AVANTES
solutions in spectroscopy

Avantes
Radiometry / Photometry
Theory and background

Ger Loop
Apeldoorn, The Netherlands

LED EVENEMENT 2013
LED applicaties voor designers, engineers en lichtarchitecten
1931 CONGRESCENTRUM
BRABANTHALLEN DEN BOSCH
WOENSDAG 27 NOVEMBER 2013


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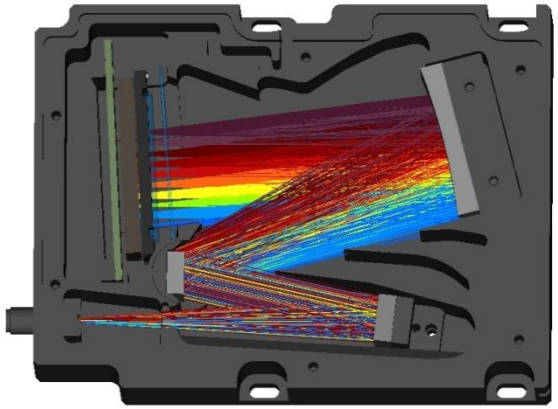
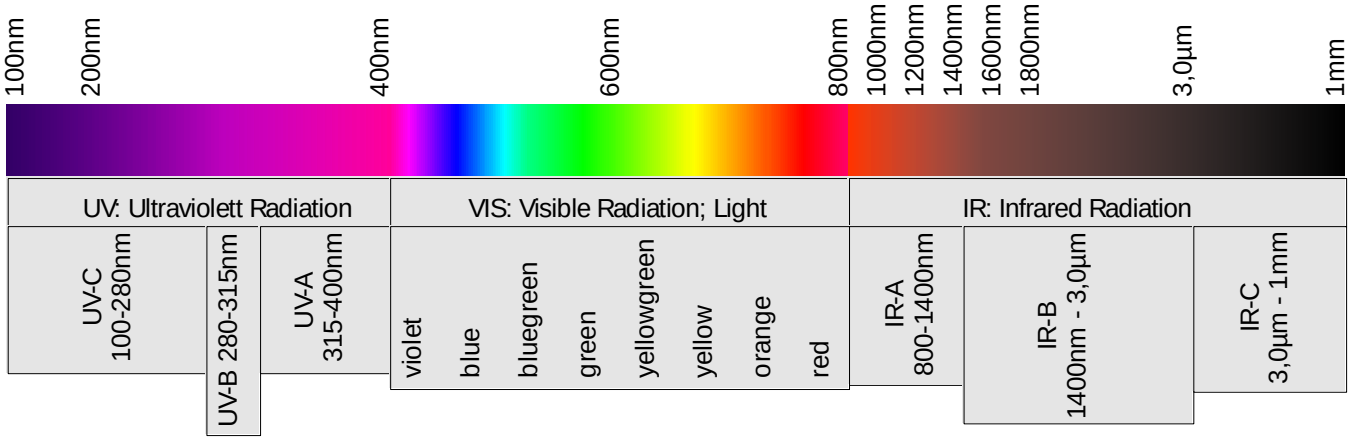
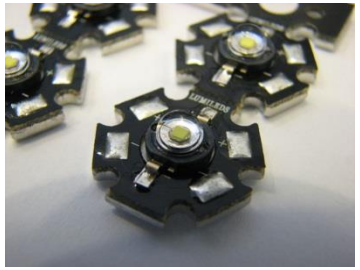
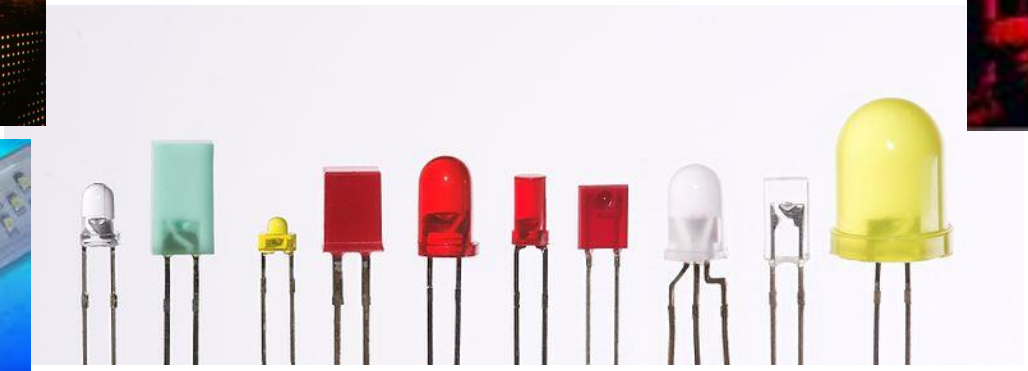


Develops, Produces and worldwide distributes spectrometers , fiber optics and accessories. Spectrometers are devices to measure Wavelengths/ light.










Mission Statement Avantes

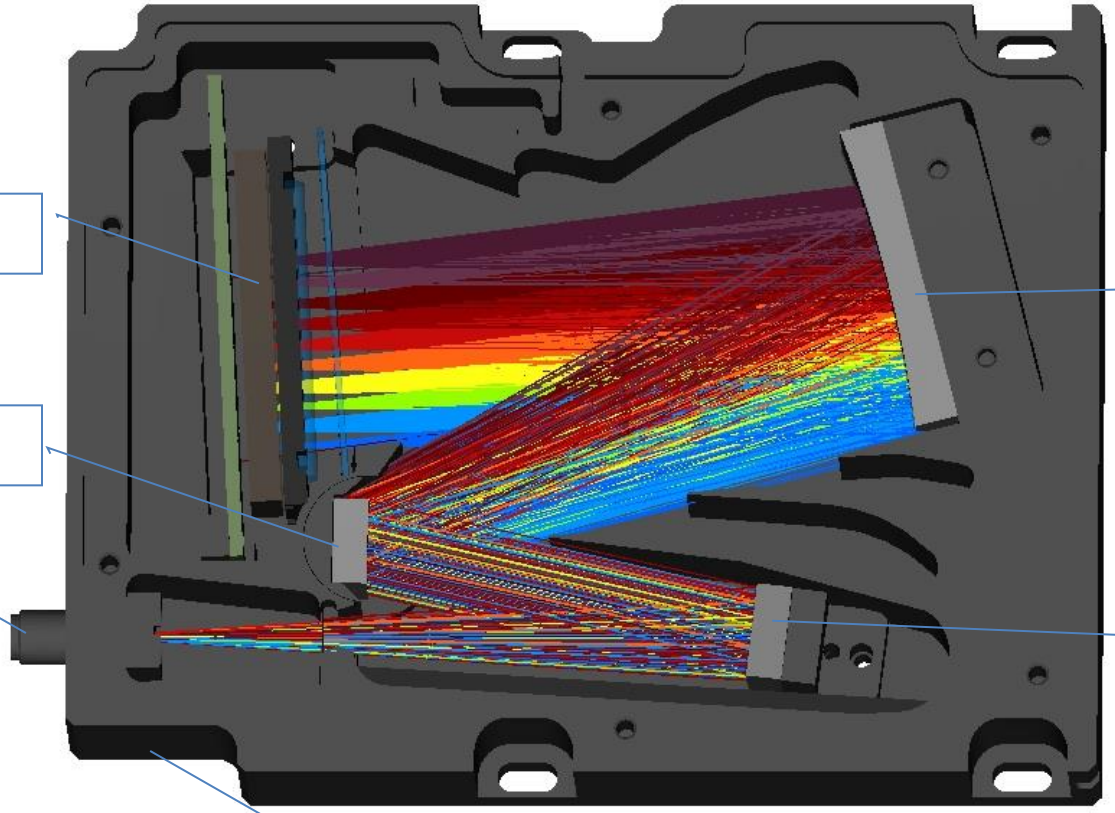
Avantes is the trendsetting, trusted leader in innovative, high quality and customer oriented optical instruments and solutions.

We achieve this through service-oriented thinking and acting, encouraging and motivating each-other with a positive critical and professional attitude of each Avantes employee.

spectrometer

an optical device for measuring wavelengths, deviation of refracted rays, and angles between faces of a prism, especially an instrument (prism spectrometer) consisting of a slit through which light passes, a collimator, a prism that deviates the light, and a telescope through which the deviated light is viewed and examined.

AvaSpec Optical Optical Bench Design: Symmetrical Czerny Turner



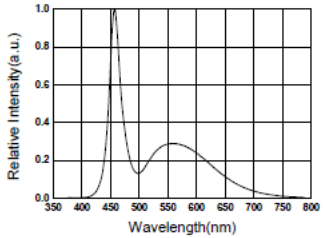
EVERLIGHT

Technical Data Sheet
3 mm Round LED (T-1)

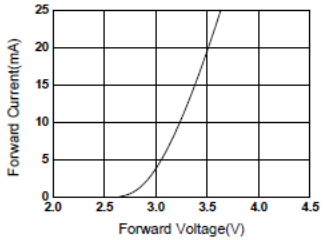
204-15UTC/S400-X9

Typical Electro-Optical Characteristics Curves

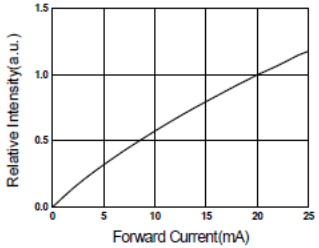
Relative Intensity vs. Wavelength



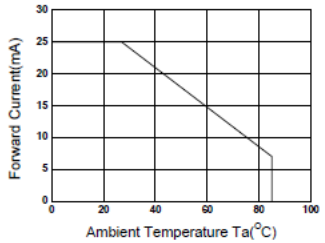
Forward Current vs. Forward Voltage



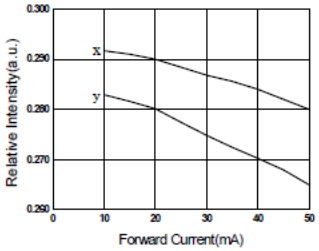
Relative Intensity vs. Forward Current



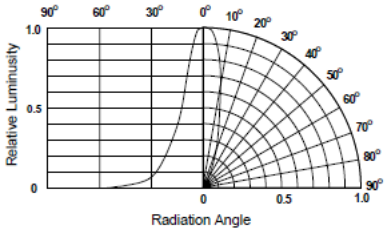
Forward Current vs. Ambient Temp.



Chromaticity Coordinate vs. Forward Current



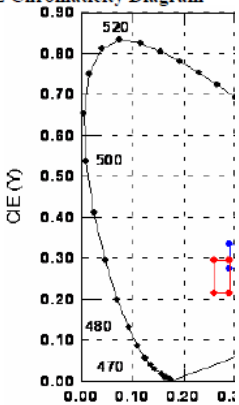
Relative Intensity vs. Angle Displacement



EVERLIGHT

Technical Data Sheet
3 mm Round LED (

CIE Chromaticity Diagram



Color Ranks (IF=20mA，Ta=2

色度等級 Color grading	CIE X Min.
B1	0.260
B2	0.275
C1	0.290
C2	0.305

*Measurement uncertainty of the colc

EVERLIGHT

Technical I
3 mm Roun

Electro-Optical C

Parameter
Forward Voltag
Zener Reverse Volt
Reverse Curre
Luminous Intens
Viewing Angl
Chromaticity Coordinates

Luminous Intensi

Iv Ranks
Min.
Max.

*Measurement Uncertai

Forward Voltage

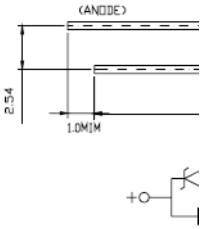
Group
Min.
Max.

*Measurement Uncert

EVERLIGHT

Technical Da
3 mm Round

Package Dimensions



Notes:

1.All dimensions a
2.Lead spacing is
3.Protruded resin

Absolute Maximum

Parame
Continuous Forward C
Peak Forward Current(
Reverse Voltage
Operating Temperature
Storage Temperature
Soldering Temperature
Power Dissipation
Zener Reverse Current
Electrostatic Discharge

EVERLIGHT

Technical
3 mm Rou

Features

- Popular T-1
- High luminov
- Typical chro according to
- Bulk, availat
- Pb free.
- ESD-withsta
- The product

Descriptions

- The series is high luminou
- The phospho blue emissio

Applications

- Outdoor Dis
- Optical Indic
- Backlighting
- Marker Ligh

Device Selectio

PART N
204-15UTC/S4

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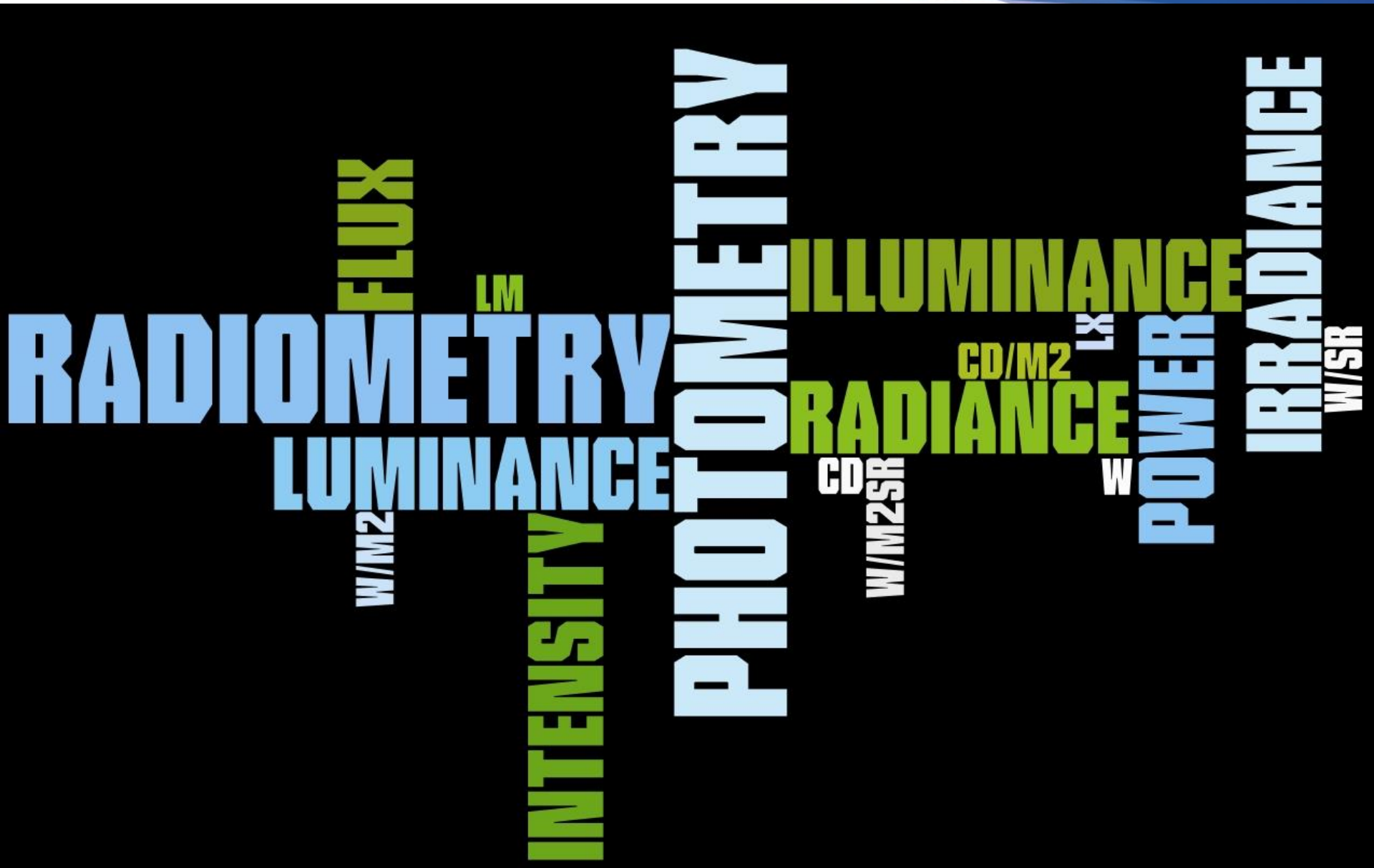
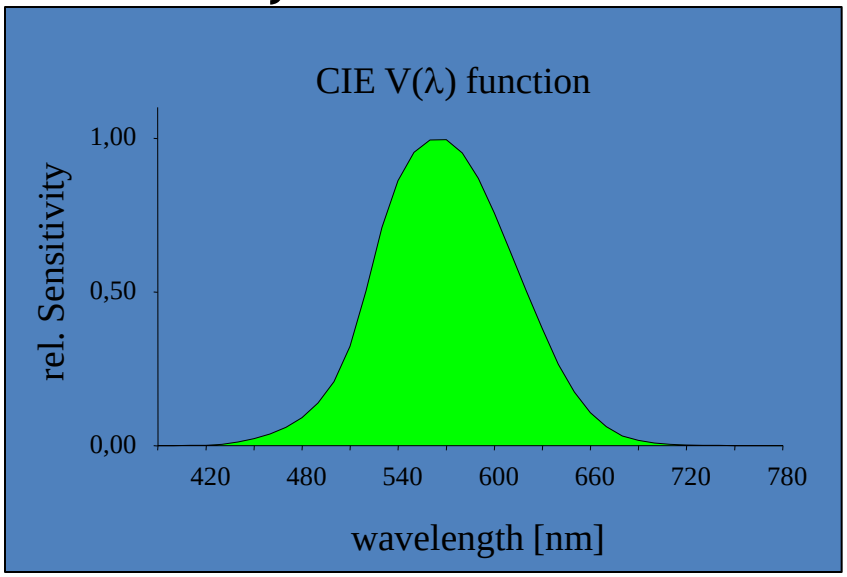
solutions in spectroscopy



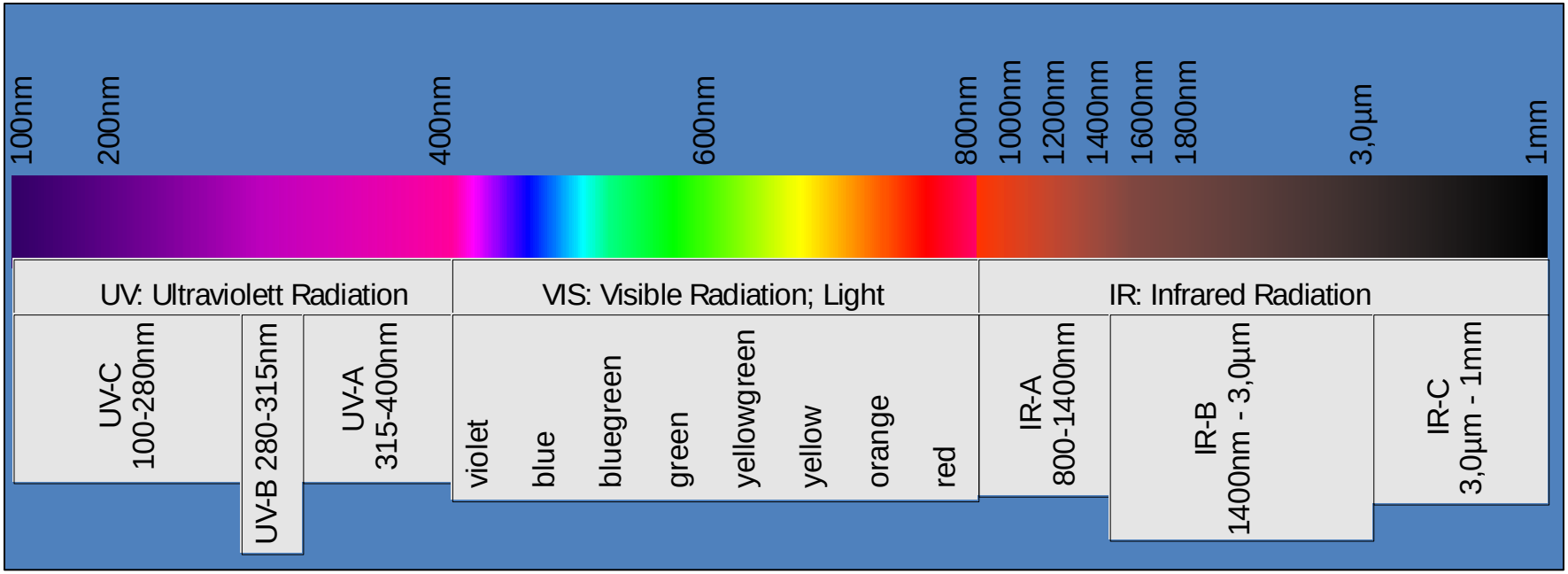
Radiometry - Photometry

Radiometry deals with the measurement of all optical radiation inclusive of the visible portion of this radiant energy

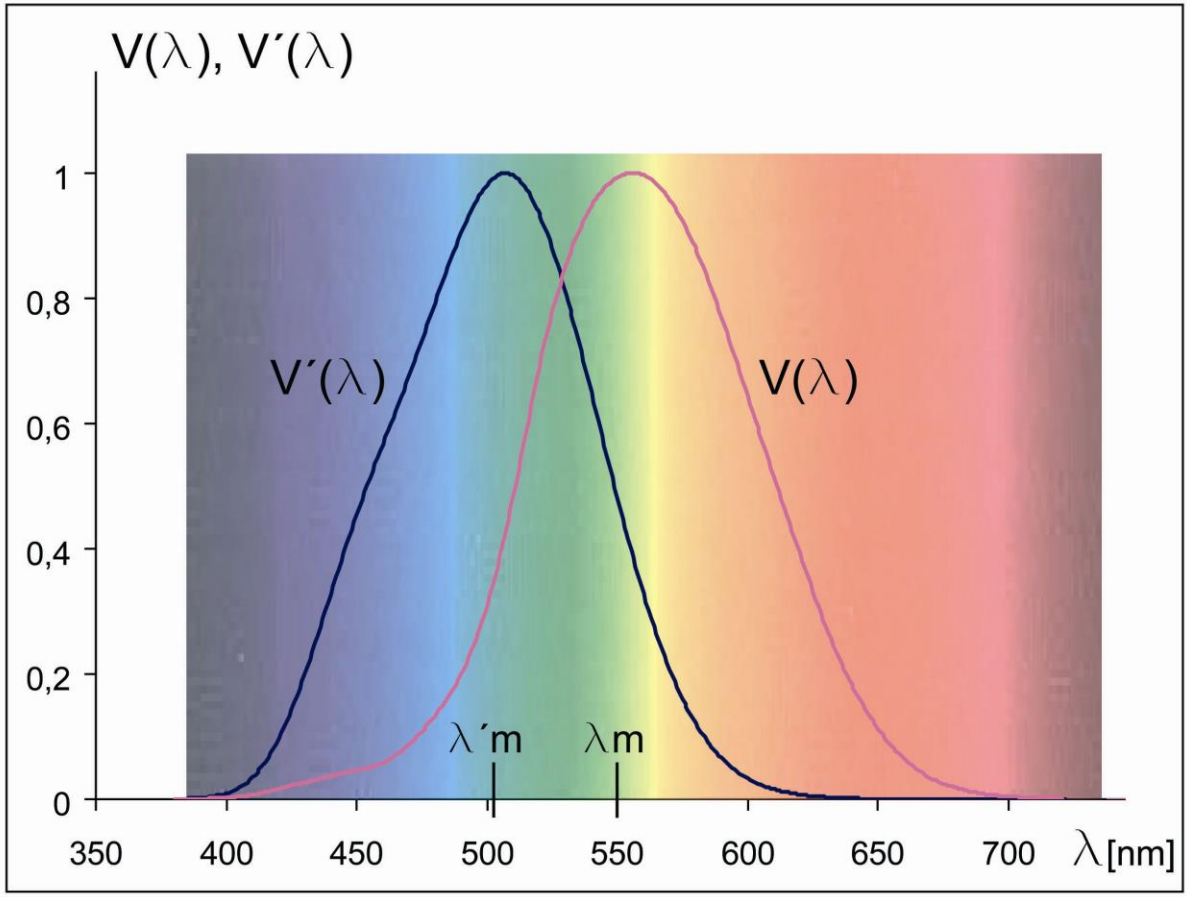
Photometry deals with the measurement of visible light energy as percepted by the human eye.



Optical Radiation / Light



Human eye Sensitivity photopic, scotopic



Radiometry - Photometry

Radiant flux:
Watt (radiometric flux)

Irradiance:
W/m^2 (radiom. flux per unit area)

Radiant intensity:
W/sr (radiom. flux per unit solid angle)

Radiance:
$W/m^2/sr$ (radiom. flux density per unit solid viewing angle)

Luminous flux:
Lumen (photometric flux)

Illuminance:
lm/m^2 (photom. flux per unit area)

Luminous intensity:
lm/sr(photom. flux per unit solid angle)

Luminance:
$lm/m^2/sr$ (radiom. flux density per unit solid viewing angle)

Radiometric / Photometric Flux

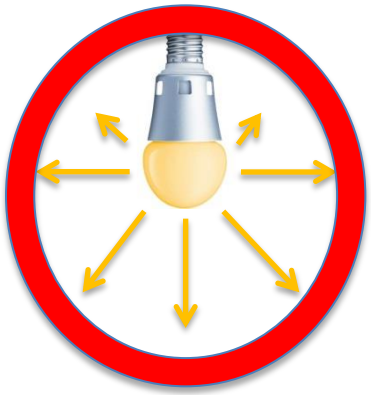
Total power of radiation emitted by a light source

Radiant Power

Φ_e (W)

Luminous Flux

Φ_v (lm)



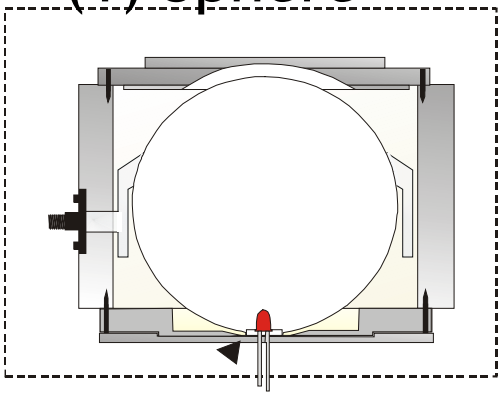
Lamps used for lighing are commonly labeled with their light output in lumens; in many jurisdictions this is required by law.

typical values:

60W incadescent	860 lm
43W Halogen	750 lm
9.5W LED lamp	840 lm
white LED at 20mA	1,2 lm

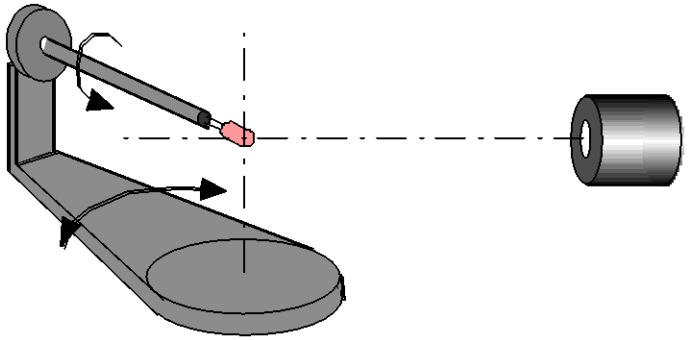
Flux measurement

(1) Sphere

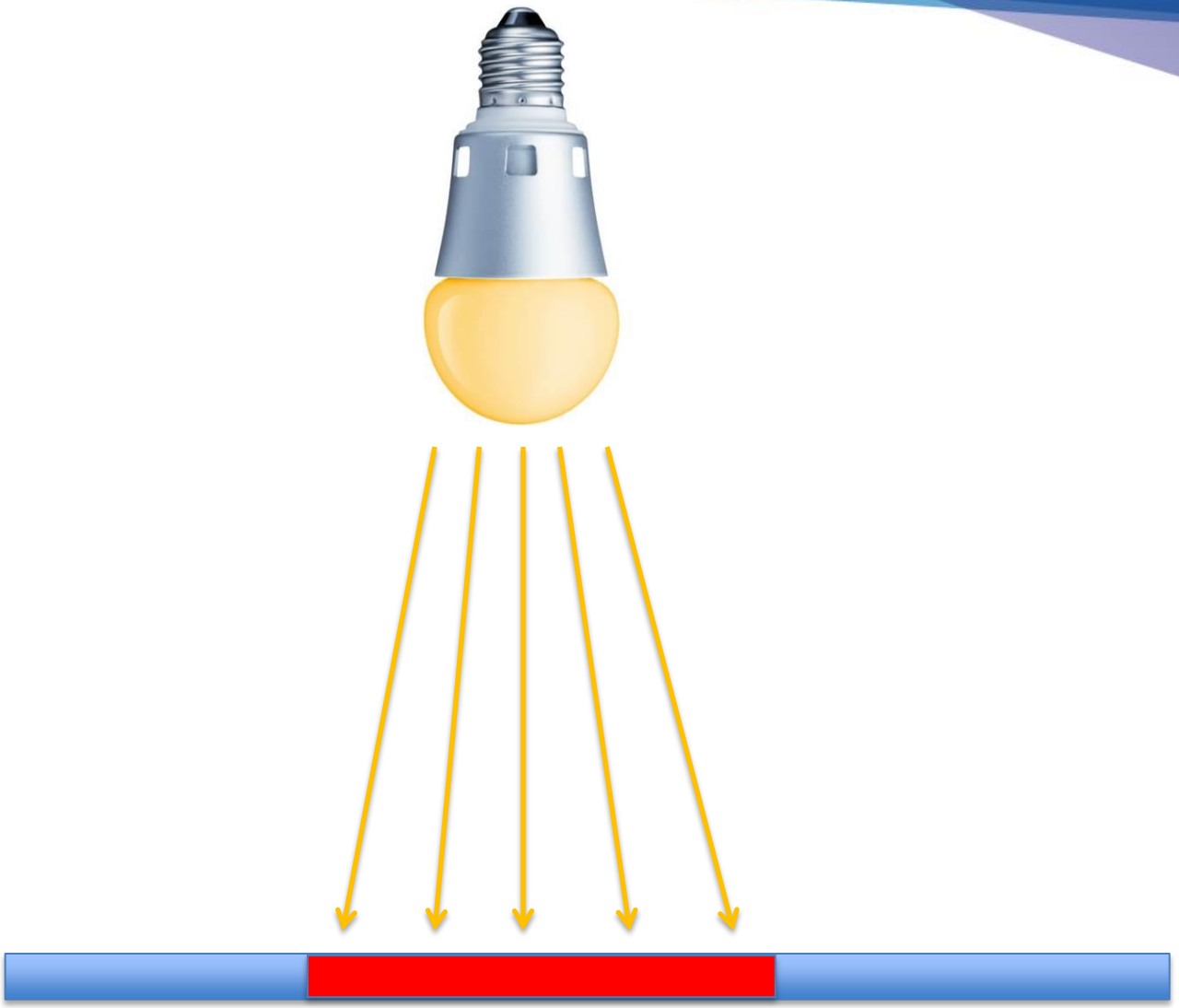


Sphere photometry is fast and widely used, but subject to more sources of errors.

(2) Goniometer



Goniophotometry is generally more accurate but time-consuming.

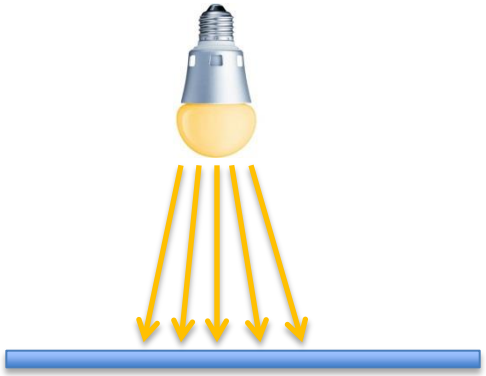


Irradiance / Illuminance

The amount of radiant power impinging upon a surface per unit area

Irradiance

E_e (W/m^2)



Illuminance

E_v lm/m^2 = lx

typical values:

sunshine, at noon	max. 100000 lx
desk at work	500 lx
clear night with full moon	0,2 lx

Inverse Square Law & Cosine Law

Inverse square law:

$$E_1 d_1^2 = E_2 d_2^2$$

Intensity per unit area varies in inverse proportion to the square of the distance

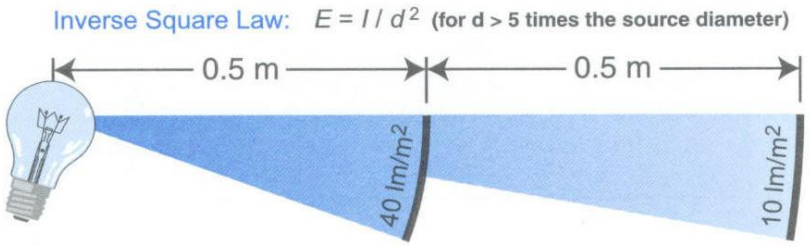
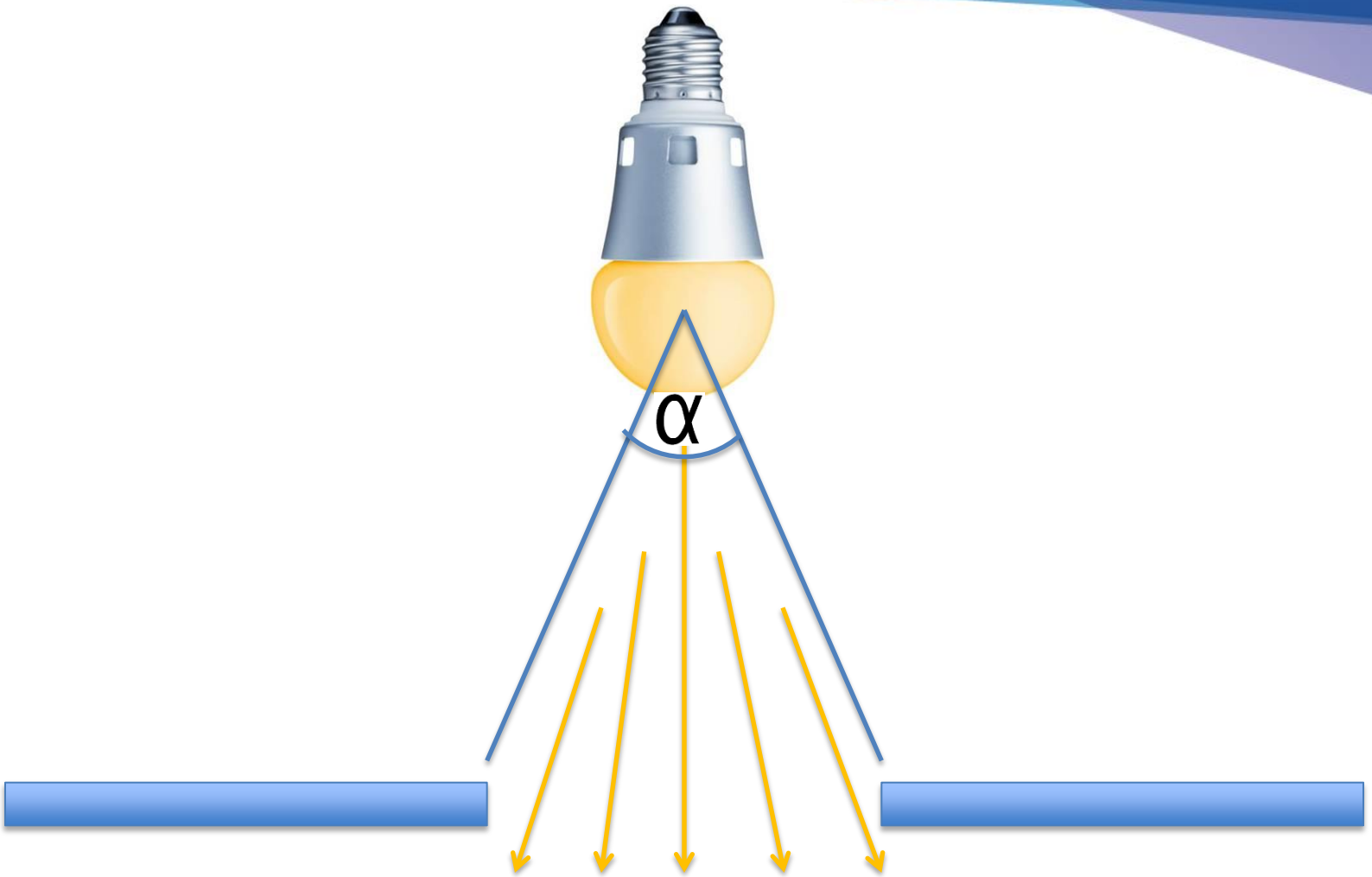


Fig. 6.1 Inverse square law.

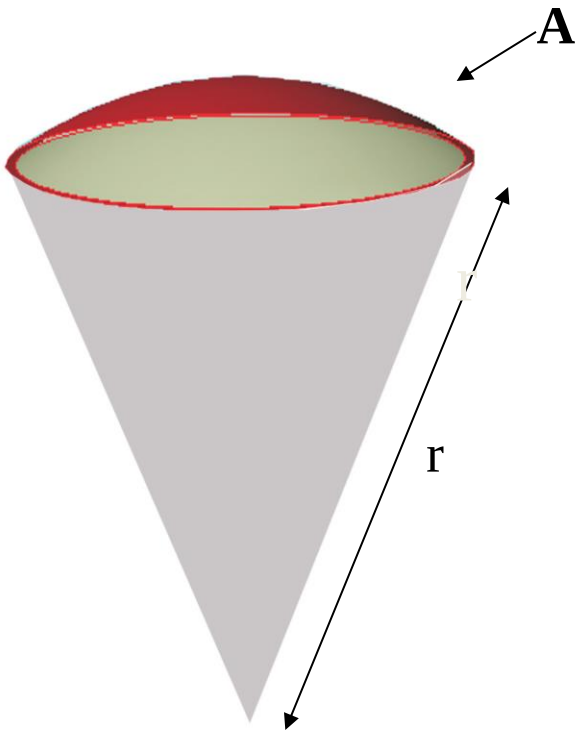
Cosine law

The irradiance will vary with respect to the cosine of the angle between optical axis and the normal to the detector


α

Solid Angle (Ω)

$\Omega = A / r^2$



Radiant / Luminous Intensity

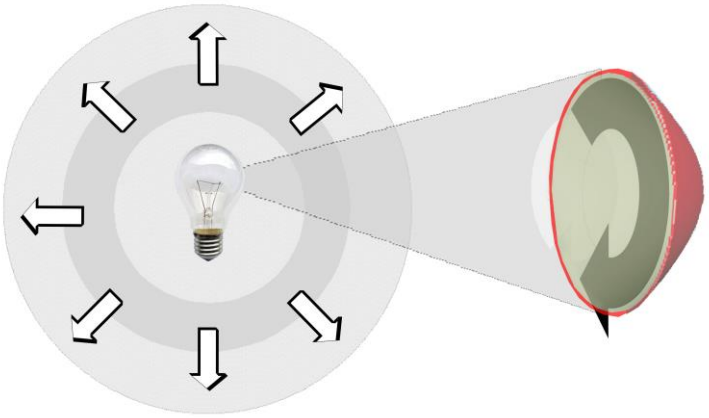
Radiant power of a source
emitted in a certain direction

Radiant Intensity

I_e (W/sr)

Luminous Intensity

I_v lm/sr = cd



typical values:	
100W light bulb	110 cd
100 W headlightup to in beam direction	106 cd
LED for signal purposes (10 mA)	1-300 mcd
white LED (20 mA, 20° beam angle)	5,6 cd

Hence, to measure the luminous intensity of a light source meaningfully, an agreed-upon fixture that defines the solid angle encompassed by the measurement and that orients the light source repeatably in an specified direction must be used. In other words, such meters have to be configured for the geometry of the source under test.

Basically, there are no off-the-shelf luminous intensity meters and comparison of measured data from two different luminous intensity meters serve no purpose, unless their measurement geometries are identical.

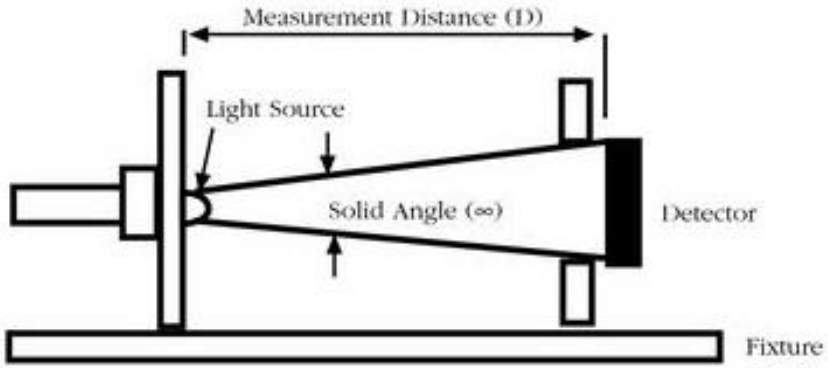


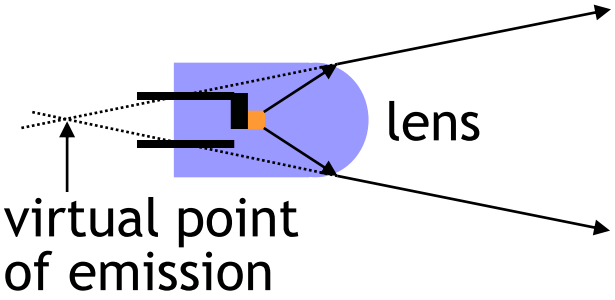
Fig. 3.2.3.4 - An example of luminous intensity meter set-up

Note: *Solid angle can be calculated from the known detector's area and measurement distance. Detector is used to measure the flux reading in lumen.*

Concept of „Averaged LED Intensity“

Problems

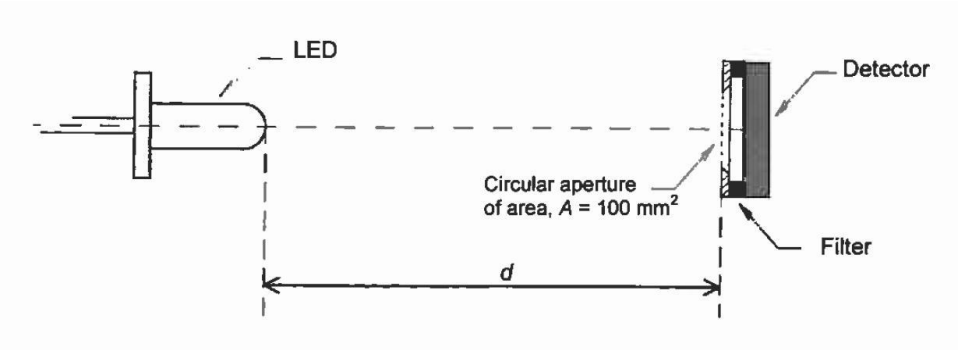
1. LEDs are NOT point sources under standard measurement conditions
2. Point of emission is difficult to determine for LEDs



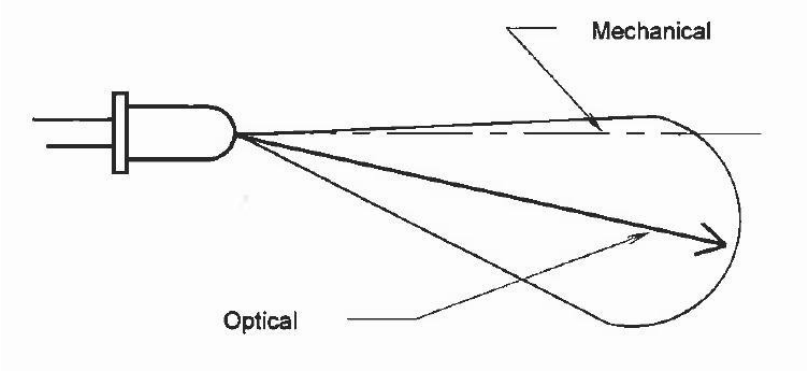
Concept of „Averaged LED Intensity“

Solution:

1. define geometrical measurement conditions



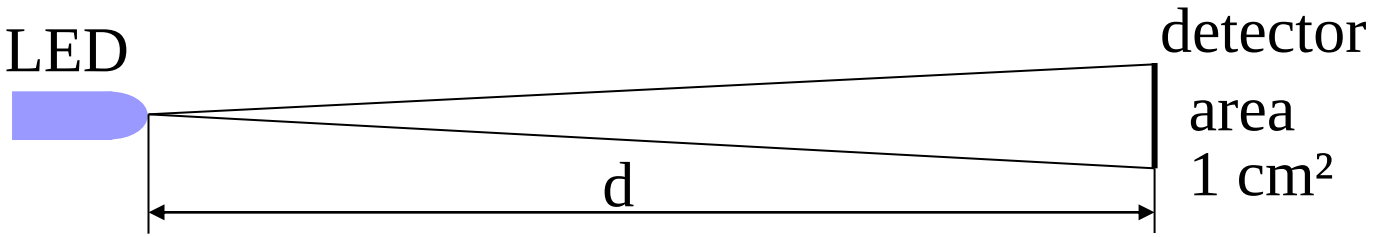
2. mechanical axis of LED is used



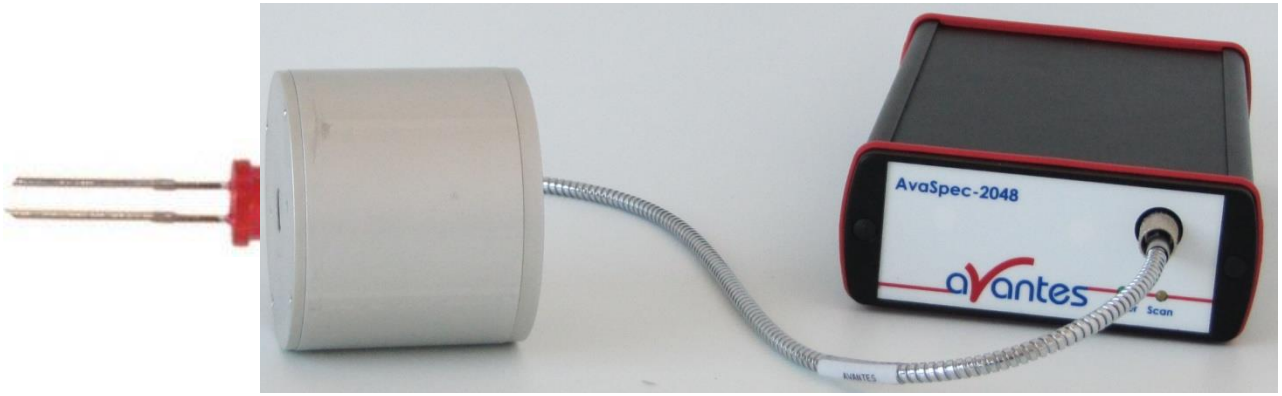
-> CIE 127 recommendation

Concept of „Averaged LED Intensity“

CIE Recommendation	Short name	Distance between LED tip and detector	Solid angle
Condition A	I_{LED-A}	316 mm	0.001 sr
Condition B	I_{LED-B}	100 mm	0.01 sr

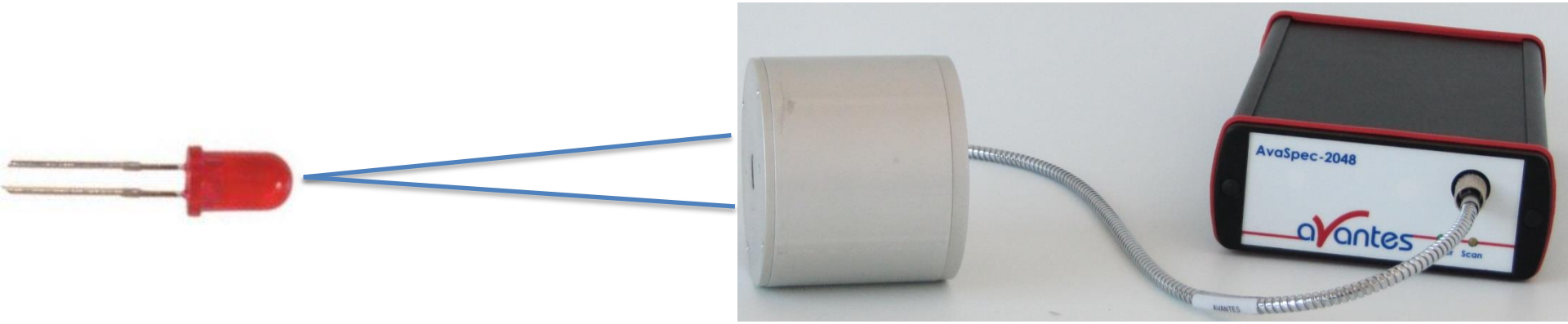


Radiometric / Photometric Flux



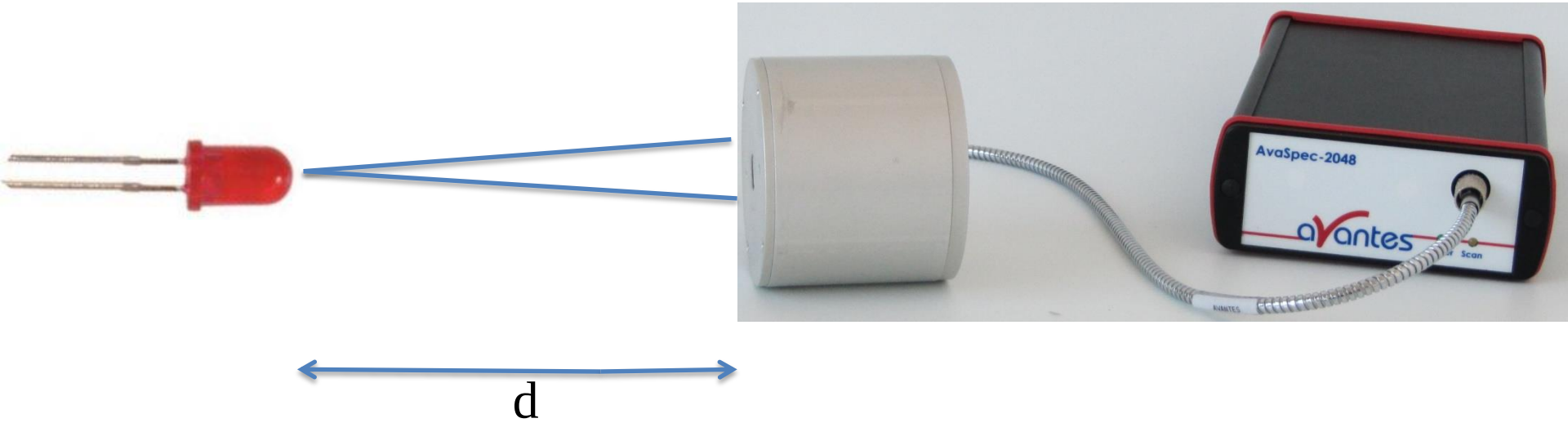
Unit: W or lm

Irradiance/Illuminance



Unit: W/cm2 or lm/cm2=lx

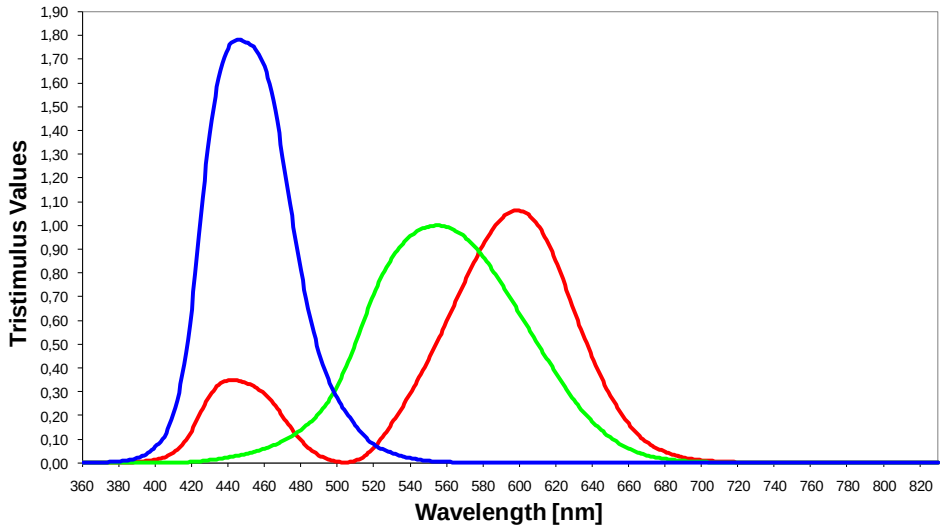
Radiant / Luminous Intensity



Unit: W/sr or lm/sr=cd

Fundamentals in Colorimetry

CIE 1931 XYZ Color Matching Functions



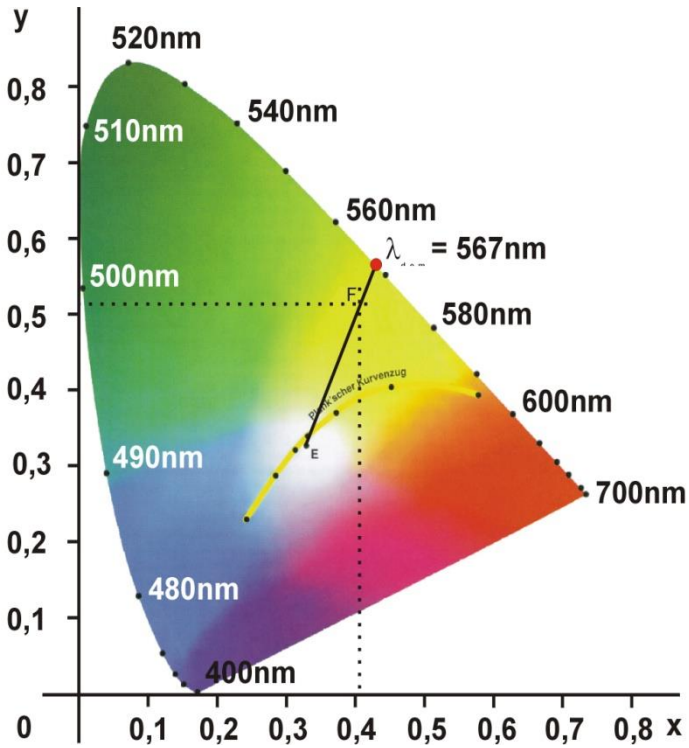
→ tristimulus values X, Y, Z

CIE 1931 Chromaticity Diagram

chromaticity coordinates x,y

$x = X / (X + Y + Z)$

$y = Y / (X + Y + Z)$

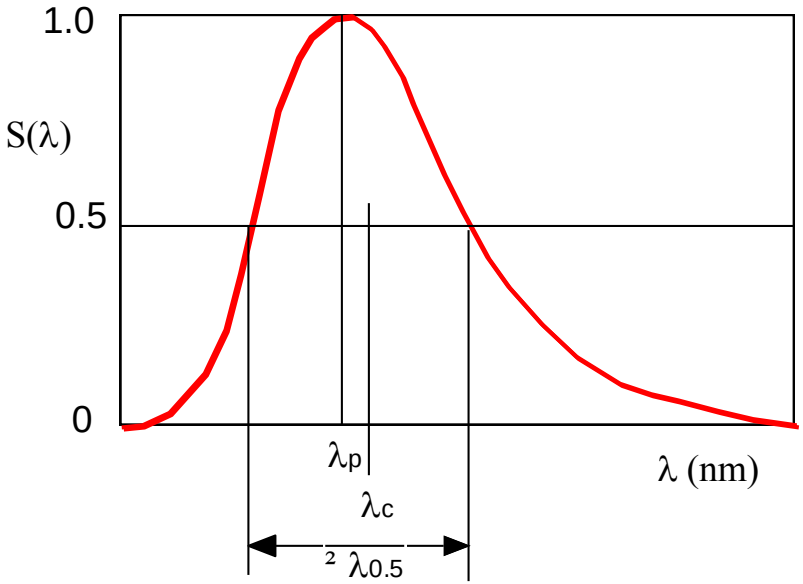


Spectral quantities for LEDs

Peak wavelength λ_p

Spectral width (at half intensity levels)
- also denoted as $\Delta\lambda$ (FWHM).

Centroid wavelength λ_c
"center of gravity wavelength"

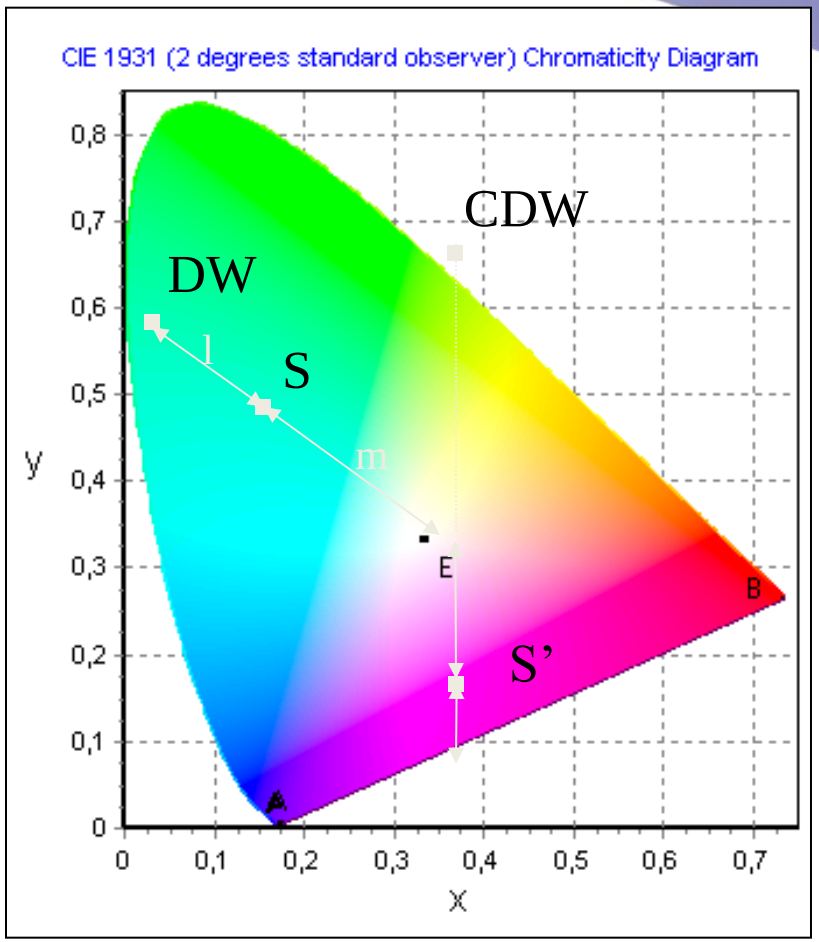


Colorimetry

Dominant wavelength (DW)
A straight line from the white point E to the measured color coordinates intersects the boundary of the color diagram at the dominant wavelength.

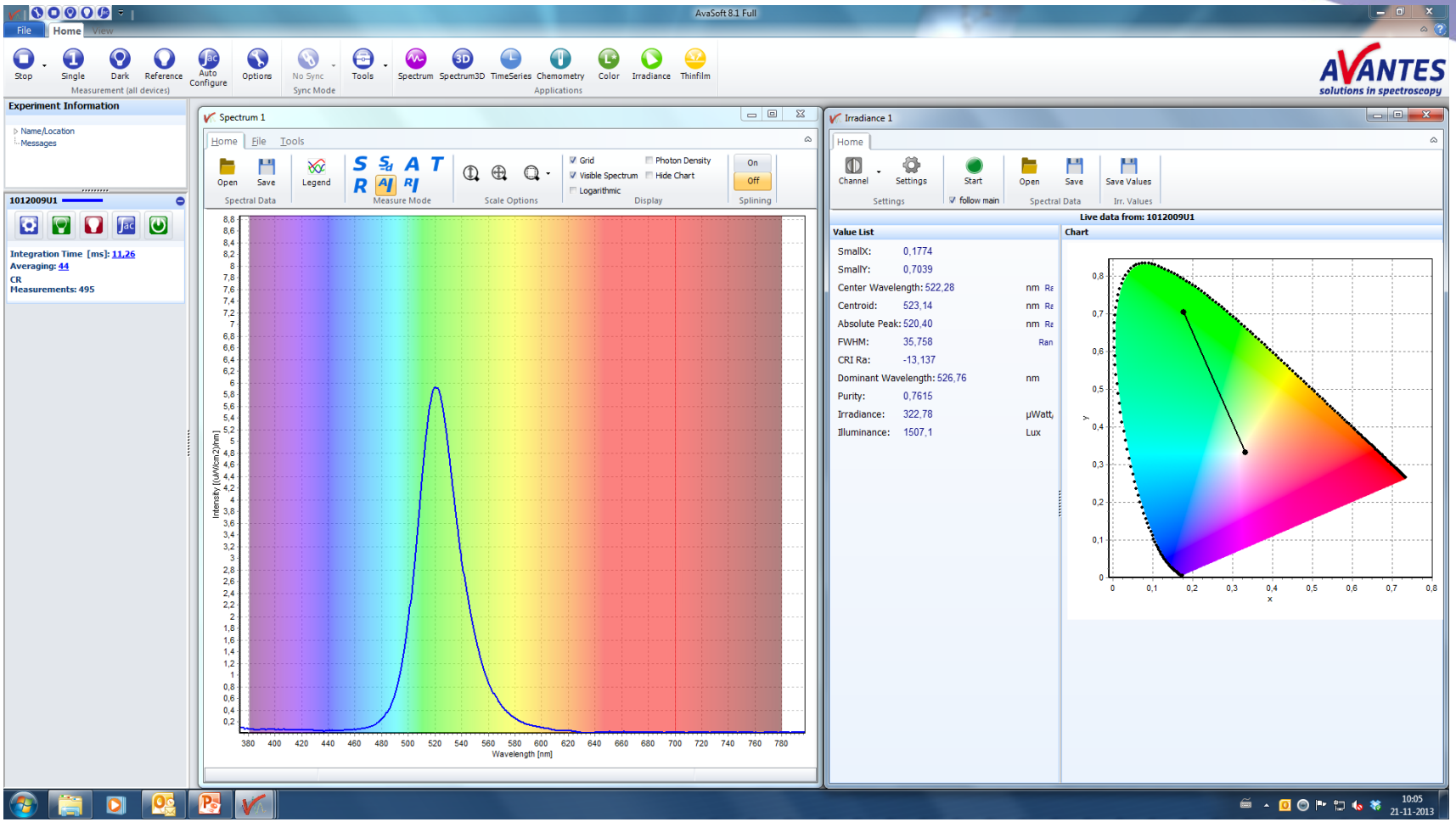
Purity: m/(l+m)
Is the ratio of the length of the line from the white point E to the chromaticity point and the length of the line from E to the boundary of the chromaticity chart.
Purity is always givenin %.

Complimentary DW (CDW)



A=380nm, B=700 nm

AvaSoft Irradiance chart



Thank you for your attention…

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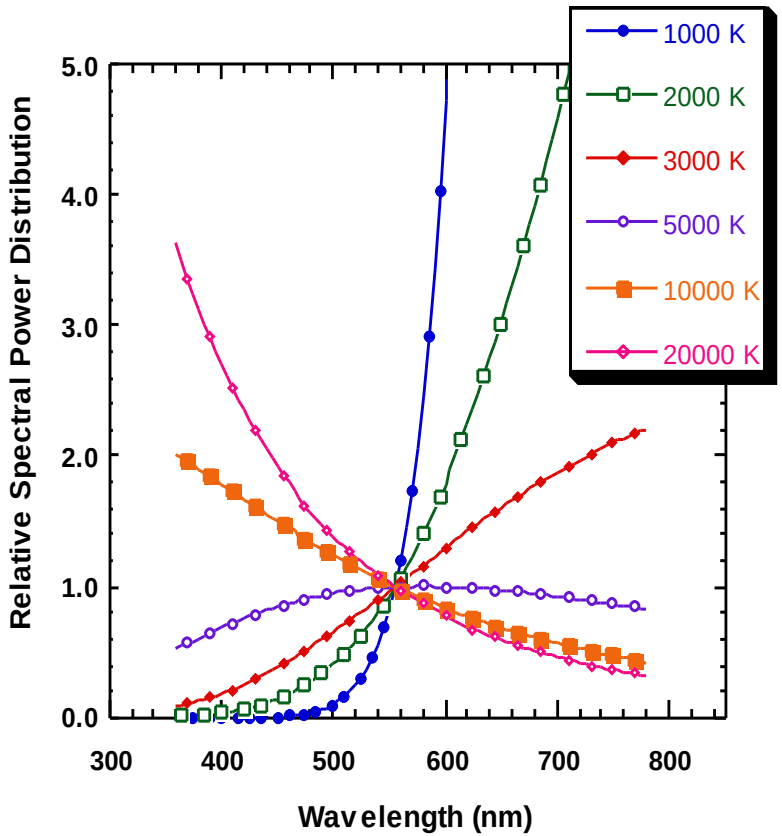
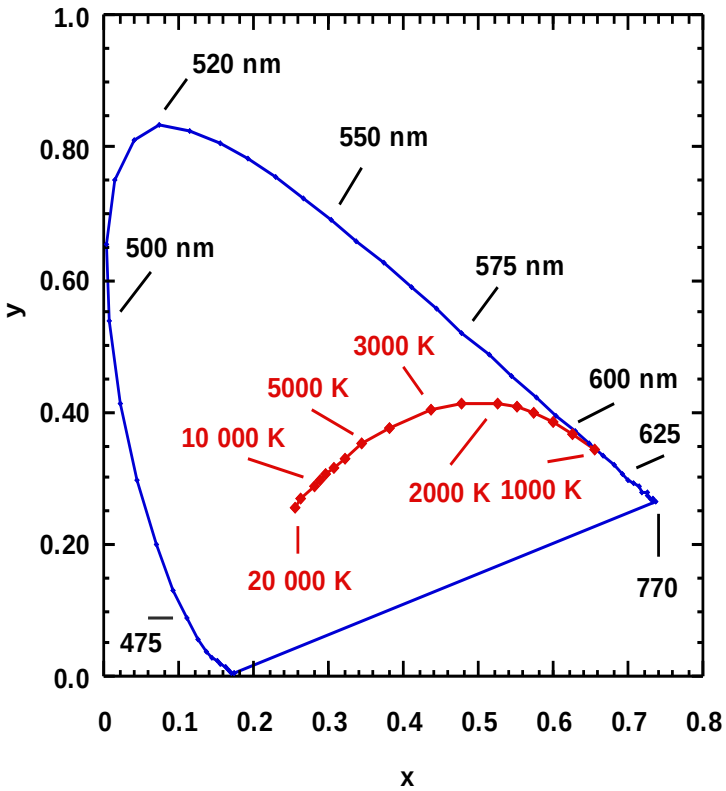
Tel +31-(0)-313-670170
Fax +31-(0)-313-670179

AvaSoft Irradiance chart

Possible usefull extra information:

Color temperature





Color rendering index

“colors are seen natural if illuminated by daylight“

color differences of objects illuminated with the test and a selected reference lamp are calculated
color differences lead to the CRI of each test color R1 to R16
color rendering index

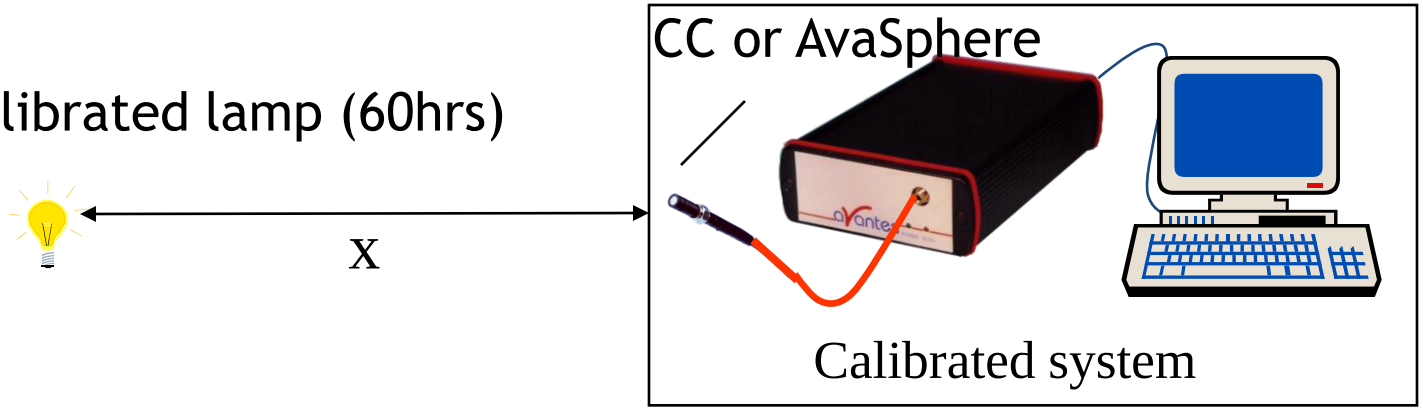
$$R_a = \frac{1}{8}\sum_{i=8}^{8} R_i$$

CRI gets a more and more important specification for light sources
0nly measurable with a spectroradiometer
Some of the R_i can be negative (but not the averaged R_a)

Irradiance calibration

Step 1: Calibrate system with known lightsource at distance x

NIST-calibrated lamp (60hrs)



Step 2: Back-Calibrate calibration lightsource with diffusor

- AvaLight-HAL-CAL (60hrs)
- AvaLight-DH-CAL (60hrs)