Color measurement standards for reflective e-paper

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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

Reflective display

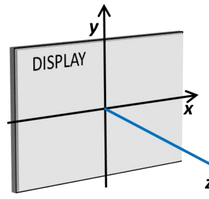
Reflective display with front light

Emissive display with backlight

MEASURE DISPLAY OPTICS

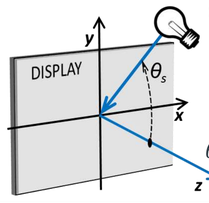
1. Measure the display's spectral emission and reflection for each display color Q

Emission



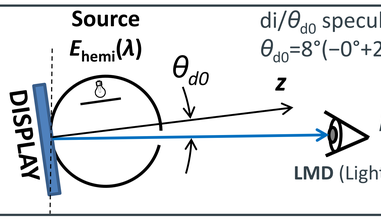
$$L_{Q,em}(\lambda)$$

Directional Reflection



$$R_{Q,dir}(\lambda, \theta_s) \cdot \frac{E_{dir}(\lambda) \cdot \cos\theta_s}{\pi}$$

Hemi-spherical Reflection



$$\rho_{Q,hemi}(\lambda) \cdot \frac{E_{hemi}(\lambda)}{\pi}$$

MODEL ILLUMINATION

2. Scale the display measurements to the actual irradiance spectra $E(\lambda)$ of reference illumination

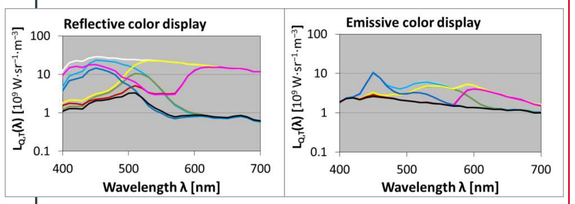
Reference Illumination	
Indoor	Outdoor
200 lx	65,000 lx
CIE A	D50
300 lx	15,000 lx
CIE A	D75

PREDICT COLOR

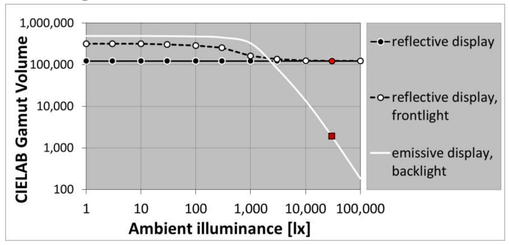
3. Summarize all components of spectral radiance contributing to total spectral display radiance

$$= L_{Q,T}(\lambda)$$

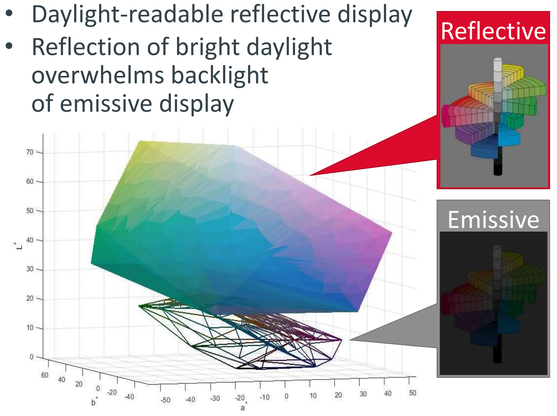
Comparison in 30,000 lx daylight



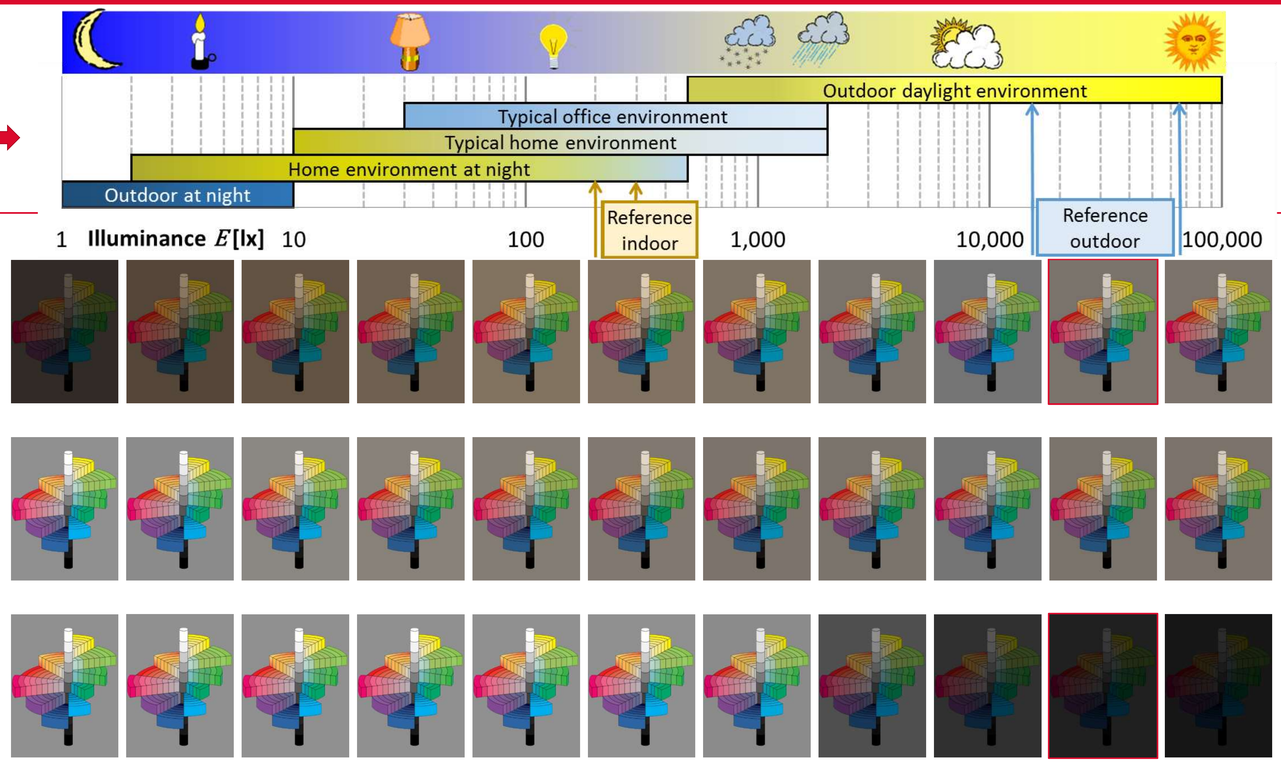
Color gamut volume vs. illuminance



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



EFFECT OF AMBIENT ILLUMINATION ON DISPLAY COLOR



CONCLUSION

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

IEC International Electrotechnical Commission

ISO International Organization for Standardization

ICDM INTERNATIONAL COMMITTEE FOR DISPLAY METROLOGY