Research and Manufacturing Synergies Between LEDS and PV

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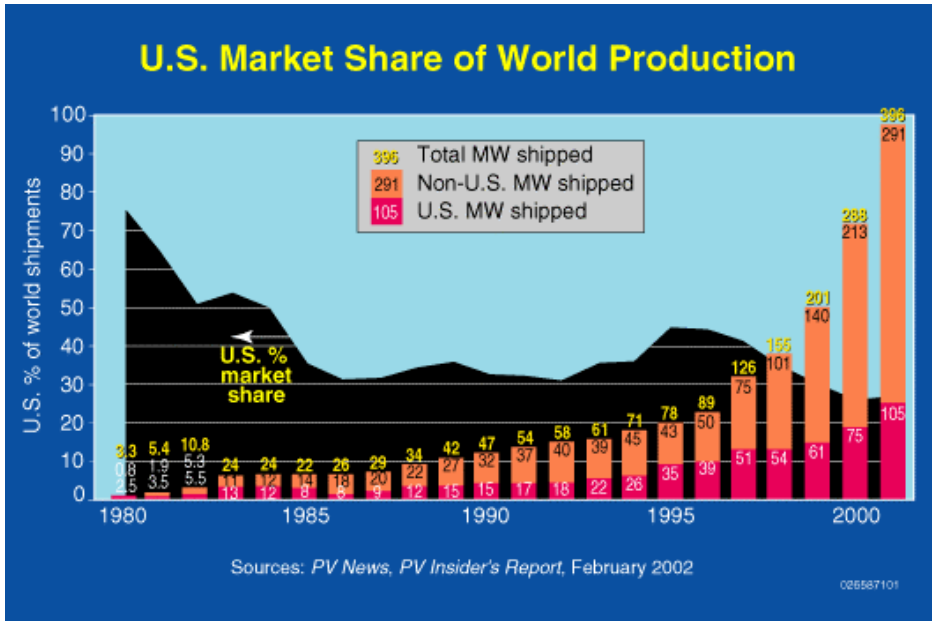
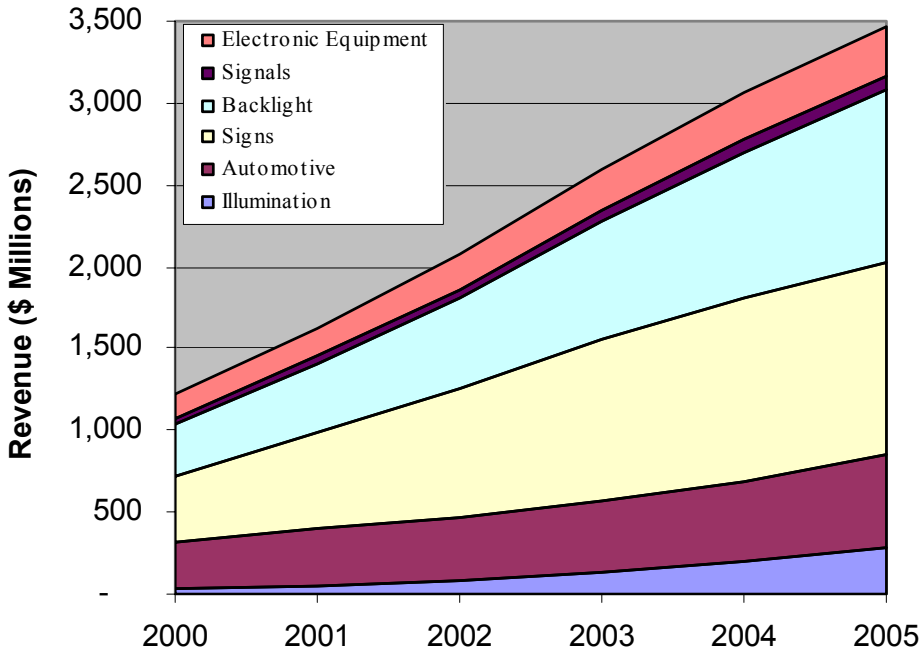
PV and LED Markets





Current Industry Size ~ $2.5B

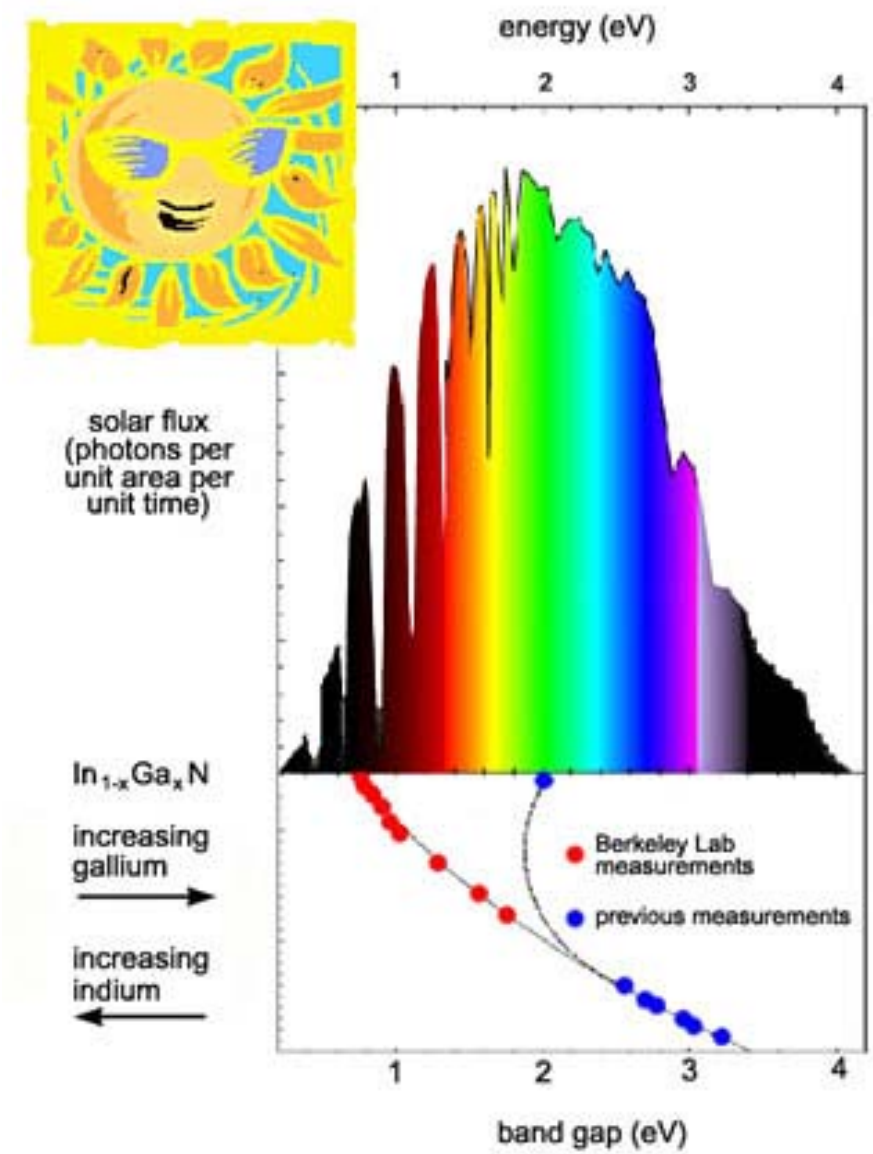
Current Industry Size ~ $2B

Source: PVMAT Program

Source: Strategies Unlimited

One Big Happy Family: PV and LEDS

Berkeley Claim



Theoretical Efficiencies:

2-Junction Solar Cell	50%
3-Junction Solar Cell	56%
36-Junction Solar Cell	72%

High Brightness LED Market Place

400nm 420nm 470nm 525nm 590nm 626nm

Applications

Illumination

Display/Signage

Automotive

Mobile

Consumer

Die (13mil) ASP

AlInGaP	AlInGaN	AlInGaN
$0.02	$0.2	$0.1

Mobile Applications Growth Will Drive Significant Cost Reductions in Nitrides

Power Requirements:

	Now	12months
Blue Keypad	2.5mW	3.0mW
Blue Backlight	3.5mW	4.5mW

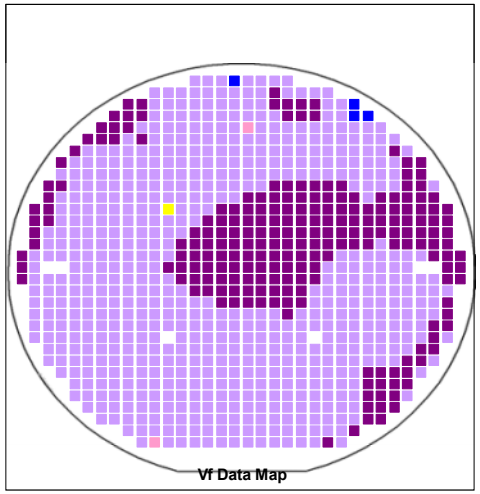
Tolerances required:

	Now	12months
Power:	+-0.25mW	+-0.15mW
Forward Voltage:	+-0.2V	+-0.1V
Wavelength:	+-2.5nm	+-1.5nm

* Driven by high quality white for full-color display backlighting

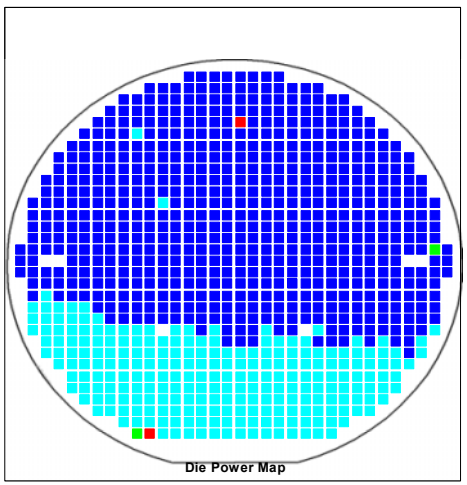
Nitride Wafer Performance Distributions

Forward Voltage



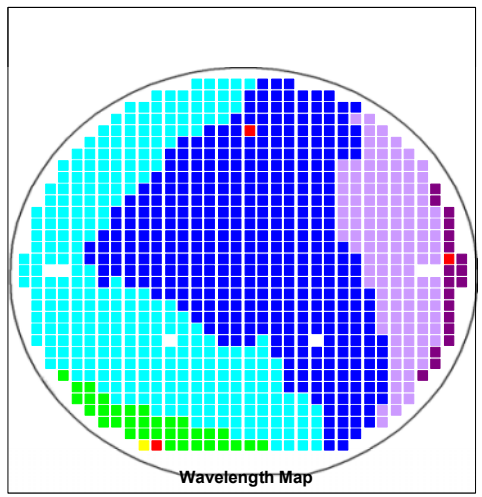
Spec. Max.:	3.97 V
95 %:	3.25
Median:	3.21
5 %:	3.18
St Dev.:	0.13
% Yield:	100.00%
< 3	3.4 - 3.5
3 - 3.1	3.5 - 3.6
3.1 - 3.2	3.6 - 3.8
3.2 - 3.3	3.8 - 3.97
3.3 - 3.4	> 3.97

Optical Power



Spec. Min.:	0.3 mW
95 %:	2.63
Median:	2.44
5 %:	2.02
St Dev.:	0.22
% Yield:	99.77%
< 0.3	2.3 - 2.8
0.3 - 0.8	2.8 - 3.3
0.8 - 1.3	3.3 - 3.8
1.3 - 1.8	3.8 - 4.3
1.8 - 2.3	>4.3

Dominant Wavelength



nm	% Yield
460-462.5	0.00%
462.5-465	2.23%
465-467.5	14.67%
467.5-470	44.60%
470-472.5	34.04%
472.5-475	3.99%
475-477.5	0.12%
477.5-480	0.00%
Other	0.35%
80% range: 466.7 - 471.7	

National Lighting Initiative Technology Targets

Year	*2002*	*2007*	*2012*	*2020*
Luminous Efficacy (lm/W)	*25*	*75*	*150*	*200*
Lifetime (khr)	*20*	*>20*	*>100*	*>100*
Flux (lm/Lamp)	*25*	*200*	*1000*	*1500*
Cost ($/klm)	*200*	*20*	*<5*	*<2*
CRI	*75*	*80*	*>80*	*>80*
Lighting Market Penetration	*Low-Flux*	*Incande-scent*	*Fluore-scent*	*All*

Scientific Challenges For High Efficiency, Low Cost LED Lighting

LED cost/performance needs to be improved by >50x to compete in the general illumination (150 Lumens/Watt, CRI>90)

State-of-the-art:

Efficiency

400nm	30%
470nm	25%
550nm	8%
590nm	10%
610nm	48%

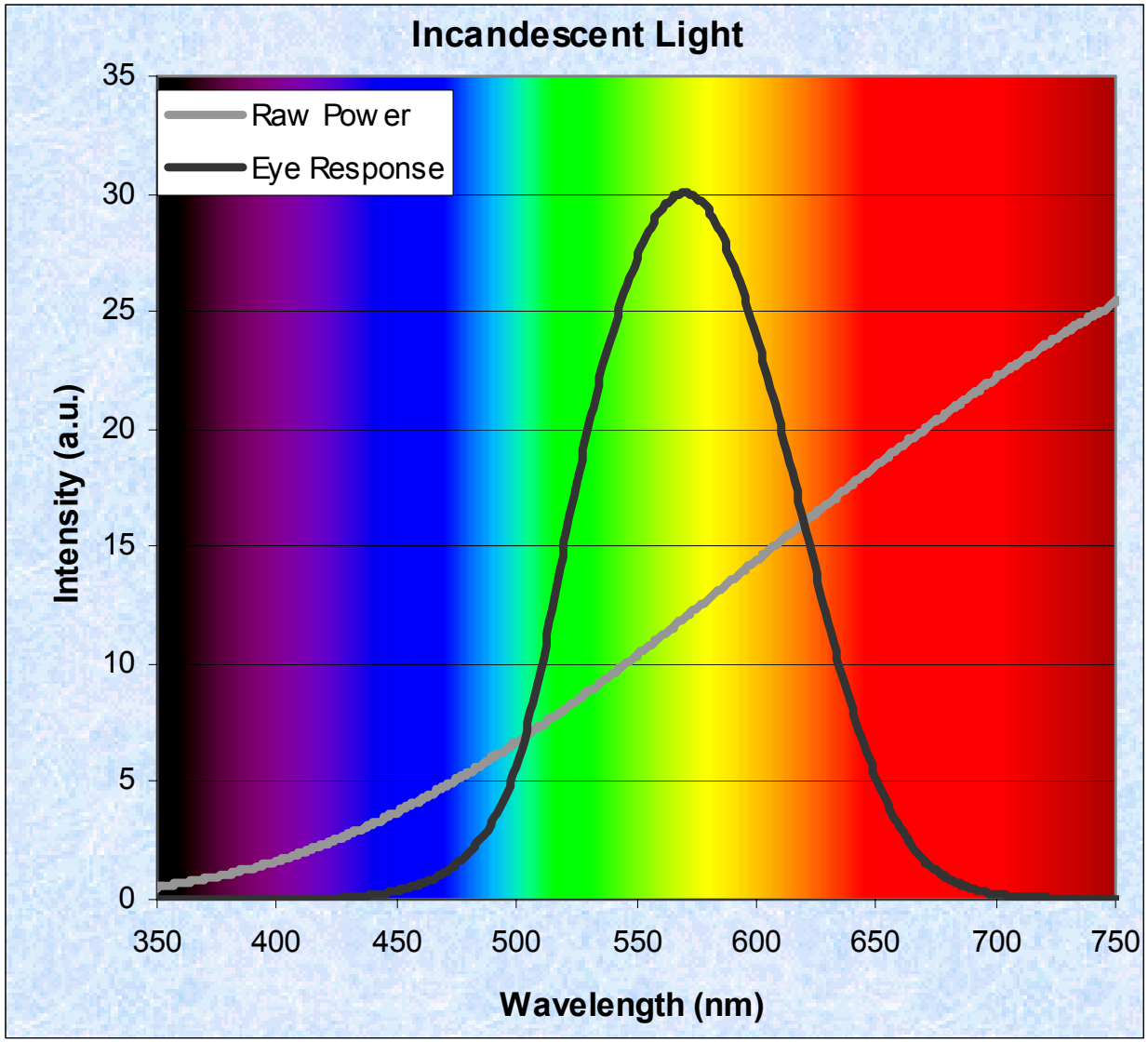
CRI

B-LED + Y-Phosphor	60-75
RGB LED	80+
UV-LED + RGB-Phosphor	90+
B-LED + RG-Phosphor	90+

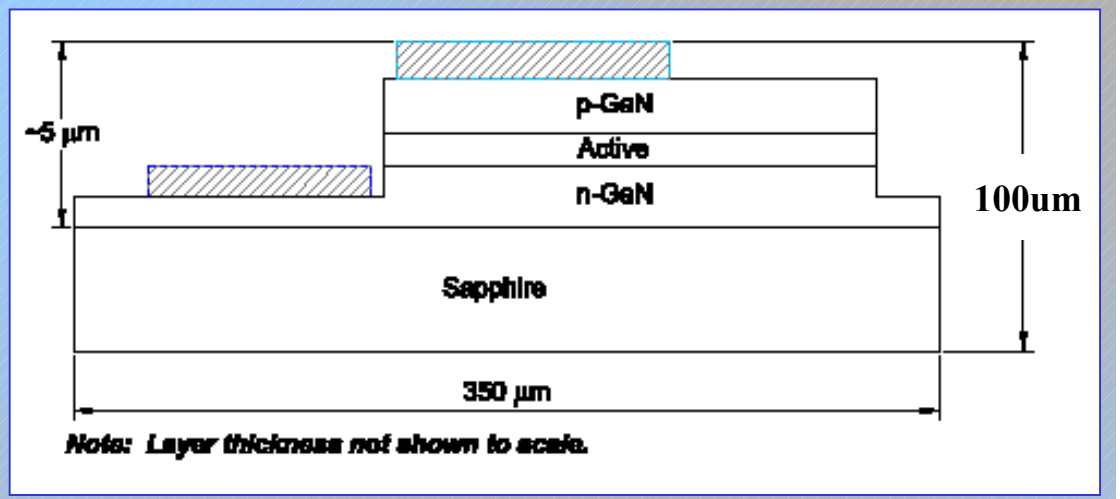
Nichia White
1.5 Lumens/Lamp
$0.5/Lamp

1000 Lumens = $333

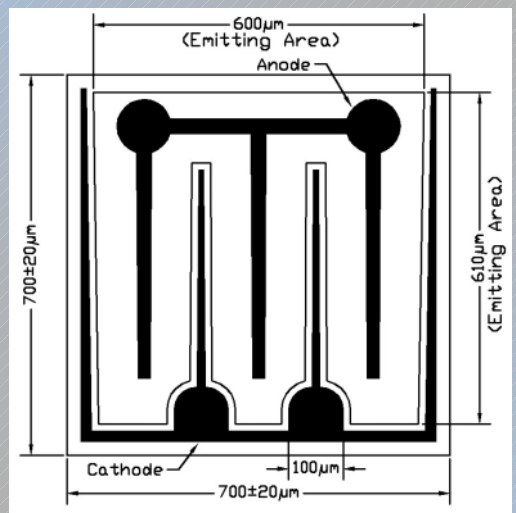
Incandescent Lighting Technologies

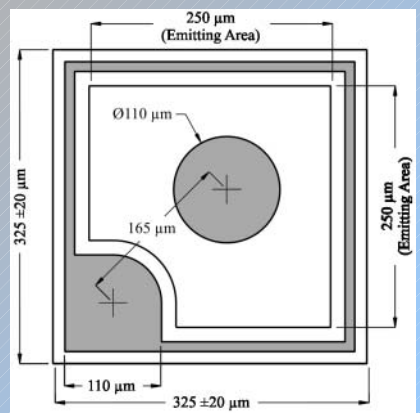


Standard AlInGaN Die Geometries



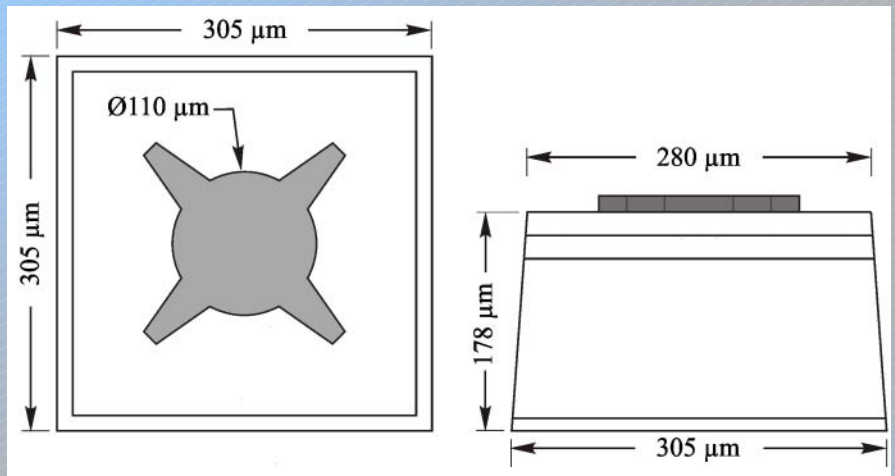
p-GaN	0.5um
InGaN/GaN	4-10 wells
n-GaN	2- 4um





Standard AlInGaP Die Geometries

POWER-BR(ite)™ AlInGaP Epi Structure

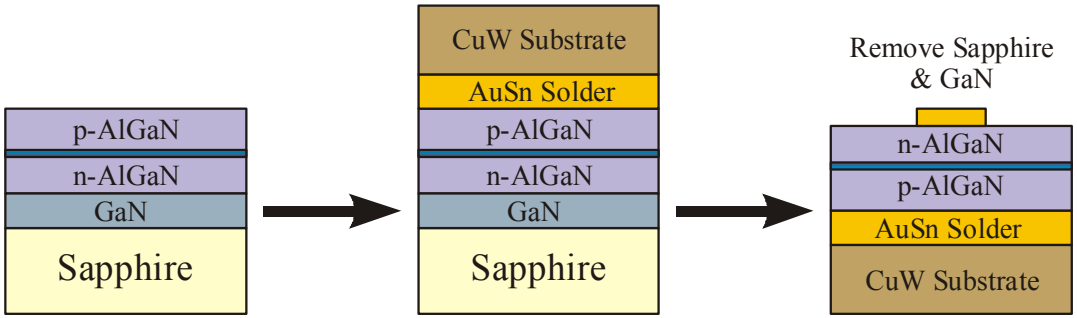


P- GaP Window
p-clad
GaInP MQW
n-clad
n-DBR
GaAs Substrate

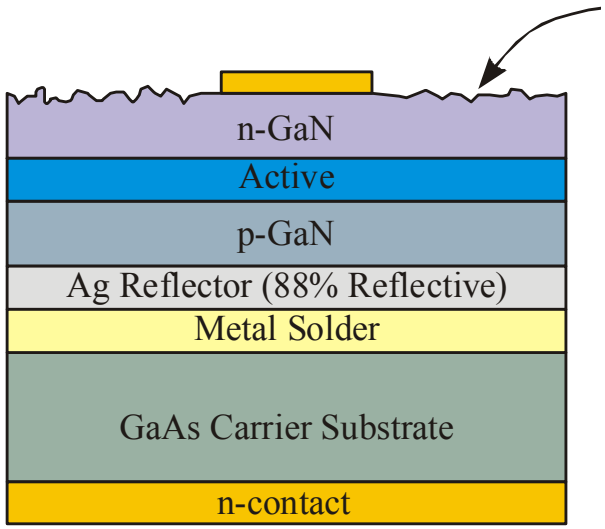
305 x 305 x 178 µm
(.012 x .012 x .007 inch)
or
(0.016x0.016x0.007 inch)

State-of-the-Art in AlInGaN Chips

Latest Nichia Structure (61 lm/W)



Latest OSRAM Structure



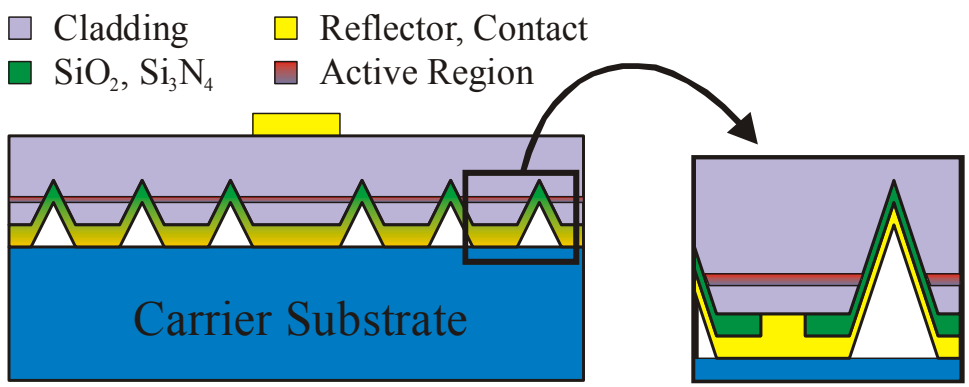
Novel Features:

Single Top/Bottom Contact
Substrate Release
Integrated Heat Sink
Integrated Reflector Layers
Integrated Light Extraction Layers

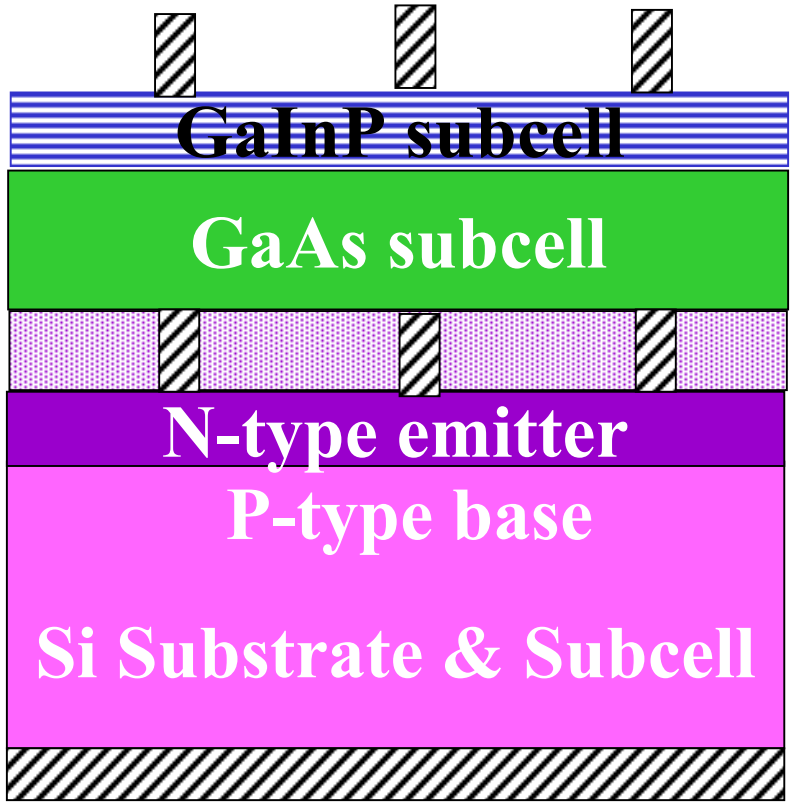
State-of-the-Art in AlInGaP Chips

LumiLeds

OSRAM



State of the art Concentrator Cells

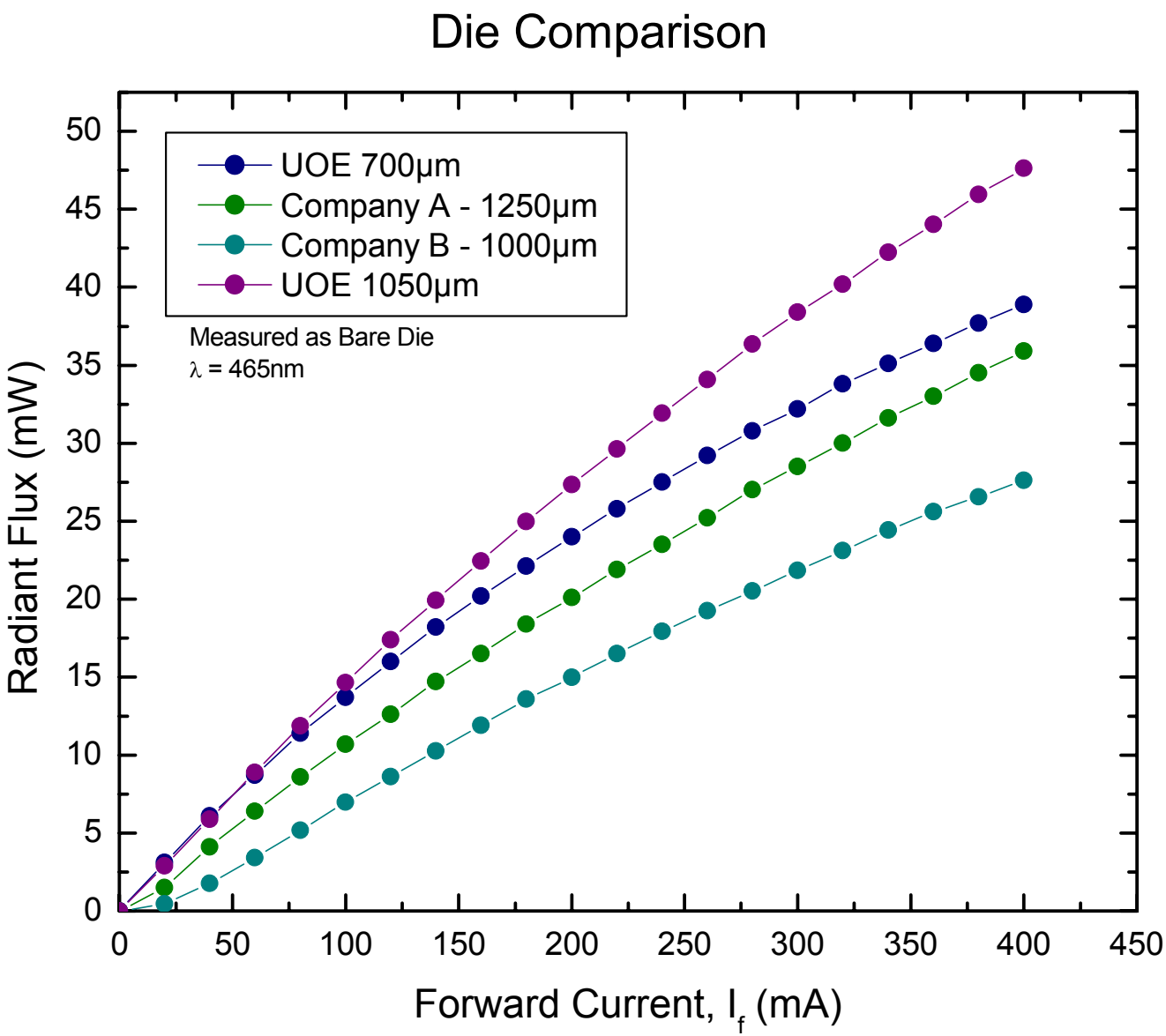


Source: Spectrolab, Inc (Sherif, King)

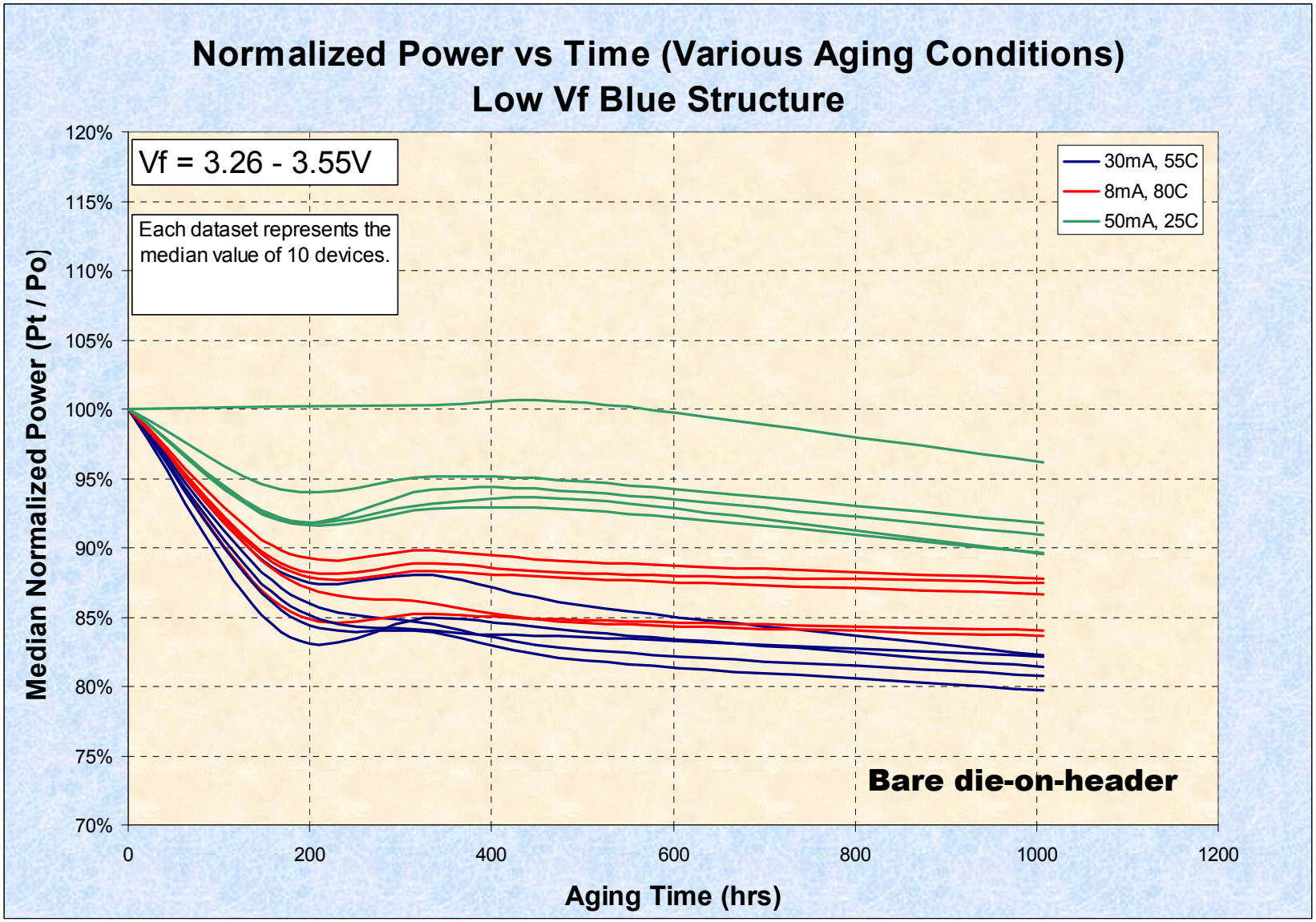
Areas of Overlap and Needed Exchange

* Most overlap in concentrator technologies
  - High Current
  - Encapsulation, AR coatings, Passivation,
  - Automated Visual Inspection
  - Thermal / mechanical modeling and Design
  - Wafer Bonding, Substrate Release
  - MOCVD Source Efficiencies, Reactor Modeling, In-Situ Diagnostics
  - Reliability Physics

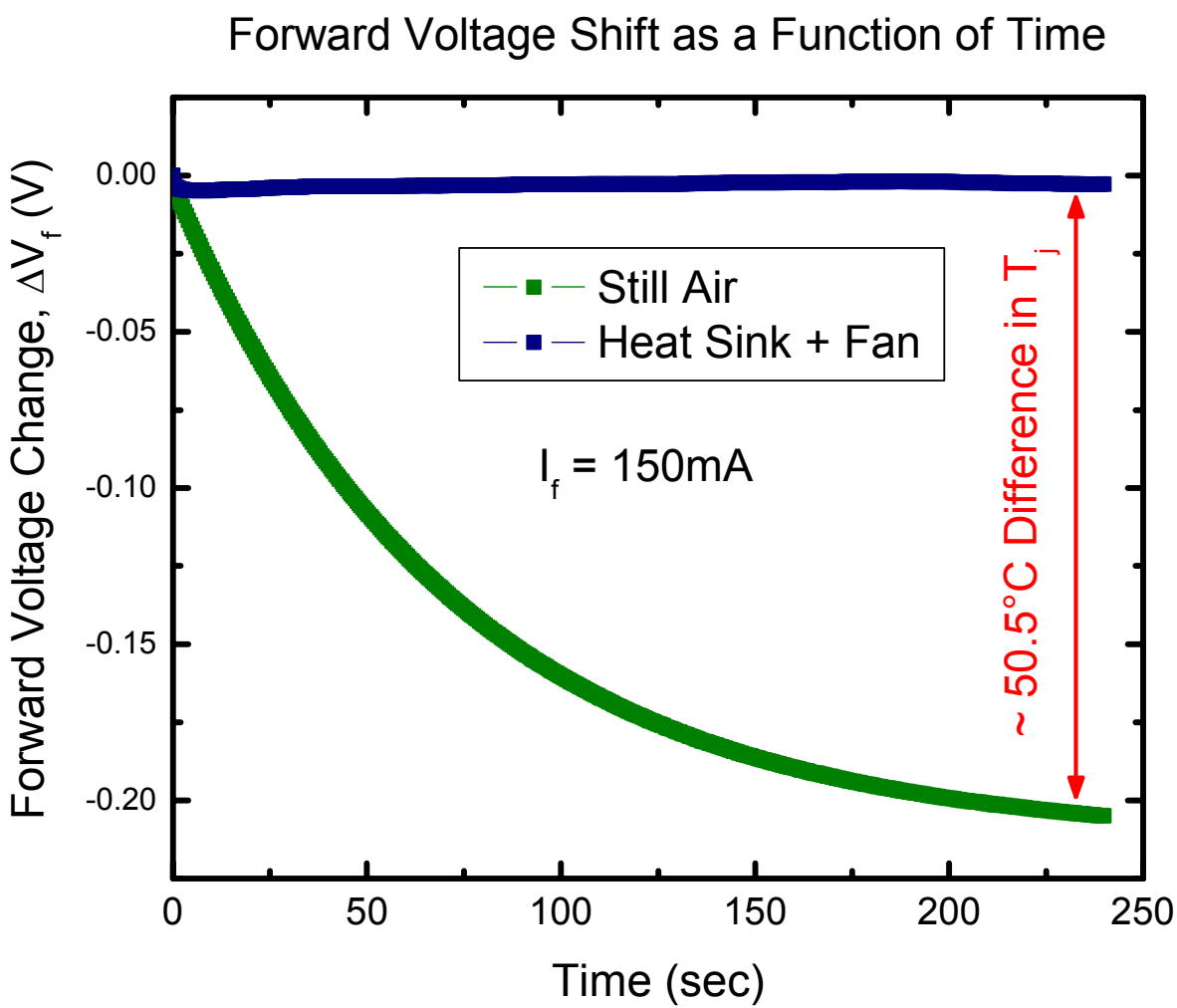
High Current Large Die Performance



Reliability



Die Performance and Thermal Environment



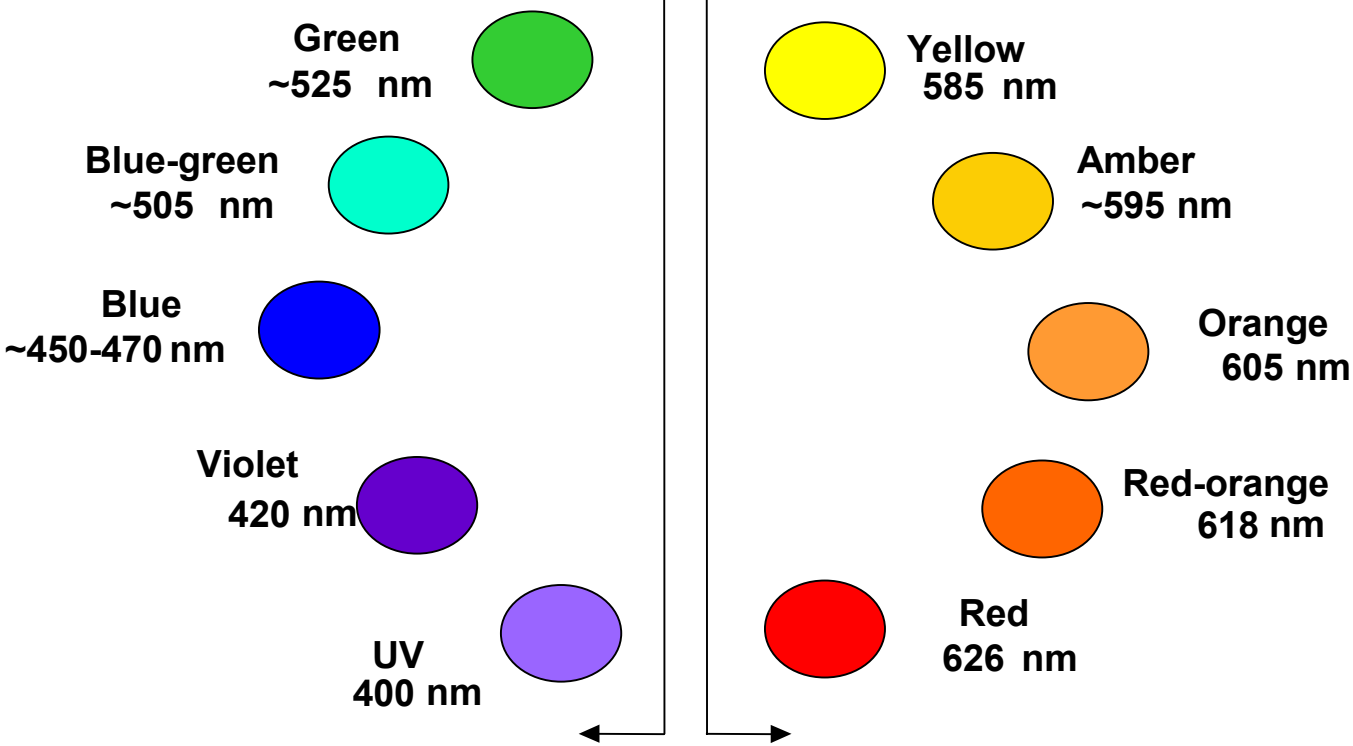
UOE High Brightness Products

POWER-Ga(i)N™

InGaN
blues and greens
"cool colors"

POWER-BR(ite)™

AlInGaP
reds and yellows
"hot colors"



DIE - EPI

~100M Die Manufactured

~1000 Wafers Manufactured

The Future Will Look Very Different