New generation of imaging colorimeters and spectrophotometers

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Agenda

1. Imaging optics
2. Luminance & Colorimetry => UMaster
3. Polarimetry => UMasterPz
4. Multispectral imaging => UMasterMS
5. High spatial resolution => Additional optics
6. Ultrahigh spatial resolution => MVP
7. Normal incidence measurements => TTO optics
Imaging optics: why telecentric optics?

Standard imaging objective

Flux collected by one element surface of detector

\[ d\phi_1 = M_\infty (1 - \frac{2F\#}{F_2})dS_1 \]

First order dependence with distance

Flux reduction versus working distance
Imaging optics: why telecentric optics?

Telecentric imaging objective on sensor side

Flux collected by one element surface of detector

$$d\phi_1 = M_\infty (1 - \frac{3F^2}{16F^2_2}) dS_1$$

First order dependence with distance

Flux reduction versus working distance
Imaging colorimetry: UMaster

UMaster imaging colorimeter
- Luminance or color measurements
- High resolution & high sensitivity
- Low stray light
- Entrance iris comparable to human pupil
- Polarization state measurements

Advanced Light Analysis by ELDIM
Imaging colorimetry: UMaster

Each system is matched closely with the CIE curves!
The electric field can be separated in two parts:

\[ E_t = E_{\text{np}} + E_p \]

Unpolarized\hspace{1cm}Polarized

Degree of polarization \( \rho \)

\[ \rho = \frac{E_x^2 + E_y^2}{I_t} = \frac{I_p}{I_t} \]

To define completely the light polarization state we need:

1. The polarization direction \( \alpha \)
2. The ellipticity \( \varepsilon = \tan(b/a) \)
3. The degree of polarization \( \rho \)
The system makes automatically the following measurements for a given wavelength:

- 3 measurements with 3 polarizer orientations: $M(0^\circ), M(45^\circ)$ and $M(90^\circ)$

- 4 measurements with additional 1/4 wave-plate: $M(0^\circ, 45^\circ)$, $M(0, 135^\circ)$, $M(90^\circ, 45^\circ)$ and $M(90^\circ, 135^\circ)$

The polarization parameters and the Stokes are deduced for each pixel of the image:

\[
S = \begin{bmatrix} I \\ Q \\ U \\ V \end{bmatrix} = I \begin{bmatrix} 1 \\ \rho \cos 2\varepsilon \cos 2\alpha \\ \rho \cos 2\varepsilon \sin 2\alpha \\ \rho \sin 2\varepsilon \end{bmatrix}
\]
Imaging polarization of a LCD backlight with BEF film
Imaging polarimetry: UMasterPZ

Imaging polarization of a LCD without top polarizer versus grey level
UMasterMS imaging spectrophotometer

- Radiance measurements
- High resolution & high sensitivity
- Low stray light
- Entrance iris comparable to human pupil
- Polarization state measurements
Filter wheel and transmittance of the 31 interference filters
GretaMacbeth color checker
24 natural object, chromatic, primary and gray scale colors

Measured reflection coefficients versus wavelength
GretaMacbeth characteristics are also reported
GretaMacbeth color checker
24 natural object, chromatic, primary and gray scale colors

Measured reflection coefficients versus wavelength
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Multispectral imaging : UMasterMS
Multispectral imaging: UMasterMS

Measured reflection coefficients versus wavelength
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GretaMacbeth color checker
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ELDIM
GretaMacbeth color checker
24 natural object, chromatic, primary and gray scale colors

Measured reflection coefficients versus wavelength
GretaMacbeth characteristics are also reported
LEDWall tile measurement of blue LEDs
Emission peak adjustment using Pearson VII model

\[ f = \frac{1}{\left[ 1 + \left( \frac{2(x-x_0)\cdot \sqrt{2^{1/M} - 1}}{\omega} \right) \right]^{M}} \]

- \( x_0 \) = wavelength mean position
- \( \omega \) = wavelength band pass
Mean wavelength of blue LEDs

Band pass of blue LEDs

Multispectral imaging: UMasterMS
Correlation between mean wavelength and band pass for blue LEDs
High spatial resolution imaging: UMaster + add. optics

<table>
<thead>
<tr>
<th>Magnification</th>
<th>Spatial resolution</th>
<th>Field of view</th>
<th>Working distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>X1</td>
<td>9x9µm</td>
<td>13.5x9mm</td>
<td>30mm</td>
</tr>
<tr>
<td>X2</td>
<td>18x18µm</td>
<td>27x18mm</td>
<td>60mm</td>
</tr>
<tr>
<td>X4</td>
<td>36x36µm</td>
<td>54x36mm</td>
<td>120mm</td>
</tr>
</tbody>
</table>

3 additional optics available for UMaster
High spatial resolution imaging: UMaster + add. optics

Individual pixels can be measured precisely
High spatial resolution imaging : UMaster + add. optics

OLED display (250 ppi pixel density)
White, Red, Green & Blue
Gamut distribution in the chromatic plane

Gamut distribution on the display surface

Single pixel characteristics can be extracted
Ultra high spatial resolution imaging: MURA MVP

MURA MVP is the new generation of ELDIM Micro Video Photometer. The system uses the UMaster technology coupled to high-quality microscope objectives.

3 magnifications available:

<table>
<thead>
<tr>
<th>Objective</th>
<th>Field of view</th>
<th>Max spatial Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>x20</td>
<td>650x440µm</td>
<td>0.5µm</td>
</tr>
<tr>
<td>x10</td>
<td>1300x880µm</td>
<td>1µm</td>
</tr>
<tr>
<td>x5</td>
<td>2600x1760µm</td>
<td>2µm</td>
</tr>
</tbody>
</table>

Optional RGB LED illumination
Ultra high spatial resolution imaging: MURA MVP

Measurements on iPod display

ON state

OFF state

Color Luminance

40µm
ELDIM proposes now a series of **double telecentric objectives** with various sizes that allow near normal incidence analysis of **small & medium display with unprecedented accuracy**. Luminance, color, polarization and radiance can be measured with the new generation of **UMaster** instruments and this new family of optics.

Available sizes:
- 9 inches
- 12 inches

**Normal incidence measurements become possible**
Thanks for your attention

Come to see us at booth 560

ELDIM
ELECTRONICS FOR DISPLAYS AND IMAGING DEVICES

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