



Gamma and the Non- linearity of Graphics Output

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Perception of Luminance

- ◆ Grey colours need only a single attribute
 - **intensity** (physics, measure of energy)
 - **luminance** (subjective human perception)
- ◆ The relationship between intensity and luminance is **non-linear**, though
 - Humans perceive intensities as **relative** (healthy eyes can perceive ~1% differences)
 - For perceptually uniform spacing of values, it is necessary to use a **logarithmic scale** of intensity



Equally Spaced Luminance

◆ Minimal display luminance

- Depends on output display device technology
- $I_0 = 10^{-3}$ to 10^{-2}

◆ Intensity steps

- $I_j = I_0 \cdot r^j$ ($r \approx 1.018$ for contrast 100:1 and 256 steps)
- This should yield a reasonably linear display



CRT Monitor

- The intensity of displayed light does **not** depend linearly on the voltage used
 - Non-linearity introduced by the cathode tube

$$\mathbf{I} = \mathbf{K} (\mathbf{V} + \boldsymbol{\varepsilon})^{\boldsymbol{\gamma}}$$

- » \mathbf{V} .. power used for CRT display (pixel value)
- » \mathbf{K} .. variable .. user control „contrast”
- » $\boldsymbol{\varepsilon}$.. variable .. user control „black level”
- » $\boldsymbol{\gamma}$.. constant .. gamma exponent



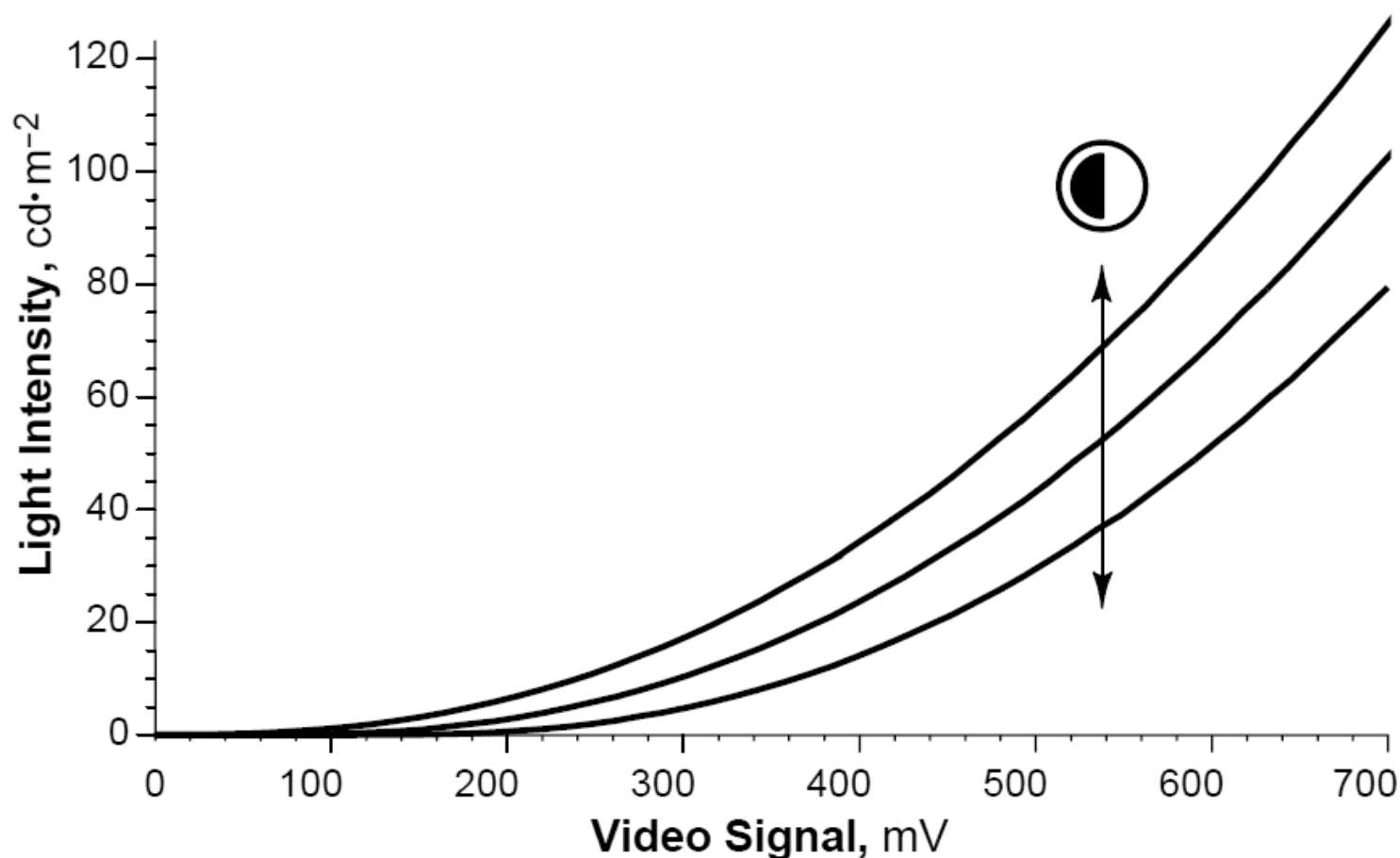
Implications of Non-Linearity

- ◆ The non-linearity of CRTs is almost exactly the inverse of our perception!
 - A positive coincidence!
 - Which should be used
- ◆ So a correction of „**gamma**“ should be performed
 - For efficient use of encoding steps (0÷255)
 - For output devices with different characteristics (print!)
 - Beware of hidden conversion functions! (SGI, Mac)
(old tech – nowadays, this is no longer an issue)



Monitor – contrast („picture“)

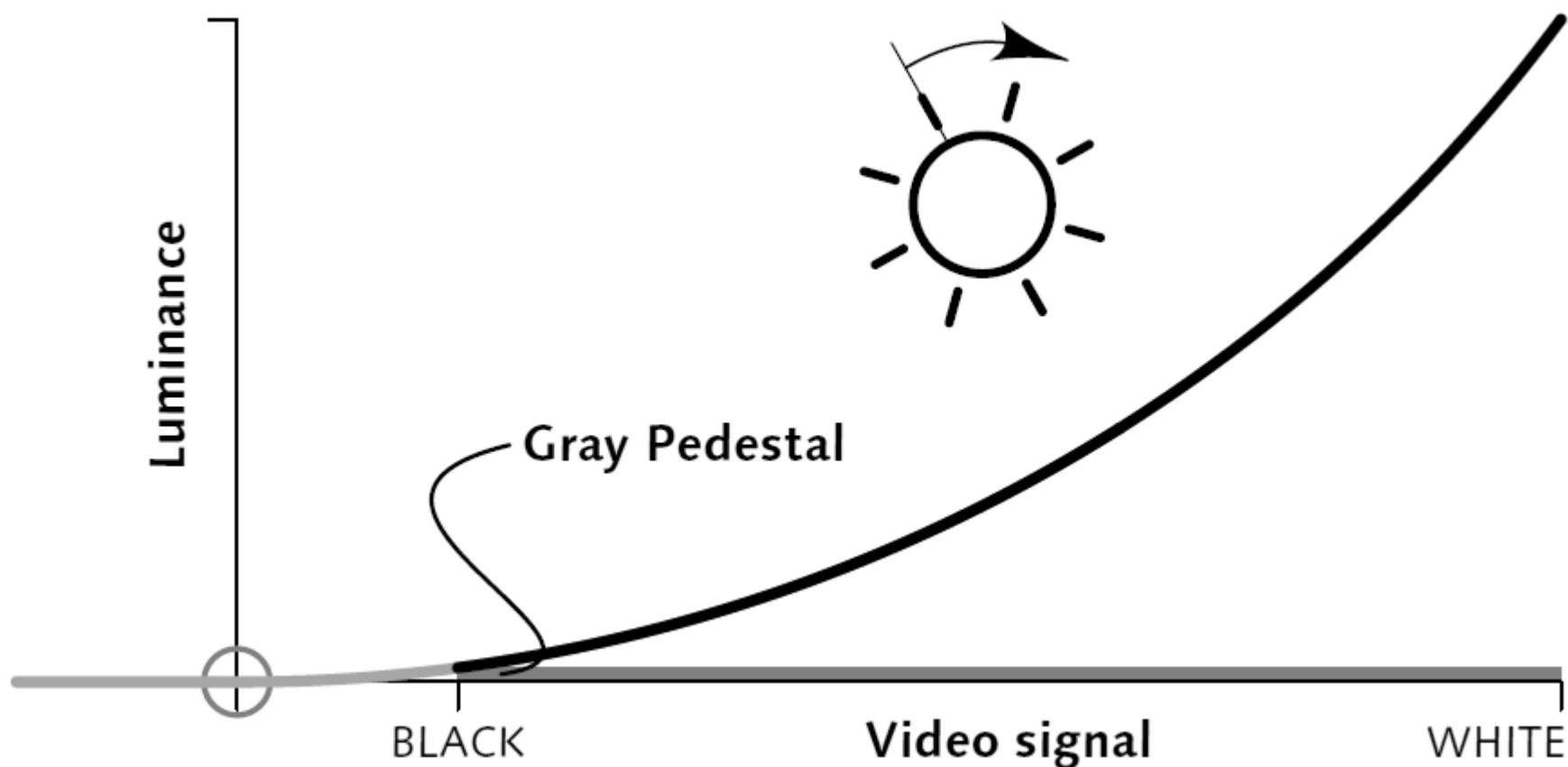
- ▶ Multiplicative constant K





Monitor – „black level“

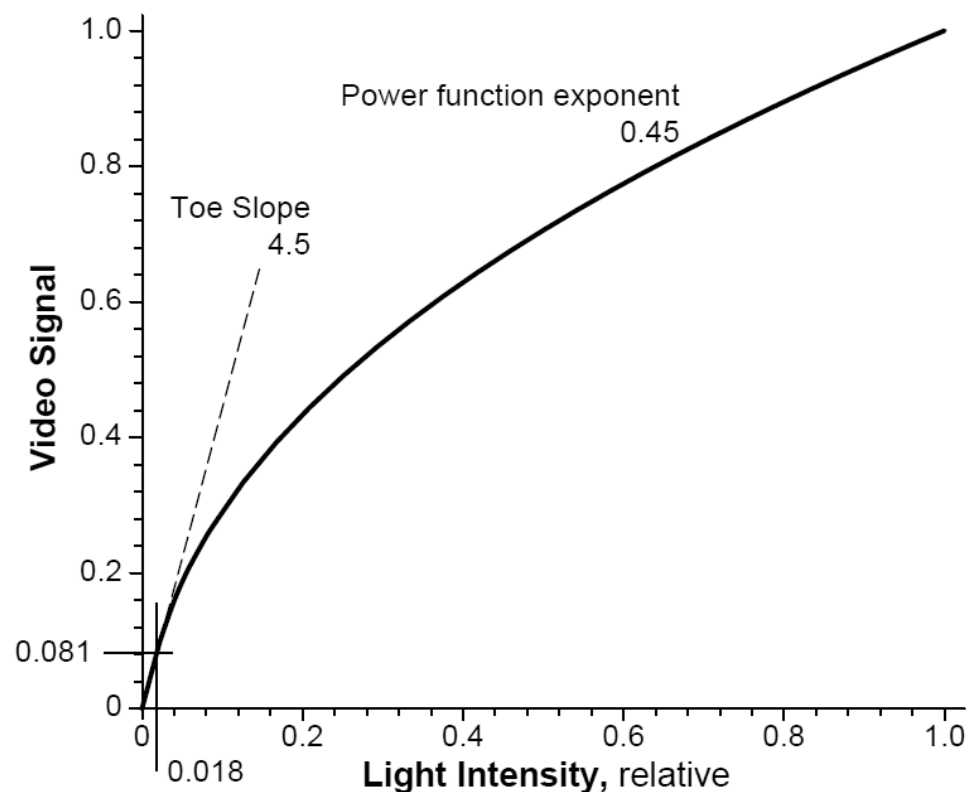
➤ Offset ε





Input „Gamma Correction“

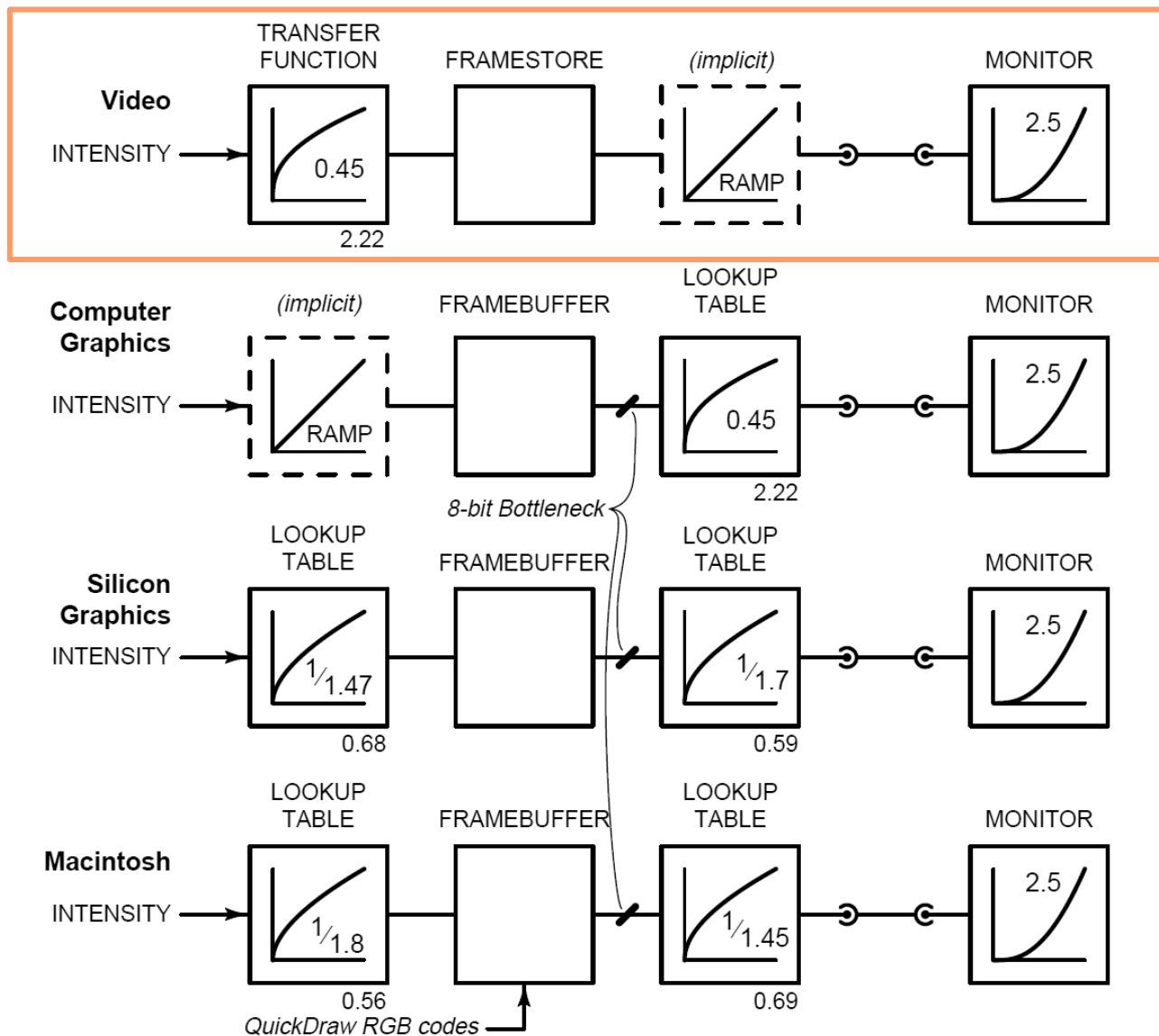
- Transformation for storing data in RAM
~ invese to the non-linearity of CRT monitors





Video Signal Processing

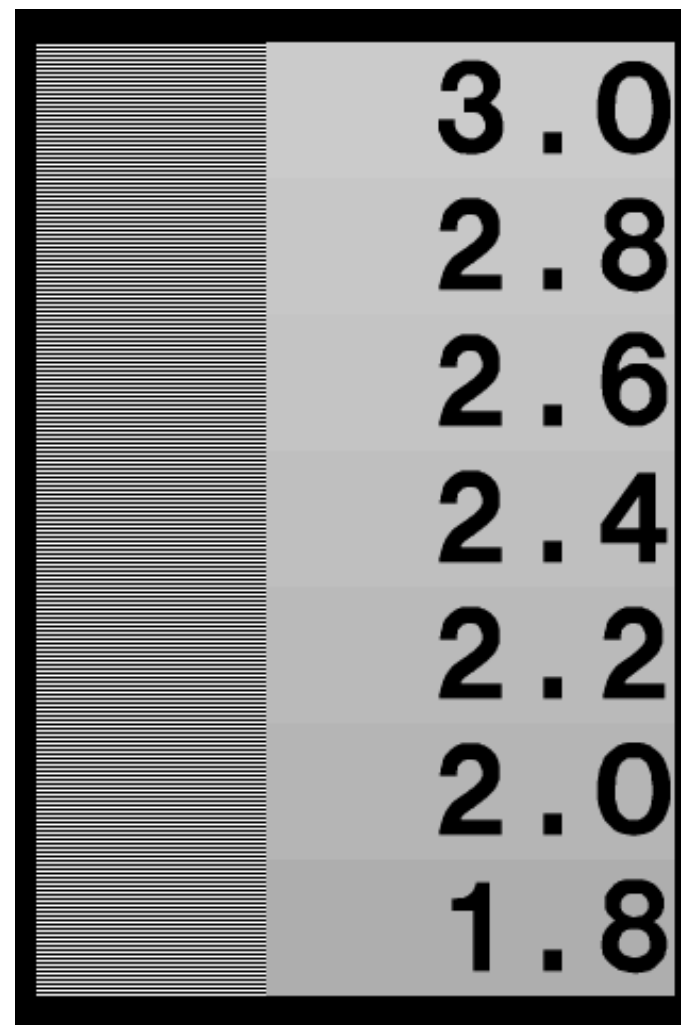
optimal





Test & Calibration Images

- ◆ Goal: find the spot where the half-toned grey value matches the greyscale tone
 - Lots of basically similar images exist
 - Can be done separately for different brightness levels
- ◆ We can read the exponent directly from the image



Monitor Adjustment - HOWTO



1. **Contrast:** set to minimum



2. Display a patch of total black (0,0,0)

3. Adjust **brightness** so that the black patch is not illuminated at all

➡ Do not touch the luminance control from then on!



4. **Contrast:** adjust to a level suitable for the current viewing conditions



End



Further information

- ➔ **Ch. Poynton: *The rehabilitation of gamma*, www.poynton.com, 2004**
- ➔ **Ch. Poynton: *FAQ about gamma*, www.poynton.com, 1998**