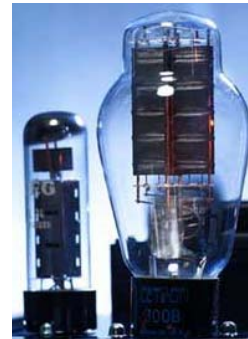


Red, Green and Blue LED-based White Light Sources

Jim Gaines
Principal Engineer

- ◆ From Tubes to Transistors (glass-electrode to semiconductor)

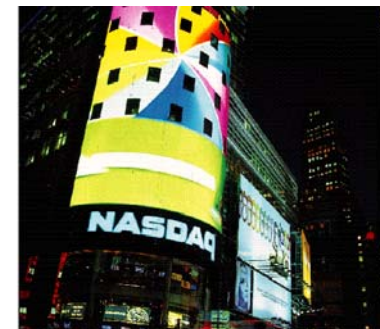
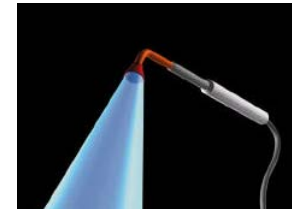


- ◆ Now: From Lamps to LEDs (SSL)



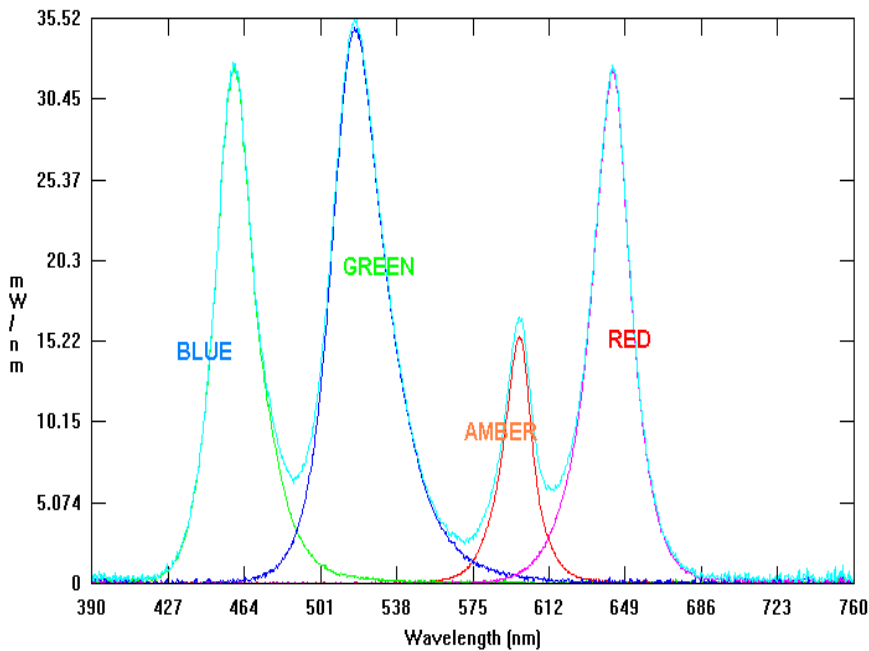
- ◆ White light generation and associated challenges
- ◆ High color rendering with **RAGB** LEDs
- ◆ Multi-chip packages
- ◆ Conclusions

- ◆ Used for signals for 30+ years
- ◆ HB LEDs are established in several areas:
 - Handheld phone backlights
 - Traffic lights
 - Car brake lights
 - Large, stadium-size displays (NASDAQ building)
- ◆ LEDs are moving towards use in illumination
 - Car headlights
 - Niche applications (step lights, flashlights, architectural lighting)
 - Mix red, green and blue LEDs to make
 - white and variable-colored light

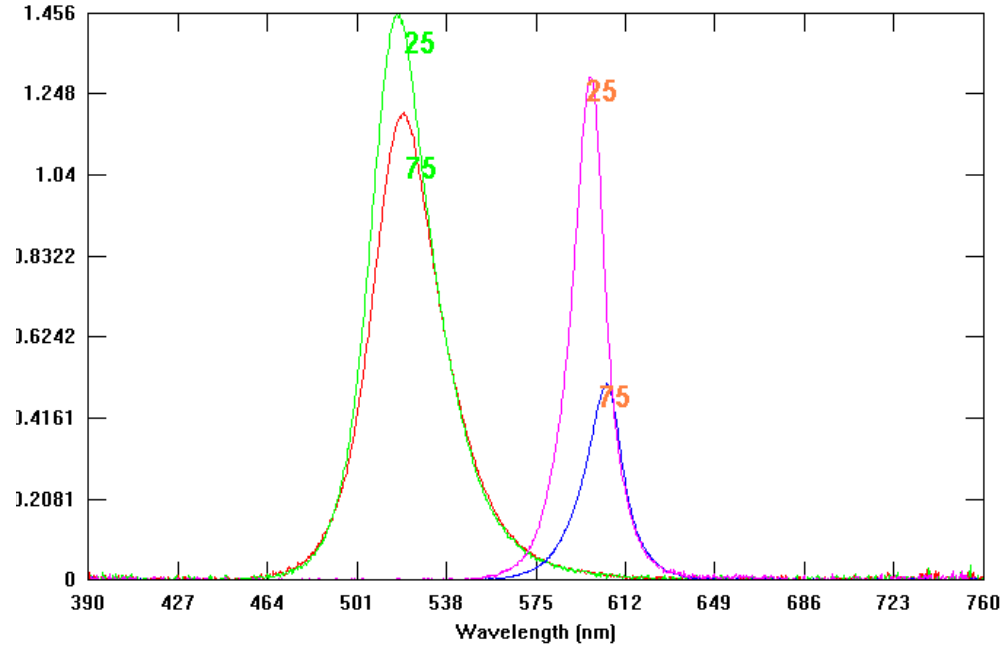


- ◆ Theoretically the most efficient solution
- ◆ Unique ability to vary lamp color
- ◆ By adding amber (**RAGB**), high color rendering index can be obtained.

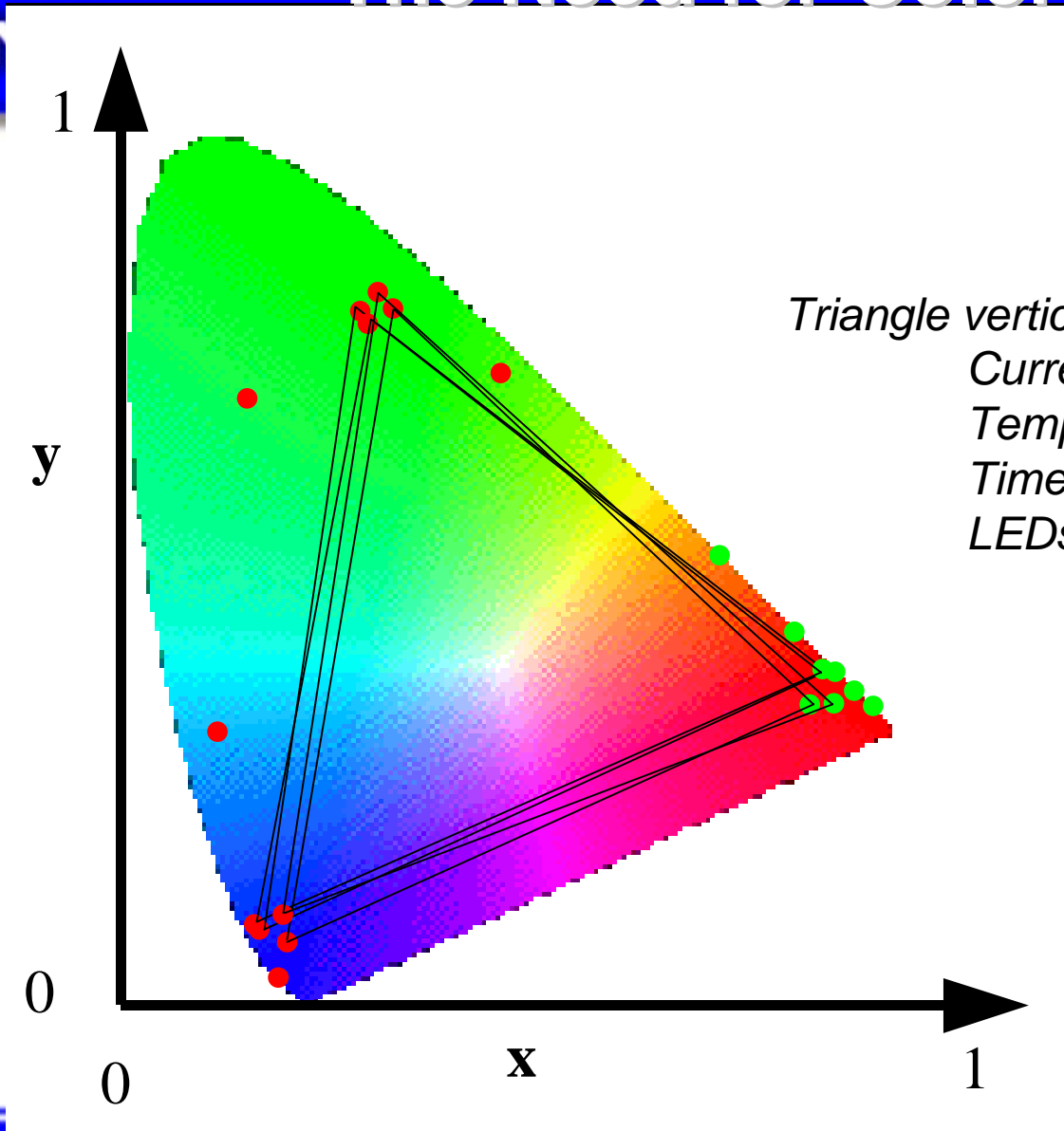
Typical LED spectra

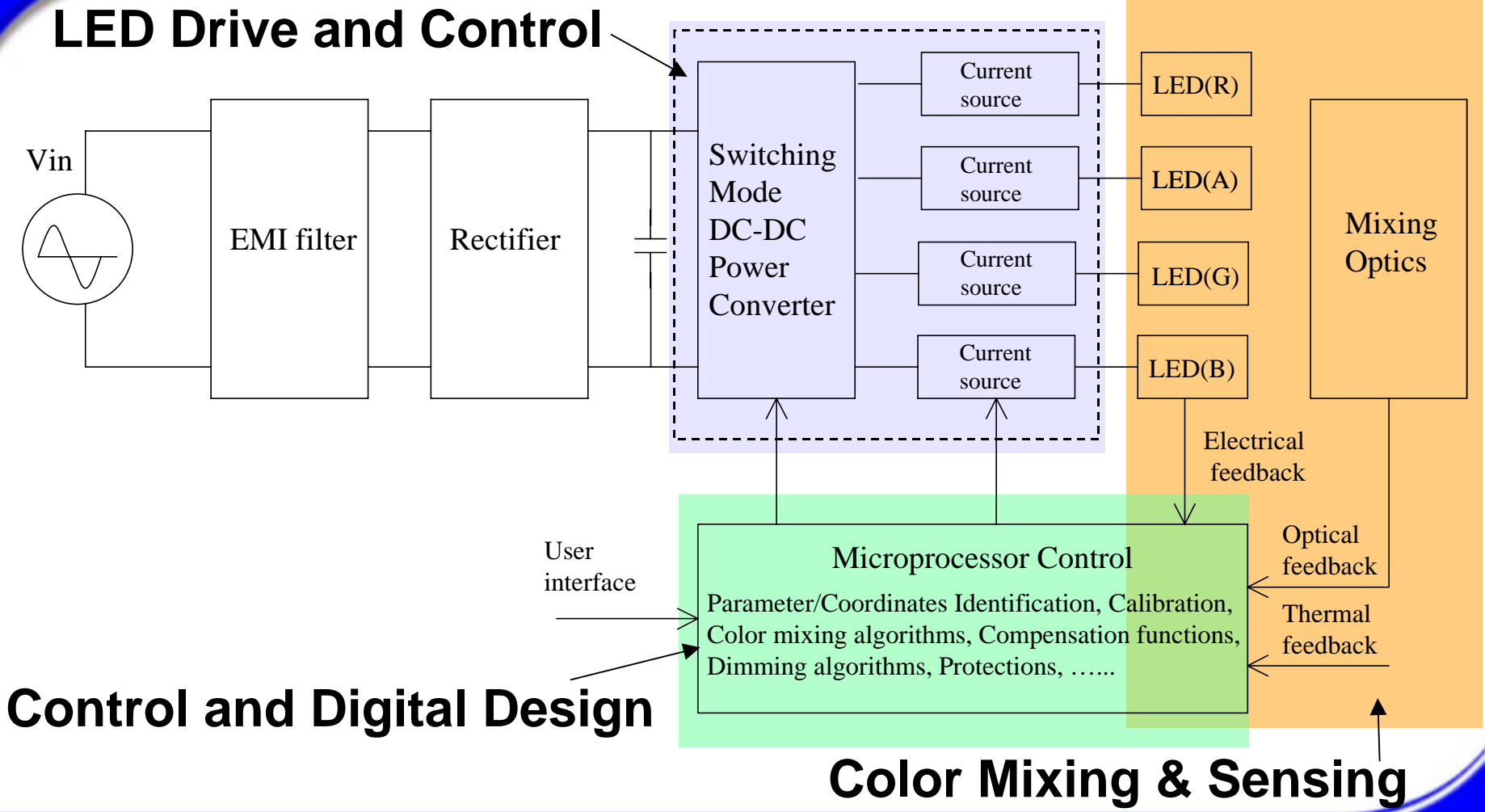


LED spectra vs. temperature



The Need for Color Control





- Spatial color mixing
- Control system design
- Photosensor placement and light sampling
- Effect of current waveform on sensing and perception
- Stability of system during dimming and color changes
- Thermal management

Multidisciplinary problem, involving optics, power electronics drivers, feedback control systems, thermal management and system architecture.



Red, Amber, Green and Blue LED-based White Light Source

for

Color Rendering Index > 90

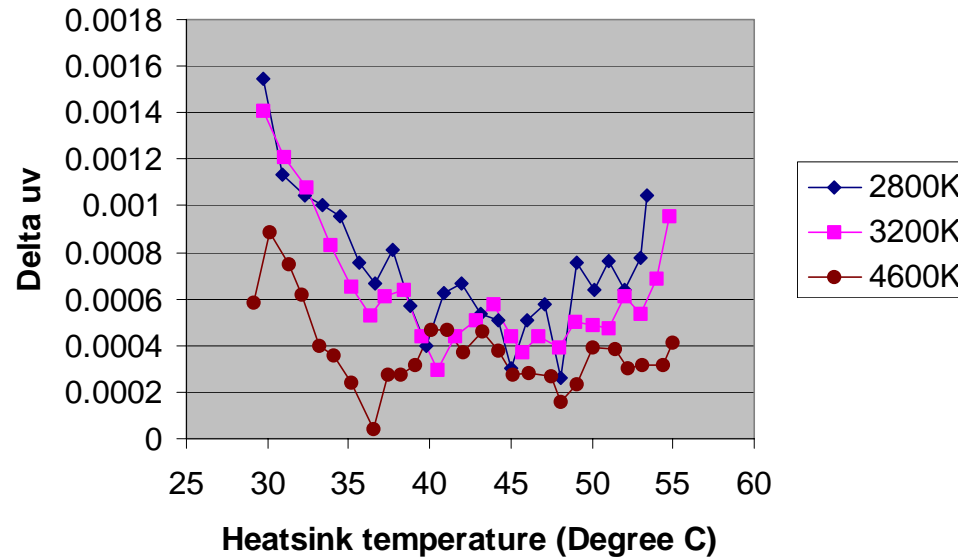
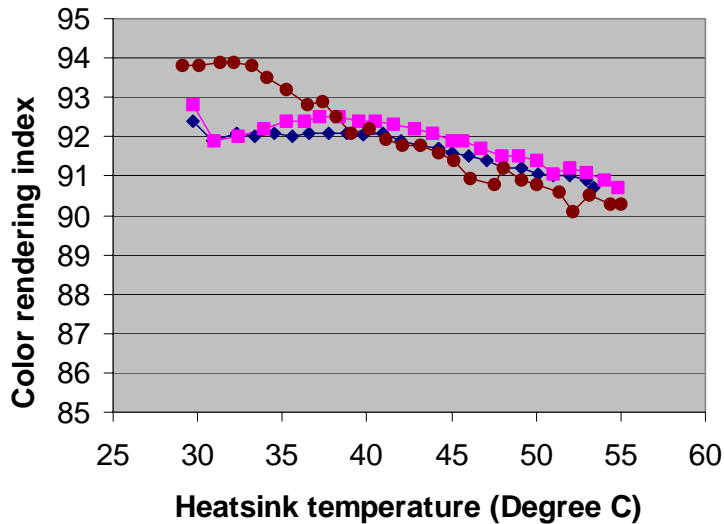
- ◆ With **RGB**, there is a single set of LED currents that produce a given set of color coordinates.
- ◆ With **RAGB**, different combinations of **R**, **A**, **G** and **B** can yield the same color.
- ◆ We can use this extra degree of freedom to maximize the Color Rendering Index.

- ◆ 64 LEDs
- ◆ Temperature feedback
- ◆ Luminous intensity feedback
- ◆ Individual color sensing



Color Rendering Index
 $R_A > 90$

Color variation
 $\Delta uv < 0.002$



For a heatsink temperature change of 25C, at 3 different color temperatures.

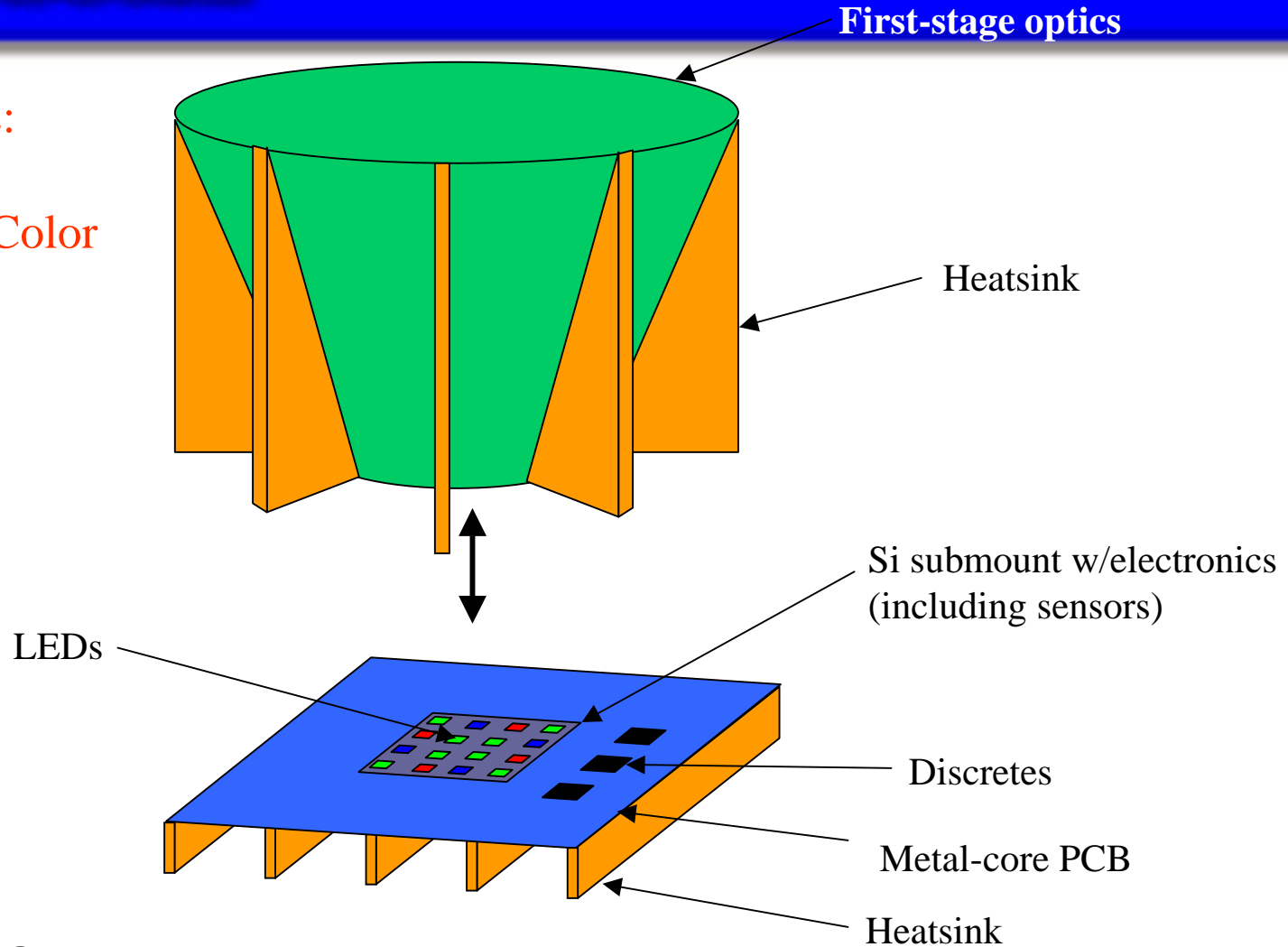
Multi-chip Packages

for

*compact, color-variable light
sources*

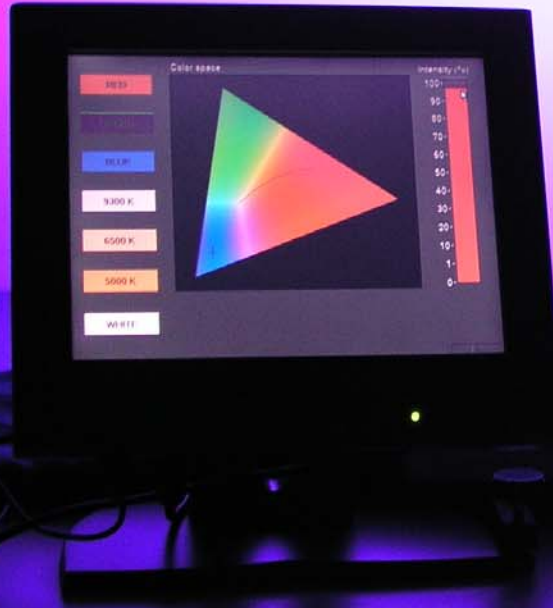
Schematic LED-System-in-Module

User inputs:
DC power,
Intensity & Color
signals



16 1W LEDs @ 75lm/W \approx 90W Halogen reflector lamp

Let's make things better.



10000 K
Color w/

Intensity (%)

- 100
- 90
- 80
- 70
- 60
- 50
- 40
- 30
- 20
- 10
- 1
- 0

9030

D50 Illuminant

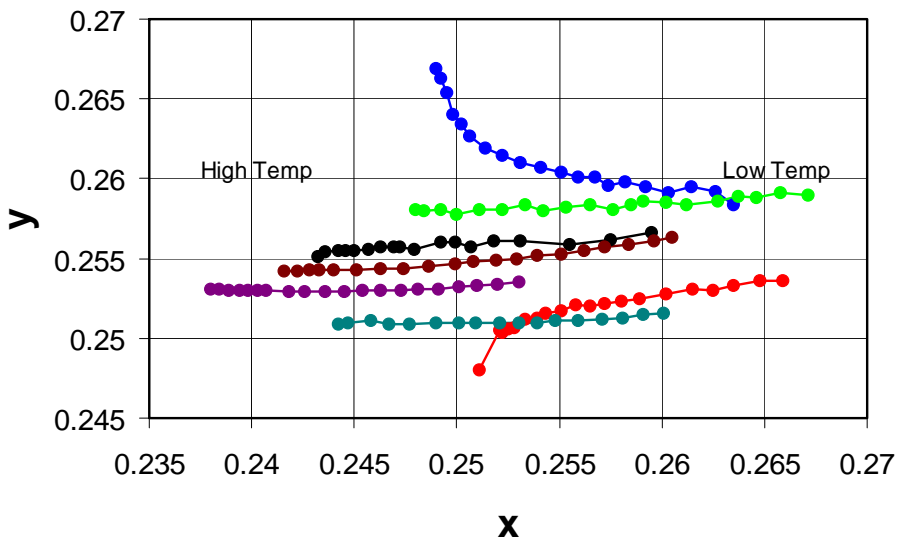
10000 K

6500 K

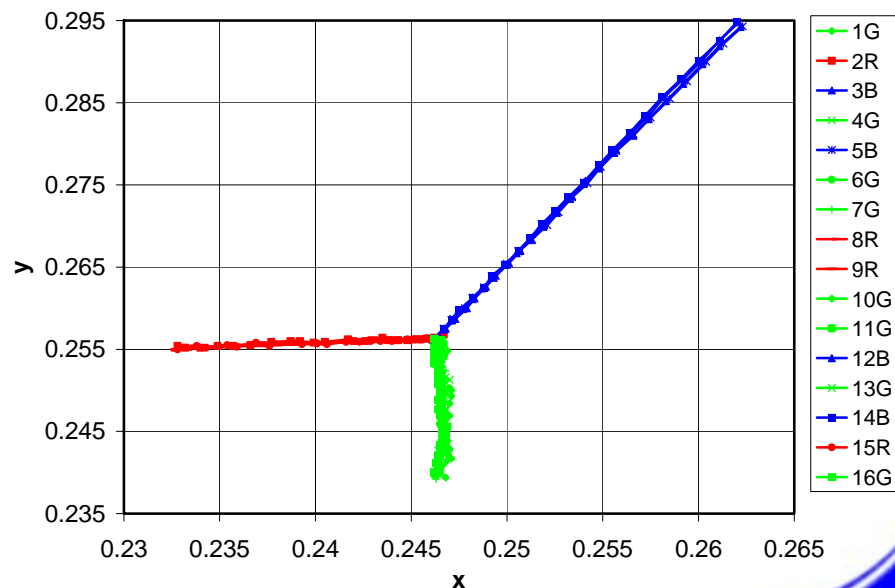
5000 K

White

Color change during warm-up



Color change when a single LED dims



- ◆ There are plenty of challenges to arrive at multi-colored LED general illumination
- ◆ Two examples of approaches to address these challenges:
 - **RAGB** lamp (electronic controls)
 - Multi-chip **RGB** lamp (color mixing optics)



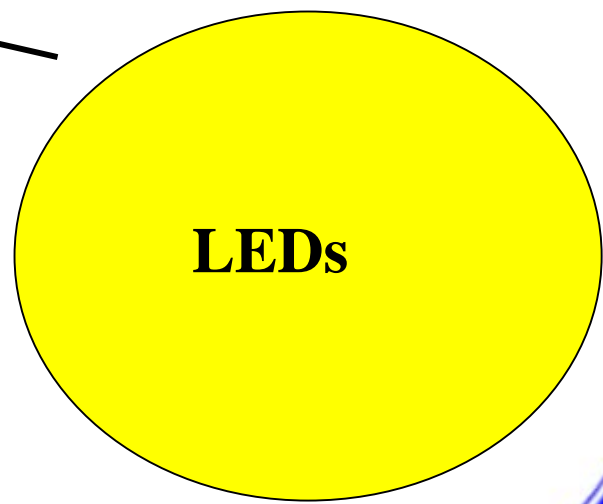
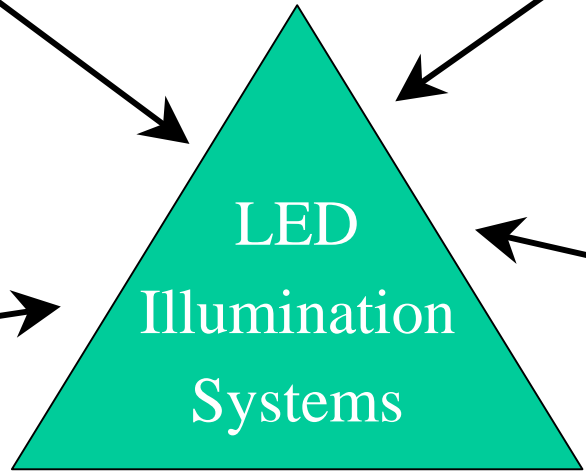
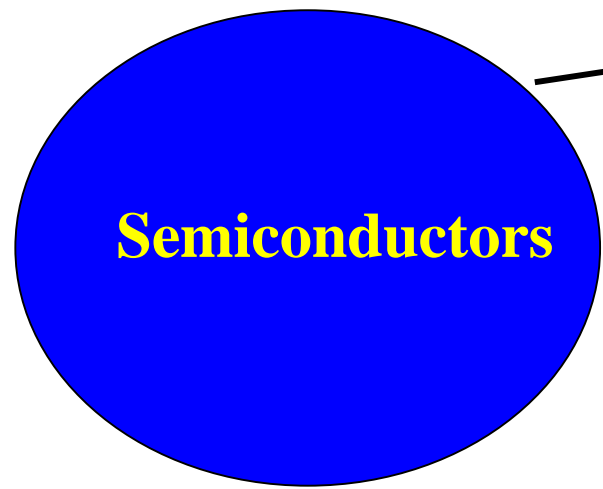
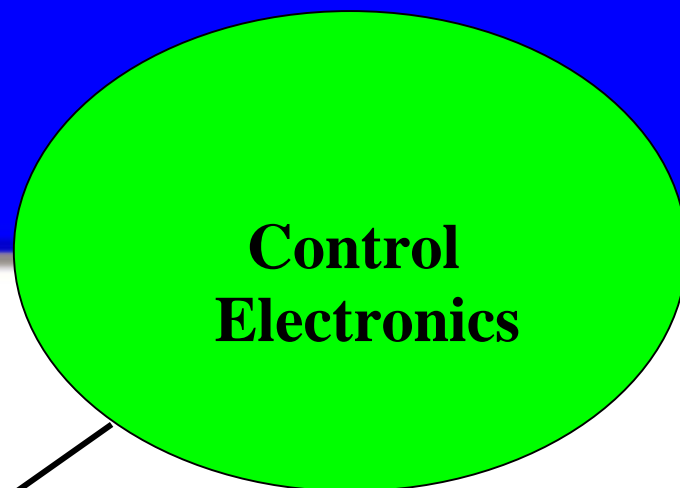
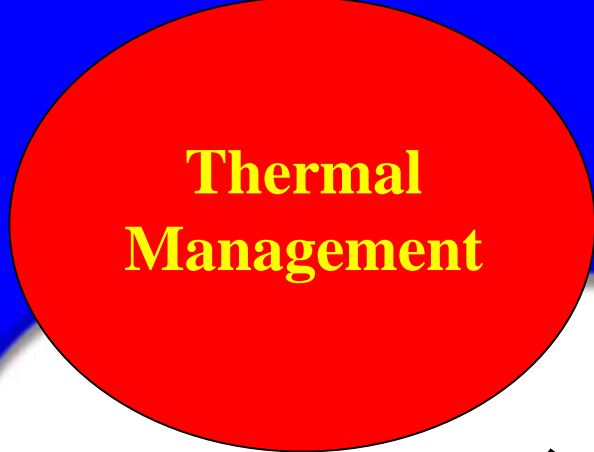
12W
17W



25W
40W



60W
80W



Let's make things better.



PHILIPS

Thank you.

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periodic updates**