

# Infrared and ultraviolet imaging with a CMOS sensor having layered photodiodes

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**Electronic  
Imaging**  
Science and Technology

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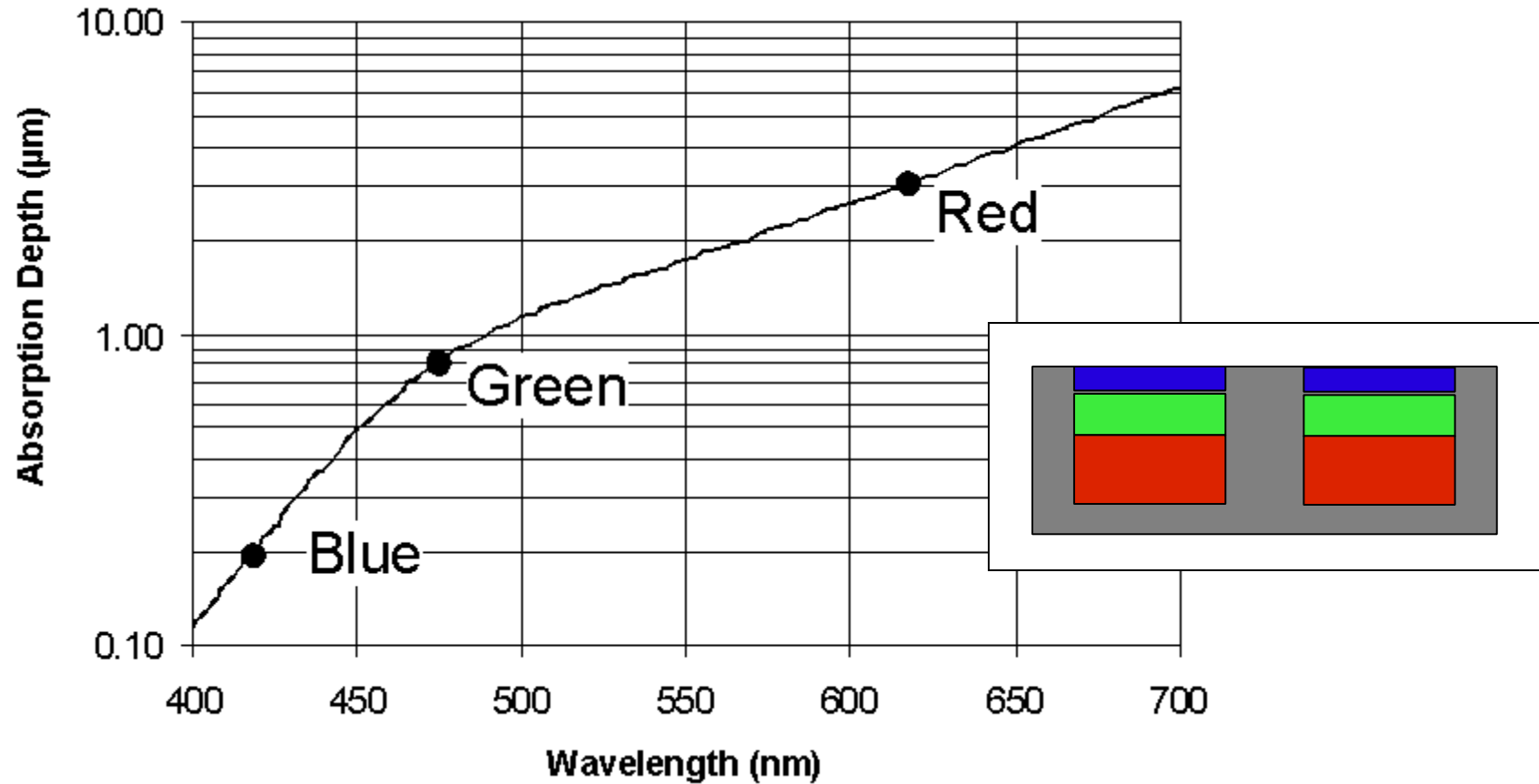
*Alternative  
Vision* 

# Summary

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- Layered image sensor
  - Construction
  - Characteristics
  - Performance
- Ultraviolet sample images
- Infrared sample images
- Color matrix example
- Possible extensions

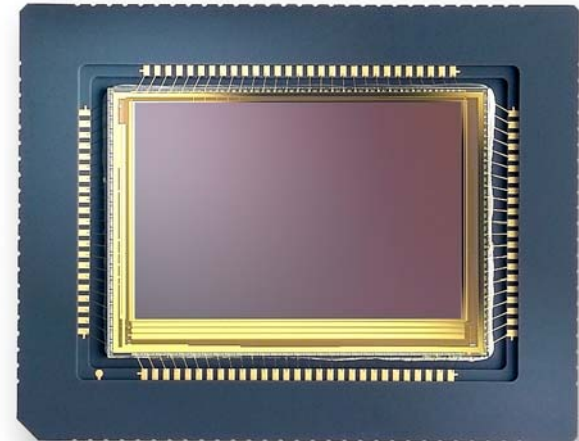
# Color separation with silicon



# Foveon X3<sup>®</sup> Pro 10M sensor

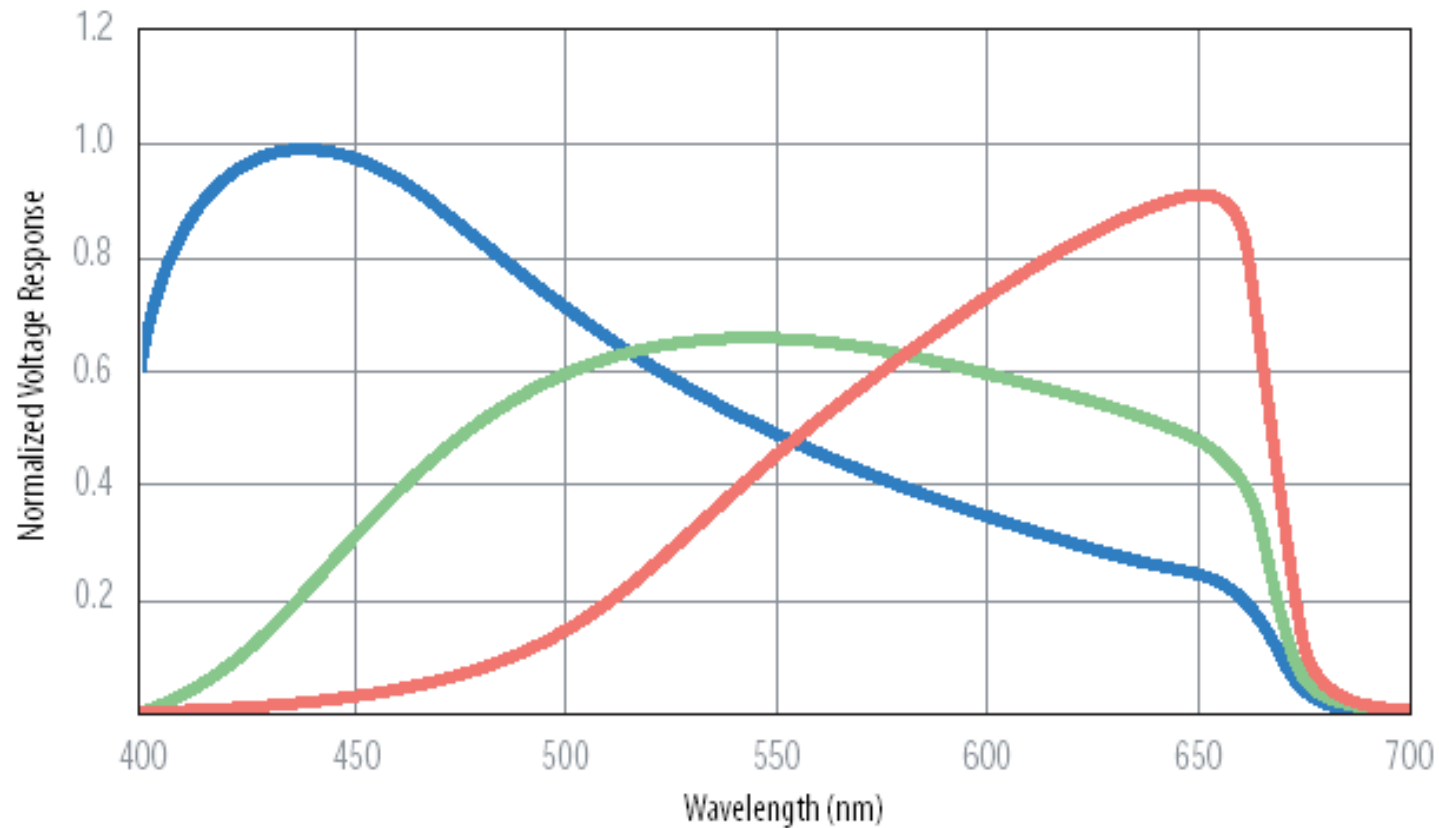
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- 2268 x 1512 active pixel locations
- 3 photodiodes per pixel location
- ~54% fill factor
- 9.12 x 9.12  $\mu\text{m}$  pitch
- Black matrix mask
- 0.18  $\mu\text{m}$ , 3.3 V CMOS
- 400 – 660 nm window
- 100-pin CLCC package



# Spectral characteristics

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Includes effect of 400-660 nm pass filter

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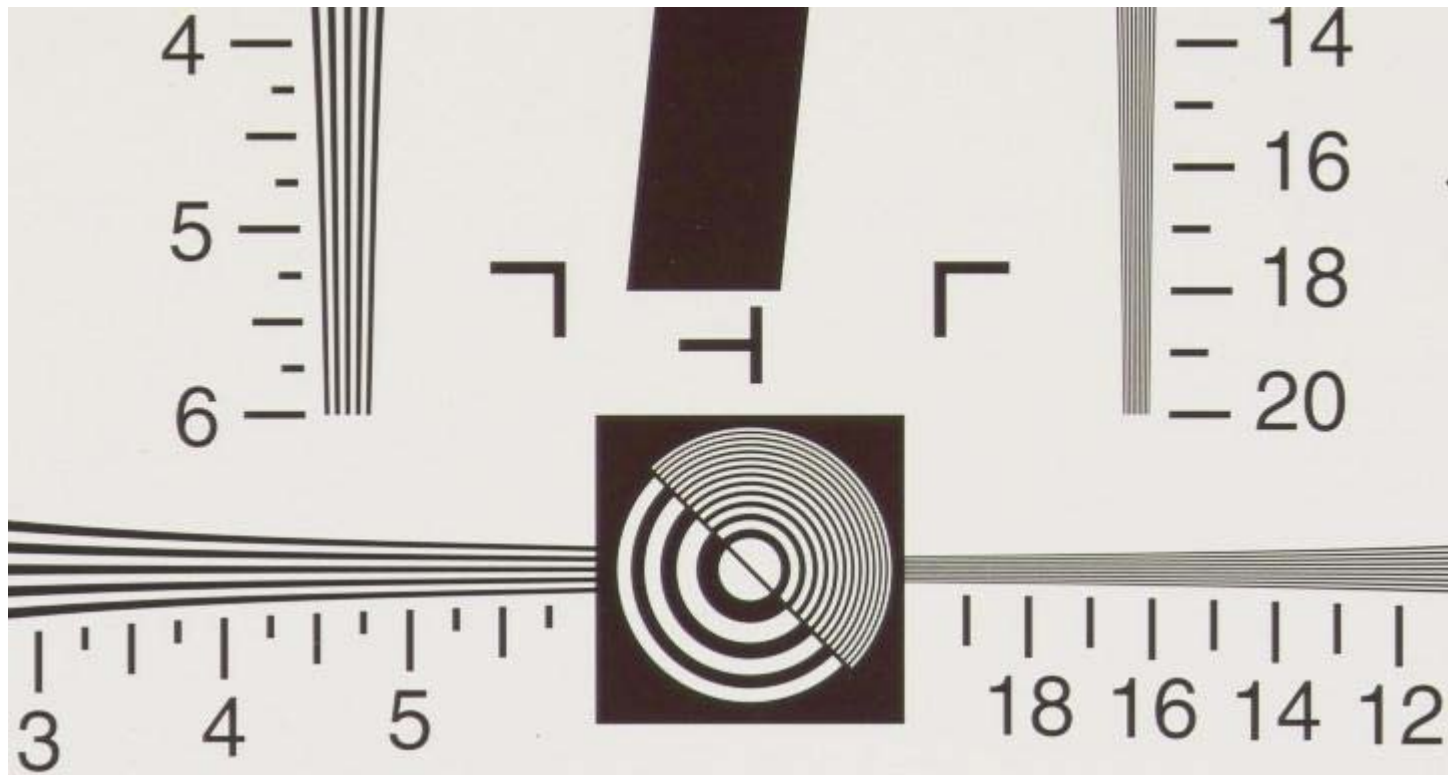
# Performance

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- 49% QE at 625 nm
- 61 db dynamic range
- Dark current  $\sim 1\text{na/cm}^2$  at 25C
- PRNU  $< \pm 1\%$
- 80 mW maximum power
- 24 MHz clock – 4.4fps for full sensor
- 7.14  $\mu\text{V}/\text{electron}$  sensitivity
- Noise = 70 electrons rms (mostly kTC)

# No color aliasing

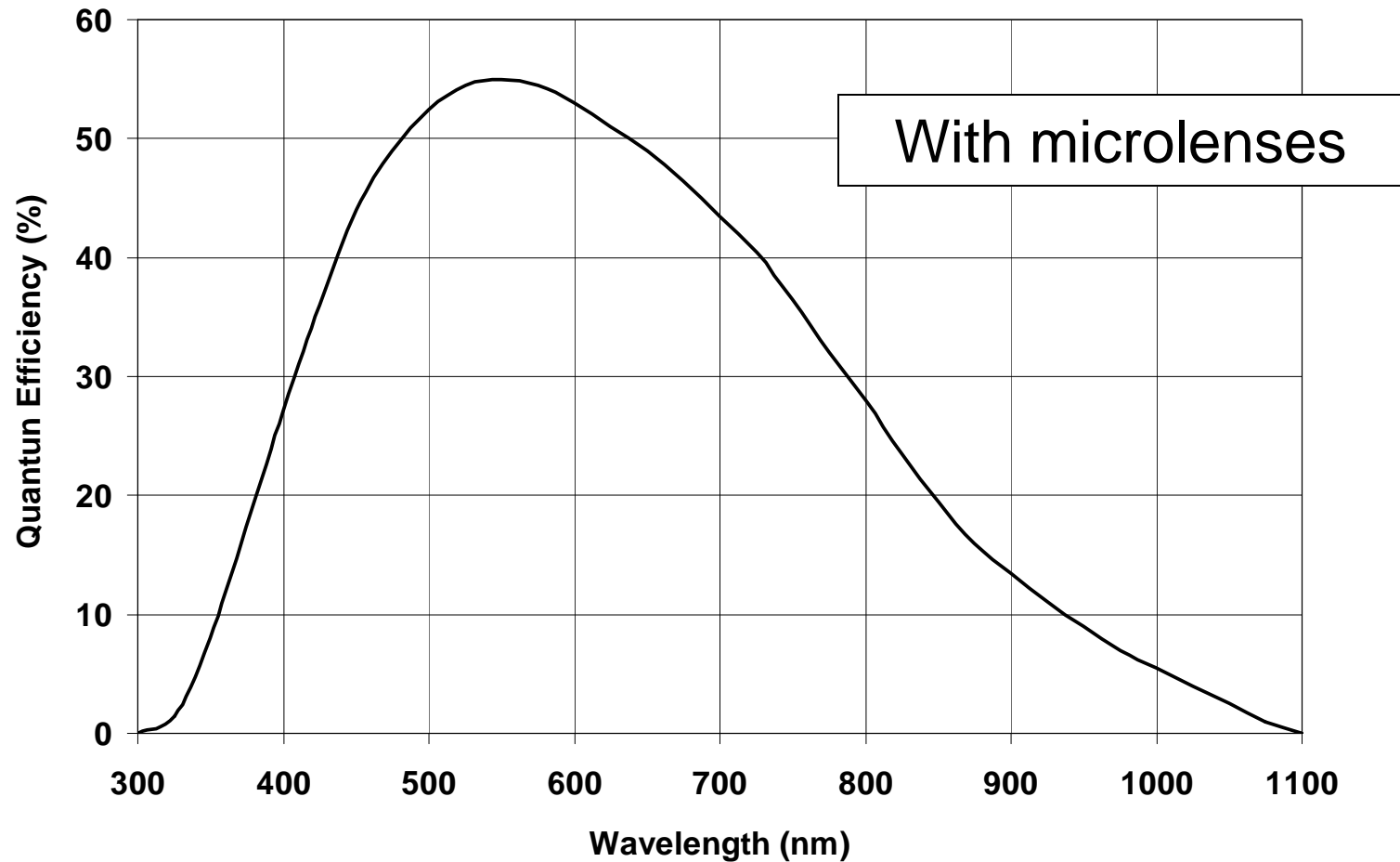
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This is a color image

# Unfiltered total spectral response

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# UV samples

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- Using a glass filter with 340-380 nm UV transmission and a small peak in the 700-800 nm range.
- UV goes almost entirely to the blue channel
- IR goes about 80% to the red channel
- A small matrix is used to cancel the IR component in the blue channel

# Double-peak sky image

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# Sky at 1064 nm

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# Water at 1064 nm

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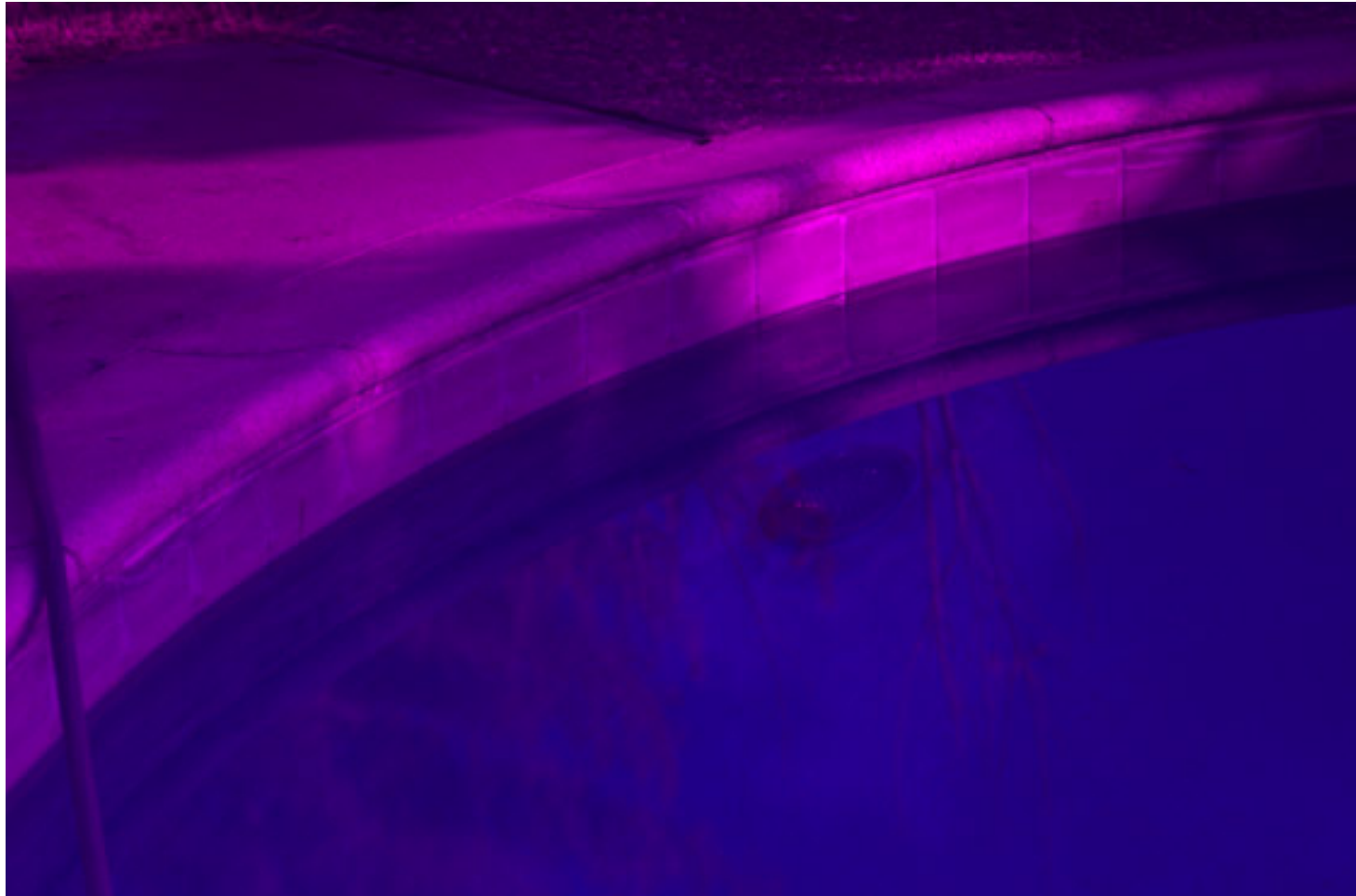
# Black water

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# UV and infrared with water

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# Simultaneous color/IR imaging

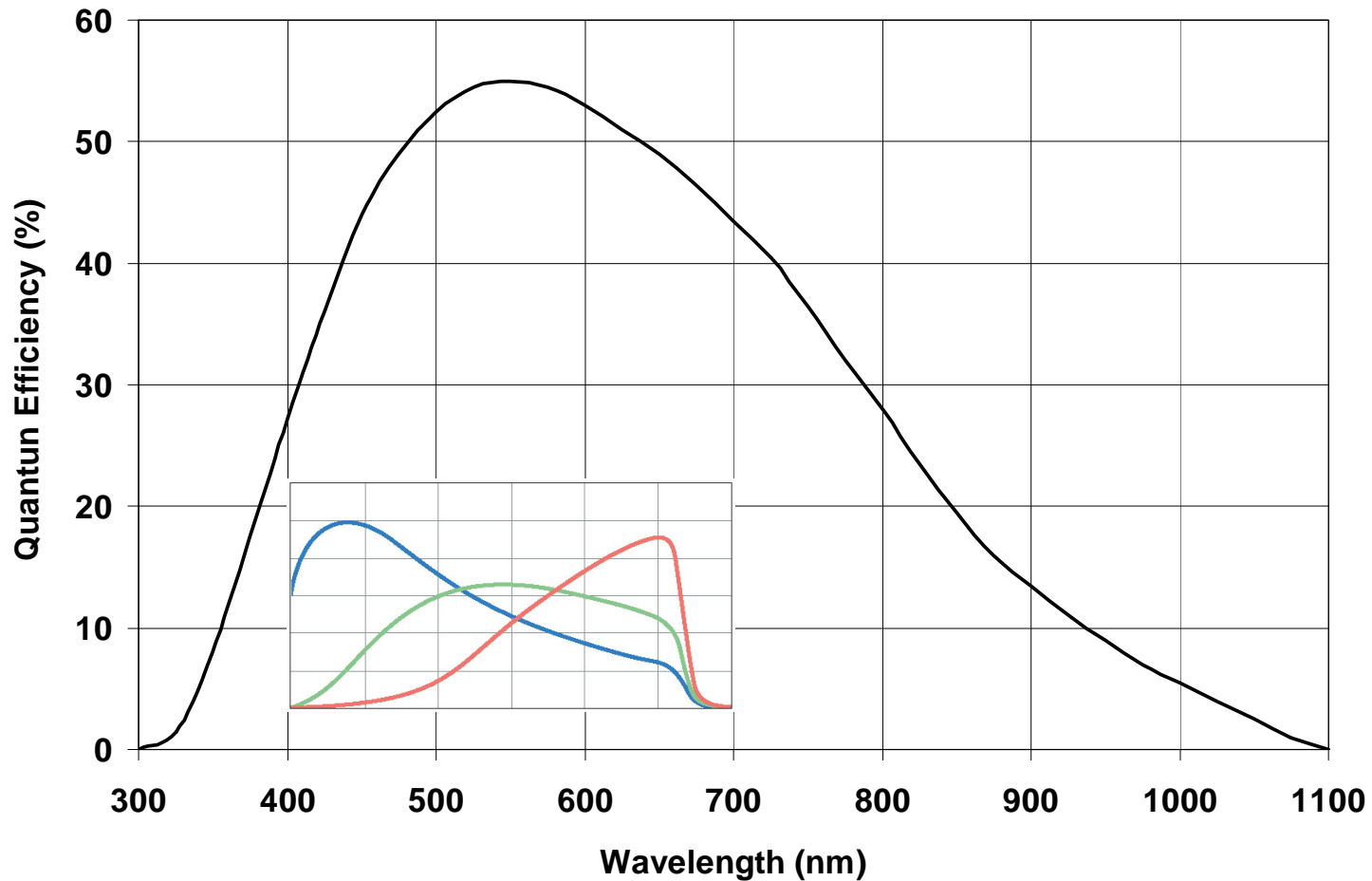
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- Color images require restriction to 400-660 nm
- This restriction can be applied at the camera or at the source
- With controlled conditions simultaneous color/infrared imaging is possible

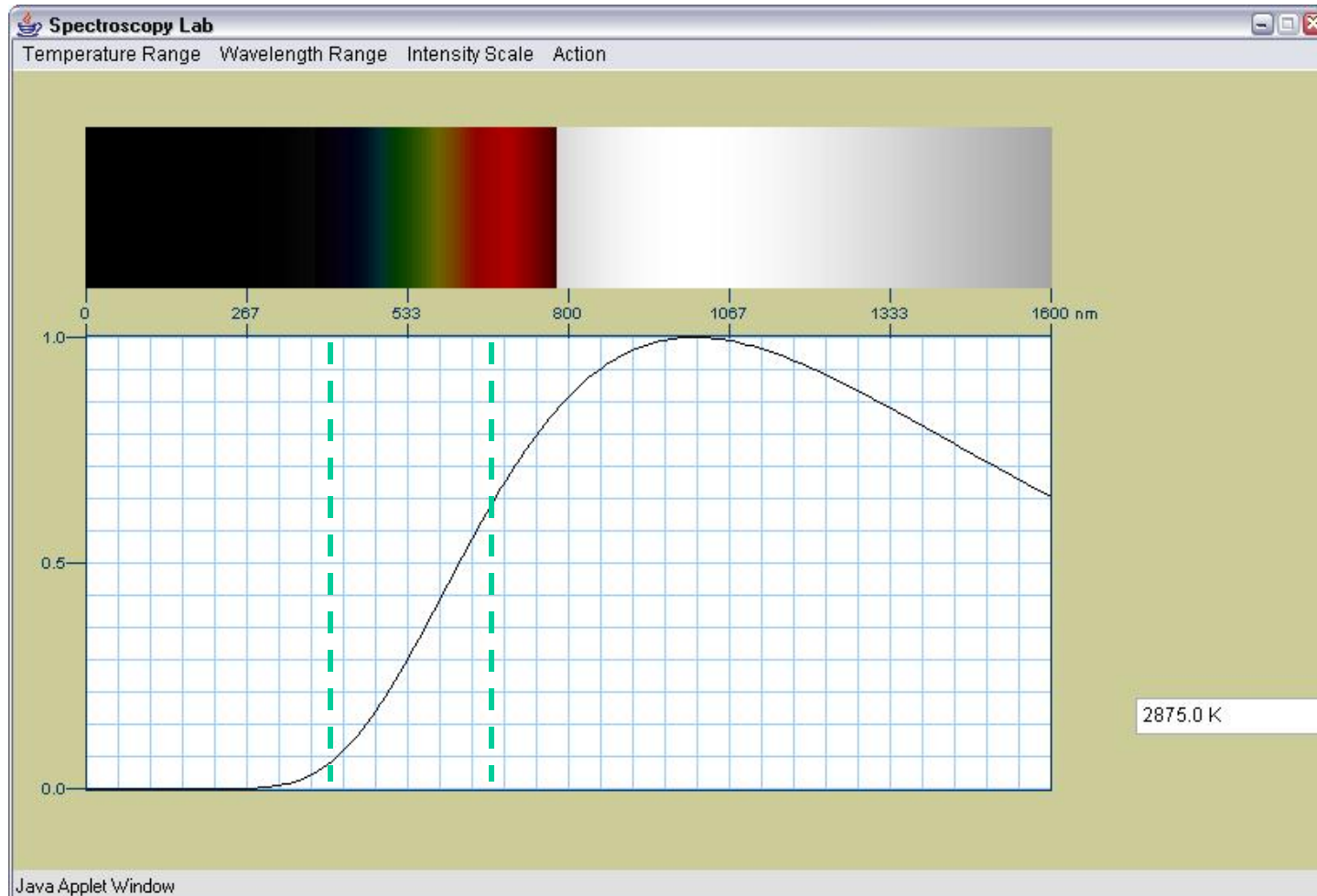
# 400-660 nm limit = color

image

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# Incandescent lamp – 2875 K



# Tungsten – filter in place

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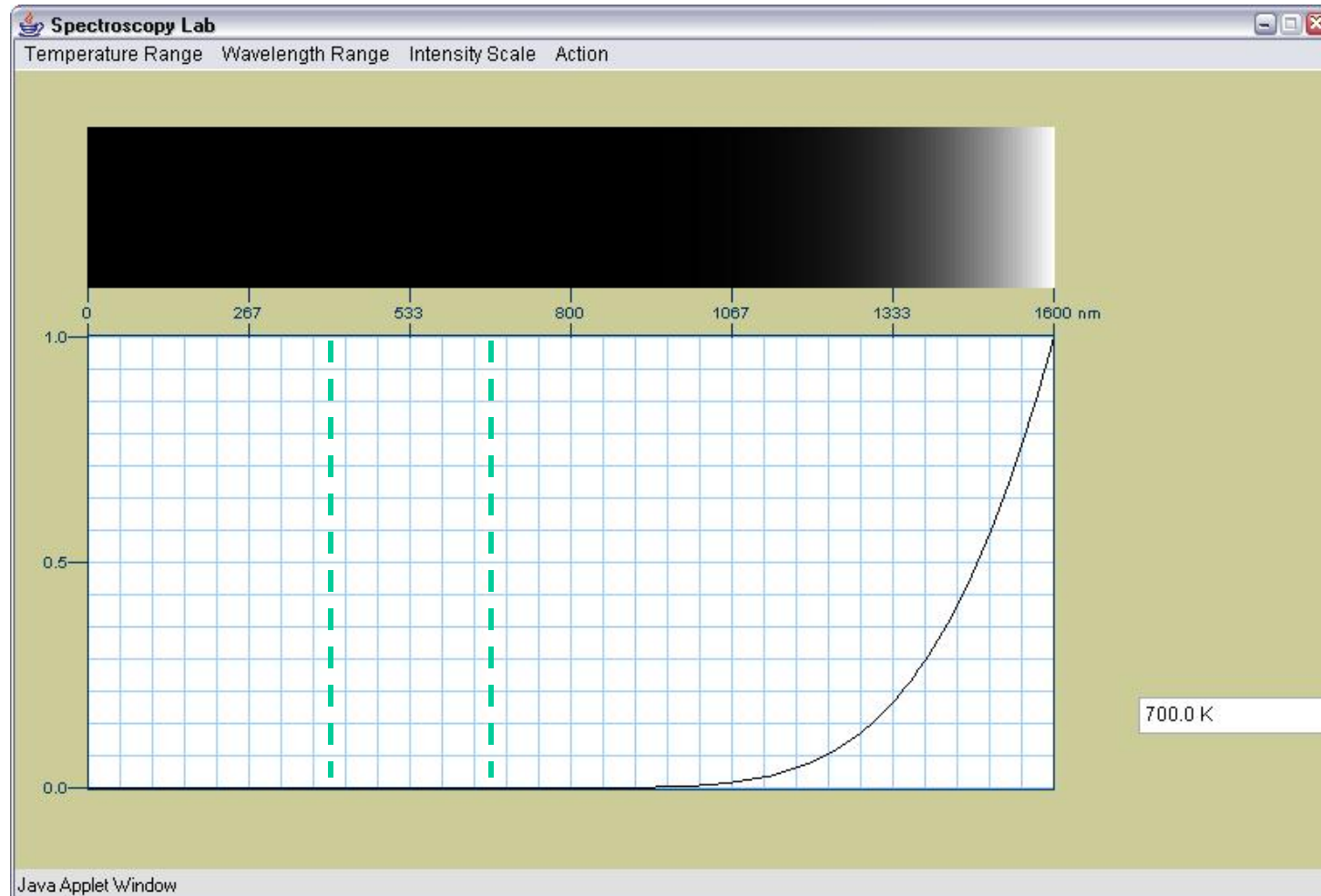


# Tungsten – filter removed

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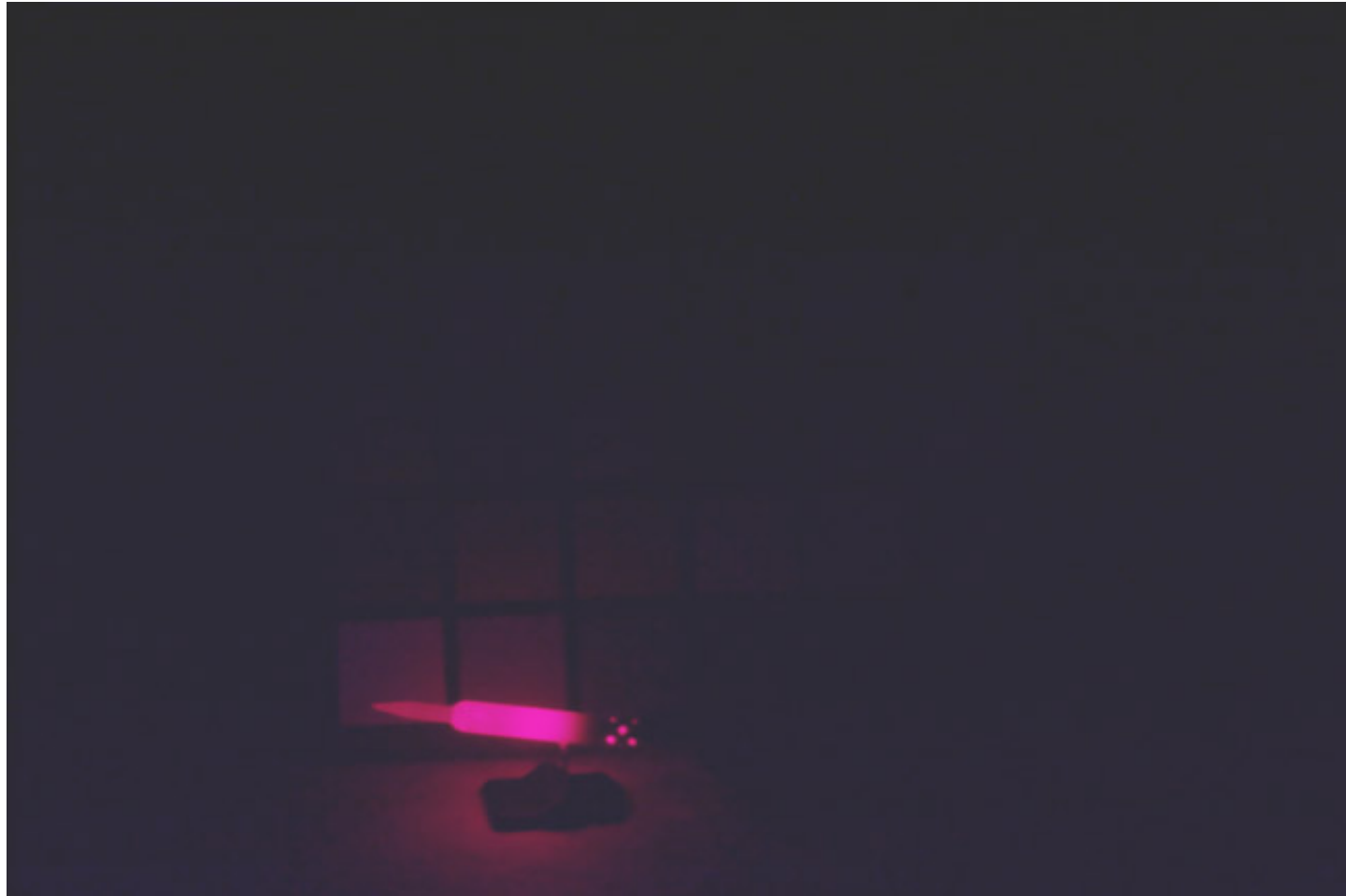


# Soldering iron tip – 700 K

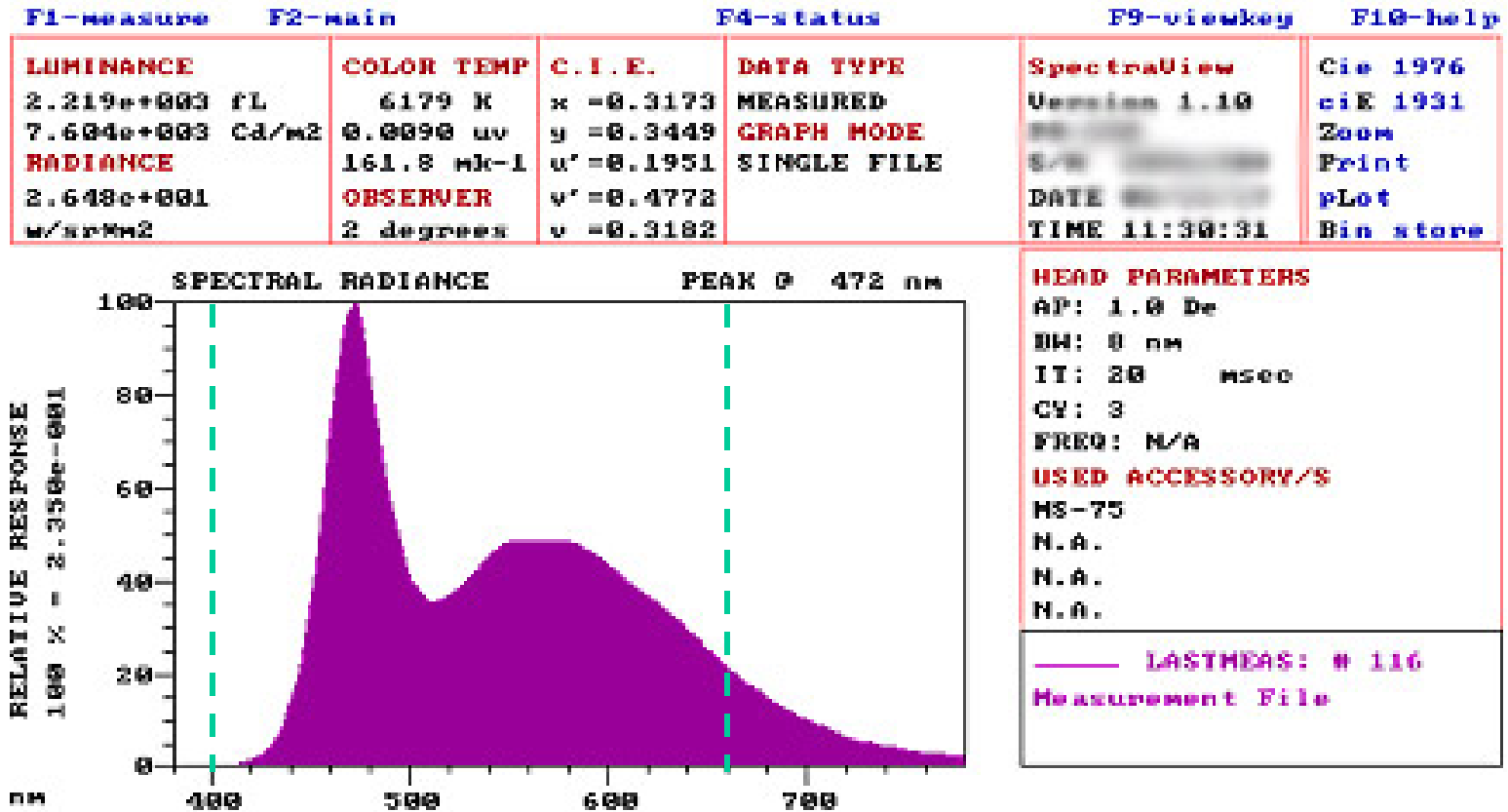


# No light, iron on

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# Spectral output



# LED light, iron on

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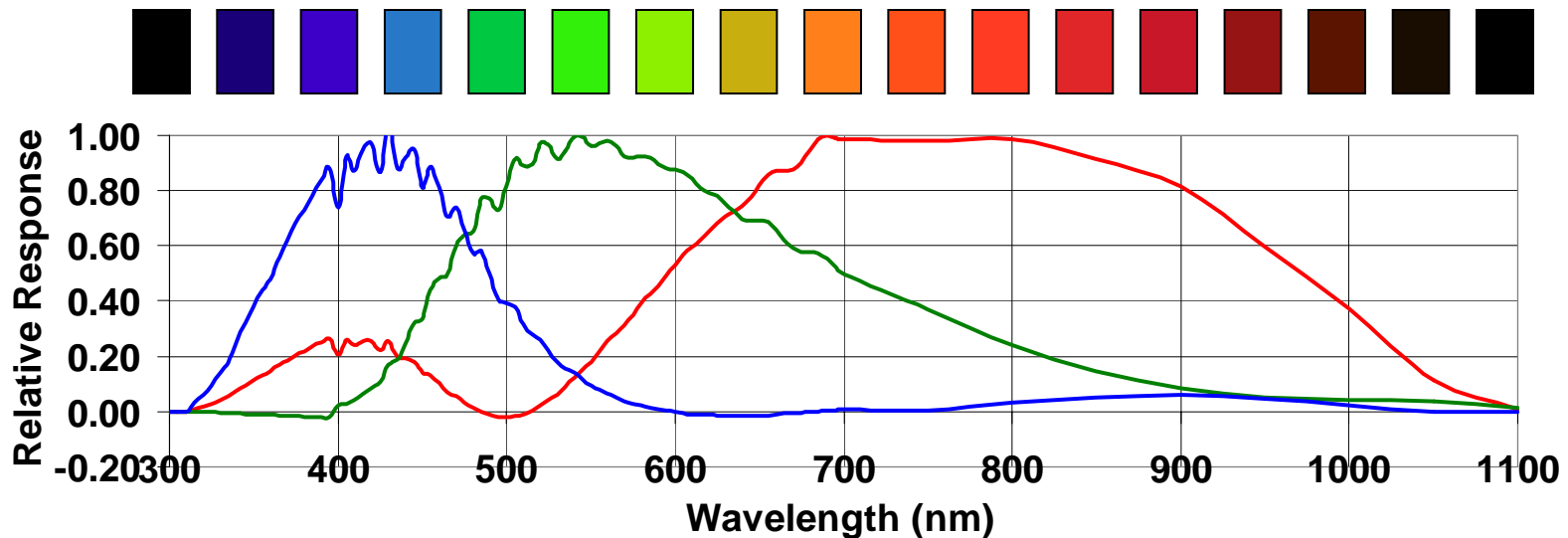
# IR Cut filter blocking test

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# Next: Infrared color mapping

- Use the 3 x 3 color matrix to apportion visible colors over the entire UV-Vis-NIR spectrum



# To be continued...

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- Special color mapping for broad spectra
- Six-channel imaging
  - UV-IR direct
- Spectral shifting
  - Transparent UV scintillators
  - Mixed fluorescent dyes
  - X-ray phosphors