A new integrating sphere design for spectral radiant flux determination of LEDs

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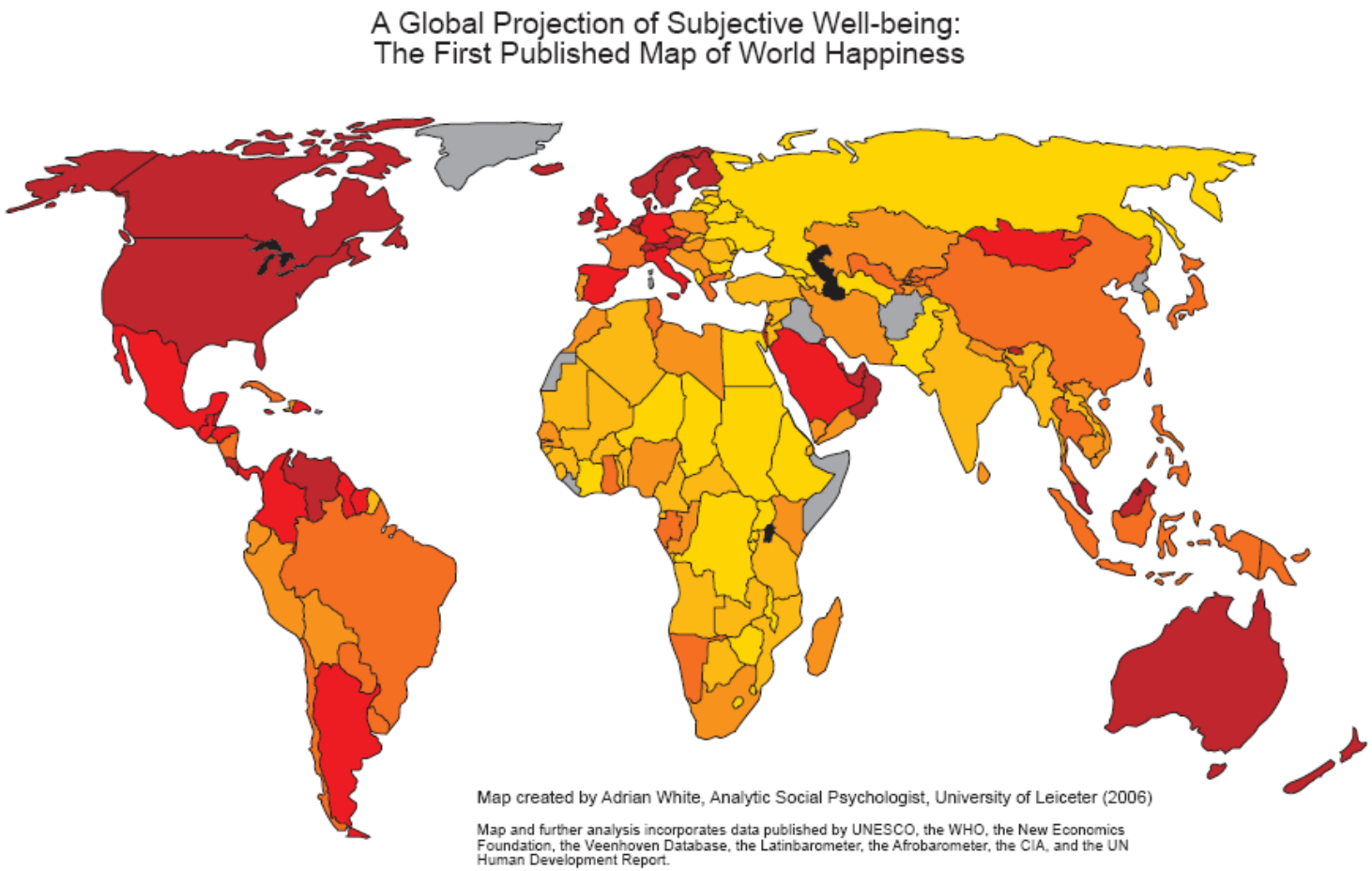
LABORATORIUM VOOR LICHTTECHNOLOGIE

Outline

- Light and Lighting Laboratory
- Introduction
- Integrating sphere theory
- Features
- Test measurements
- Preliminary results
- Future research

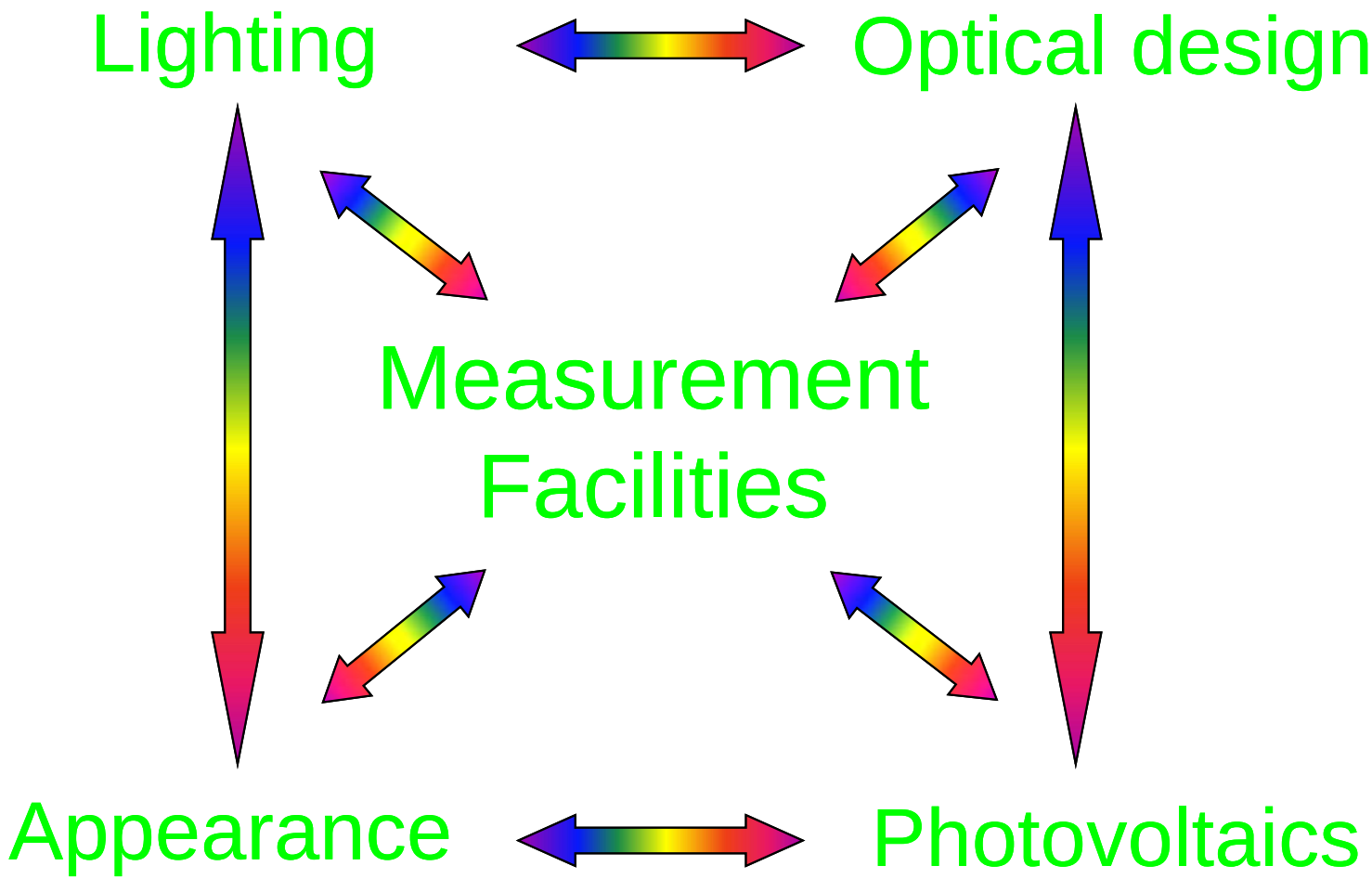
Location: Gent, Belgium



Location: Gent, Belgium

Staff

Topics


Lighting
Optical design
Measurement Facilities
Appearance
Photovoltaics

Measuring instruments

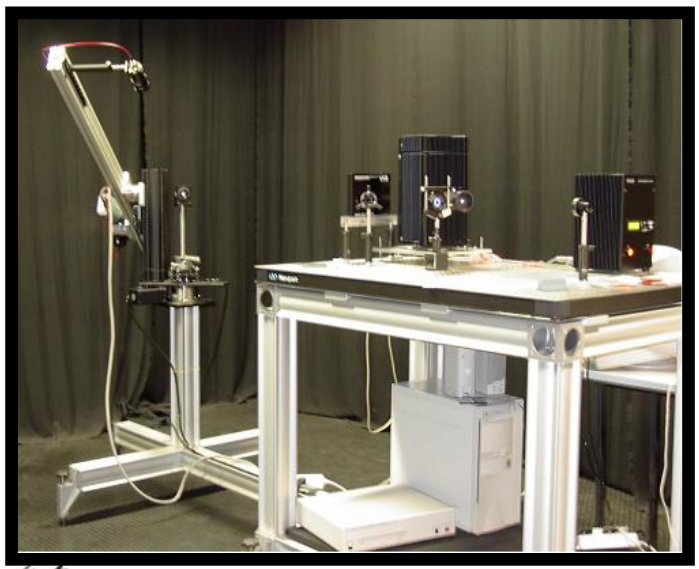
8/d spectral reflectance and transmittance

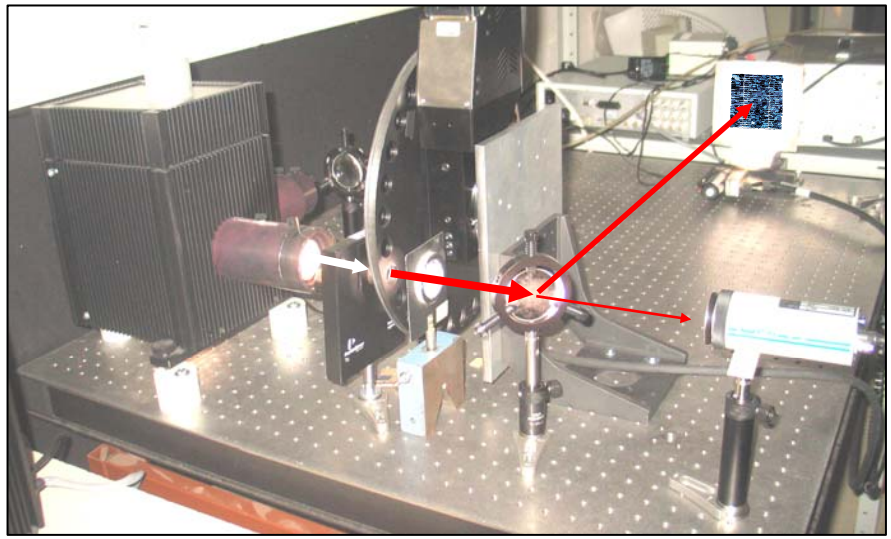
Goniometer for spectral retro-reflection

Near Field Luminance Goniometer

Measuring instruments

Photometric/colorimetric camera





Spectral response

Absolute spectral BSDF

F. Leloup et al, Applied Optics, Vol. 47, No. 29, pp. 5454-5467, 2008.

LEDs

- LED technology is developing very fast
- Technology will become mature for general lighting applications
- Luminous flux and efficacy are very important and sensitive data, used to impress and push the market
- Specifications are strongly dependent on junction temperature
- Need for standard measuring procedures

Approaches

Spatial resolved

Spatial integrated

Goniometer

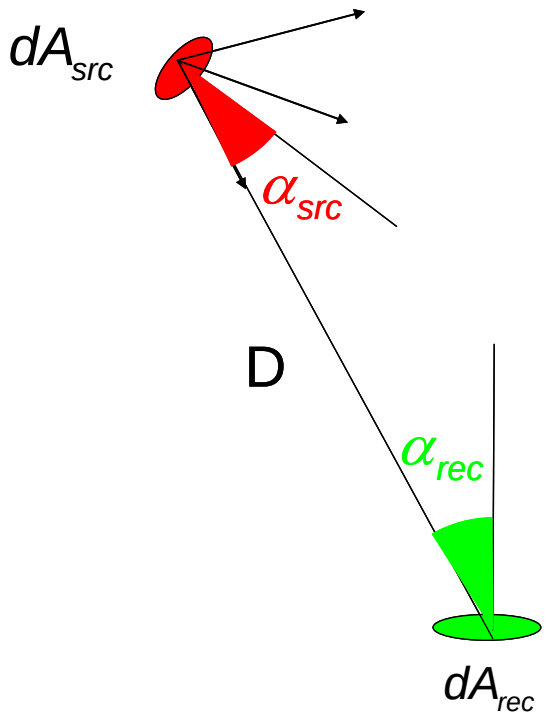
Integrating sphere

Approaches

Spectral integrated	Spectral resolved
Photometer	Spectrograph

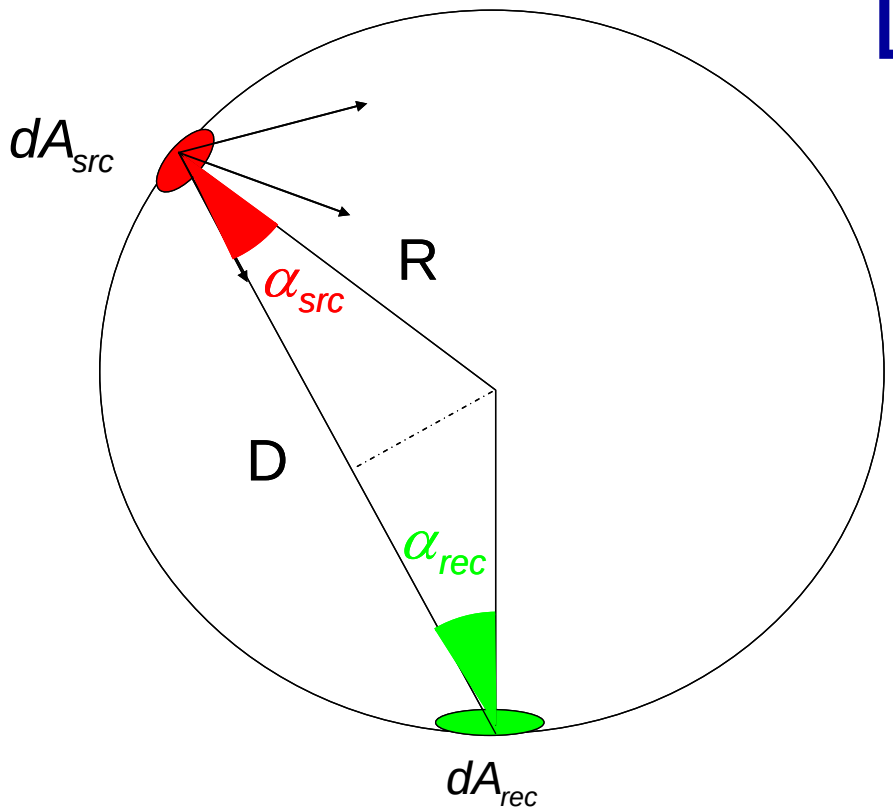
Spectrum, CRI, CCT

Basics



$$E_{e,\lambda}(receiver) = \iint L_{e,\lambda}(\alpha_{src}, \beta_{src}).\cos\alpha_{src}.\frac{\cos\alpha_{rec}}{D^2}.dA_{src}$$

Basics



Sphere geometry:

$$E_{e,\lambda}(receiver) = \frac{1}{4R^2}.\iint L_{e,\lambda}(\alpha_{src},\beta_{src}).dA_{src}$$

Basics

Lambertian coating:

$$L_{e,\lambda} = \frac{\rho}{\pi}.E_{e,\lambda}$$

$$E_{e,\lambda}(receiver) = \frac{1}{4\pi R^2}.\iint \rho.E_{e,\lambda}.dA_{src}$$

Uniform coating:

$$E_{e,\lambda}(receiver) = \frac{\rho}{4\pi R^2}.\iint E_{e,\lambda}.dA_{src}$$

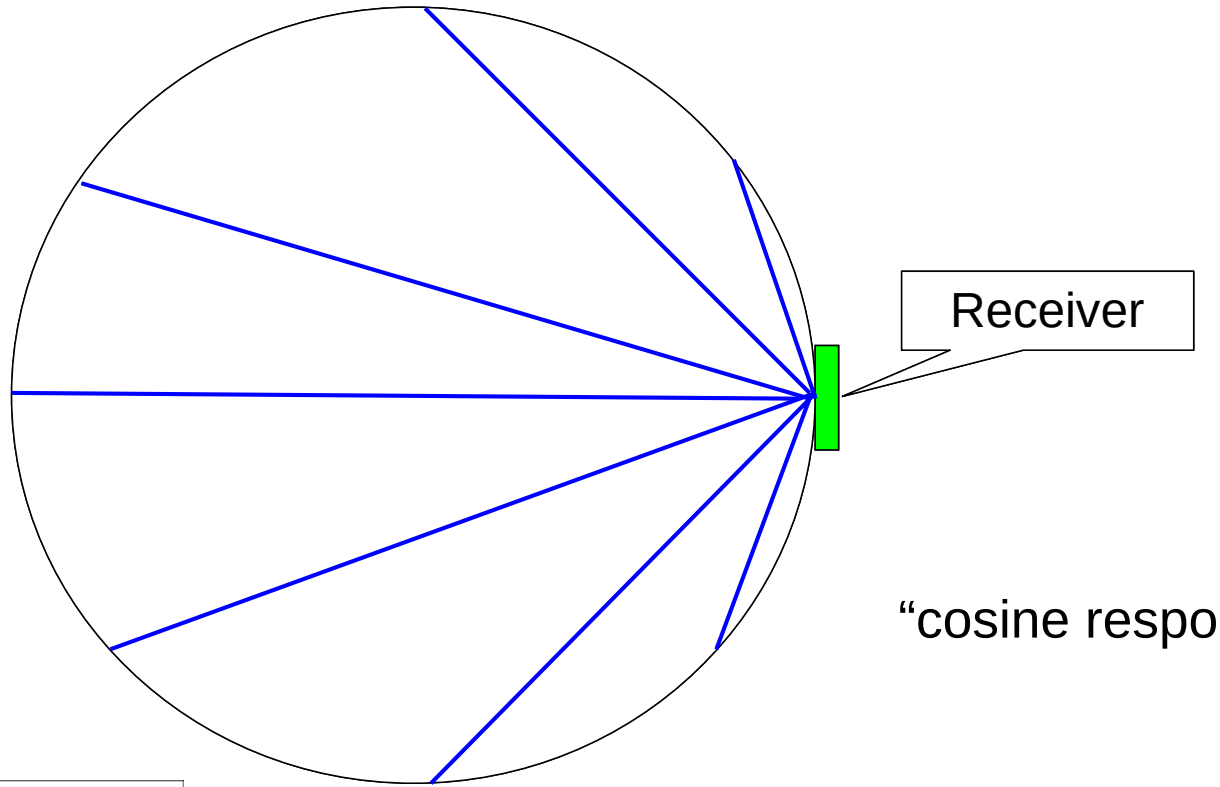
$$= \frac{1}{4\pi R^2}.\frac{\rho}{1-\rho}.\Phi_{e,\lambda}$$

Spectral neutral coating:

$$E(receiver) = \frac{1}{4\pi R^2}.\frac{\rho}{1-\rho}.\Phi$$

Error sources

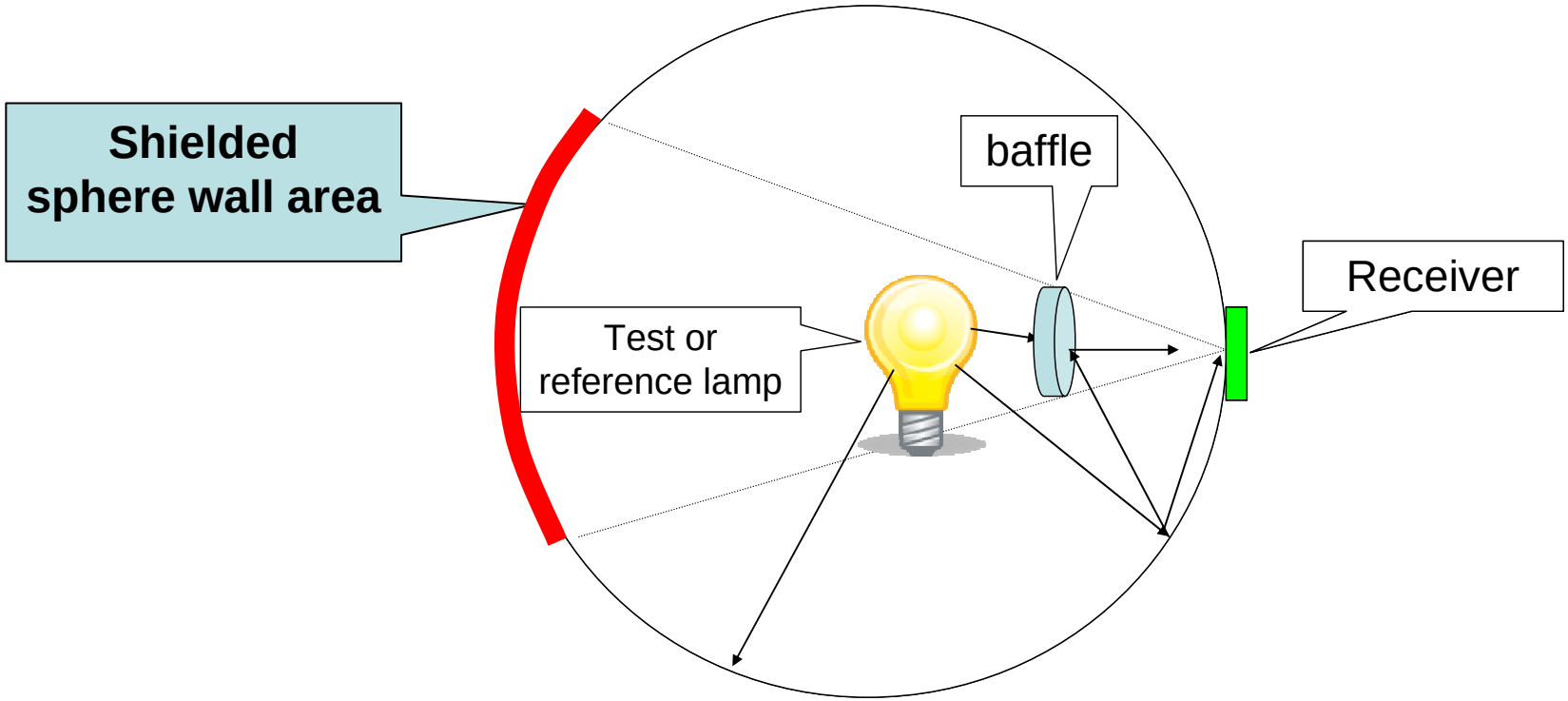
Receiver response must be proportional to irradiance over the hemispherical FOV



“cosine response”

Error sources

Direct incidence must be eliminated: use of a baffle!



Substitution method using a similar reference lamp

List

- Wall mounted LED

  Backward radiation!
- Unique geometry of reference, sample and detection port

  Very small baffle area!
- Absolute detector based approach with an external irradiance calibration source

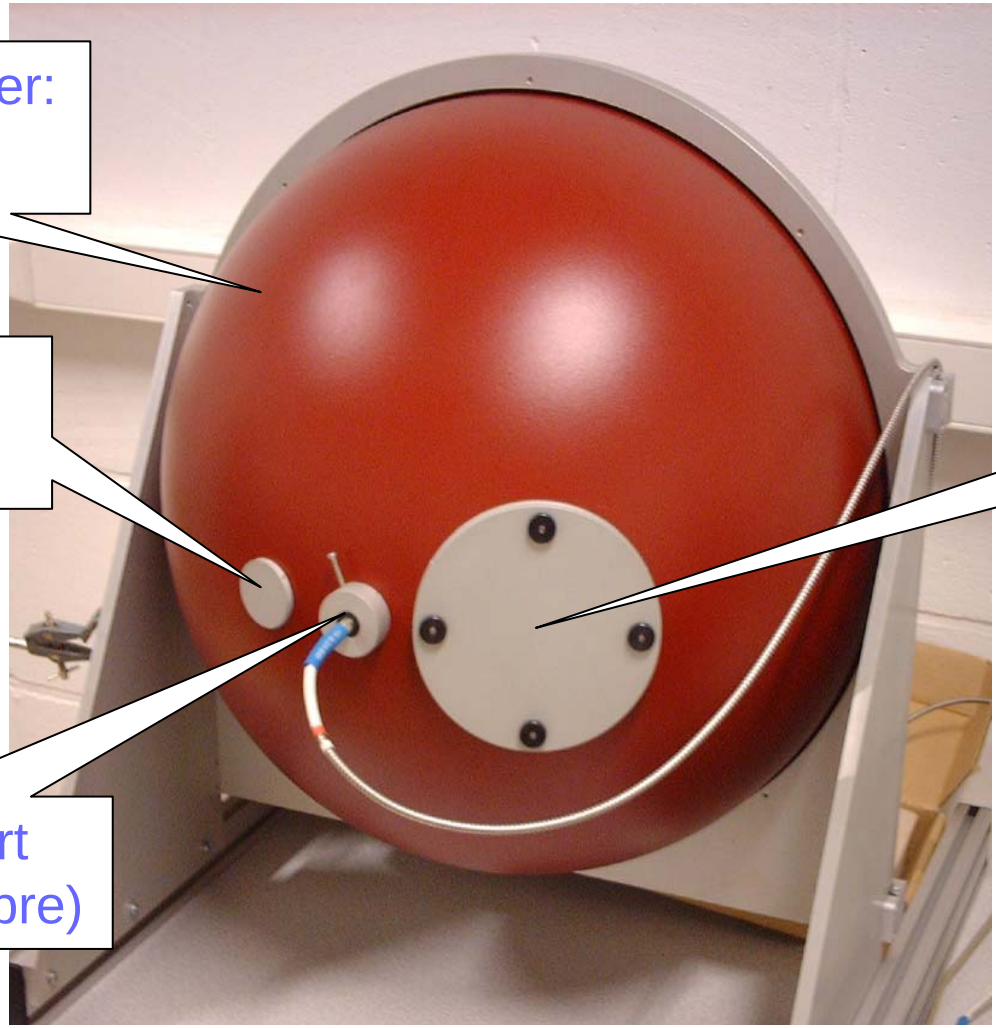
  Additional open port!

  Collimated reference beam!
- Spectral resolved measurements

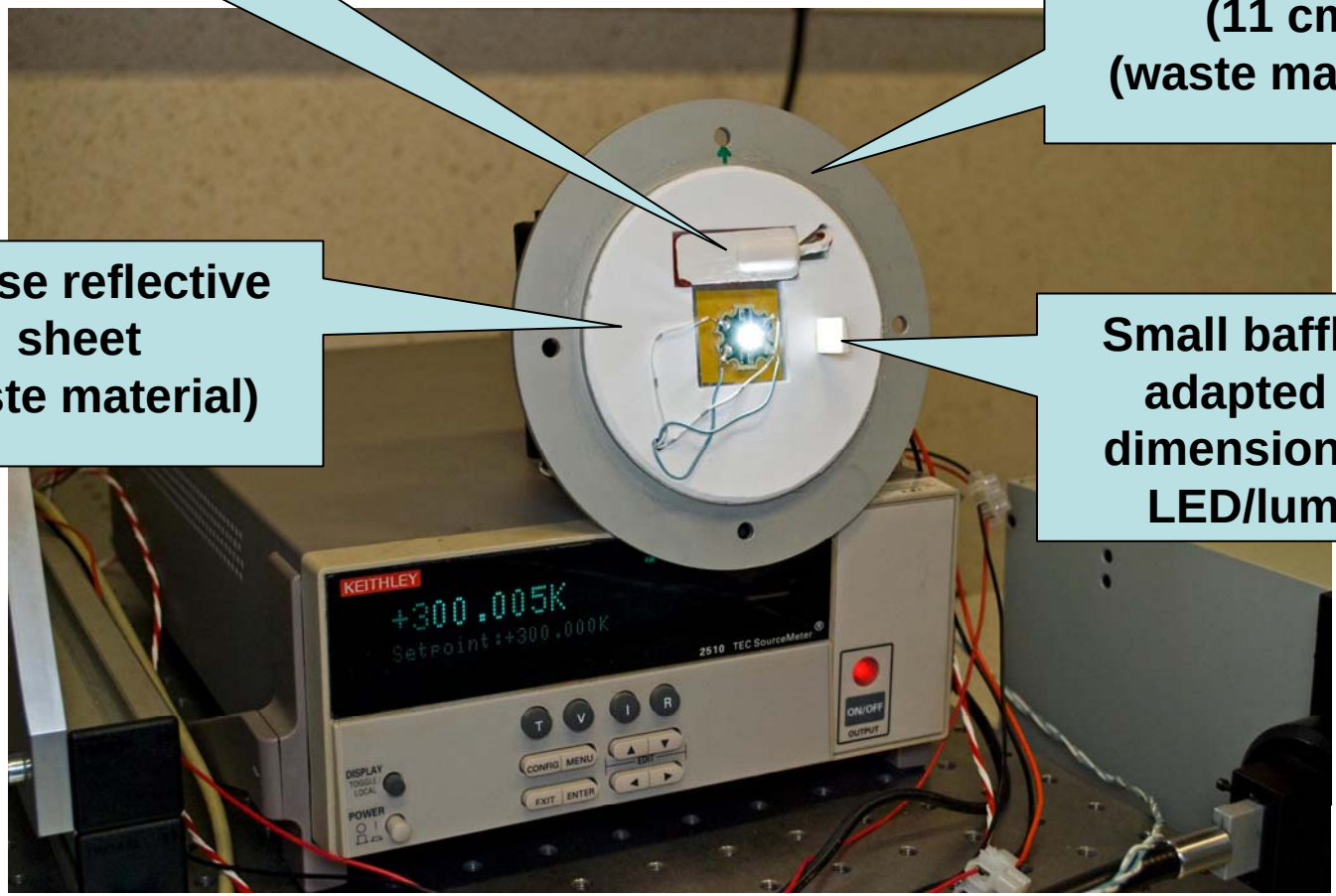
  Spectral calibration!

  Signal to Noise levels!

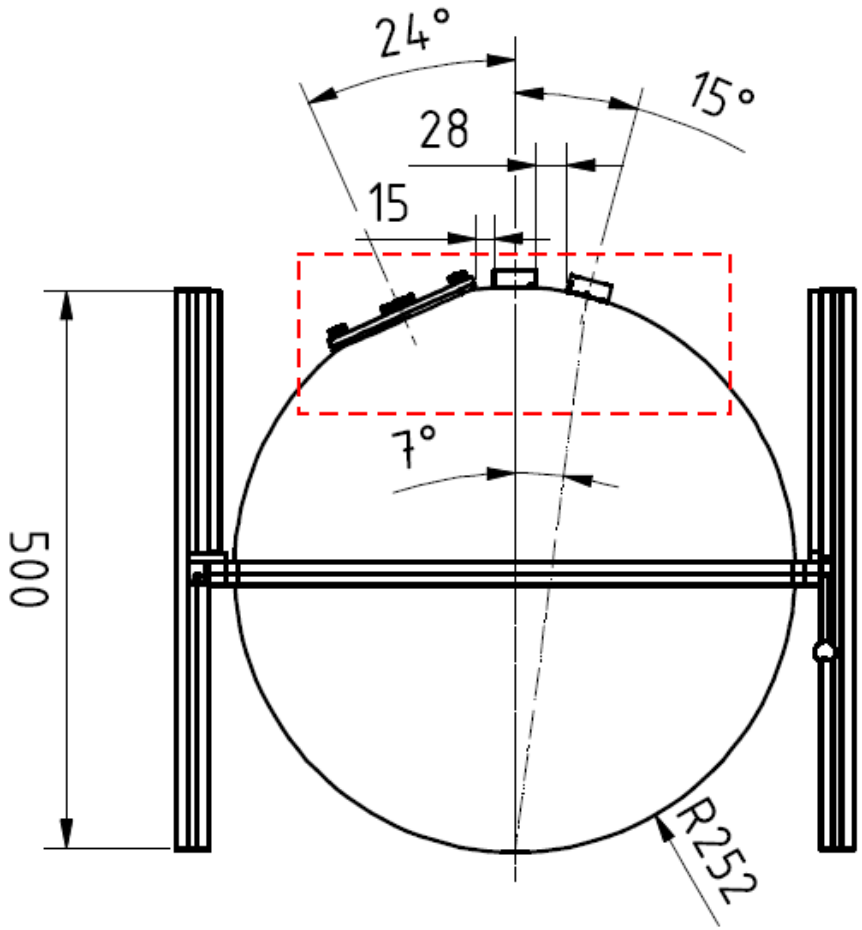
Unique geometry

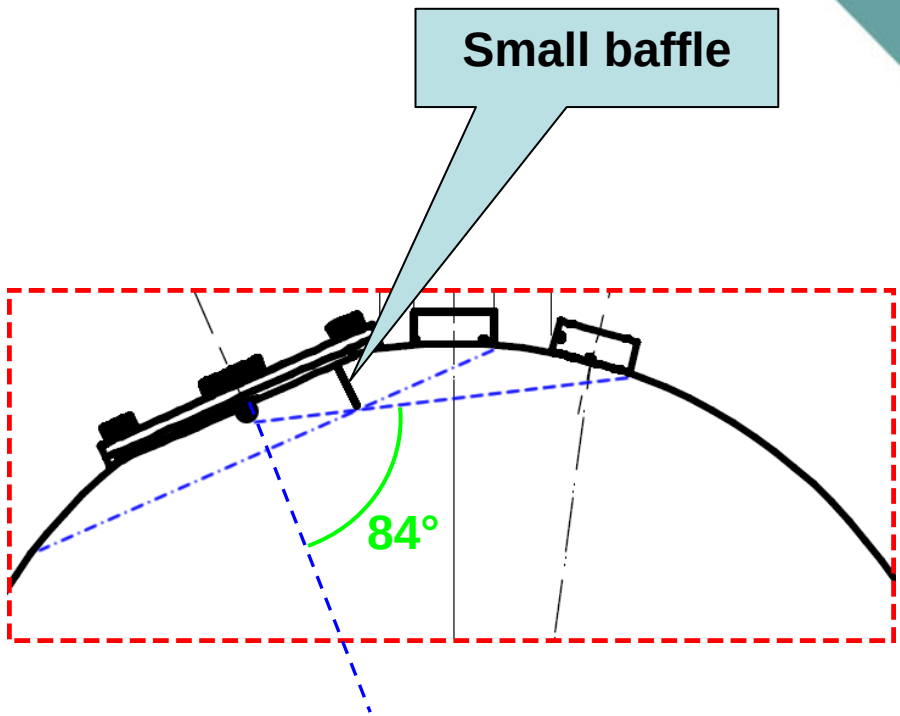


Sample port


Pt 100 temperature sensor
Sample plug (11 cm) (waste material)
Diffuse reflective sheet (waste material)
Small baffle; to be adapted to the dimensions of the LED/luminaire
KEITHLEY
+300.005K
Setpoint:+300.000K
2510 TEC SourceMeter
ON/OFF
OUTPUT
POWER

Geometry/ baffle





One baffle to shield two ports

Direct flux hitting baffle ánd shadow region is small

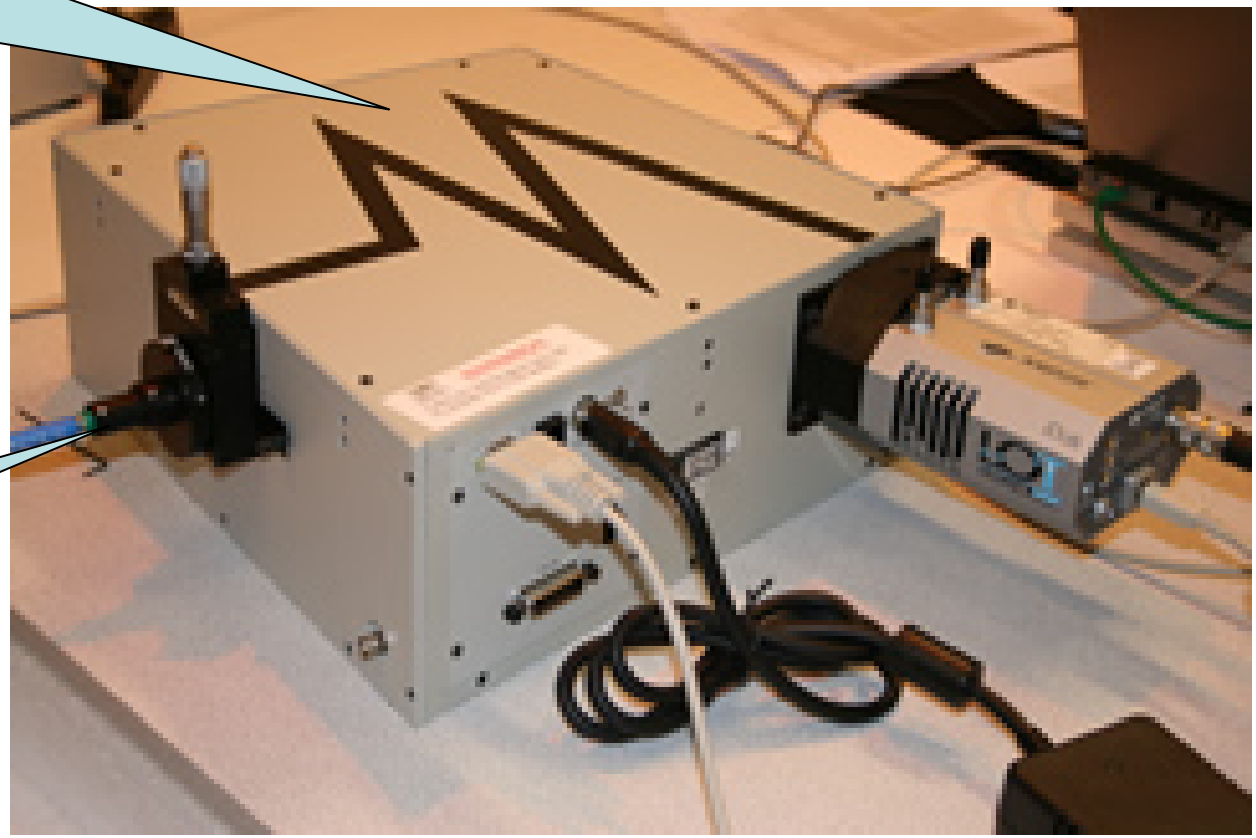
External irradiance calbration source

Primary reference source, at 50 cm

Secundary reference source

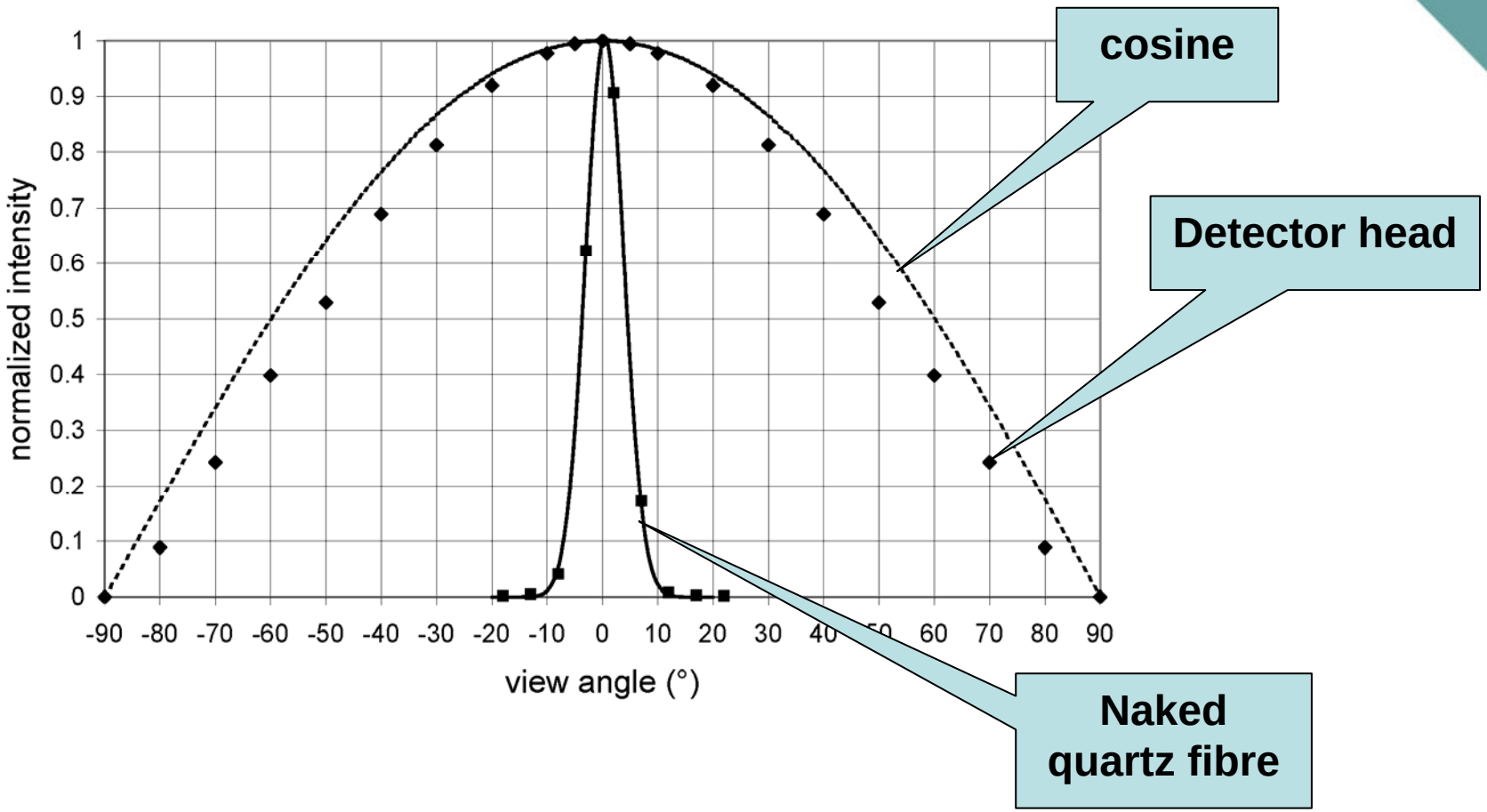
Spectral resolved measurements

¼ m Spectrometer, 4 nm bandwidth, full VIS wavelength coverage



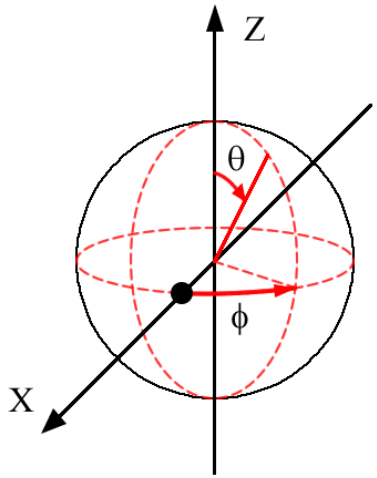
Circular to rectangular quartz fibre

Angular response of the receiver



Diffusing power versus signal strength!

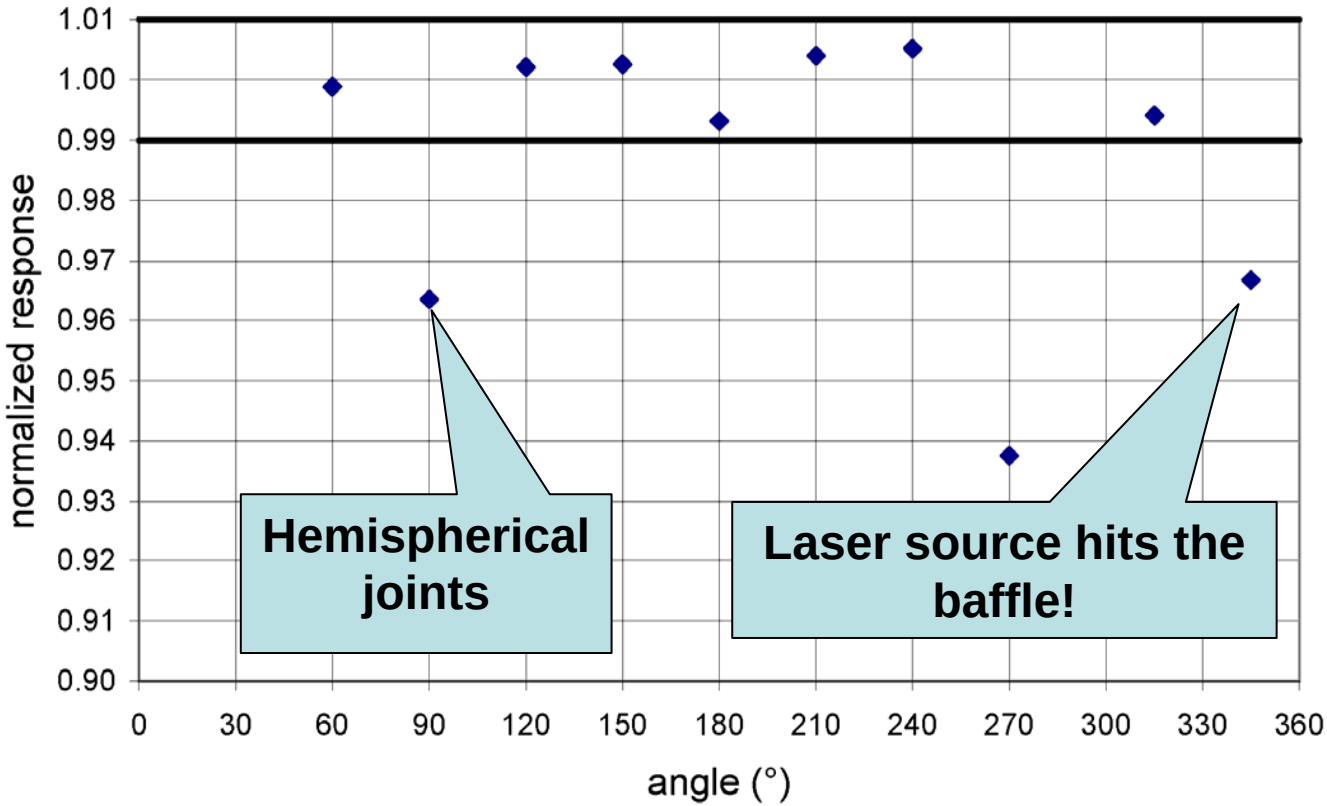
Spatial Response Distribution Function



Detector direction

Variations of SRDF within 1%

$\theta = 90°$



Sphere factor

For an ideal sphere:

$$E(receiver) = \frac{1}{4\pi R^2} . \frac{\rho}{1-\rho} . \Phi$$

Measured with calibrated luxmeter: 1442 lux

Calculated from spectral irradiance: 60.5 lm

$$\frac{1}{4\pi R^2} . \frac{\rho}{1-\rho} = 23.8$$

$$\rho = 0.95$$

Spatial integrated versus spatial resolved

$$\Phi = 35.0\ lm$$

$$\Phi = 35.3\ lm$$

Efficiency of a clear lens

$FWHM = 120°$

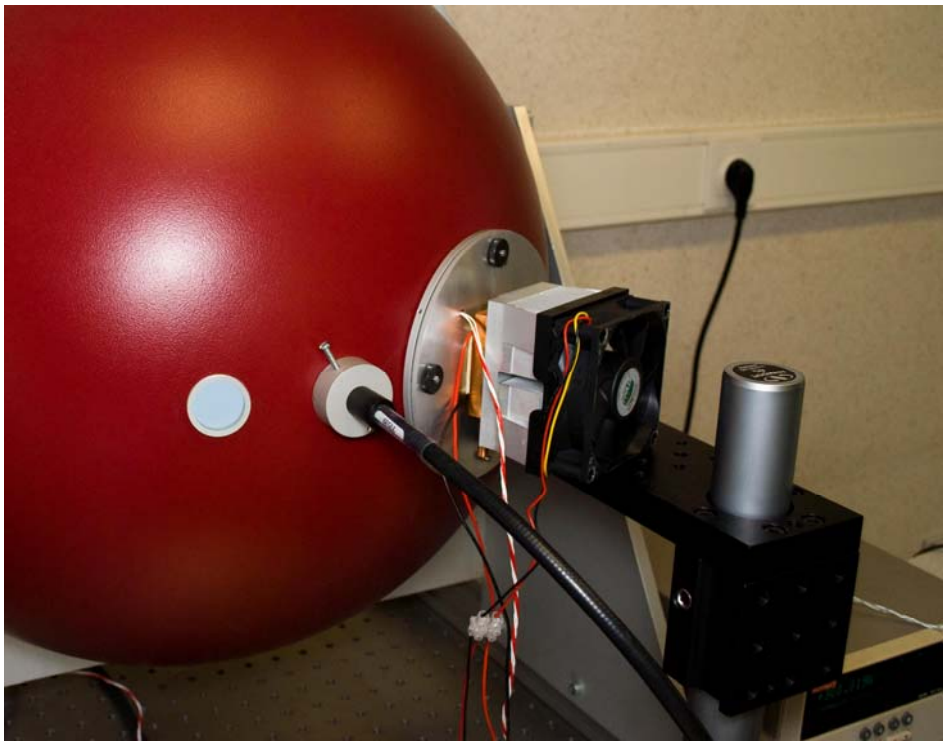
$\Phi = 35.3\ lm$

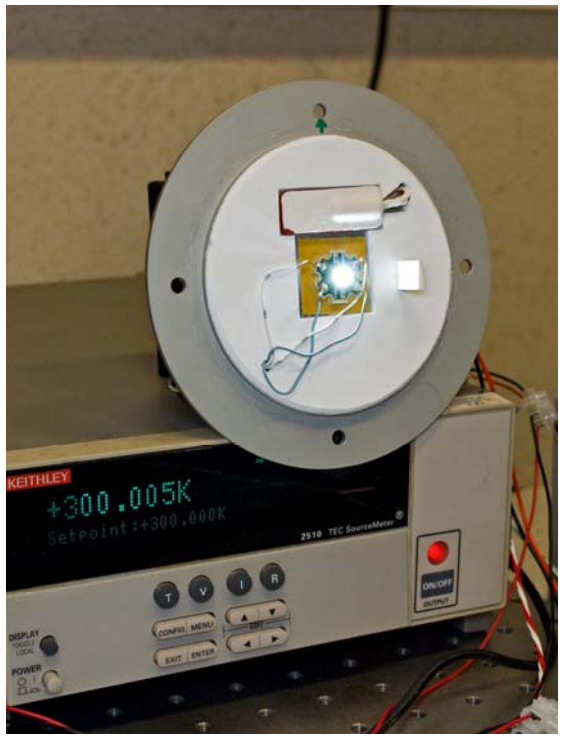
$FWHM = 10°$

$\Phi = 34.5\ lm$

2.2% *loss*

Temperature controlled LED

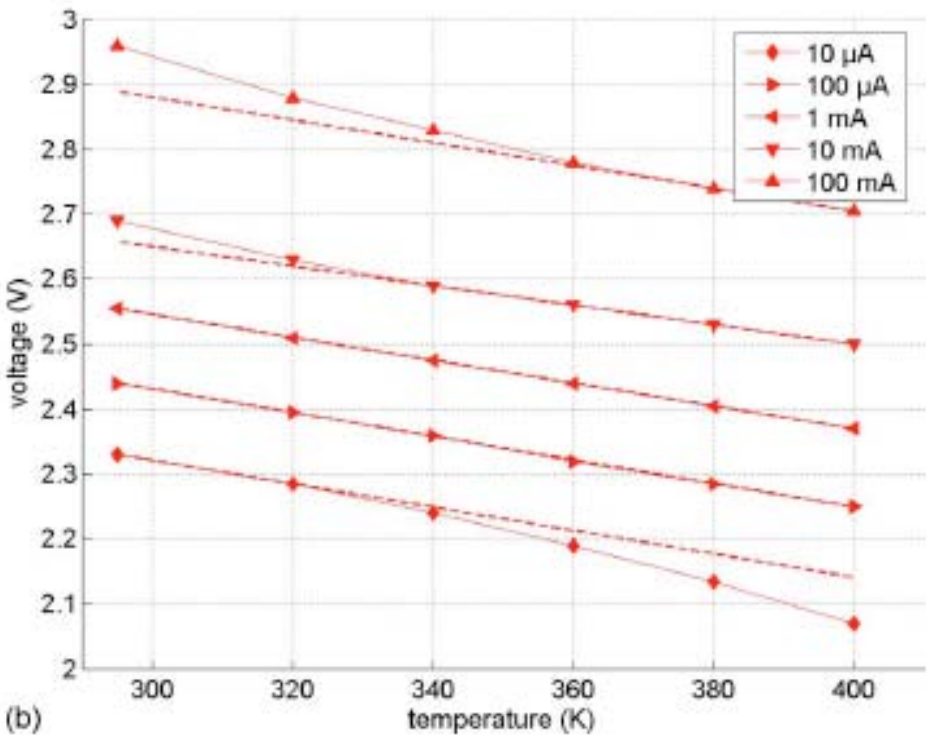




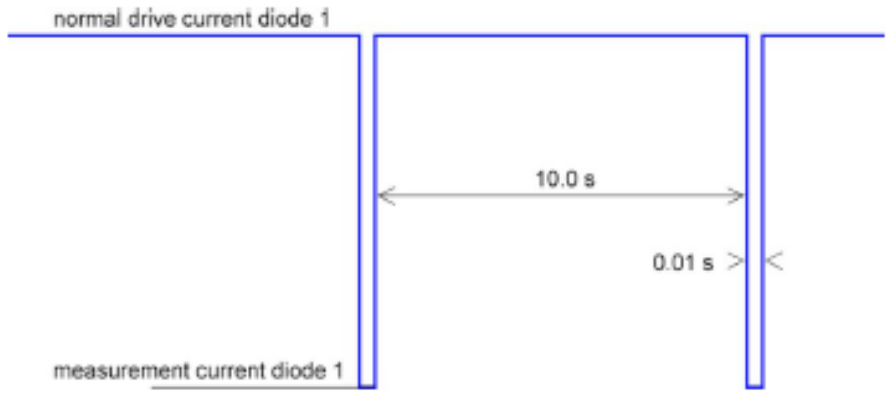
Pt100 and peltier drive are used to reach a setpoint

Plug was thermally isolated from sphere body

LED junction temperature

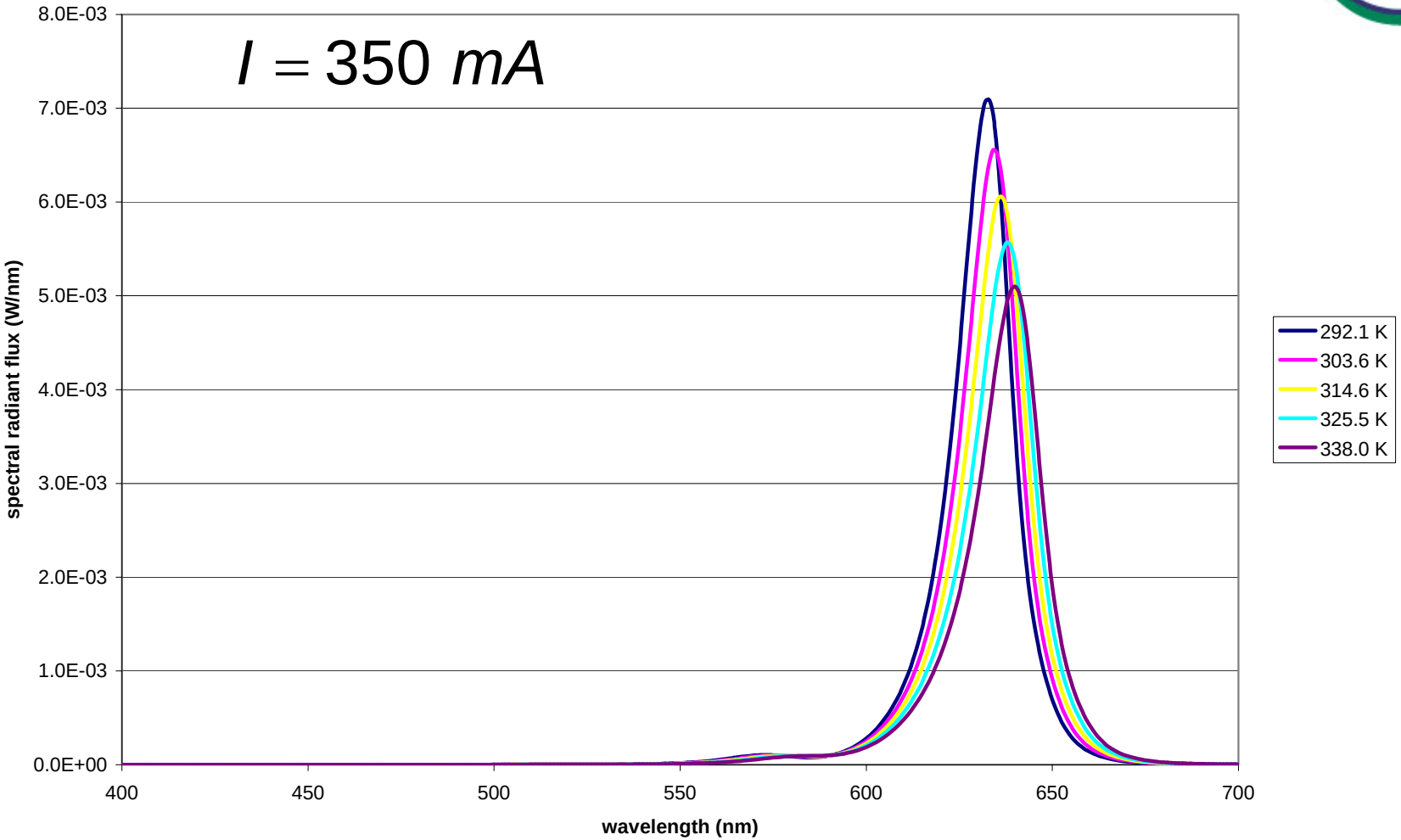


Calibration curves at low drive current

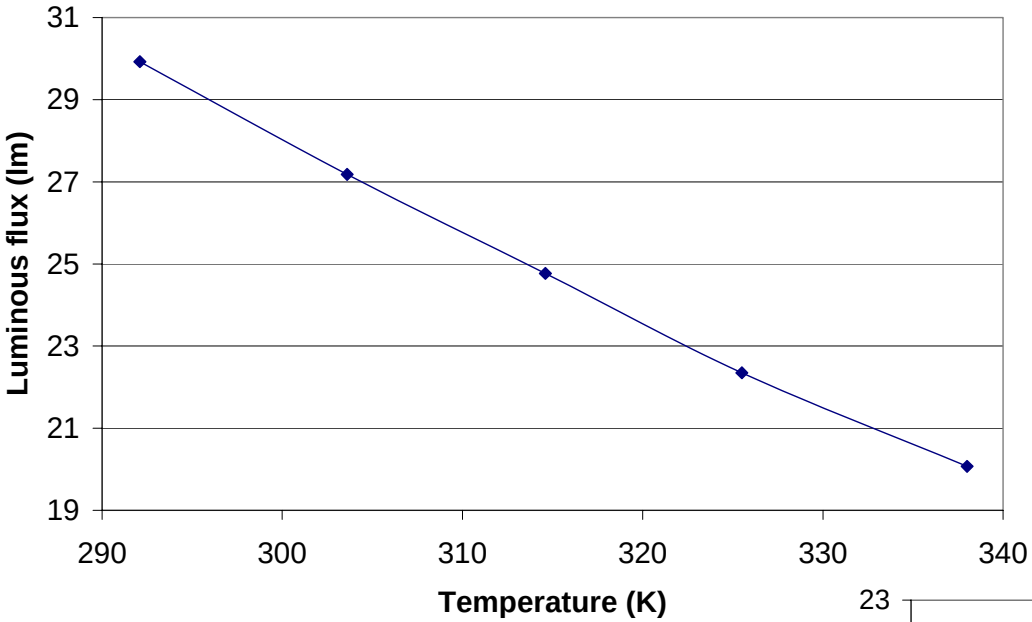


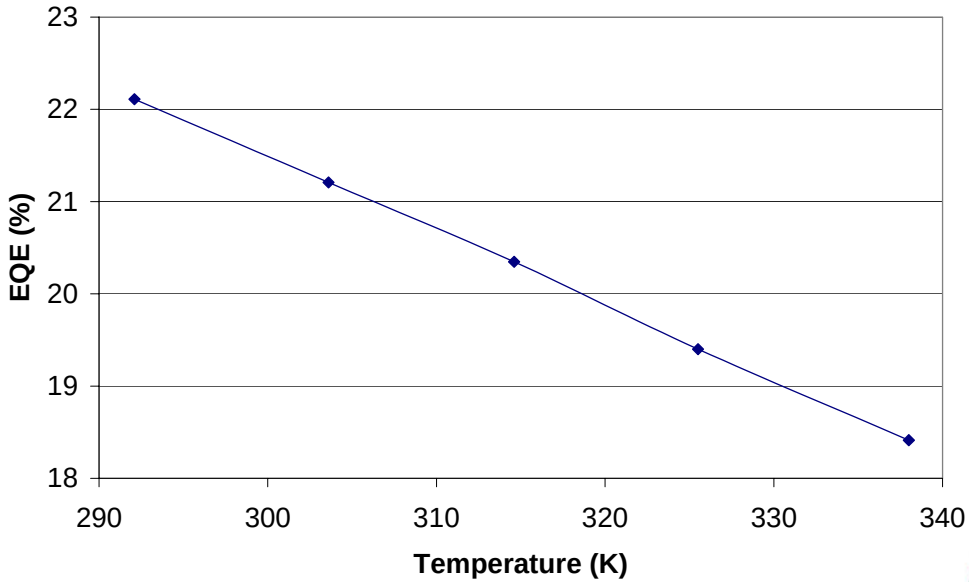
Keppens, A., Ryckaert, W. R., Deconinck, G. and Hanselaer, P., High power light-emitting diode junction temperature determination from current-voltage characteristics, J. Appl. Phys., 2008, 104, 9.

Temperature controlled red LED: spectra



Temperature controlled red LED





- Uncertainty budget
- Stray light correction
- Standard LEDs
- Benchmarking (including remote phosphor LEDs)
- LED measurements at constant temperature but different drive currents
- Standardization procedures

www.lichttechnologie.be

Acknowledgements:

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