



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

EXPERIENCES FROM A FIELD STUDY

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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

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?

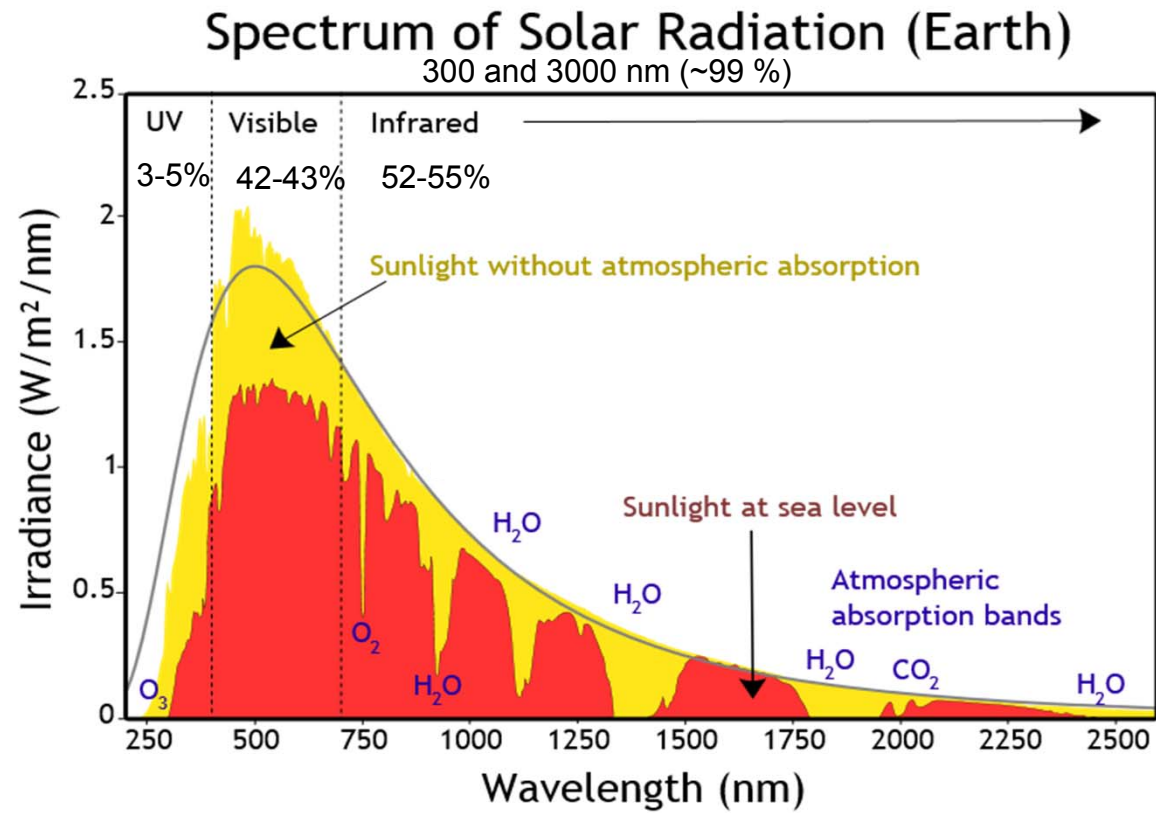
Radiation

- Daylight
- Electric light

- Heat / IR?
- UV?
- Darkness?



Global solar radiation (energy)



Source: http://upload.wikimedia.org/wikipedia/commons/4/4c/Solar_Spectrum.png



Total global solar radiation (energy)

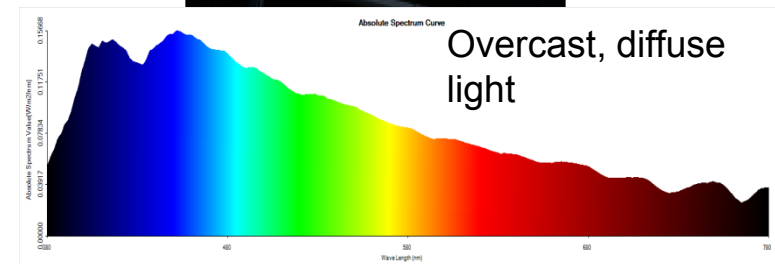
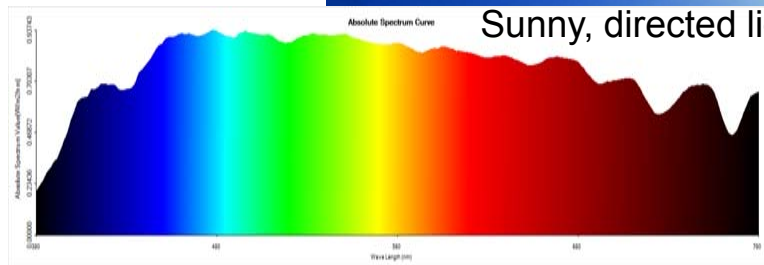
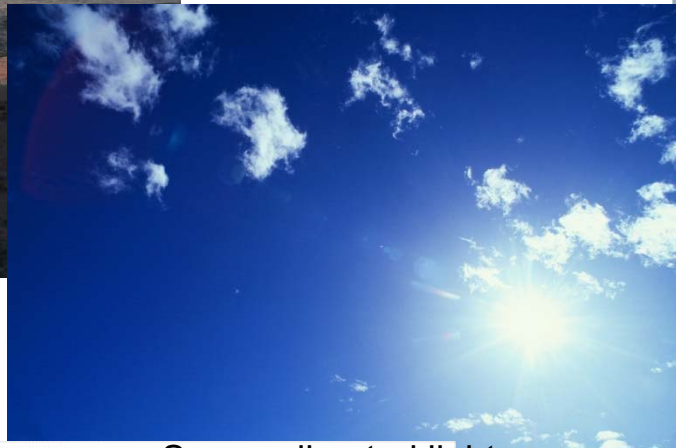
The sum of:

- direct,
- diffuse, and
- reflected solar radiation

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



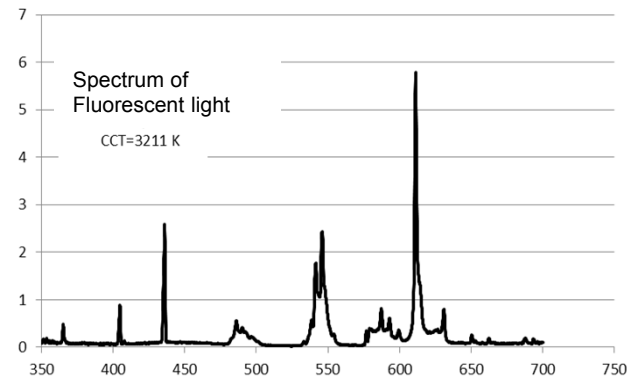
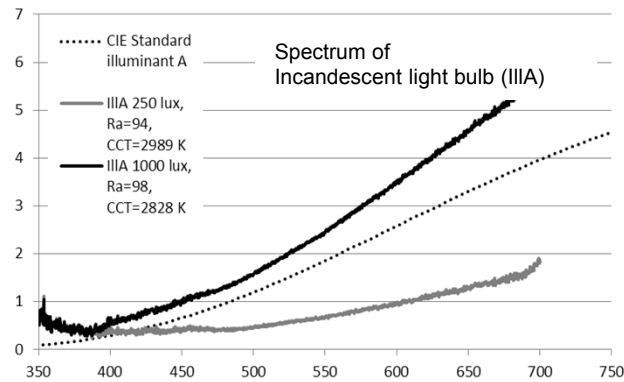
Daylight



Electric light



Relative spectral composition – electric lighting

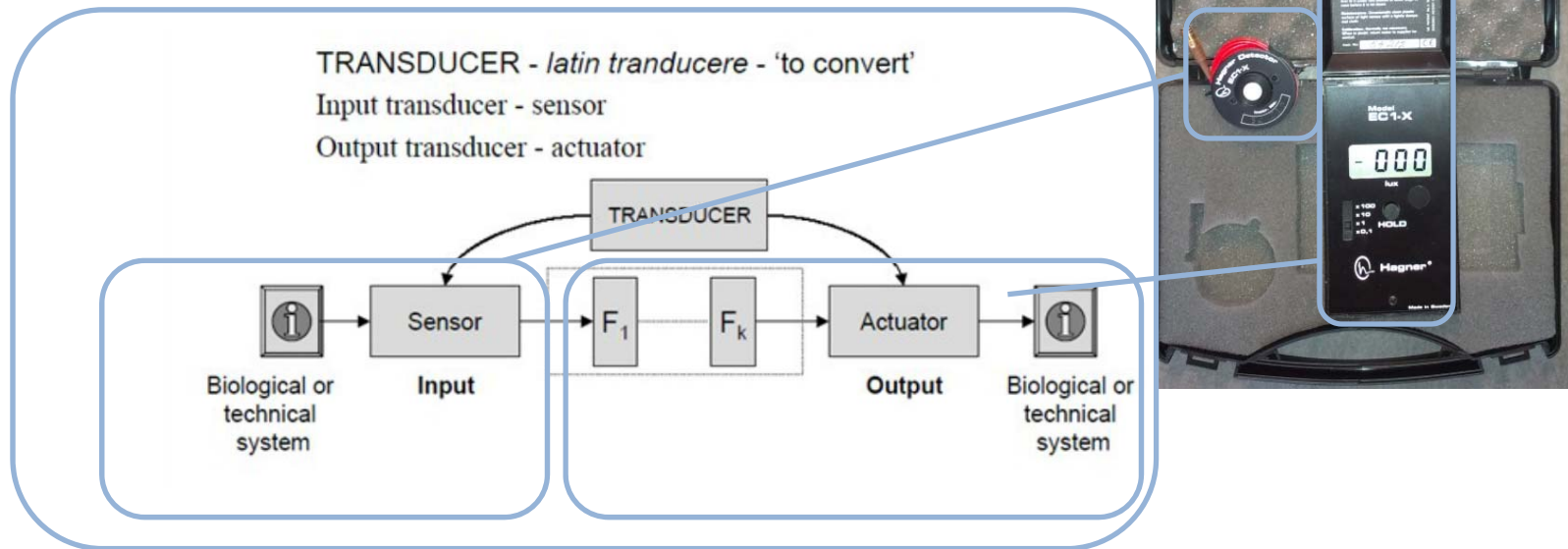


Illumination (electric light and daylight)

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

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

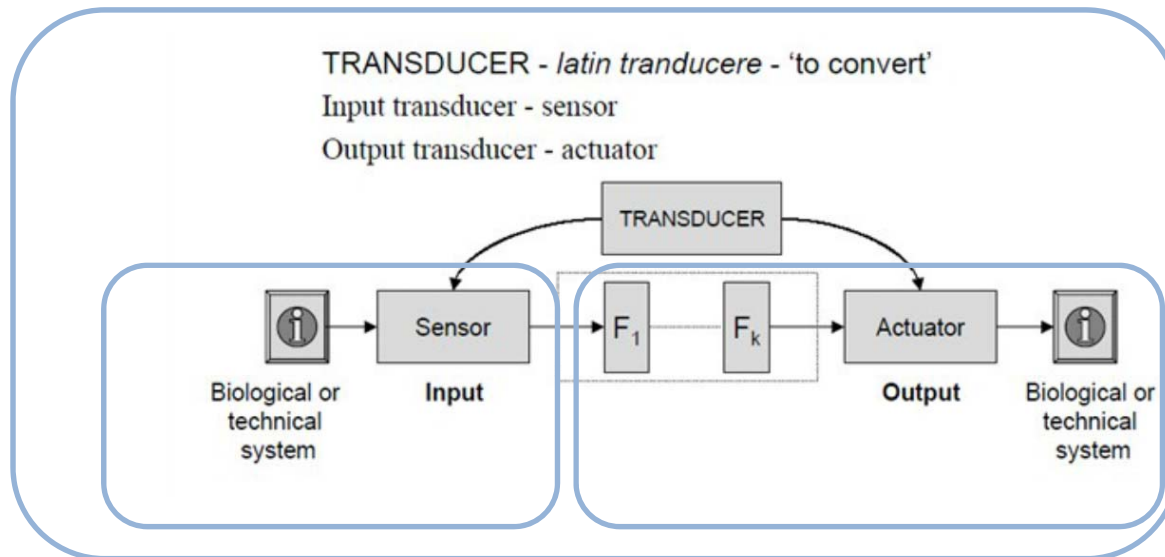
Measuring systems



Measuring errors can happen many places in the measuring system!



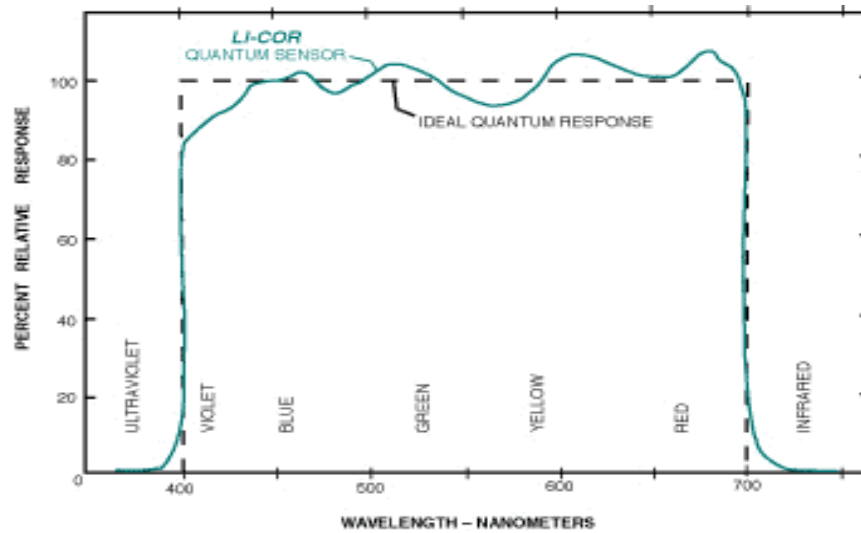
Measuring systems



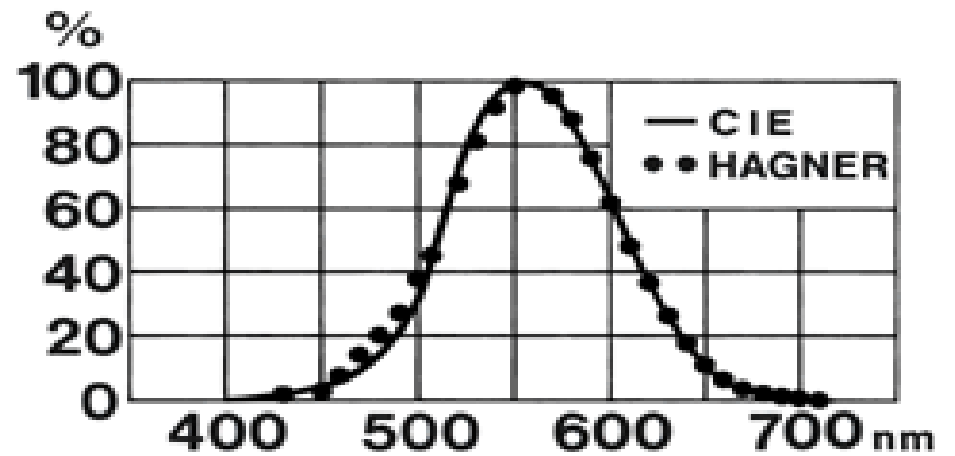
Measuring errors can happen many places in the measuring system!



Spectral sensitivity (Input transducers/detectors, differences)



Courtesy: www.licor.com



Courtesy: 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)

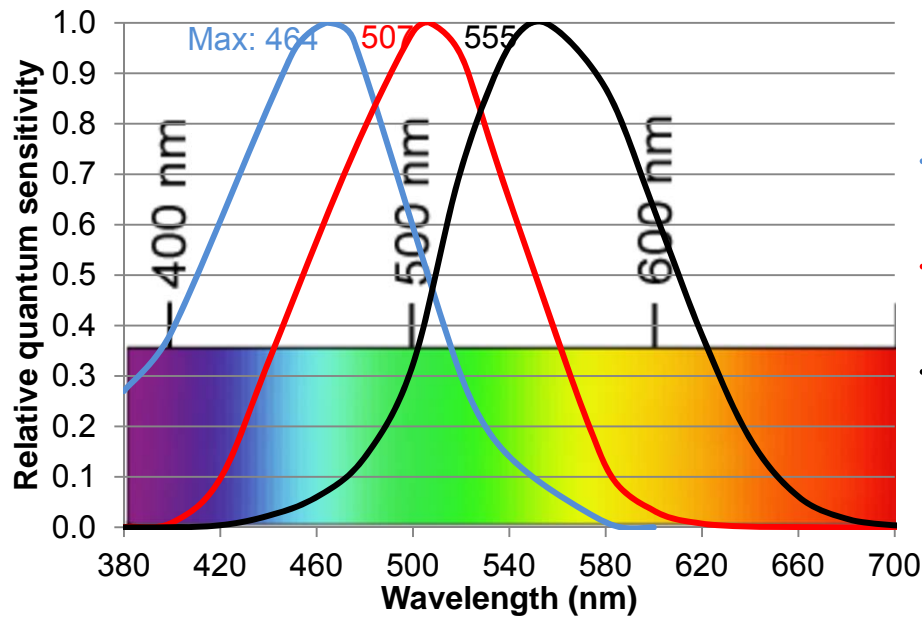
Courtesy: Figueiro *et al.* 2013, *Light. Res. Technol.* 45(4), Modified figure



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'_{λ}
- Photopic factor V_{λ}

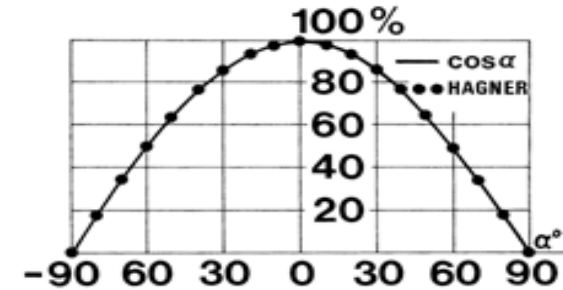
← Mesopic factor $V_{mes}(\lambda)$

Action Spectrum for Melatonin Regulation a Novel Circadian Photoreceptor

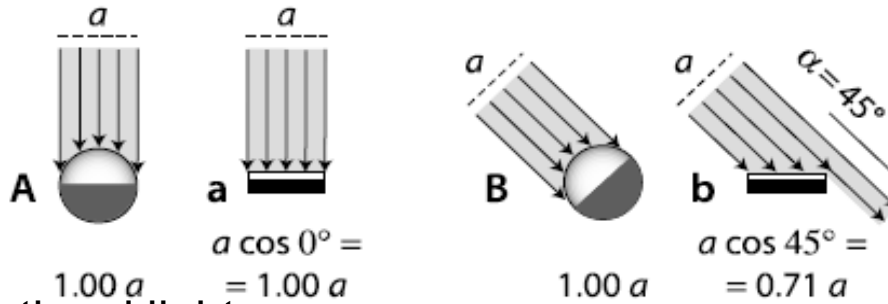
The Journal of Neuroscience, August 15, 2001, 21(16):6405-6412

George C. Brainard,¹ John P. Hanifin,¹ Jeffrey M. Greeson,¹ Brent Edward Gerner,¹ and Mark D. Rollag²
¹Department of Neurology, Thomas Jefferson University, Philadelphia, Pa, ²Physiology and Genetics, Uniformed Services University of Health Sciences

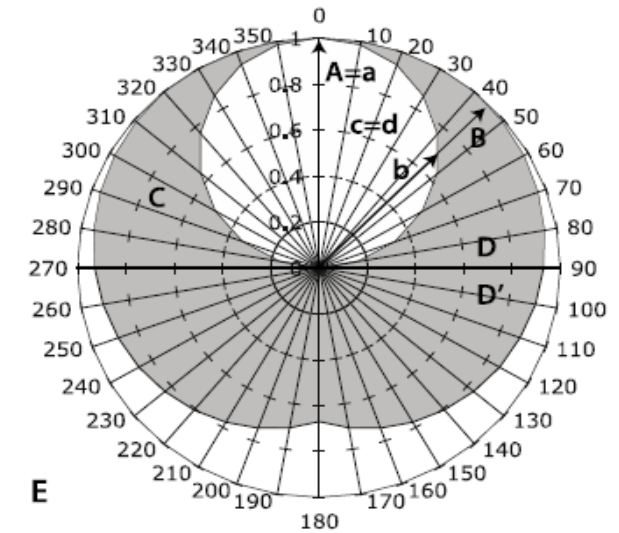
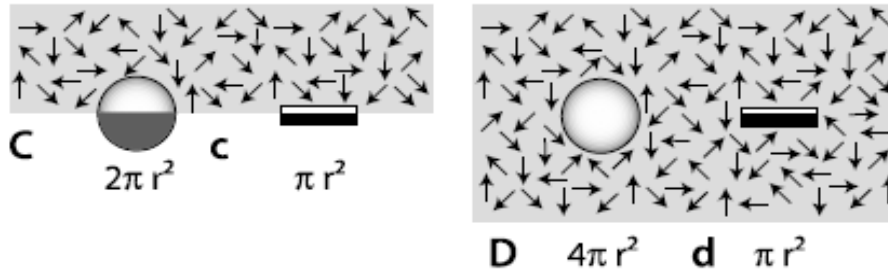
Spatial sensitivity (direct and diffuse radiation)



One directional light:



Multi directional light:



Courtesy: Eva Rosenqvist, University of Copenhagen

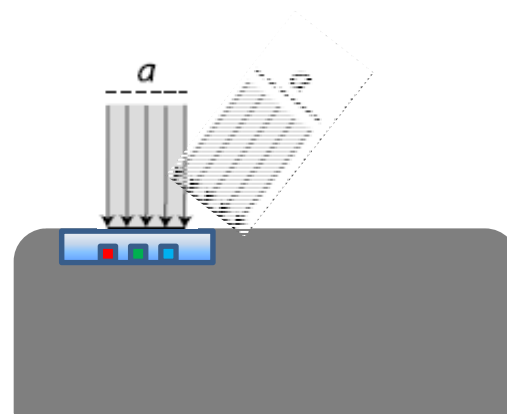


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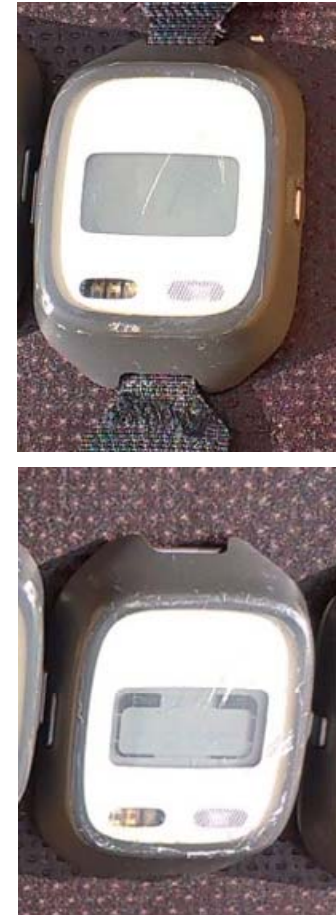
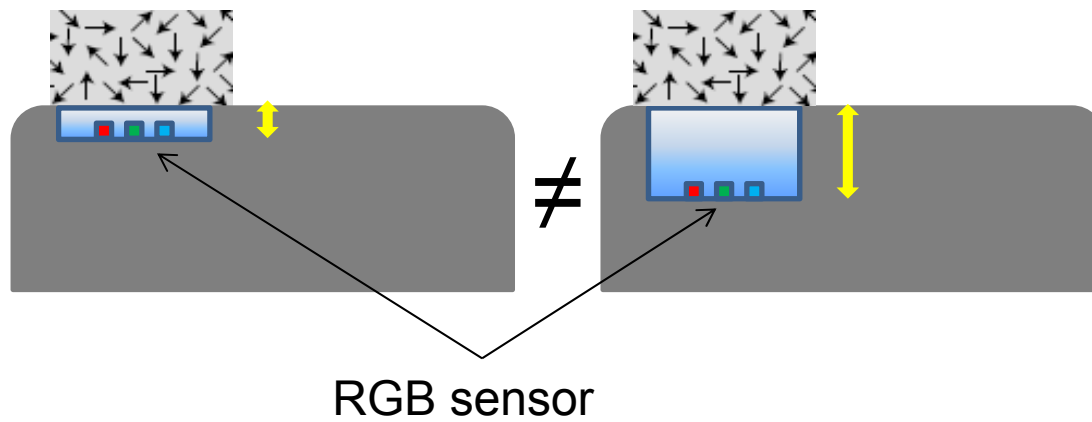
Spatial sensitivity, direct light

**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

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

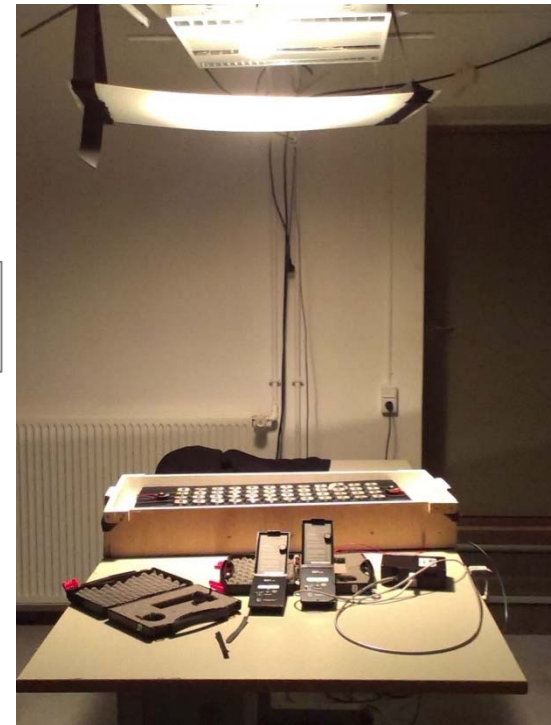
Preferable a **one-dimensional unit of light** exposure



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!)

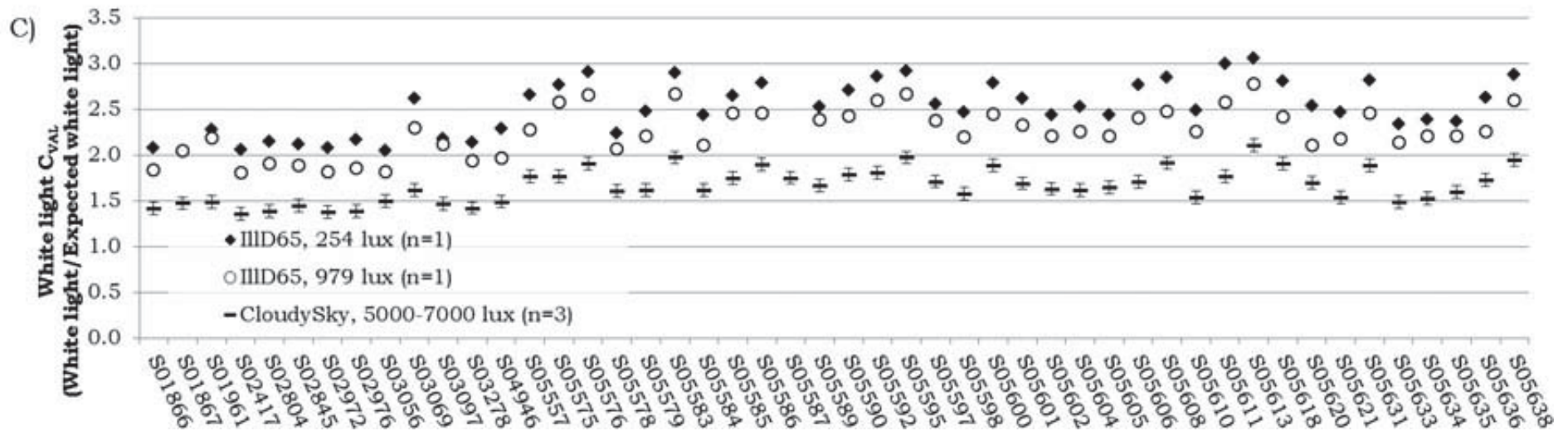


Calibration

In the lab – Standard light source "D65"



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

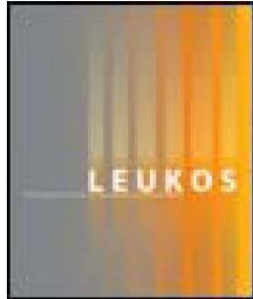
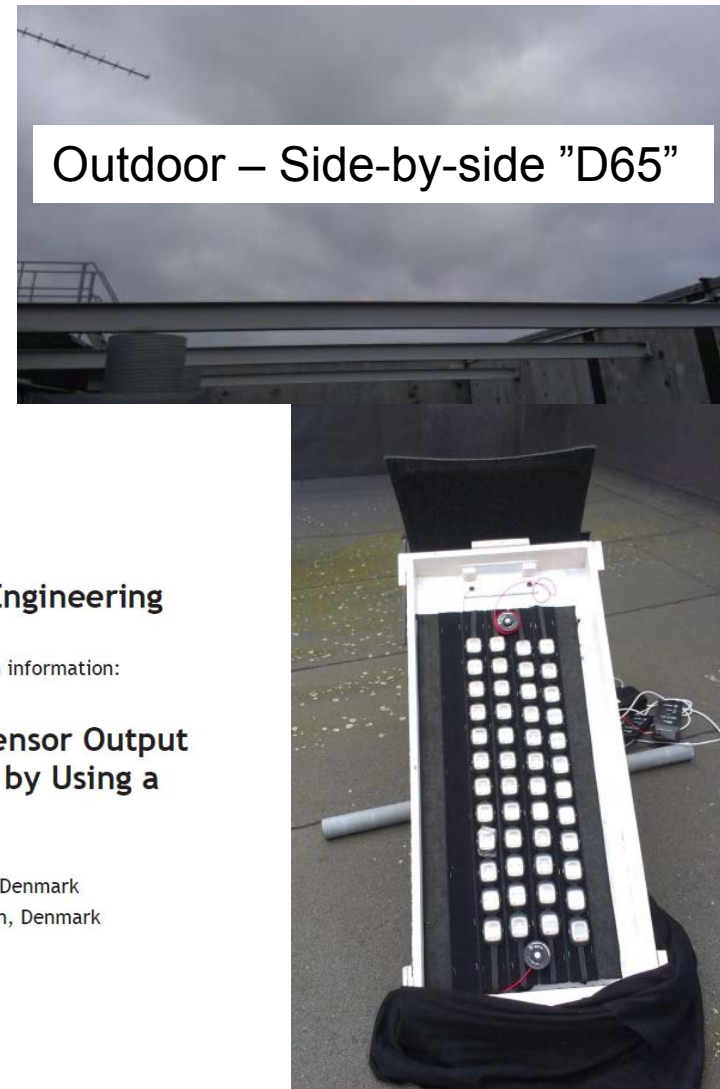


$$\text{White light } C_{val} = \frac{\text{White light}}{\text{Lux}_{\text{Ref-Meas}}}$$



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

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<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

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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:

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