Impact of High Dynamic Range (HDR) Displays on LED Demand

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Outline of Presentation

- High Dynamic Range (HDR) technology on display performance
  - Challenge: Limited dynamic range and Poor utilization of gray levels
  - Goal: Simultaneous control of lighting and gray levels
- Background
  - Dynamic range of mage capture and image display
  - Controlling the dynamic range of displays
  - Increasing gray level resolution
- Technology
  - Process: Computer process frame data, expand gray levels, adjust light
  - Examples of process and algorithms
- Commercial status
  - Technology, Patents, and Players
  - Forecast of LED backlight utilization in LCDs
- References

Improving Passive Displays

- Challenge:
  - LCDs and projection displays cannot match the dynamic range of cinema much less the real world
  - Contrast range of conventional LCD is used to set both overall frame brightness as well as show gray levels within the frame
  - Both contrast and gray level detail are compromised in dark and bright frames

- Goal of HDR:
  - Use the full gray level and contrast capability of LCD and projection displays, especially in dark and bright images
  - Achieve darker blacks and brighter whites and use all gray levels
  - Improve color contrast and gray level resolution
  - Reduce power consumption

Challenge:

Capturing and Displaying Nature

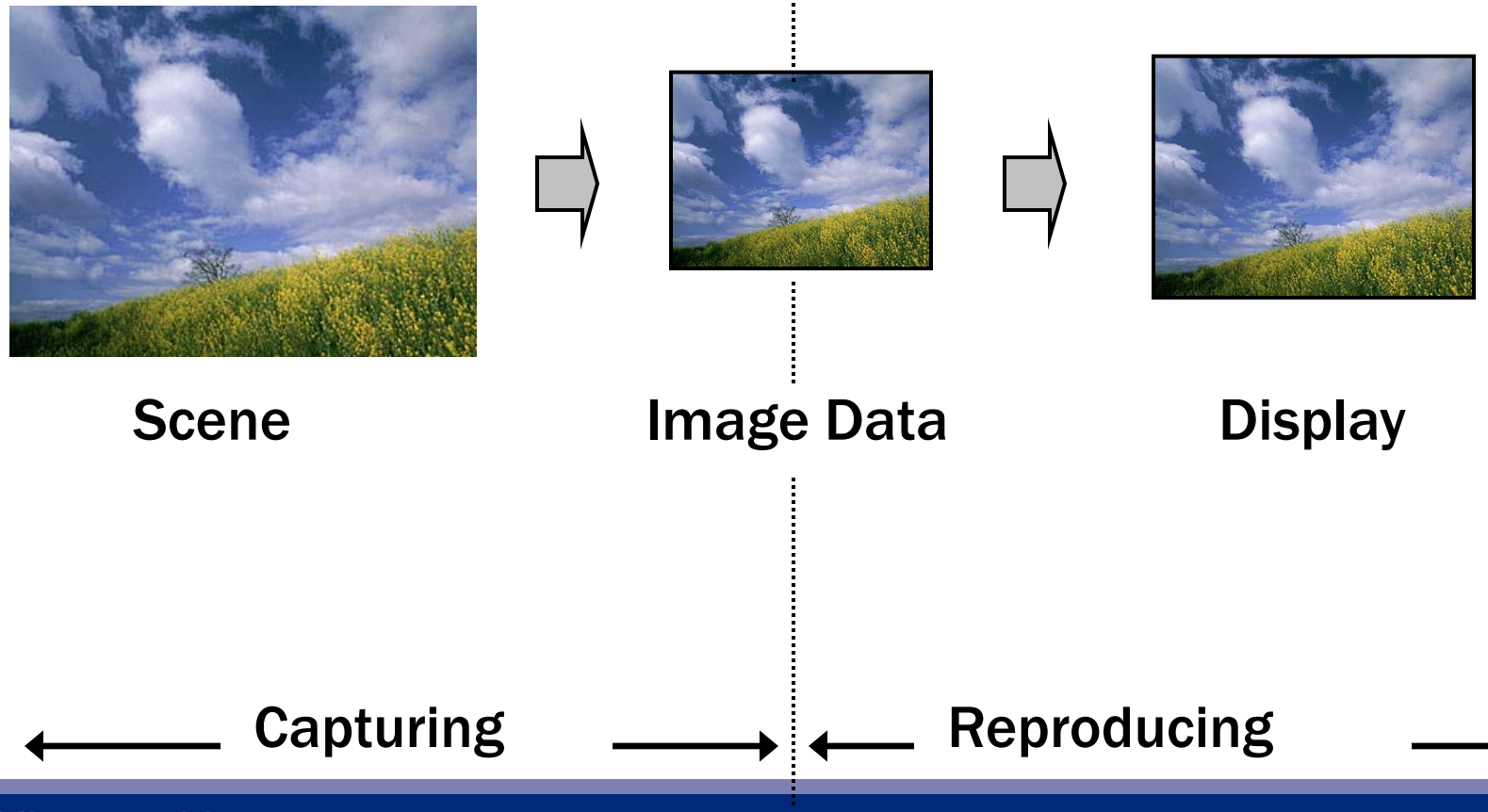
Brightness

- Wide spectrum of lighting in nature
  - Bright clouds > 10,000 Lux
  - Night time illumination <<10 Lux
- Natural light range exceeds the detection range of the eye and imagers
  - Pupil of eye controls light for sight
  - Cameras use exposure controls (f-stop and shutter) to modulate captured light
  - Effect is to dynamically adjust captured light to match the fixed contrast range of the imager (eye, film, or CCD)
- Conventional displays have limited brightness range and lack capability to dynamically adjust brightness range

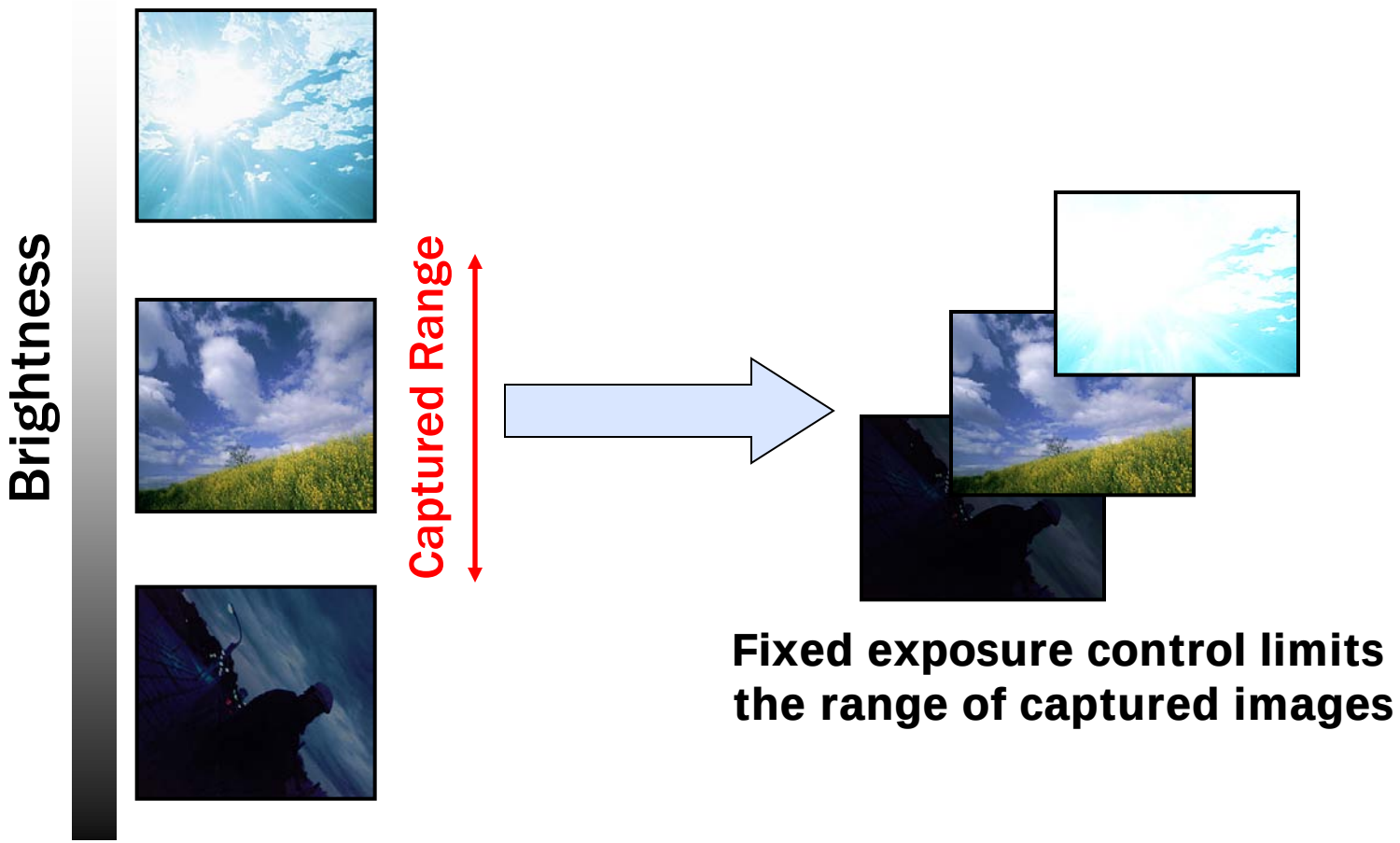
Example Photos from Seiko Epson Presentation

Challenge:

Capturing, Storing and Displaying Images

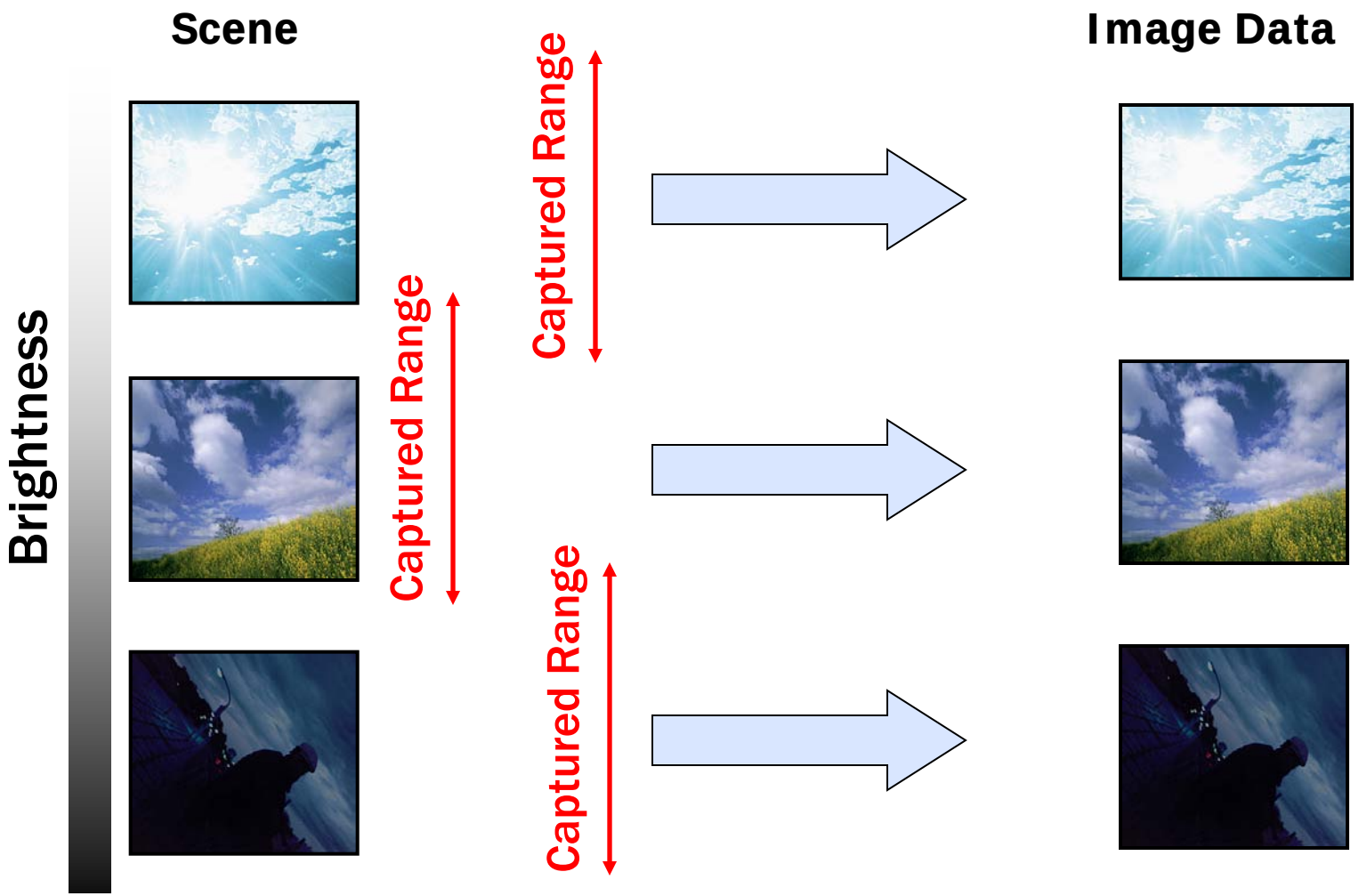


Fixed Exposure Limits Image Capture

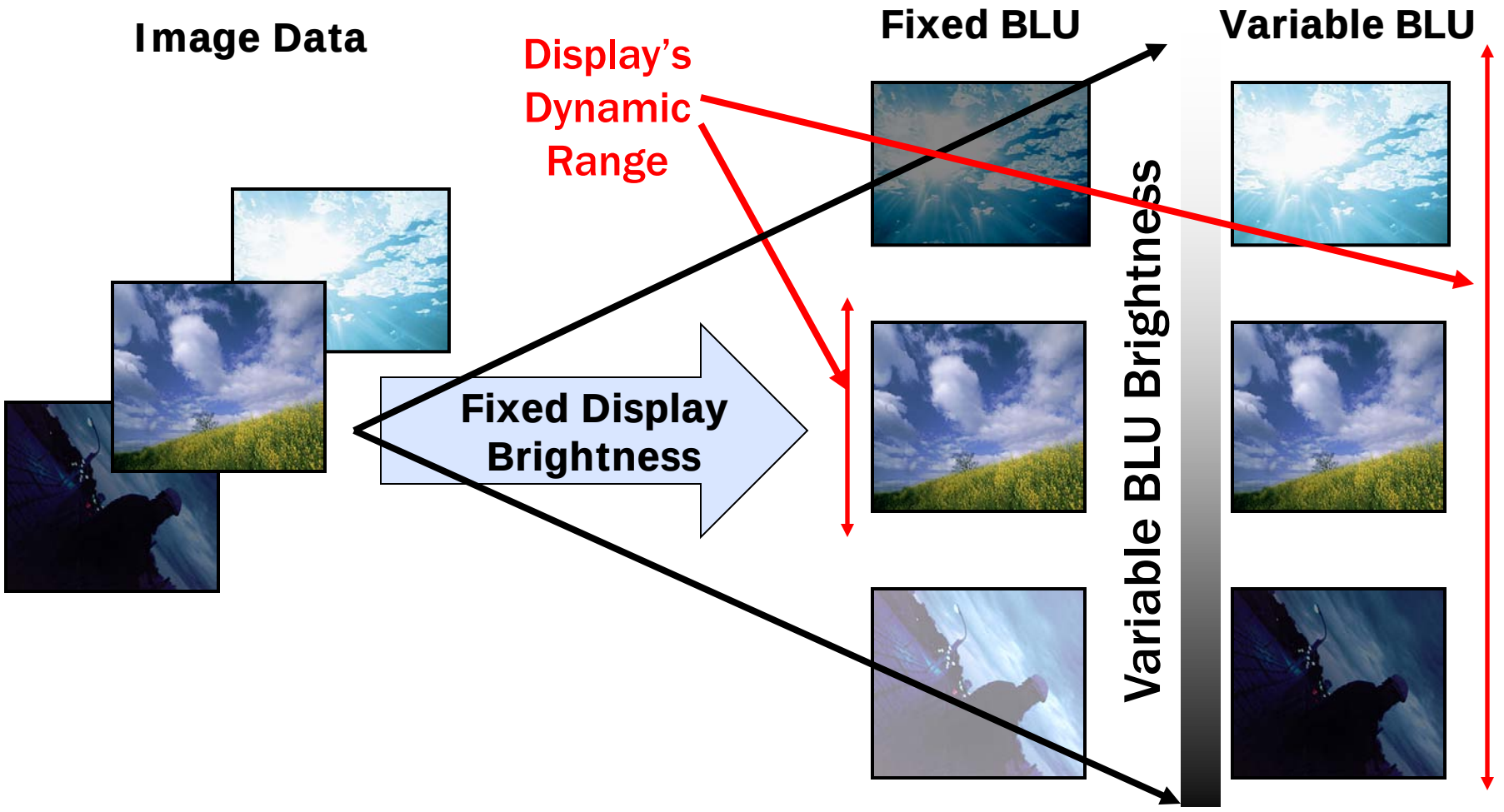


Fixed exposure control limits the range of captured images

Variable Exposure Control Extends Range



Fixed vs.. Variable BLU Brightness



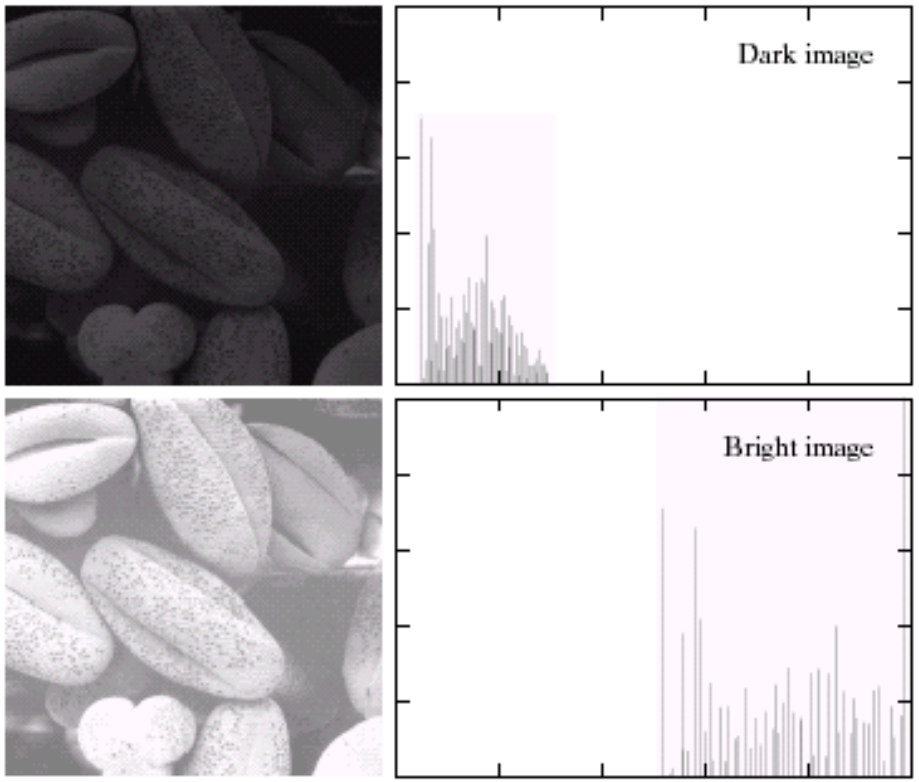
Dynamic Range Control of Lighting

- LCD and MD projection displays consist of two independent display elements: the lamp and the passive pixel imager
  - Independent control is simple and straight forward
  - Backlight or lamp intensity levels can be dynamically adjusted each frame
  - Wide range of control algorithms are feasible
- Basic High Dynamic Range (HDR) approach
  - Increase lamps intensity for bright images
  - Lower lamp intensity for dark images
- Many more sophisticated algorithms are being used

Captured Images with Poor Contrast

- Backlight intensity to extend dynamic range is not enough
  - Dark and bright images usually have poor gray level utilization
  - Backlight modulation alone does not improve contrast
  - Gray level equalization, stretching, clipping can be applied simultaneously and synchronously with backlight modulation
- HDR Imaging combines both lighting modulation and input image processing
  - Basic HDR: White light modulation plus histogram processing
  - HDR II: RGB lighting modulation and RGB histogram processing
  - HDR III: HDR II plus spatial RGB lighting modulation

Examples: Unbalanced Histograms



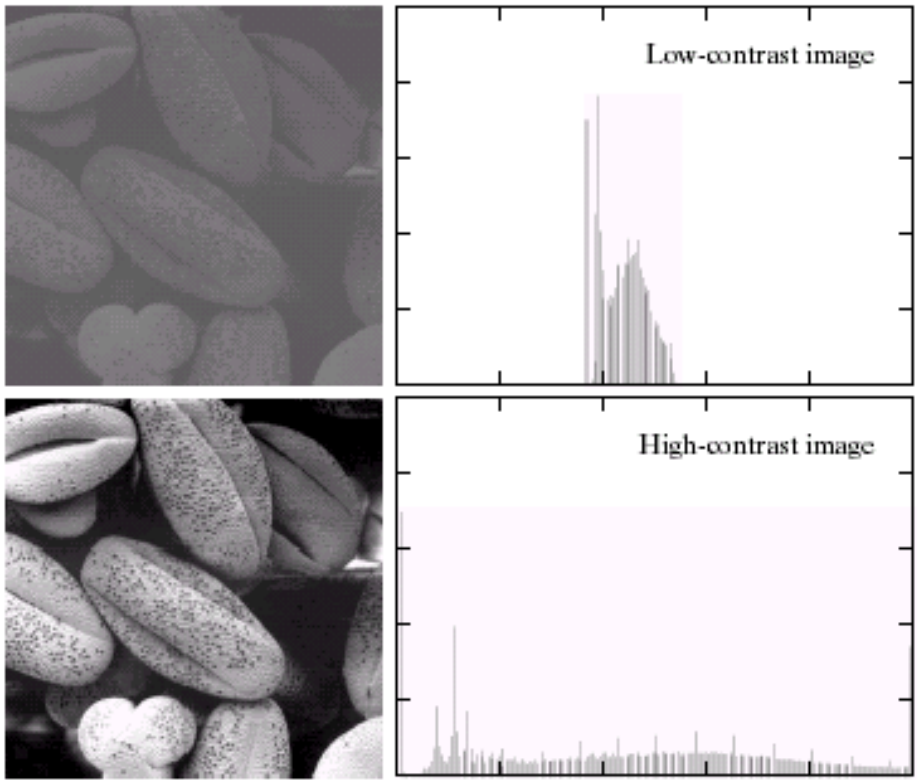
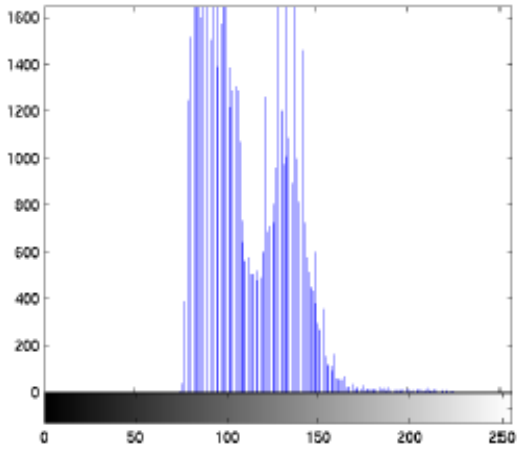
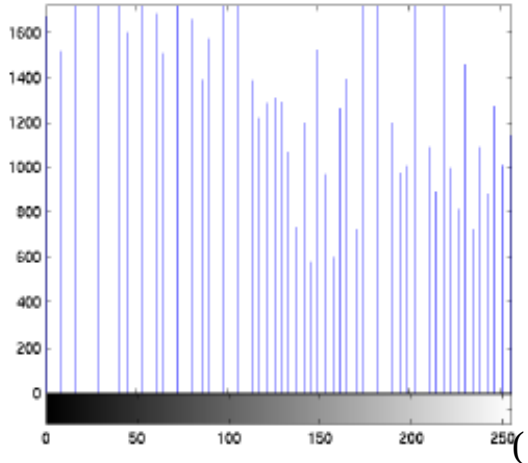


Figure is from slides at Gonzalez/ Woods DIP book website (Chapter 3)

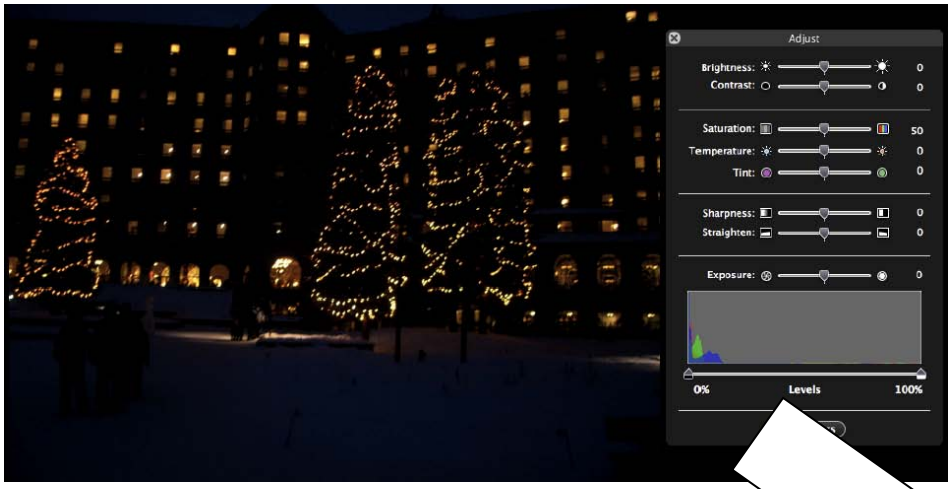
Examples of Histogram Equalization

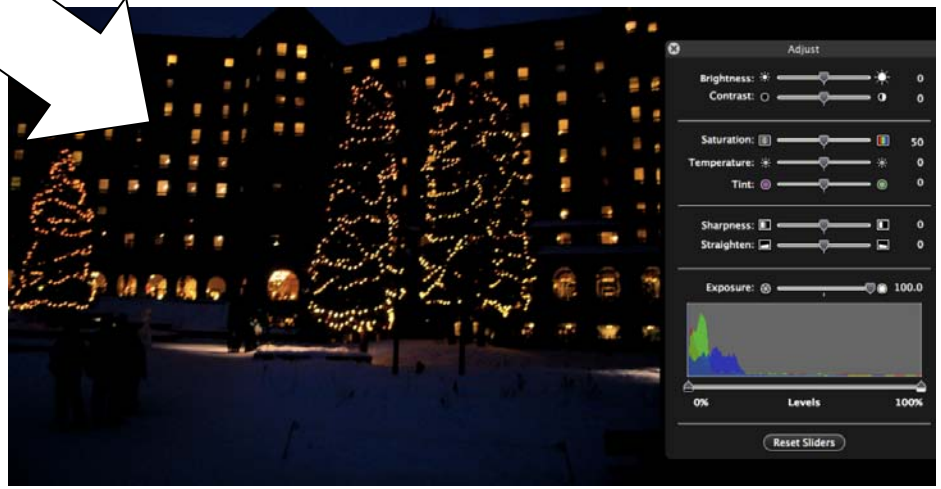




(From Matlab Image Toolbox Guide Fig.10-10 & 10-11)

Examples: Lamp + Color Gray Level

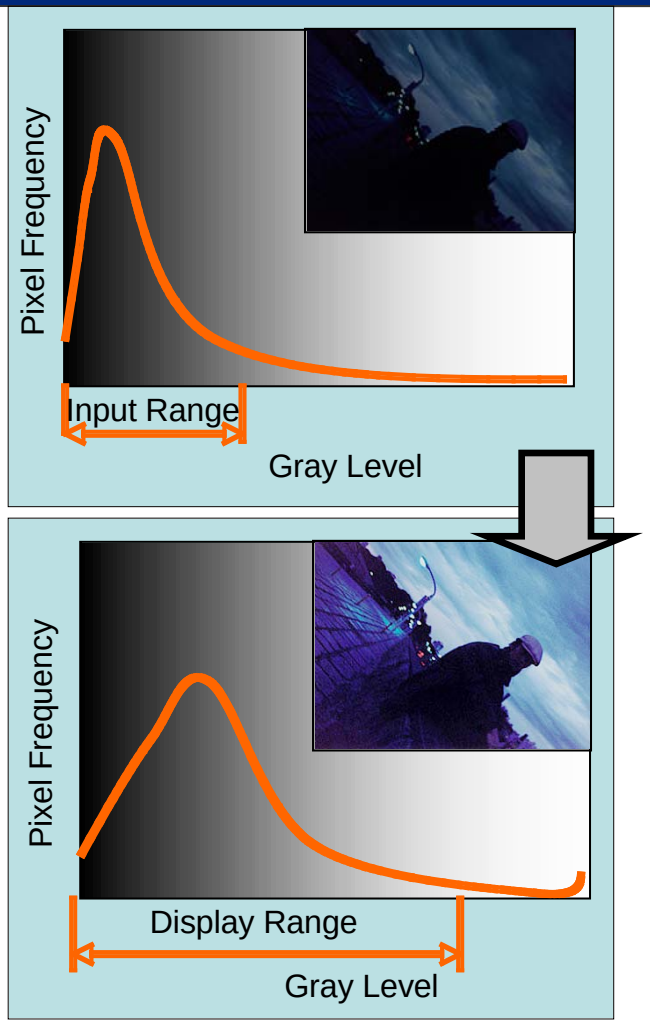




How does HDR work?

- **The HDR technology dynamically, frame by frame, characterizes the brightness and color of an input image using an embedded algorithm in a micro-computer control.**
- **The frame pixel information is processed to simultaneously set the brightness of the LCD light source and to increase the number of gray levels used in the video signal fed to the display pixels**
- **The increase in the utilization of gray levels improves the image detail and contrast while the synchronous lamp modulation adjusts the displayed image brightness**

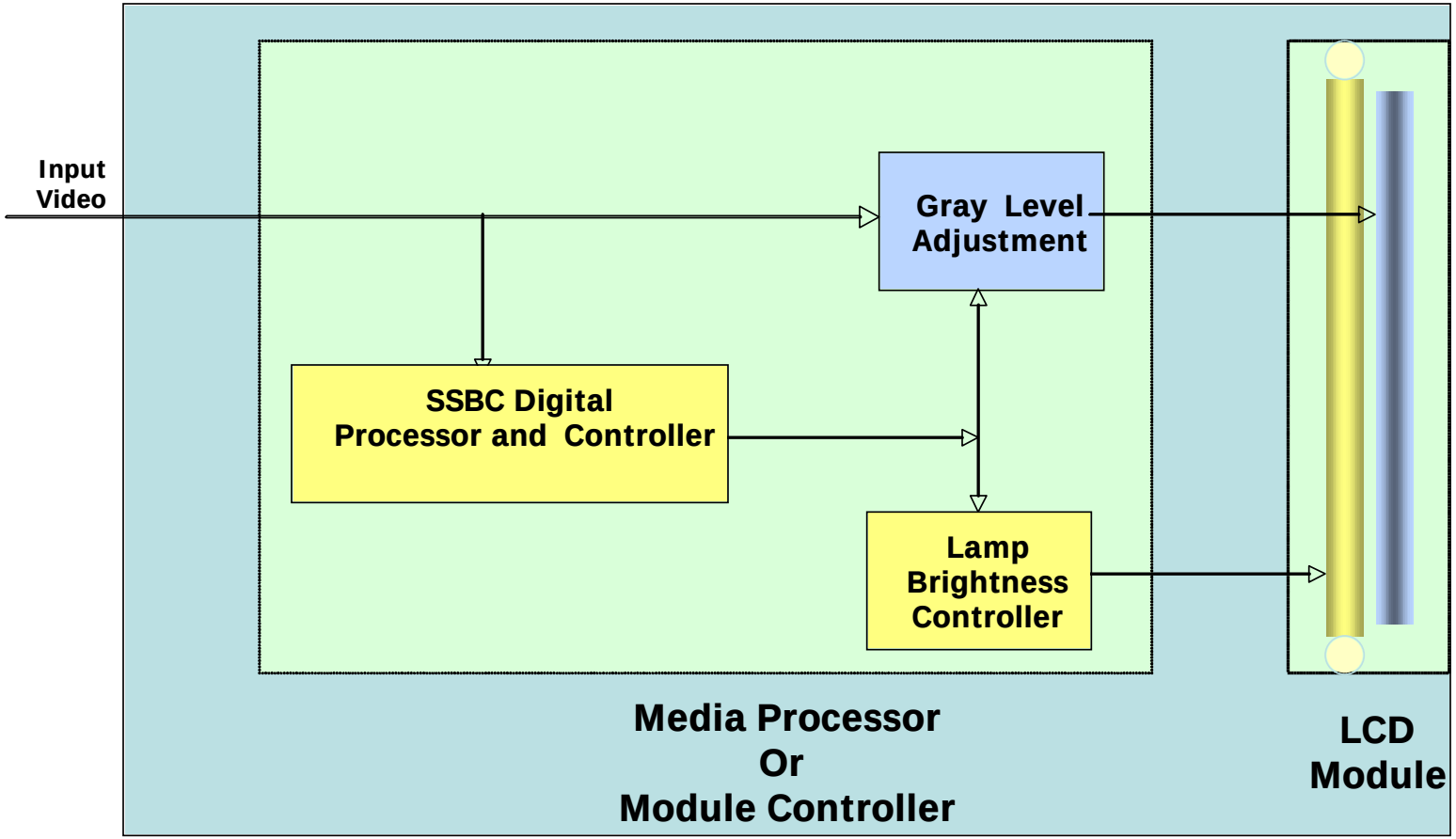
Expanding the Gray Levels



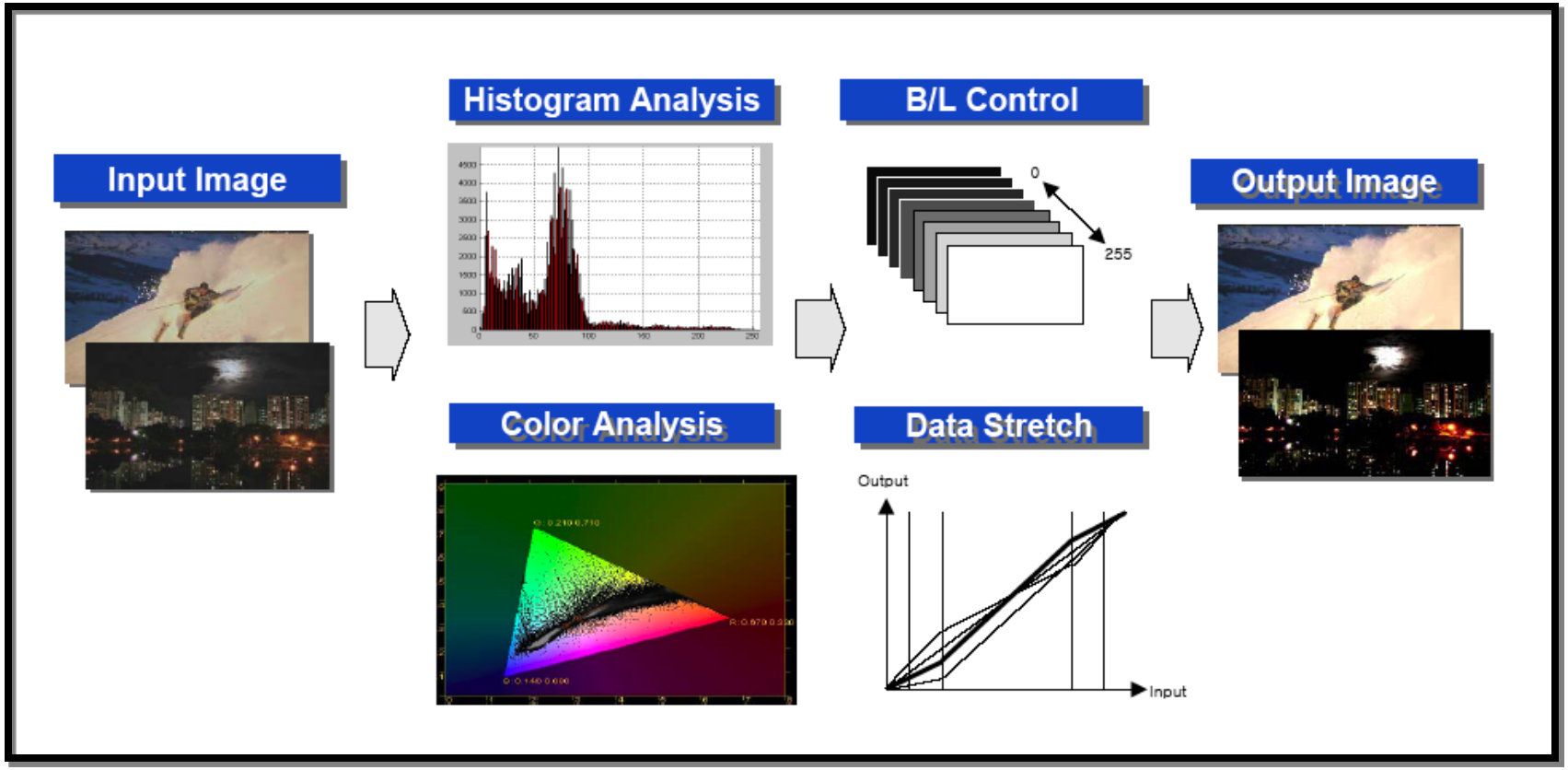
- Dark Input Frame
  - Video gray levels are compressed
  - Image detail is lost
  - Contrast is compromised
- HDR Processed Video to Display
  - Video gray levels are stretched to make optimal use of full gray scale capability of the display
  - Improved image detail
  - Higher contrast
- Synchronous Lamp Adjustment
  - Gray level stretch results in increased brightness of displayed image
  - Backlight is turned down to compensate (not shown)

Graphics from Seiko Epson Presentation

System Architecture



Full Process



Graphic from LG.Philips LCD SID04 Presentation

Lamp Options

- Conventional CCFL Lamps used in LCDs are compatible for Basic HDR
  - Excellent dynamic range with time domain duty cycle
  - Wide range of duty cycles with high efficiency
  - Constant color temperature with duty cycle
  - HCFL lamps are superior in range
- Projection arc lamps are HDR compatible for basic HDR
  - Projectors with HDR now available from Panasonic, Epson, and Mitsubishi
  - Arc lamp control options include duty cycle and dynamic iris control
- HDR modulation of RGB LED backlights are on the horizon
  - Enables independent synchronous optimization for each color
  - Extends color gamut as well as dynamic range of brightness

Summary of Benefits and Features

- Benefits
  - More cinema-like video performance of AMLCDs and projectors
  - Dramatic improvement in image detail in dark and bright images
  - Improved contrast especially noticeable at wide viewing angles
  - Reduces display power consumption

- Next Generation Improvements
  - Independent processing for each primary color to optimize display color gamut for RGB light sources (HDR II)
  - Improved video in cameras, cellphones and handhelds
  - Spatial modulation of RGB LED backlights (HDR III)

HDR Technology and Players

- HDR Technology and Patents
  - Fergason Patent Properties (FPP) gateway patents
  - Numerous patents filed and issued to FPP licensees
  - BrightSides technology and patents related to HDR III
  - Landmark Sharp Patent related to HDR III
- Wide scale commercialization of Basic HDR and HDR II
  - Broad adoption in LCD TV and MD projection
  - Recent implementations in monitors, notebooks, and mobile
  - Initial promotion of HDR II
- Initial implementations of HDR III are emerging
  - Sharp video editing monitors and TVs
  - Heavy promotion of HDR III during 2006 at CES, CEATAC, and FPD International

HDR Gateway Patents

- LCD Pioneer, Jim Fergason, holds gateway patents
  - Fergason Patent Properties call the technology System Synchronized Brightness Control (SSBC™)
- Two issued US patents with 71 issued claims
  - Additional US and foreign patents are pending
- Issued claims cover basic HDR as well as HDR II
  - Broad adoption of white light modulation and histogram stretch
  - Claims cover independent modulation of RGB lamp components

History of SSBC™ Licensing Program

Company	Licensee since:	Products
Matsushita Electric (Panasonic)	2001	LCD TV and Projectors
LG.Philips LCD	2003	LCD Modules for TV, monitors, notebooks, and mobile
Epson	2004	Projection Engines and Projectors
Sharp	2005	LCD TVs
Samsung	2006	LCD Notebook Modules
Chinontec	2006	Projectors and Engines

- One additional licensee not announced
- Two licenses expected to be completed in 1Q07
- Primary implementations in LCD TV and LCD TV modules
- Emerging applications in monitor, notebook, and mobile monitors
- Broadly available in MD projection TVs and front projectors

Beyond Basic HDR

- HDR II combines independent modulation of RGB backlight component colors in LED backlights
  - Emerging applications in mobile and notebooks to improve image quality and lower power
  - Potential application in LCD TV and MD RPTV
- HDR III implements spatial modulation of RGB LED backlights
  - Focus is improved imaging
  - BrightSide Technologies offer integrated image capture, storage, and display approach (16 bit color)
  - Sharp introduces professional monitor
  - High costs will slow adoption in TV and monitors

HDR III LED Lit LCDs

BRIGHTSIDE™ Technologies Inc

World's First Extreme Dynamic Range Display

BrightSide introduces the DR37-P, a spectacular breakthrough in display technology that uses an array of LED backlights to deliver 10 times the brightness and 100 times the contrast of existing televisions and computer monitors. BrightSide's Extreme Dynamic Range displays deliver more vibrant images and allow you to see your data in vivid detail.

- Extreme Dynamic Range
- Over 3000 cd/m^2 Brightness
- Contrast Ratio > 200,000:1
- High Definition 1920x1080
- 37" Screen
- 16 bits per color
- IMLED – Individually Modulated Array of LED backlights

- Company offers integrated image capture, data storage, and display for HDR III imaging
  - Supports 16 bit color
  - Data encoding
  - Algorithms for spatial backlight LED modulation
- Offers premium products
- Licensing technology

QuickTime™ and a TIFF (Uncompressed) decompressor are needed to see this picture.

Sharp Mega-Contrast LCD

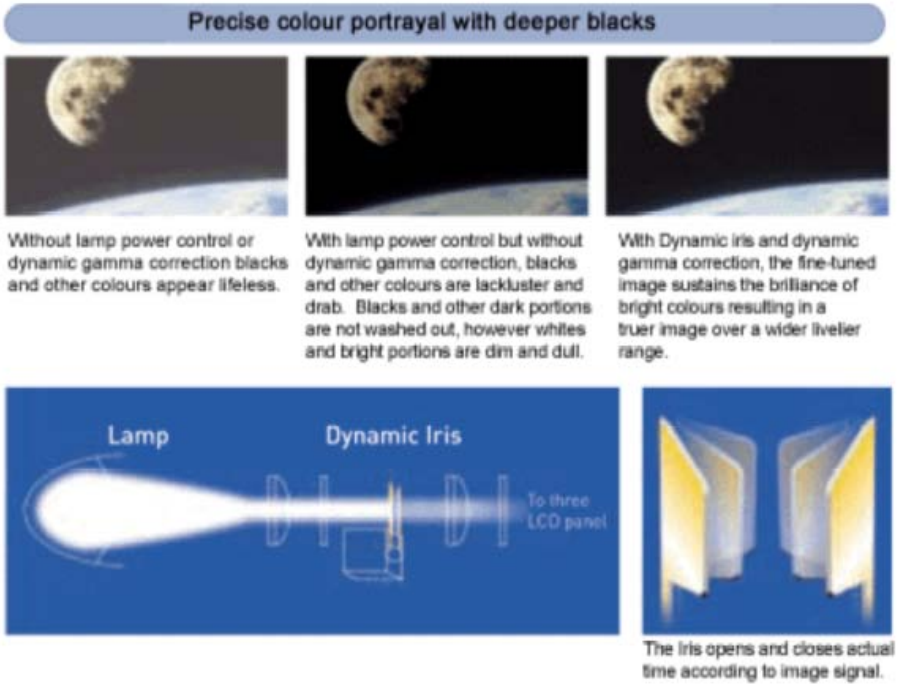
- Sharp aims the Mega Contrast LCD display at the professional TV and movie production industry.
  - Enables filmmakers and video producers to check video images to the most demanding levels of clarity and color Advanced Super View Premium

- Specifications
  - LCD Screen size: 37-inch Resolution: 1,920 V x 1,080 H
  - Contrast ratio: 1,000,000:1 Luminance: 500 cd/m2

Samsung CES05 Placard for LCD TV

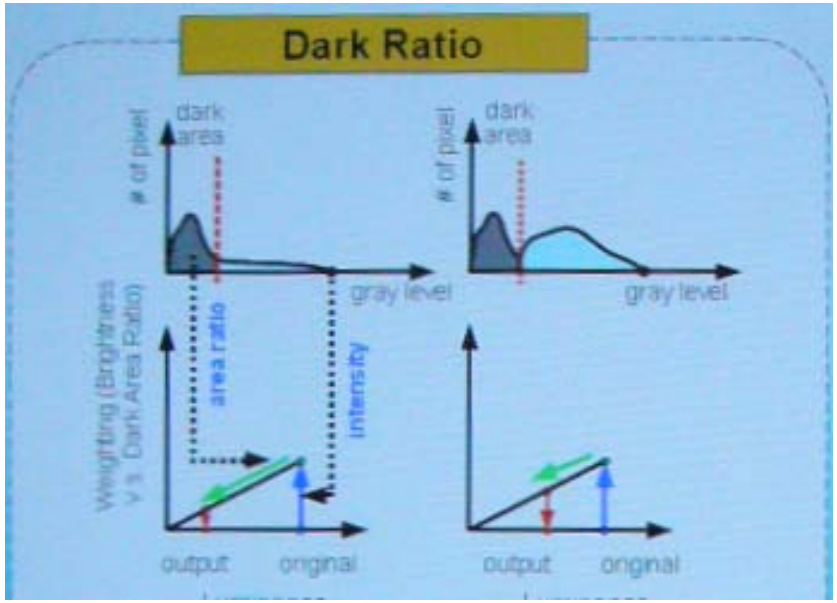
Claim 6X Dynamic Range Capability to reach 5,000:1 Contrast

Panasonic Dynamic Iris

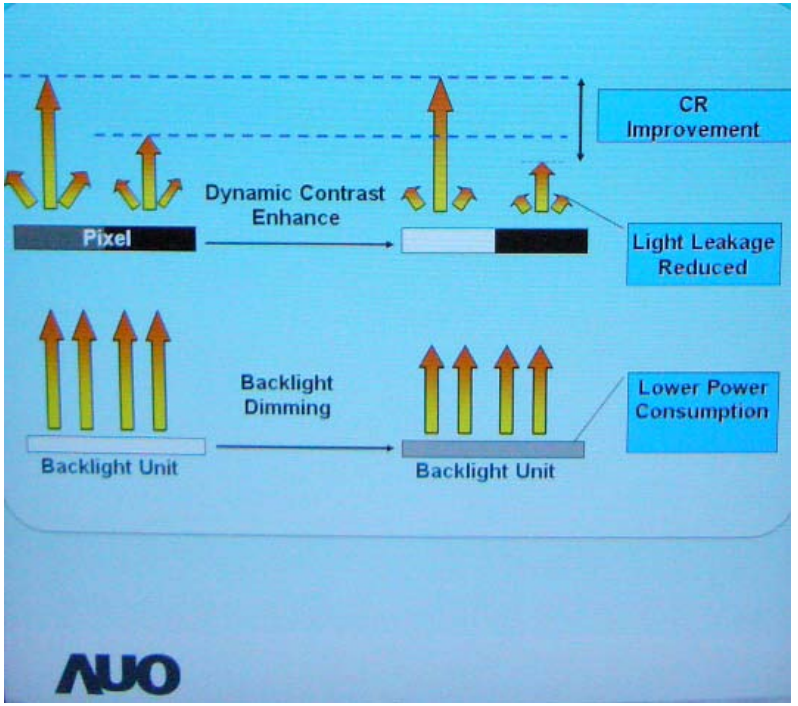


- Dynamic Iris
  - Mechanical iris used to modulate porjection lamp output
- Simultaneous lamp and gamma adjustment
  - Histogram analysis
- Dynamic Contrast > 2000:1

AUO Dynamic Backlight Dimming

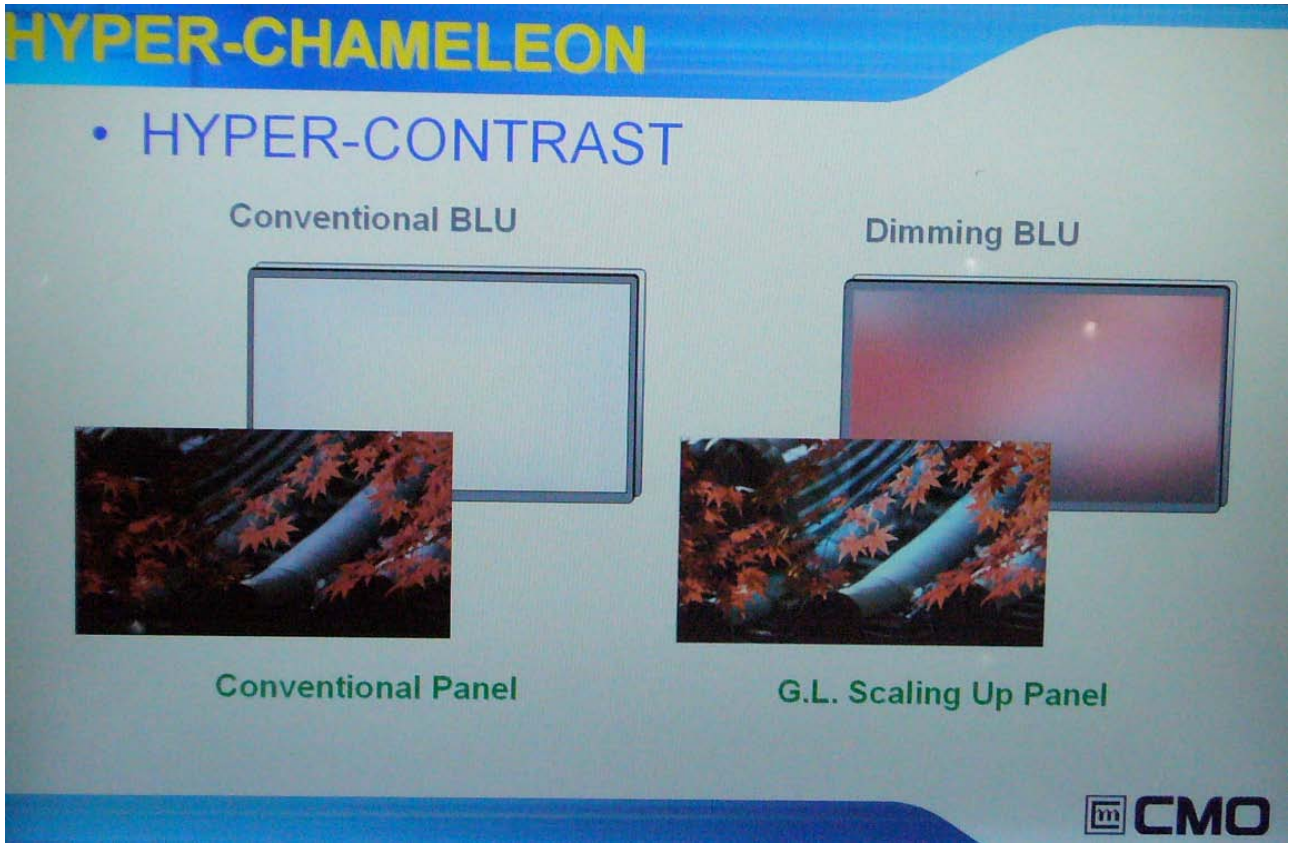


Histogram Control



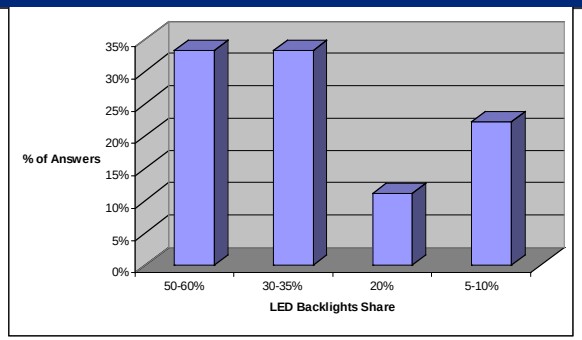
Gray Level Increase

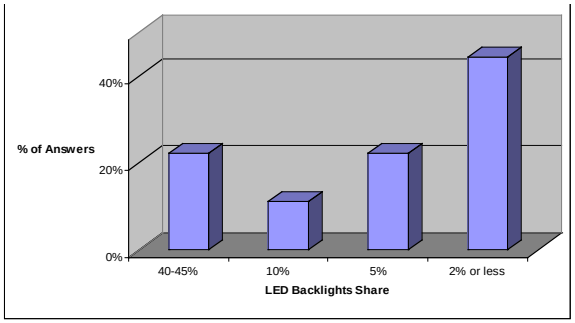
CMO Hyper-Chameleon with LED BLU

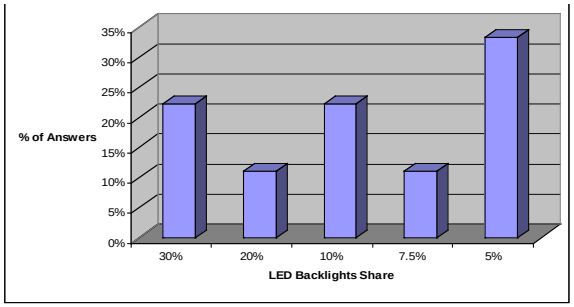


CMO at FPD Intl 2006

Market Survey of LED BLU Utilization



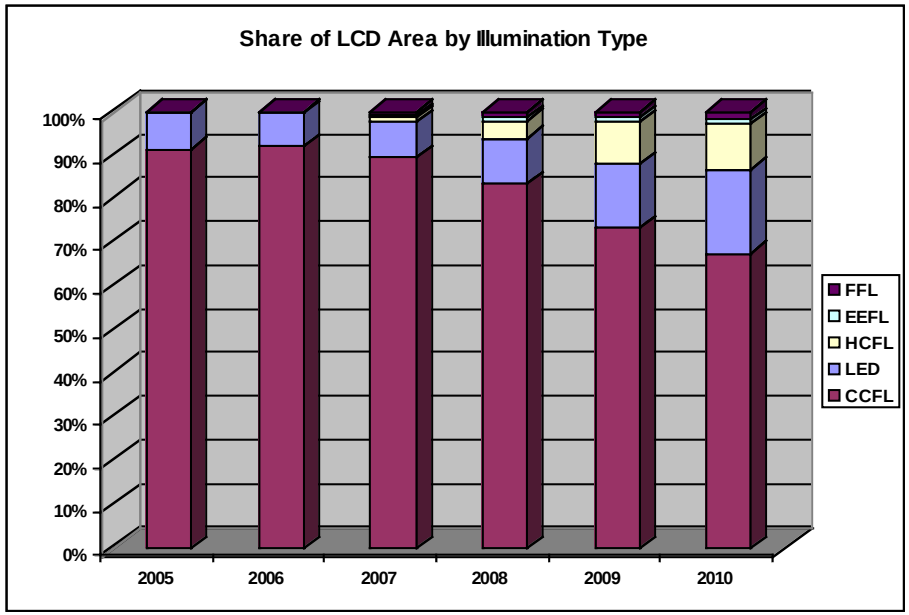




- Notebooks
  - Thinner, lighter designs drive demand
  - Logical extension of wide LED use in mobile
  - >70% respondents predict share > 30% by 09
- Monitors
  - Mature market price pressure limits LED use
  - Differentiated niche markets only
- Television
  - High color gamut and HDR drive market
  - Highly competitive price down environment
  - Must compete with HCFL
  - Half of respondents forecast LED share > 10%

Source: MCG Study: LCD Brightness Enhancement 2006

LCD Backlight Forecast



- Technology Winners
  - LEDs in mobile and TV
  - HCFL in TV
- LED share
  - Dominance in small mobile
  - > 30% share of notebooks by 09
  - 10% of TV in 2010
- Critical LED issue: Lumens/$
  - Forecasted cost > 2X CCFL
  - Cost down for enhancement films
  - Optimization of enhancement optics

Source: MCG Study LCD Brightness Enhancement 2006

MCG:

Decision Support for the Display Industry

- Decision Support: Business and market analysis, start up support, investment due diligence,
- Services: Market and product studies, custom consulting projects, deal making, technology licensing
- Focus: Display supply chain, especially optical films, microdisplays, personal viewers and projection, HDR technology
- Team: Four seasoned display veterans with project support from a wide range of display technical experts
- Personnel, reports, and current studies: See www.mcgweb.com