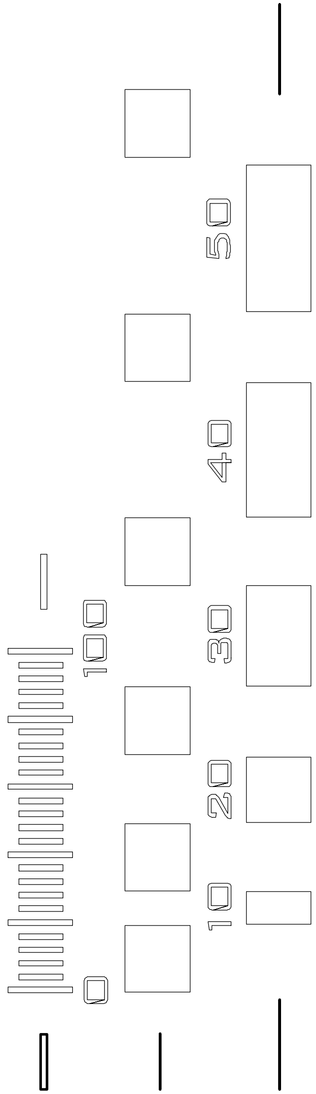
Display Measurement and Evaluation



Christine Wall – National Physical Laboratory

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Overview

- Why measure displays?
- What will you measure?
- Units of measurement for light.
- Instruments that can be used.
- Examples of measurement.
- Summary.

Why measure displays?

- To allow comparison between manufacturers
- Quality control in display manufacture
- To meet ‘health and safety’ specifications
- To allow displays to be used in experiments on the human visual system by displaying colours of known chromaticity and luminance

In short …. to ensure readability…and safety…

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What sort of displays?

Displays are used in:

- Air traffic control
- Car speedometers
- Design of jet engines
- Surgical diagnostics
- Keyhole surgery
- Military applications (night vision goggles,missile guidance systems etc)

These are safety critical so let's get it right first time here!!!

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What will you measure?

Spectral Information

Phosphors, lamp + filters
OLEDs,laser illuminated…

Affects colour, brightness readability

Environmental Information

Temperature, EM fields,stray light

Affects distortion, contrast

DISPLAY CHARACTERISTICS

Temporal Information

refresh rate, flicker, grey-scaling

Affects visual fatigue, artefacts, contrast

Spatial Information

pixel size, viewing angle, polarisation

Affects resolution, viewing field

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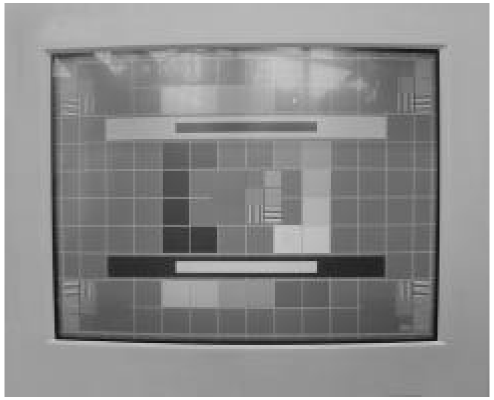
What will you measure?

Display Characteristics
- spectral
- temporal
- spatial
- environmental



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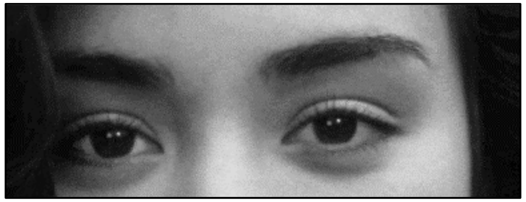
Human Eye Characteristics
- spectral
- temporal
- spatial



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Display Measurement

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What will you measure?

Optical characteristics:

Brightness, colour, contrast, screen uniformity,

Electrical characteristics:

Total power consumption, efficiency

Physical characteristics:

Size, weight, dimensions

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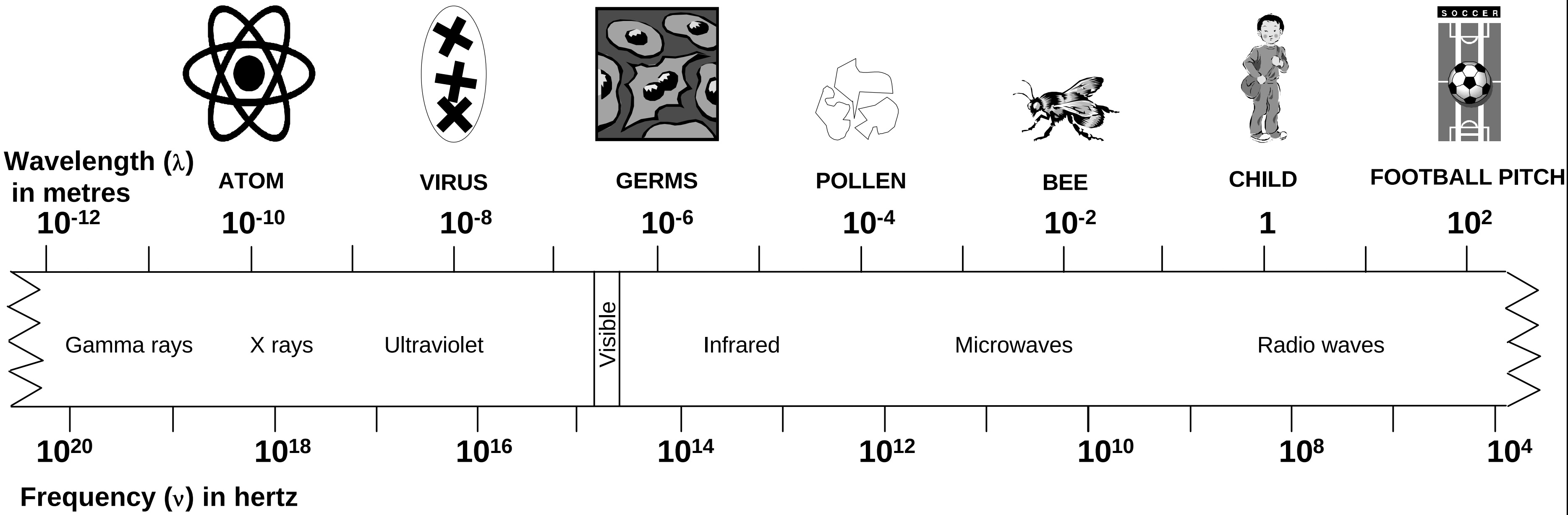
Light measurement

Visible light is a very small part of the electromagnetic spectrum



http://scholar.hw.ac.uk/site/chemistry/topic3.asp

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Light Measurement

Radiometry: measurement of **RADIATION** from any part of the EM spectrum.

Photometry: Considers **VISIBLE** light only (from the Greek “phos” meaning “light”) 380 to 780 nm

The photometric response of the eye $V(\lambda)$ is based on a “standard human observer”… not one person but the average of a number of experiments carried out on white male students in 1920’s (so it’s not perfect… but it is accepted!)

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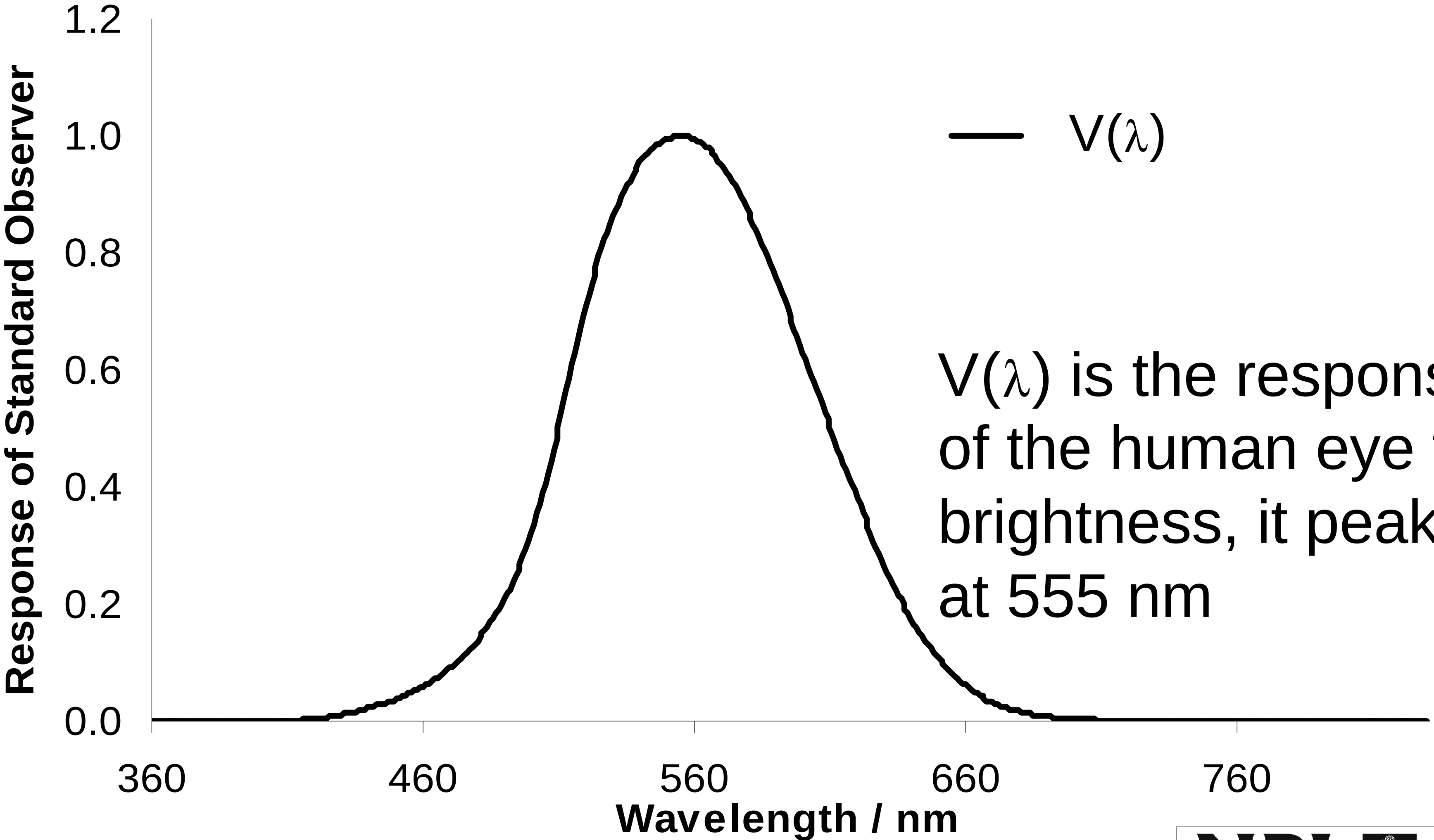
Light: the photometric response



V(λ) is the response of the human eye to brightness, it peaks at 555 nm

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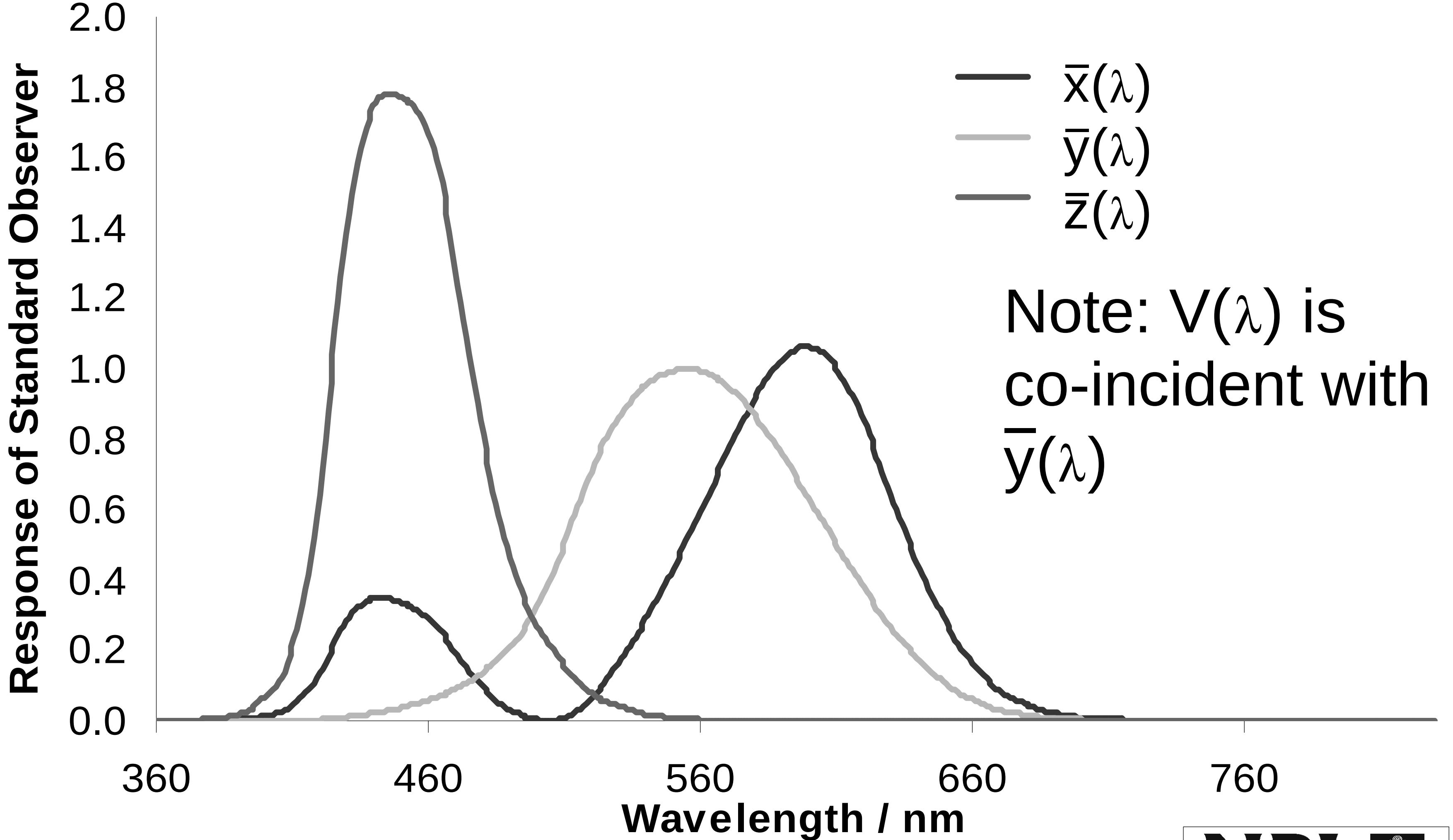
Light: the photometric response



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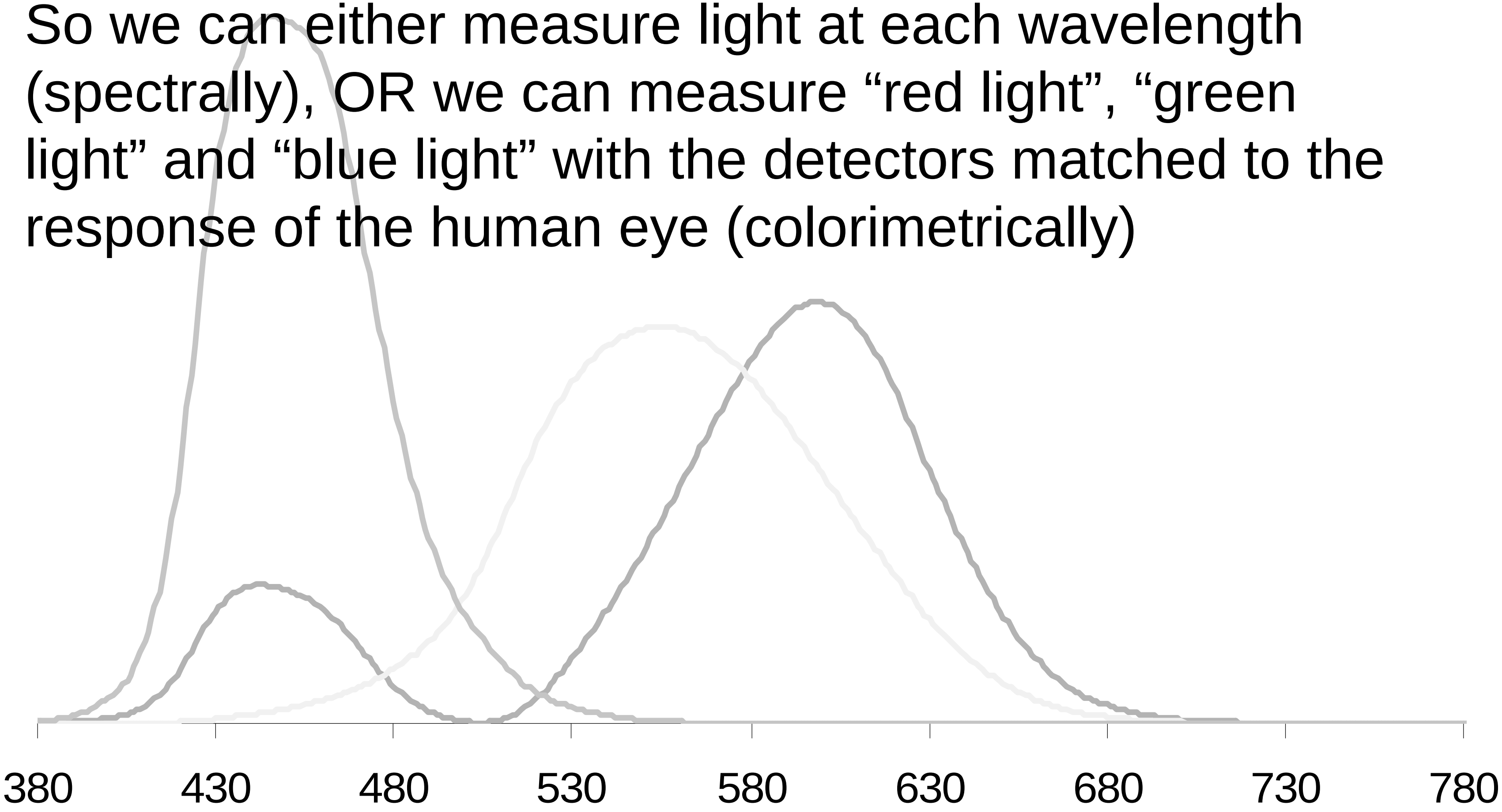
Light: the photometric response

So we can either measure light at each wavelength (spectrally), OR we can measure “red light”, “green light” and “blue light” with the detectors matched to the response of the human eye (colorimetrically)



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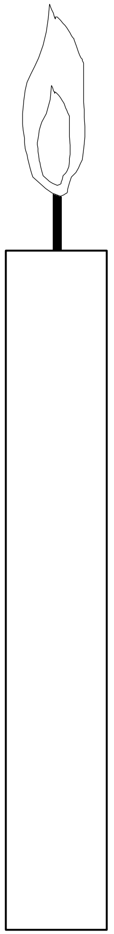
Light: Basic Units

Candela: The **SI** unit of light

“The candela is the luminous intensity of a source that emits monochromatic light of wavelength 555 nm and that has a radiant intensity of 1/683 watts per steradian in a specified direction”

One candela will radiate one lumen in all directions, so… 1cd = 1lm/sr



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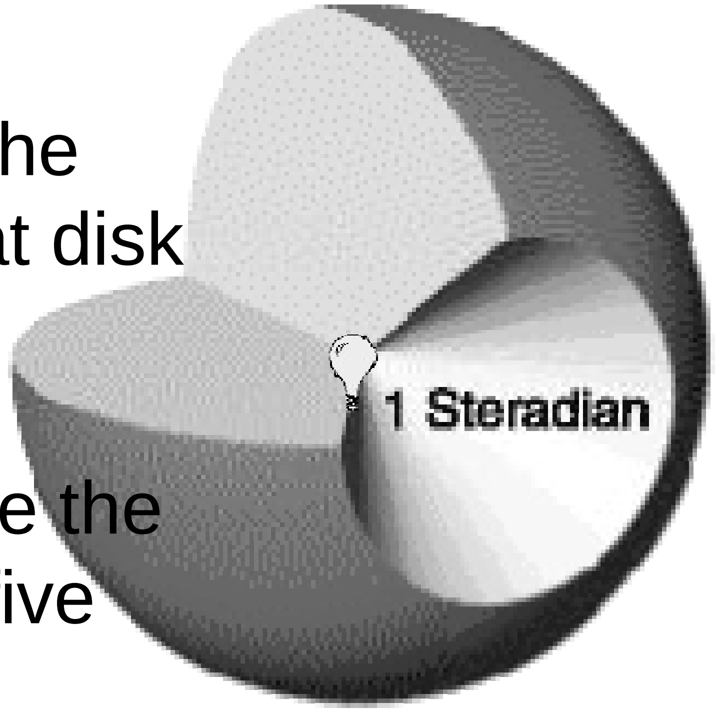
Light: Basic Units

Solid angle; a sphere contains 4π steradians. One steradian is the solid angle which cuts off a spherical surface area equal to the square of the radius

Five times rule.
If the radius is 5 times larger than the circular area, you can assume a flat disk instead of a spherical surface.
This is useful for displays, and for conversion between units. Separate the instrument and display by at least five times the measurement diameter.



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Light: Basic Units

Flux is rate of energy flow in joules per second i.e. *power*, in this case *optical* power.

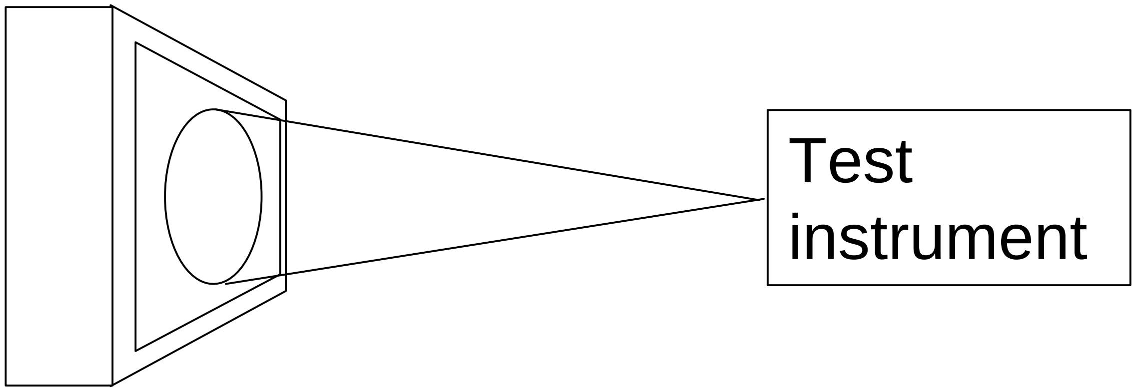
Radiant flux: all light joules/second (≡ watts)

Luminous flux: visible light lumens/second

Light: Basic Units

Luminance (cd/m^2 = lm/sr/m^2)

Flux density of a source per solid viewing angle: it is *independent* of distance for a uniform extended source because the measured area will increase as you move away cancelling the inverse square law



Note: always quote the angular acceptance of your instrument

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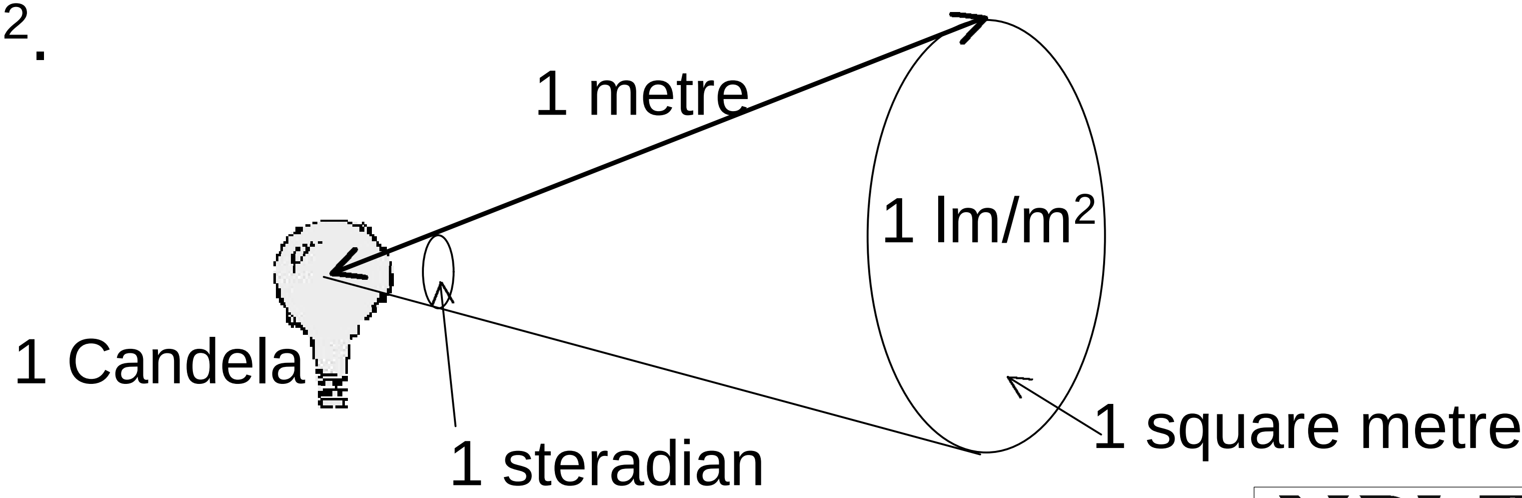
Light: Basic Units

Illuminance (lux = lm/m^2)

Illuminance is a characteristic of an non-luminous surface. It is a measure of flux per unit area. A surface placed one meter from an isotropic light source of 1 candela will have an illuminance of 1 lm/m^2.



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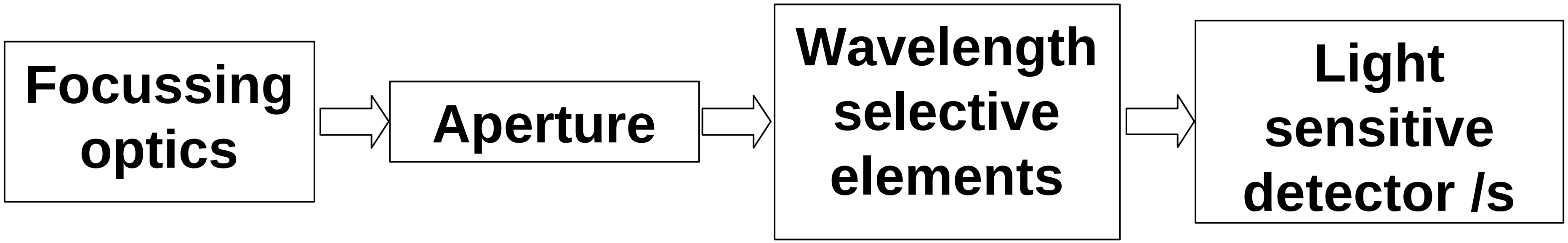
Instruments for displays measurement



There may also be temperature control, diffusers, memory and computational software…..

Instruments for displays measurement

Photometric measuring instruments

Colorimeter (3 detectors)

Luminance meter (1 detector)

Radiometric measuring instruments

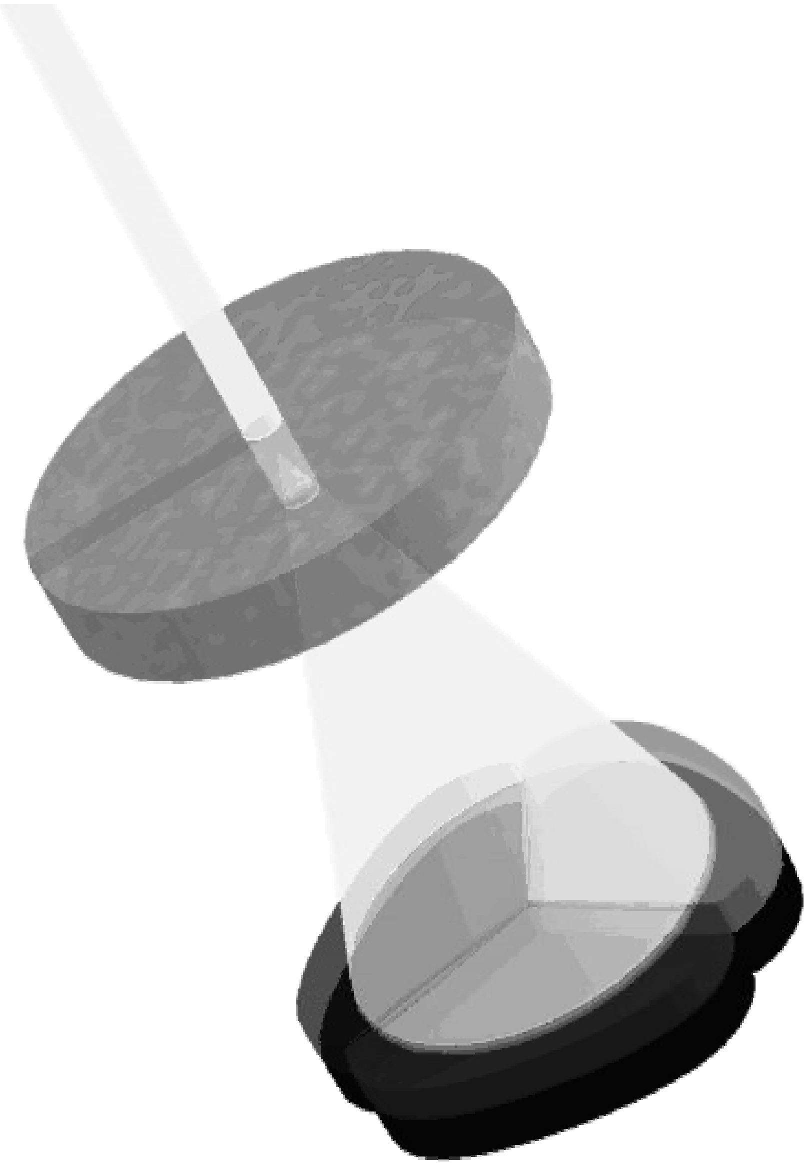
Scanning Spectroradiometer (1 detector)

multi-channel Spectroradiometer (1000’s detectors)

Colorimeter

Pro
Stable
Portable
Cheap
simple

Con
Accuracy



Sources of Errors
Imperfect CIE emulation
Sample time ‘beats’ with display
Detector saturation
Spatial resolution
Stray light.

Luminance meter

<u>Pro</u>

Stable
Portable
Cheap
simple

<u>Con</u>

Accuracy
No colour information

<u>Sources of Errors</u>

Imperfect CIE emulation
Sample time ‘beats’ with display
Detector saturation
Spatial resolution
Stray light.

www.minolta.com

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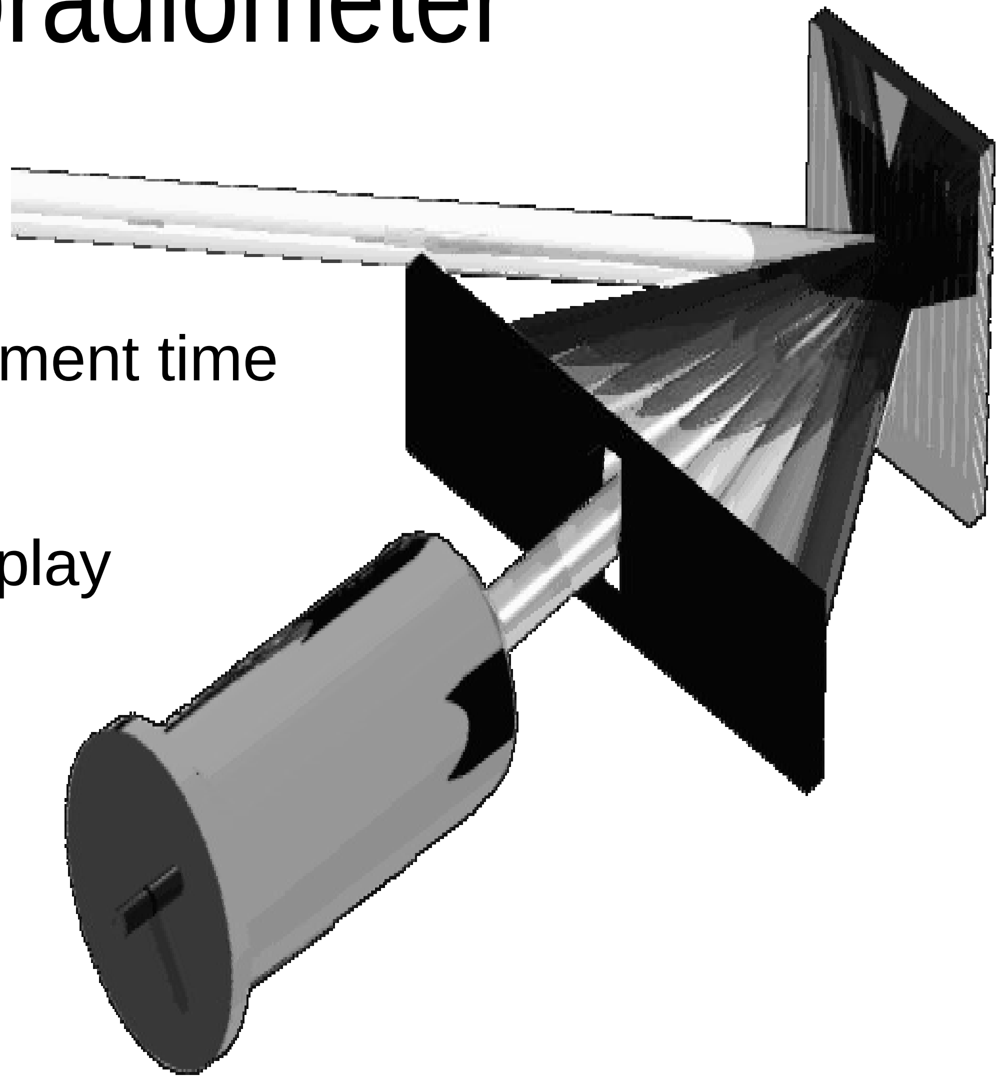
Scanning Spectroradiometer

Pro
Accurate
Versatile

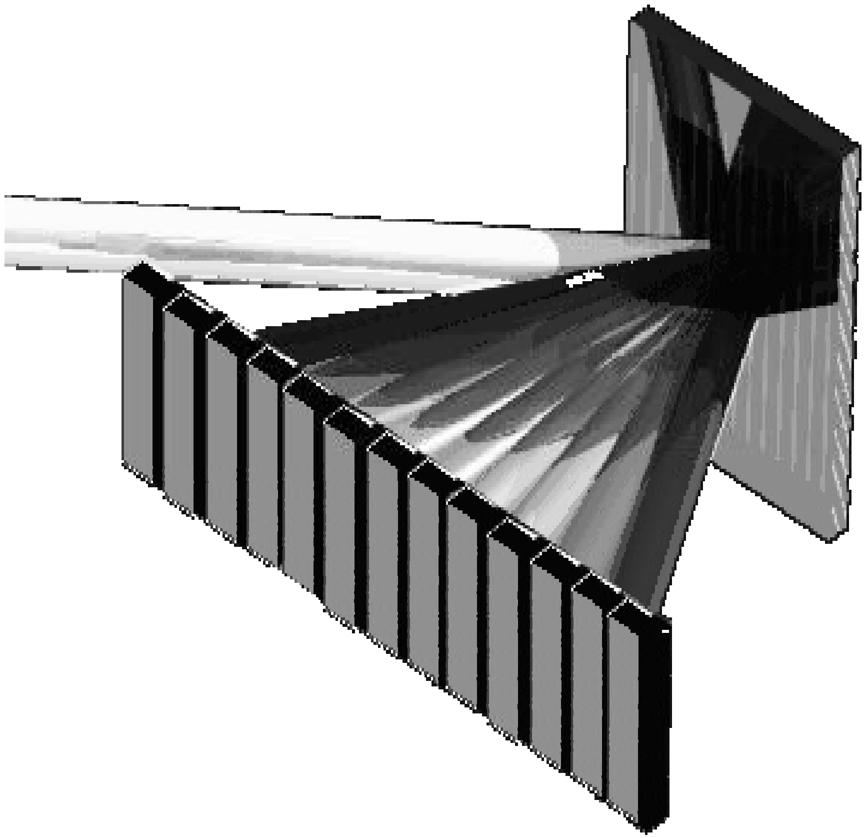
Con
Bulky
Expensive
Long measurement time



Sources of Errors
Sample time ‘beats’ with display
Detector saturation
Spatial resolution
Stray light.
Wavelength (drift and error)
Bandwidth

Multi-channel Spectroradiometer

Pro	**Con**
Fast	limited versatility
Medium cost	limited accuracy
Compact	
Accurate	
spectral	

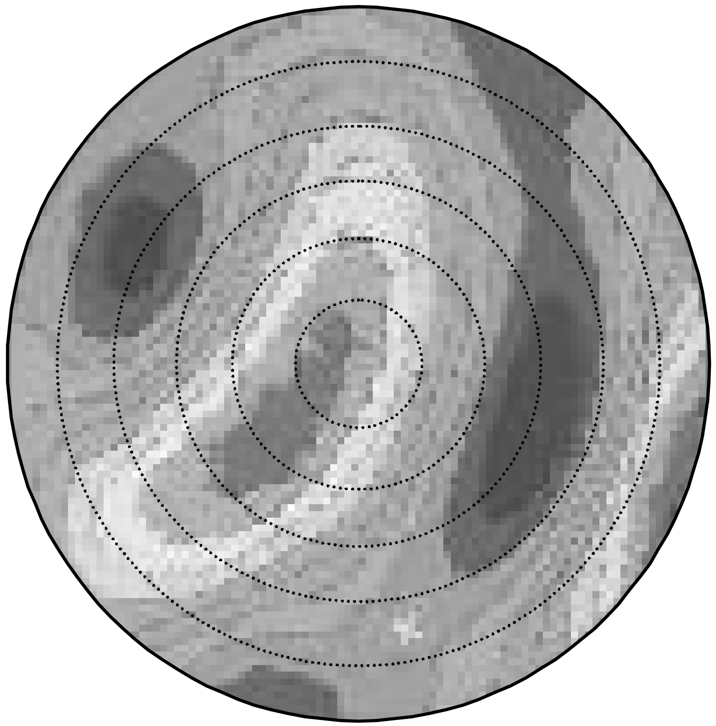


Sources of Errors

Sample time ‘beats’ with display
Detector saturation
Spatial resolution
Stray light.
bandwidth

Special Instruments: conoscope

Colorimeter or luminance meter with angular information



Typical result for contrast

www.eldim.fr
www.autronic-melchers.com

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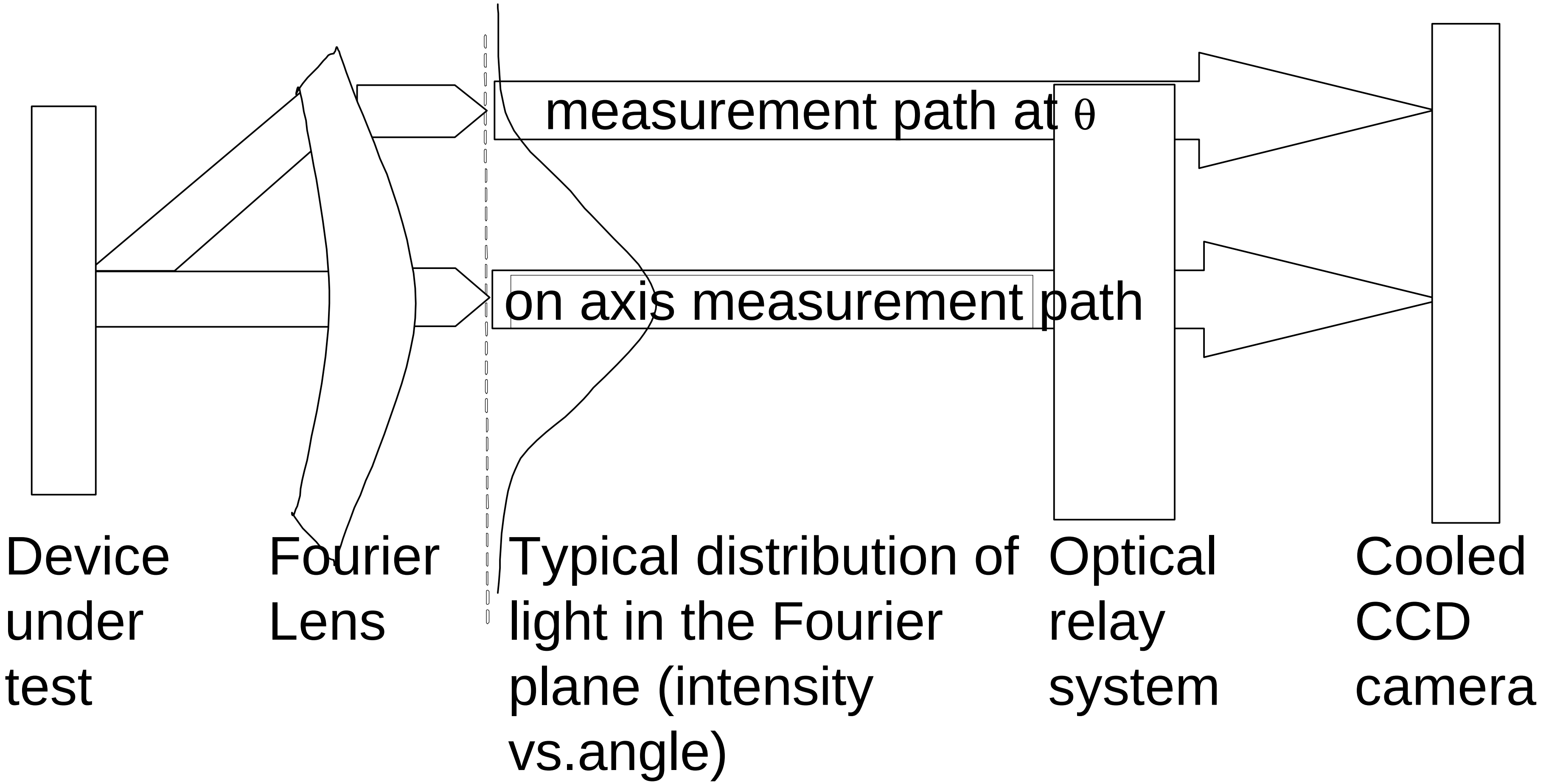
Special Instruments: Conoscope



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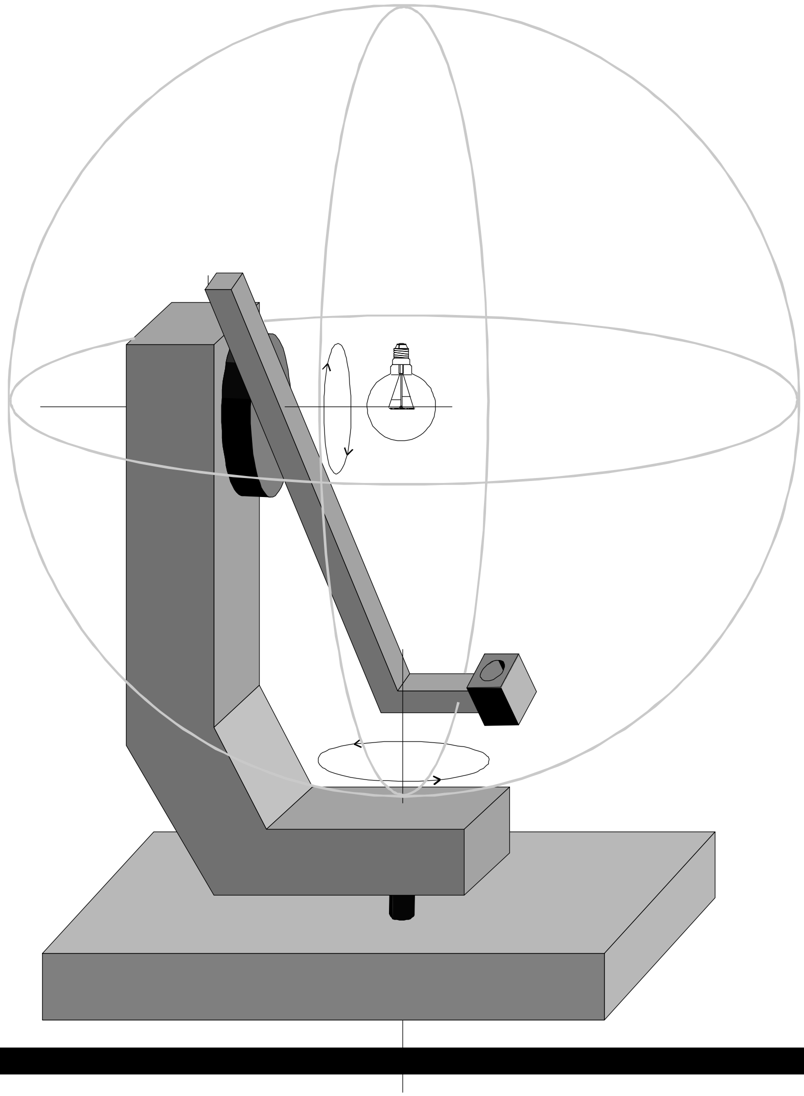
Special Instruments: goniometer



Spectral or non-spectral information can be collected, as any instrument can be used. Angular information from *any* angle can be collected

Can be slow

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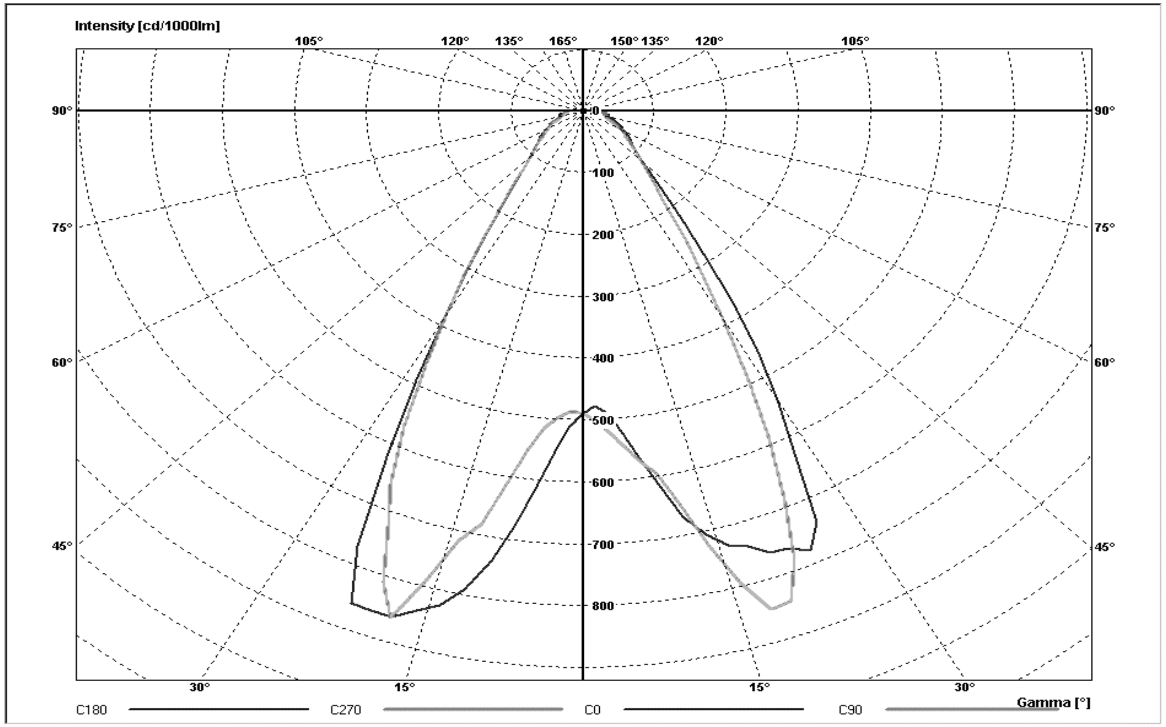
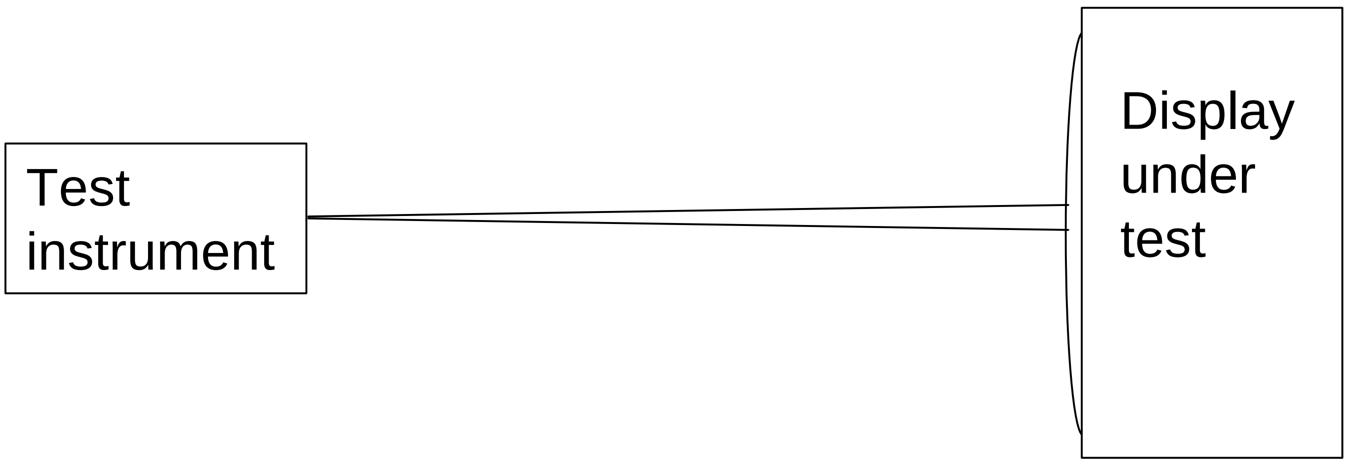
Special Instruments: goniometer



Goniometer results from LED’s

Measurement Geometry

The geometry of display testing is always test dependent. But the most basic test is looking at the centre of the screen, normal to the screen, at a distance 5 times greater than the measurement area. The instrument aperture is usually set to be similar to the human eye's pupil (~20 arc minutes)



Measurement Geometry

NPL's test lab.

Testing normal to the display screen, using a scanning spectroradiometer.

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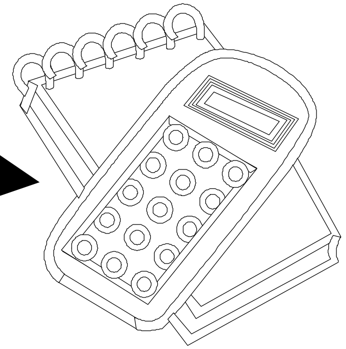
Calibrating a display screen

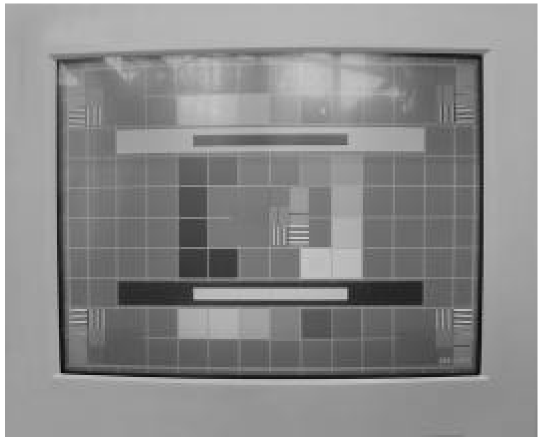
2. Measure a stable well characterised light source



3. Make a correction file

5.Apply correction file to find calibrated result

4. Measure display



1. Select the instrument

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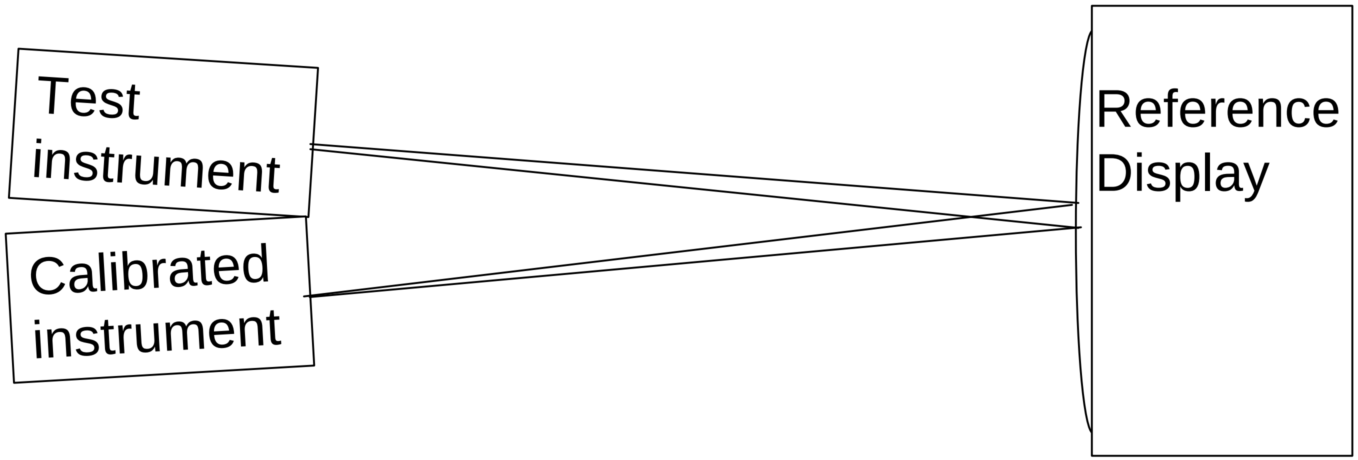
Calibrating an instrument

Using the calibrated instrument (usally a high accuracy device) set a test colour on the reference display.
Measure with the instrument under test
Enter error into memory channel, or create look up table



Typical values of display measurements

Luminance	100 cd/m^2 for a CRT on full 70 cd/m^2 for and LCD on full 400 cd/m^2 for a plasma display on full
Colour	0.330 x, 0.330 y for a white CRT (CIE 1931 colorimetric units)

Contrast Ratio 5:1 to 300:1 very variable

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Summary

1) Think about what you want to measure and what units you will use. (colour, luminance, contrast)
2) Ensure the measurement relates to the human eye.
3) Select the right instrument for the measurement.
4) Set up your measurement to emulate usage conditions.
5) Make the measurements and calculate an uncertainty budget.