

High Dynamic Range Displays

Werner König

Prof. Dr. O. Deussen

AG Computergrafik und Medieninformatik

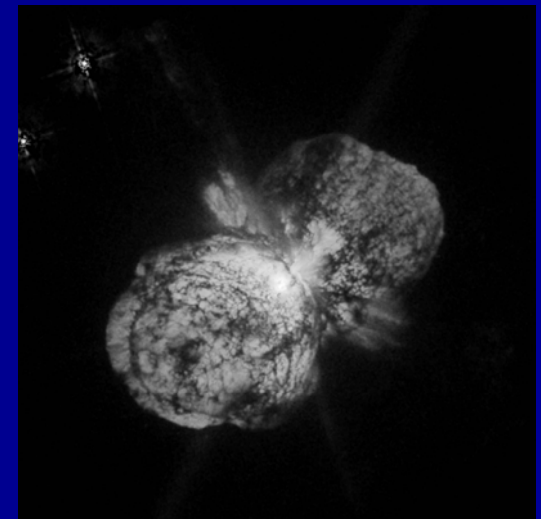
Outline

- I. Introduction
- II. Human Perception
- III. Limitation on Displays
- IV. Projector-based Display
- V. LED-based Display
- VI. Conclusion
- VII. Future Work
- VIII. References

Applications (low contrast)

- Astronomy, Medical Analysis
- Image modeling, rendering, processing, compositing
- Entertainment
- User Interface Design
- Research

DEMO (foil, HDRShop)



Luminance

- Human Luminance Recognition
Range: $\sim 10^{-5} - 10^4$

0.003 cd/m² –
0.00003 cd/m²



0.03 cd/m² –
0.3 cd/m²



300 cd/m² –
30,000 cd/m²



30 cd/m² –
300 cd/m²



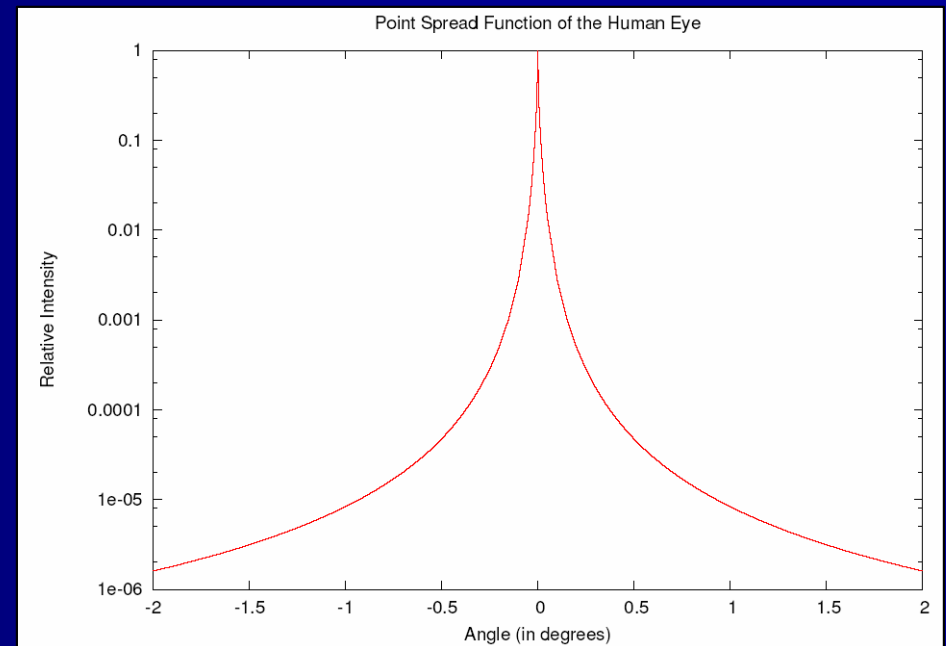
3 cd/m² –
30 cd/m²



1 cd/m²

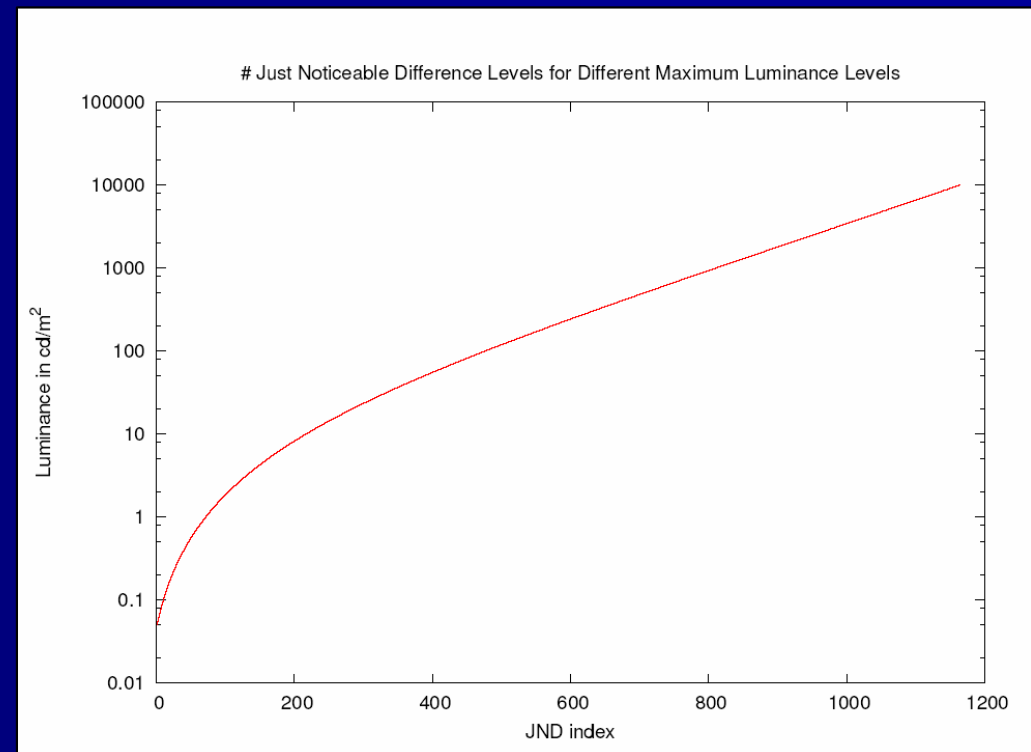
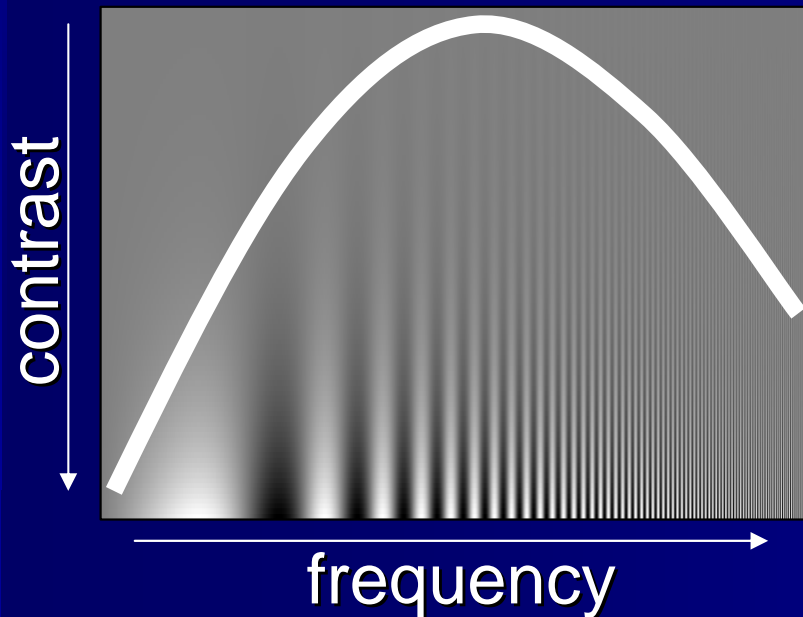
Human Perception

- 9 orders of magnitude totally
- 5 orders effectively simultaneously
- Local contrast perception 150:1
 - Above that → blurry, indistinct
 - Scattering of energy on the retina with higher boundary contrast



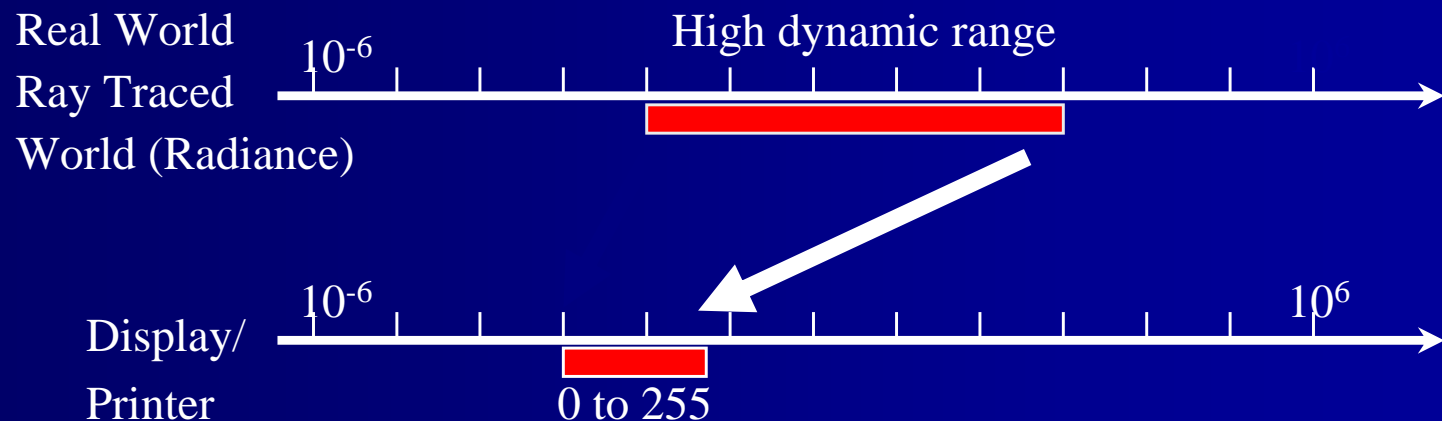
Contrast – Bit – Steps

- Just Noticeable Differences (JND)
- Contrast & Spatial Frequency
- Contrast \neq Bit depth
- 8 bit \rightarrow 256 tonal steps



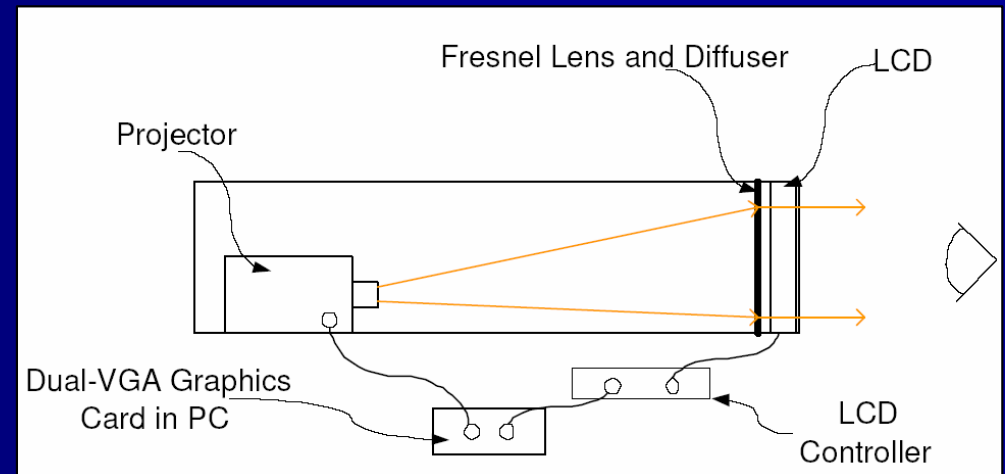
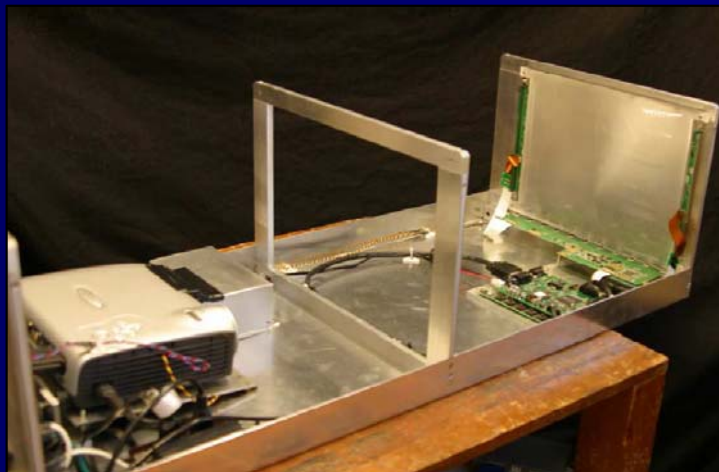
Limitations on conventional Displays

- Black state: regardless light transmission
- White state: max. 16% transmission (LCD)
- Limited Dynamic Range
- 8-bit device → 256 tonal steps



Projector-based Display

- Combination of projector and LCD
 - Brightness increase, keep black state
- LCD as optical filter
- Multiplication of the dynamic range of each modulator

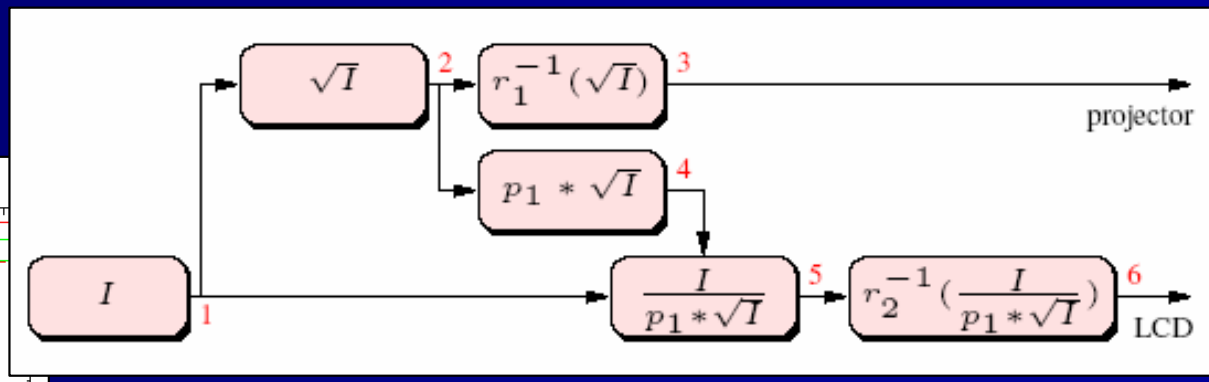
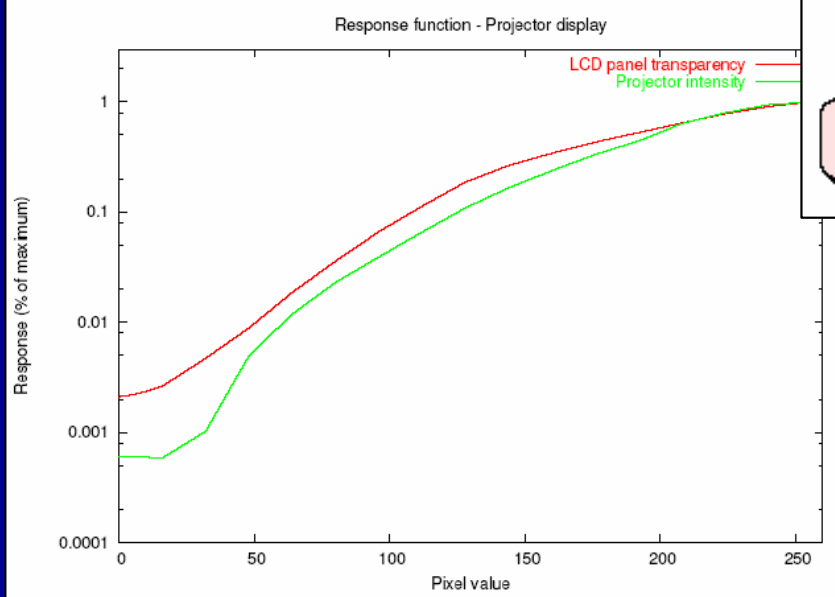


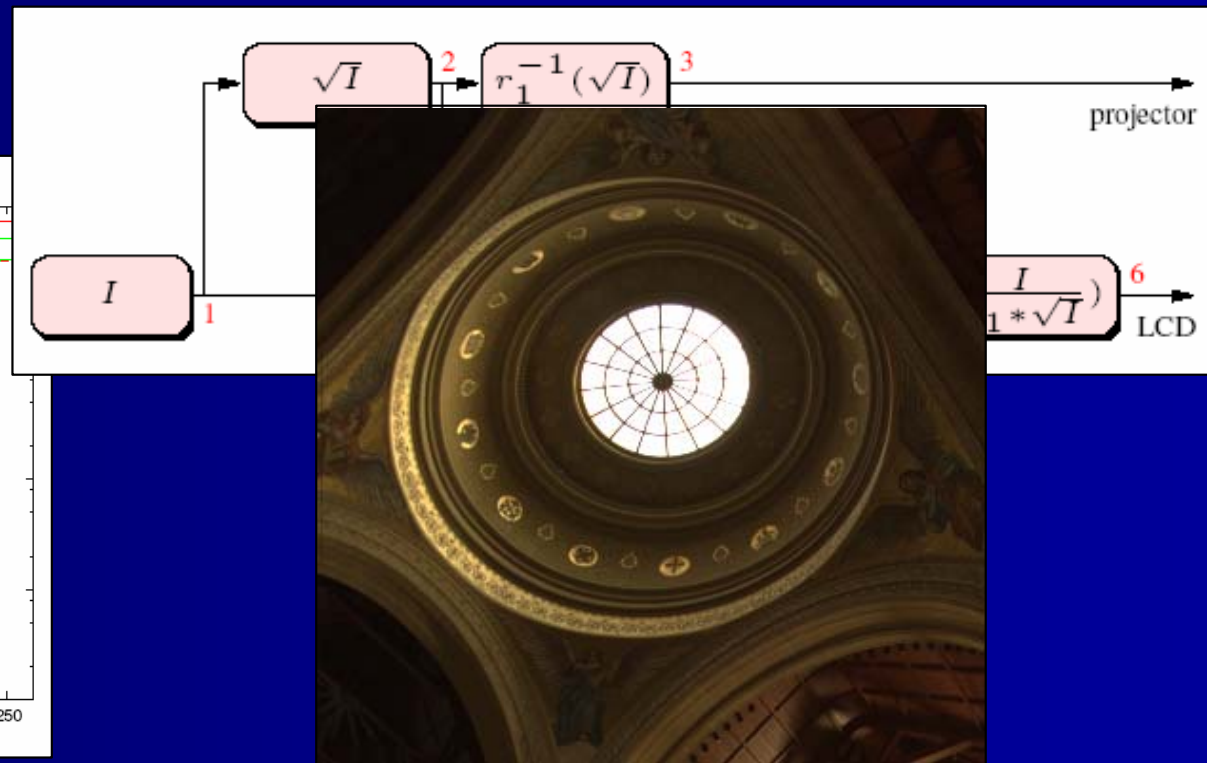
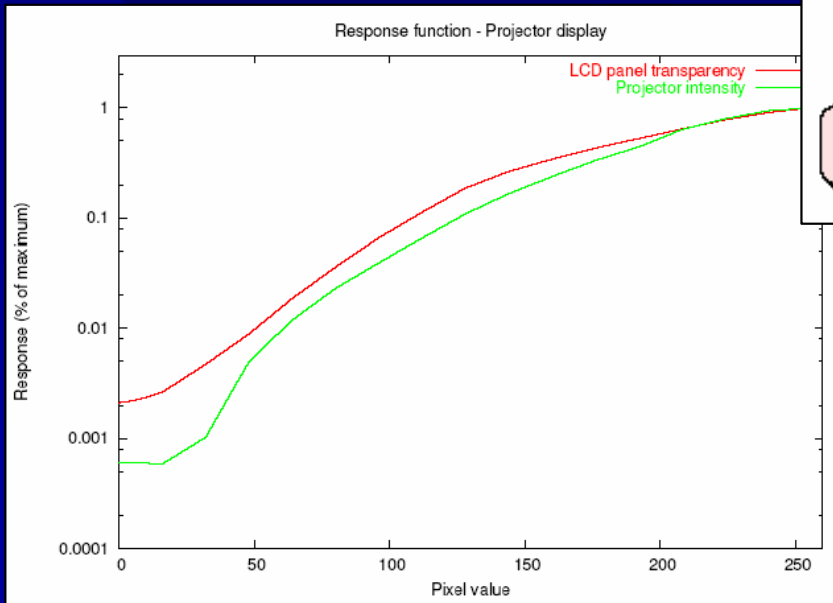
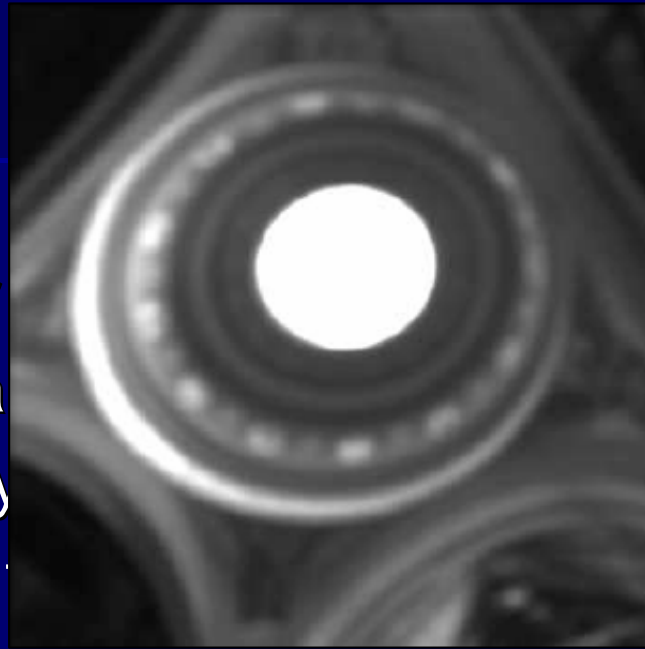
Hardware Setup

- Digital Mirror Device without color wheel 800 : 1
- LCD without backlight and optical layers 300 : 1
- Light output is result of the two modulations:
 - Theoretical Range 240.000 : 1
 - Imperfections of optics → measured 54.000 : 1
- Luminance: measured 0.05 – 2.700 cd/m² Lumens
- Combinations: 8-bit devices: $256^2 = 65536$ steps
→ 17.000 distinct luminance levels

Driving the Projector Display

- Problems for correctly rendering HDR images:
 - Projector and LCD aren't linear,
 - Different dynamic range
 - Blurring of the projector image





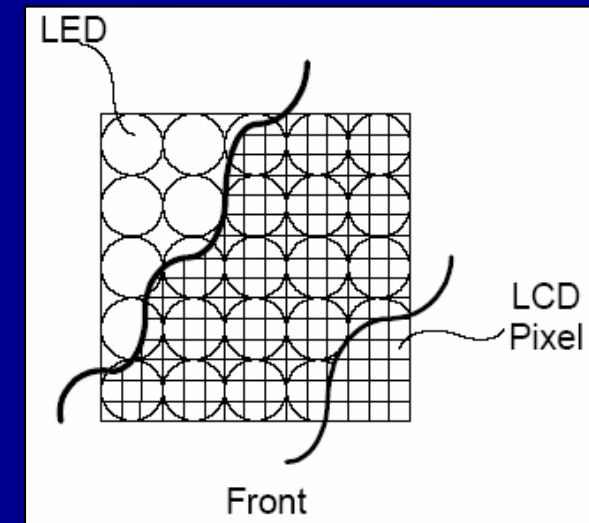
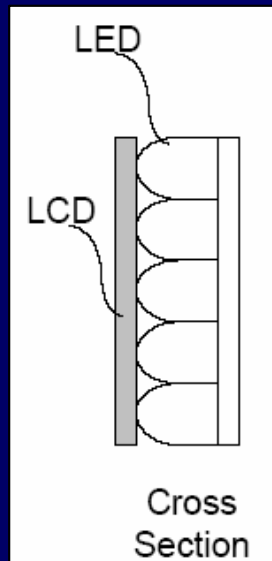
Pros & Cons

- + High dynamic range
- + High luminance

- Large form factor
- High costs
- High power consumption
- Thermal management problem (noise)
- Need of high video bandwidth
- Calibration issues

LED-based Display

- Active matrix array of ultra bright LEDs as backlight
 - Low resolution, 12 mm diameter
 - High brightness, 250.000 cd/m²
 - No emission in off state

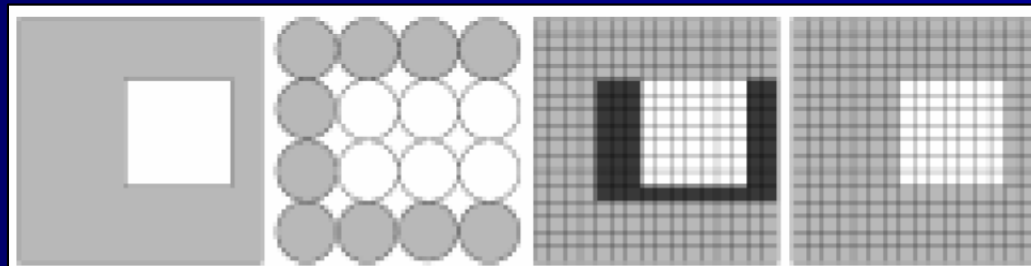


Hardware Setup

- 760 white LEDs (1 Watt, 8-bit Digital-Analog Converter)
- 18,1" LCD with 500:1 and 1280 x 1024
- Max measured Luminance: 8.500 cd/m²
 - Full LED emission & full LCD transmission
- Minimum is complete dark (whole display)
 - LED in off state, LCD pixel black value
 - Min 0.03 cd/m² on checkerboard pattern larger than 20mm (LED emission overlap)

Driving the LED Display

- Contrast over 100.000 : 1, over 17.000 Steps
- Prediction of 1139 JNDs for this luminance range
- Compute intensities for every LED
- LED has wider support
- LCD corrects low LED resolution
 - Over-sharpening LCD image if necessary
 - Mask luminance effects at high contrast boundaries



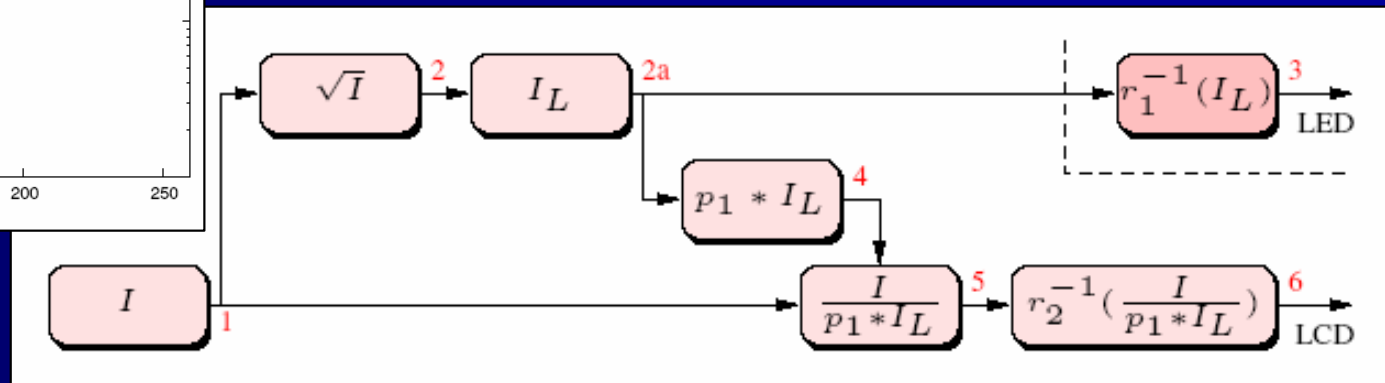
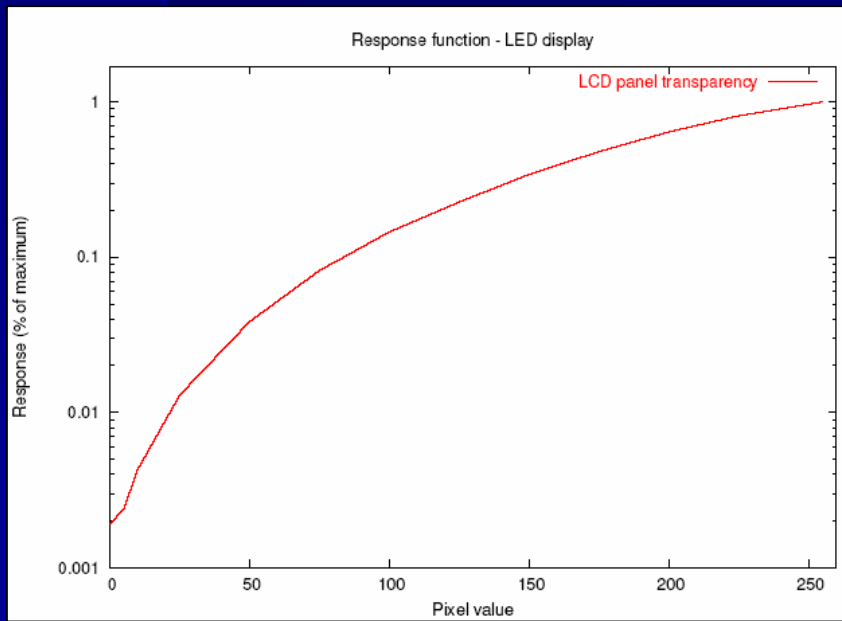


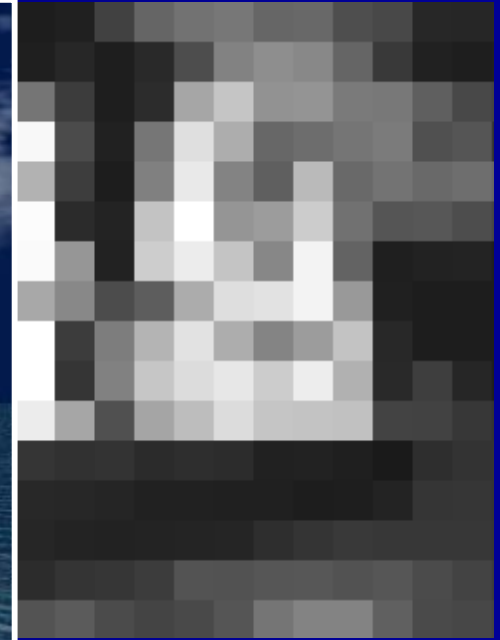
Image Modulation



High resolution colour LCD



High Dynamic Range Display



Low resolution AM LED array

Pros & Cons

- + High dynamic range
- + High luminance
- + Same form factor as conventional LCD
- + Costs less than Projector-based Display
- + About the same power consumption as LCD

Pros & Cons

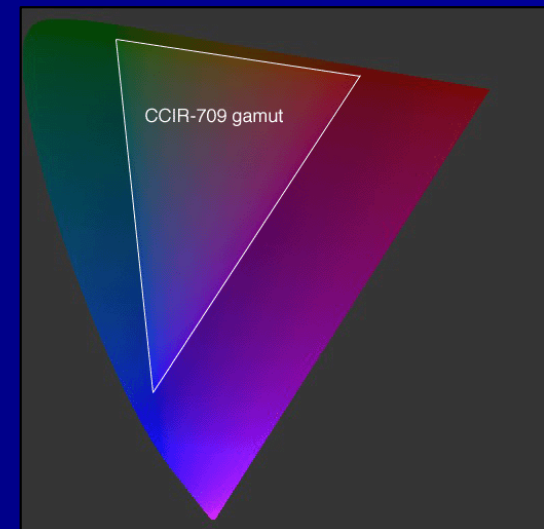
- + No special thermal management needed
 - + Small video bandwidth
 - Complex LED image rendering
(resolved on new GPUs)
- Ready for home and commercial use

Conclusions

- High Contrast, no disadvantages
- Flashing LED backlight reduce motion blur artifacts
- Simplifies problems of global luminance non-uniformity
- Room has to be really dark to see luminance differences under 0.1 cd/m^2
→ decrease range

Future Work

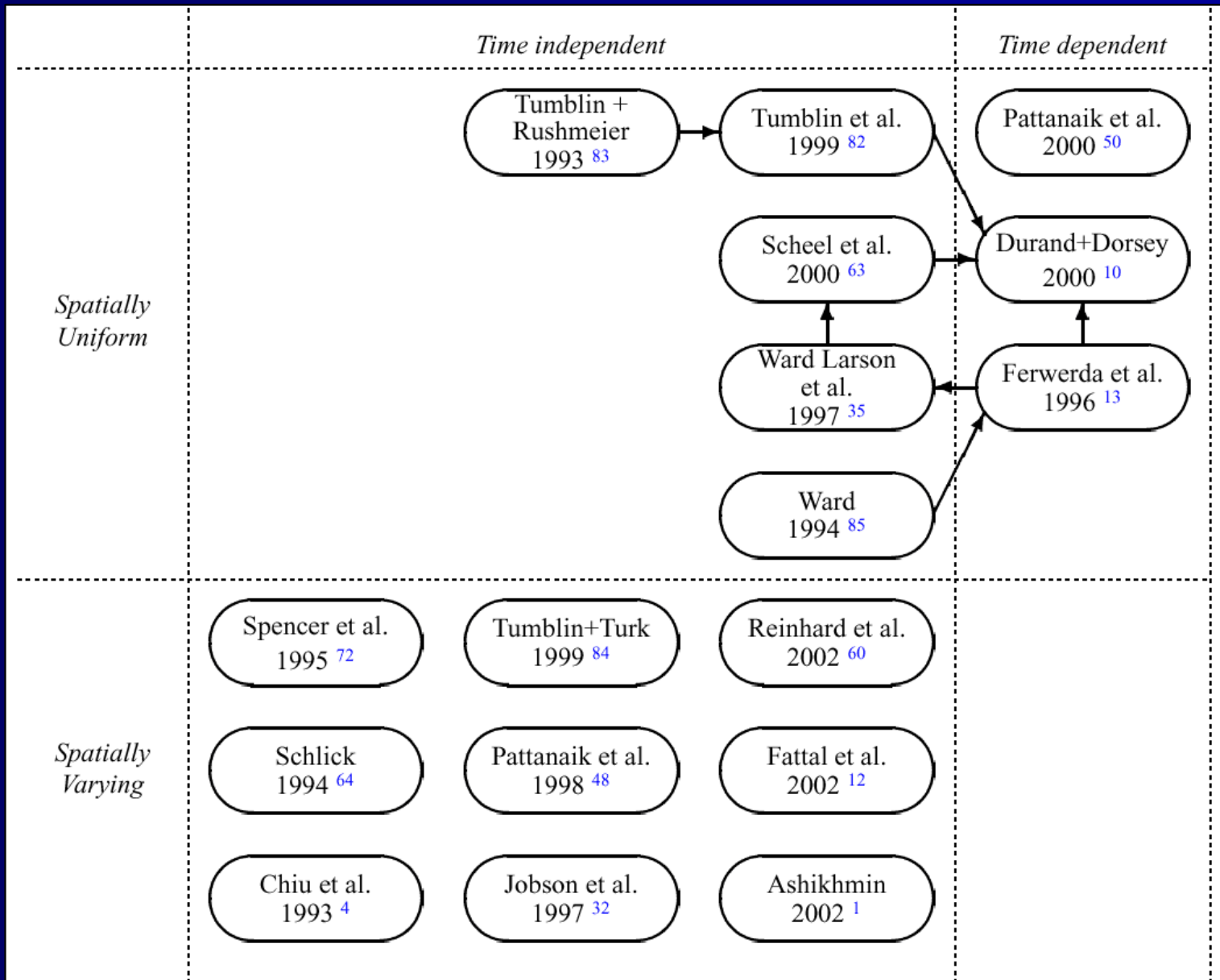
- Image computation on display hardware (16 bit digital input)
- Brightness for directing user attention, HCI
- Triple color LEDs or different color LEDs (98% color gamut instead of 66%)



References

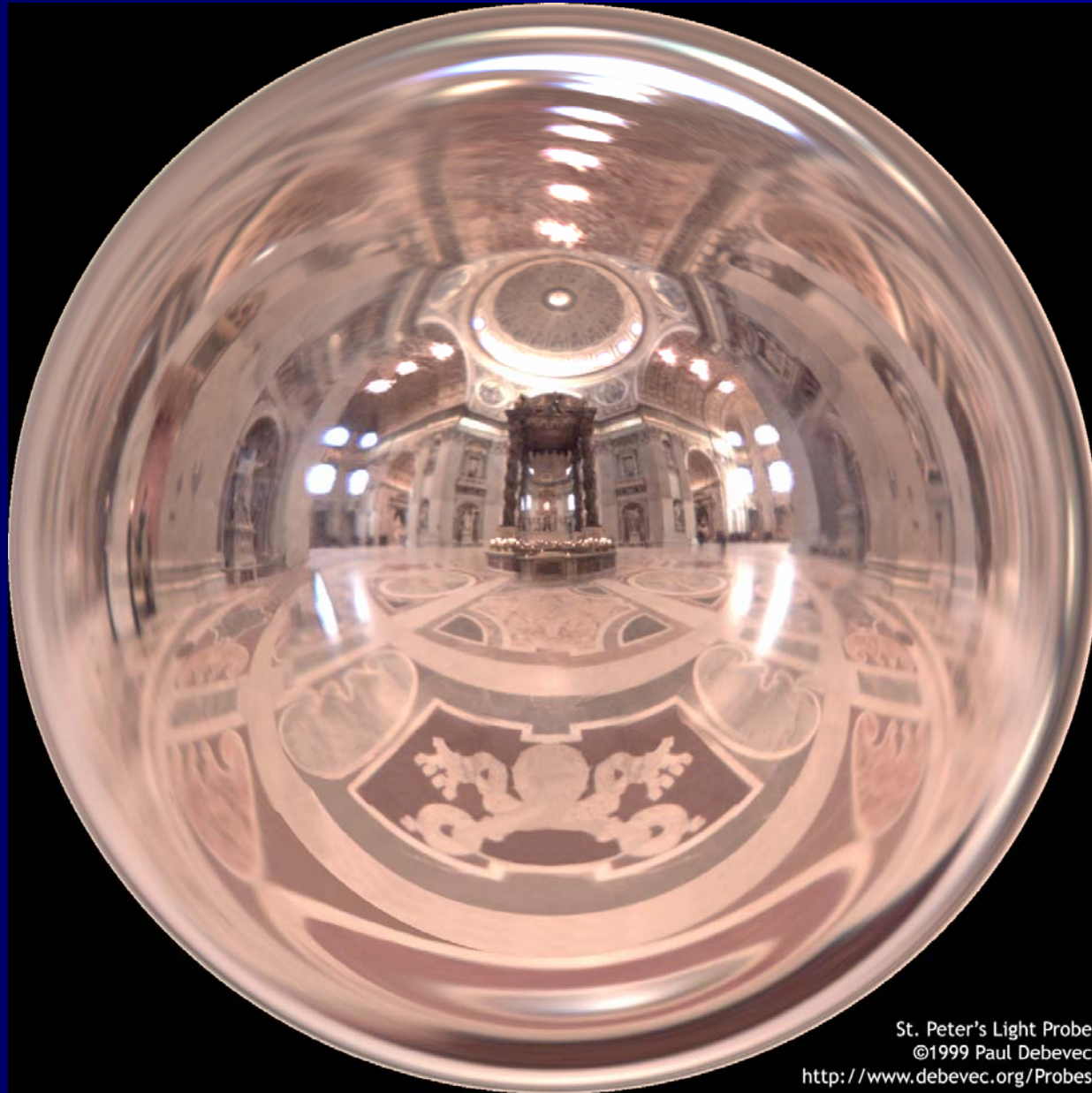
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- Sunnybrook Technologies, <http://www.sunnybrooktech.com/>

Tone Reproduction Methods



Taxonomy of Tone Reproduction Methods

St. Peters Light Probe



St. Peter's Light Probe
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<http://www.debevec.org/Probes>

Luminance Example

