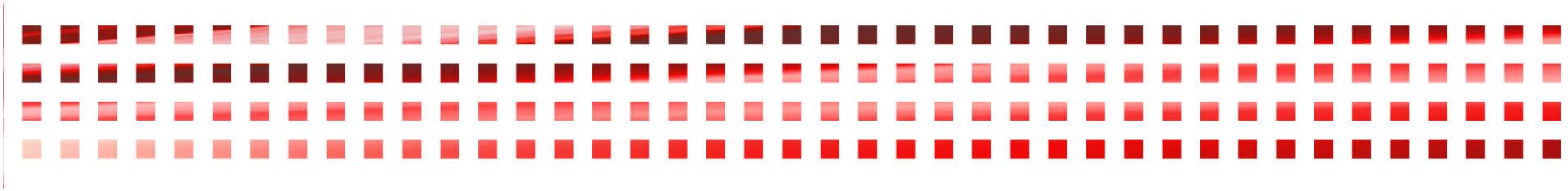
Basics of display image quality



Johanna Rousson – Research engineer – Barco Healthcare

Introduction

- **A medical display is not a standard display, but it accounts for**
  - Resolution and orientation
  - Contrast
  - Viewing angle
  - Luminance Uniformity
  - Grayscale display function
  - Colorscale display function
  - Temporal response
  - Image consistency & QA management

… to generate the best image quality and clinical performance

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Resolution and orientation

Resolution and orientation

2x 5 MP

- Dual head displays → portrait
  - Portrait
  - 2x 5MP
- Fusion displays → landscape
  - Landscape
  - 2x portrait images
  - 12MP

12 MP

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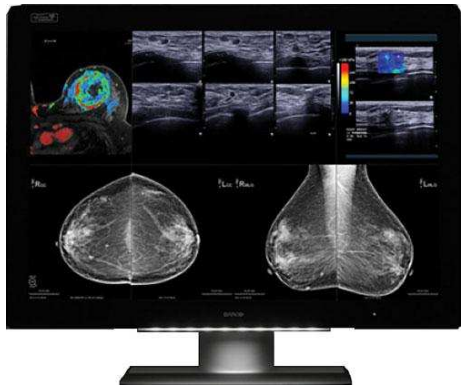
Resolution and orientation



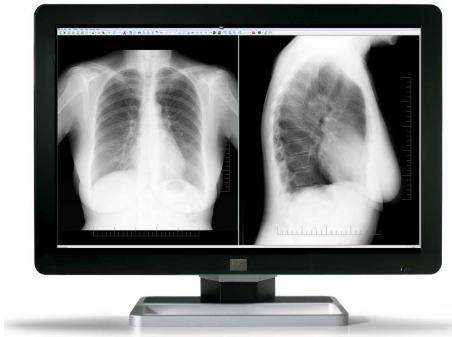
12 MP

Pixel pitch 168 µm

- Higher resolution allows to see much more detail without panning or zooming the image. As a result, image quality is higher and productivity is increased.
- Smaller pixel pitch allows to see smaller details.

5 MP

Pixel pitch 165 µm



6 MP

Pixel pitch 199 µm

Typical displays 250µm ≤ pixel pitch ≤ 400µm

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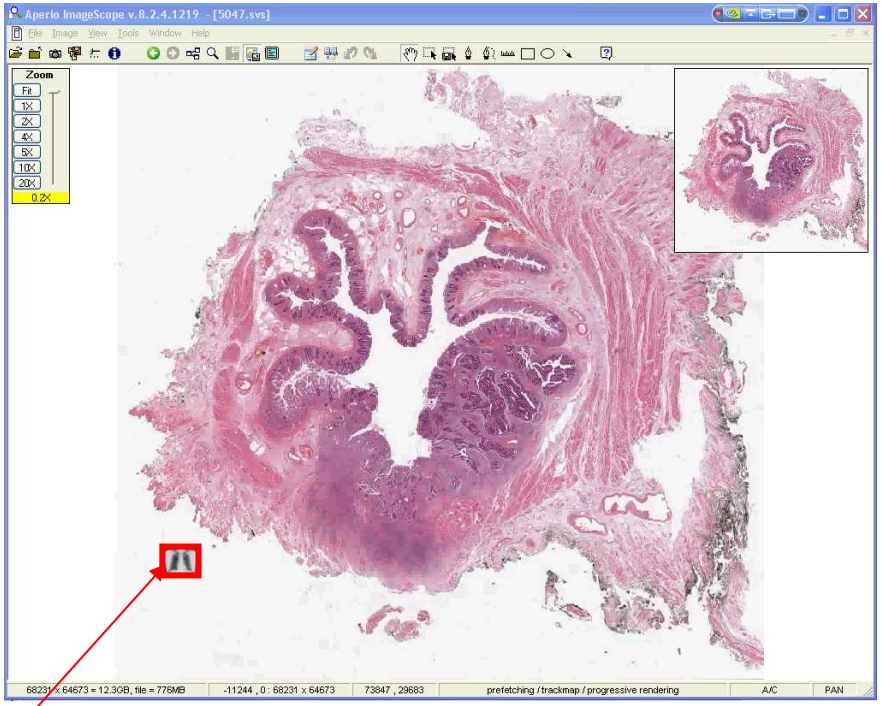
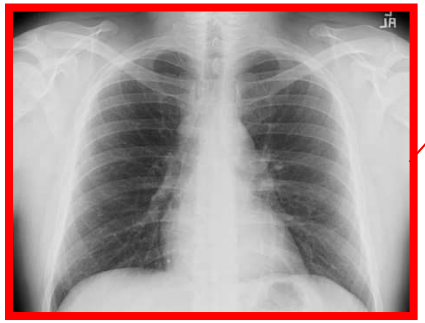
Resolution and orientation

16h30: Influence of displays parameters on digital pathology systems

- Pathology slices
  - 200000 dots per inch
  - Up to 10 gigapixels in size
  - 24 bit color
  - 500MB compressed





Comparison between a radiographic image and a digital slide

Source: University of Leeds – Darren Treanor

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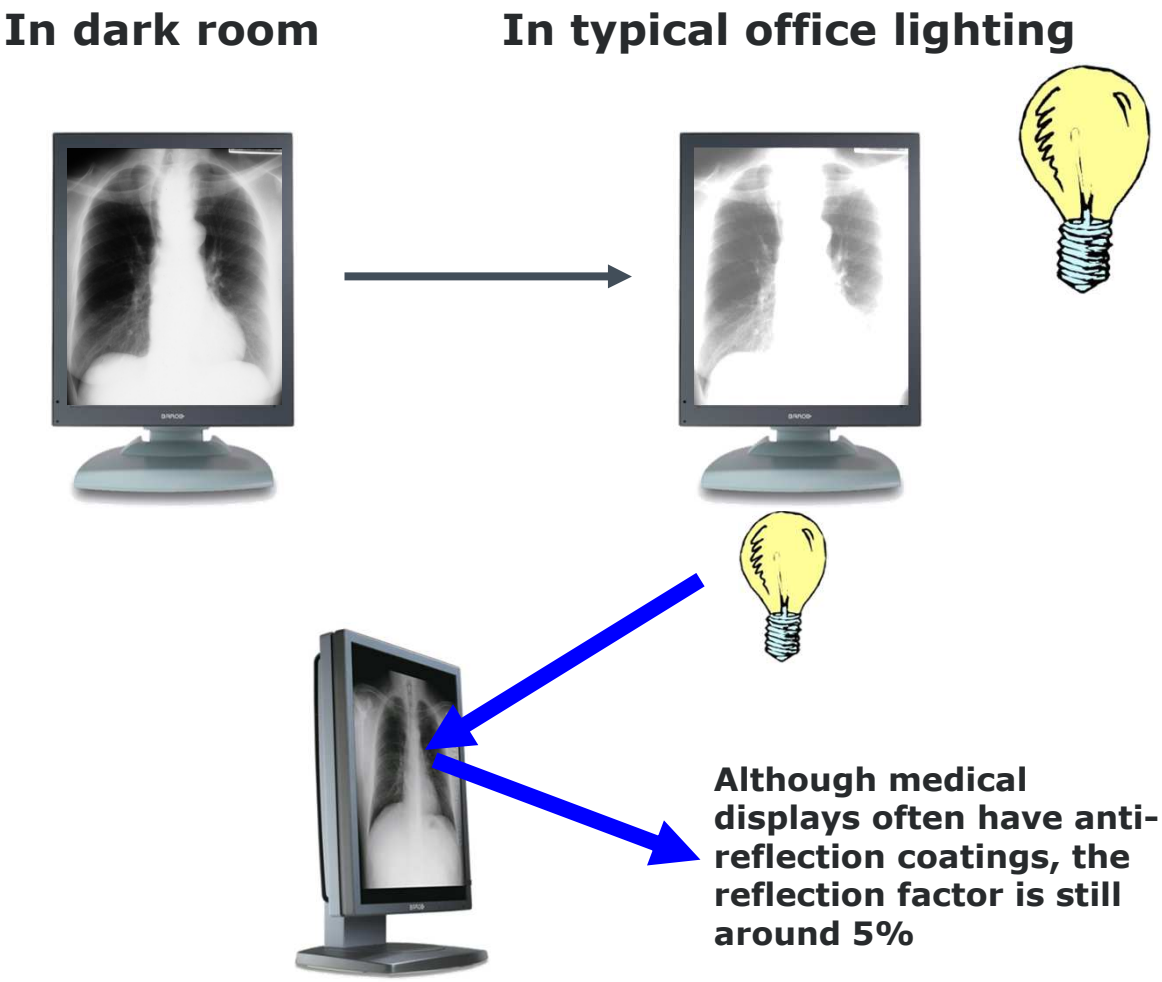
Contrast

Contrast

Influence of ambient light



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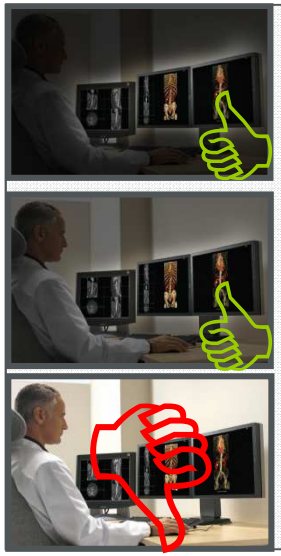
Contrast

- Panel contrast ratio:
  - typical 800:1 – 1200:1

- Quality control defines “Luminance ratio”

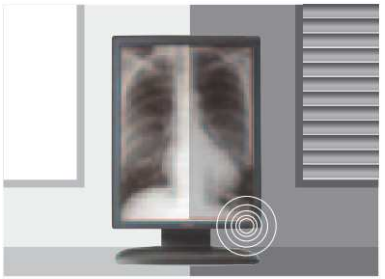


$$\frac{L_{white} + L_{ambient}}{L_{black} + L_{ambient}} > 250$$

$L_{ambient}$ is the reflected ambient luminance from the display

ALC

Ambient Light Control



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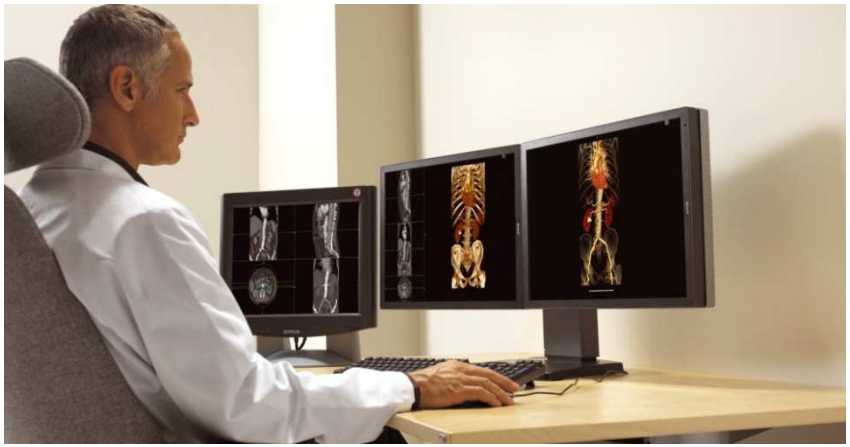
Viewing angle

Viewing angle

- As medical workstations combine multiple heads, viewing inevitably happens from different viewing angles. Thus, displays should enable a wide viewing angle (at least 80°).



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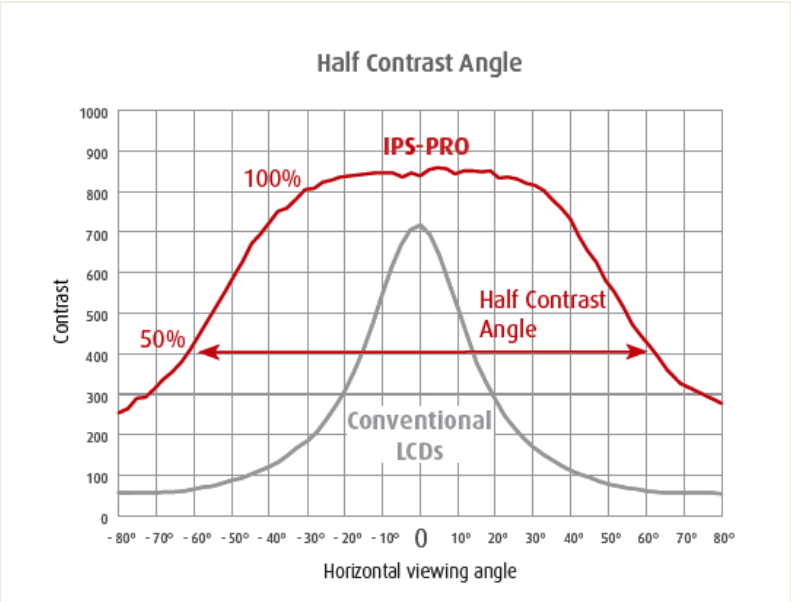
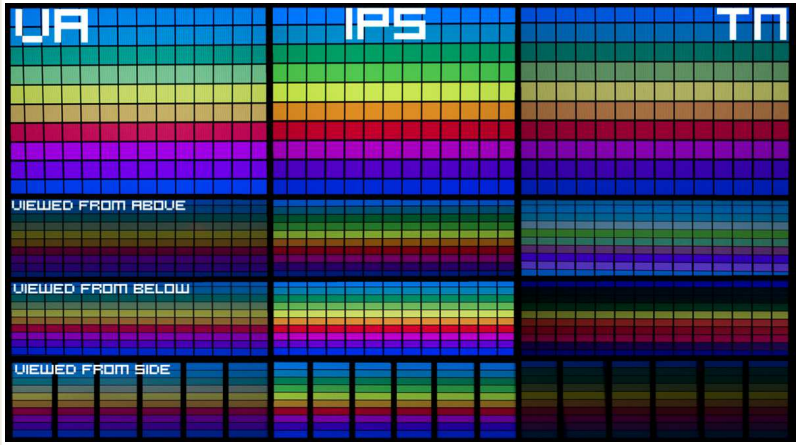
Viewing angle

- Medical grade displays use a technology with the best state-of-the-art viewing angle characteristics.





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Luminance uniformity

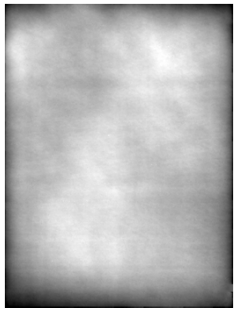
Luminance uniformity

- LCDs suffer from non-uniformity behavior causing arbitrary patterns that interfere with medical imaging content

- Cause for this spatial noise :
  - Non-uniformity of backlight : fall-off towards the corners
  - LCD cell tolerances

Panel non-uniformity

Backlight non-uniformity



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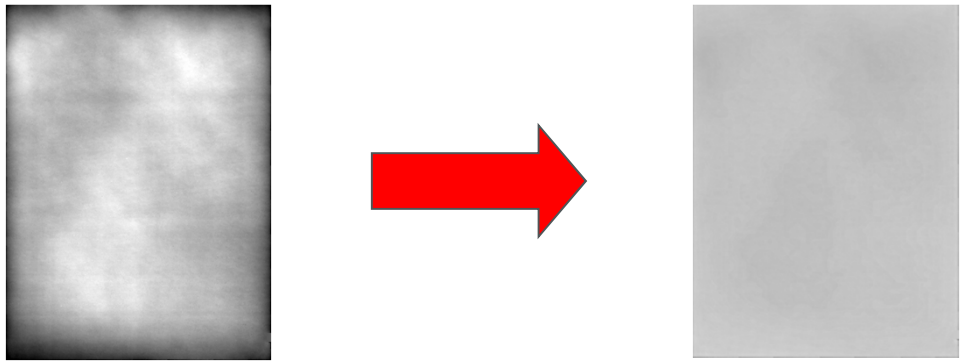
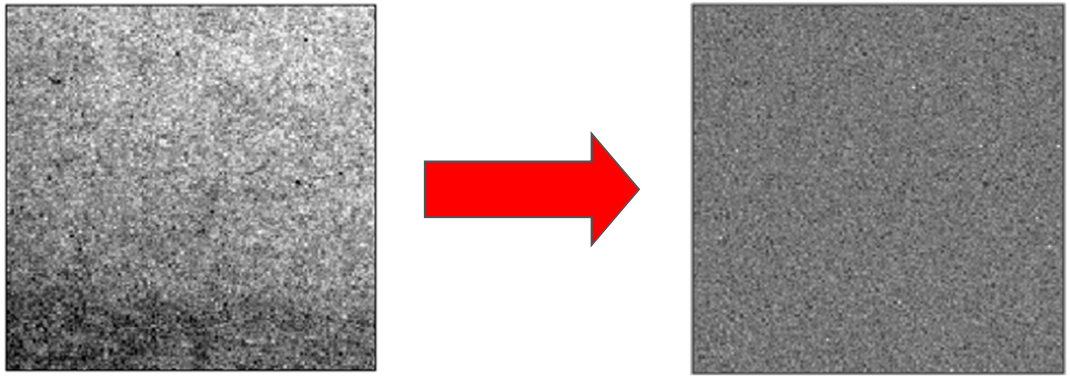
Luminance uniformity

- Luminance corrections
  - Backlight non-uniformity → Correction on all (except black) luminance levels



  - LCD cell tolerances → Correction on all (except black) luminance levels



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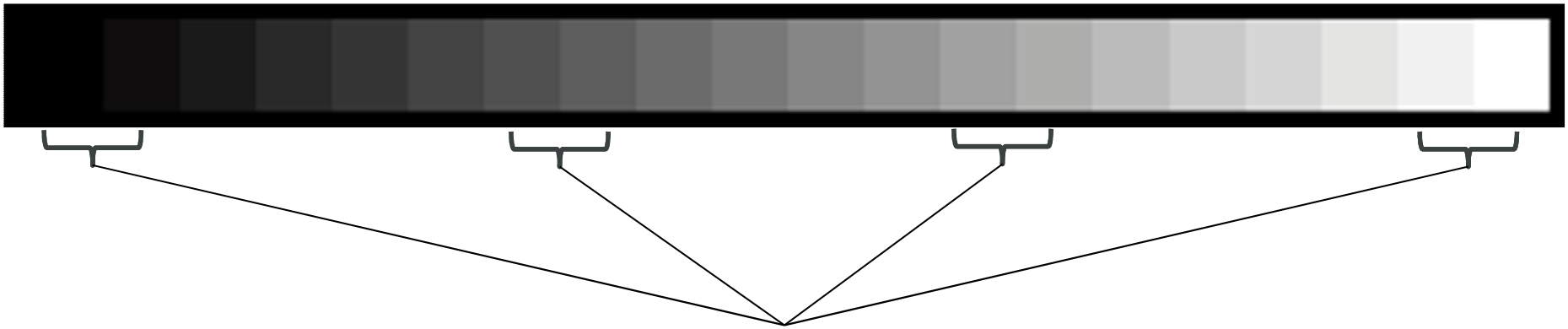
Grayscale Standard Display Function & DICOM luminance calibration

Grayscale Standard Display Function (GSDF) - DICOM compliance

What is the GSDF?



Same perceived luminance difference

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Grayscale Standard Display Function (GSDF) - DICOM compliance

What is the GSDF?

Not calibrated display (native curve)

Calibrated display (GSDF)

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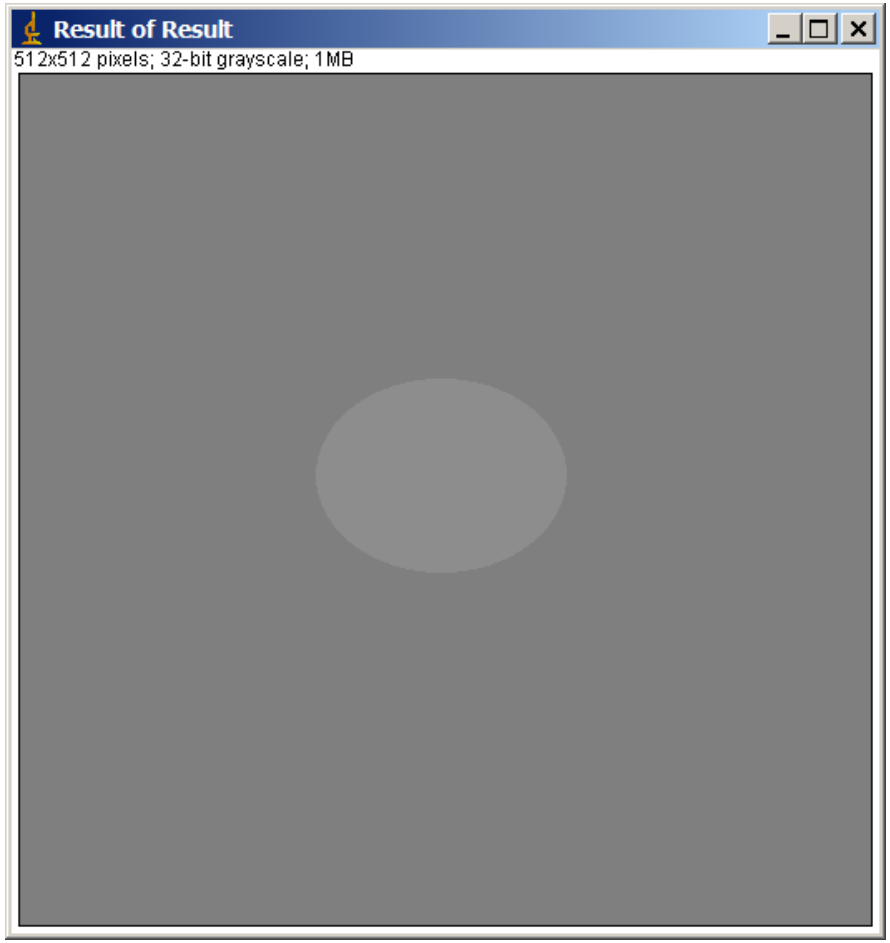
What is a JND?



- JND depends on :

- Spatial frequency - Luminance level

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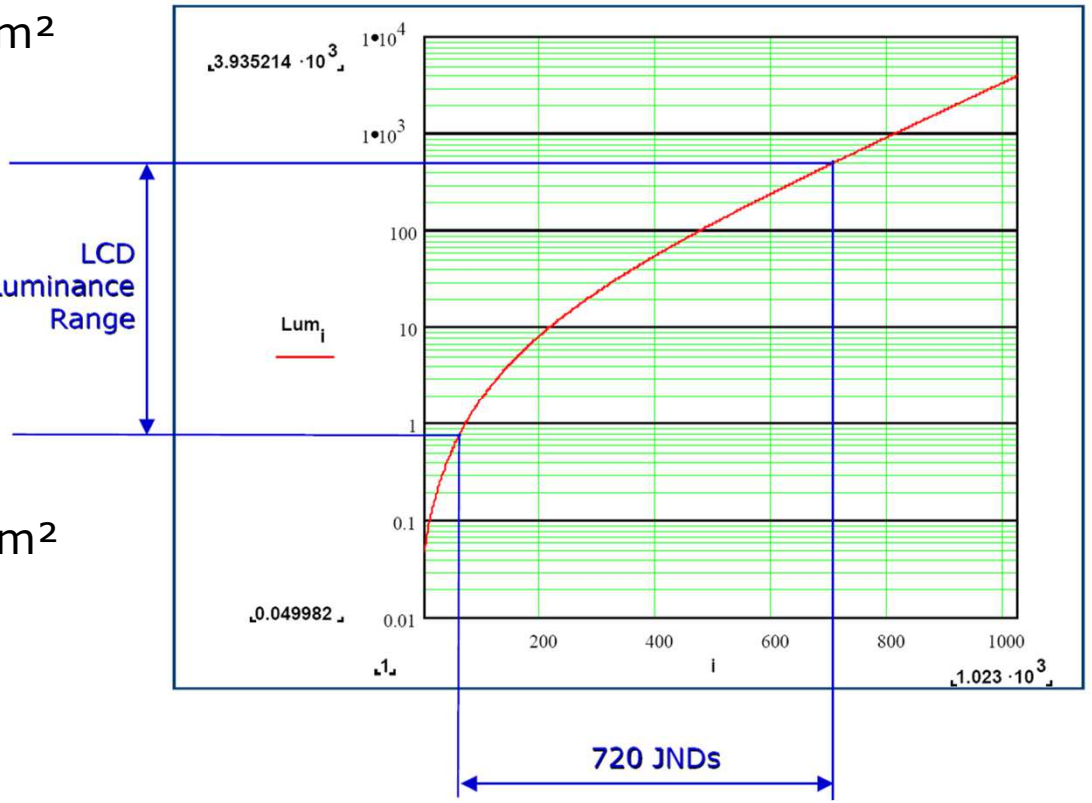
Luminance/JND range

Between 0.8-500 cd/m²

720 available JNDs

Between 10-1000 cd/m²

600 available JNDs



- Larger luminance range → more JNDs to display → more visible details

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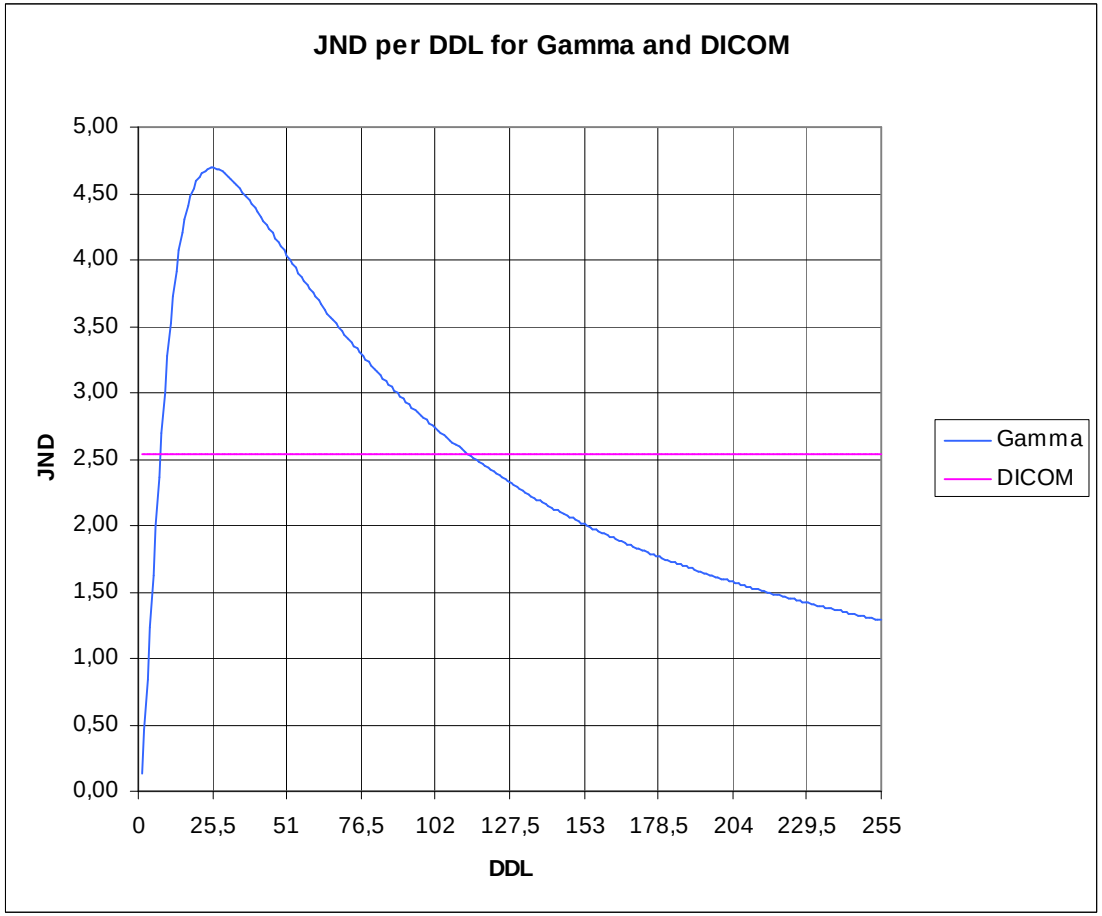
Grayscale Standard Display Function (GSDF) calibration algorithm – DICOM compliance



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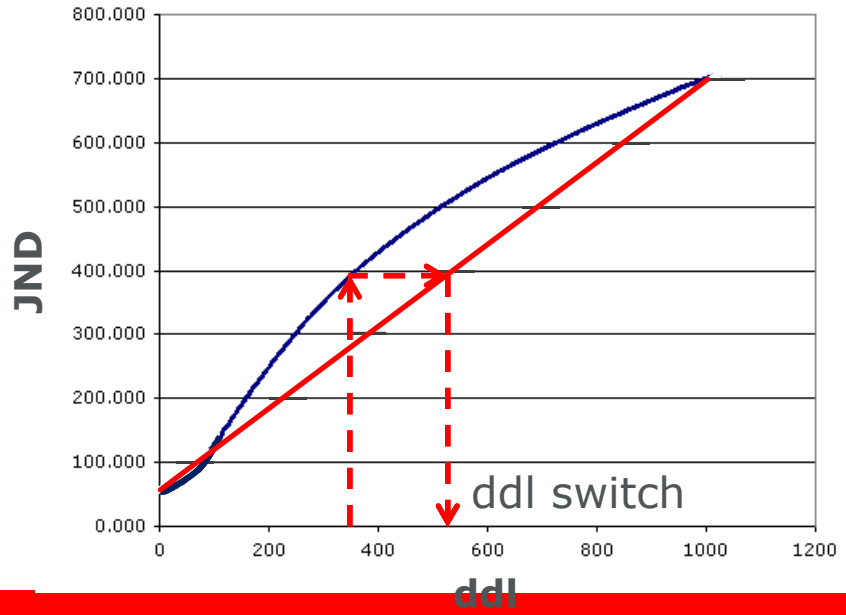
Grayscale Standard Display Function (GSDF) calibration algorithm – DICOM compliance

L = f(ddl) L_{max} L_{min}

Model of Barten:
L = f(JND)
JND = f(L)



Native curve

Target curve

Look Up Table

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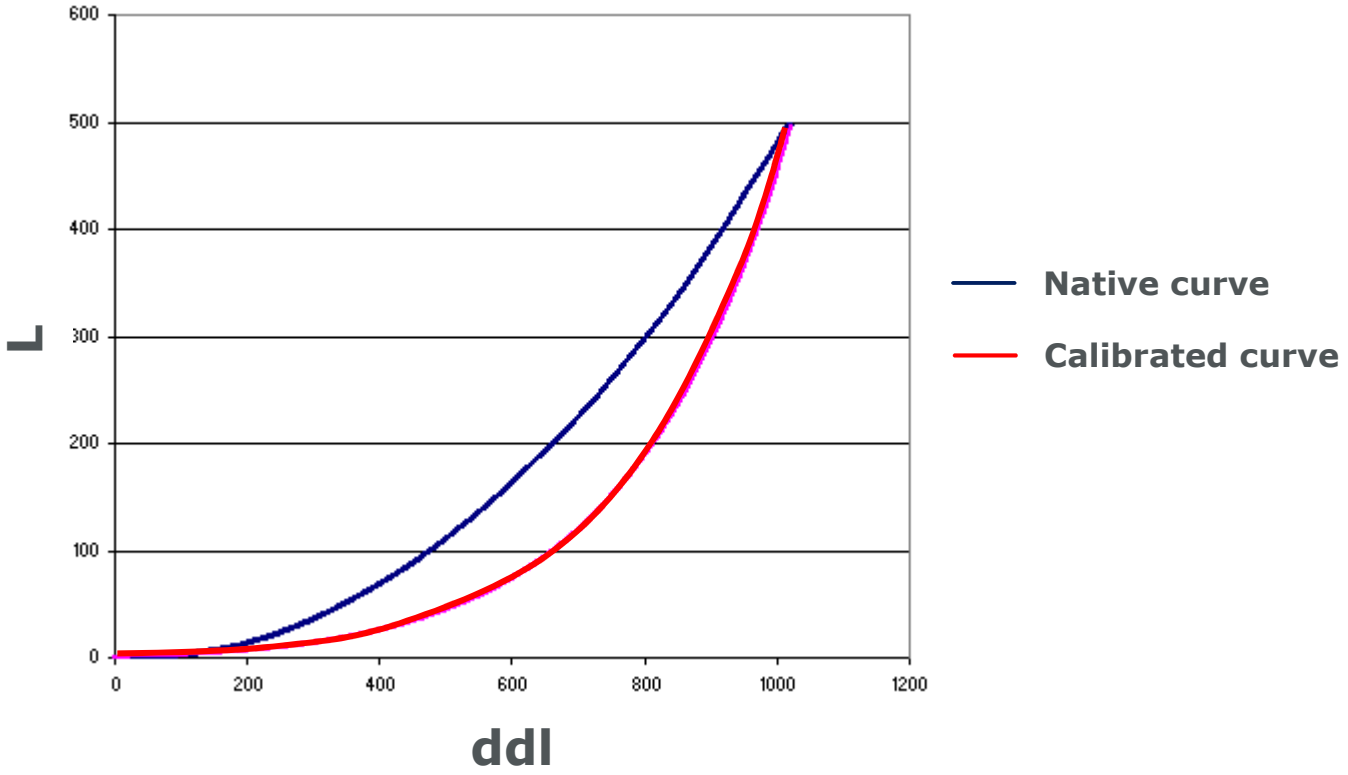
Grayscale Standard Display Function (GSDF) calibration algorithm – DICOM compliance



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Grayscale Display Function (GSDF) calibration algorithm – DICOM compliance

Display not calibrated:

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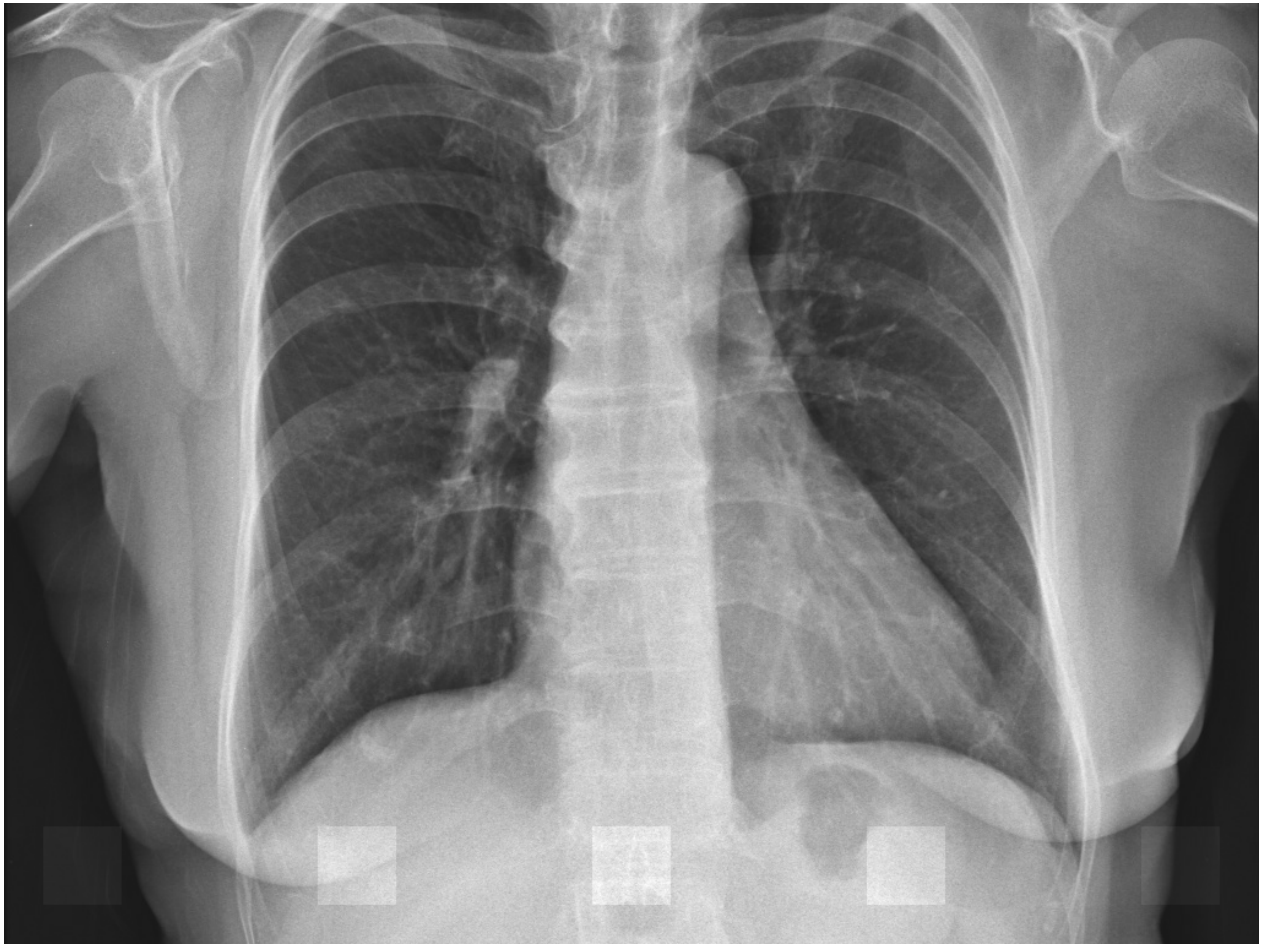
Grayscale Display Function (GSDF) calibration algorithm – DICOM compliance

Display GSDF calibrated:



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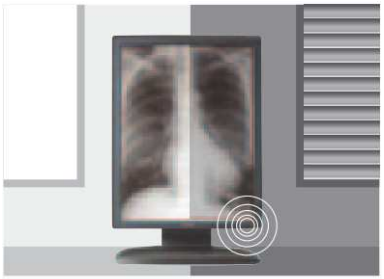
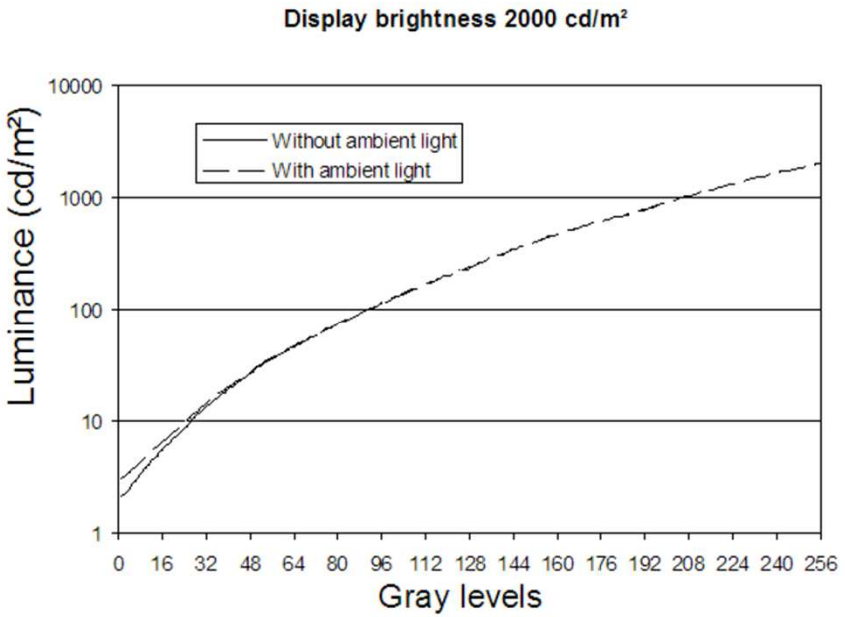
Grayscale Display Function (GSDF) calibration algorithm – DICOM compliance

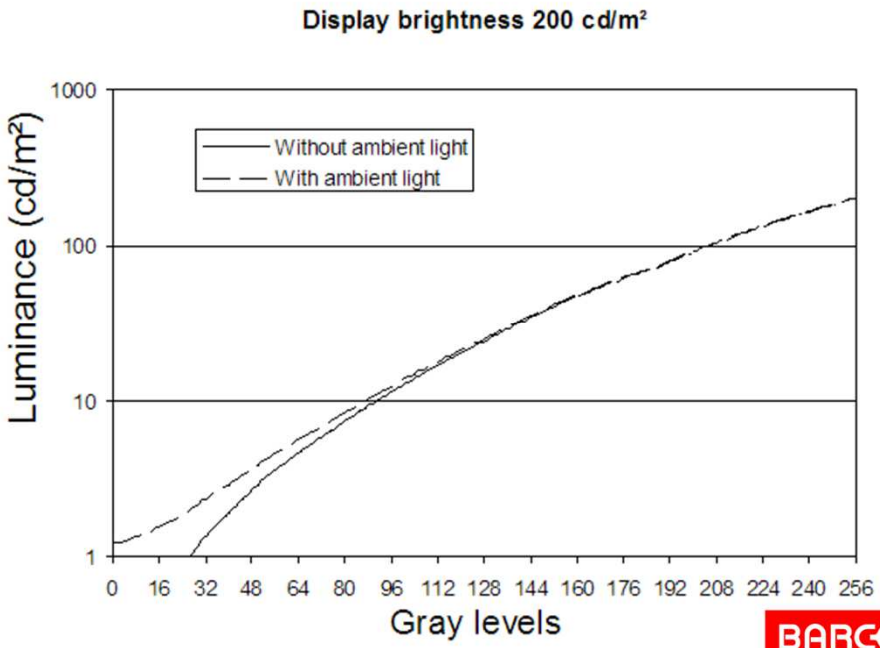


DICOM compliance under all lighting conditions thanks to ALC

Influence of ambient light

- Higher display brightness reduces the effect of ambient light and makes it possible to use the display in brighter environment





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Color Standard display function

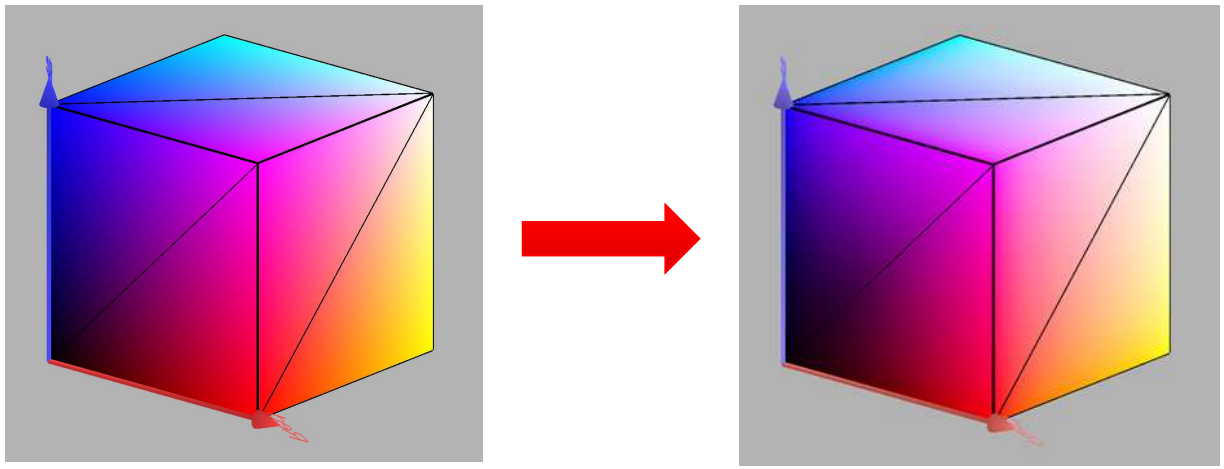
Color Standard Display Function (CSDF)

What is the CSDF?

Perceptually linear color calibration (**Color Standard Display Function**)

Comparable to Dicom **Grayscale Standard Display Function** philosophy, but for color.

Everywhere the same perceptual color differences



sRGB

Barco Coca

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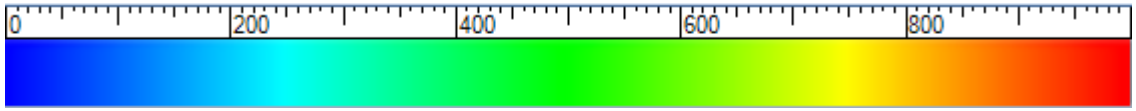
Colorscale Standard Display Function (CSDF)

What is the CSDF?

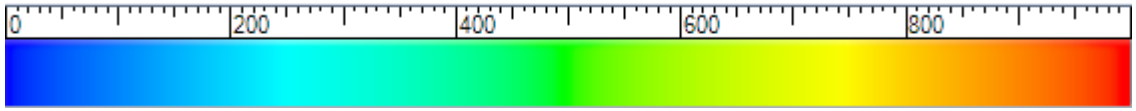
11h30: Color calibration and ICC profiles

Not calibrated display (native curve)



Demo 1: Color calibration and color test patterns

Calibrated display (GSDF)



Demo 2: Color calibration and ICC profiles

ΔE2000 instead of ΔJND

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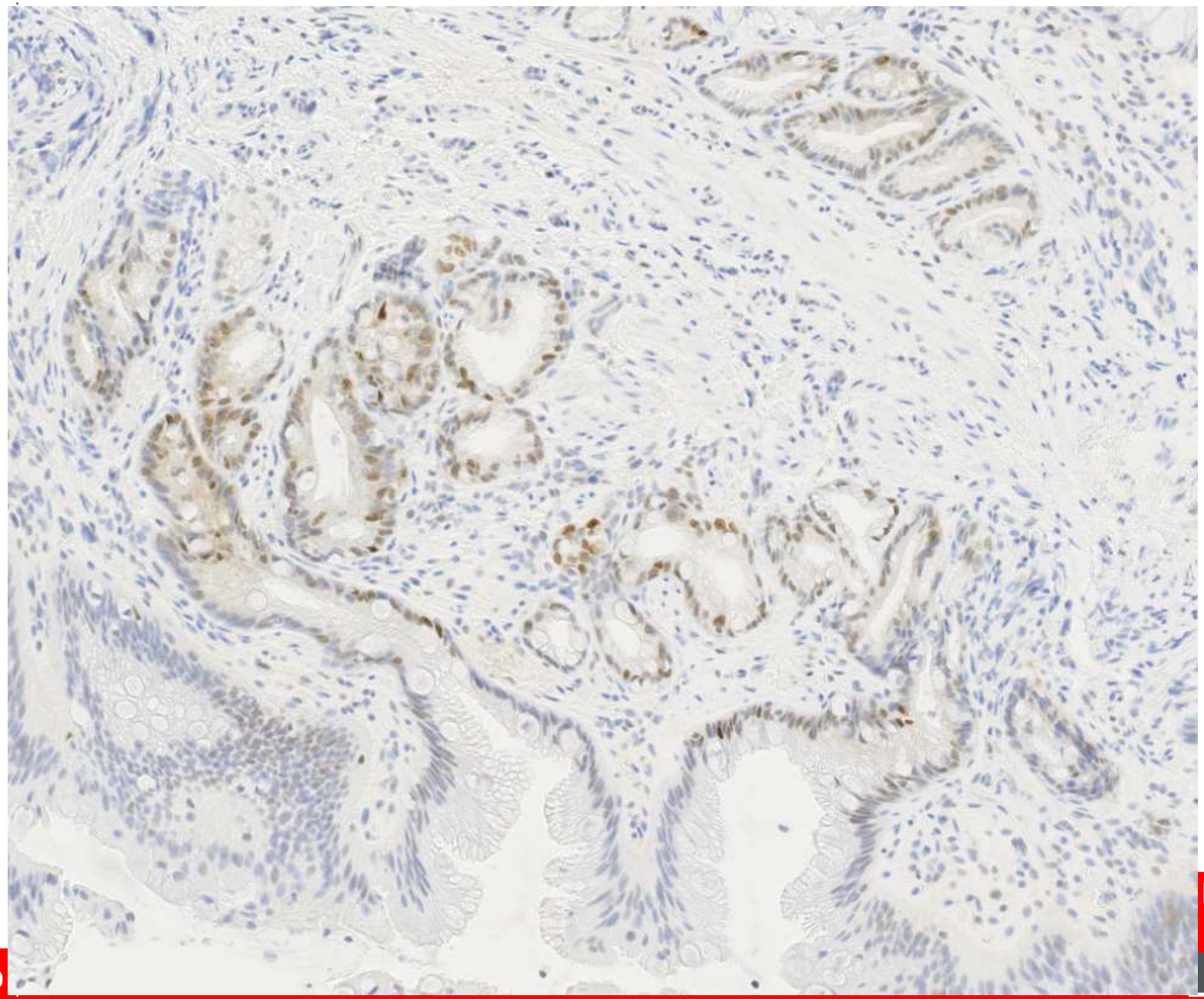
Not calibrated display (native curve)

Negative case



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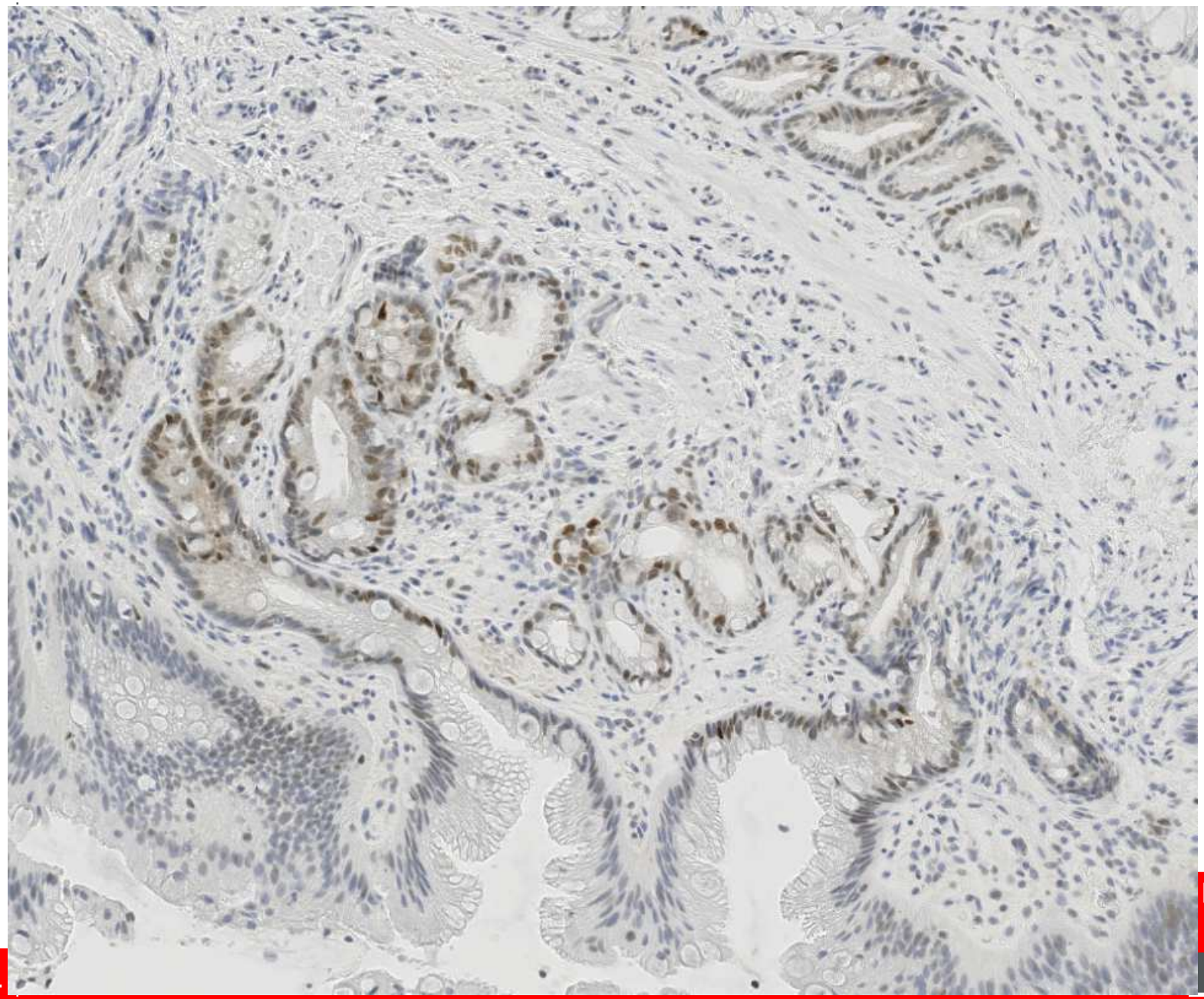
CSDF calibrated display

Negative case



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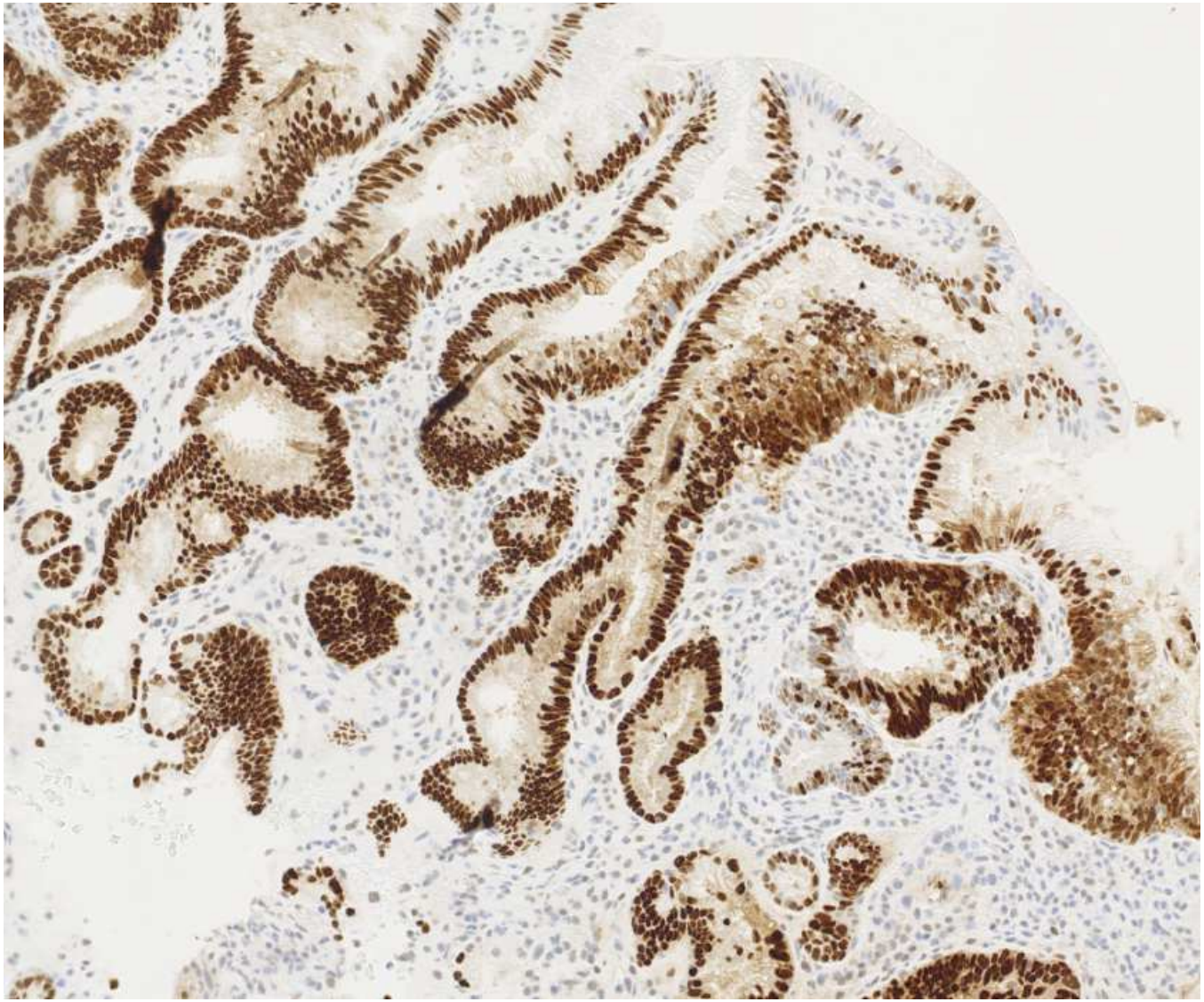
Not calibrated display (native curve)

Positive case



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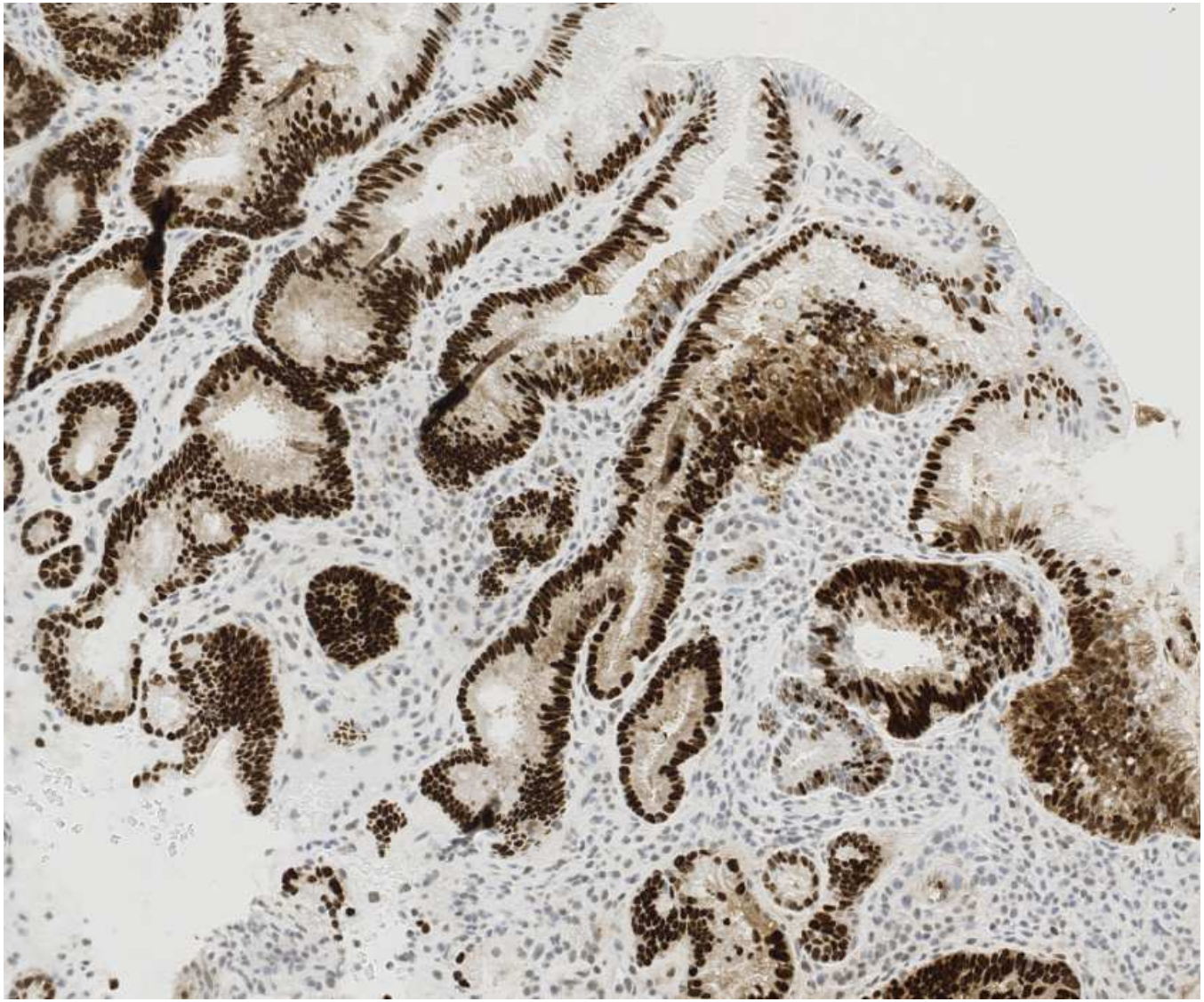
CSDF calibrated display

Positive case



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Temporal response

Temporal response

- Traditional displays:
  - Slow response time
  - Average transition time for a 12MP medical display is 20ms (10%→90%)
  - Therefore 2-3 display frames are needed before 90% of the transition is reached
  - When panning through a slice → motion blur
  - Motion blur can mask subtle image features

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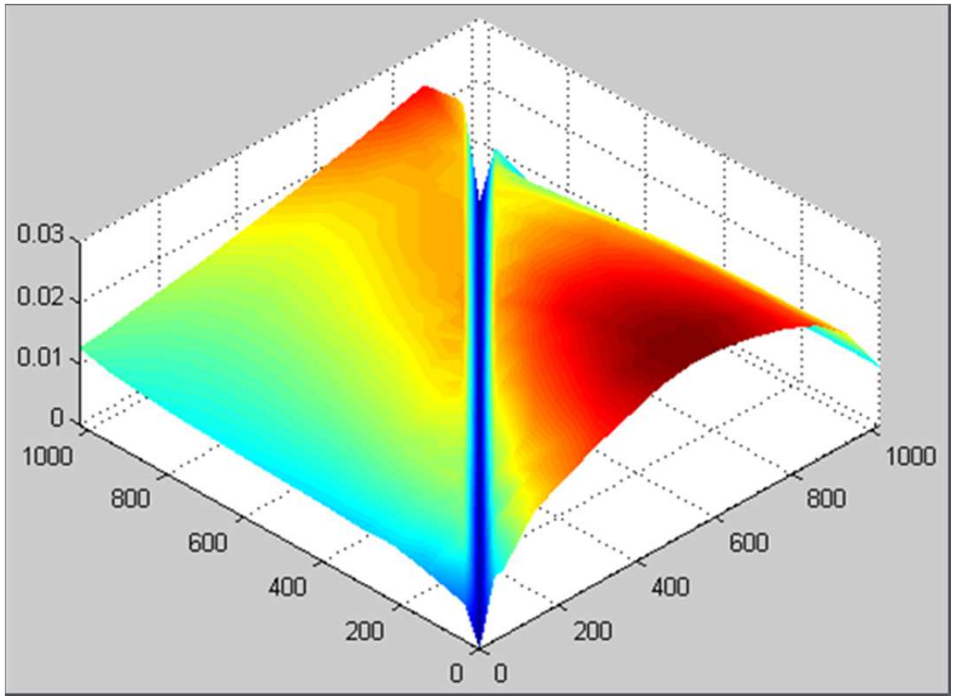
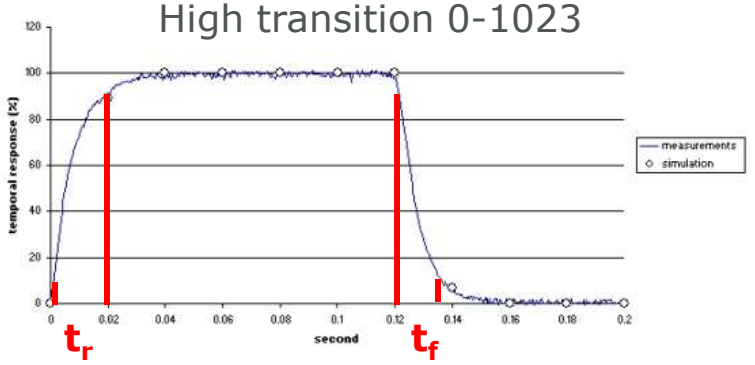
Temporal response

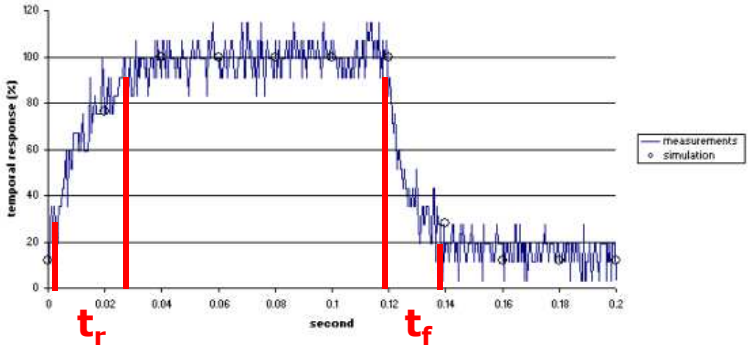
- Traditional displays:
  - Slow response time
  - Non-uniform response time
  - Non-symmetrical response time



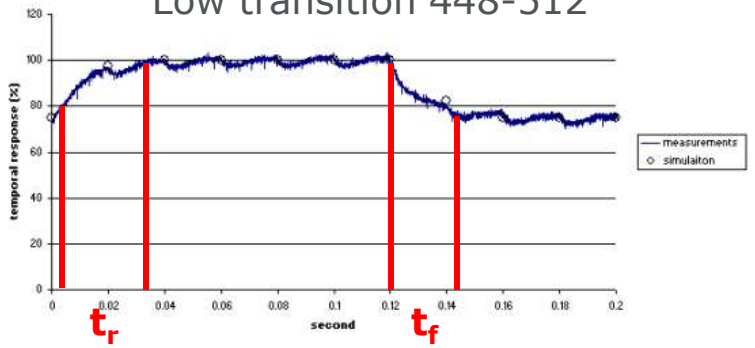
High transition 0-1023



Middle transition 192-576



Low transition 448-512



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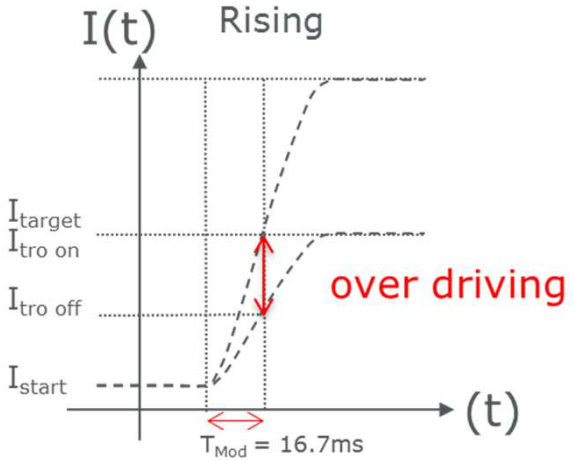
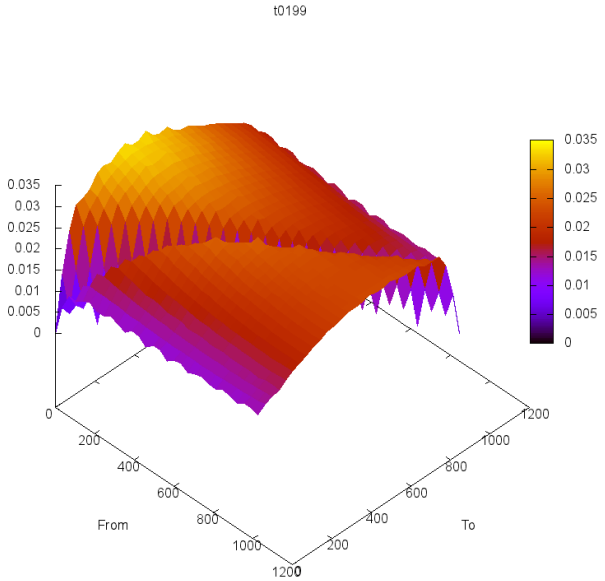
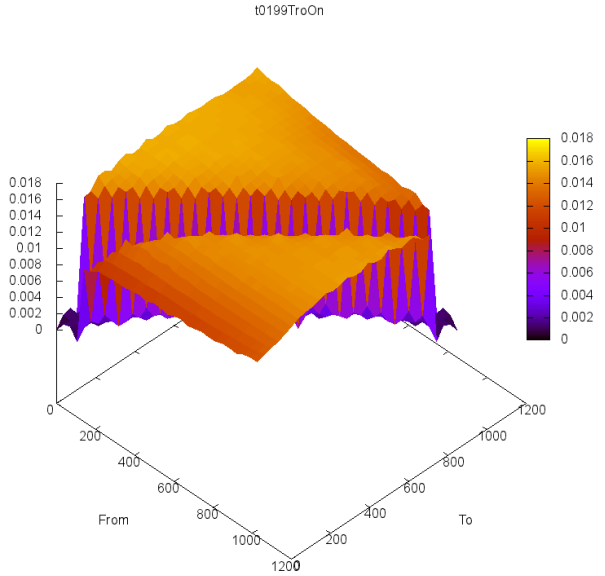
Temporal response

- Rapid frame technology
  - Faster response time
  - More uniform across transitions
  - More symmetrical





OFF



ON

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Image consistency and QA management

Image consistency and QA management

- Front sensor (i-guard)
  - Luminance and/or color sensor mounted in front of the display

- Backlight sensor

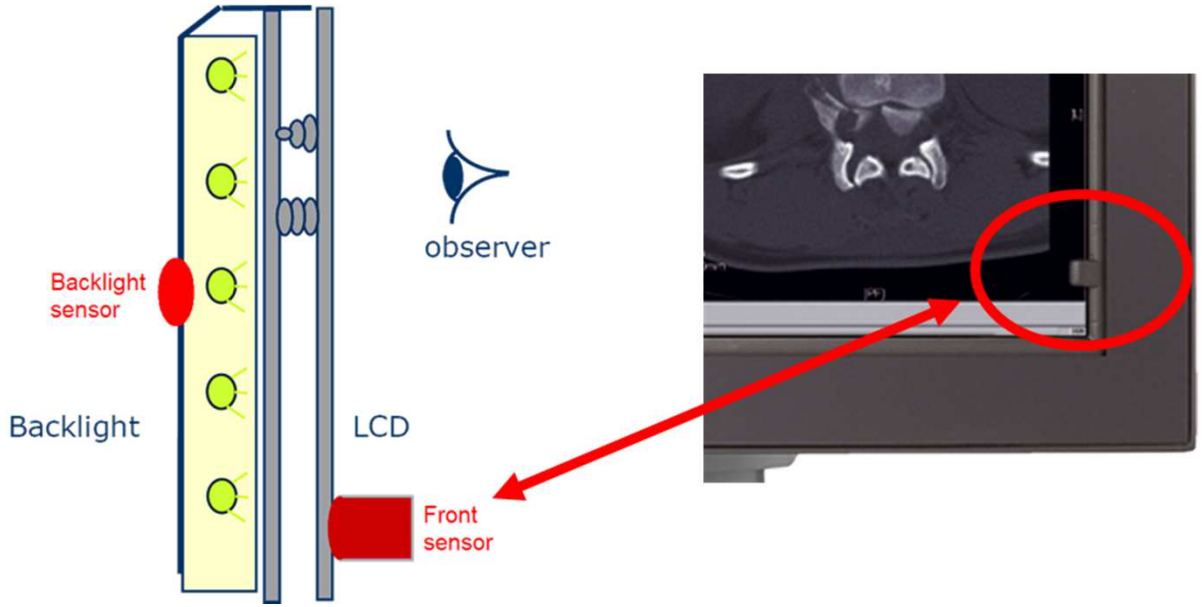

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Image consistency and QA management

- Front sensor (i-guard) + software
  - Measure patches to ensure the display is still DICOM compliant
- Backlight sensor + software
  - Check maximum luminance over time and boost the backlight if required to ensure a constant maximum luminance
- QA management
  - Either integrated in the display or stand-alone (PC or server)
  - Ensure the communication between the sensors, software, and the display

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Conclusion

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Conclusion

- **A medical display is not a standard display, but it accounts for**
  - Resolution and orientation
  - Contrast
  - Viewing angle
  - Luminance Uniformity
  - Grayscale display function
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  - Temporal response
  - Image consistency & QA management

    … to generate the best image quality and clinical performance

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Thank you

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