# Luminance distribution measurements

# Luminance Distribution Measurements
## *OptiLight*

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## Introduction

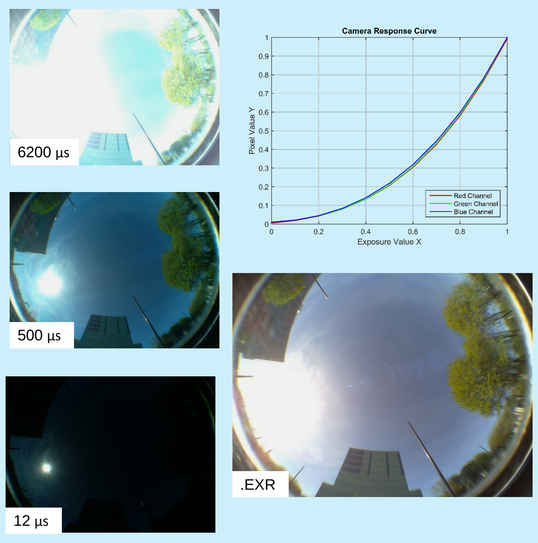
- Part the interdisciplinairy project: ***OptiLight - Mathematical Optimizations for Human Centric Lighting***.
- Despite growing understanding of the impact of light on wellbeing, performance and circadian rhythms, benefits of this understanding cannot (yet) easily be harvested in practical systems.
- Scalable algorithms are lacking that can be used in automated systems.
- There exists a huge gap between results obtained in controlled environments and practical deployment.

- This project aims at developing **Models for Human Centric Lighting** based on field studies.
- Luminance distribution is expected to be important for visual aspects, consensus for non-visual metrics is not there (yet).

## I. A Practical Device for Measuring the Luminance Distribution[1]

Low cost components
- Single board computer
- Camera
- Fisheye lens

Image sequence to form High Dynamic Range (HDR) image
- 7 exposures with shutterspeeds ranging from 250,000 to 12 µs
- Specific camera response curve by radiometric self-calibration
- .EXR format by HDR builder developed by Ward[2].

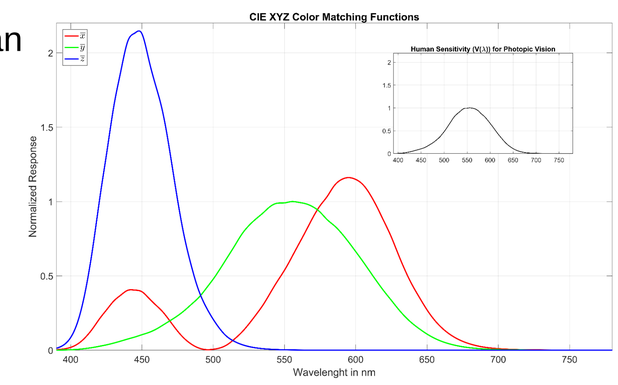



$$L_{3{,}000\ K} = k \cdot (0.2319 \cdot R + 0.7073 \cdot G + 0.0608 \cdot B)$$
$$L_{D65} = k \cdot (0.2125 \cdot R + 0.7125 \cdot G + 0.0721 \cdot B)$$
$$L_{14{,}000\ K} = k \cdot (0.1585 \cdot R + 0.7230 \cdot G + 0.1185 \cdot B)$$

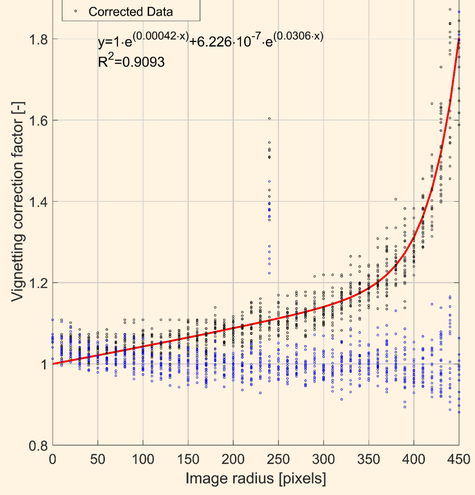
*$L_{ref}$ = Luminance reference $T_{cp}$; k = calibration factor; R,G,B = HDR tristimulus'*

The luminance calculation is based on the analogy between the color matching function $\bar{y}(\lambda)$ with the $V(\lambda)$ curve representing the human sensitivity for photopic vision.

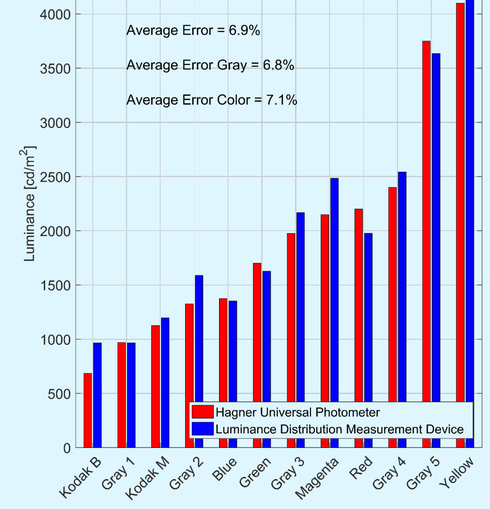
- The RGB tristimulus' of the HDR image are converted to CIE XYZ tristimulus'.
- Dependent on correlated color temperature ($T_{cp}$) → reference $T_{cp}$'s




Corrections
- Vignetting filter (light fall-off)
- Linear calibration factor (*k*)




- The accuracy stays within the range of 3.0% to17.5%.
- Calculation time = 35 s.
- Measurement period = 8 s.

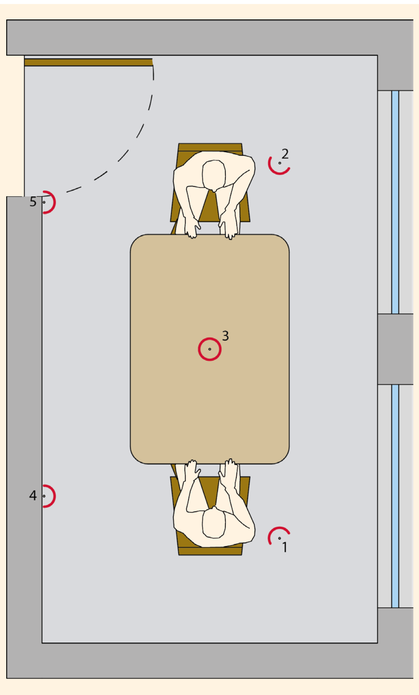



## II. Pilot Field Study

Measurements in small meeting room using practical luminance distribution measurement device.
- Requirements
  - Intuitive controllable lighting system
  - Electrical light + daylight
- Benefits
  - Multiple users
  - New preference for every meeting
  - Multiple light indicators are based on luminance distribution

| Aspects | Indicator |
|---|---|
| Quantity | Illuminance; Luminance |
| Glare | UGR; DGP |
| Distribution | Uniformity; Luminance ratios |
| Directionality | Vector to Scalar Ratio |
| Dynamics | Luminance Variability |

**Objectives:**
- Correlations between indicators
- Normative aspects/indicators
- User preferences lighting quality indicators




Measurement Points (MP)
MP 1,2 = approximation visual field users[3]
MP 3 = Top down view on table
MP 4,5 = Luminance distribution through window

## III. Implementation

Building management systems tend cause annoyance due to inadequate sensory input (photocell).
- Luminance distribution provides spatially resolved data
- Suitable for open and closed loop systems

The effectiveness of luminance distribution measurement device compared to photocell can be modelled based on field measurements conducted with the practical luminance distribution measurement device. This device is able to conduct both spot and spatially resolved measurements.

## IV. Conclusion

- Luminance distribution can be measured in a practical and economical way.
- Luminance distribution measurements provide the opportunity to evaluate multiple light quality aspects simultaneously.
- A luminance distribution measurement device can improve the effectiveness of building management systems.

[1]Kruisselbrink, T., Aries, M., Rosemann, A. (2017). A Practical Device for Measuring the Luminance Distribution. Accepted in The International Journal of Sustainable Lighting.
[2]Ward G. Anyhere Software n.d. http://www.anyhere.com/ (accessed March 7, 2016).
[3]Fan, D., Painter, B., & Mardaljevic, J. (2009). A Data Collection Method for Long-Term Field Studies of Visual Comfort in Real-World Daylit Office Environments. In *26th Conference on Passive and Low Energy Architecture*. Quebec City.