Standards and Metrology for Reflective LCDs

Michael E. Becker
Display-Metrology & Systems

www.Display-Metrology.com
Standards and Metrology for Reflective LCDs

◆ Metrology Standards for (reflective) LCDs
  • Who needs them and why?
  • Review of Existing Standards
  • De-facto Metrology for Reflective LCDs

◆ Illumination Geometries & Terminology
  • Set of basic geometries
  • Specification of illumination
  • Directional, conical illumination
  • “Diffuse” illumination

◆ Two Novel Device Concepts
  • Display - Dome: Flexible Illumination
  • Display - Meter: Scanning of Viewing-Cone

◆ Summary and Conclusions
Motivation: Apples & Oranges

Why metrology standards?

Contrast-ratio of reflective STN-LCD

Measuring Setup 1: \( C_R = 3 \)

Measuring Setup 2: \( C_R = 12 \)

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!
De-facto Metrology for reflective LCDs

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

<table>
<thead>
<tr>
<th>Reflective</th>
<th>Transmissive</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta_{ir}$</td>
<td>$\theta_{it}$</td>
</tr>
<tr>
<td>Source</td>
<td>Source</td>
</tr>
</tbody>
</table>

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

$\rightarrow$ scanning of VC not possible!
$\rightarrow$ scanning of VC possible!

Who needs metrology standards?

- **Manufacturer of LCDs**
- **Manufacturer of Components for LCDs** (e.g. LC-Material, Polarizers, Retarders)
  - Research and Development
  - Quality Control and Assurance
  - Product Specification (Data Sheet !)
- **Manufacturer of Electronic Devices** (i.e. System Integrator / OEM)
  - Incoming Inspection
  - Evaluation and Rating of the Final Product
- **Public Health & Safety Institutions**
- **Test Houses**
  - Assurance of Minimum Ergonomic Performance
Metrology Standards for LCDs

- IEC SC47/WG2 - Documents 61747- N: 
  *Transmissive LCDs (cells, modules, “monochrome”, ...)*

- IEC 61966 - 4 Multimedia systems and equipment – 
  *Colour measurement and management – Part 4: Equipment using liquid crystal display panels*

- Electronics Industry Association of Japan 
  EIAJ ED-2522, ED-2511, ... LCDs 
  EIAJ ED-2523 MM Reflective LCDs

**VESA “Flat Panel Display Measurements Standard”**
most valuable well founded source of information

**Dr. Kelley’s Seminars on Display Metrology**
IEC Standards for LCDs

IEC SC47 - Flat Panel Displays

WG2 - Document Series 61747

1 Generic Specifications
2 Terminology and Letter Symbols
3 Sectional Specifications, Blank Detail Specifications
4 Essential Ratings and Characteristics
5 Environmental Endurance ..., Visual Inspection
6 Measuring Methods (MM)

✦ MM for Matrix-type LCD-modules - transmissive
  (CD for voting in preparation)

✦ New Work Item: MM for Reflective LCDs !
Metrology Standard for Reflective LCDs

Clear identification of how to measure which quantities

◆ Detailed **characterization of the electro-optical properties** versus viewing-direction (e.g. BRDF, 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**

 yöntematyczność

Results must not depend on instrumentation, location, time, operator, etc.,
Method and setup must be **robust** (= insensitive to parameter variations)
Results must be **unambiguous** and **meaningful** (.. human visual system)
Unlimited number of conditions for illuminating displays

Sources differ in
- **geometry**: location (direction), extension (size)
- **emission**: intensity, spectrum, temporal fluctuations
Specifying Illumination Conditions

Illumination as “seen” from the measuring spot

Contour-line representation in a polar coordinate system with $\theta$, $\phi$

- Intensity and chromaticity vs. direction of incidence, e.g.

  \[
  \text{Luminance} = f(\theta, \phi) \quad \Delta u' = f(\theta, \phi) \quad \Delta v' = f(\theta, \phi)
  \]

  $\Delta$ with respect to a reference direction / source spectrum

- Specification of all geometrical details of illumination setup
Basic Illumination Geometries

- **Directional source $S$ and receiver $R$**
- **Multi-directional illumination with gloss-trap $S_1$ (spex)**
- **Multi-directional illumination with head-shadow $S_H$ and gloss-trap $S_1$ (suppression of haze included)**
- **Multi-directional illumination Observer-shadow (head & trunk) Normal observation**
**Directional illumination** with (quasi) collimated (parallel) beam: max. +/-5° deviation from optical axis (e.g. CIE No. 38, 1977) i.e. \( \text{atan} \left( \frac{r_{ms} + r_s}{d} \right) \leq 5° \)

Intensity across beam at measuring spot and other locations?

\[
d \quad \text{direction of illumination, source at distance } |d|
\]
\[
r_{ms} \quad \text{radius of measuring-spot (field of view)}
\]
\[
r_s \quad \text{radius of source (directionally uniform emission)}
\]

\[
r_s / |d| \to \infty \text{ “point source”}
\]
**Conical illumination**
extended source, illumination from a solid angle (cone) \( \Omega \)
\[
I = \frac{d\phi}{d\omega} = f(\theta) = \text{constant} \?
\]

\( \Omega \rightarrow 2\pi \) *hemispherical* illumination
\( \Omega \rightarrow 0 \) *directional* illumination
"Diffuse" (multi-directional) illumination

\[ \Omega / \theta_{\text{max}} = \frac{2\pi}{90^\circ} \]

\[ I = \frac{d\phi}{d\omega} = f(\theta) \]

\[ \Omega = 2\pi \text{ hemispherical illumination} \]

\[ I = f(\theta) = \text{constant} \rightarrow \text{isotropically diffuse illumination} \]
**Display-Dome**

**Illumination**
- Controlled light & shadow
- Various source sizes and locations
- Various intensities and spectra

**Detection**
- Measurement at distinct directions (up to 16 directions)
- Spectral and fast photometric

Display-Metrology.com
**Illumination**
- Multidirectional illumination
- Controlled shadows (e.g., observer)
- Gloss-trap (adjustable width)
- Various intensities and spectra

**Detection**
- Scanning of viewing-cone (0° up to 70° with $\Delta \theta = 5^\circ \Rightarrow 15$ channels)
- Spectral and fast photometric detection
- High-resolution BRDF (optional)
Summary & Conclusions

- We have reviewed the currently existing metrology standards for LCDs and illustrated the need for MM for reflective LCDs.

- The existing metrology for reflective LCDs lacks specification of the setup and its details. The evaluations cannot be compared.

- Appropriate specification of the measuring setup (illumination and detection) and a common terminology should reduce confusion.

- We have introduced a versatile and flexible approach for realization of a wide range of illumination geometries with simultaneous detection of the spectrum of reflected light.

- We have introduced a novel apparatus for fast scanning of the viewing-cone of reflective displays with spectral and fast photometric detection and optional BRDF evaluation.