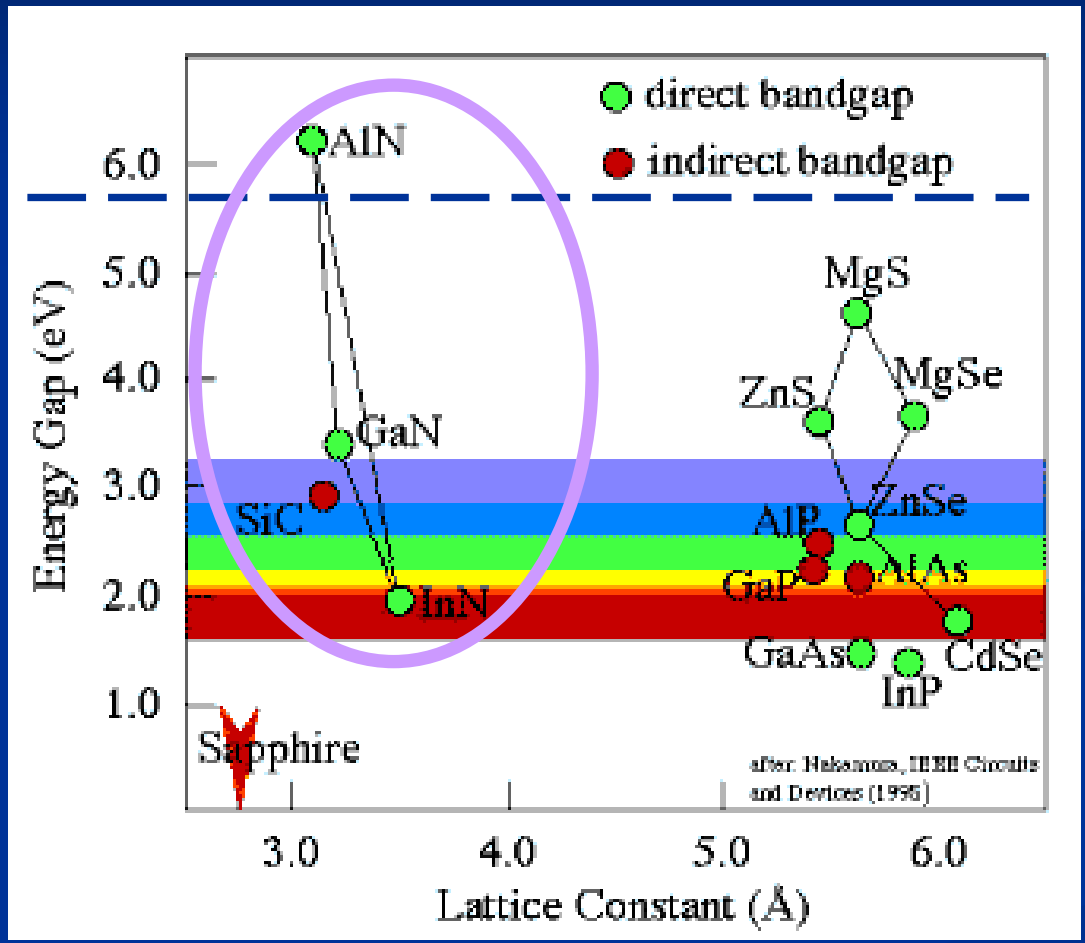
- Hg Lamps generate a lot of UV light from excited mercury atoms
  - They also generate a lot of heat (IR)
  - Limited lifetime, complicating process stability
  - Bulky, fragile assemblies make moving systems more complicated
- LED can generate UV light efficiently with significant advantages over Hg Lamps
  - No IR, no unwanted wavelengths
  - Lower power consumption
  - No Hg
  - Compact, reliable, rugged, lightweight
  - However, very low irradiance and high cost have been barriers for UV LEDs… **UNTIL NOW**

Outline

- LED Basics
- Photonic Lattice LEDs
- Ultra high power LED design
- PhlatLight® UV LEDs – Data
- Summary

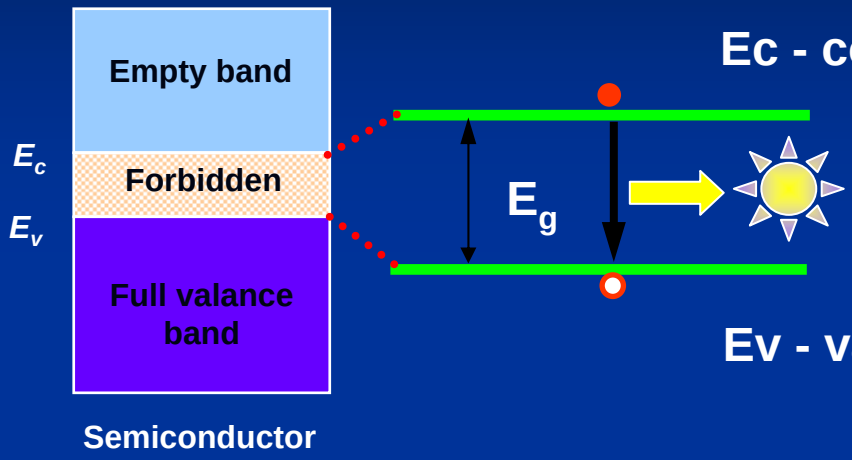
AlN – GaN – InN Materials

UVC to Visible Wavelengths



- Alloy structures comprised of AlN, GaN and InN cover UVA through UVC regions
- Focus on blue LEDs for lighting have led to the optimization of near UV and blue LEDs
- Increasing importance of deep UV applications leading to more R&D in higher power UVA through UVC LEDs

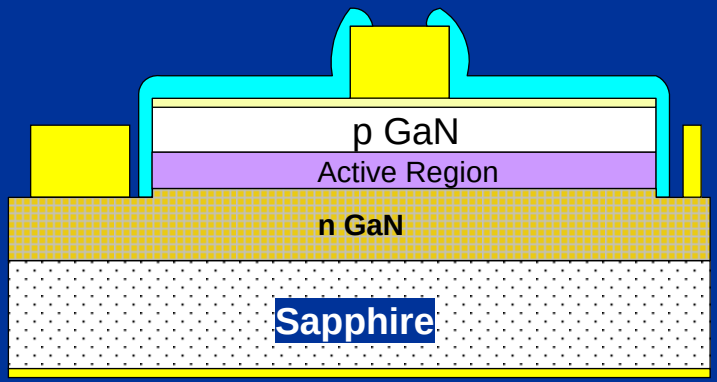
LEDs – Semiconductor Light Generation



Ec - conduction band edge

Engineered, multilayered crystal structure to efficiently convert current to light. Materials used, layer design and crystal quality determine color and efficiency

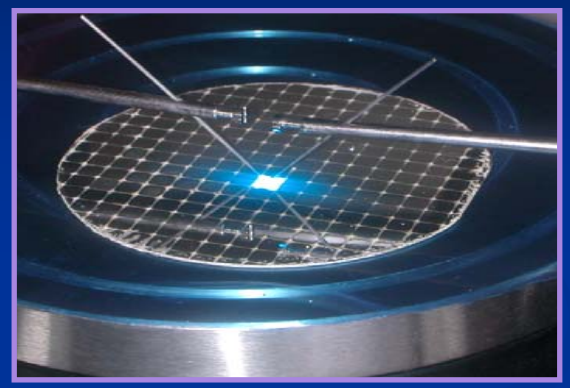
Ev - valance band edge



- **The LED generates light in the active region – light is emitted in all directions**
- **The composition of the active region determines the LED wavelength**
- **Today, most LEDs are small, low power chip designs like the one shown**

LEDs – New designs for higher power operation

- New designs are emerging that work well at higher power
- These new designs are typically vertical, metal bonded types
  - More efficient light extraction
  - Better thermal performance
- Applied to power chips, typically about 1 mm^2 and inside a larger power package with a lens
- UV Power Output is still low, **<1W per LED**



PhlatLight™ technology: High Power Solid State LEDs

- **PhlatLight™ = Photonic Lattice** Light Emitting Diodes
  - An intricate microstructure embedded in the LED
  - Efficient, uniform, collimated light extraction from the chip surface
  - Enables ultra-high power large area devices

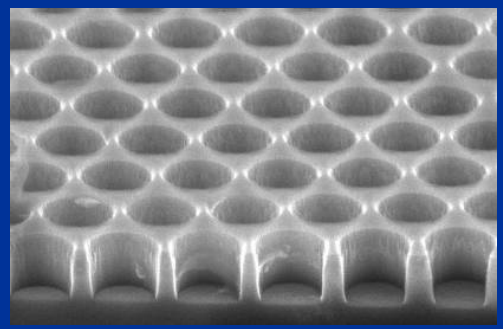
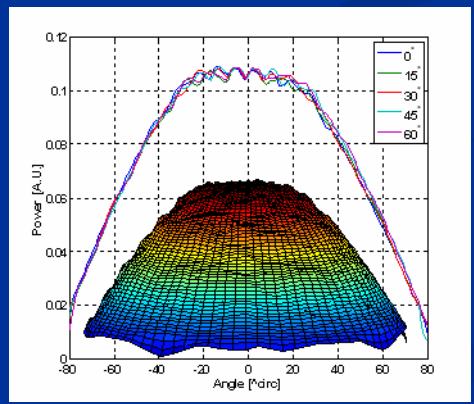
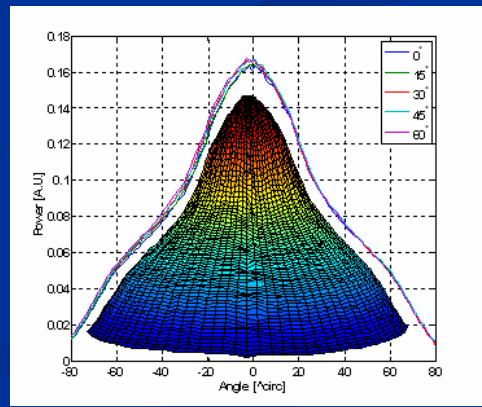


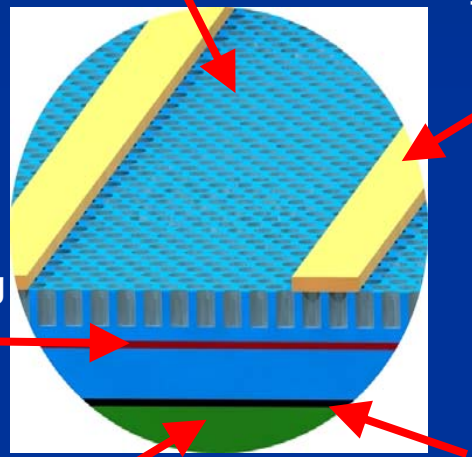
Illustration of a photonic lattice pattern





Lambertian vs. collimated light output

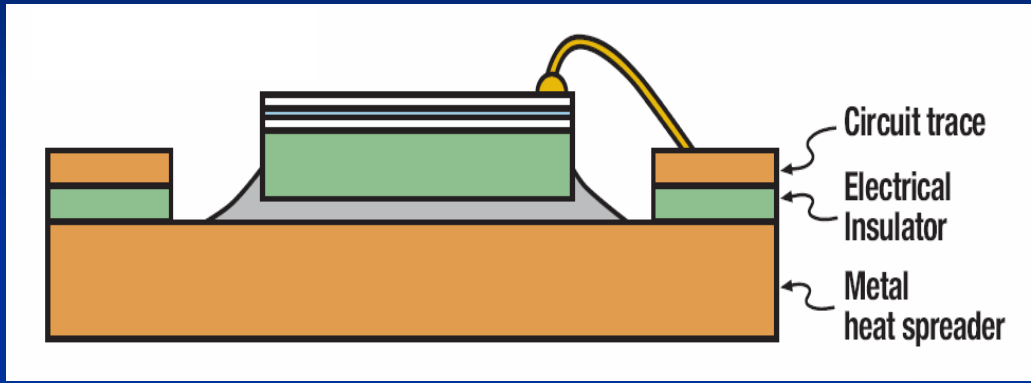
Device Construction – another view

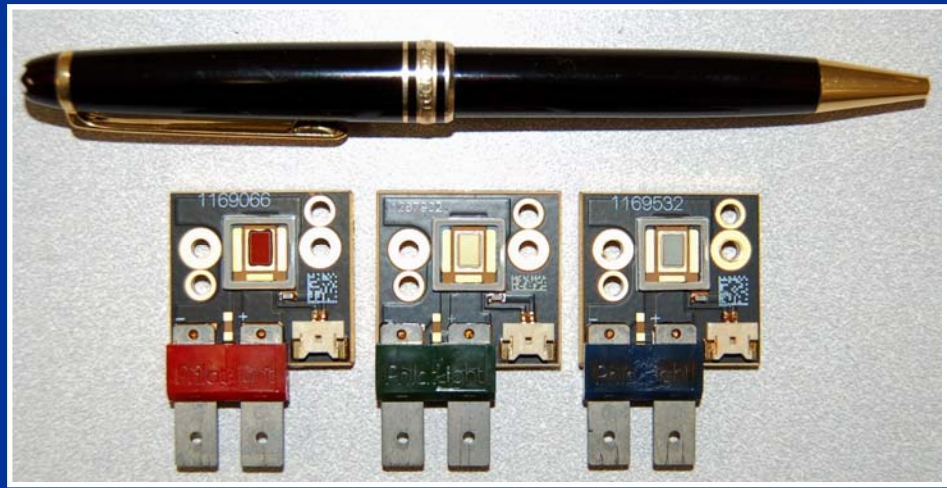


- The Photonic Lattice extracts light efficiently directly into air
- No performance penalty for very large chips
- No encapsulation required
- Collimation possible without a lens
- Optical output powers measured in Watts

Packaging for high power operation

- Very high power operation (up to 90 W)
- Very good thermal performance
- Air cavity package
  – no issues with UV
- **Irradiance levels that rival high power Hg lamps!!!**





PhlatLight LED reliability (in the visible) is proven

- This LED technology is inherently reliable
  - No encapsulants which can fail
  - 60,000 hours to 70% power reduction
- Fully qualified in several product launches
  - Luminus and customer qualification programs
  - Full suite of mechanical and environmental tests
  - High power and high current operation
- > 2 million hrs actual device hours lifetime testing
  - Continuous current and pulsed
  - Most under accelerated conditions

PhlatLight LEDs are ideal for UV applications

- A scalable large area chip technology
- Breakthrough electrical and thermal “vertical” chip design
- High reliability under extreme operating conditions
- No encapsulation – ideal for high performance operation from UVA through UVC

Large-area chip instead of multi-LED arrays
More Irradiance than with array approaches

Ultra-high Power UV LEDs

PHLATLIGHT® UV High Power LEDs

PRELIMINARY DATASHEET

LUMINUS

- Very high UV flux from a large monolithic chip
- Photonic lattice technology for high efficiency and high power operation
- Chip surface power density over 80 W/cm^2 without concentrating optics
- Instant On/Off
- ROHS Compliant packaging
- Ultra-low thermal resistance for very long life and stable operation

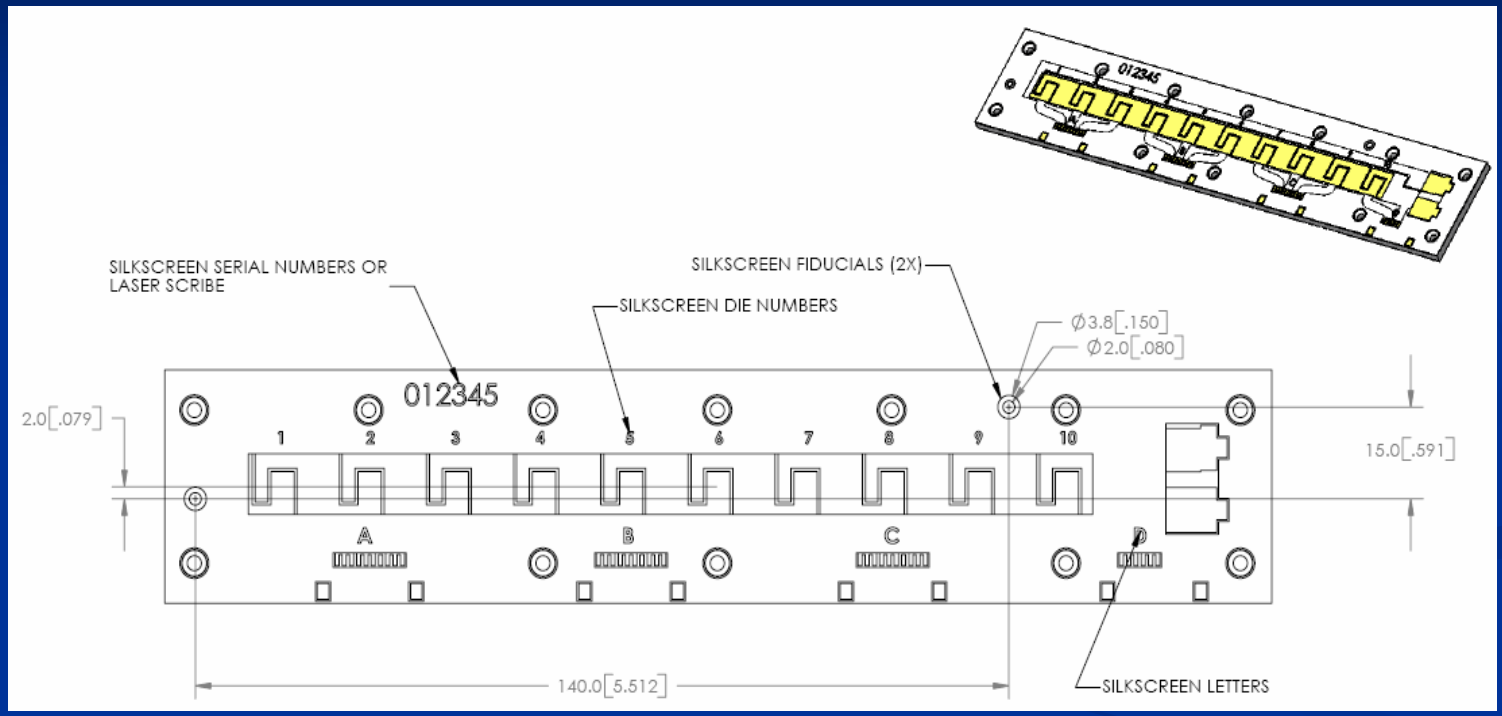
SUMMARY TABLE

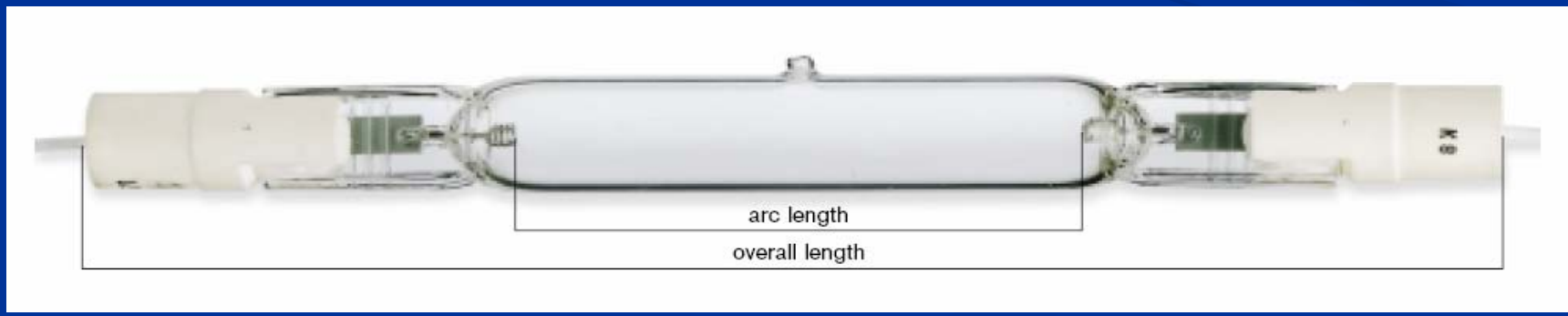
Parameter	Unit	Wavelength	
		380 nm	400 nm
Drive Current	A	18	
Forward Voltage	V	4.3	
Radiant Power	W	5	10
Irradiance*	W/cm^2	40	80
FWHM	nm	15	

NOTES:

- For best comparison to real world operating conditions, test data is reported for continuous operation in thermal equilibrium
- Irradiance is reported for measurement at the chip surface. Suitable optics can achieve up to 50% of the chip surface levels at distances of up to 30 mm from the package
- Shorter wavelength devices are under development

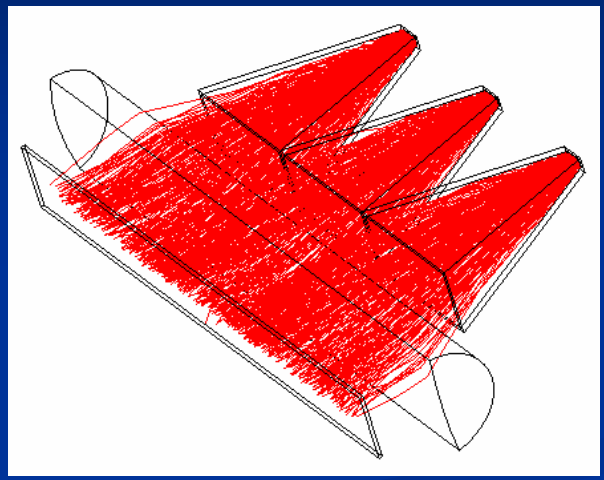
UV Large Die Array for Hg Lamp Replacement
(in development)

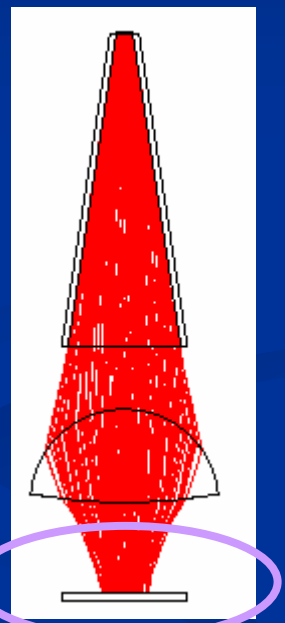




High Irradiance Optical Design (to mimic an Hg lamp)

- Design: Taper and relay lens
  - Light emitted from LED (high angle) is collected and reduced to a low angle
  - Simple relay lens reforms image onto curing area
- Benefits:
  - Simple 2-3 component
  - High Irradiance
  - Good uniformity along irradiated strip





Estimated Irradiance at work surface	
380 nm	20 W/cm²
400 nm	40 W/cm²

Summary

- Luminus Devices PhlatLight™ LEDs are designed to generate very high UV output power from a single chip
- High power operations up to 2.5 A/mm^2 with excellent reliability
- Enabling compact, very high irradiance UV curing solutions
- UV prototypes available now with irradiance levels rivaling Hg lamps in a single chip, compact format
- Shorter wavelengths and new packaging formats under development for a wide range of UV curing applications