

Standards for Electronic Displays: Status Quo and Agenda



Green Blue
Black Red



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Contents

◆ Standards

- What is a standard ?
- How are standards made ?
- Who needs standards ?
- ...

◆ Standards for electronic displays

- Review of current standards activities
- Typical structure of a standard
- Introduction of some standards

◆ Metrology Standard for Reflective LCDs Review of the Status

◆ Outlook

Standards for Electronic Displays

What is a Standard ?

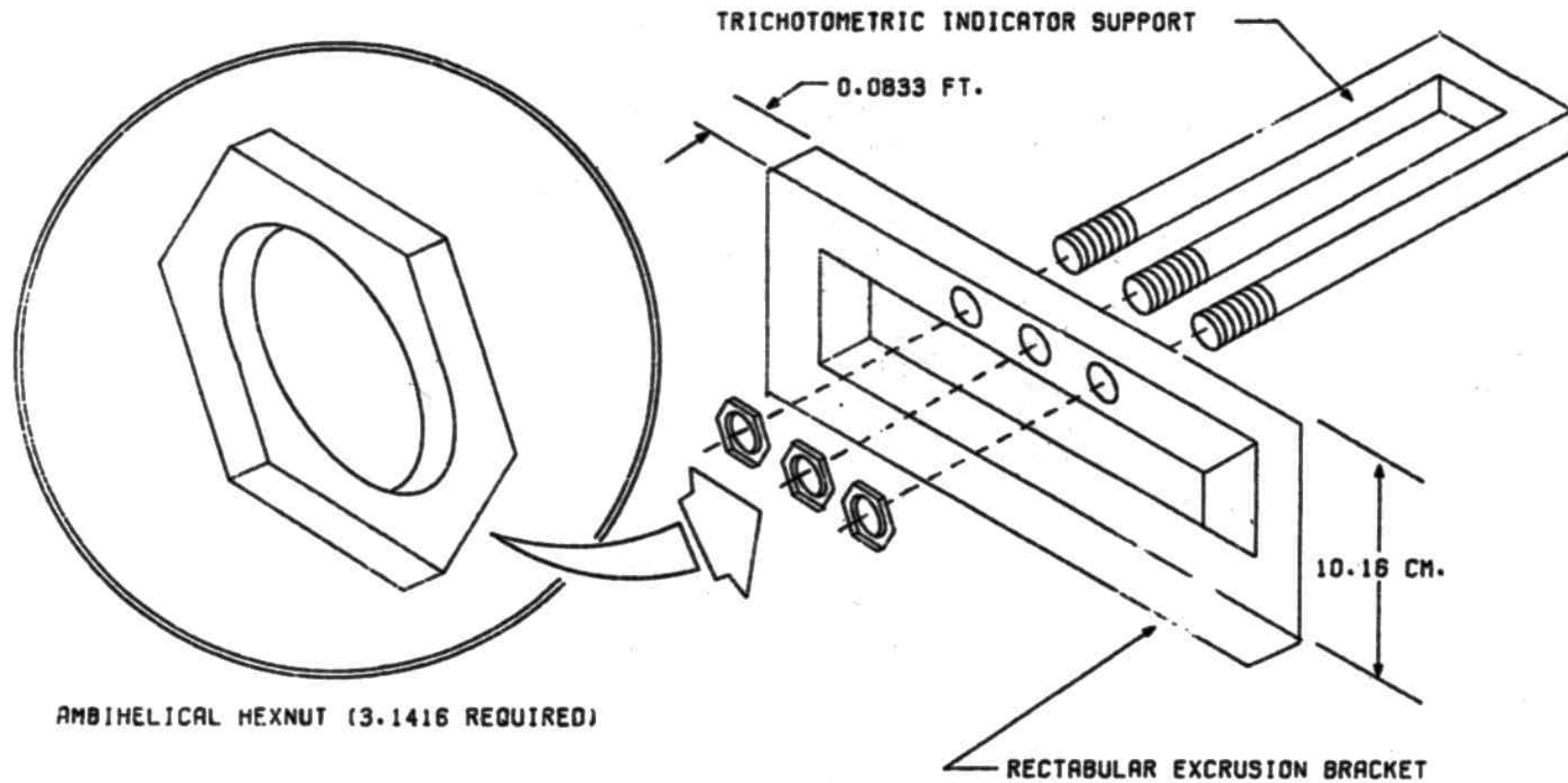
- ◆ An agreed basis for communication of technical data, on a national and international level
- ◆ Definition of mechanical, electrical, data and other interfaces "... to make things fitting ..."

Black Red Green Blue

- ◆ Definition of **terminology**, letter symbols, measurement and evaluation methods, etc.
- ➔ **Understanding between communicating parties in industry, commerce and daily life**



Definition of the Interface



... to make things fitting !?

NEC-Mitsubishi Sues ViewSonic for Overstating Contrast Ratio of LCD Monitors

Norwalk, Connecticut, March 7, 2003

On November 15, 2002, NEC-Mitsubishi Electronic Display filed a complaint for injunctive relief and damages against ViewSonic Corporation in the United States District Court, Northern District of Illinois. NEC-M's public relations department is now alerting individual members of the trade press to the suit.

The complaint alleges that ViewSonic has been engaging in "a false, misleading, and deceptive marketing campaign designed to promote its LCD monitor product line.... ViewSonic's false and misleading marketing campaign consists of unsubstantiated and inconsistent representations as to the contrast ratio specifications of ViewSonic's LCD monitors." Later in the complaint NEC-M alleges, "As a result of the material, false, misleading and inconsistent representations of fact described, NEC-M's existing and potential customers have been confused, mistaken or deceived and will likely be confused, mistaken or deceived in the future." NEC-M asks, in part, for injunctive relief and "actual and compensatory damages in an amount to be determined, but in excess of \$1,000,000."

How reliable are Standards ?

- ◆ Standards may contain errors, they may use different terms, definitions and symbols, etc.
- ➔ Standards are no holy cows !

How old do Standards get ?

- ◆ Standards need care and update to stay alive and applicable
- ➔ In rapidly developing areas permanent maintenance is required (e. g. electronic display devices)

How are Standards made ?

- ◆ The actual work is done in "working groups"
- ◆ The working groups comprise representatives from all interested groups:
 - device and component manufacturers (suppliers) ,
 - users (corporate and private customers),
 - metrology instrumentation manufacturers
 - etc.
- ◆ The working groups provide proposals for voting on national or international level (several iterations possible)
- ◆ If an agreement has been reached (e.g. 2/3 majority) the standard is accepted and published

Who is making standards ?

- ➔ Those who do participate in the working groups ...
- ➔ Those who consider it worthwhile ...
- ➔ Those who invest in it ...

How can *inadequate standards* be avoided ?

- ➔ **By voting NO for a while, if there is a rejecting majority
(see e.g. ISO 13406-2 !) ...**
- ➔ **By providing experts and significant contributions,
by investing time and efforts ...**

Who uses Display Standards ?

◆ **Manufacturer of Displays / Display Components**

- Research and Development (metrology),
- Quality Control and Assurance,
- **Product Specification (⇒ Data Sheet !).**

◆ **Customers - Users (Private / Corporate)**

Manufacturer of Electronic Devices

(i.e. System Integrators / OEMs)

- Product selection, purchasing decision,
- Incoming Inspection,
- Evaluation and Rating of the Final Product.

◆ **Public Health & Safety Institutions**

◆ **Test Houses**

- Certification of Minimum Ergonomic Performance

Economical Considerations

Significant and unambiguous evaluation and specification of product performance is needed:

- **as a basis for product comparison and selection**
(depending on the application),
- **as basis for purchasing decisions (corporate / private),**

and thus

- ➔ **to avoid distortion of commercial competition,**
- ➔ **to avoid disappointed customers & lawsuits ...**

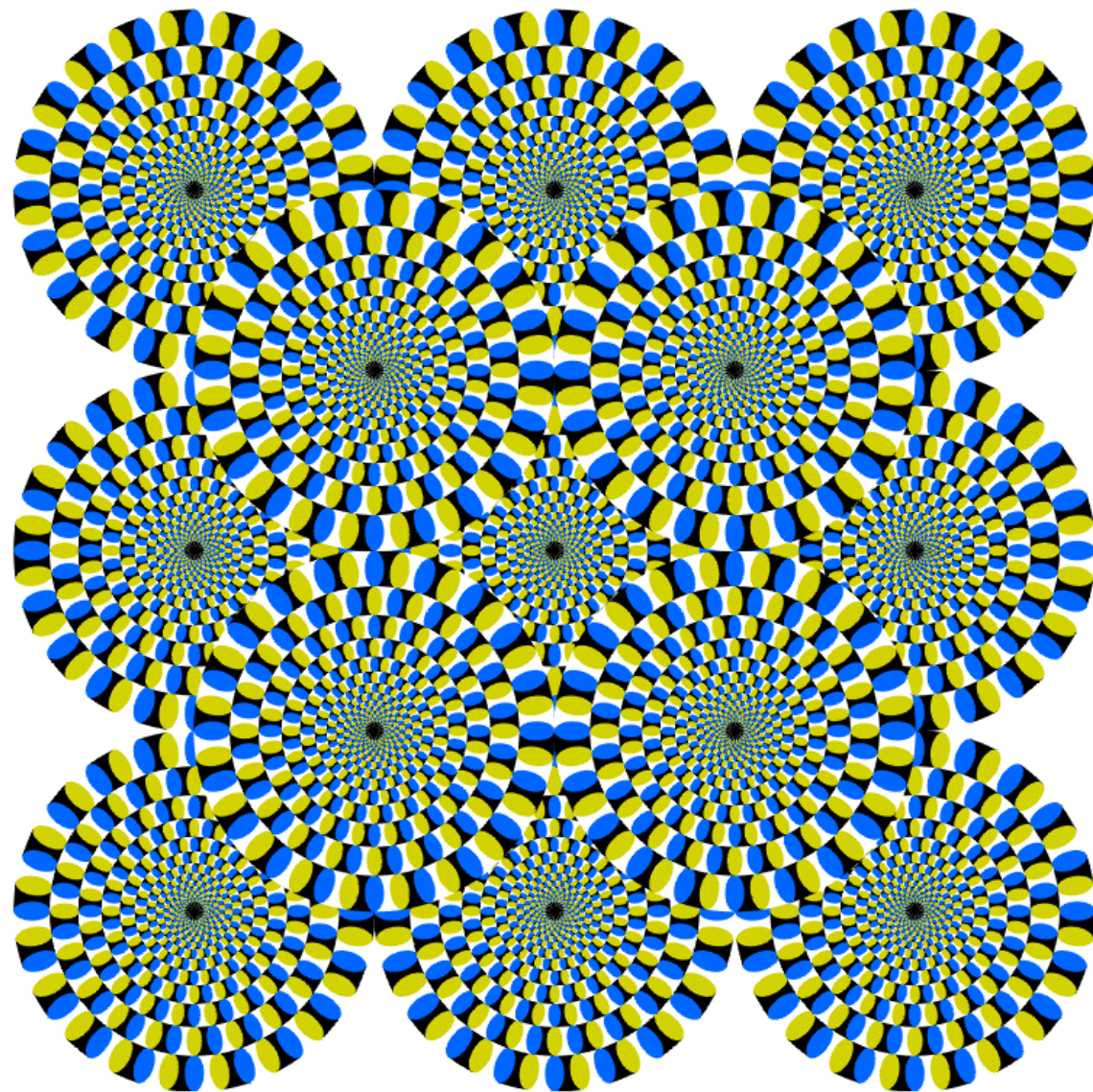


ISO / IEC Directives, Part 3: Drafting and Presentation of International Standards

The objective of a ***data sheet*** is to define clear and unambiguous provisions in order to facilitate international trade and communication.

To achieve this objective, the ***data sheet*** shall be as **complete** as necessary; **consistent**, **clear** and **concise**; and **comprehensible** to qualified persons who have not participated in its preparation.

Standards for Electronic Displays



Display Standards Organizations & Activities

- **AAPM: American Association of Physicists in Medicine**
- **ANSI: American National Standards Institute**
- **ASTM: American Society for Testing and Materials**
- **CIE: Commission Internationale de l'Eclairage (*Colorimetry of Displays*)**
- **CORM: Council for Optical Radiation Measurements (USA)**
- **EIA: Electronic Industries Association (USA)**
- **JEITA: Japan Electronics & IT Industries Association (former: EIAJ)**
- **IEC: International Electrotechnical Committee (LCDs, PDPs, OLEDs, etc.)**
- **IEEE: Institute of Electrical and Electronics Engineers**
- **ISO: International Organization for Standardization (*Visual Ergonomics, etc.*)**
- **NEMA: National Electrical Manufacturers Association**
 - DICOM Grayscale Standard Display Function
- **NIDL: National Information Display Laboratory (USA)**
- **SAE: Society of Automotive Engineers**
- **SMPTE: Society of Motion Picture and Television Engineers**
- **VESA: Video Electronics Standards Association (USA)**

Flat Panel Display Measurement Standard

Reversal of effect

**The variety of different standardization activities
- if not properly synchronized -
may provide more confusion than help !**

⇒ **Contradictory terms and definitions**

⇒ **Contradictory measurement methods**

Approach of marketing division:

Choose the "standard" that provides the best numbers ?

Who could support a standards synchronization ?

SID ? (see J. Greeson: "Display Standards in Trouble", ID Magazine 12(1994), p. 24)

Nobody will do it for you ⇒ do it yourself

ASTM Color & Appearance Measurement

- D 2244-02e1 Test Method for Calculation of Color Tolerances and Color Differences From Instrumentally Measured Color Coordinates
- **E 167-96 Practice for Goniophotometry of Objects and Materials**
- E 179-96 (2003) Guide for Selection of Geometric Conditions for Measurement of Reflection and Transmission Properties of Materials
- E 259-98 (2003) Practice for Preparation of Pressed Powder White Reflectance Factor Transfer Standards for Hemispherical and Bi-Directional Geometries
- E 275-01 Practice for Describing and Measuring Performance of Ultraviolet, Visible, and Near Infrared Spectrophotometers
- E 284-03a Terminology of Appearance
- E 308-01 Practice for Computing the Colors of Objects by Using the CIE System
- E 387-84 (1995)e1 Test Method for Estimating Stray Radiant Power Ratio of Spectrophotometers by the Opaque Filter Method
- **E 691-99 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method**

ASTM Color & Appearance Measurement

- E 1331-96 (2003) Test Method for Reflectance Factor and Color by Spectrophotometry Using Hemispherical Geometry
- E 1336-96 (2003) Test Method for Obtaining Colorimetric Data from a Visual Display Unit by Spectroradiometry
- E 1345-98 (2003) Practice for Reducing the Effect of Variability of Color Measurement by Use of Multiple Measurements
- E 1349-90 (1998) Test Method for Reflectance Factor and Color by Spectrophotometry Using Bidirectional Geometry
- E 1392-96 (2002) Test Method for Angle Resolved Optical Scatter Measurements on Specular and Diffuse Surfaces
- E 1455-03 Practice for Obtaining Colorimetric Data from a Visual Display Unit Using Tristimulus Colorimeters
- E 1682-96 (2001) Guide for Modeling the Colorimetric Properties of a Visual Display Unit
- E 1808-96 (2003) Guide for Designing and Conducting Visual Experiments
- G 138-03 Test Method for Calibration of a Spectroradiometer Using a Standard Source of Irradiance

SMPTE

Society of Motion Picture and Television Engineers

- **RP 145-1999** *SMPTE C Color Monitor Colorimetry*
- **RP 166-1995** *Critical Viewing Conditions for Evaluation of Color Television Pictures*
- **RP 167-1995** *Alignment of NTSC Color Picture Monitors*
- **RP 133-1991** *Specifications for Medical Diagnostic Imaging Test Patterns for Television Monitors and Hard Copy Recording Cameras*

ISO Technical Committees (excerpt from 188)

- **JTC 1** Information technology
- **TC 20** Aircraft and space vehicles
- **TC 22** Road vehicles
- **TC 23** Tractors & machinery for agriculture and forestry
- **TC 36** Cinematography
- **TC 42** Photography
- **TC 130** Graphic technology
- **TC 159** Ergonomics

ISO Standardization

TC 42 **Photography**

Dec. 2003:

Proposal for formation of a *TC on Flat Panel Display Modules*

TC 130 **Graphic technology**

ISO 12646:2004

Graphic technology - Displays for colour proofing - Characteristics and viewing conditions

ISO Standards: Ergonomics of Electronic Displays

◆ **ISO 9241-1/17 (under revision)**

Ergonomic requirements for office work with visual display terminals

◆ **ISO 13406-1/2**

Ergonomic requirements for work with visual displays based on flat panels
(i.e. LCD-monitors)

◆ **ISO 15008**

Road vehicles — Ergonomic aspects of transport information and control systems — Specifications and compliance procedures for in-vehicle visual presentation

◆ **ISO 4513**

Road vehicles — Visibility — Method for establishment of eyellipses for driver's eye location

ISO Standards: Ergonomics of Electronic Displays

ISO 13406 revised → ISO 9241-301 ... 307

Ergonomic Requirements and Measurement Techniques for Electronic Visual Displays

- Part 301 *Introduction*
- Part 302 *Terminology*
- Part 303 *Ergonomic requirements*
- Part 304 *User performance test methods*
- Part 305 *Optical laboratory test methods*
- Part 306 *Field assessment methods*
- Part 307 *Analysis and compliance test methods*

Revisions to ISO 13406-2 / 9241

- Image formation times (IFTs)
 - Full-swing transitions are best-case IFTs
 - Moving images feature more transitions between intermediate gray-levels
 - ➔ **Combinations of min. 20 or 72 start and end-levels**
- Viewing-direction classes (4 classes)
 - Class IV is *privacy-screen* (not included in scope of STD)
 - Class III represents *absolute minimum requirement*
 - remaining 2 classes not sufficient
- Pixel-fault classes
 - Class I zero defects (**that's what we all want !**)
 - Class II specified # defects per million pixels (# too large)
 - Class III/IV # defects too high

Revisions & Extensions to ISO 13406-2 / 9241

- Viewing-direction classes (4 classes)
 - Class IV VC of 15° (absolute minimum)
 - Class III VC of 30° (comfortable range) (ITU recmd. 4 CRT-TV)
 - Class II VC of 45° (multi-user, e.g. TV) (29% distortion @ 45°)
 - Class I VC > 45° (public address)
- Contrast under ambient illumination (@ design VD)
 - with diffuse illumination of e.g. 250 lx
(large aperture source, specular excluded)
 - with directional illumination of e.g. 2000 cd/m²
(small aperture source, specular included)
- Viewing-cone = range of viewing-directions that is usable for the *intended application* under realistic conditions (e.g. amb. illumin.)
- Realistic specification of viewing-cone

IEC Technical Committees and Subcommittees (total of approx. 180)

◆ **SC 62B**

DIAGNOSTIC IMAGING EQUIPMENT

◆ **TC 100**

AUDIO, VIDEO AND MULTIMEDIA SYSTEMS AND EQUIPMENT

◆ **TC 110 *FLAT PANEL DISPLAY DEVICES***

became a full Technical Committee in December 2003

IEC Electronic Display Standards - TC 110

- **LCDs** IEC 61747- N, IEC 61966 - 4
- **PDPs** IEC 61988 *Plasma Display Panels*
 - Part 1 *Terminology and letter symbols*
 - Part 2.1 *Measuring methods – optical*
 - Part 2.2 *Measuring methods – opto-electrical*
 - Part 3 *Guidelines of mechanical interface*
 - Part 4 *Environmental, endurance and mechanical test methods*
- **OLEDs** IEC 62341-1/6 *Organic Electroluminescent Displays*
- **MEMs ...**

**IEC SC47C recently transformed into a full technical committee,
TC 110: Flat Panel Display Devices**

IEC Standards for LCDs

◆ **TC110/WG2 IEC 61747- N:**

Transmissive LCDs (cells, modules, monochrome, color, ...)

status: accepted

◆ **TC100 Multimedia syst. & eqpmnt. IEC 61966**

*Colour measurement and management – Part 4:
Equipment using liquid crystal display panels*

status: accepted

◆ **Electronics Industry Association of Japan (now JEITA)**

EIAJ ED-2522, ED-2511, ... LCDs

EIAJ ED-2523 **MM Reflective LCDs**

status: accepted

IEC TC110 - Flat Panel Displays

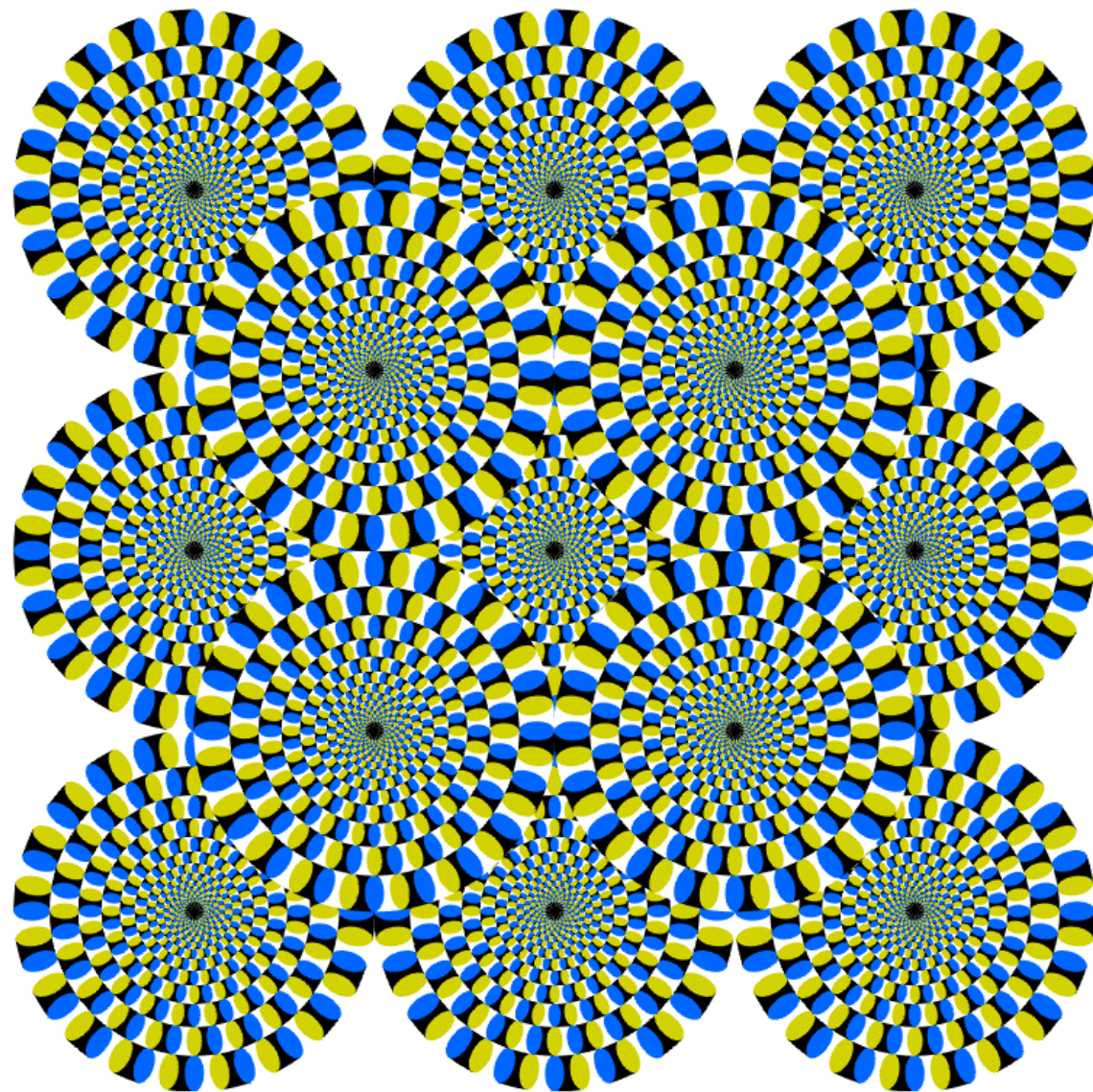
WG2 - Document Series 61747: LCDs (transmissive)

- 1 *Generic Specifications*
- 2 *Terminology and Letter Symbols*
- 3 *Sectional Specifications, Blank Detail Specifications*
- 4 *Essential Ratings and Characteristics*
- 5 *Environmental Endurance Tests*
- 6 *Visual Inspection*
- 7 *Measuring Methods*

➔ MM for matrix-type LCD-modules - transmissive
(CD for voting in preparation)

➔ **New Work Item: MM for Reflective LCDs !**

Standards for Electronic Displays



Standards for Electronic Displays

INTERNATIONAL ELECTROTECHNICAL COMMISSION

TECHNICAL COMMITTEE NO. 47: SEMICONDUCTOR DEVICE

SUB - COMMITTEE NO. 47C:
OPTOELECTRONIC DISPLAY AND IMAGING DEVICES

PROPOSAL ON FPD BY PACT
~ COMMENTS OF SECRETARY/SC47C ~

1. Progress

Nov. 1995 PACT (President's Advisory Committee of future Technology) submitted comments and recommendations on standardization of FPD. (See attached)
The contents of the recommendations as follows:

Recommendations

1. A number of subjects in FPDs have been identified which are important and require standardization urgently. The IEC should start standardization of these subjects.
2. The first important and urgent is **reflective LCDs**.

Metrology Standards for Reflective LCDs

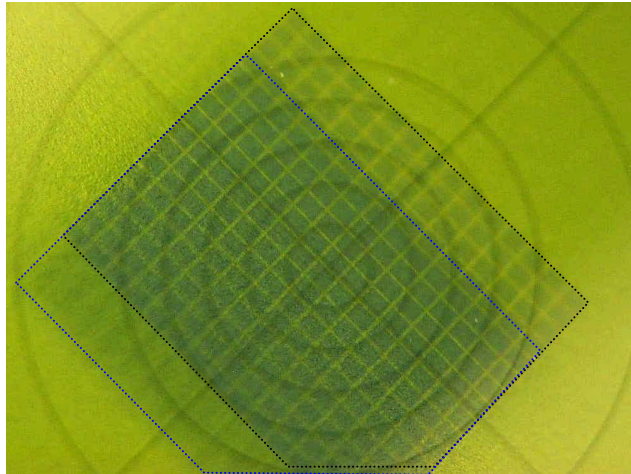
- ◆ **Reflective LCDs in production since mid-seventies**

- ◆ **Measurement and evaluation of reflective LCDs is not easy**
(e. g. IDRC 1991 Digest, p. 195, SID 2001 Digest, p. 322, etc.)

- ◆ **Two ways of measurement actually practiced:**
 - **directional illumination → high contrast values**
 - **"diffuse" illumination → lower contrast values**

- ⇒ **distortion of competition (if not properly specified)**

Rating of Reflective LCDs



Contrast-ratio of reflective STN-LCD

Measuring Setup 1: $C_R = 3:1$
???

Measuring Setup 2: $C_R = 12:1$

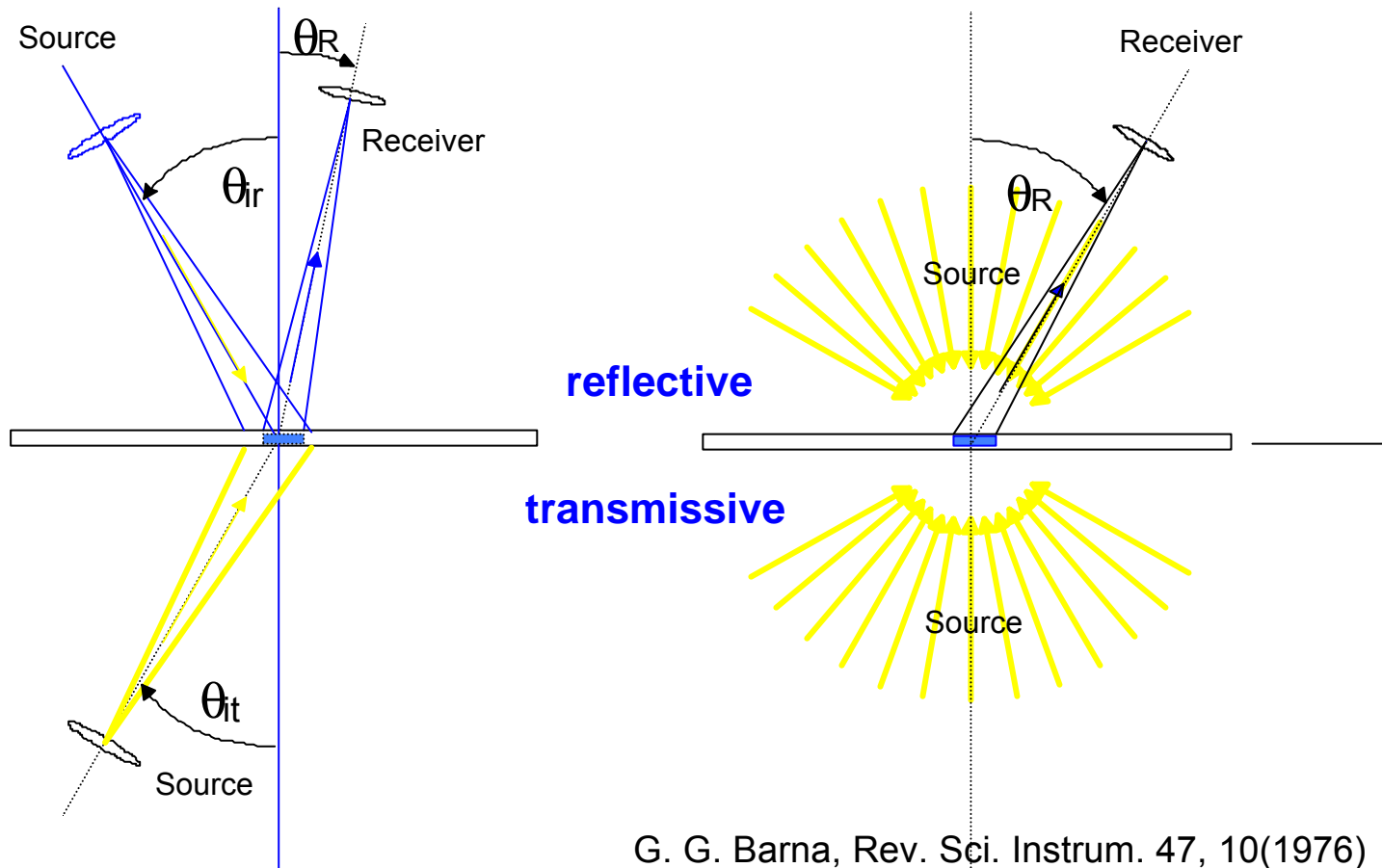
Both setups are performing properly

Missing specifications of ...

- Illumination:
- ♦ Geometry (angular and lateral distributions)
 - ♦ Spectrum, stability, ...
- Detection:
- ♦ Size and location of field-of-view (measuring spot)
 - ♦ Direction of measurement (viewing-direction)

➔ **To make product specifications comparable !**

Standards for Electronic Displays



G. G. Barna, Rev. Sci. Instrum. 47, 10(1976)

Source at direction \mathbf{q}
 $\theta_{ir} + \theta_R = 30^\circ$ ($\theta_{ir} \neq \theta_R$)
 $\theta_{it} = \theta_R$

reflective
 transmissive

Light incidence from large solid-angle
 (e.g. $\theta_{max} \geq 70^\circ$)

MEASUREMENT METHODS FOR REFLECTIVE LCDs

- ◆ **Contrast of reflective LCDs is *not an intrinsic sample property***
- ◆ **Contrast and reflectance *not meaningful without detailed specification of the apparatus and the setup !***

Measurement Methods need to be

- **robust** = insensitive to small parameter variations
- **reproducible** = not dependent on time, location, apparatus, operator, etc.
- **unambiguous** = arrangements, accessories and procedures for measurement and evaluation clearly described
- **significant / meaningful** = related to what we see (ambient)

Metrology Standards must provide:

Clear identification of how to measure which quantities

- ➔ Same basic characteristics as in transmissive case

Results for

- ◆ Detailed **characterization of the electro-optical properties** vs. *viewing-direction* (e.g. BRDF, reflectance-spectra and other data as required e.g. for subsequent numerical simulation)
- ◆ Basis for prediction of the **visual performance** in real application situations (i. e. over a wide range of different illumination situations)
- ◆ Testing the conformity with **product specifications** (i.e. acceptance screening) and/or **minimum performance requirements**

LCD-Characteristics

Electro-optical

stationary

f (Electrical Driving | VD, J)

- Luminance / Contrast / Chromaticity
- EOTF, Grey-Scale Fidelity
- Frame Response, *Flicker*

dynamic

- Image Formation Time, Transition Times
- Image Sticking Relaxation
- *Jitter* (temporal + lateral variation)

Viewing-direction effects

f (Viewing-Direction | ED, J)

- Luminance, Luminance Contrast Ratio C_R
- Chromaticity, Color Difference, etc.
- Scattering (transmission, reflection)

Lateral variations

f (Location on Display | VD, ED, J)

- Luminance (e. g. crosstalk)
- Chromaticity
- *Jitter* (lateral + temporal variation)

as a function of

Illumination

- directional, spectral and temporal distribution

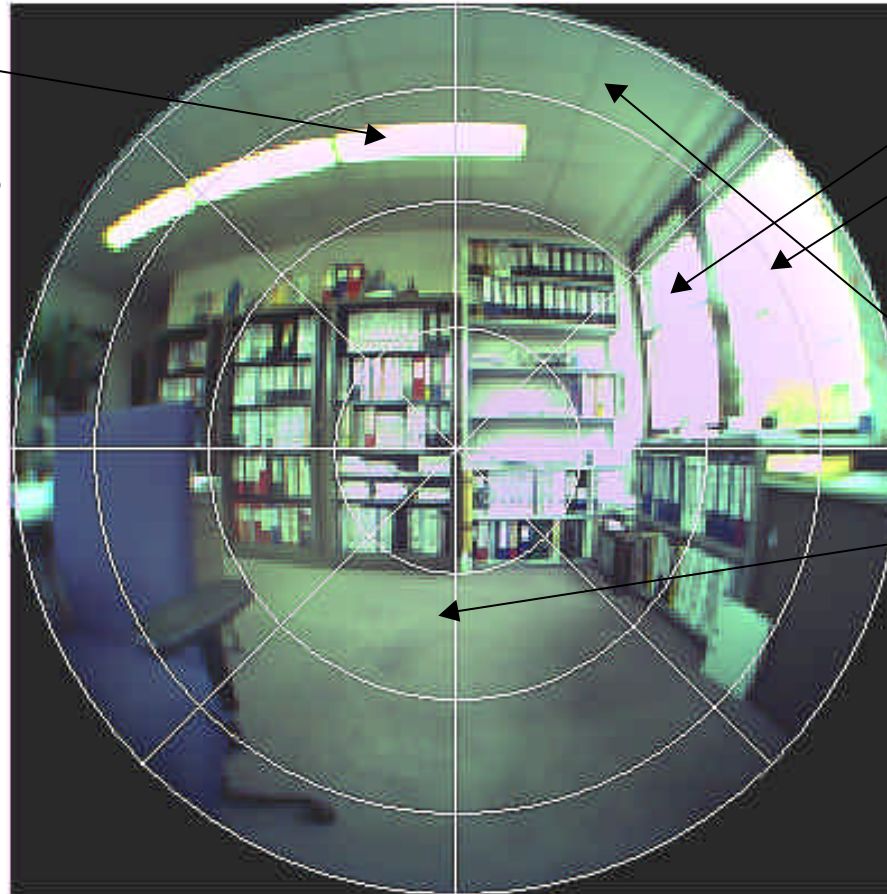
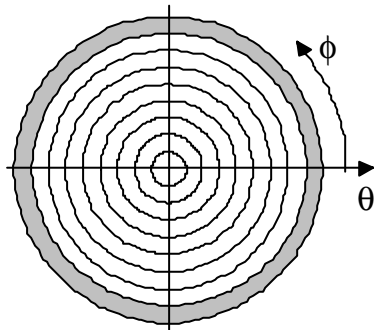
Observer

- CIE 1931 - 2° standard observer

Standards for Electronic Displays

Indoor lighting

- Fluorescent lamps
 - Incandescent lamps
 - other sources
- ~ 1 kcd/m²



Daylight
~ 10 kcd/m²

Background
(floor, ceiling)
~ 100 cd/m²

➔ Unlimited number of conditions for illuminating displays

Sources differ in

- ◆ **geometry:** location (direction), extension (size)
- ◆ **emission:** intensity, spectrum, temporal fluctuations

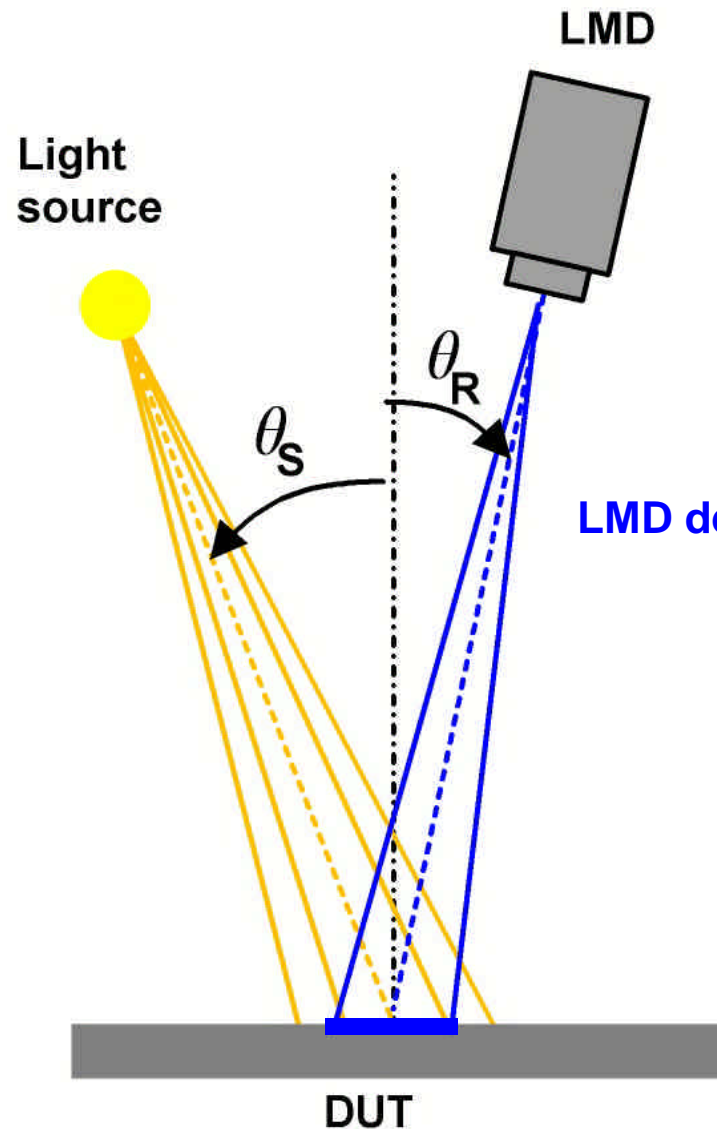
IEC 61747

MEASUREMENT METHODS FOR REFLECTIVE LCDs

Standard Measuring Conditions

- Introduction into measurement and evaluation of reflectance
- Introduction of the BRDF and its measurement
- Basic illumination geometries (according to CIE 38)
 - *directional illumination*
 - *conical illumination (intermediate state)*
 - *hemispherical illumination*
- Standard measuring geometries
 - 1 Directed illumination
 - 2 Ring-light illumination
 - 3 Conical illumination
 - 4 Hemispherical illumination

Standards for Electronic Displays



Directional illumination

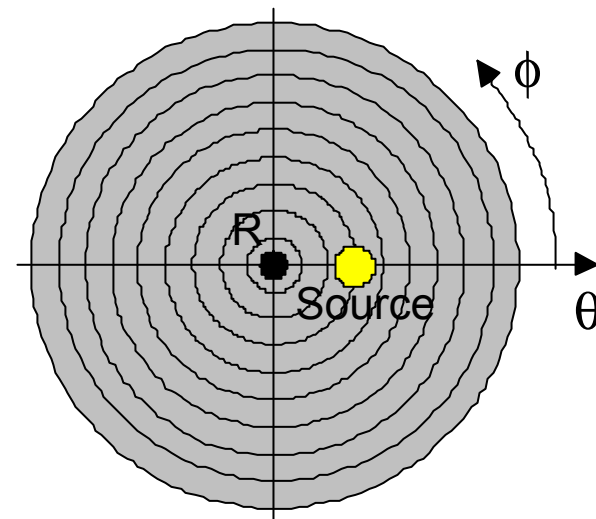
directional:

max. deviation from optical axis = $\pm 5^\circ$

No need for collimated beam

$$\theta_S + \theta_R = 30^\circ (\theta_S \neq \theta_R)$$

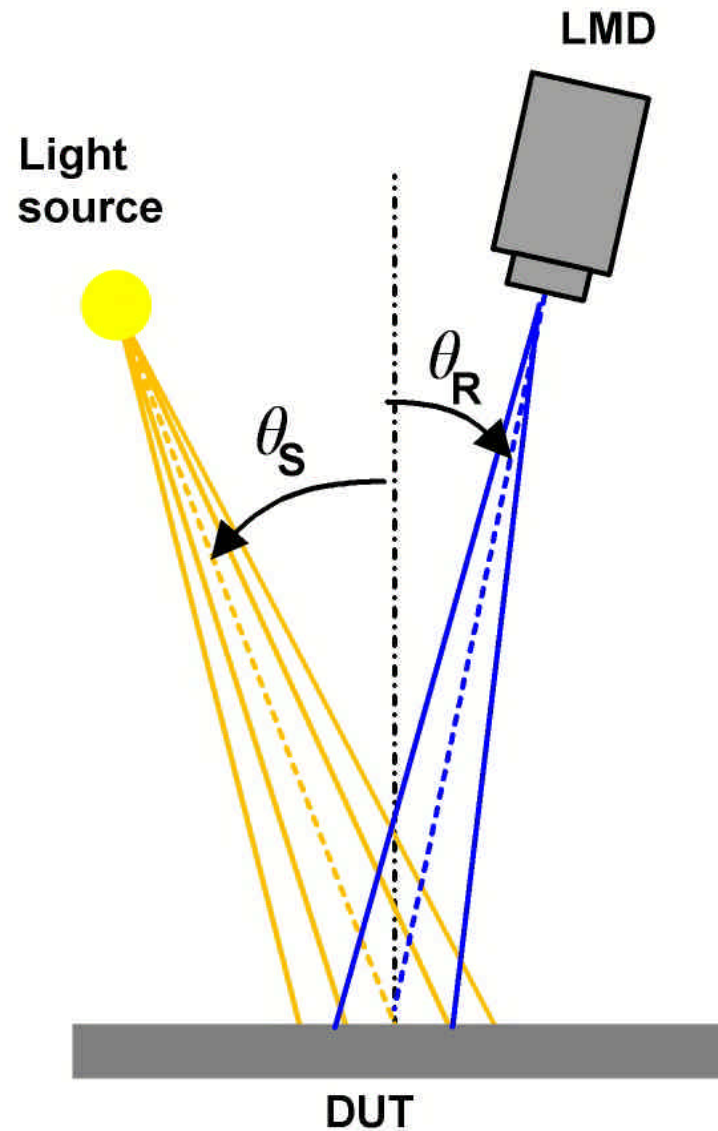
LMD determines measurement field



$$\theta_S = 30^\circ \pm 5^\circ$$

$$\theta_R = 0^\circ$$

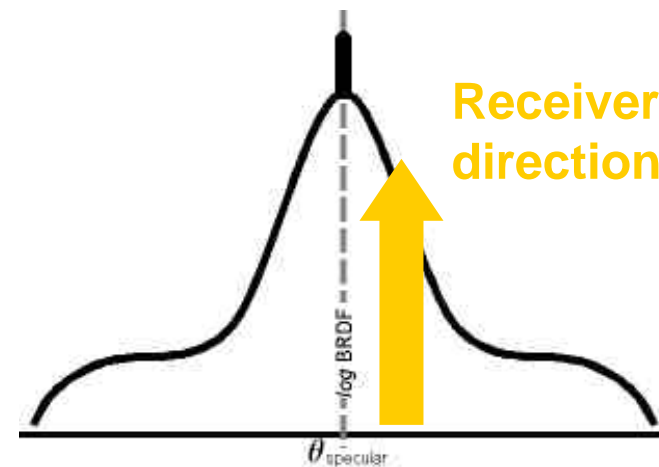
Standards for Electronic Displays



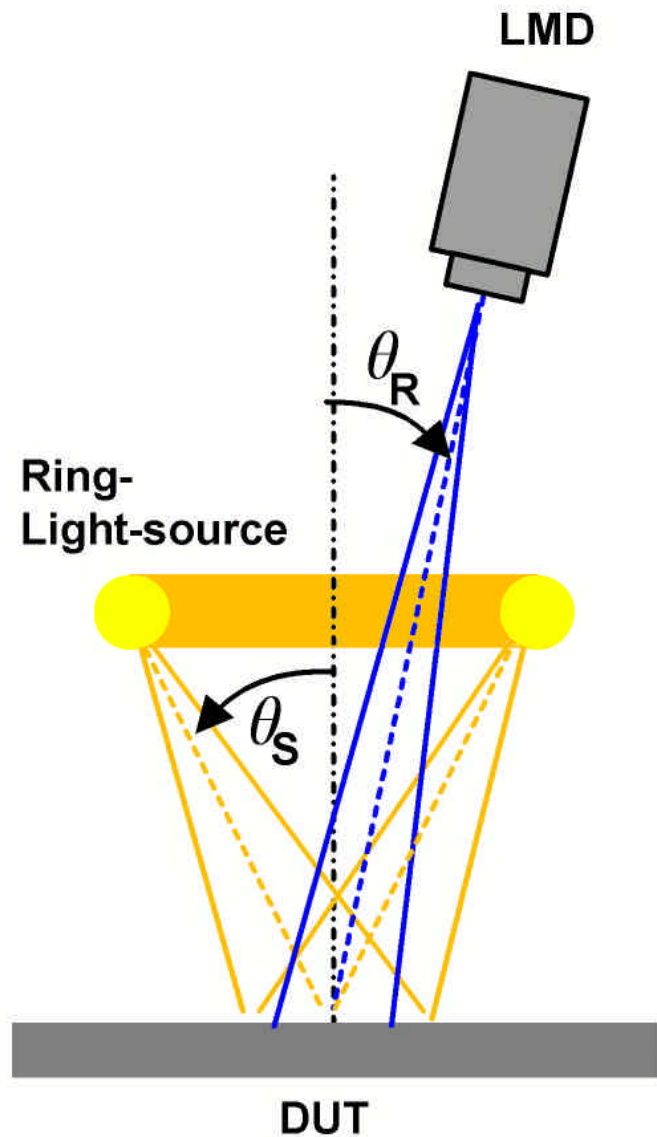
Directional illumination

Sensitivity to variations of receiver direction in the presence of haze:

high sensitivity - receiver on slope of haze

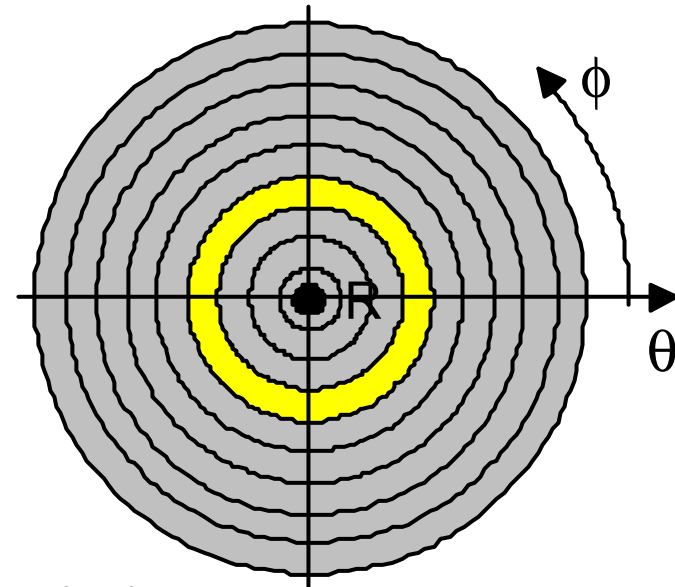


Standards for Electronic Displays



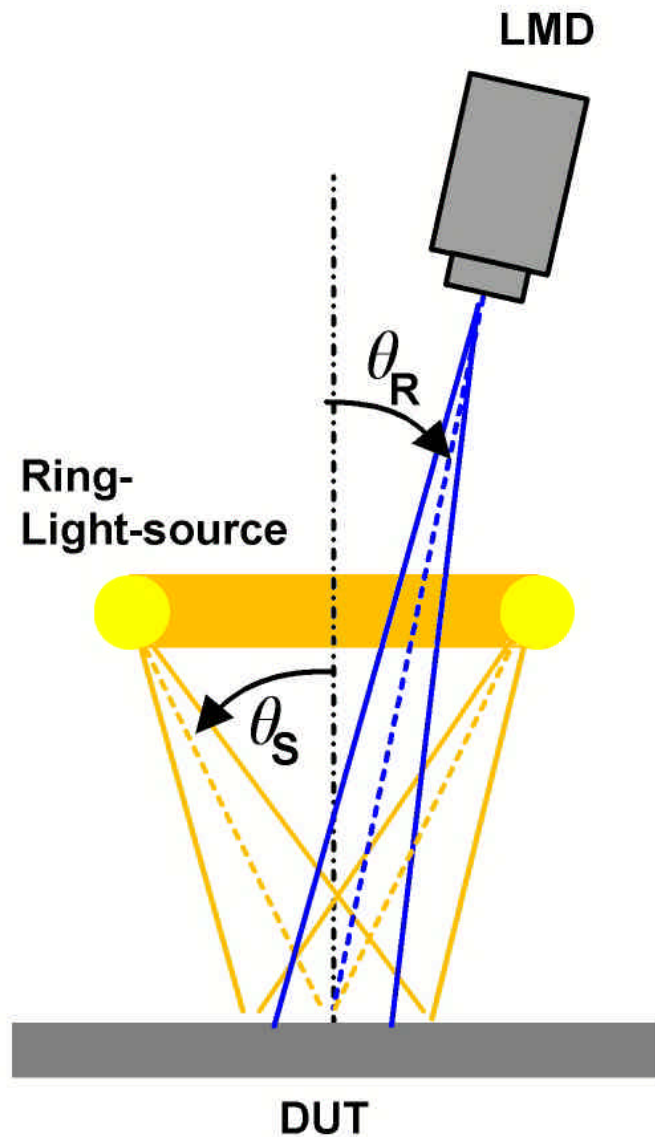
Ring-light illumination

- directional in inclination:
max. deviation from optical axis = $\pm 5^\circ$
- rotational symmetry in azimuth



$$\theta_S = 35^\circ \pm 5^\circ$$
$$\theta_R = 0^\circ$$

Standards for Electronic Displays

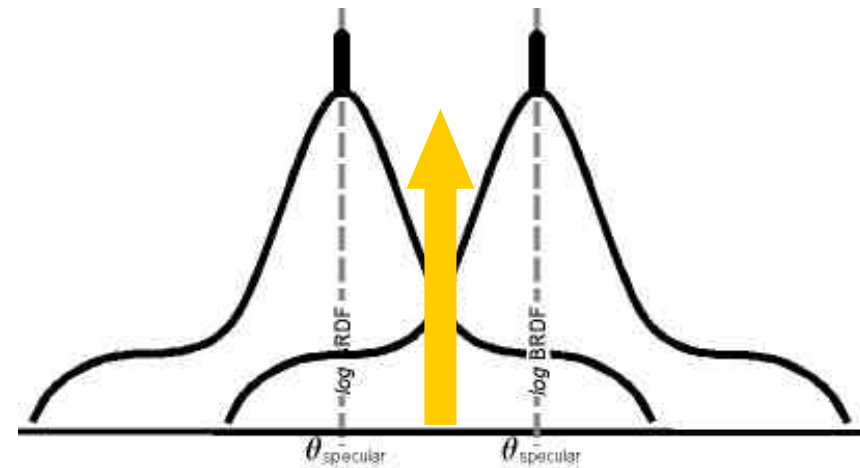


Ring-light illumination

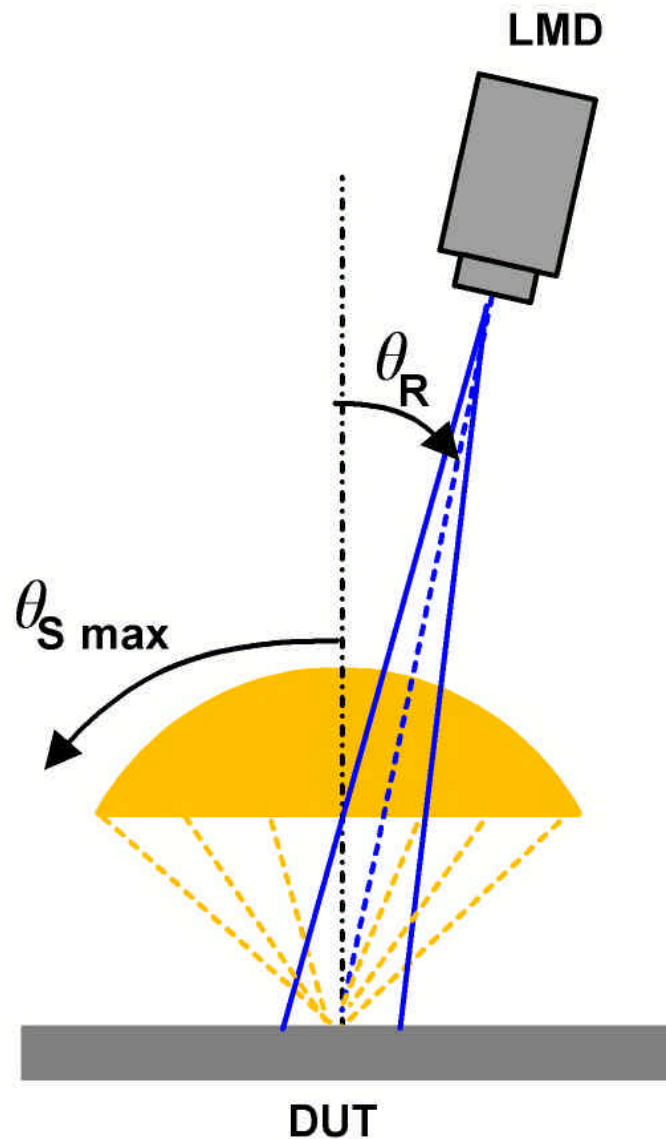
Sensitivity to variations in receiver direction in the presence of haze:

moderate sensitivity - receiver on slope of two haze curves

→ some compensation
best if receiver normal, $\theta_R = 0^\circ$



Standards for Electronic Displays



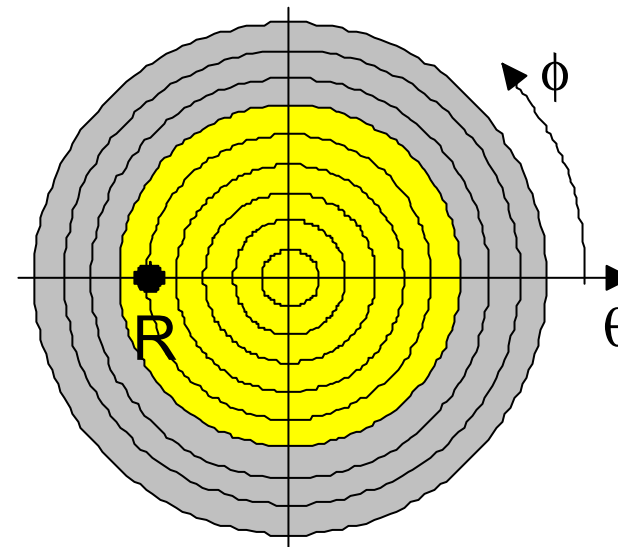
Conical illumination

Sensitivity to variations in receiver direction
in the presence of haze:
low sensitivity - receiver on plateau of BRDF

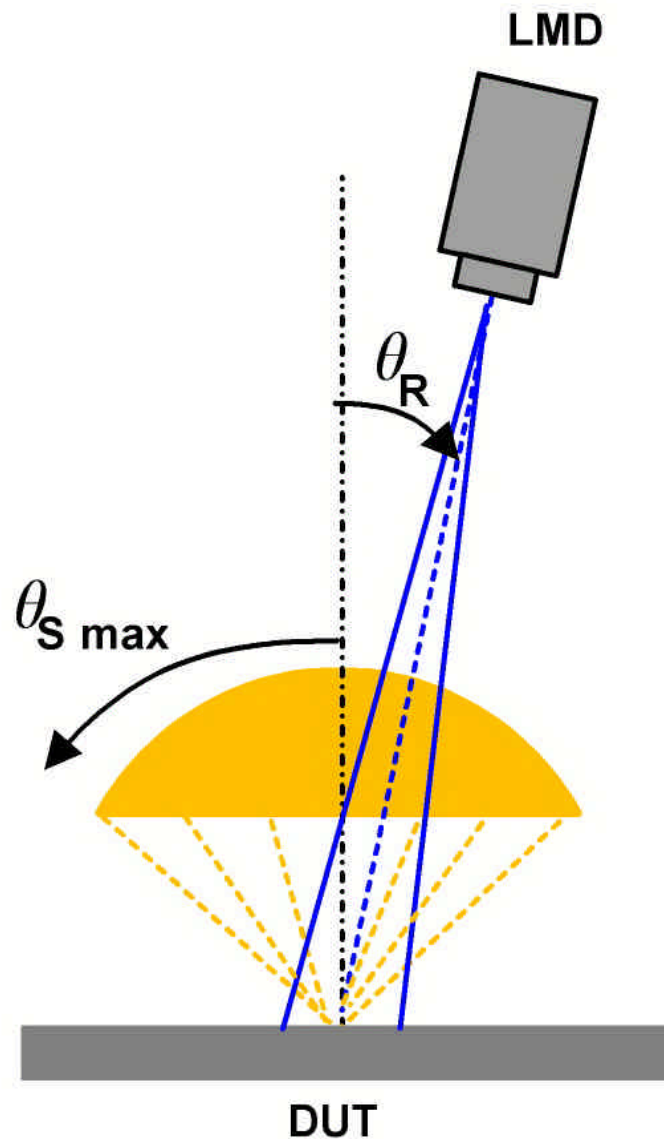
Aperture in illumination required for receiver

CAUTION

Haze extends into direction of receiver
→ size of aperture affects reflectance



Standards for Electronic Displays



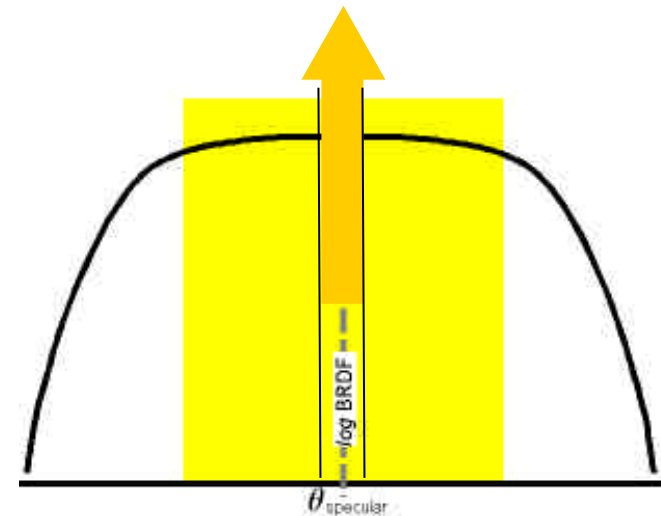
Conical illumination

Sensitivity to variations in receiver direction
in the presence of haze:
low sensitivity - receiver on plateau of BRDF

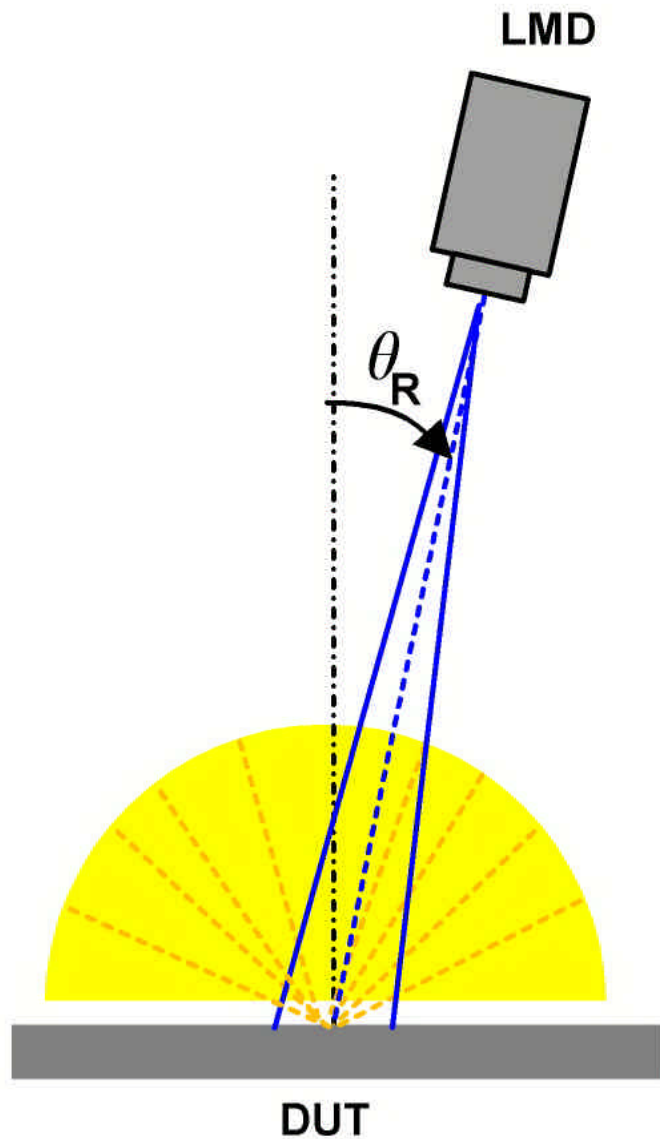
Aperture in illumination required for receiver

CAUTION

Haze extends into direction of receiver
→ size of aperture affects reflectance



Standards for Electronic Displays



Hemispherical illumination

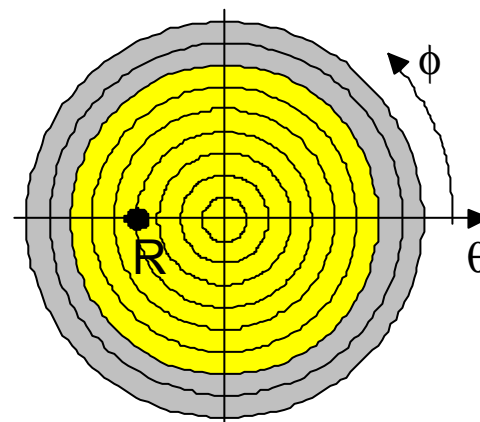
Luminous intensity $I(\theta = 70^\circ) \geq 0.5 I_{\max}$

$\theta_{\max} \geq 70^\circ$

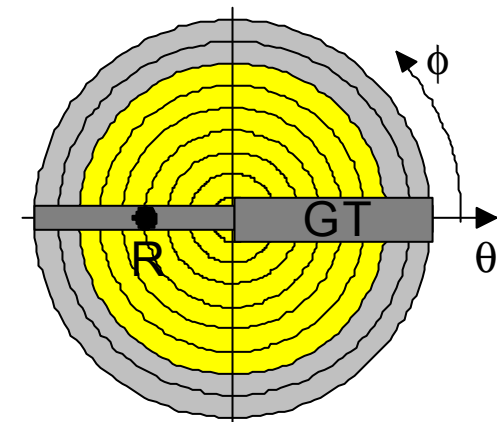
For each receiver direction there is a specular illumination source !

Alternatives

Inclusion / exclusion of specular reflections e.g. from front surface

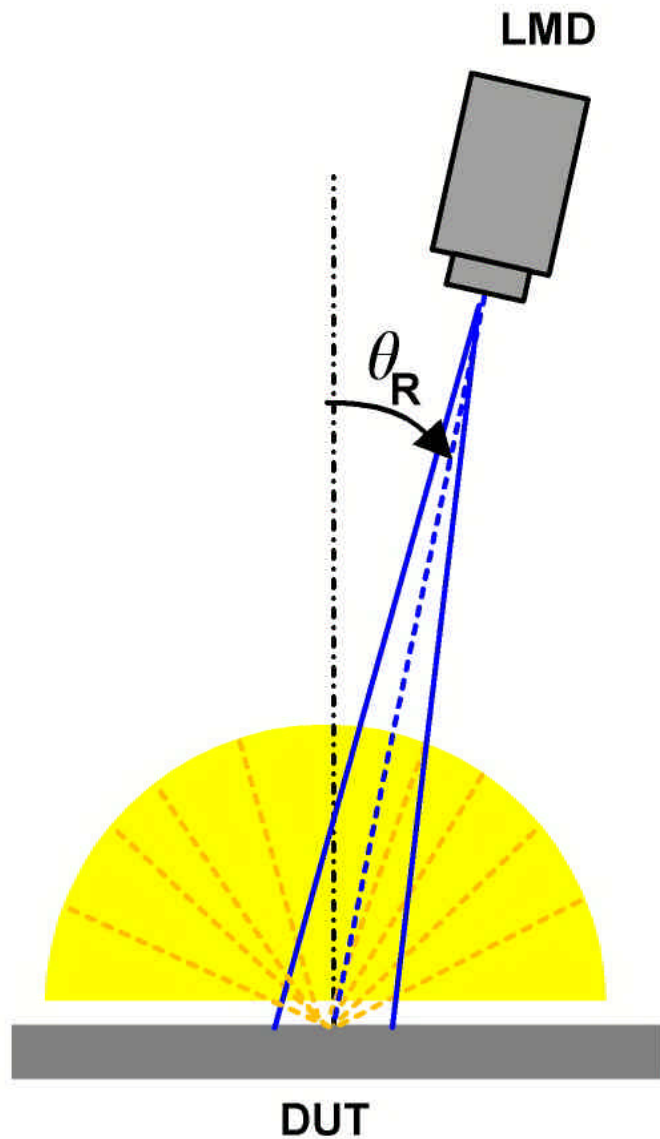


Spinc



Spex (gloss trap)

Standards for Electronic Displays



Hemispherical illumination

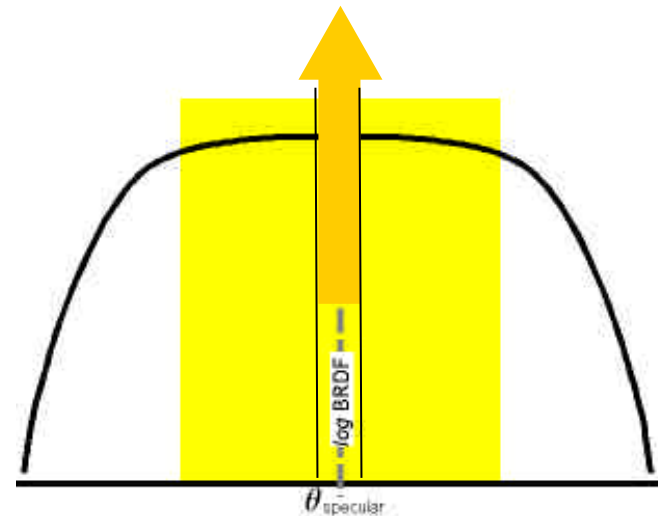
CAUTION

Haze extends into plane of receiver inclination

→ size of gloss-trap affects reflectance

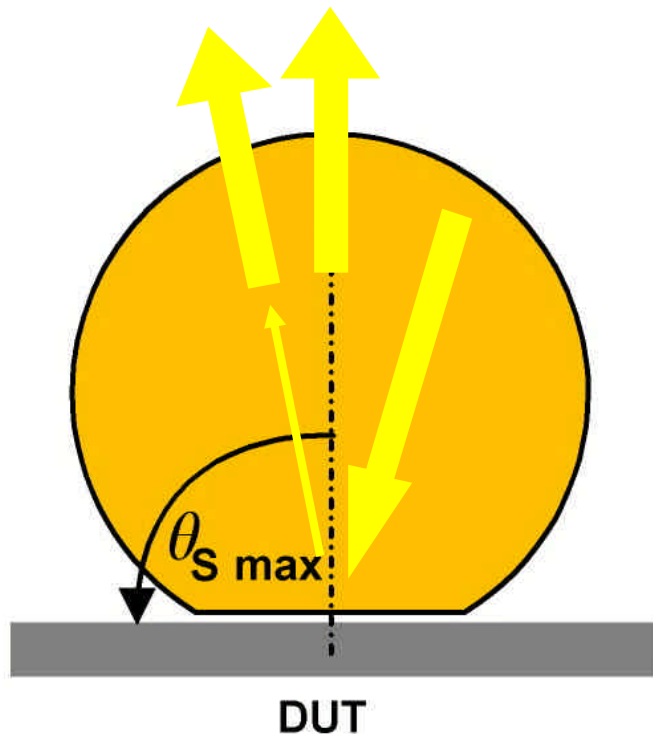
→ detailed specification of
gloss-trap geometry required !

(SID'01 Digest p. 322)



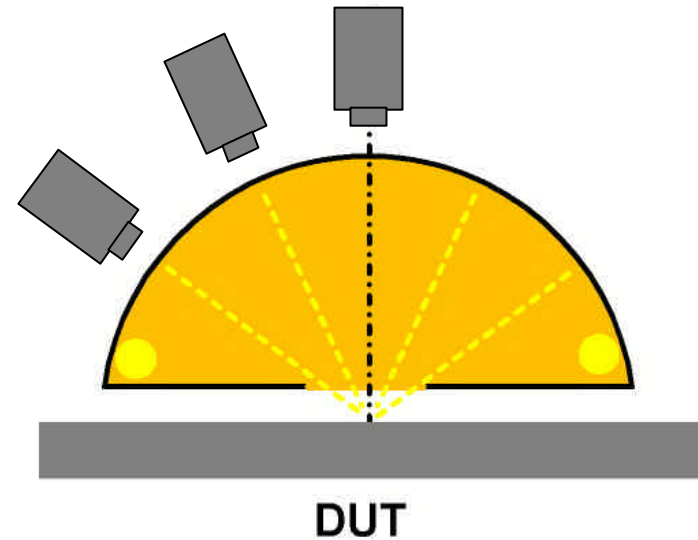
Hemispherical illumination

Spinc / Spex



Basically easy realization of uniform hemispherical illumination: styrofoam boxes, spheres, etc.

Receiver aperture chosen to in/exclude specular surface reflections



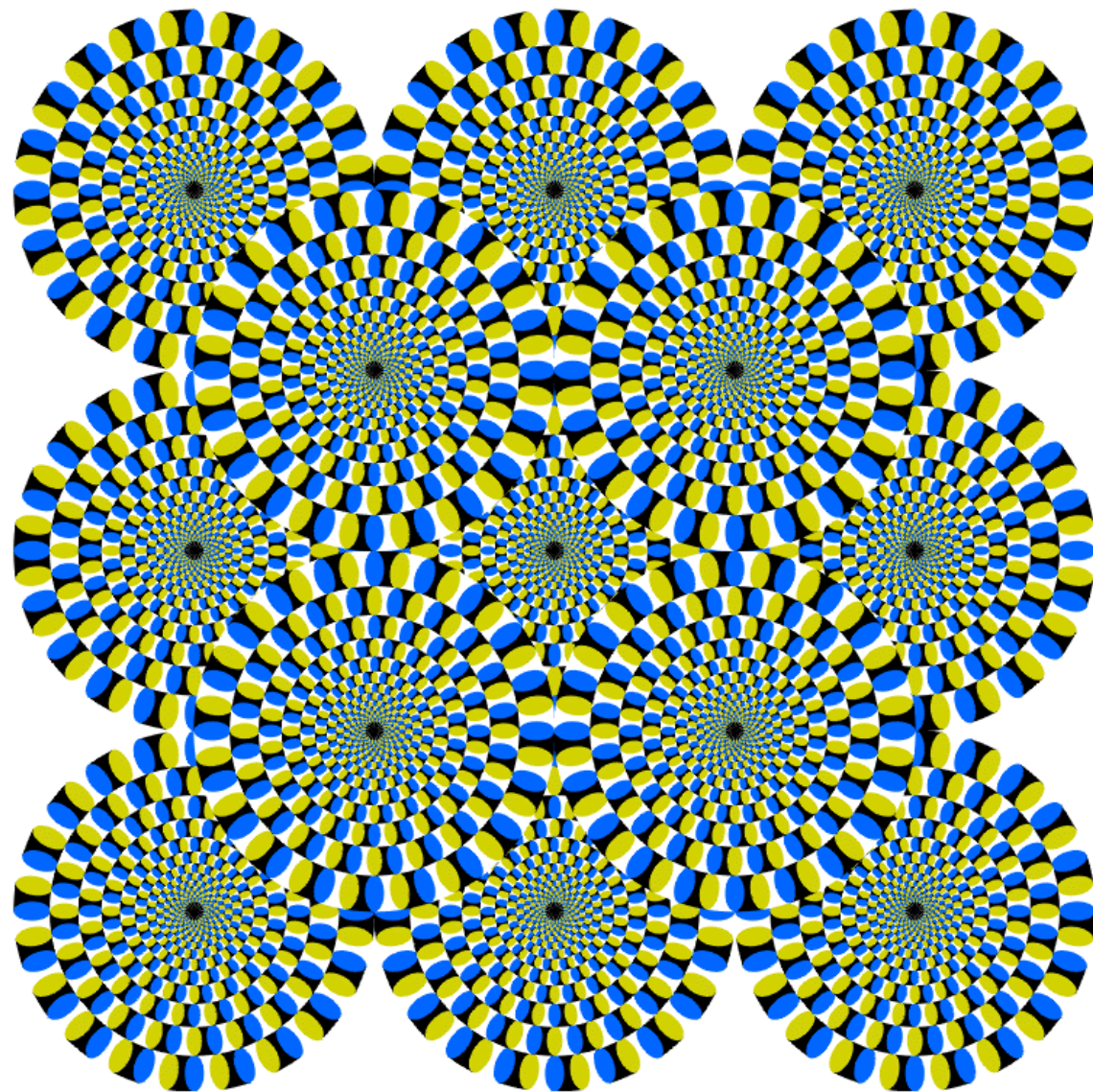
Hemisphere better suited for variable receiver inclination



Robustnes of measurement arrangements in the presence of haze !

- **Directional** **not robust**
 (LMD on slope of haze)
- **Ringlight** **fairly robust**
 (LMD on slope of two haze curves
 → some compensation)
- **Conical** **fairly robust**
 (LMD normal)
- **Hemispherical** **robust**

Standards for Electronic Displays



Outlook

ISO

◆ Re-structuring of ISO 9241 (former 13406)

in order to include

- all types of electronic displays (including projection displays, virtual-image displays, etc.),
- all types of applications (not restricted to office work)

work in progress ...

CIE

◆ *Colorimetry of Displays* ???

Outlook

IEC TC110

◆ **IEC TC110/WG2**

*Transmissive LCDs (to be continued ...)
some parts soon under revision*

◆ **IEC TC110/WG2**

Reflective LCDs (new work item, started)

◆ **IEC TC110/WG4** IEC 61988

Plasma Display Panels (to be continued ...)

◆ **IEC TC110** IEC 62341-1/6

Organic Electroluminescent Devices (new work item, started)

Data Sheet Requirements

- ◆ **Data sheets shall allow the purchaser to specify and buy the exactly the product that is required or wanted for a specific application.**
- ◆ **Data sheets from different companies shall all be based on the same standards.**
- ◆ **Product requirements strongly vary with the intended application ...**

Standards for Electronic Displays

From the confusing variety of raw measurement data ***clear characteristics*** have to be distilled that are meaningful even for the interested layperson (private customer)

Avoid meaningless *marketing lingo*, e.g.

- "tested according to ISO 13406"
- "viewing angle 170°"

- **Each customer has deserved meaningful characteristics for the purchasing decision**



Action Proposals

- ◆ Take an active part in the standardization process
- ◆ Provide or include experts with hands-on experience ...
- ◆ Synchronize your activities with other standards-bodies active in the same field (do it yourself !)
- ◆ Make sure that the customers gets reasonable ratings and characteristics for their purchasing decision
- ◆ Make sure that the applicable standards are up-to-date
- ◆ Let the contrast out of the dark-room
- ◆ Bring the "viewing-angle" down to earth

Standards for Electronic Displays

Thank you very much for your attention !



Questions, comments & remarks are welcome