International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

International
Organization for
Standardization

Recent Advances in Standardization of Display Metrology and Light Measurement

Michael E. Becker
Instrument Systems GmbH
München, Germany

DISPLAY WEEK 2015
SID SAN JOSE

DIN
Workshop Farbnormung
Internationale und europäische
Ausrichtung der Normung

Instrument Systems
light measurement

Standards Organizations

CIE **Fundamentals of photometry and colorimetry**
Terminology, basics of light and color measurement, and characterization of the performance of light measurement devices (e.g. ISO/CIE 19476:2014).

IEC **Data sheets for electronic display components and devices - Applicability**
IEC TC110: "Standardization, ... of terms and definitions, letter symbols, essential ratings and characteristics, measuring methods, specsifications for quality assurance and related test methods, and reliability."

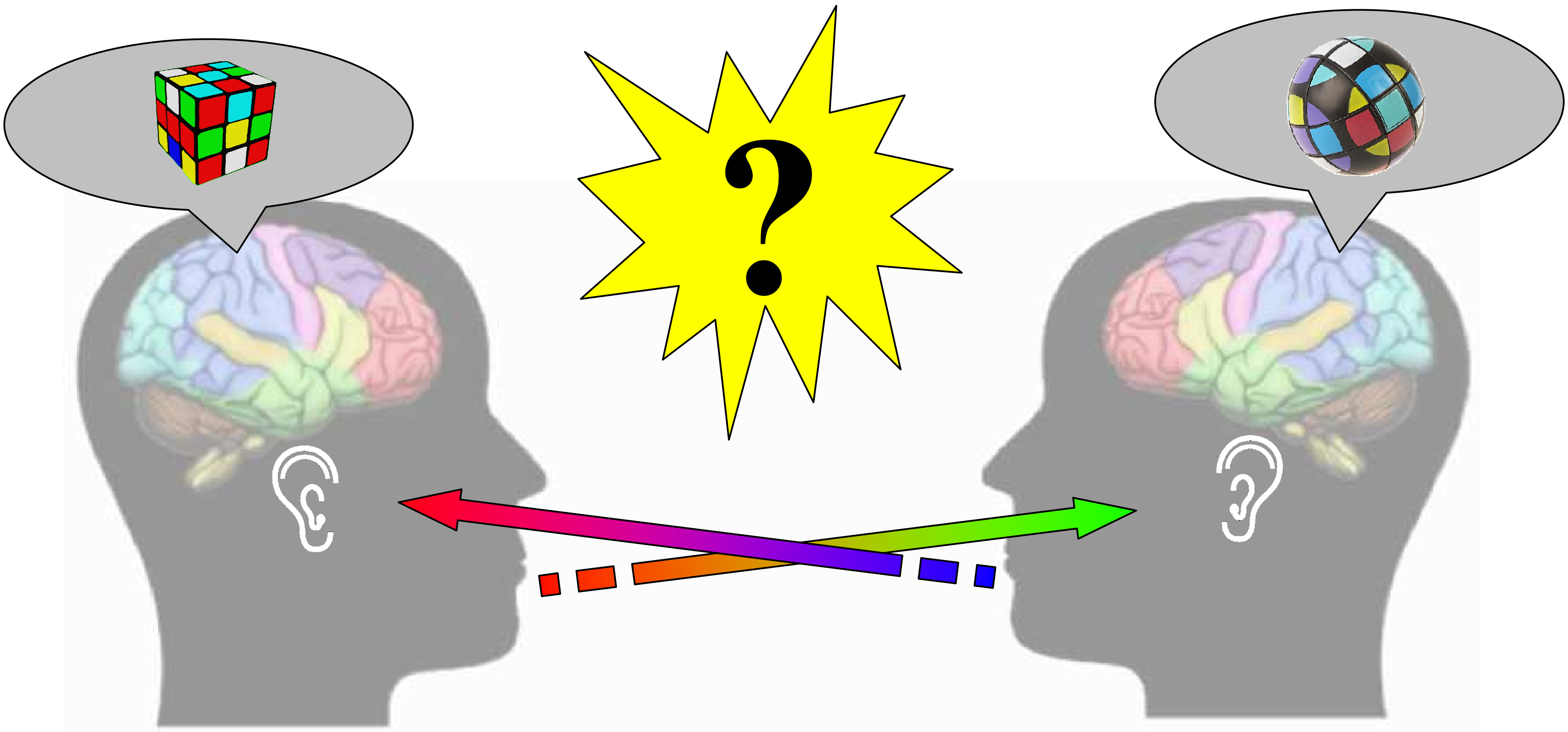
- Measurement methods for electro-optical display devices (LCD, OLED, ePaper, etc.).
- Consolidation of the scattered measurement methods for LCDs (among others IEC 61747-30-6).
- Introduction of methods for the measurement of speckle in laser display devices (IEC 62906-5-2).
- Measurement methods for transparent displays (OLED and LCD) are under consideration.

ISO **Ergonomics of human-system interaction - Usability**
The WG2 of the ISO/TC159/SC4 is currently revising and extending ISO 9241 part 305 ("optical laboratory test methods for electronic visual displays") with respect to standardized indoor and outdoor ambient illumination conditions, the corresponding measurement and modeling approaches, as well as discussing measurement methods for reflective (ePaper) and transparent displays.

ICDM **Most valuable pool of practical experience**
Measurement methods, procedures, instrument diagnostics, tutorials, etc.
More than 500 pages of distinguished expert knowledge.

Standards: Basis for Communication

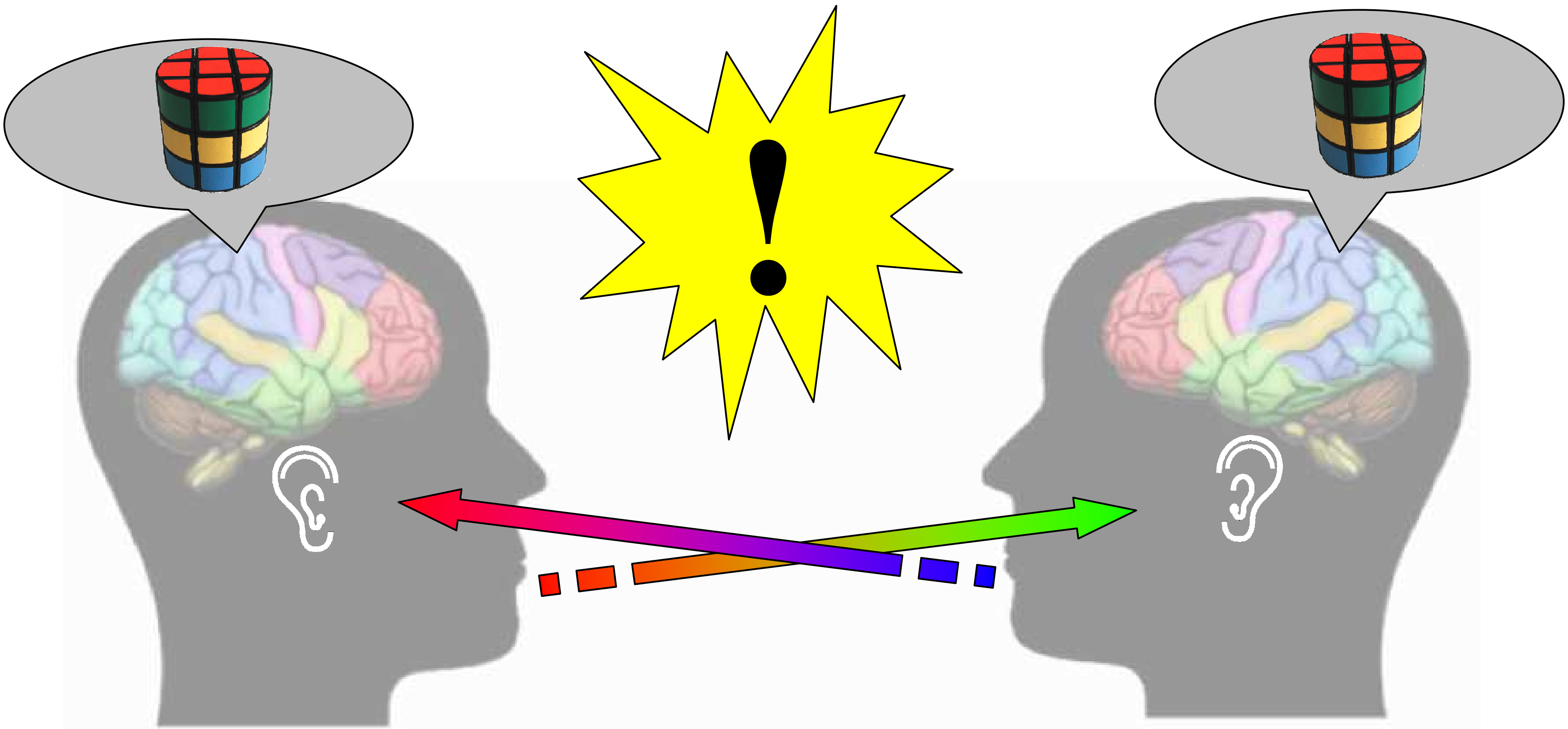
The prerequisite for successful communication and thus **understanding** is the use of a common set of terms (vocabulary).



Standards: Basis for Communication

The prerequisite for successful communication and thus **understanding** is the use of a common set of terms (vocabulary).

In any field of science and technology it is essential that a specific **taxonomy** and a **terminology** is defined and maintained by a solid authority, which in the present case (measurement of light on color) is the CIE.



Standards: Basis for Communication

The prerequisite for successful communication and thus **understanding** is the use of a common set of terms (vocabulary).

In any field of science and technology it is essential that a specific **taxonomy** and a **terminology** is defined and maintained by a solid authority, which in the present case (measurement of light on color) is the CIE.

radiance

luminance

brightness

illuminance

flux

intensity

Standards: Basis for Communication

The prerequisite for successful communication and thus **understanding** is the use of a common set of terms (vocabulary).

In any field of science and technology it is essential that a specific **taxonomy** and a **terminology** is defined and maintained by a solid authority, which in the present case (measurement of light on color) is the CIE.

International Lighting Vocabulary

The aim of the International Lighting Vocabulary is to promote international standardization in the use of quantities, units, symbols and terminology in this field.

CIE S 017/E:2011 ILV: International Lighting Vocabulary – New Edition

Many new terms have been added, to reflect changes in technologies and practices, existing terms have been updated as necessary, and obsolete terms have been removed.

This Standard comprises **203 pages and presents the definitions of 1448 terms related to light and lighting.**

Standards: Basis for Communication

http://www.electropedia.org/iev/iev.nsf/index?openform&part=845

International Lighting Vocabulary

The aim of the International Lighting Vocabulary is to promote international standardization in the use of quantities, units, symbols and terminology in this field.

CIE S 017/E:2011 ILV: International Lighting Vocabulary – New Edition

Many new terms have been added, to reflect changes in technologies and practices, existing terms have been updated as necessary, and obsolete terms have been removed.

This Standard comprises **203 pages and presents the definitions of 1448 terms related to light and lighting.**

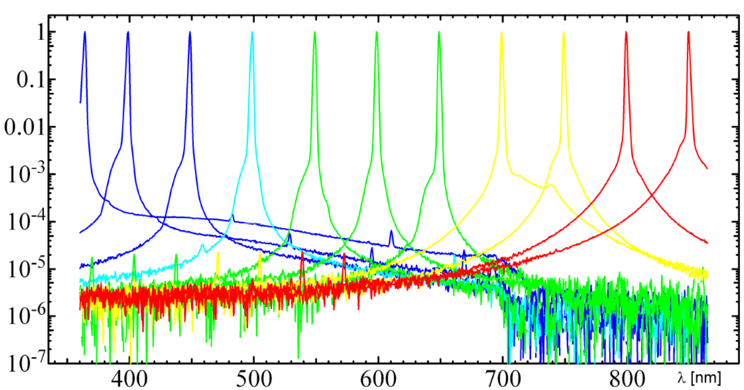
Array spectrometers

Evaluation of the chromaticity of light sources, displays and surfaces is recently largely relying on the application of ***array spectrometers***.

> The convenience of these instruments (e.g. fast measurements) often obfuscates problems hidden in the details, e.g. the variation of the **bandpass function** with wavelength and the effect of stray light in the spectrograph.

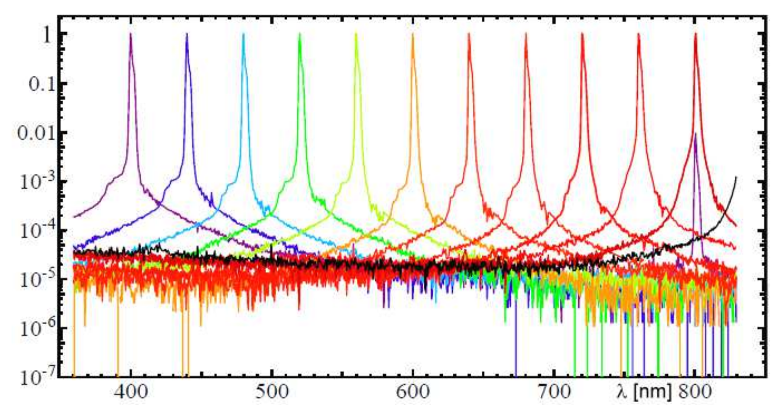
CIE 214:2014: "Effect of Instrumental Bandpass Function and Measurement Interval on Spectral Quantities" presents a **study of bandwidth corrections** applied to measured spectra for compensation of the variation of the line-spread function of the spectrometer (LSF) with wavelength.

It introduces a **correction algorithm** that can be used for any real bandpass function and it provides guidance on how to apply that correction together with a discussion of the theoretical and experimental limits to its applicability.



LSFs of two array spectroradiometers

A. Sperling - PTB



ISO/CIE 19476:2014: Characterization of the Performance of Illuminance Meters and **Luminance Meters** (replacing CIE S 023/E:2013).

Approaches for characterization of the instruments by a range of ***performance quality indices*** and diagnostics for checking LMD performance.

> We should know the properties, capabilities and limitations of our instruments in order to restrict the measurements to those that can be carried out with a sufficient level of uncertainty.

The standard introduces **quality indices**; it defines measurement procedures and methods for numerical evaluation of these indices and it defines calibration conditions for luminance meters.

- **spectral properties, UV and IR response,**
- **directional response,**
- **linearity,**
- **effect of temporal modulations,**
- **effect of polarization of light,**
- **calibration uncertainties.**

Also applicable to spectroradiometers used for display metrology.

The CIE TC2-59 is currently working on extending the basic work of ISO/CIE 19476 to the special case of **imaging luminance measurement devices (iLMDs)**.

This impatiently awaited document is currently in the status of a working draft ("Characterization of imaging luminance measurement devices"), an **extension to colorimetry** should be the next step.

CIE TC2-75: "Photometry of Curved and Flexible OLED and LED Sources"

started to explore the special aspects related to non-planar displays and light sources in 2012.

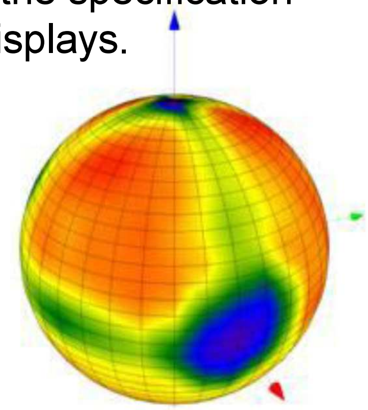
Objective: to prepare methods for characterization of the photometric and colorimetric quantities of non-planar light sources including the traceability of suitable calibration procedures.

The motivation for this work is given primarily by Solid State Lighting (SSL): change of chromaticity across the light source area.

This unwanted effect is present also in extended planar light sources and displays, but it is especially pronounced and thus possibly annoying in the non-planar case.

So there is a need for **measurement and evaluation procedures** (characteristics, e.g. maximum acceptable color difference), **diagnostics and calibration methods** as a basis for the specification of non-uniformities of chromaticity and luminance of non-planar light sources and displays.

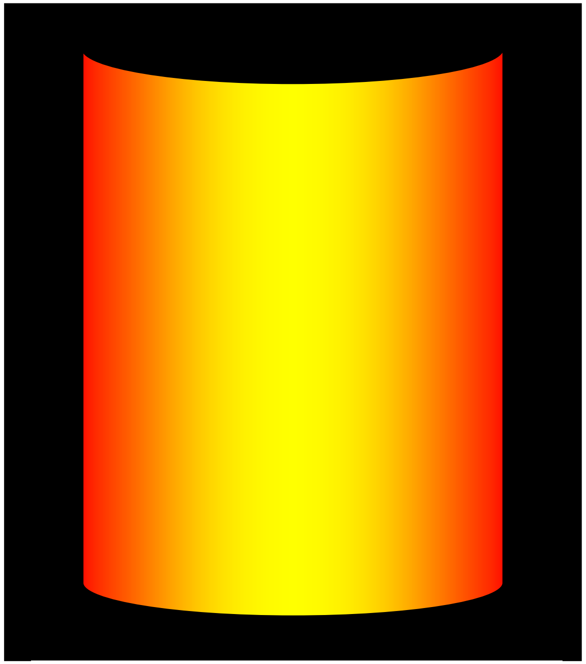
Measurement of the **total flux** of non-planar light sources in an integrating sphere may require special (directed instead of isotropic) light sources for calibration, since the directed emission of the sample may emphasize non-ideal properties of the sphere and thus cause increased calibration uncertainties.



Non-uniformity of integrating sphere - A. Sperling - PTB

Non-planar Light Sources

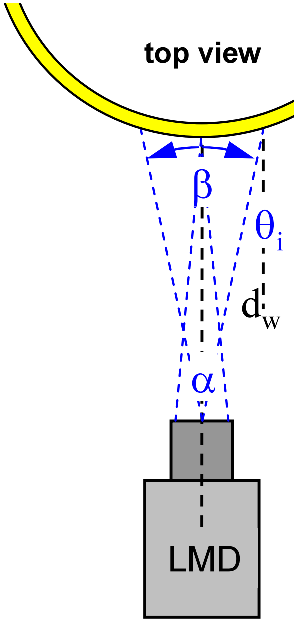
View of a cylinder surface when the spectrum of emitted radiance changes with the angle of inclination (distinct changes shown for illustration purposes).

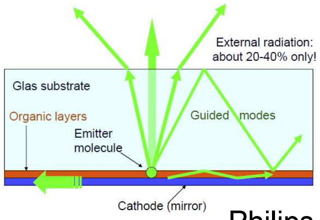


This variation becomes visible as a change of chromaticity across the light source area.

This unwanted effect is present also in extended planar light sources, but it is especially pronounced and thus possibly annoying in the non-planar case.

Light emitting cylinder: direction of observation approaches 90° (angle of inclination) at the periphery of the cylinder surface → all directions of observation over the range ±90° are contained in one visual scene, so changes of emission with direction of observation and especially the resulting chromaticity differences become very distinct.





Philips

A new chapter of light measurement ?

Measurement of luminance and chromaticity of non-planar light sources (displays) requires more attention:

- to the geometric details of the measurement setup and
- to the conditions of the LMD.

The **entanglement between lateral and directional variations** however is existing in the case of planar objects as well (e.g. evaluation of lateral uniformity with an imaging LMD where each position on the sample surface is measured from a different direction), but it can be much easier neglected there, since the effects are more subtle and not that obvious.

> Flexible samples are often intentionally wrapped around a cylinder in order to make use of the pronounced variation of the angle of inclination across the cylinder surface. The reflectance characteristics of ***fabric, paper and strands of hair*** can conveniently be measured in a cylindrical configuration with illumination by a linear light source.

Laterally integrating LMDs ("spot meters"): the measurement field diameter should be much smaller than the local radius of curvature (factor of 30 to 100 depending on the acceptable value of inclination at the periphery of the measurement field) to avoid averaging over a too wide range of inclination angles.

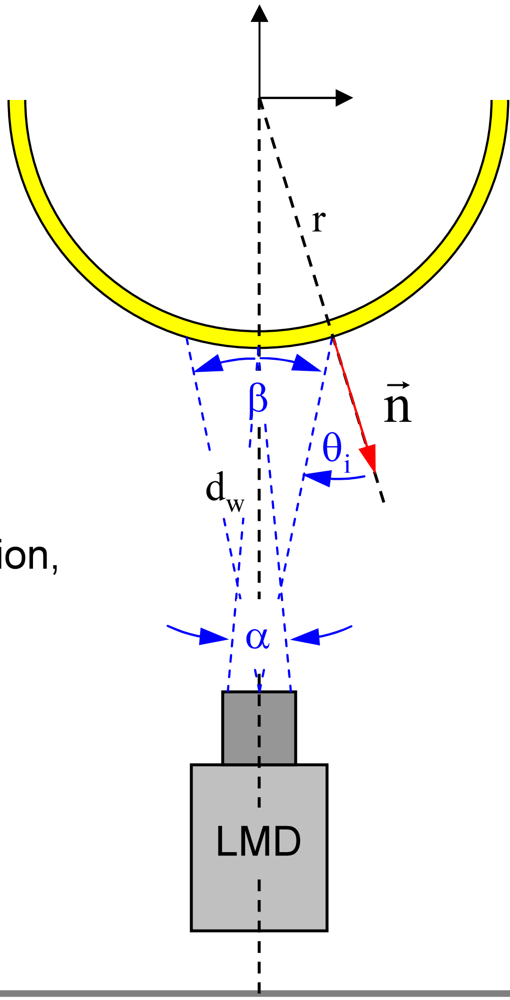
Imaging LMDs: the gradient of both luminance and chromaticity can be directly indicated, regions of interest and measurement fields (spots) for evaluation can be chosen accordingly. Thus analysis and representation from the **perspective of the observer** is possible.

Control of Imaging Details

➲ Measure, calculate, and evaluate details of the imaging conditions.

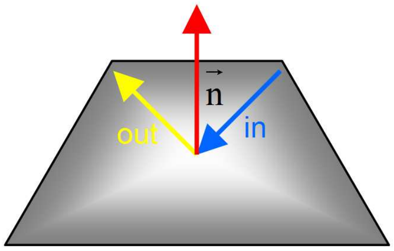
$$\theta_i = \arcsin\left(\sin\left(\beta/2\right)\cdot\frac{r+d_w}{r}\right)$$

➲ Specify the geometry of the measurement setup.



This used to be recommended for the case of planar samples, it becomes indispensable in the case of non-planar samples in order to make measurements reproducible.

The surface normal vector $\vec{n}$ should be known at each position on the sample surface (3D scanning, measurement and calculation, etc.).



International Electrotechnical Commission TC 110

Current status of working groups (WG), maintenance teams (MT) and advisory groups (AG) in IEC TC110:

- WG 2 Liquid crystal display devices
- WG 4 PDP – discontinued
- WG 5 OLED displays
- WG 6 3D Display Devices (3DDD)
- WG 7 Electronic Paper displays (EPD)
- WG 8 Flexible display devices (FDD)
- WG 9 Touch and interactive displays
- WG 10 Laser display devices
- MT 62595 LCD Backlight Unit
- AG 11 Advisory Group on Strategy

Project team 62977 (Common Optical Measurements)**:**
Consolidation of optical measurement methods of IEC TC110.
A similar process has been started with respect to the scattered measurement methods for LCDs.

> IEC TC110 is now undertaking efforts to make standardization work **more effective** for all parties that contribute their knowledge and experience, and the resulting standards more transparent and applicable for the users.

The subject of ***non-planar displays*** and the definition of suitable measurement and evaluation methods is currently also discussed within the IEC TC110. Care must be taken here in order to avoid overlaps, duplications and the resulting waste of resources.

IEC 62341-6-2 Ed. 2.0:2013 - Organic light emitting diode (OLED) displays - Part 6-2: Measuring methods of visual quality and ambient performance

The first international standard with a detailed specification of the illumination conditions during measurements for evaluation of the visual display performance under realistic illumination conditions.

> "Ambient performance" in this context has to be understood as the short form of "performance under specified ambient illumination conditions".

Setup and procedures of IEC 62341-6-2 have been developed and introduced by Kelley, Lindfors and Penczek (JSID 2006).

Illumination conditions for electro-optical measurements of displays under ambient illumination in indoor or outdoor application situations:

1 **uniform hemispherical diffuse illumination** for simulation of background lighting in a room, or, hemispherical skylight incident on the display, with the sun occluded.

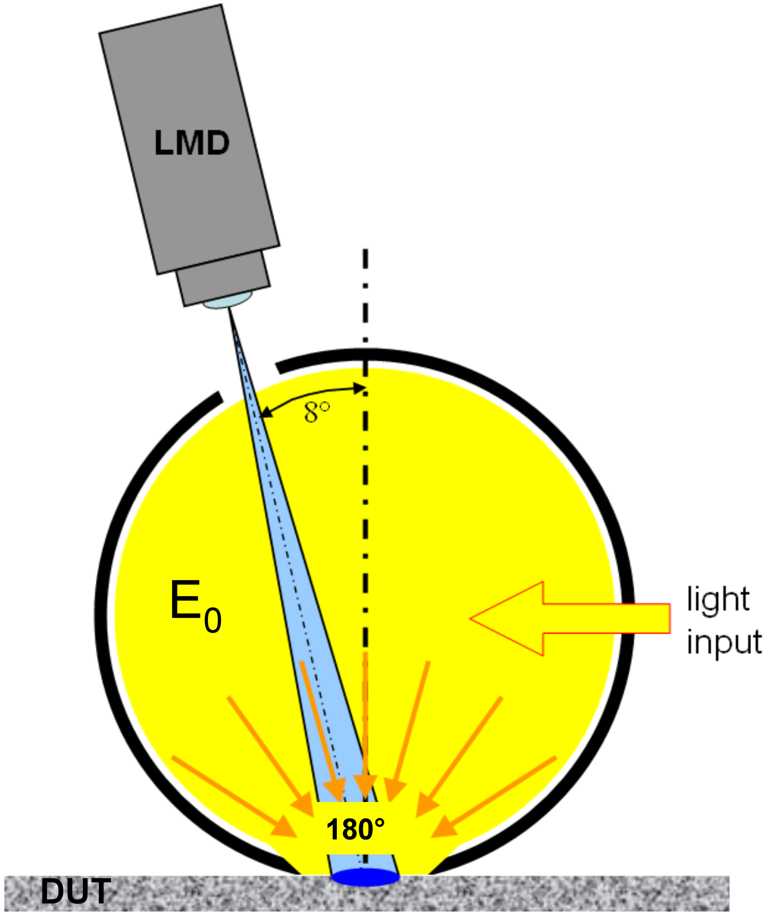
2 **directed illumination** in a dark room for simulation of the effect of lamps in a room, or, outdoors of direct sunlight (0.5° subtended angle).

The standard specifies the spectral distribution of the illumination by standard illuminants (e.g. CIE A, D65, D50) and the levels of illuminance for obtaining results corresponding to typical application situations, cases and surrounds, e.g. contrast and chromaticity for a typical TV viewing room, office environment or outdoors.

IEC 62341-6-2 Ed. 2.0:2013 - Organic light emitting diode (OLED) displays - Part 6-2: Measuring methods of visual quality and ambient performance.

Uniform hemispherical diffuse illumination for the display under test (DUT) can be provided by placing it into the center of an integrating sphere, or by a smaller type of integrating spheres that only illuminates the part of the DUT which is placed at the sample port.

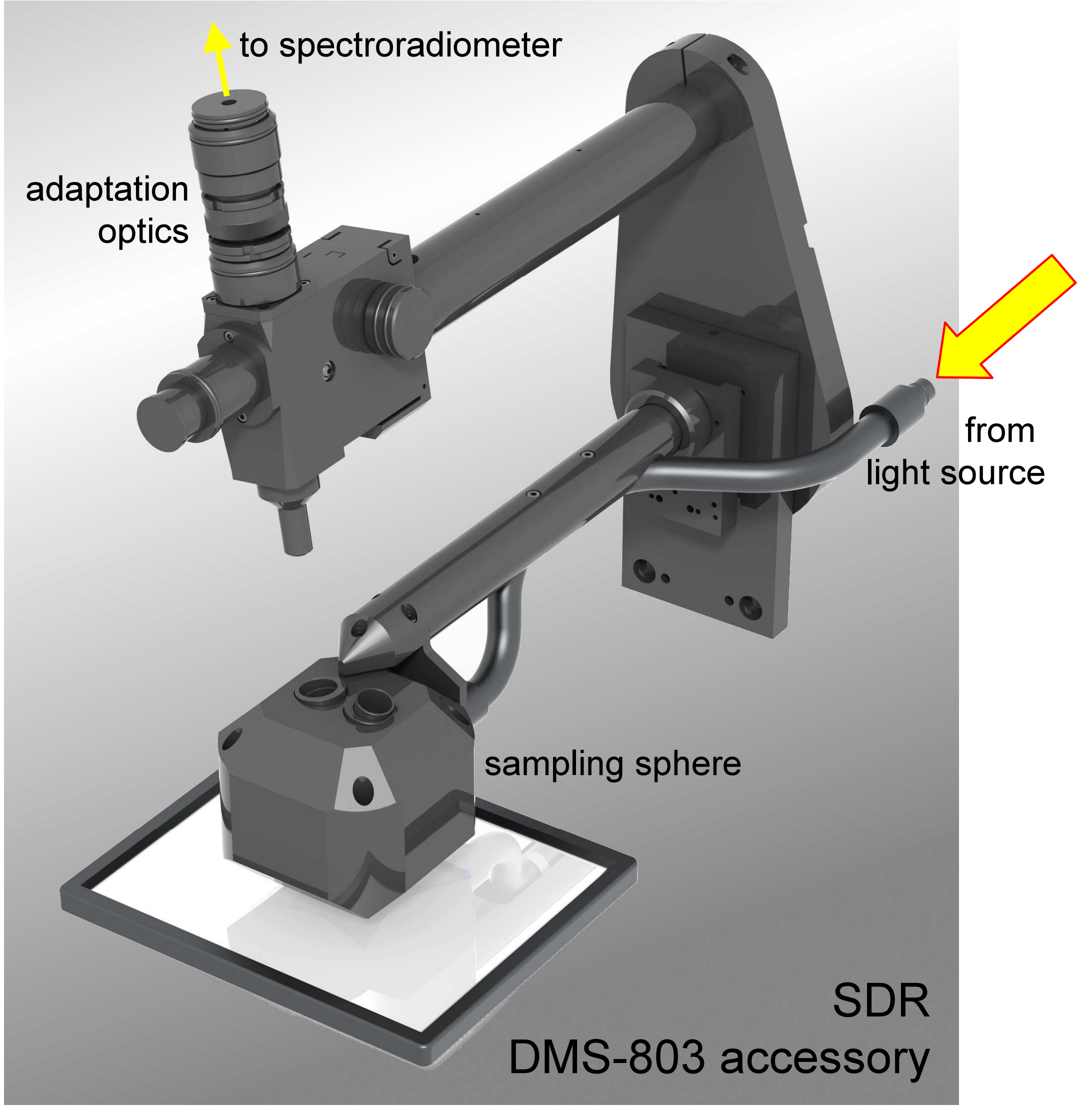
IS ISP 9000
190 cm inner
diameter



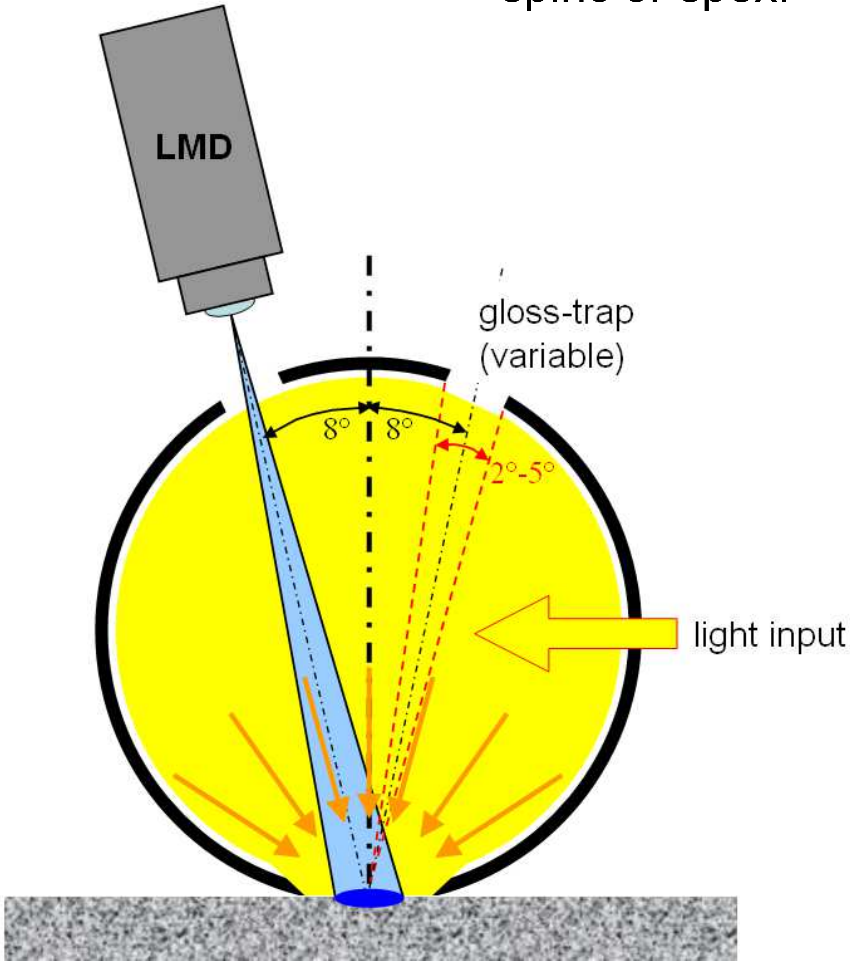
SID 2014 37.1

Uniform Hemispherical Diffuse Illumination

SDR: Measurement and evaluation of **spectral diffuse reflectance**



CIE d/8° geometry,
ideal isotropic ("diffuse") illumination,
spinc or spex.



SID 2014 37.1

... and Results

Uniform hemispherical diffuse illumination	
Indoors	
Illuminants: Light source closely approximating CIE Standard Illuminant A, CIE Standard Illuminant D65, or fluorescent lamp FL1.	
Results	**Illuminance levels**
Indoor contrast and color for a typical TV viewing room.	60 lx of hemispherical diffuse illumination, specular included.
Indoor contrast and color for typical office environment.	300 lx
Outdoors	
Illuminants: Light source closely approximating skylight with the spectral distribution of CIE Illuminant D75.	
Results	**Illuminance levels**
Daylight contrast and color	15 000 lx of hemispherical diffuse illumination, specular included.

Directional illumination	
Indoors	
Illuminants: CIE Standard Illuminant A, CIE Standard Illuminant D65, or fluorescent lamp FL1	
Results	**Illumin. levels / geometry**
Indoor contrast and color for a typical TV viewing room.	40 lx angular subtense <8°
Indoor contrast or color for typical office environment.	200 lx with display in vertical orientation, angular subtense <8°
Outdoors	
Light source approximating CIE daylight Illuminant D50; angular subtense ~0.5°, @ inclination θ_s in vertical plane. LMD normal to display surface area.	
Results	**Illumin. levels / geometry**
Daylight contrast and color	65 000 lx at an inclination angle of θ_s = 45 ° to display normal.

SID 2014 37.1

Draft document 61747-30-6

Measurement methods for **liquid crystal display modules** under ambient illumination, based on the same approach as described above for OLED displays, are currently under discussion.

Two complementary performance characteristics for LCDs:

➲ variation of luminance, contrast and chromaticity with viewing direction under dark room conditions, and

➲ performance under ambient illumination evaluated for one viewing direction;

? other combinations are possible, but are they feasible ?

Transparent displays (LCD and OLED technology)

considered for advertising purposes (shop-windows and showcases, also combined with touch-screens) and other similar applications (e.g. refrigerator doors) where **real scenes and objects are overlaid with additional visual information (augmented reality, AR).**

Two cases have to be distinguished for the display:

on-screen and **through-screen performance**.

RGB-LCDs have transmittance levels in the range of 5% to 10% (now upt to 25%),
→ the scene behind the display must be illuminated with high intensity to be sufficiently visible and

and

→ the **scattering of the display** must be controlled to avoid excessive haze and thus blurring of the image of the scene behind the screen.

On-screen performance of transparent displays is hampered by the mixing of the scene behind the display with the visual content shown on the display.

In the case of OLED displays, the on-screen visual information can be emphasized by high intensity emission of light.

Laser Display Devices, IEC 62906: Part 5-2: "Optical measuring methods of speckle", first draft August 2014.

The possibility to project images on free-form surfaces both in transmissive and reflective mode of operation with laser light sources stimulates the imagination of designers not only in the automotive industry.

A "display on demand" could be realized with transmissive projection screens that are an integral part of the dashboard area of a car. Without visual information to be displayed, this screen would be dark and look just like the surrounding plastic parts, only on demand the display becomes visible together with the visual information to be presented.

Improved diode-lasers and speckle-reduction techniques move such "conformable" (i.e. free-form) displays within reach and thus provide motivation for the standardization of laser projection displays.

Further improvements in that field will be critically depending on successful **suppression of speckle**, a visually annoying interference phenomenon and thus measurement and evaluation methods for this effect should soon be standardized.

ISO - International Organization for Standardization

ISO 9241:1992 "Ergonomic requirements for office work with visual display terminals (VDTs)" with measurement methods required for compliance evaluation.

ISO 13406-2:2001 "Ergonomic requirements for work with visual displas based on flat panels -- Part 2: Ergonomic requirements for flat panel displays"

- ➲ Flat-panel display "classes" with different numbers of permitted defect pixels.
- ➲ **Classification of Viewing Direction Range Classes** (limits for variations of luminance, contrast and chromaticity with viewing direction) and
- ➲ **Reflection Classes** (contrast reduction and glare induced by ambient light sources).

ISO 9241-3xx (ISO 9241-300:2009-06: Ergonomics of Human System Interaction), with the scope extended beyond office work (**ISO 13 406-2: 2001**) to general applications of visual display screens.

*The ISO 9241-300 sub-series establishes requirements for the ergonomic design of electronic visual displays. These requirements are stated as performance specifications, **aimed at ensuring effective and comfortable viewing conditions for users with normal or adjusted-to-normal eyesight.** Test methods and metrology, yielding conformance measurements and criteria, are provided for design evaluation.*

ISO TC159 SC4 WG2

Current activities of ISO/TC159/SC4 WG2:

➲ **revision** of ISO 9241 part 305 ("optical laboratory test methods for electronic visual displays")

➲ **extention** of ISO 9241 part 305 with respect to

standardized indoor and outdoor ambient illumination conditions,
the corresponding measurement and modeling approaches,

➲ discussion of **measurement methods for reflective displays** (ePaper) and **transparent displays**.

Standards Organisations