



**LIGHT EXPOSURE ASSESSMENT OF DANISH INDOOR,  
OUTDOOR AND NIGHT-SHIFT WORKERS**

EXPERIENCES FROM A FIELD STUDY

BY: JAKOB MARKVART, SENIOR RESEARCHER AT SBI



DANISH BUILDING RESEARCH INSTITUTE  
AALBORG UNIVERSITY COPENHAGEN

# Light exposure assessment

- The Lux@r project
  - The context of this talk
- Light and light exposure
  - What When and Where
- Light as a “one-dimensional unit” – things that matters:
  1. Spectral sensitivity
  2. Spatial sensitivity

# Lux@r

Funded by: Danish Working Environment Authority  
(Arbejds miljø forsknings fonden)

Project title:

“Health Consequences of the **Light Environment** at Work, Indoor and during Night”  
(Lux@r)



Source: [http://www.luxar.dk/?page\\_id=42](http://www.luxar.dk/?page_id=42)

Partners involved:

- Occupational and Environmental Medicine, Aarhus University, Denmark
- National Research Centre for the Working Environment, Copenhagen, Denmark
- VELUX A/S, Hoersholm, Denmark
- Department of Occupational Medicine, Danish Ramazinni Centre, Aarhus University Hospital, Denmark
- Department of Occupational Medicine, Bispebjerg Hospital, Copenhagen, Denmark
- Department of Energy Performance, Indoor Environment and Sustainability of Buildings, Danish Building Research Institute, Aalborg University, Copenhagen, Denmark

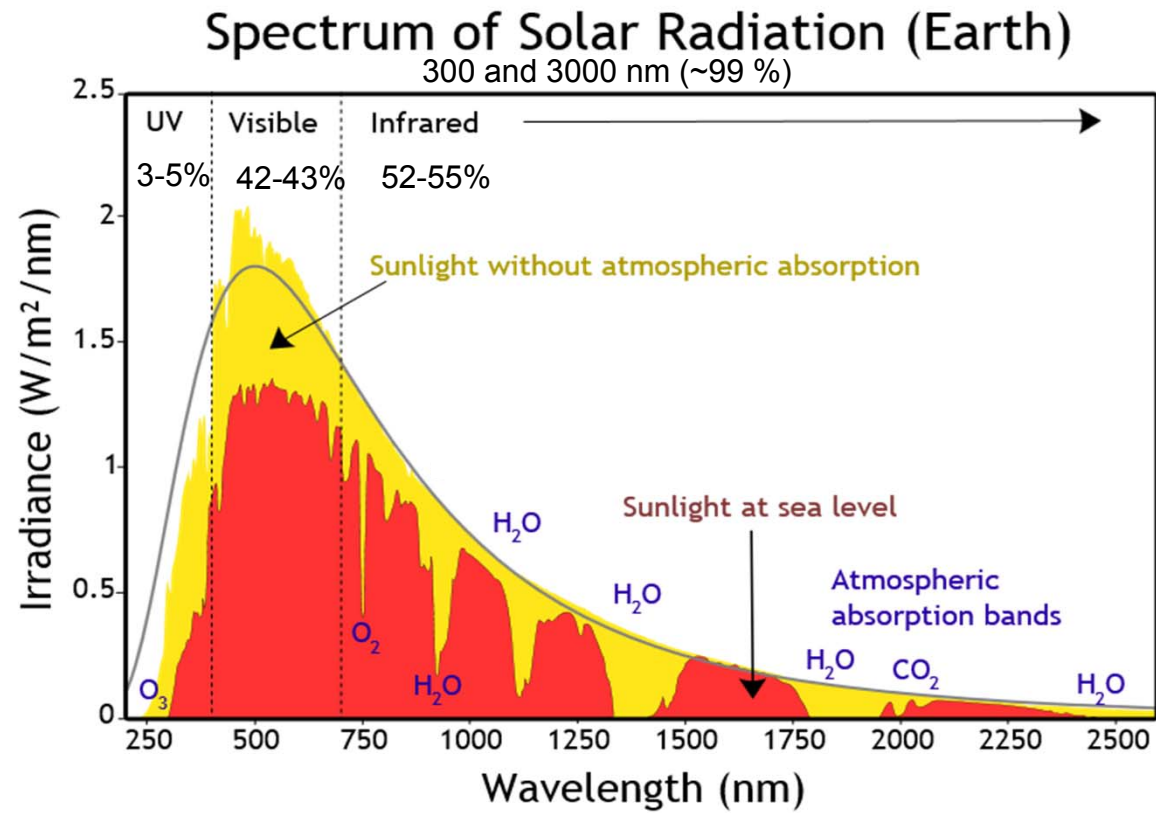
# Light - What do we (want to) measure?

## Radiation

- Daylight
- Electric light
  
- Heat / IR?
- UV?
- Darkness?



# Global solar radiation (energy)



Source: [http://upload.wikimedia.org/wikipedia/commons/4/4c/Solar\\_Spectrum.png](http://upload.wikimedia.org/wikipedia/commons/4/4c/Solar_Spectrum.png)

## Total global solar radiation (energy)

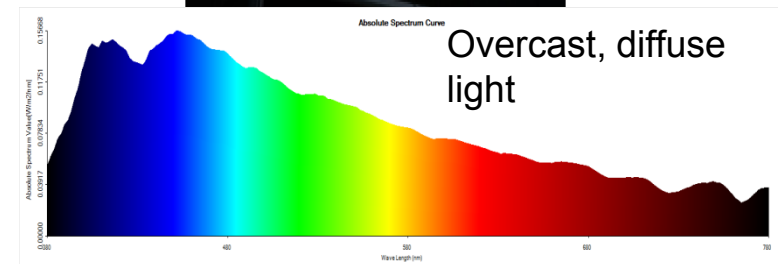
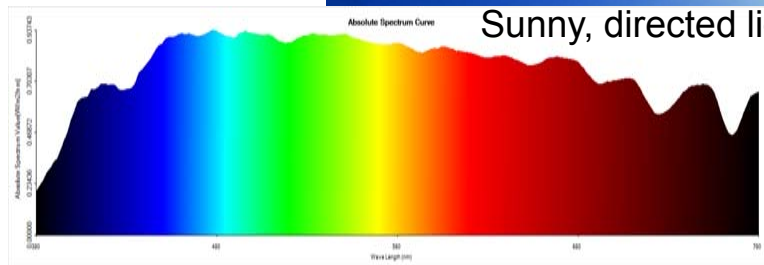
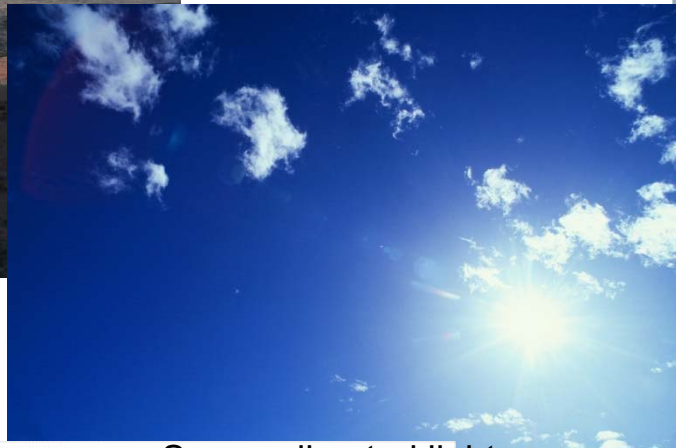
The sum of:

- direct,
- diffuse, and
- reflected solar radiation

The daylight spectrum and intensity is continuously changing....



# Daylight

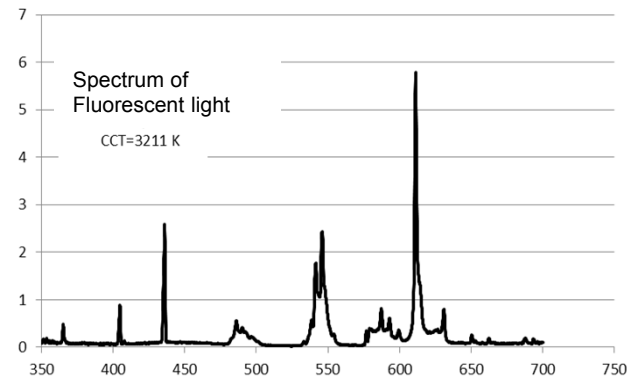
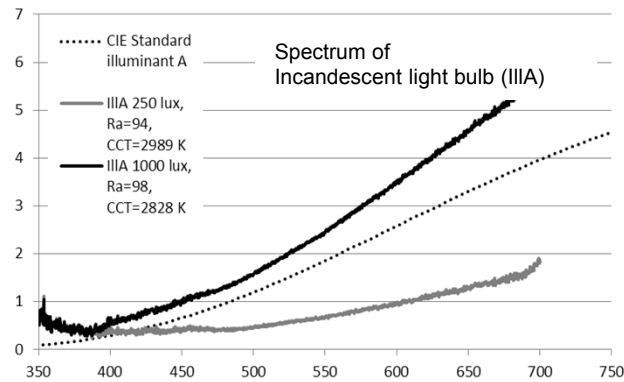


# Electric light





# Relative spectral composition – electric lighting

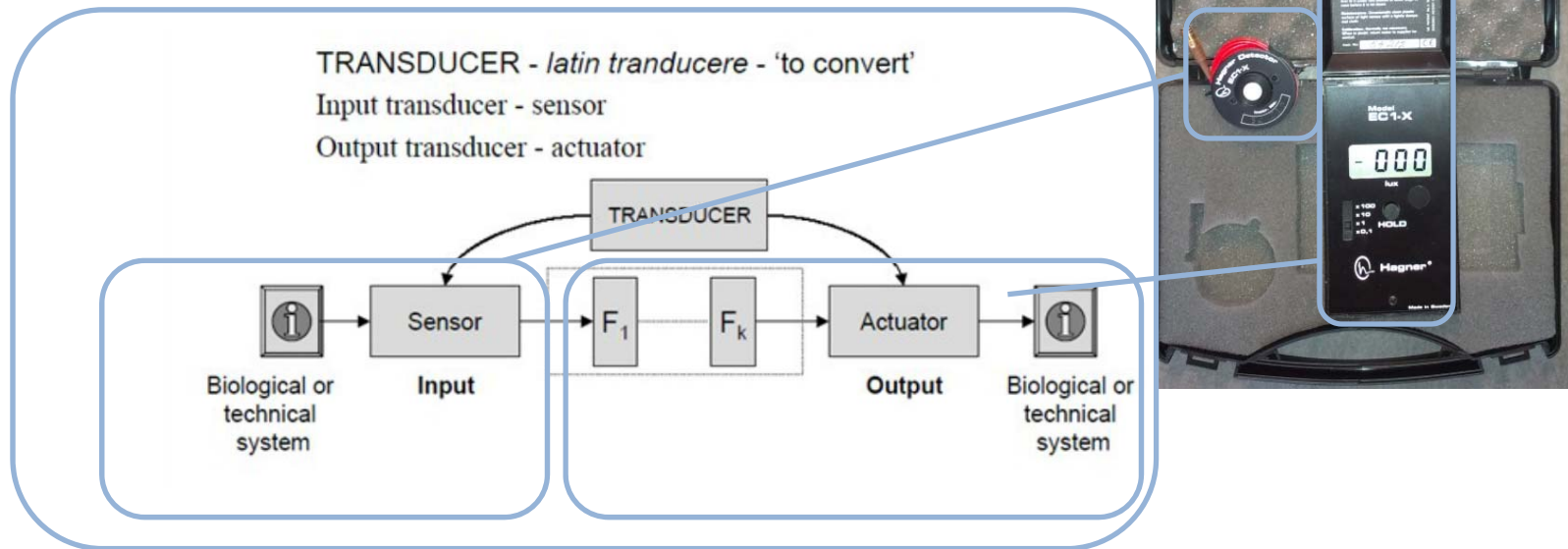


# Illumination (electric light and daylight)

- The sum of:
  - direct,
  - diffuse, and
  - reflected electric light

The spectrum and intensity of light exposure is continuously changing....because people move!

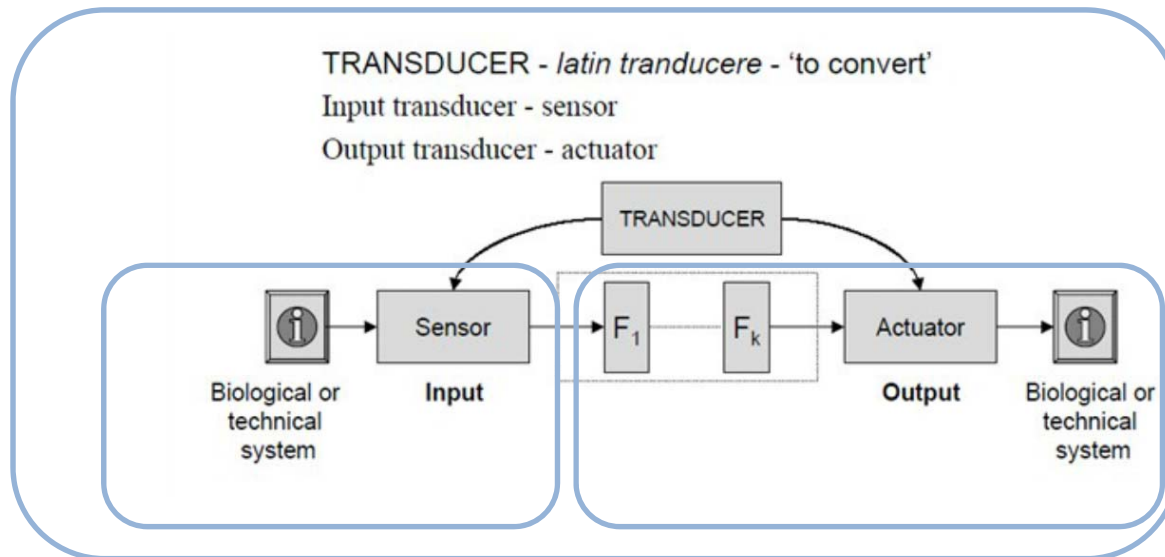
# Measuring systems



Measuring errors can happen many places in the measuring system!



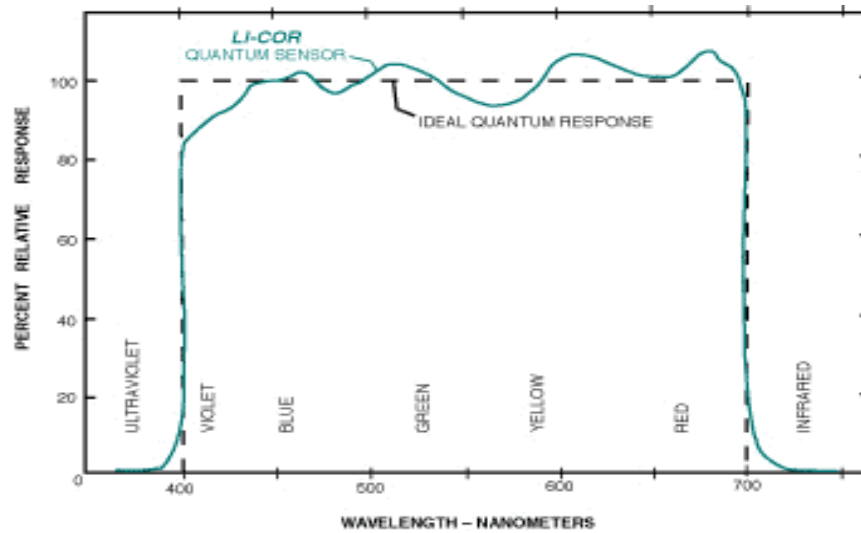
# Measuring systems



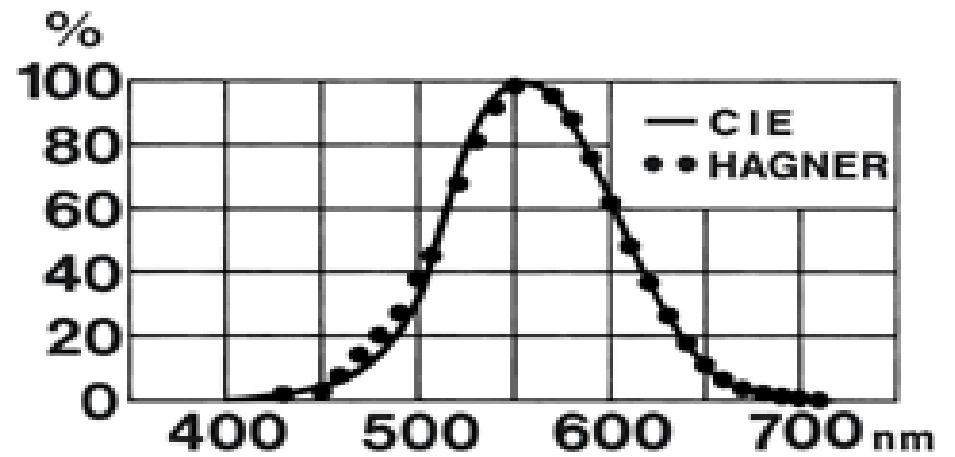
Measuring errors can happen many places in the measuring system!



# Spectral sensitivity (Input transducers/detectors, differences)



Courtesy: [www.licor.com](http://www.licor.com)



Courtesy: [www.hagner.se](http://www.hagner.se)



# Spectral sensitivity (Input transducers/detectors, differences)

Discrepancies between  $V(\lambda)$  and the spectral response of a photometric instrument are characterized by the  $f1'$  statistic.

The measuring system used in Lux@r:

$f1'$  statistic = 83% (white light)

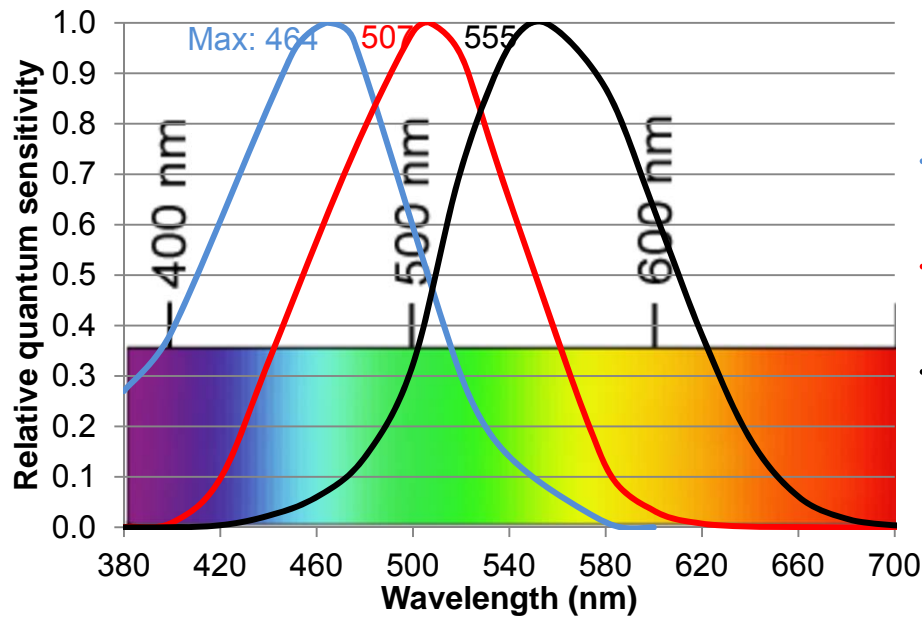
Courtesy: Figueiro *et al.* 2013, *Light. Res. Technol.* 45(4), Modified figure



# Spectral sensitivity, Human

Photopic vision

$V(\lambda)$  is based on the relative amount of power at each wavelength required to produce a criterion brightness response in a 2° foveal field of view



- Melatonin suppression
- Scotopic factor  $V'(\lambda)$
- Photopic factor  $V(\lambda)$

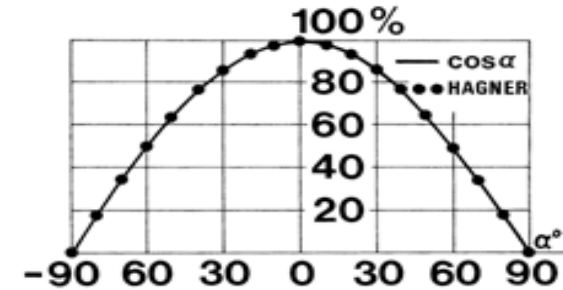
← Mesopic factor  $V_{mes}(\lambda)$

## Action Spectrum for Melatonin Regulation a Novel Circadian Photoreceptor

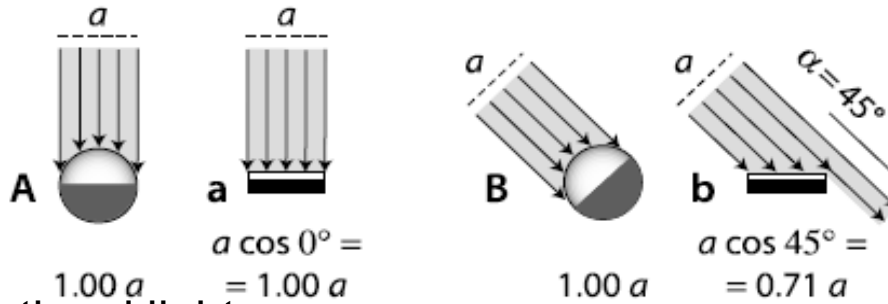
The Journal of Neuroscience, August 15, 2001, 21(16):6405-6412

George C. Brainard,<sup>1</sup> John P. Hanifin,<sup>1</sup> Jeffrey M. Greeson,<sup>1</sup> Brent Edward Gerner,<sup>1</sup> and Mark D. Rollag<sup>2</sup>  
<sup>1</sup>Department of Neurology, Thomas Jefferson University, Philadelphia, Pa  
<sup>2</sup>Physiology and Genetics, Uniformed Services University of Health Sciences

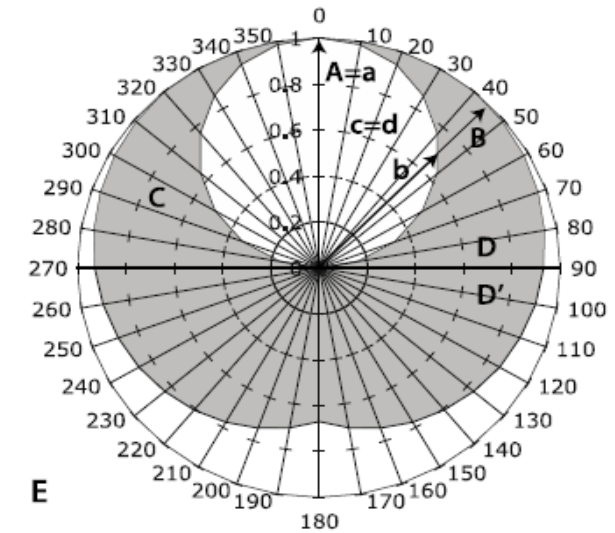
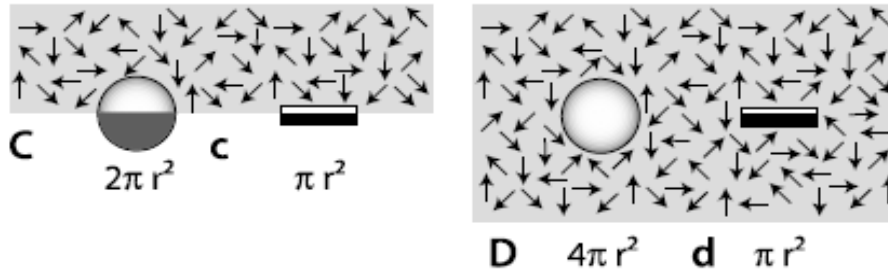
# Spatial sensitivity (direct and diffuse radiation)



One directional light:



Multi directional light:



Courtesy: Eva Rosenqvist, University of Copenhagen



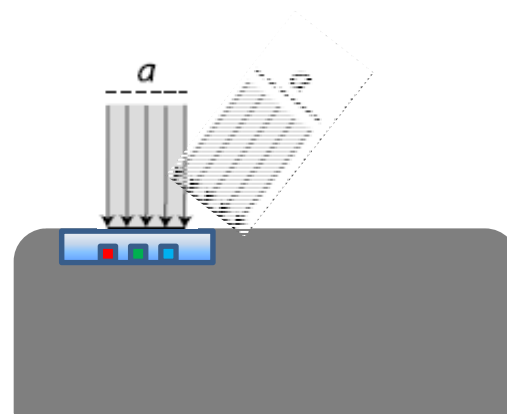
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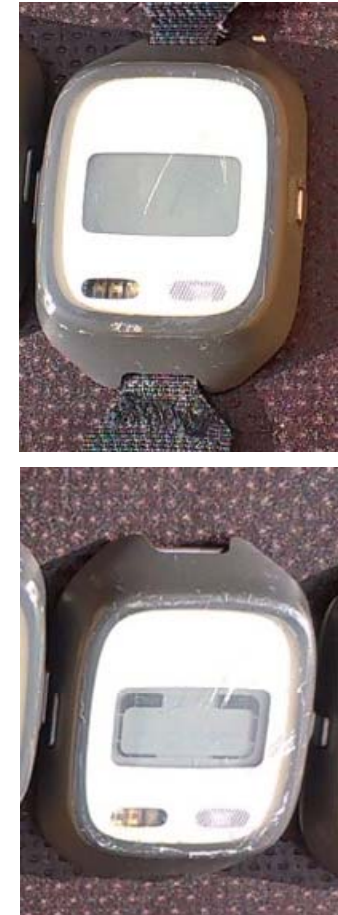
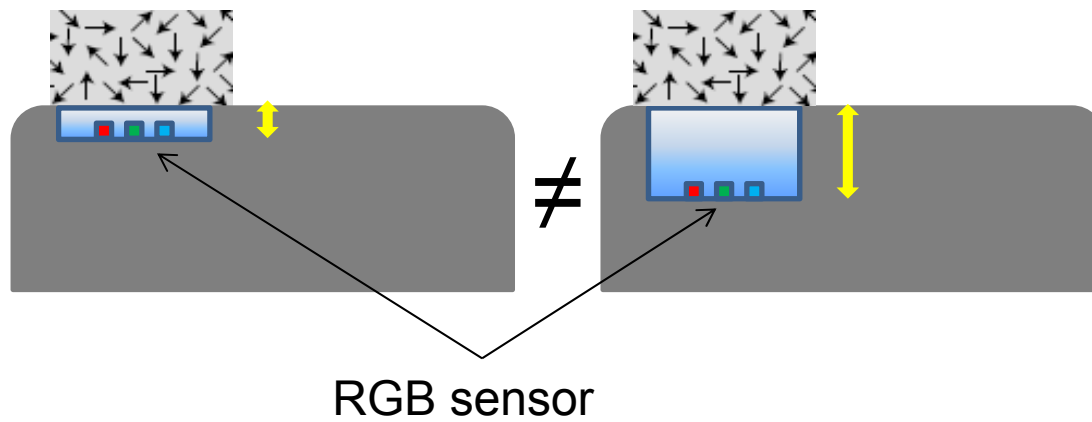
# Spatial sensitivity, direct light

**Figure of  
Actiwatch  
spectrum  
spatial  
sensitivity**



Courtesy: Price *et al.* 2012, *Light. Res. Technol.* 44, 17-26

# Spatial sensitivity, diffuse light



# Sensor response, Spatial and spectral sensitivity

Importance:

Know your sensor / measuring system concerning:

1. spectral and
2. spatial  
sensitivity

Why:

Because light exposure changes with time, place and position!

# Human light exposure measurements

**We want to find relations between....**

**Health** (circadian rhythms, sleep quality, depression, cancer....etc.)



Source: [http://www.luxar.dk/?page\\_id=42](http://www.luxar.dk/?page_id=42)

.....AND ...**light**...

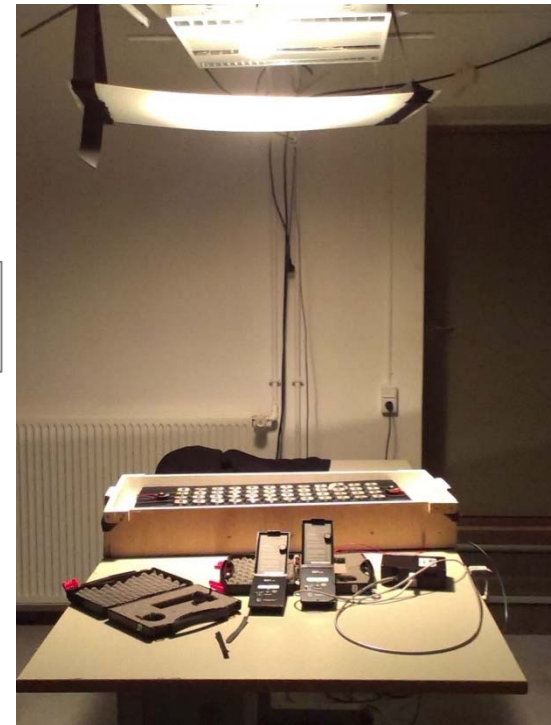
Preferable a **one-dimensional unit of light** exposure



Side-by-side calibration  
(to compensate for the inter-equipment variability)

Inverse Square Law:  $E_v = I_v/d^2$

(d = 15 x diameter of light source!)

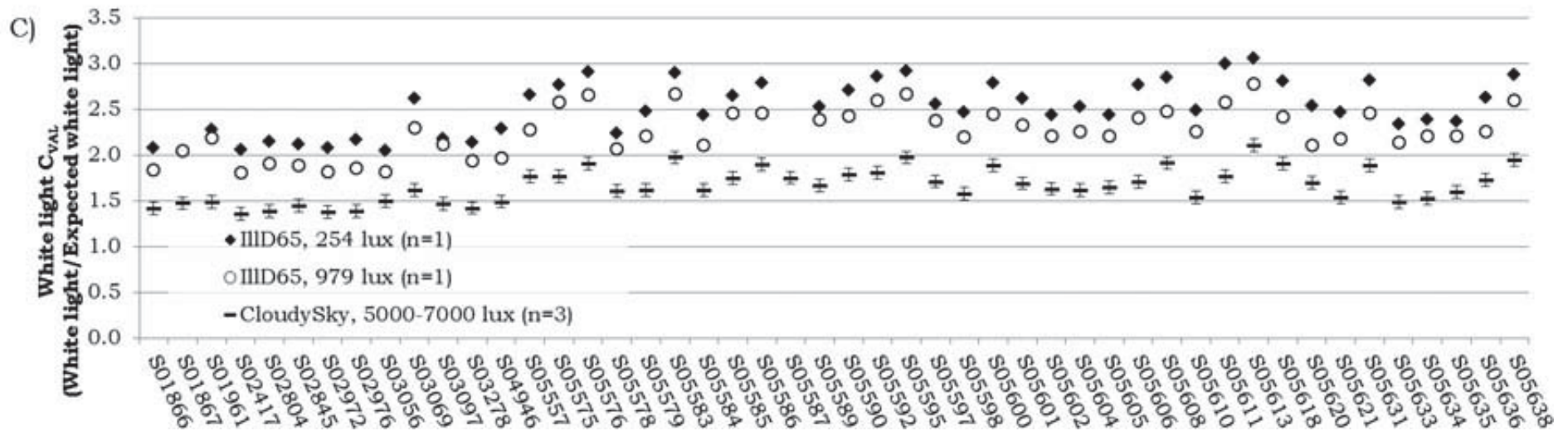


# Calibration

In the lab – Standard light source "D65"



# Directed vs. multi-directional "D65" (single) vs. (side-by-side)

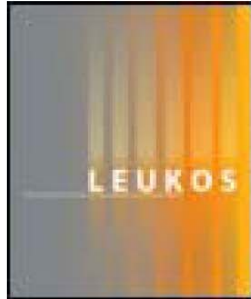


$$\text{White light } C_{val} = \frac{\text{White light}}{\text{Lux}_{\text{Ref-Meas}}}$$



## Conclusion

- >60% variation between devices
- Use a diffused overcast sky for side-by-side calibration



### LEUKOS: The Journal of the Illuminating Engineering Society of North America

Publication details, including instructions for authors and subscription information:  
<http://www.tandfonline.com/loi/ulks20>

#### Comparison and Correction of the Light Sensor Output from 48 Wearable Light Exposure Devices by Using a Side-by-Side Field Calibration Method

Jakob Markvart<sup>a</sup>, Åse Marie Hansen<sup>b</sup> & Jens Christoffersen<sup>c</sup>

<sup>a</sup> Danish Building Research Institute, Aalborg University, Copenhagen, Denmark

<sup>b</sup> Department of Public Health, University of Copenhagen, Copenhagen, Denmark

<sup>c</sup> VELUX A/S, Hørsholm, Denmark

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# Light exposure measurement – Some few results

Not published ...yet....

## Conclusion:

- Light is a multi-dimensional unit!
- Be aware of:
  - Inter-equipment variations and
  - inter-human variations
- The variation in the light exposure is huge! AND....
  - Depends on:
    - Season
    - Weather
    - Location (in- or outdoor)
    - Individual habits  
(like e.g. work and commuting habits)
    - .....?
  - And....
    - Measuring equipment

## Thanks and contact info:

**Jakob Markvart** Cand.Hort., Ph.d., Senior Researcher  
Department of Energy Performance, Indoor Environment and Sustainability  
of Buildings;

Danish Building Research Institute (SBI)

Phone: (+45) 2497 6033,  
Email: [jam@sbi.aau.dk](mailto:jam@sbi.aau.dk)

**Aalborg University Copenhagen** | A.C. Meyers Vænge 15 | DK-2450  
Copenhagen SV