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

Peter Hanselaer, Arno Keppens
Light and Lighting Laboratory
Catholic University College Sint-Lieven, Gent (B)
Outline

- Light and Lighting Laboratory
- Introduction
- Integrating sphere theory
- Features
- Test measurements
- Preliminary results
- Future research
A Global Projection of Subjective Well-being: The First Published Map of World Happiness

Map created by Adrian White, Analytic Social Psychologist, University of Leicester (2006)

Map and further analysis incorporates data published by UNESCO, the WHO, the New Economics Foundation, the Veerhoven Database, the Latinobarometer, the Afrobarometer, the CIA, and the UN Human Development Report.

May 6 2009, Peter Hanselaer
Light&Lighting Laboratory

Location: Gent, Belgium
Staff
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

Introduction

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
Introduction

Approaches

Spatial resolved

Goniometer

Spatial integrated

Integrating sphere
Introduction

Approaches

Spectral integrated
Photometer

Spectral resolved
Spectrograph

Spectrum, CRI, CCT
Integrating sphere theory

Basics

\[ E_{e,\lambda} (receiver) = \int \int L_{e,\lambda} (\alpha_{src}, \beta_{src}) \cdot \cos \alpha_{src} \cdot \frac{\cos \alpha_{rec}}{D^2} \cdot dA_{src} \]
Integrating sphere theory
Basics

Sphere geometry:

\[ E_{e,\lambda} (\text{receiver}) = \frac{1}{4R^2} \iint L_{e,\lambda}(\alpha_{\text{src}}, \beta_{\text{src}}) \cdot dA_{\text{src}} \]
Integrating sphere theory

Basics

Lambertian coating:

\[ L_{e,\lambda} = \frac{\rho}{\pi} \cdot E_{e,\lambda} \]

\[ E_{e,\lambda}(\text{receiver}) = \frac{1}{4\pi R^2} \cdot \int \int \rho \cdot E_{e,\lambda} \cdot dA_{\text{src}} \]

Uniform coating:

\[ E_{e,\lambda}(\text{receiver}) = \frac{\rho}{4\pi R^2} \cdot \int \int E_{e,\lambda} \cdot dA_{\text{src}} \]

\[ = \frac{1}{4\pi R^2} \cdot \frac{\rho}{1 - \rho} \cdot \Phi_{e,\lambda} \]

Spectral neutral coating:

\[ E(\text{receiver}) = \frac{1}{4\pi R^2} \cdot \frac{\rho}{1 - \rho} \cdot \Phi \]
Receiver response must be proportional to irradiance over the hemispherical FOV
Direct incidence must be eliminated: use of a baffle!

Substitution method using a similar reference lamp
Features

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

Sphere diameter: 50 cm

reference port (2.5 cm)

detection port (diffuser and fibre)

sample port (11 cm)
Features

Sample port

Pt 100 temperature sensor

Diffuse reflective sheet (waste material)

Sample plug (11 cm) (waste material)

Small baffle; to be adapted to the dimensions of the LED/luminaire
### Geometry/ baffle

**Features**

One baffle to shield two ports

Direct flux hitting baffle and shadow region is small

84°
Features

External irradiance calibration source

Primary reference source, at 50 cm

Secondary reference source
Features

Spectral resolved measurements

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

Circular to rectangular quartz fibre
Angular response of the receiver

Test measurements

Diffusing power versus signal strength!
Spatial Response Distribution Function

Test measurements

Variations of SRDF within 1%

$\theta = 90^\circ$

Detector direction

Hemispherical joints

Laser source hits the baffle!
For an ideal sphere:

\[ E(\text{receiver}) = \frac{1}{4\pi R^2} \cdot \frac{\rho}{1-\rho} \Phi \]

Measured with calibrated luxmeter: 1442 lux

Calculated from spectral irradiance: 60.5 lm

\[
\frac{1}{4\pi R^2} \cdot \frac{\rho}{1-\rho} = 23.8
\]

\[ \rho = 0.95 \]
Test measurements

Spatial integrated versus spatial resolved

\[ \Phi = 35.0 \text{ lm} \]

\[ \Phi = 35.3 \text{ lm} \]
Test measurements

Efficiency of a clear lens

$FWHM = 120^\circ$

$\Phi = 35.3 \text{ lm}$

$FWHM = 10^\circ$

$\Phi = 34.5 \text{ lm}$

2.2% loss
Preliminary results

Temperature controlled LED

Pt100 and peltier drive are used to reach a setpoint
Plug was thermally isolated from sphere body
Preliminary results

**LED junction temperature**

Calibration curves at low drive current

Preliminary results

Temperature controlled red LED: spectra

$I = 350 \ mA$

![Graph showing spectral radiant flux (W/nm) vs. wavelength (nm) for different temperatures.](image)
Preliminary results

Temperature controlled red LED

\[\text{Luminous flux (lm)}\]

\[\text{Temperature (K)}\]

\[\text{EQE (%)}\]

May 6 2009, Peter Hanselaer
Further research

- 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:
The authors wish to thank the IWT of Flanders for financial support