**ABSTRACT**

- Displays are viewed in ambient light
- Ambient light, necessary for e-paper, can disturb emissive display color
- Display characterization must include ambient lighting conditions
- New standards predict display color by combining optical measurements with ambient illumination models

**OBJECTIVE**

- The “perfect display” is betrayed as imperfect by reflected ambient light
- Measurements must predict display color in ambient lighting conditions

**CHALLENGE**

Ambient display colors will depend on:
- Illumination levels and spectra
- Type of display

**EFFECT OF AMBIENT ILLUMINATION ON DISPLAY COLOR**

<table>
<thead>
<tr>
<th>Illuminance E [lx]</th>
<th>Reference indoor</th>
<th>Reference outdoor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,000</td>
<td>100,000</td>
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<td>1,000</td>
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</tbody>
</table>

**MODEL ILLUMINATION**

1. Measure the display’s spectral emission and reflection for each display color \( Q \).
   \[ L_{Q,em}(\lambda) \]

2. Scale the display measurements to the actual irradiance spectra \( E(\lambda) \) of reference illumination.
   \[ E_{dir}(\lambda) \cdot \cos \theta_S / \pi \]
   \[ E_{hemi}(\lambda) / \pi \]
   \[ R_{Q,dir}(\lambda, \theta_S) \cdot \cos \theta_S / \pi \]

**PREDICT COLOR**

3. Summarize all components of spectral radiance contributing to total spectral display radiance.
   \[ = L_{Q,T}(\lambda) \]

4. Predict color gamut in ambient illumination:
   - Daylight-readable reflective display
   - Reflection of bright daylight overwhelms backlight of emissive display

**CONCLUSION**

- Standardized measurement methodology can predict color capability of displays in realistic lighting conditions