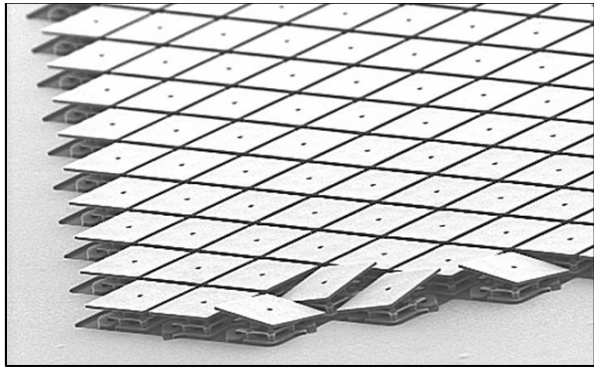
Solid-State Light Sources for DLP® based Display Products

Sajjad Khan

6/13/2011

A combination of 147 Christie Roadster S+20K DLP® and Christie CP2000-ZX DLP Cinema® projectors were selected to project dynamic visuals for the opening ceremony at the 2008 Beijing Summer Games held on August 8th inside the newly-built Beijing National Stadium. Christie projectors will also be used for the closing ceremony on August 24th as well as the Beijing 2008 Paralympics Opening and Closing Ceremonies on September 6th and 17th respectively.

Agenda

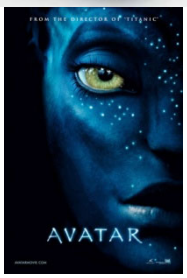


1. What is the right LED or RGB LED combination for a certain DLP chip?
2. What are the major differences between Laser and LED based systems?
3. How a typical LED based DLP system works?
4. Choice of DLP Chip
5. Systems Challenges that need to be addressed

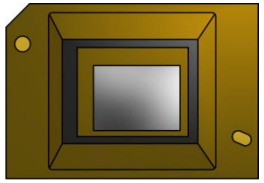
DLP Chipsets and their applications

(a few examples only)

DC4K



Digital Cinema
Lamp Based



.55" XGA

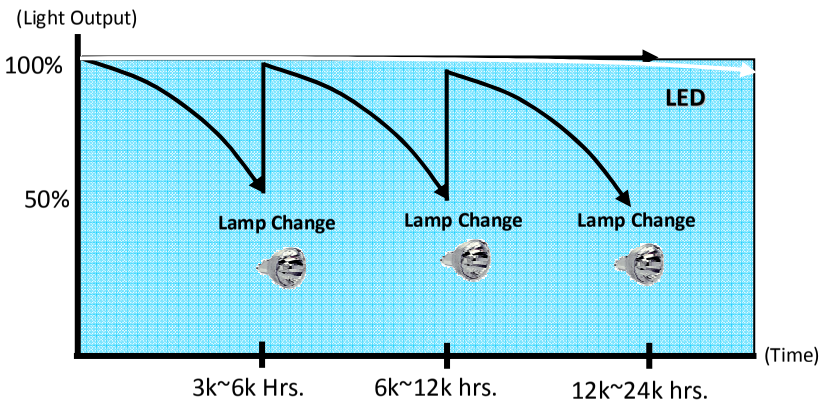
Front Projection
Lamp Based

.3" WVGA

Pico Projectors
LED Based

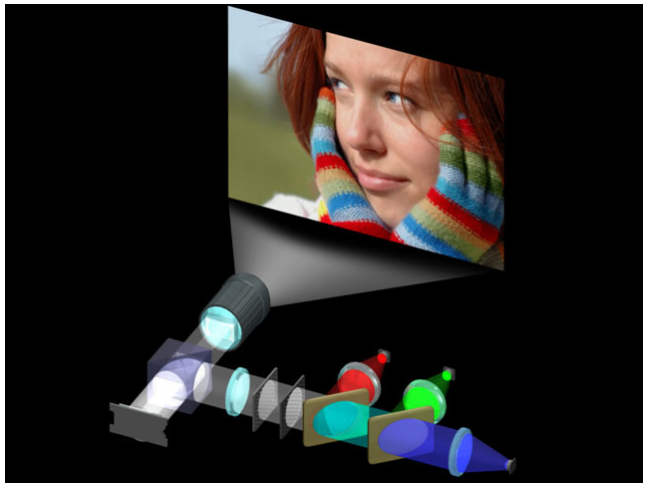
Why solid-state and DLP® technologies Together?

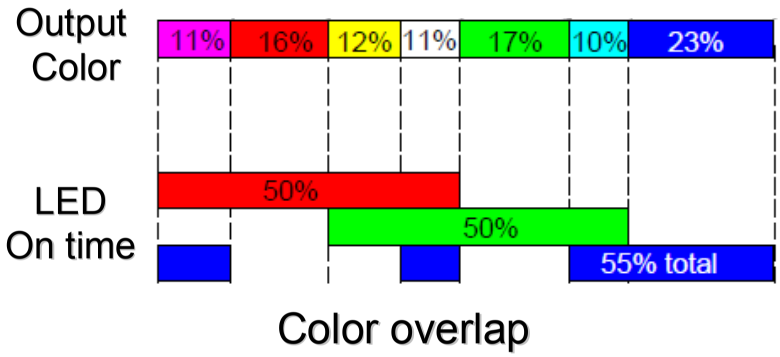
Two technologies famous for their Durability, DLP® & solid-state light sources, combine for the ultimate in Performance!

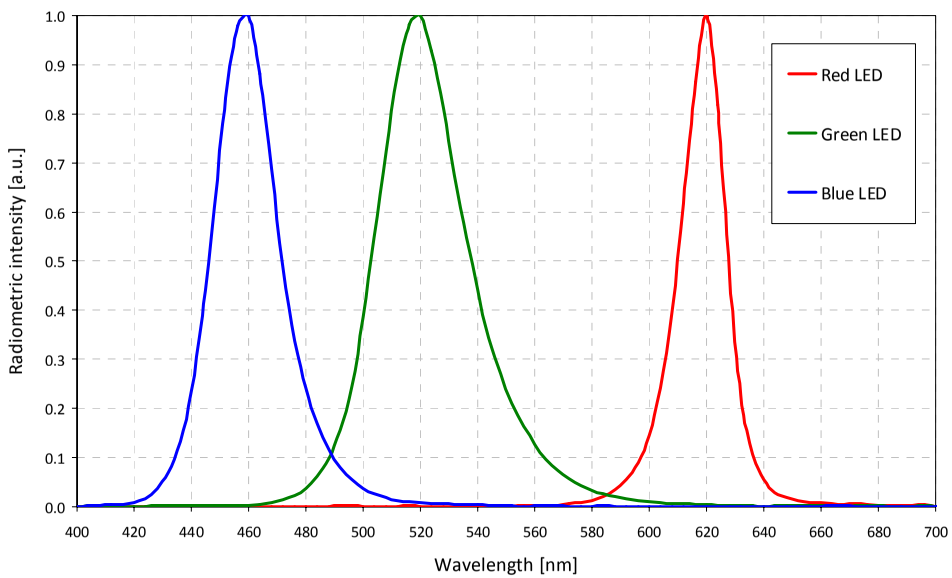


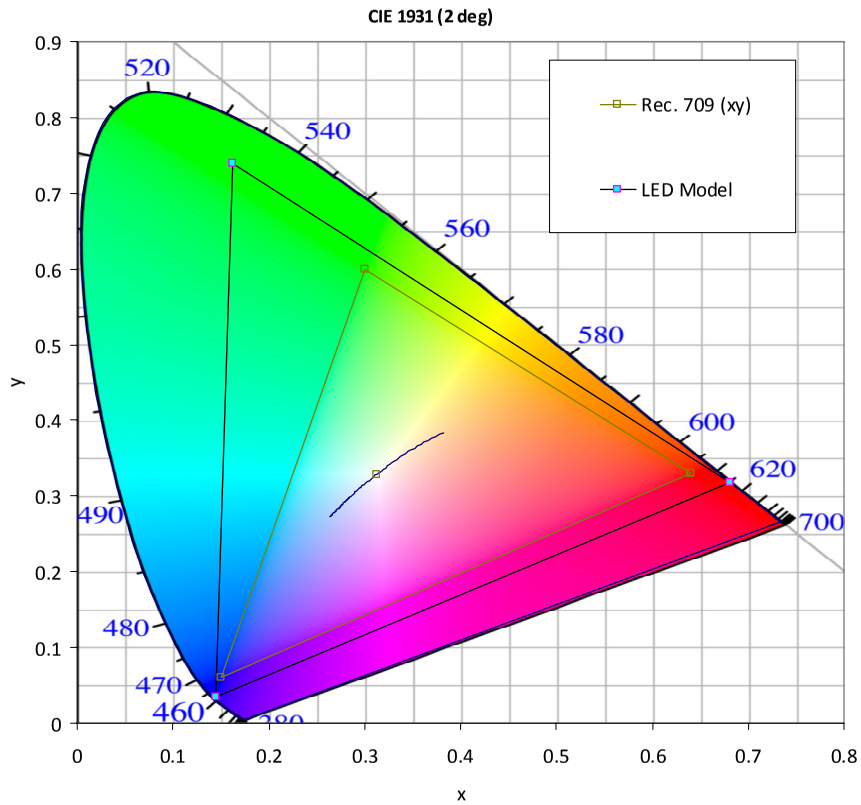
- **Not polarized**
  - → No extra losses as in 3LCD
- **Reliability**
  - → >100,000 hrs and counting
- **No lamp replacements**
  - → Total Cost of Ownership
- **Fast response times**
  - → Instant On/Off, no motion blur
  - → unlike 3LCD, both technologies (DLP® and LEDs/LDs) have microsecond response times
- **Color saturation**
  - → unmatched Image Quality, and wide color gamut
- **Perceived Brightness Boost**
  - → Helmholtz-Kohlrausch effect (in some cases)

How a typical LED based DLP system works…



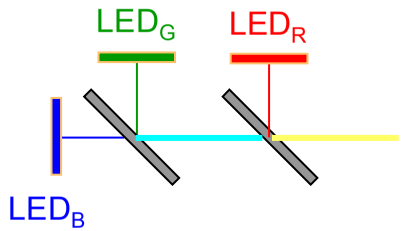






LED Illumination Approaches

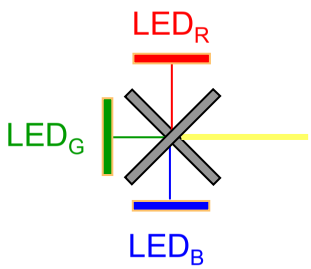
Conventional 3 Channel Approach



Benefits:
- In-line system
- Different channels have different efficiency
- Non 45 degree incidence allowed
- Simpler cooling solution
- 1 channel has higher efficiency

Drawbacks:
- Larger form factor
- 2 channels have lower efficiency than the 3rd channel

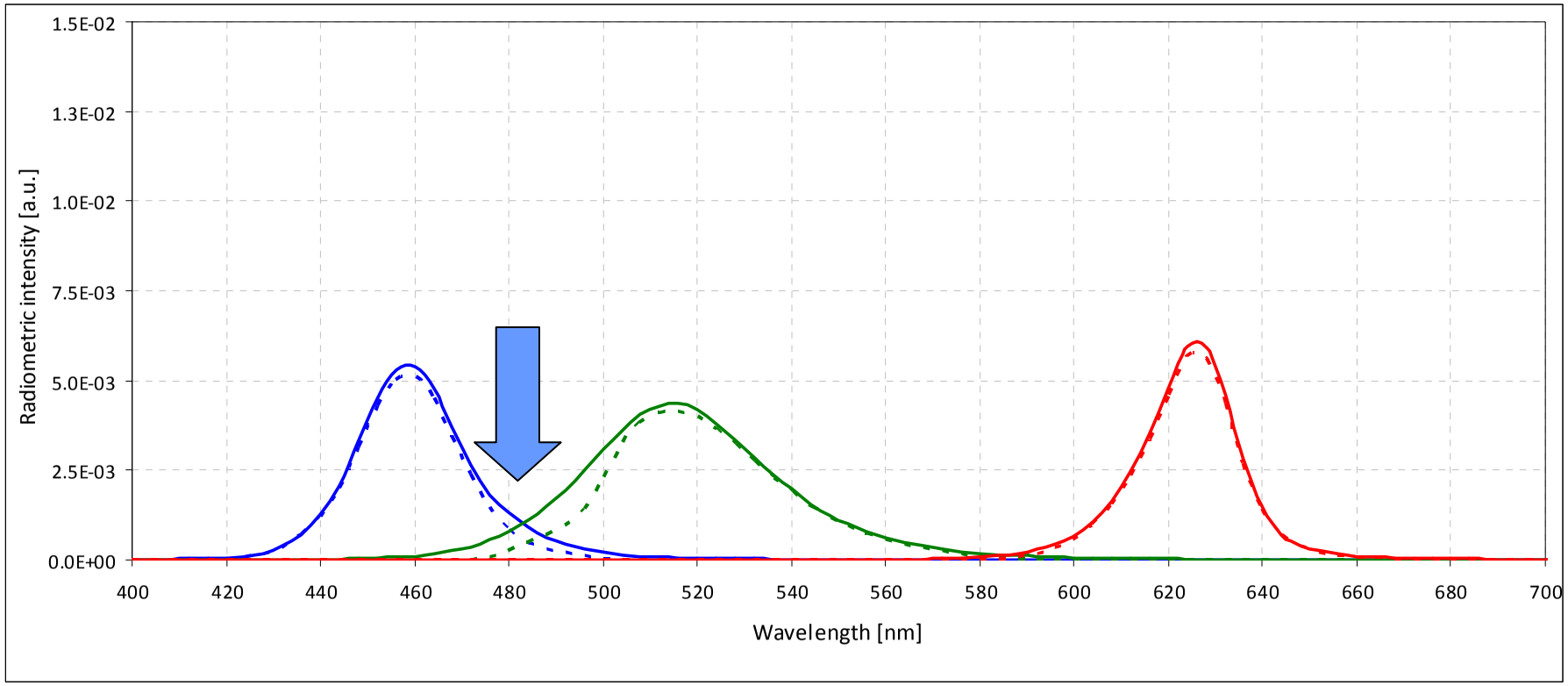
Dichroic Cross Approach



Benefits:
- Compact system form factor
- All channels have almost the same efficiency

Drawbacks:
- Difficult cooling solution
- Non 45 degree incidence NOT allowed

Spectral overlap

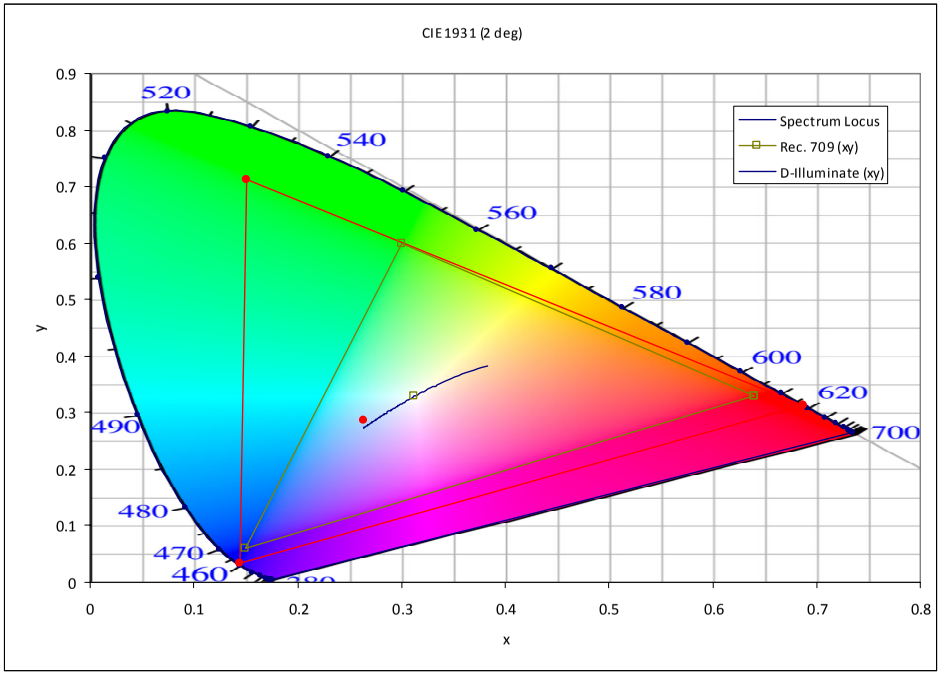


Notes:

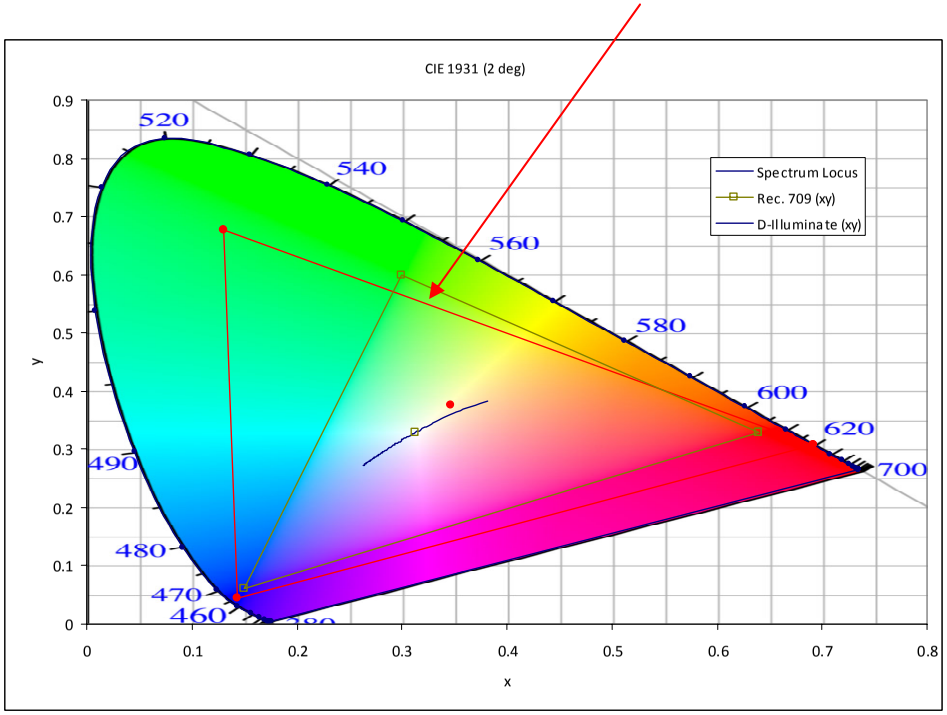
- **Choice of color filter is critical for max efficiency**
- **Energy in cyan band is lost due to dichroic filter slope**
- **Choice of green LED is important to minimize this spectral overlap region**
- **Different vendors have different center wavelength for Green**

A word on LED color gamut

- Meets Rec 709 gamut standard
- Yellows are good looking



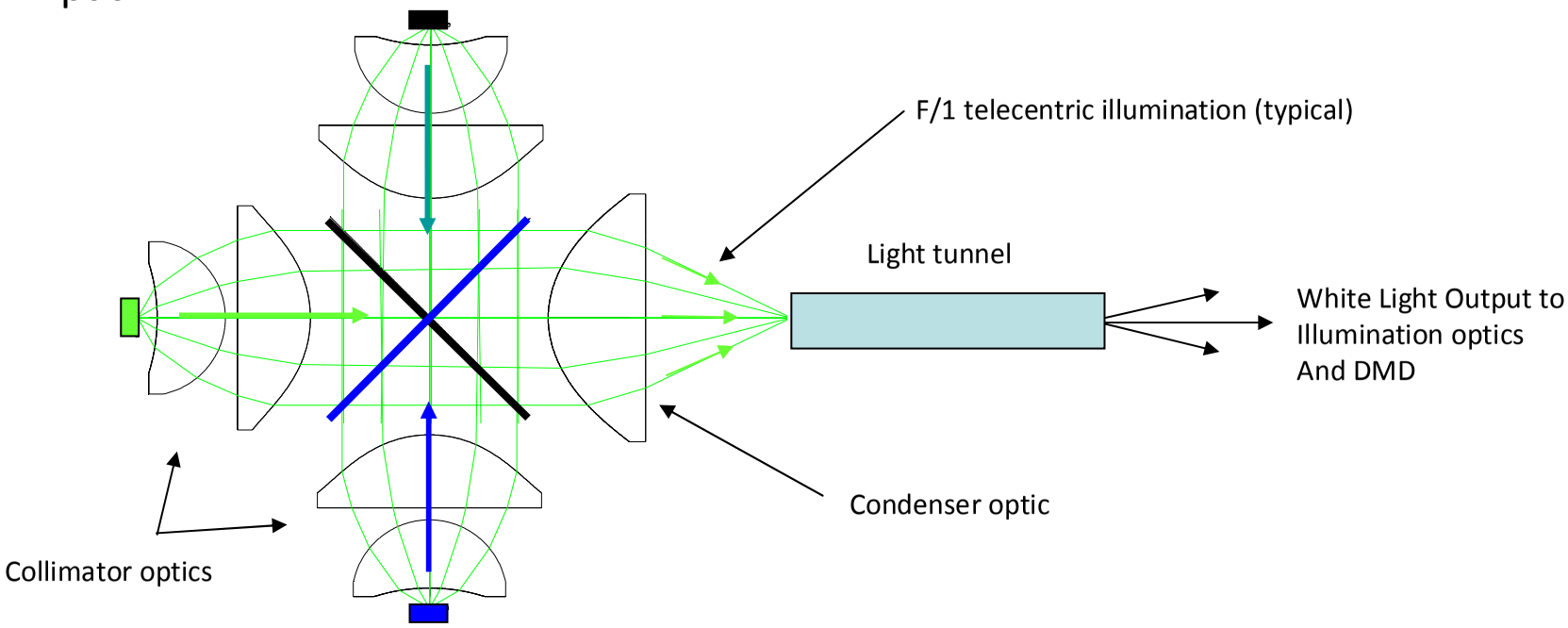
- Rec 709 gamut is clipped here.
- Yellows are not very good looking



Note:
- These are only two example LEDs
- Different LEDs from different vendors behave differently
- Thermal solution also impacts color gamut

Collector Optics for LED

- A two lens element collimator optic collects light from the LED
- Collimators collect up to 160 degree of emitted LED light
- Each color is recombined using dichroic beamsplitter plates (X dichroic shown)
- A single condenser lens creates an image of the LED surface at the light tunnel input



Coupling efficiency is a function of LED area and collimator collection angle

Etendue matching

DLP Chip etendue:

$$\pi n d^2 (\sin \theta_{tilt})^2 \cos(2\theta_{tilt})(H_{\#rows} \times V_{\#columns})$$

LED etendue:

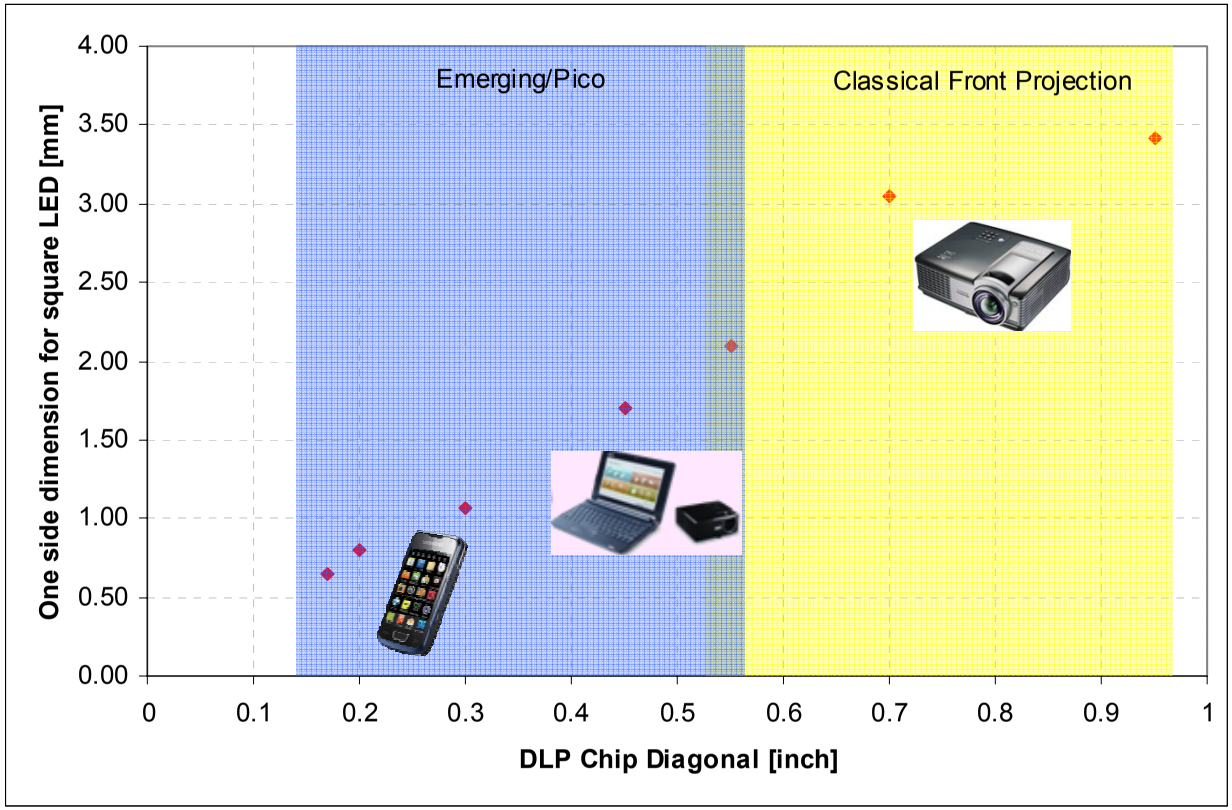
$$\pi n w_{LED\_width} \times h_{LED\_height} (\sin \theta_{collimator\_collection\_angle})^2$$

For maximum light coupling efficiency:

LED etendue = DLP Chip etendue

Where *n* is refractive index of an optical material, *d* is micromirror pitch, and H and V are the number of pixels in a row and a column for a certain resolution display (e.g.: 640 X 480 for VGA resolution).

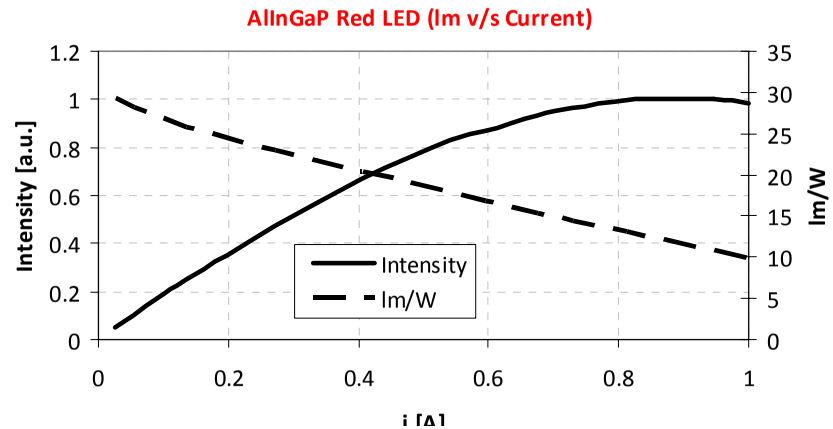
How to select an LED for a DLP Chip…



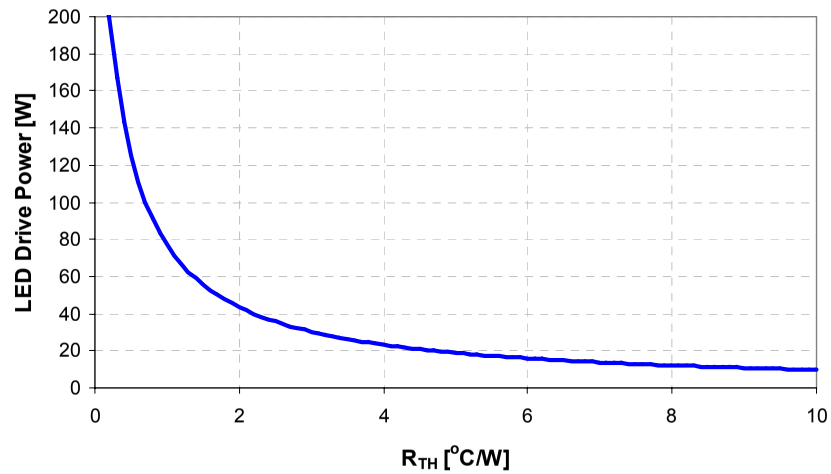
- LED die area needed for a certain application depends upon DLP-chip chosen, and optical design (F/# of optics)
- In general, the bigger the DLP-chip, the more the LED die area needed to optimize brightness

Thermal Challenges

Droop:
- Rate of return is dynamic
- It depends upon:
  - Forward current, If
  - Thermal solution, Rth
- A more linear LI response is desired



LED Thermal Resistance (Rth):
- LED packaging is very important
- Lower thermal resistance package allows for driving the LEDs harder
  - → more lumens out
  - → Lower Tj



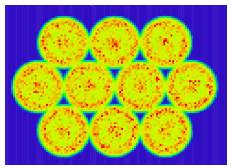
$$T_j = R_{Th} * V_F * I_F + T_{Heatsink}$$

System Thermal Resistance (Rth):
- Tj linearly depends upon system Rth.
- System Rth determines peak allowed If

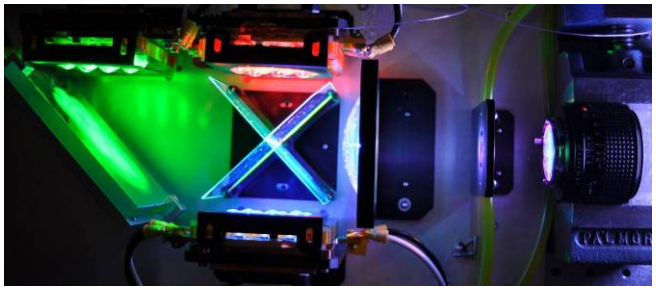
Solid-State Illumination Update

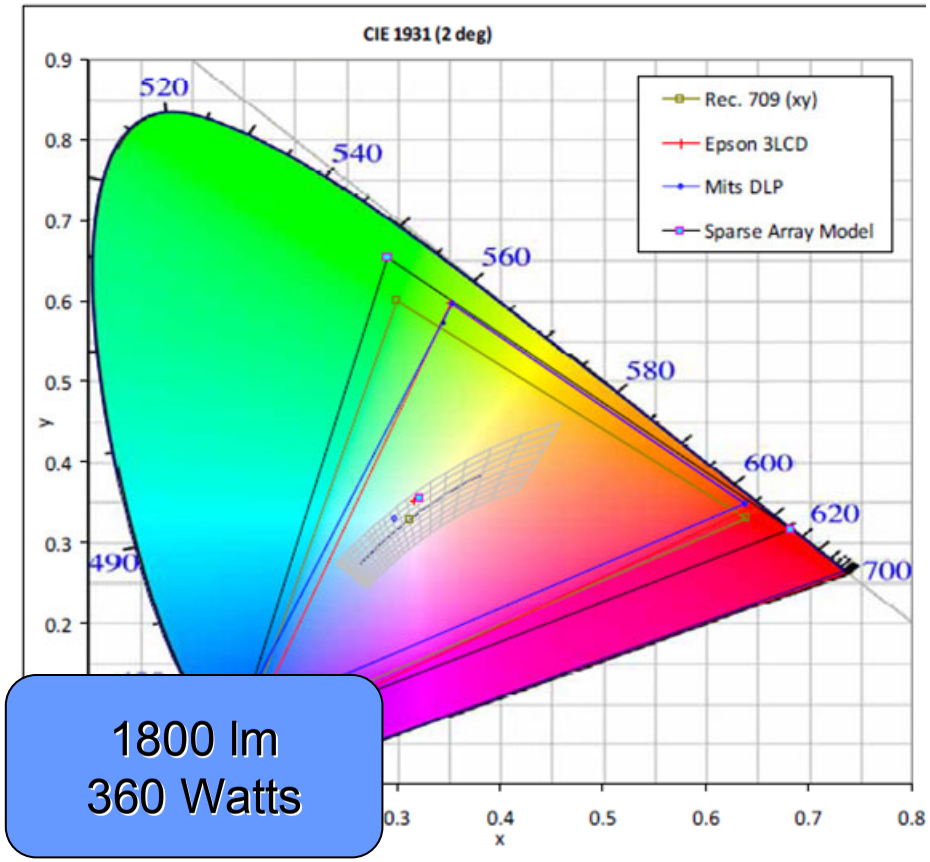
Array LED solution

- **Achieved performance:**
  - Brightness: 1800 lm (1000lm in 2009)
  - Power: 360 W (full ON white screen) Avg. power <250W (depends upon image content)
  - Color: Wider than Rec.709 (better than flat LCDs)
- **Issues in work:**
  - LED reliability: Spec is 6 amps @ 50% DC – Demo 7 amps 82% DC – testing is ongoing
  - Size reduction activities. Once new boards performance quantified, will accordingly pursue new paper designs, <u>if needed</u>.



Arrayed LED





1800 lm
360 Watts

Technology Comparison

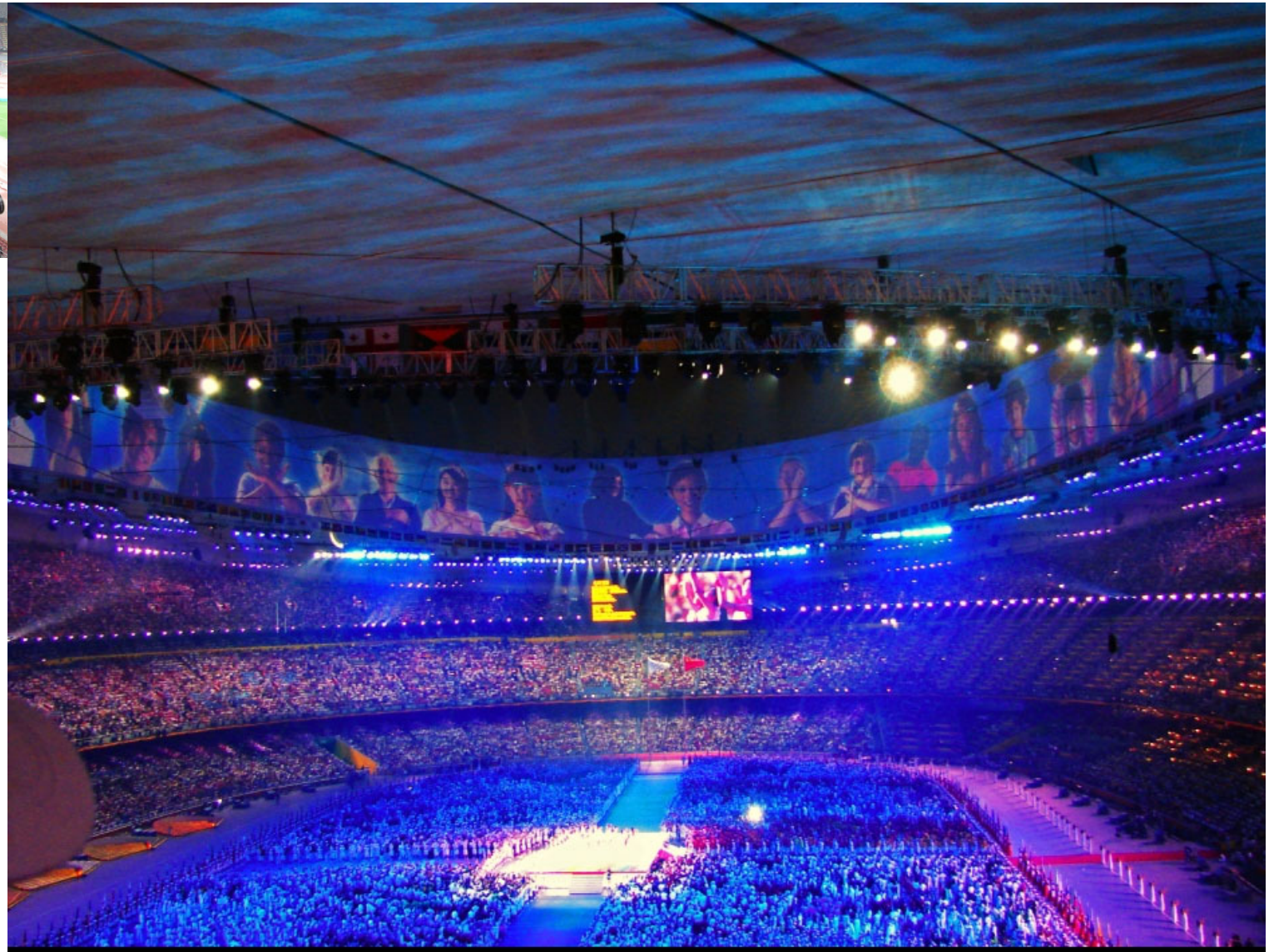
	Lamp	LED
Brightness	2200 lm	1800 lm
Color	Good	Best
Power consumption	250W	360W
Efficiency	8.8 lm/W	5 lm/W
Light source Lifetime	2-5k hrs	~20k hrs
Light source type	Gas/Plasma	Solid-state
Reliability issues	Lamp bulb and color wheel	None
Eco-friendly	Mercury	Green
Instant On/Off	No	Yes
Total Cost of ownership	2x	1x

: Good / Better

: Need improvement

Thank You

Contact Info:
Sajjad Khan
Sajjad.Khan@ti.com



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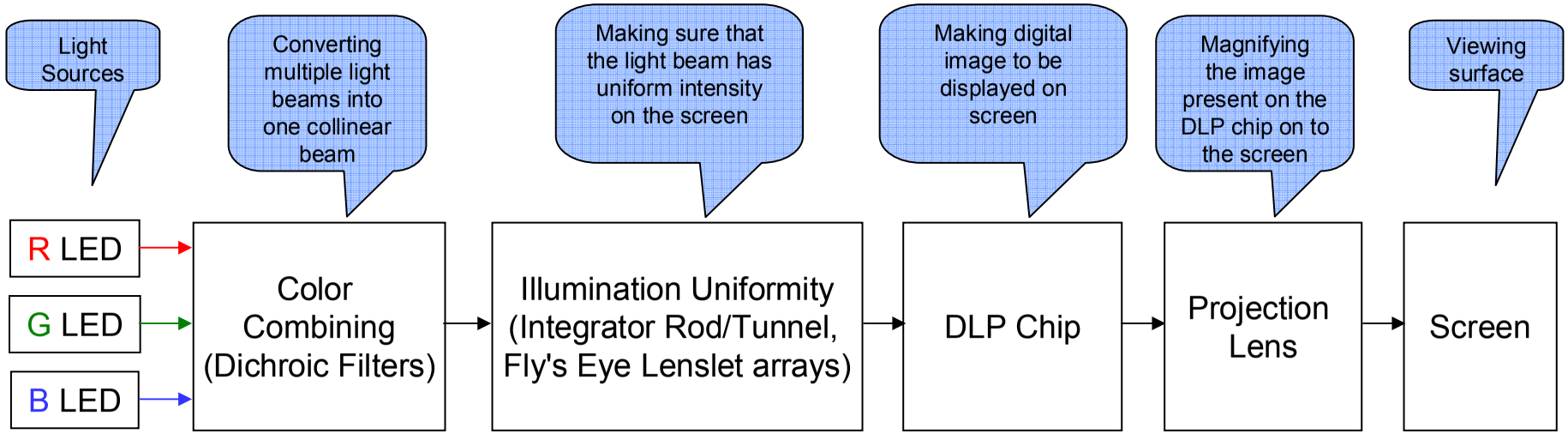
It's amazing. It's the mirrors. ™

Backup

LED-based DLP Display Block Diagram



Goals are to:

- Minimize cost
- Increase efficiency
- Increase brightness
- Minimize # of components
- Minimize system size (volume)

Desirable LED Characteristics for projection

- More lumens, AND fewer Watts (High lm/W)
- More lumens in a smaller Area (High lm/mm^2)
- Low thermal resistance LED package
- Higher Junction Temp limit
- Higher extraction efficiency