Advancements in LED Technologies

and their contributions to Display Technologies

Presented by
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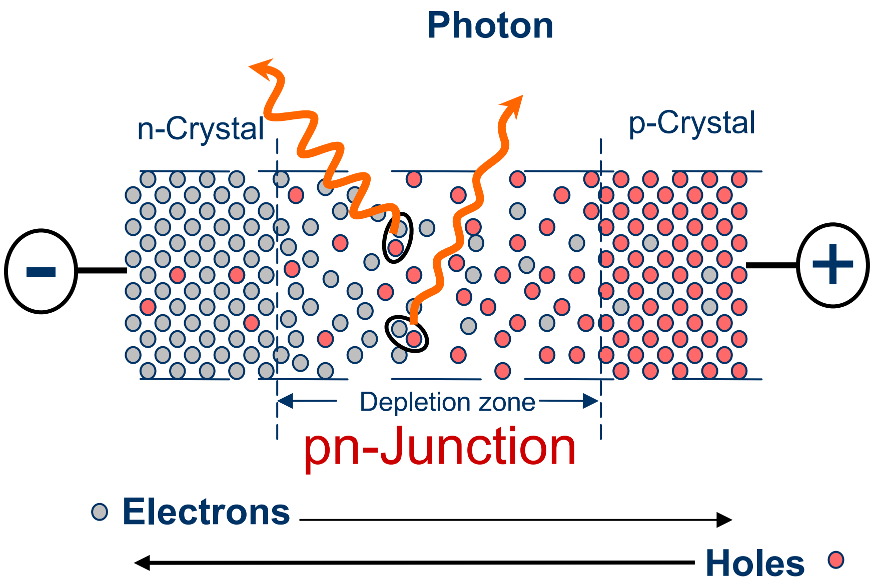
Opto Semiconductors

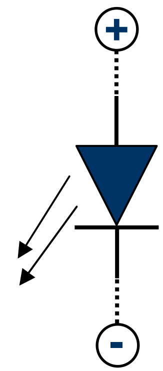
OSRAM

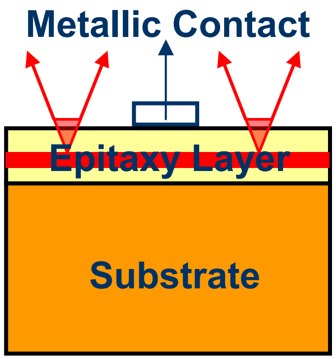
Agenda

- What is a LED?
- Key LED characteristics
- 7-segment LED display
- 5x7 dot matrix display
- Large area video display
- LCD backlighting
- Projection Display
- Q&A

How Does a LED Emit Light?



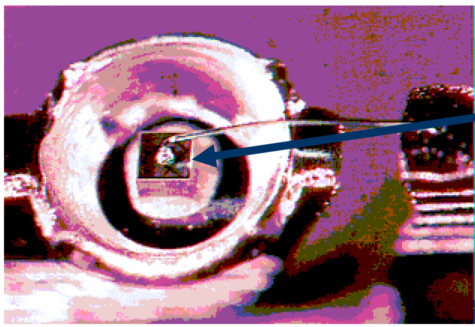




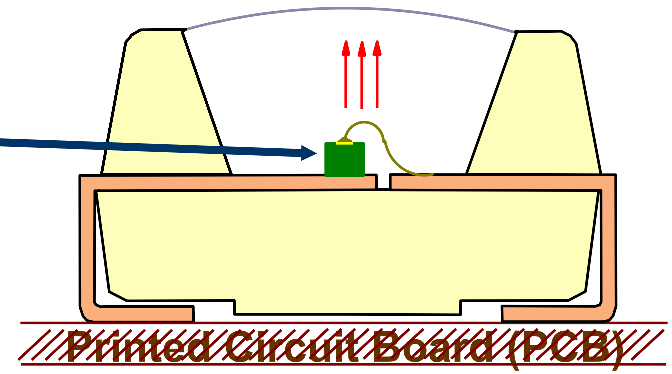
The PN junction of the diode is biased in forward direction:

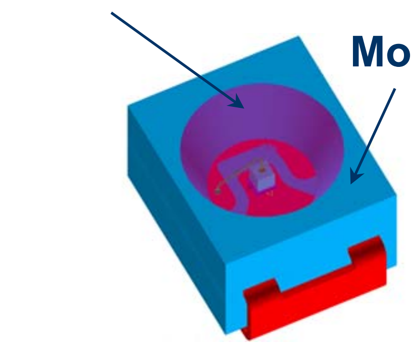
- Free charges are forced into the depletion zone
- Electrons recombine with holes and emit photons

Typical LED packaging – radial (through-hole) & SMT (surface mount)

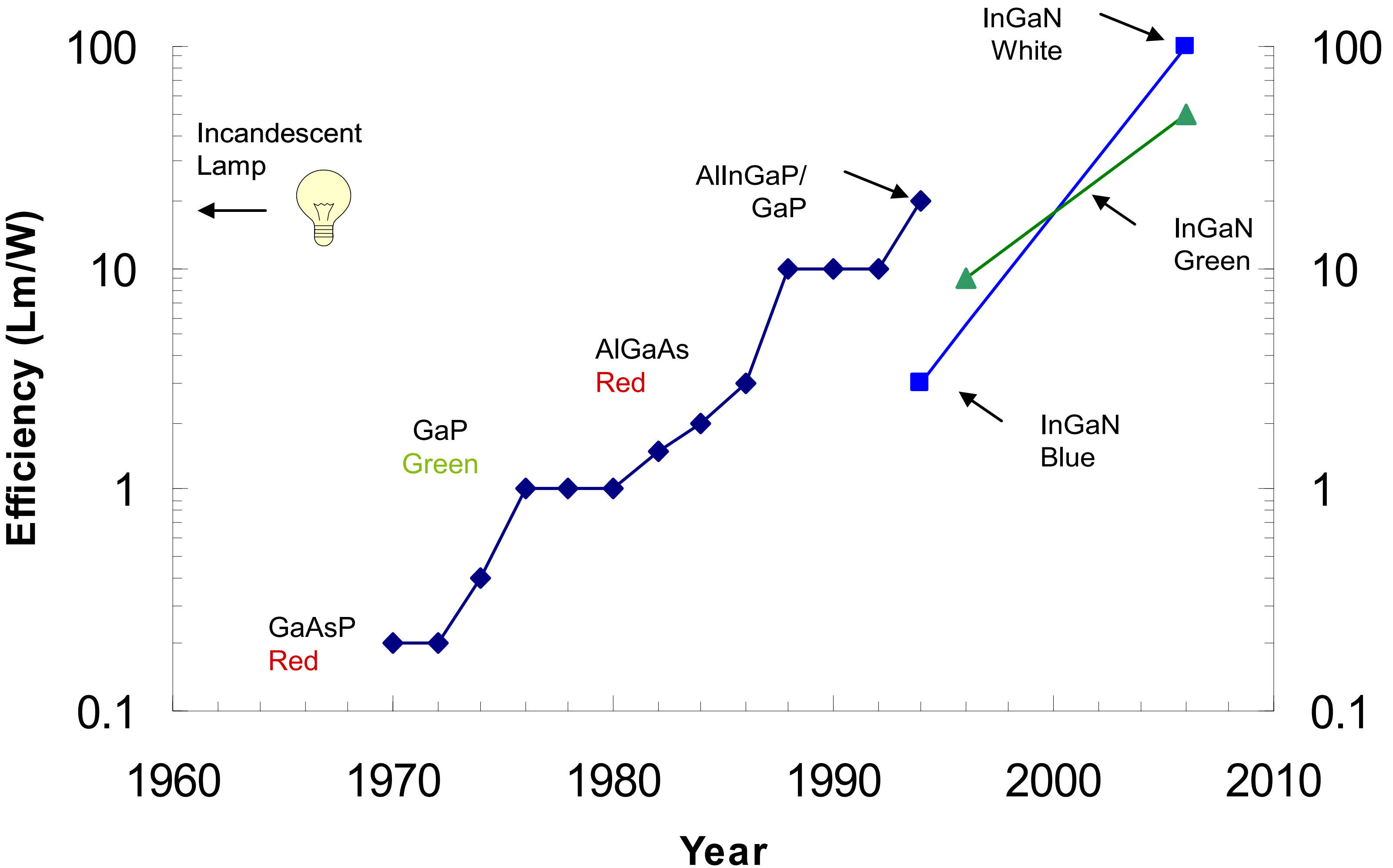


LED Chip

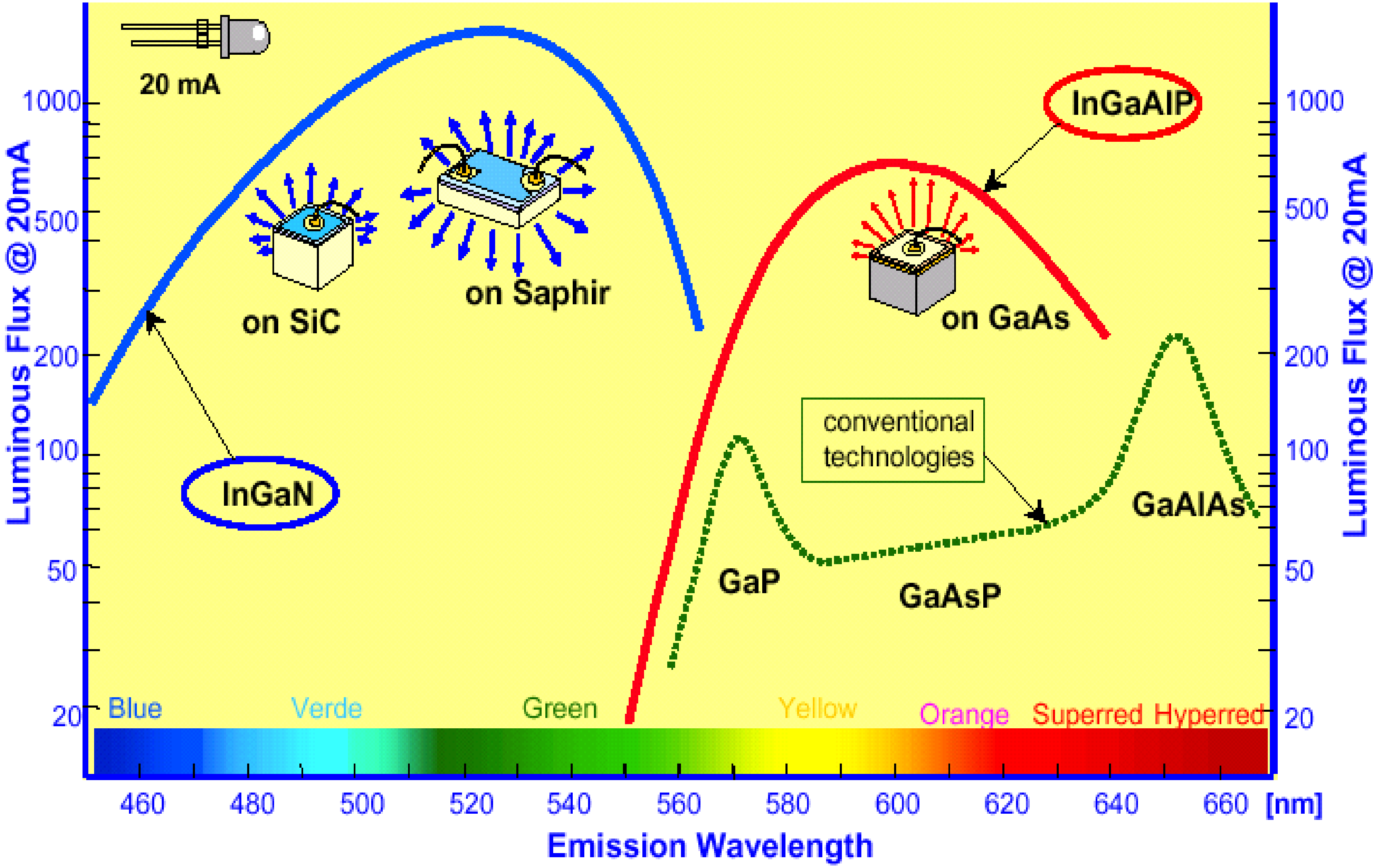




LED Technology Timeline



Visible LED Technologies



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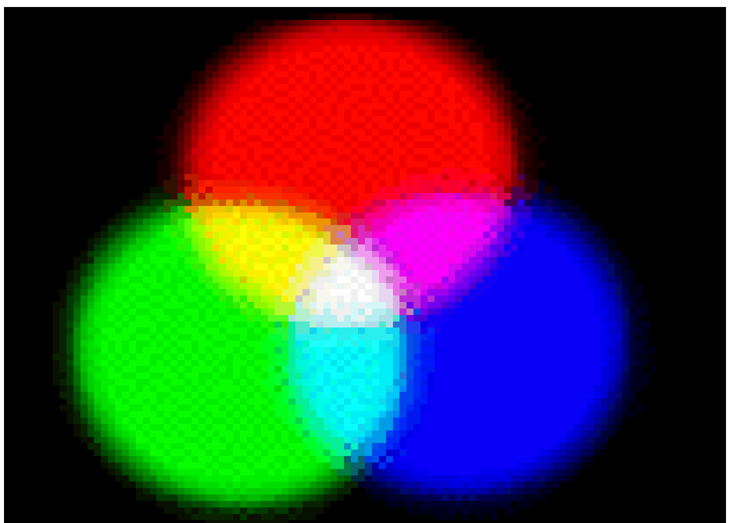
How Do We Get White Light?

Tri-Color Colorimetry

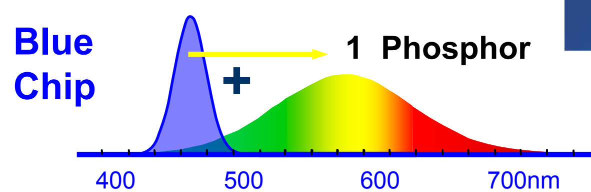
Red/ Green/ Blue – primary colors

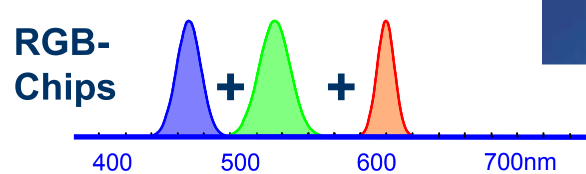
White – mixture of 3 primary colors



White = Red + Green + Blue

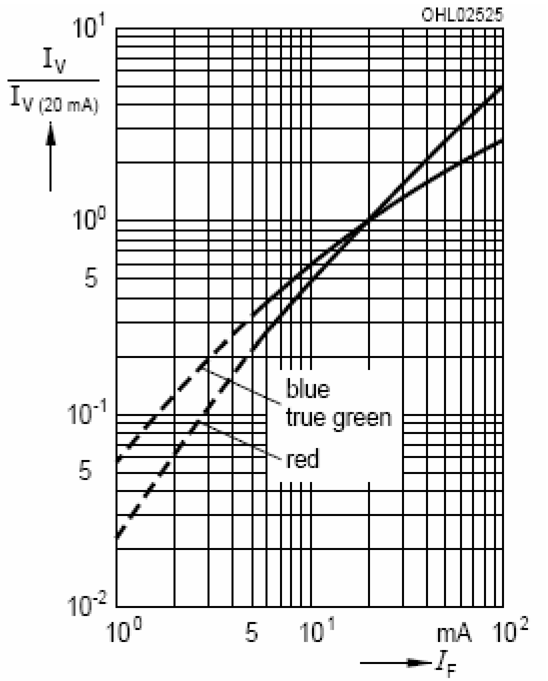
White LED Concepts

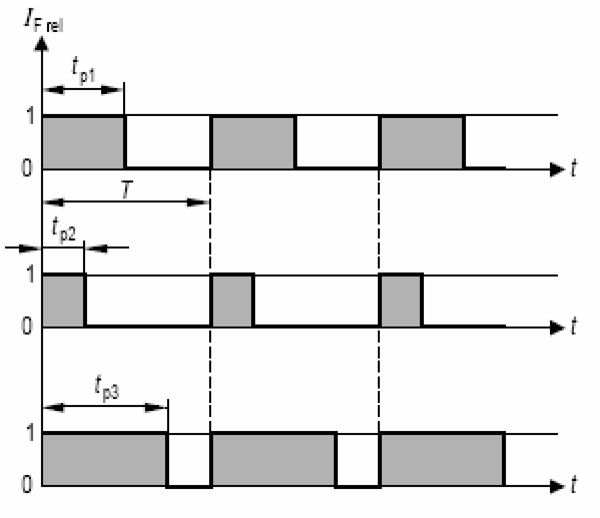


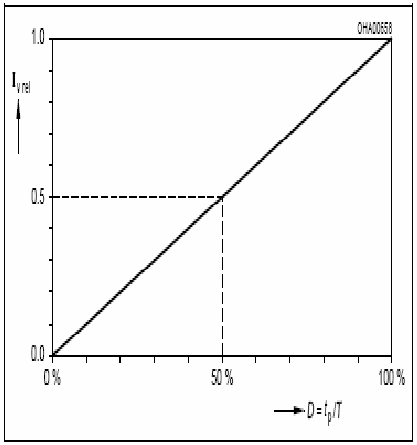


Emission Wavelength

Output of LED vs Forward Current I_F







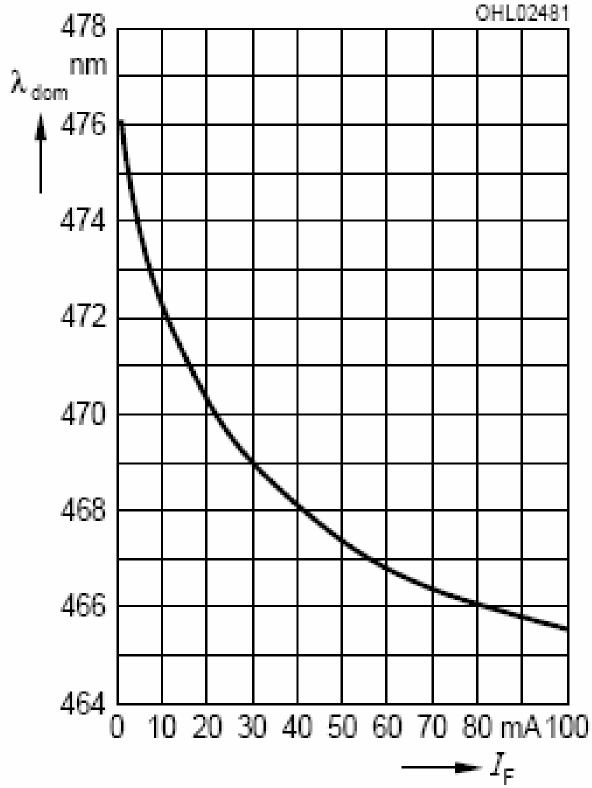
Drive current vs. Brightness not truly linear.

Duty Cycle = t_p/T

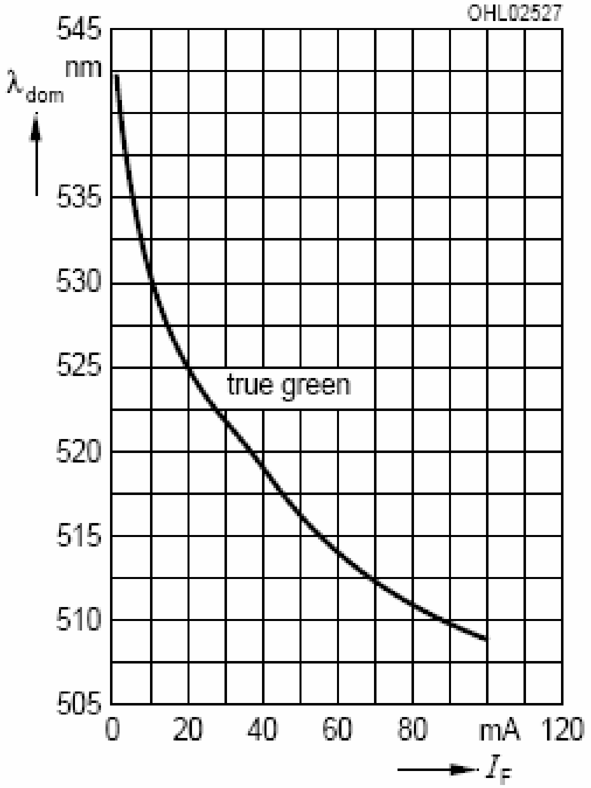
PWM duty cycle vs. Brightness linear.

Effect of Drive Current on Emitted Wavelength

blue, $\lambda_{dom} = f(I_F)$; T_A = 25 °C

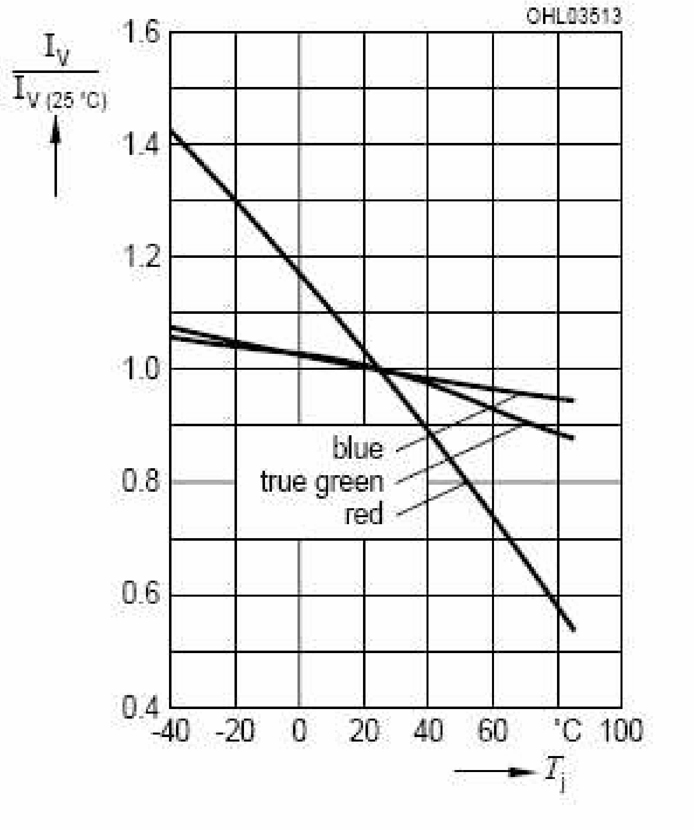


true green, $\lambda_{dom} = f(I_F)$; T_A = 25 °C



Reduction in wavelength for green, followed by blue with increasing current. Red is stable.

Junction Temperature – Brightness Reduction



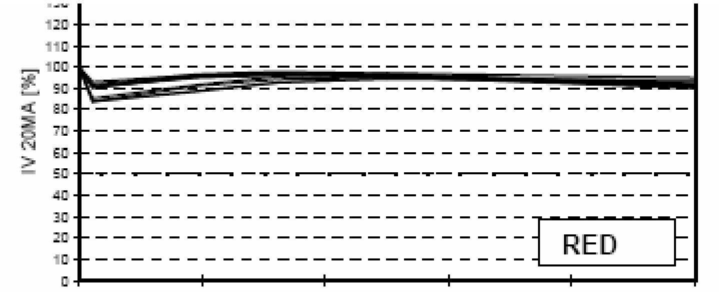
With increasing operating temperature,

•All Leds experience reduction in light output.

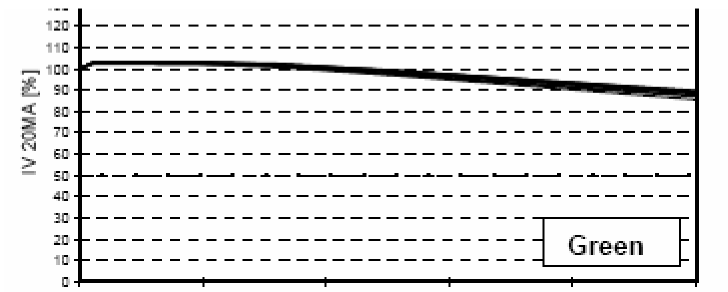
• Red at ~8X relative to blue.

• Green at ~2x relative to blue.

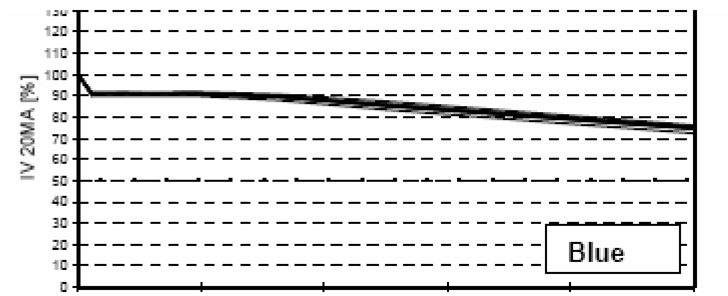
Different brightness degradation rates



At 10khrs, red I_v ~ 93%



At 10khrs, green I_v ~ 89%



At 10khrs, blue I_v ~ 78%
or ~ 85% normalized.

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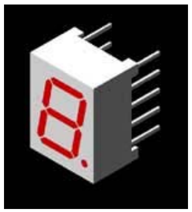
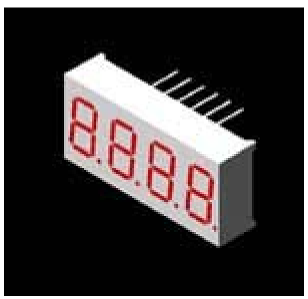
7-segment Displays (circa 1970)





Features:

- Digit height < 1” typical
- Numeric characters, some limited Alpha.
- Low voltage low current drive
- Solid state, lasts long time
- Uniformity - sometimes marginal
- Considered low tech, low innovation product.
- Very low cost, < $0.10 per digit
- Declining $ market

Applications
- Clock radio, CE appliance, toys, etc.

Competing technologies:
- Vacuum Fluorescence (VF)
- LCD

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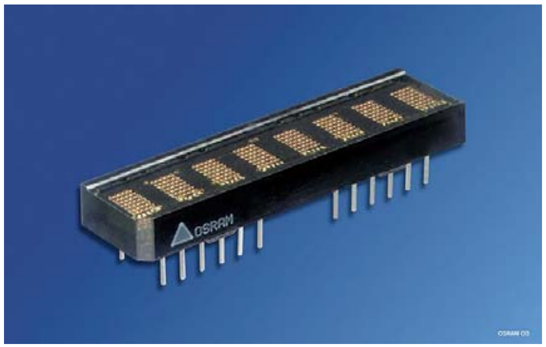
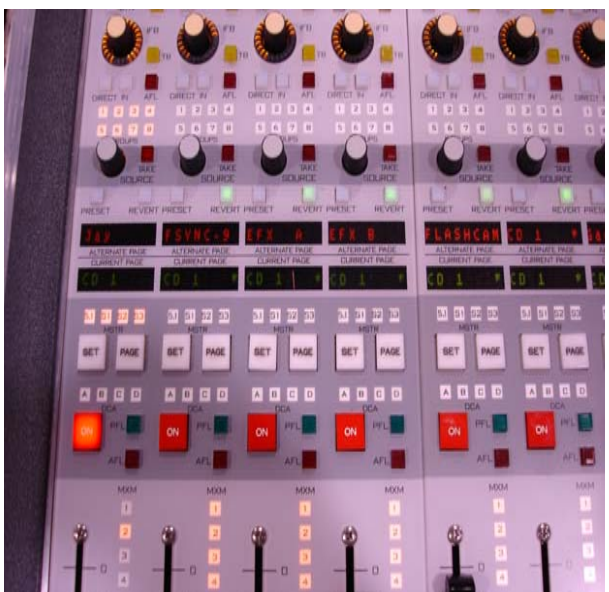
Multi-digit Dot Matrix "Intelligent" Displays





Features
•Solid state, rugged
•Typically 5x7 dot matrix
•Emissive
•Digit height < 0.5" typical
•Built-in decoder-driver circuit
•Very footprint economical (.18" digit on 0.4" package)

Applications
•Avionics, military, remote datacom, network , medical equipment, etc.
•Audio-video control panels.

Competing Technologies
•LCD, OLED, VF

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Large Screen LED Video Displays

Features
- Sunlight viewable
- > 50khr life
- Vivid colors – lots of pop
- Scalable

Applications
- Digital billboards – static and video
- Arenas, stadiums, malls, conventions
- Signs

Competing Technologies
- Outdoor – none (incandescent, Jumbotron dead)
- Indoor – projection, plasma, LCD.

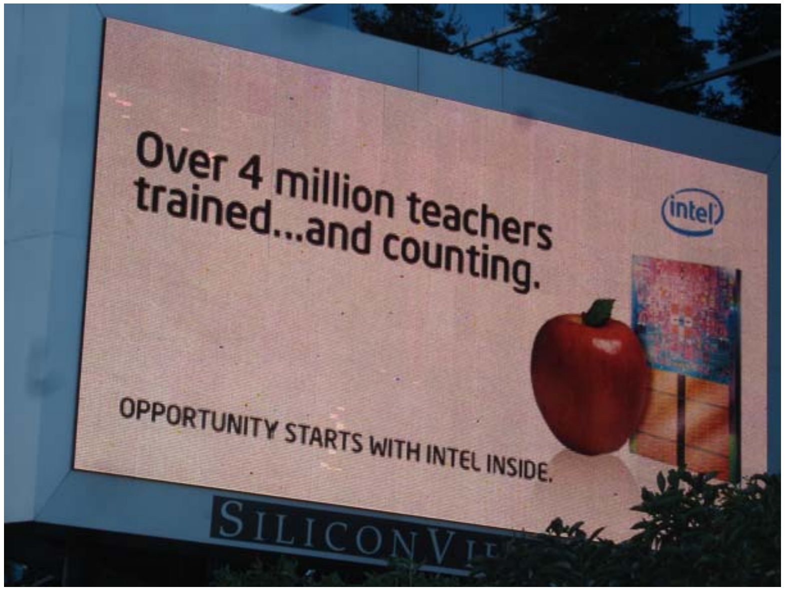
LED Full Color Video display for Indoor and Outdoor

Key metrics	Outdoor	Semi-outdoor	Indoor
Panel Brightness	> 5000 cd/m^2	1000-5000 cd/m^2	400-1000 cd/m^2
pixel Brightness	> 500 mcd	< 500 mcd	< 100 mcd
Pixel Pitch	10 to 50 mm	4 to 10 mm	3 to 10 mm

Discrete LEDs

Multi led

Route 101 at Whipple
2-sided screens look different after 68K hours?



North-West facing

South-East facing

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LED Backlighting Timeline

1990	2” Green LED backlighting in cell phone
2993	2” white backlight for color LCD in cell phone
2005	3.5” white backlight for PDA
2006	7” white backlight for automotive displays
2006/7	13.3” Notebook backlight with white LED

Why LED Backlighting?

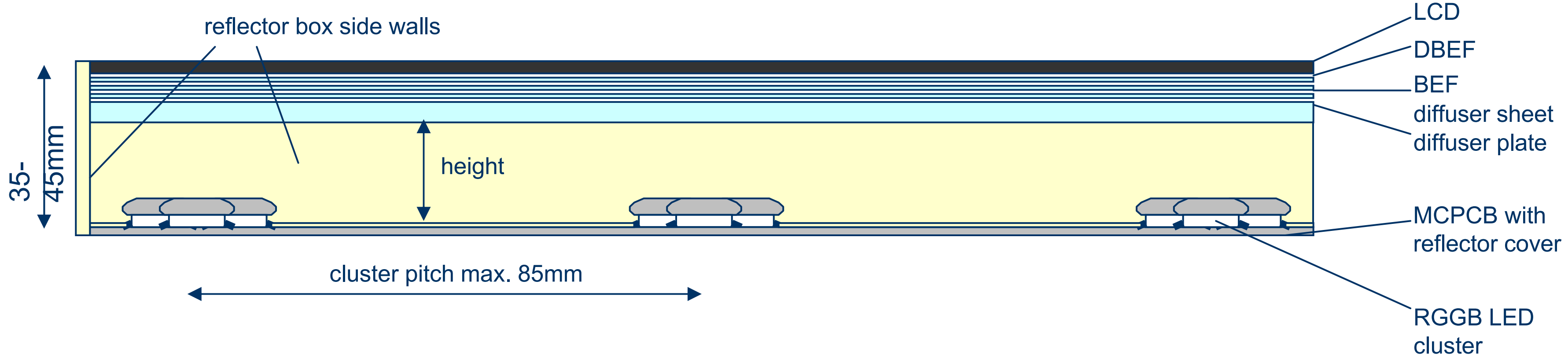
	Notebook	Specialty	TV
Extended battery operation	↑↑↑	↑	
Thinness of backlight	↑	↑	↑
Mercury free, lead free	↑	↑	↑
Lowe weight	↑		
Low Voltage DC (low EMI)	↑	↑	
Vibration and shock safe	↑	↑ ↑	
Fast switching speed (less than 100 ns)			
Sequential color control possible - color filter high cost (25% of material cost) and inefficiency (14%)			
Reduction of motion artifacts by pulsed operation			
Dynamic contrast enhancement (1D / 2D dimming)		↑	↑
Wide operating temperature range: - 40°C to +85°C	↑	↑ ↑	
Wide color gamut with RGB LEDs > 100% NTSC		↑	↑ ↑
Higher brightness levels (not easily achievable with CCFL).		↑ ↑	
Infinite dimming steps by pulsed operations		↑	↑

SONY 70XBR

Scalable Backlight Concept

Schematic build up with RGGB

Golden DRAGON® ARGUS® used in SONY 70XBR

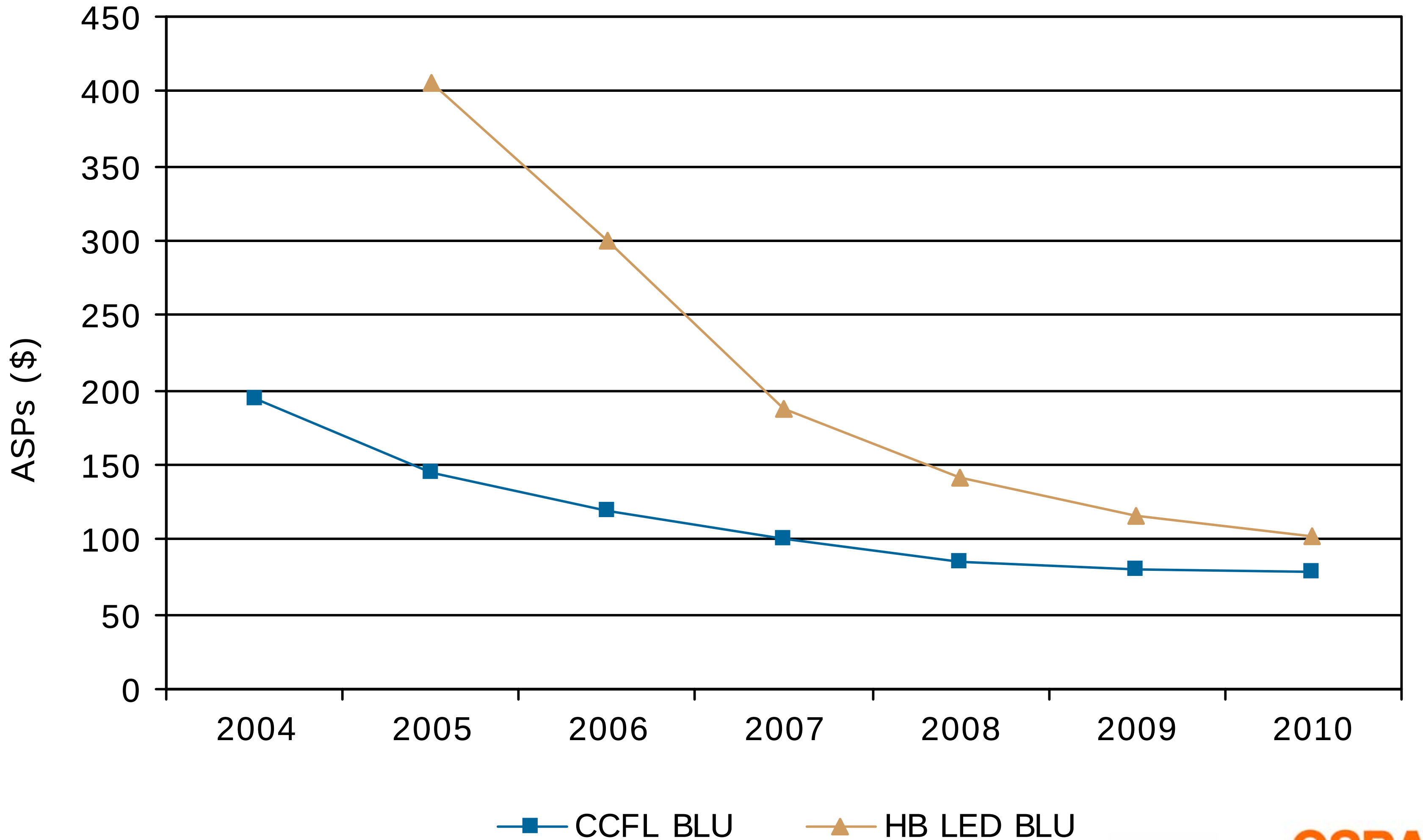


Efficient, homogeneous and slim solution backlight concept

Barriers to mass implementation

- High cost of LED as screen size increases
- Tight matching of large number of LEDs needed (cost and availability)
- Color drift due to temperature requires closed loop feedback
- Differential color drift of the 3 colors requires closed loop color sensing

ASP of CCFL vs. LED for 32" LCD (source iSuppli)



ductors OSRAM

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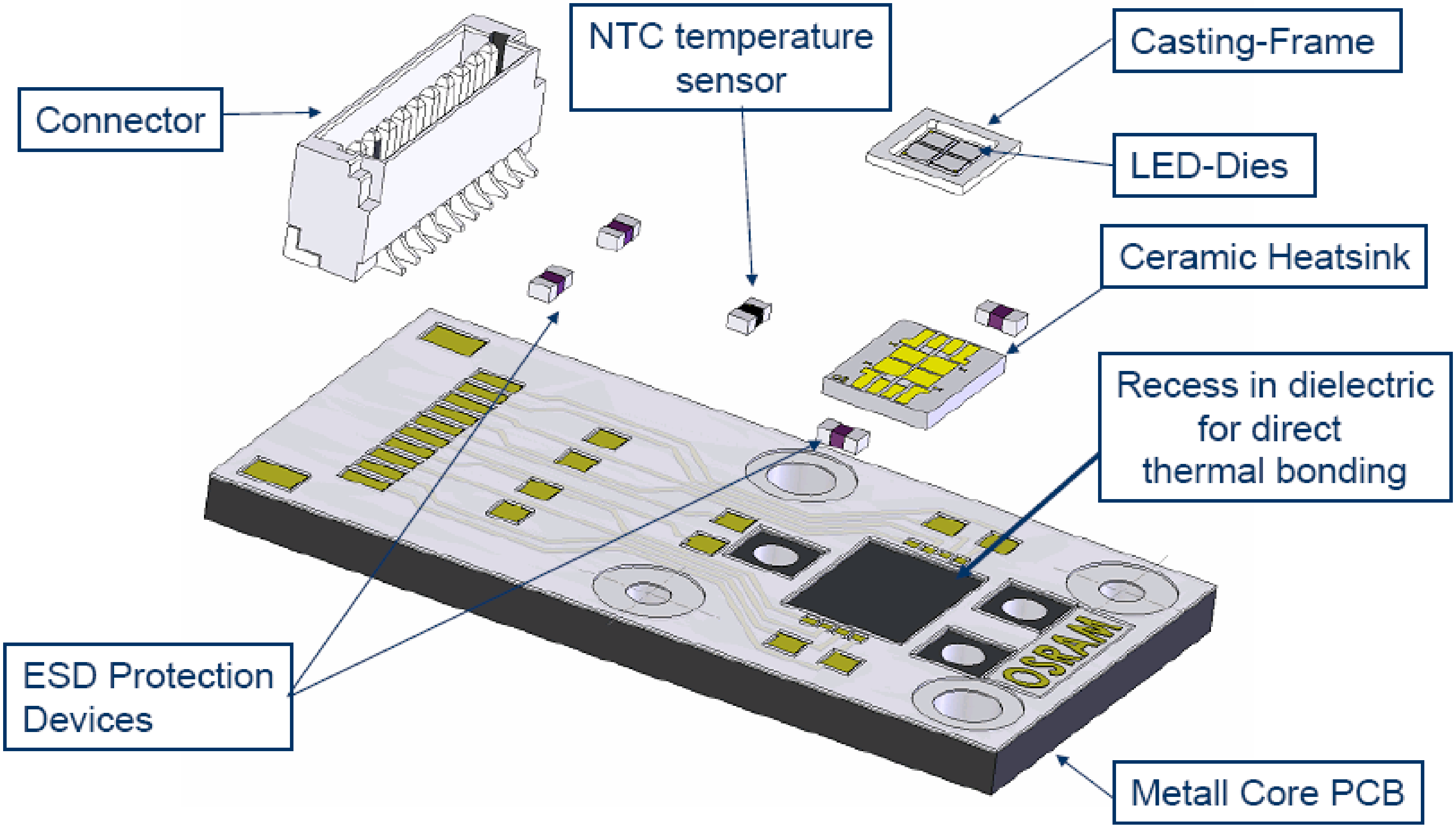
Assembly of the OSTAR® Projection Module



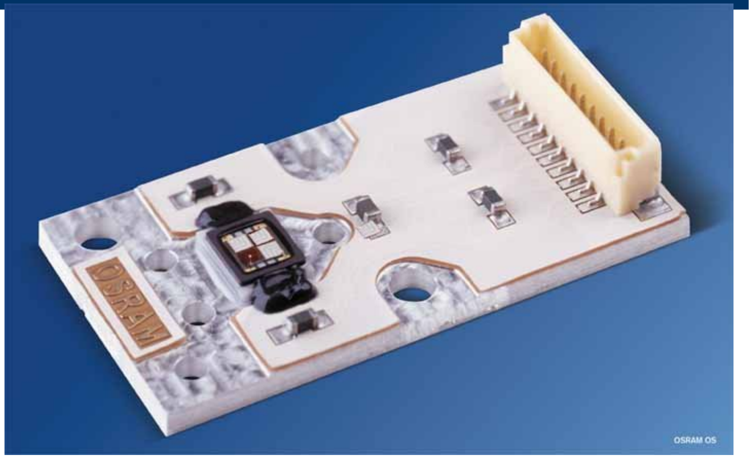
4-chip and 6-chip OSTAR® Projection

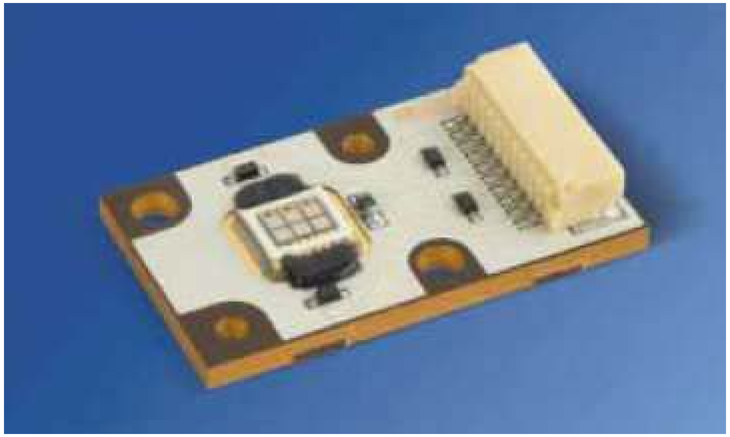
Multi-color 4-Chip RGGB OSTAR:
- Red = 67 lm @ 1A / chip
- Green = 64 lm @ 1A / chip
- Blue = 14 lm @ 1A / chip

Monochrome 4-Chip OSTAR:
- Red Module = 268 lm @ 1A

Green Module = 248 lm @ 1A
Blue Module = 56 lm @ 1A

New 6Chip-OSTAR in all variants
- Red Module = 316 lm @ 1A
- Green Module = 306 lm @ 1A
- Blue Module = 72 lm @ 1A



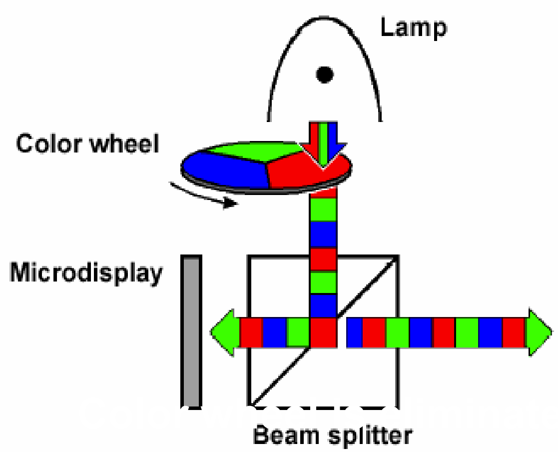


Projection System – Lamp vs. LED

Eliminates color wheel

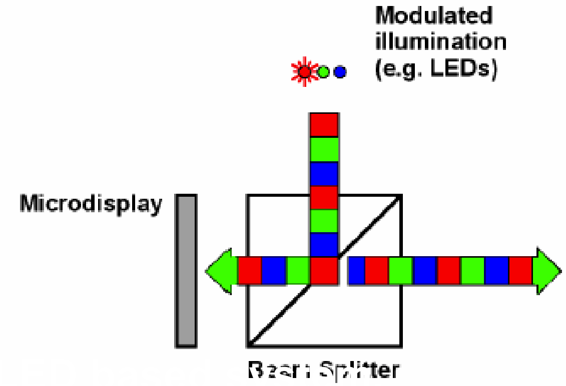
Conventional lamp

- Uses a color wheel or Color Link Color Switch™
- Proven solution with high light output
- Shutter or compensation cell needed



LED based system

- High color purity.
- Solid state devices. Stable output & 30k+ hour life (10+ years @ 8hrs/day)
- Low voltage/5V supply.
- Pulsed operation – low power.



Benefits of LED vs Lamp for Projection

•Longer lamp life - 50k hrs compared to 5k for discharge lamp.

•No moving part (color wheel) for LED = higher reliability

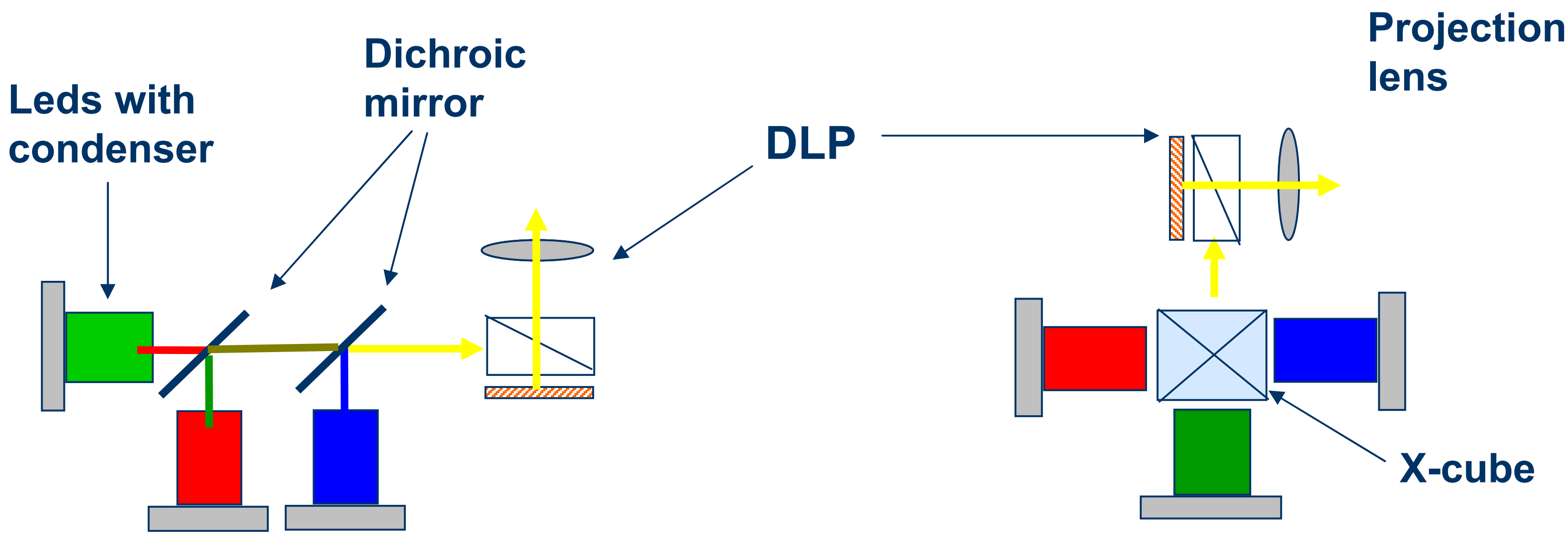
•Wider color gamut > 105% NTSC with LED compared to 80% with discharge lamp.

Instant on vs. few minutes for discharge lamp.

•Mechanical robustness – no glass envelope

• No high voltage ignition circuit needed.

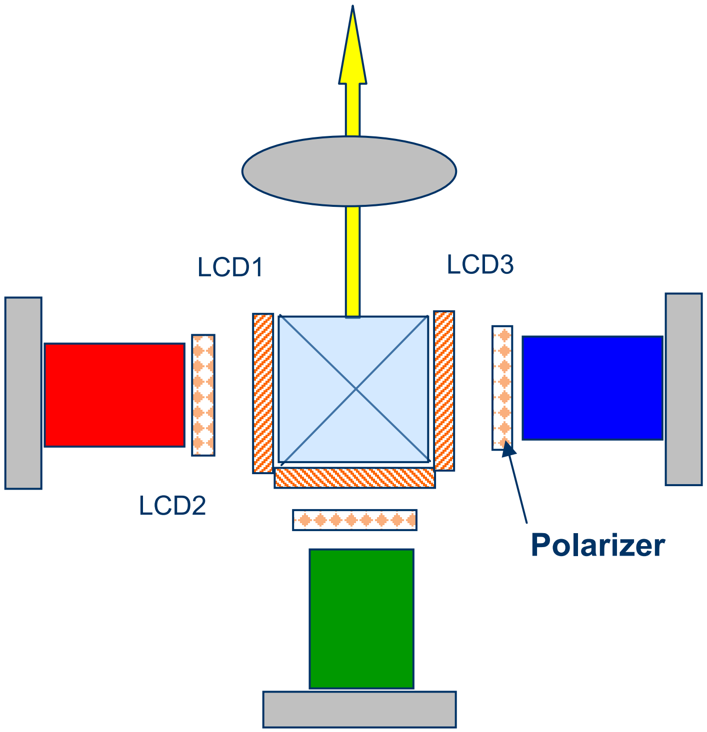
Projection with single panel DLP / LCoS



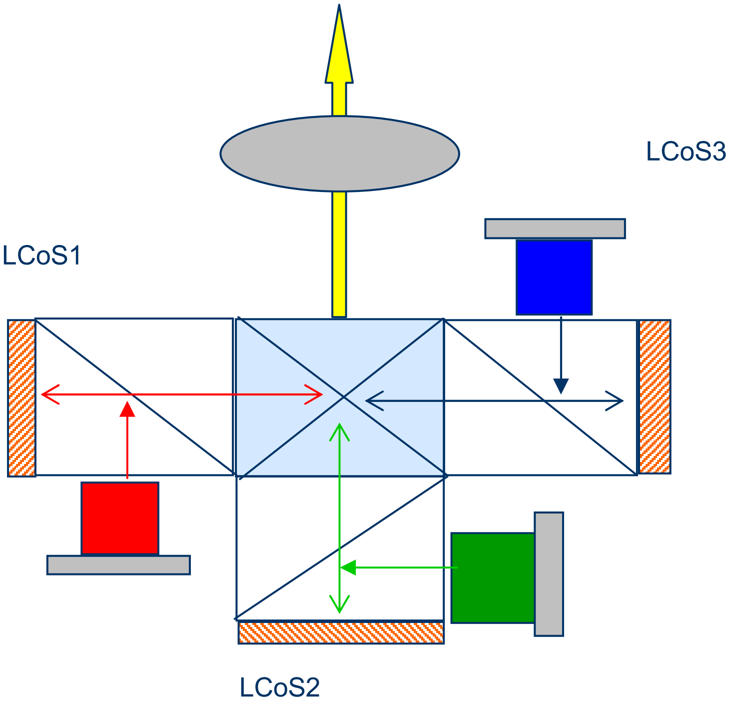
Light engine using dichroic mirrors for combining RGB.

Light engine using X-cube for combining RGB.

Projection with 3-panel LCD / LCoS



3-panel LCD

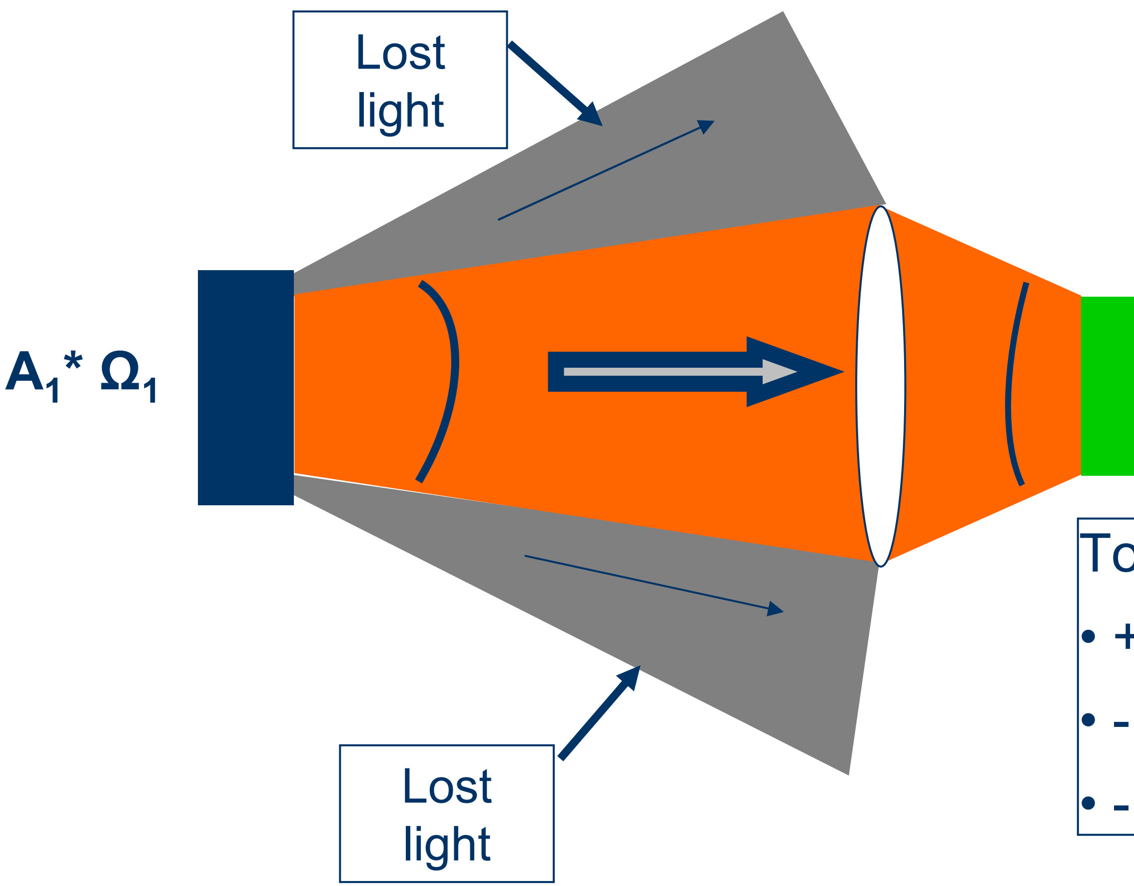


3-panel LCoS

Pocket Projectors powered by LEDs (2007)

Challenge of LED for Projection - Etendue

When $A_1 * \Omega_1 = A_2 * \Omega_2$



To increase light throughput:

- + luminance
- - Area
- - Ω

LED Projection Now and in the Future

2007

- **Pocket Projectors – Samsung et al at 25-100 lumens.**
- **RPTV – Samsung and NuVision at 400 nits for 60”**

2008

- **Front Projectors at 500 lumens.**
- **Micro-projector (plug in accessory) – 10 lumens. Some microdisplay makers, discouraged by the RPTV market place, are redirecting their attention to this segment.**

2009

- **Embedded pico-projector – cell phone, PDA, camcorder, etc.**

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Thank you for your attention!

Rich Hawkins

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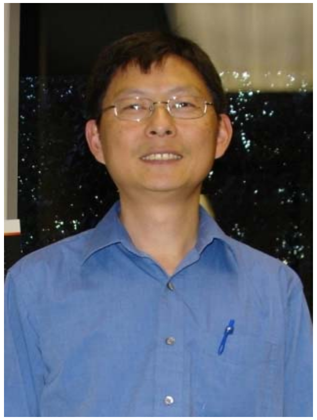

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