Design issues in advanced display systems that affect calibration capability and quality

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Challenges to the Display Manufacturer

- **Many different markets**
  - Traditional CRT business replacement
  - Digital photography
  - Gaming and other Entertainment
  - Full motion video display
- **Many different physical interfaces**
  - Traditional analog xVGA (various resolutions)
  - DVI
  - sVideo
  - Component video
  - HDMI

Challenges to the Display Manufacturer (cont)

- **One Major Technology for desktop display: LCD**
- **Wide variety of customer requirements for a single technology.**
- **How do we decide the best mix of features for a given display model?**
- **Important point: The processor used in many displays for manipulating the video image data is often more powerful than the processor in the computer that is driving the display.**

Display Features drive the design and target market

- **High Luminance**
- **High Contrast ratio**
- **High Resolution**
- **Wide Viewing Angle**
- **High Speed Video Response**
- **Wide Gamut**
- **Cost Sensitivity**
- **Problem: features are often contradictory, for example: it′s difficult to achieve wide viewing angle, high resolution and high speed video response in the same panel.**

Color-Critical Still-Image Displays

- **Small market when compared to CRT office replacement or entertainment**
- **Maximum luminance not too important**
- **Wide field of view somewhat important**
- **Resolution very important**
- **Video bandwidth not important**
- **Color Gamut Very Important**
- **Contrast Ratio moderate importance in photo print preview applications.**
- **Moderate cost sensitivity**

Color-Critical Motion Picture Displays

- **Extremely small market**
- **Low luminance is preferred.**
- **Video bandwidth is important**
- **Wide field of view is important (Collaborative viewing)**
- **Moderate resolution (HDTV minimum 1080H)**
  - Moderate resolution, for image only applications
  - Editing applications often utilize the same screen for program input so resolution requirements may increase.
- **Contrast Ratio is extremely important (>2000:1)**

Displays for Color Critical Markets

- **Require Calibration**
  - Control of the visual properties of the display
- **Require Characterization**
  - Feed back display properties to software for color rendering or adjustment
- **These processes require accurate measurement and control of key parameters**

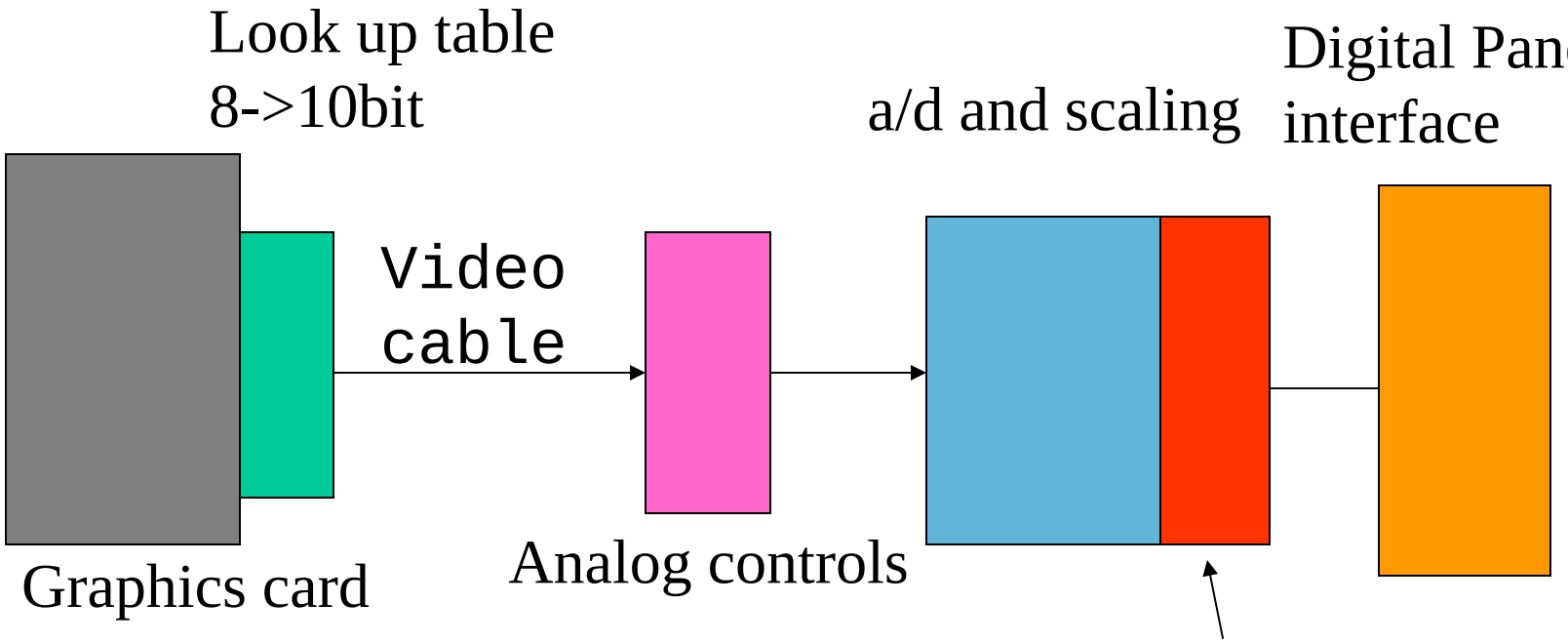
Some basic control and calibration issues

- **Control of white point**
- **Control of black point**
- **Control of gamma**
- **Control of grey tracking**
- **Control of maximum luminance**
- **Generation of an appropriate color profile.**

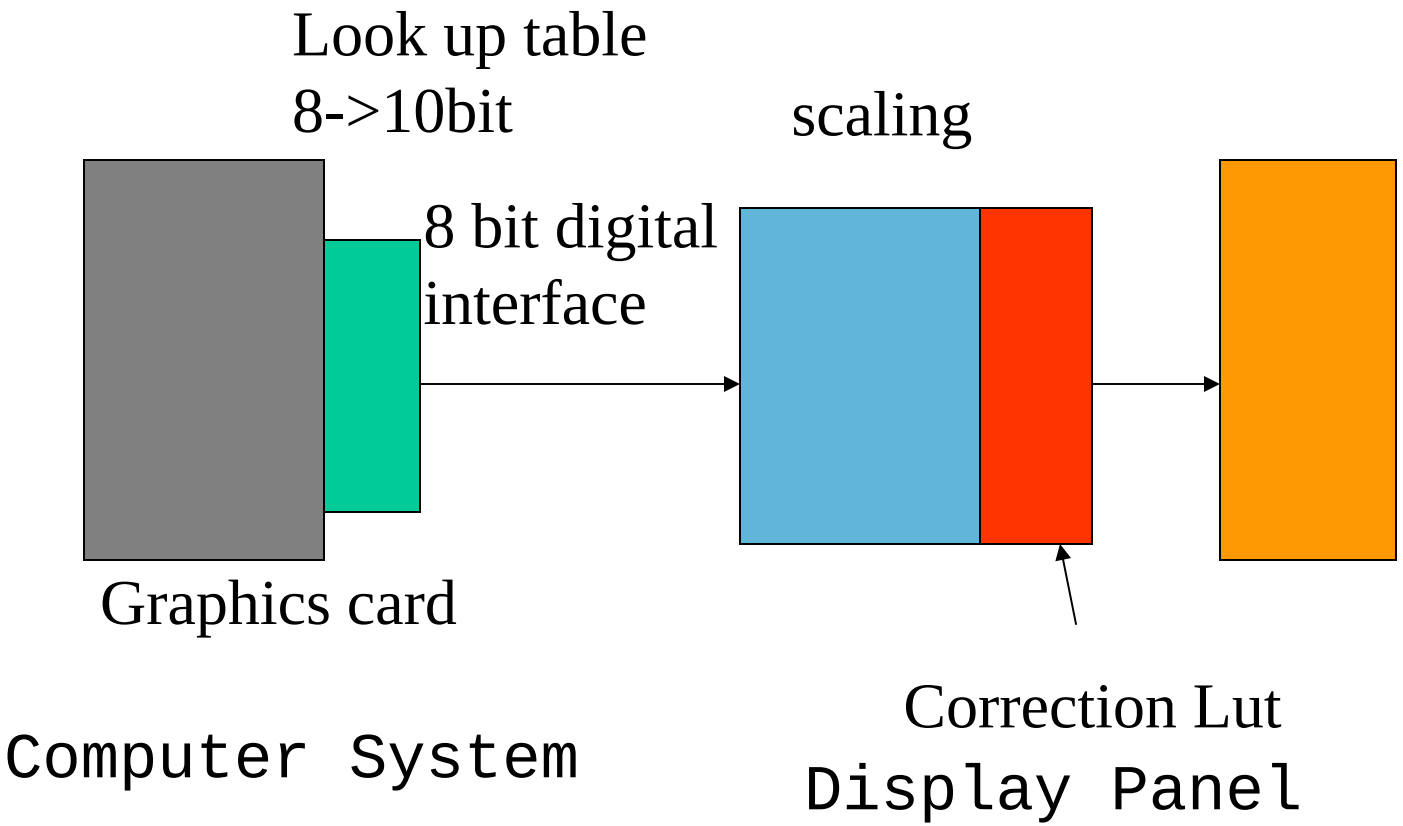
Goals

- **Display is characterized by:**
  - White point (Yxy)
  - Gamma
  - Contrast ratio (Ratio of white luminance to black luminance)
  - Grey-scale tracking

System Block Diagram (Analog interface)



System Block Diagram (Digital interface)



Methods of Adjusting white point

- **Use DDC/CI digital control mechanism**
  - Allows remote control of display from computer via signal lines in the display interface cable.
- **(Analog) RGB gains of input signal**
  - Not optimum, may limit dynamic range
- **(Digital)RGB balance of backlight**
  - Potentially the optimal solution, but the settling time of the lamp servo, may make this adjustment very time consuming.
- **(Digital) RGB adjustment of gamma in Display Engine**
  - Potential problems with Quantization
  - Speed of download can be a problem.

Adjusting Gamma

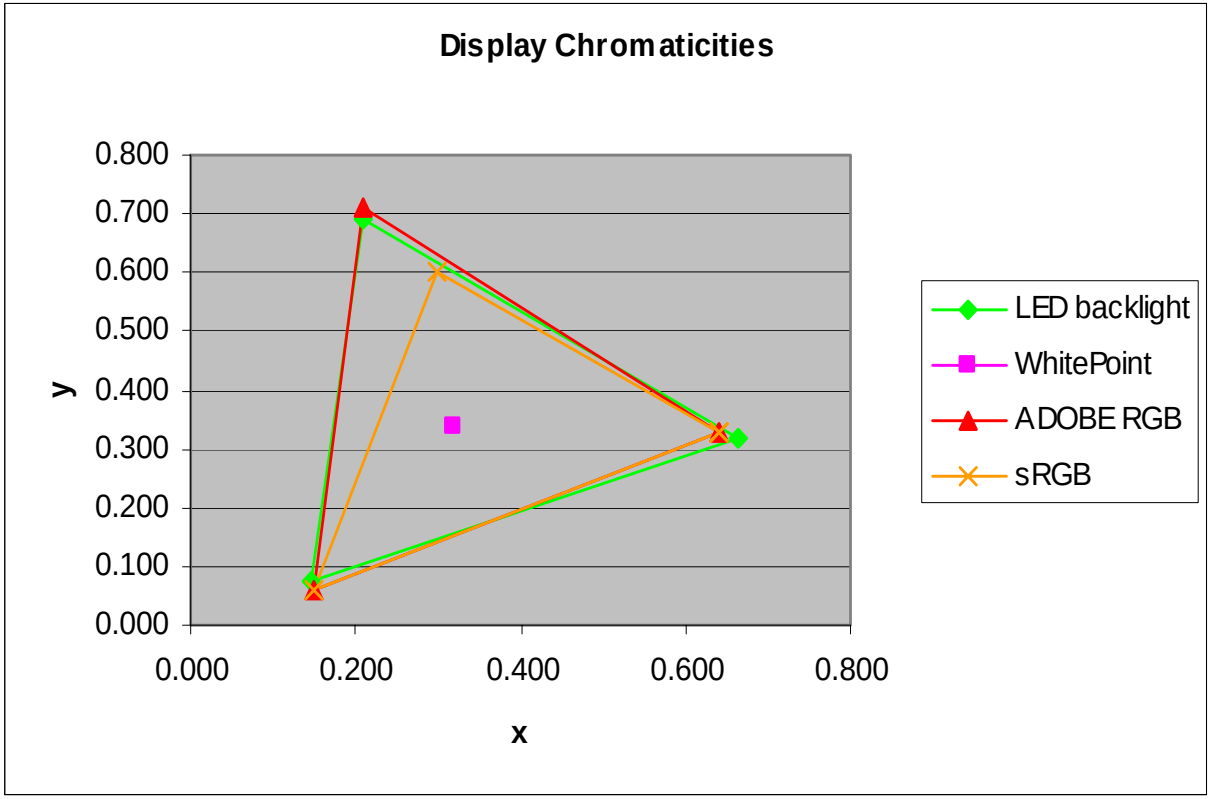
- **Graphics Card**
  - Quick, accurate, but can lead to quantizing error.
  - Leads to problems with mirrored displays Multiple displays attached to a single frame buffer can’t be calibrated independently
- **Display Engine LUT adjustment**
  - Optimal solution, but the time to download the LUT to the display via DDC/CI can be very long.

Some conclusions

- **Color adjustment of modern WG display is challenged by interface speed and adjustment speed of back light system**
- **Adjustment of Look Up tables on the panel using DDC controls is complicated by DDC/CI data rates from video card.**
- **Alternative, vendor specific interfaces can be employed but software is complicated by new interfaces.**

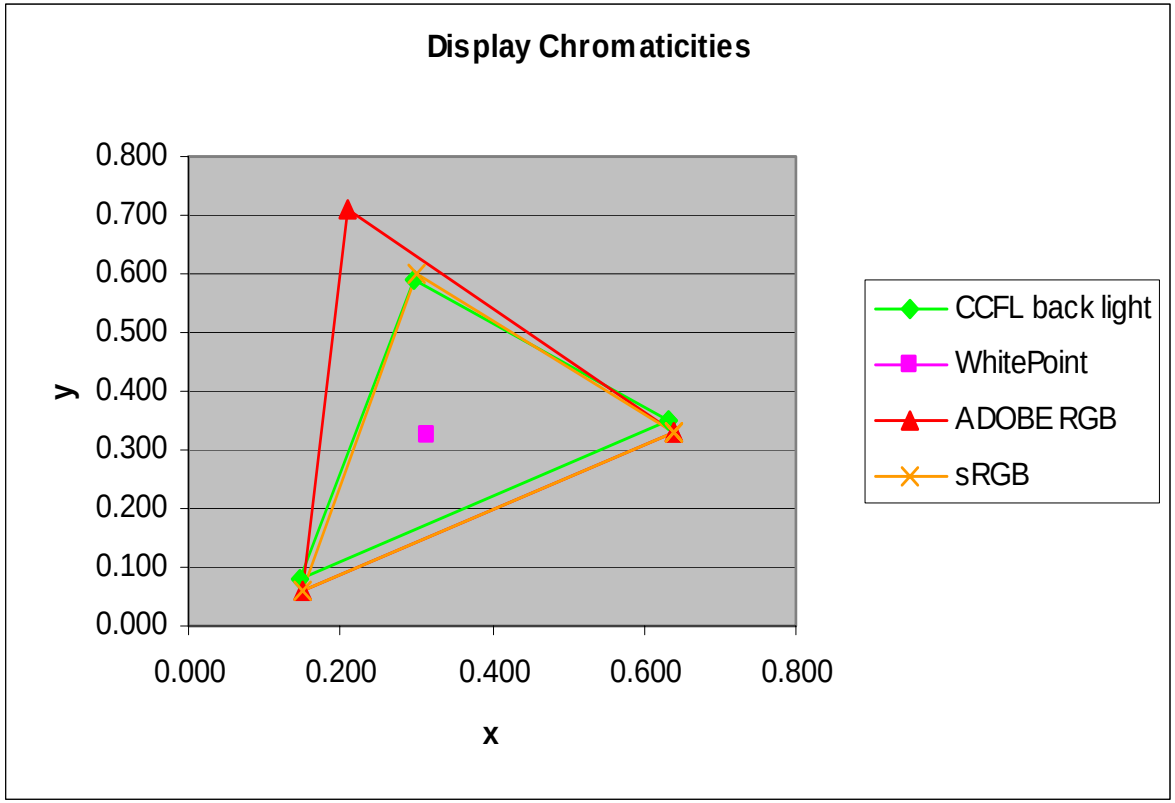
Measuring Wide Gamut Displays

- **LED back light**

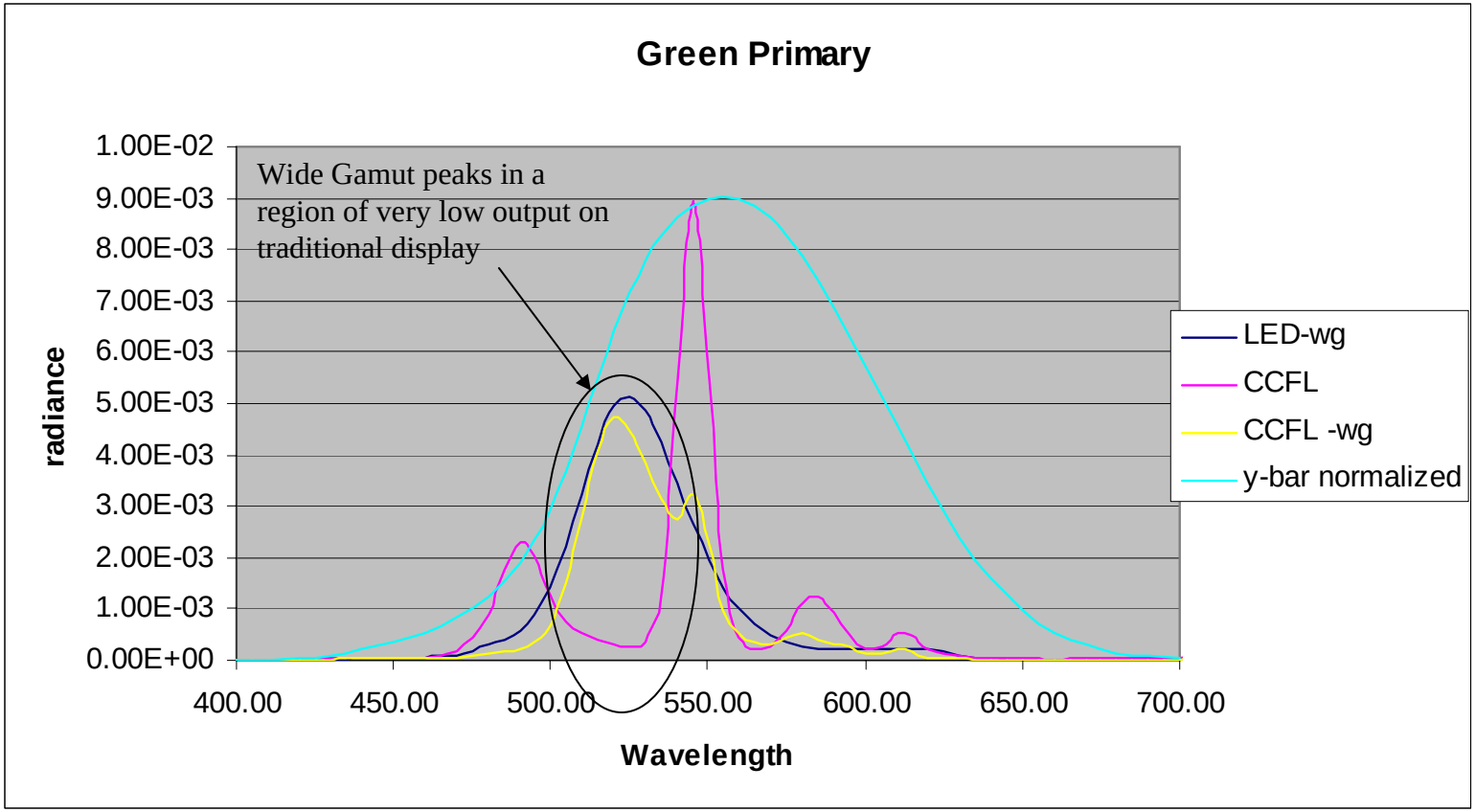


Measuring Wide Gamut Display

- **Traditional CCFL**



Spectral Differences based upon back light technology



Primary Measurement Problem

- **The large difference between the new, wide gamut displays and the traditional CCFL backlights requires improvements in device calibration.**
- **Traditional CCFL: most energy at 550nm**
- **Wide Gamut: Broader and shifted towards 520 nm.**
- **Note that most energy in the Wide Gamut output is in a region where there is little output from the traditional ccfl.**
- **Supplementary WG calibration is generally required for all sensors.**

Gray Scale Color Tracking

- **Color tracking performance of LCD may have some issue to discuss.**
- **Fixed white point of backlight system may have problem.**
- **There is an interaction between the spectrum of the lamp and the panel filters.**
- **Polarization effects are not achromatic**

Gray Scale Color Tracking

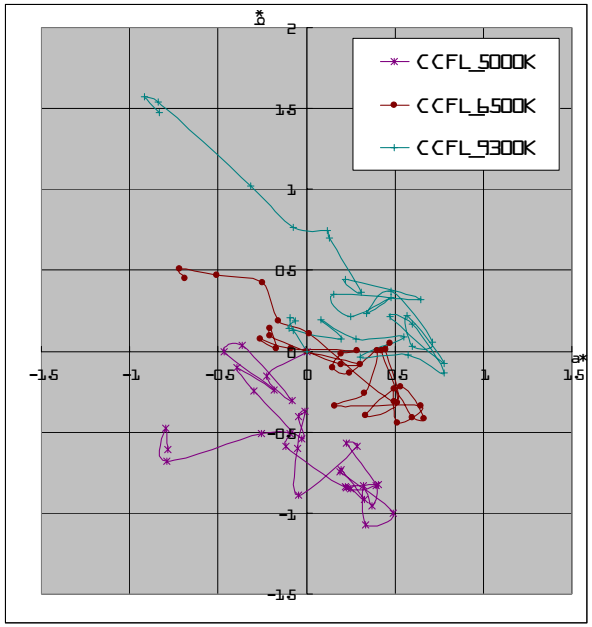
- **Chromatic Spectrum of LCD monitor**

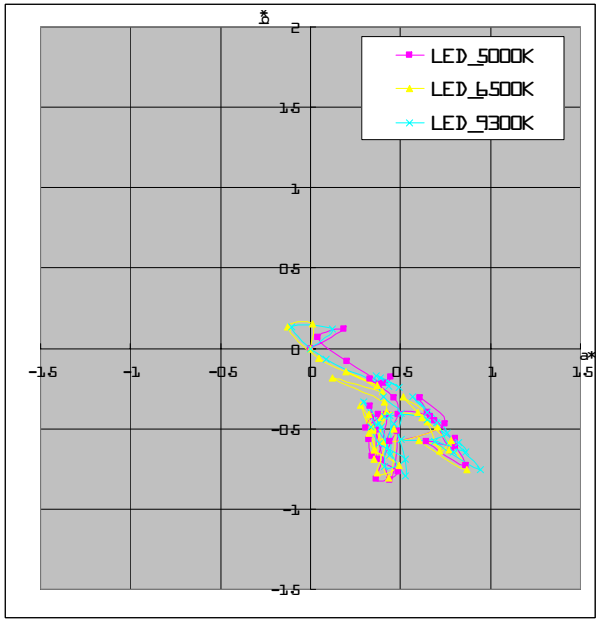
= Chromatic spectrum of backlight x transmission spectrum of LCD panel.

- **Low Steps of Gray Scale are most affected by the chromatic spectrum of the back light.**

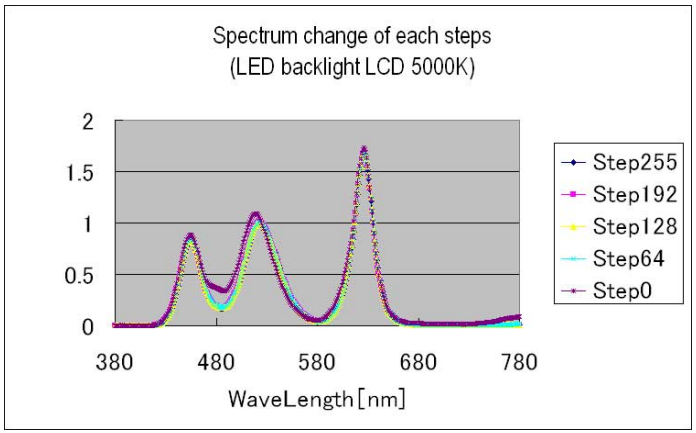
Examples

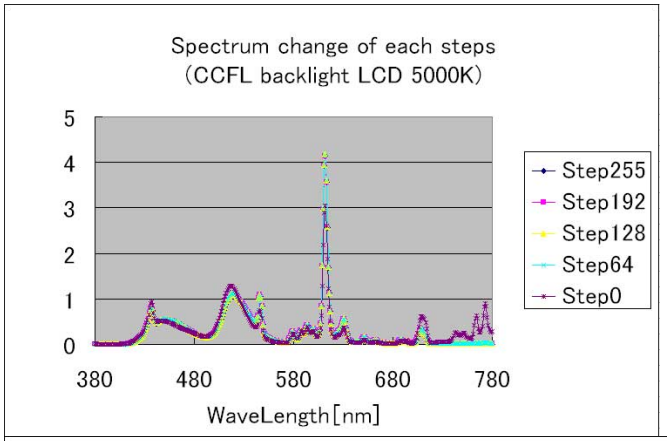
- **Difference of color tracking performance in different backlight system.**

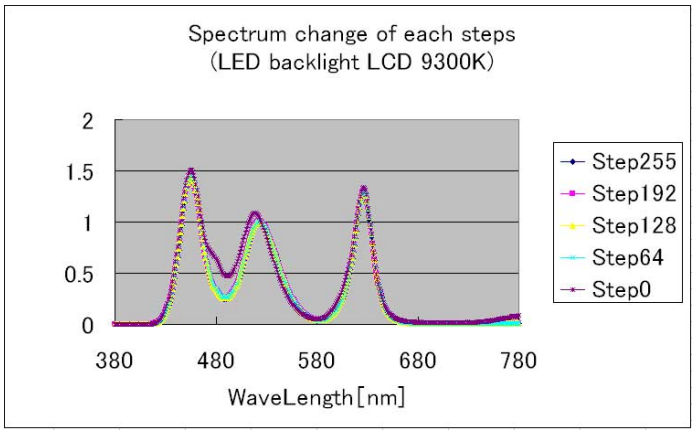


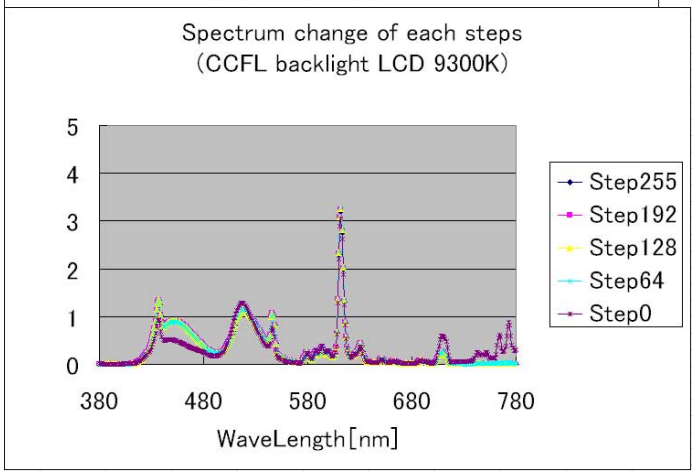


Spectrum change









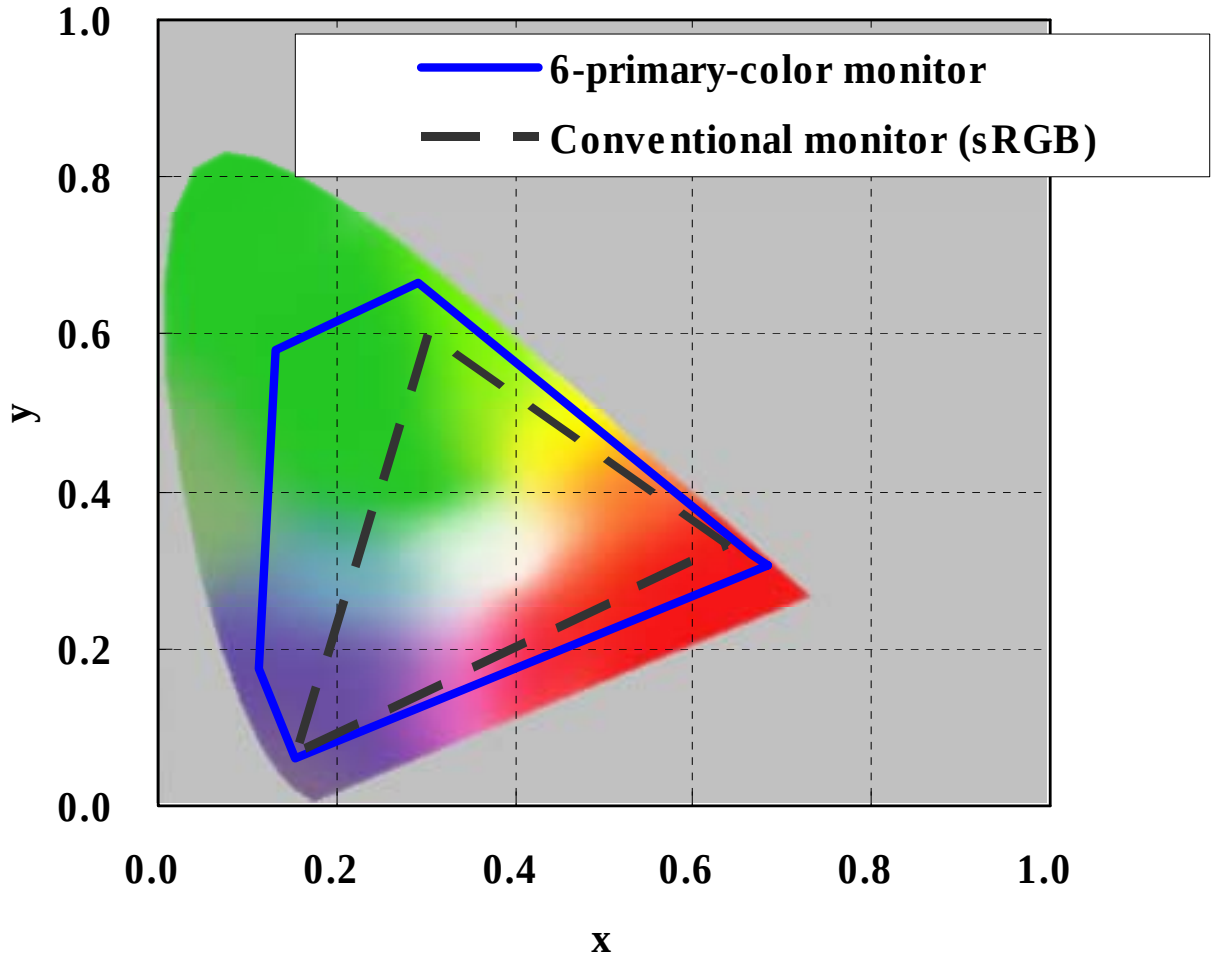
New Internal Color models in displays

- **Printing and Display have different primary color systems Display: RGB primary color**
- **Printing: CMY primary color**
- **RGB high saturated colors are difficult to be covered by traditional printing methods**
- **multi-primary printing has been introduced to increase gamut.**

New Internal Color models in displays

- **Conventional type of display can not cover whole gamut of printing.**
- **RGB wide gamut display could cover the offset printing color space. However not available to support the all various type of printings, (i.e. Ink Jet Printer)**
- **Multi-primary color display provides new solution.**
  - Multi-primary display requires internal color model to render and RGB image onto the display

6-primary color display



Natural Color Matrix

- Natural Color Matrix is an original technology developed by Mitsubishi Electric. It is also deployed by several other licensees. Six basic colorations (RGB and YMC) can be adjusted separately.

CRT

LCD

Conclusions

- **The latest generation of displays offer challenges in measurement instrumentation design.**
  - High luminance
  - Wide Gamut
  - Wide dynamic range
- **Internal Display Color Models such as Natural Color Matrix require a more complex profile because there are not enough degrees in a Matrix Shaper Profile.**
- **Multi primary displays need both wide measurement range and an advanced display profile.**
- **Smarter displays require smarter approaches to building profiles!**
- **ICC Version 4 profiles provide the mechanism to characterize these latest technologies.**