



LUND  
UNIVERSITY

# Flicker and Temporal Light Artefacts

JOHANNES LINDÉN, DESIGN SCIENCES, LUND UNIVERSITY



# Visual ergonomics group

## Ergonomics and Aerosol Technology

DESIGN SCIENCES | FACULTY OF ENGINEERING, LTH



Johannes Lindén  
Light Researcher  
PhD Physics



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Assistant Professor  
PhD Visual Ergonomics BSc Optometry

## Design Sciences



Department of Design Sciences covers six divisions:

- Ergonomics and Aerosol Technology
- Industrial Design
- Innovation Engineering
- Packaging Logistics
- Product Development
- Rehabilitation Engineering (Certec)



# Lighting lab

## Ergonomics and Aerosol Technology

DESIGN SCIENCES | FACULTY OF ENGINEERING, LTH

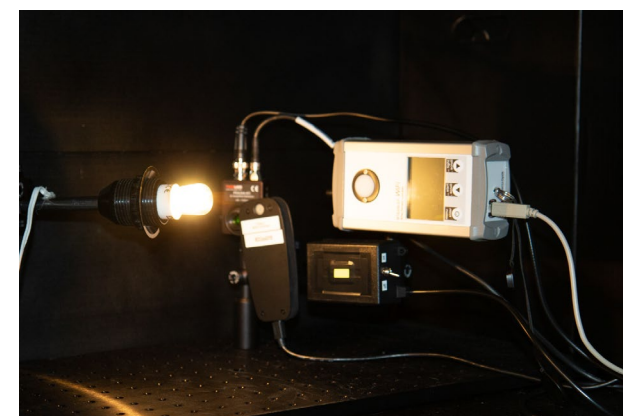
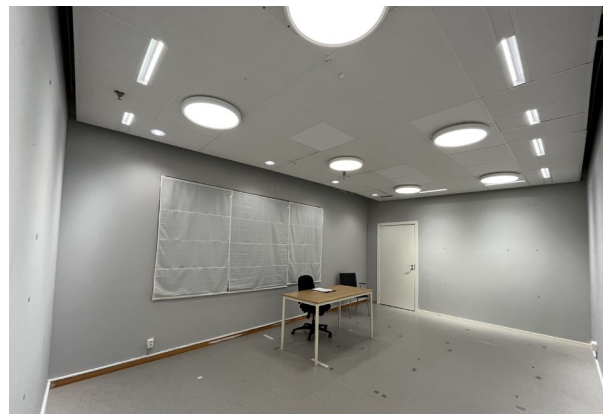
Conducts lighting research with respect to human health and safety, regarding aspects such as:

- Visual ergonomics
- Comfort
- Glare
- Flicker

Houses a lighting lab for assessment of lighting conditions and light source performance, both in lab and in the field.

## Environmental Psychology

Department of Architecture and Built Environment | LTH, Faculty of Engineering

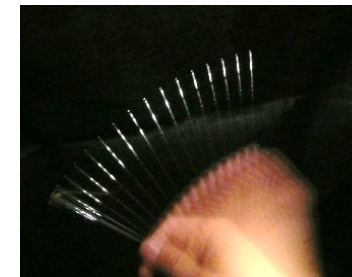


# Temporal light artefact – “Flicker”

- **Flicker ( $P_{st}^{LM}$ )** (< 80 Hz)  
perception of visual unsteadiness induced by light that fluctuates with time, for a **static observer** in a **static environment**
- **Stroboscopic effect (SVM)** (80 Hz – 2000 Hz)  
change in motion perception induced by light that fluctuates with time, for a **static observer** in a **non-static environment**
- **Phantom array effect (ghosting)** (80 Hz – 11kHz)  
change in perceived shape or spatial positions of objects, induced by light that fluctuates with time, for a **non-static observer** in a **static environment**



Eyes and light source  
“steady”



Light source or  
object in light  
moving



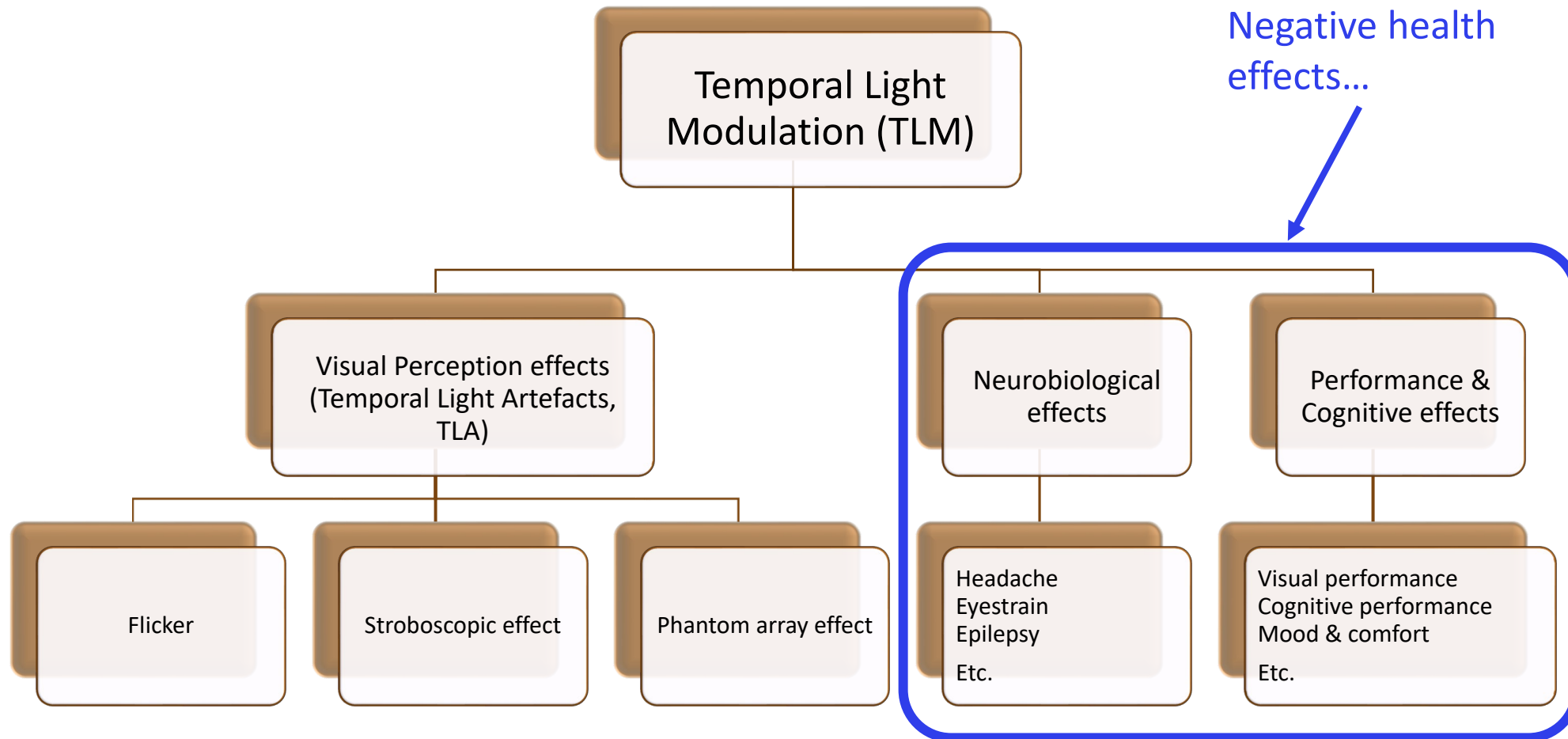
Eyes moving

The effect above is called Temporal Light Artifacts (TLA).  
TLAs are caused by Temporal Light Modulation (TLM)

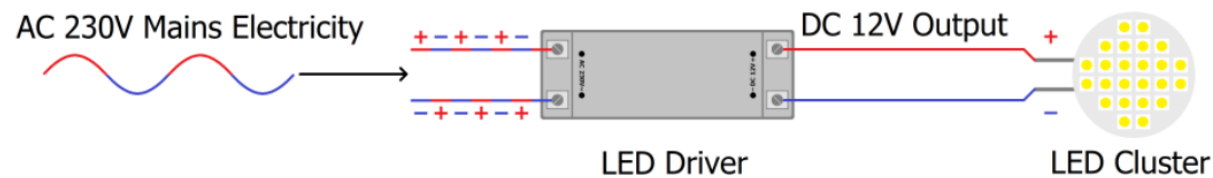
# What is flicker?

- Strictly speaking...
- Flicker is not something light or a lamp **does**, it's something **you see**.
- Flicker is a special case of **Temporal Light Artefacts (TLA)**
- TLAs are caused by **Temporal Light Modulation (TLM)**

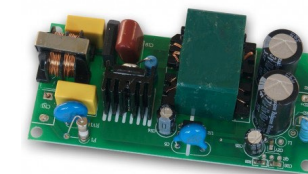
# Temporal Light Modulation (TLM)



# LEDs do not ~~flicker~~ modulate temporally



It's not you.  
It's me.



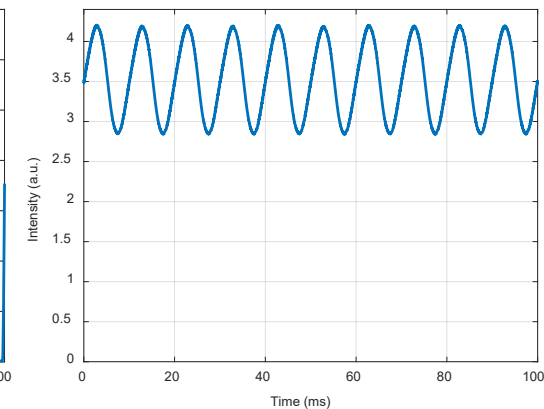
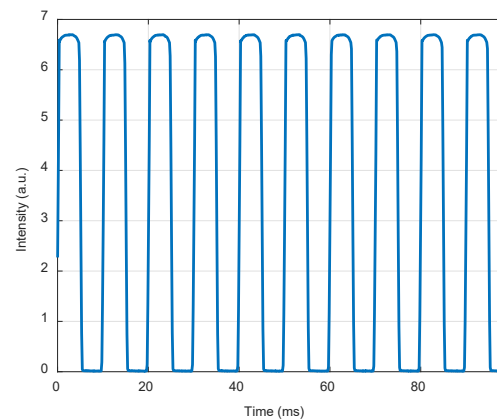
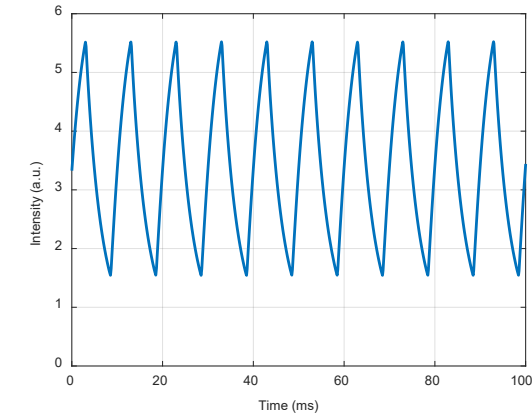
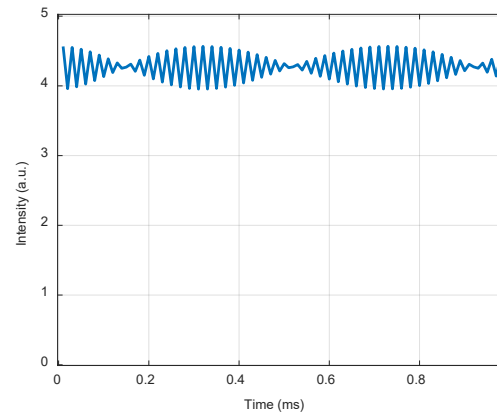
- It's always the driver.
- The LED only mirrors the current from the driver.
- LEDs should have direct current (DC). A **diod** is a rectifier (ensretter).
- TLM shouldn't be a problem.

# Temporal Light Modulation (TLM)

Example of a time-modulated light output from LED light bulbs.

Note: It's never the LED itself causing TLM. It is the DRIVER.

TLM often becomes a problem in various dimming techniques.





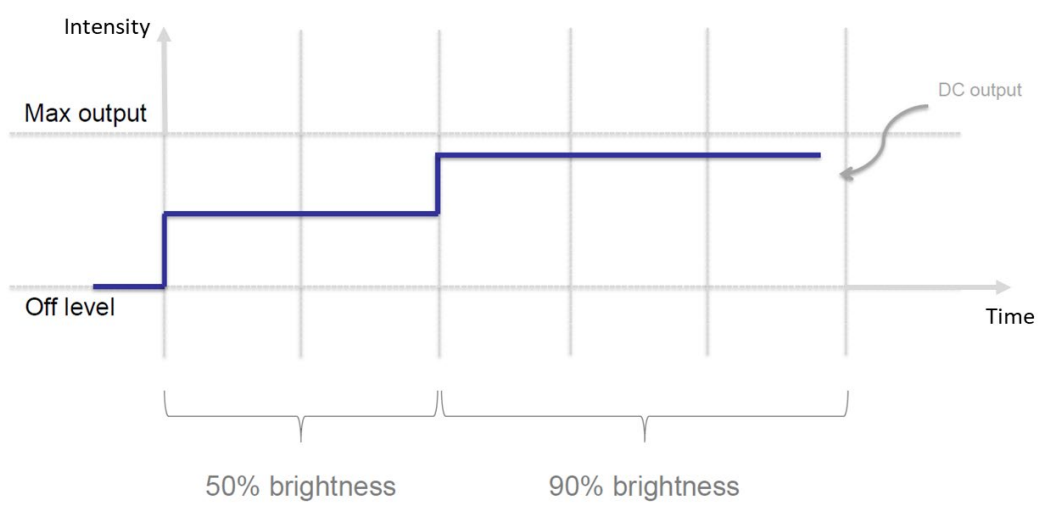
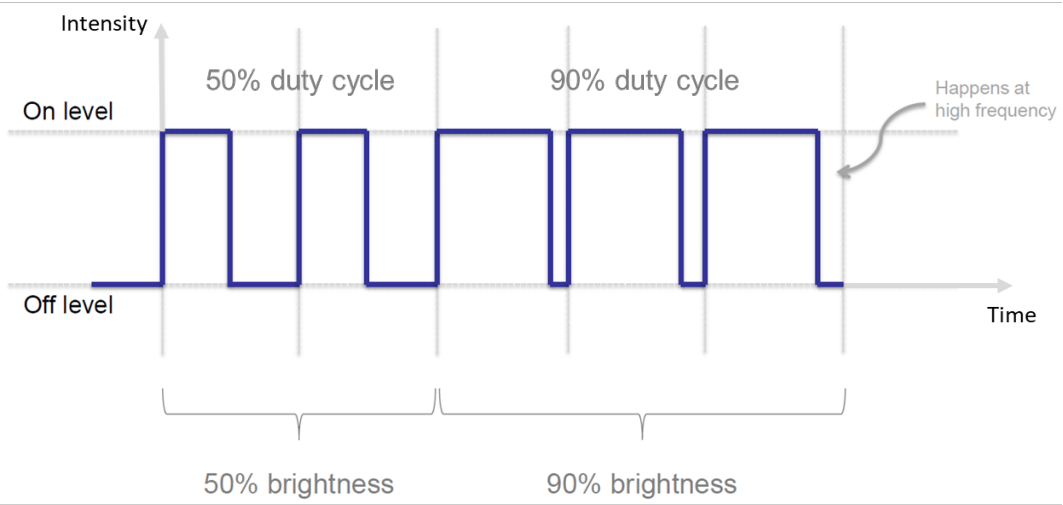
# PWM vs. CCR dimming

Pulse Width Modulation (PWM) is a dimming technique based on temporal variations. Needs to be at very high frequencies to avoid problems.

Constant Current Reduction (CCR) is an alternative dimming technique to PWM (also called Amplitude Modulation). Totally free of temporal modulation, however it might lead to color shift.

- 😊 • Cheaper components
- 😞 • Introduce TLM

- 😊 • No TLM
- 😞 • Risk of chromaticity shift



# How do we measure TLM?



# Old ways to assess TLM

- Percent Flicker (Note: same as Modulation Depth)
- Flicker Index

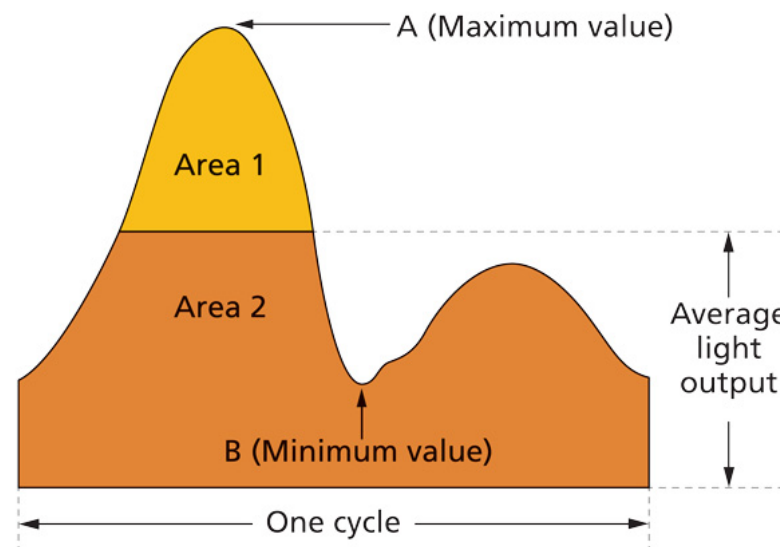
Neither Percent Flicker or Flicker Index take the frequency into account.

That means that two waveforms with different frequencies can give the same measurement result, but one might cause TLA and one might not.

Other measures are needed.

$$\text{Percent Flicker} = 100\% \cdot \frac{(A - B)}{(A + B)}$$

$$\text{Flicker Index} = \frac{\text{Area 1}}{(\text{Area 1} + \text{Area 2})}$$



Source: IESNA Lighting Handbook, 10th Edition

# How to measure TLAs

- For **Flicker:**  
Short-term flicker indicator  
Symbol:  $P_{st}^{LM}$   
P stands for “Perceptability”  
st stands for “short-term”  
LM stands for “Light Measurement”  
 $P_{st}^{LM} = 1$  means 50% chance of observation
- For **Stroboscopic effect:**  
Stroboscopic Visibility Measure (SVM)  
Symbol:  $M_{vs}$   
 $M_{vs} = 1$  means 50% chance of observation  
Note: The abbreviation SVM is often confused with the symbol  $M_{vs}$
- For **Phantom Array**  
- None existing

**No measure addressing subliminal effects. Research needed!**



**IEC TR 61547-1:2020** Equipment for general lighting purposes - EMC immunity requirements - Part 1: An objective light flickermeter and voltage fluctuation immunity test method. (2017).

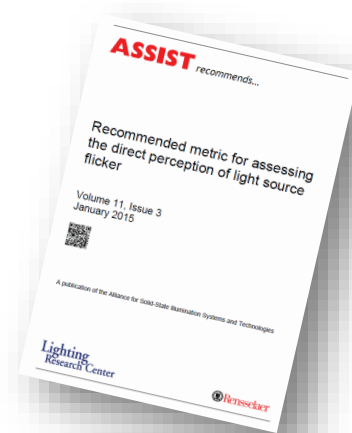


Sekulovski, D, et al. (2016). **CIE TN 006:2016:** Visual Aspects of Time-Modulated Lighting Systems – Definitions and Measurement Models. [http://files.cie.co.at/883\\_CIE\\_TN\\_006-2016.pdf](http://files.cie.co.at/883_CIE_TN_006-2016.pdf)

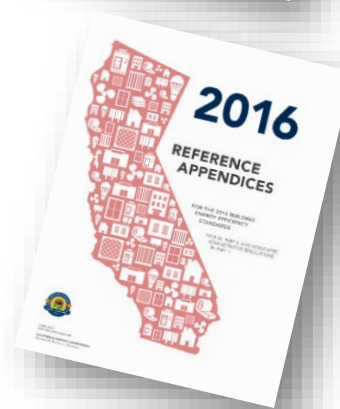


# Other TLM measures

- Assist Mp
- Compact Degree Flicker (CFD)
- VFMA (FMA (Flicker Modulation Amplitude) define by VESA).  
VFMA = 2 x Flicker Percent
- JA8 (California Energy Commission, Title 24: 2016. Reference appendices)
- ...



Bierman, A. (2015). *ASSIST recommends... Recommended metric for assessing the direct perception of light source flicker* (Vol. 11).



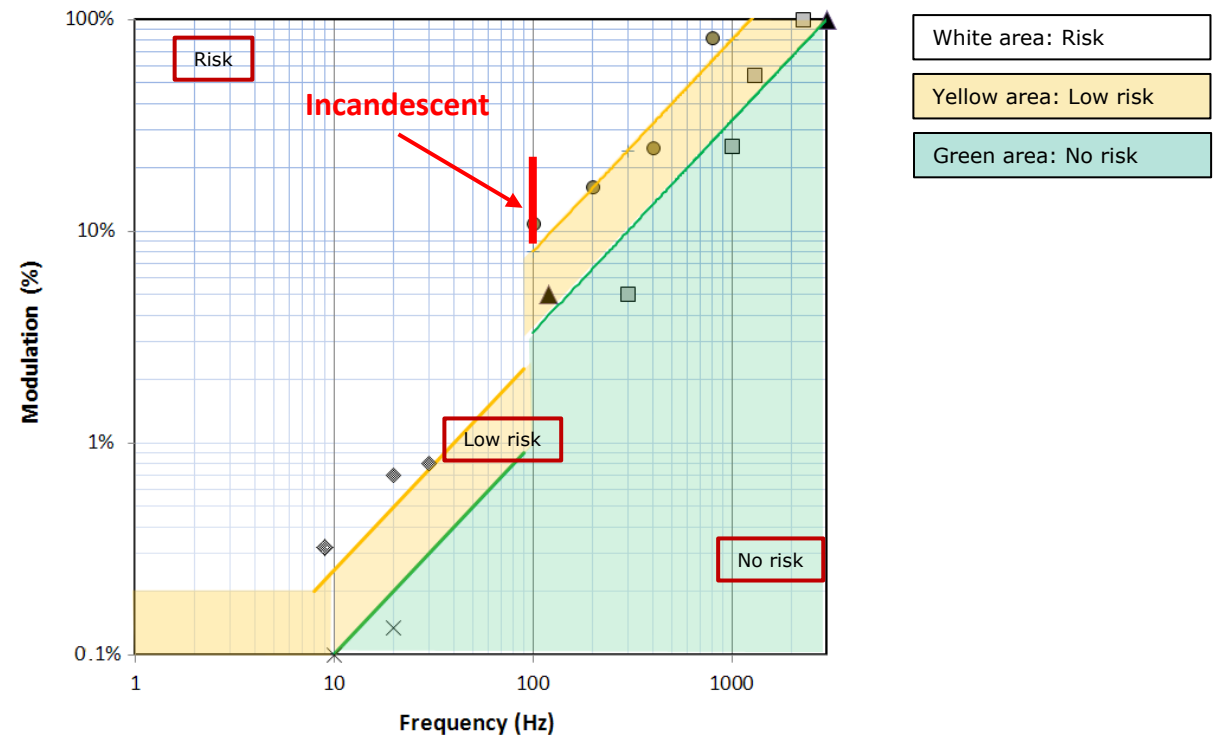
California Energy Commission. (2015). *2016 Reference appendices for the building energy efficiency standards*. Retrieved from <http://www.energy.ca.gov/2015publications/CEC-400-2015-038/CEC-400-2015-038-CMF.pdf>



# IEEE Std 1789:2015 Limit recommendations

Drawbacks with IEEE recommendations:

- Hard to apply on complex waveforms.
- Modulation depth doesn't tell the whole story. Makes no difference between sine- or square wave, neither duty cycle.
- Even incandescent bulbs ends up in the risk zone.



Markers refers to different research investigations on influence of modulated light on health.



IEEE Power Electronics Society. (2015). **IEEE Std 1789-2015** - IEEE Recommended Practices for Modulating Current in High-Brightness LEDs for Mitigating Health Risks to Viewers. <https://doi.org/10.1109/IEEESTD.2015.7118618>

# EU legislation on eco-design

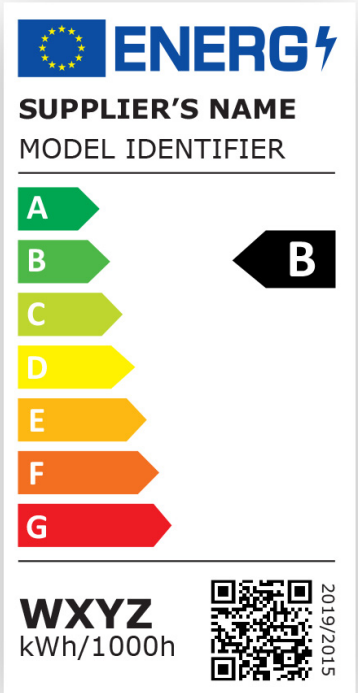
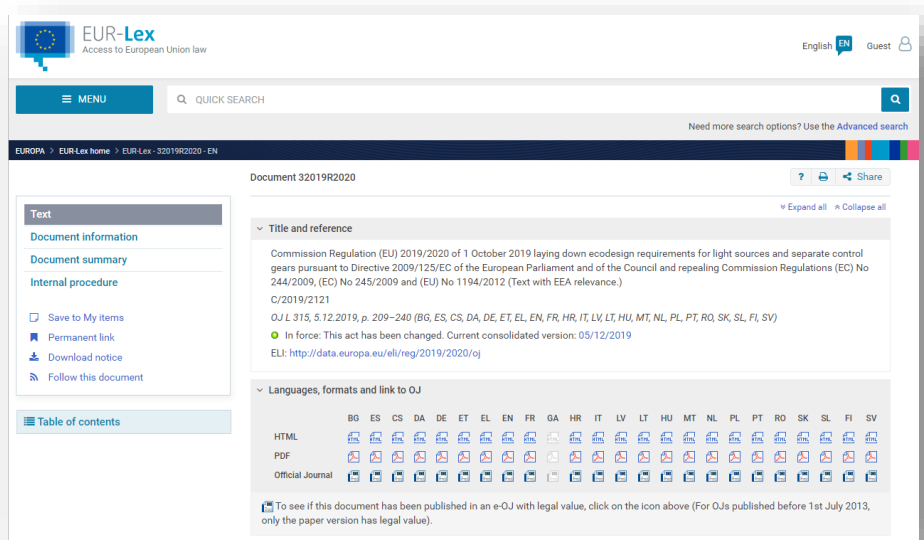
New ecodesign directive contains legislation on levels of flicker and stroboscopic visibility.

Note: At full load.

TLA	Limit
Flicker	$P_{st}^{LM} \leq 1$
Stroboscopic Visibility	$M_{vs} \leq 0.9$ Expected $M_{vs} \leq 0.4$ from sept 2024

Enter into force September 2021

Expected  $M_{vs} \leq 0.4$  in 2024



[https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L\\_.2019.315.01.0209.01.ENG&toc=OJ:L:2019:315:TOC](https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2019.315.01.0209.01.ENG&toc=OJ:L:2019:315:TOC)  
<https://ec.europa.eu/energy/en/regulation-laying-down-ecodesign-requirements-1-october-2019>

# Energy label

- <https://eprel.ec.europa.eu/screen/home>



IKEA Of Sweden AB  
LED2119G3

**General information**

<b>TYPE OF LIGHT SOURCE</b>	
Lighting technology used	LED
Non-directional or directional	Non-directional
Light source cap-type (or other electric interface)	E27
Mains or non-mains	Mains
Connected light source (CLS)	No
Colour-tunable light source	No
High luminance light source	No
Anti-glare shield	No
Dimmable	Yes

**GENERAL PRODUCT PARAMETER S**

Energy consumption in on-mode	3 kWh/1000h
Useful luminous flux	470 lm
Beam angle correspondence	Sphere (360°)
Correlated colour temperature	2 200 K
On-mode power	2,5 W
Standby power	0,00 W
Colour rendering index	80
Outer dimensions	175(Height) x 125(Width) x 125(Depth) mm
Claim of equivalent power	Yes
Equivalent power	40 W
Chromaticity coordinate	x: 0,458 y: 0,417
Spectral power distribution in the range 250 nm to 800 nm, at full-load	Image

**PARAMETER S FOR LED AND OLED LIGHT SOURCE S**

R9 Colour rendering index	9
Survival factor	1,00
Lumen maintenance factor	0,37

**PARAMETER S FOR LED AND OLED MAIN S LIGHT SOURCE S**

Displacement factor	0,80
Colour consistency in MacAdam ellipses	6
Claims that an LED light source replaces a fluorescent light source without integrated ballast of a particular wattage	No
Flicker metric	1,0
Stroboscopic effect metric	0,4

**ENERGY LABEL**  
IKEA Of Sweden AB  
LED2119G3

3 kWh/1000h

Download the label for printing  
Big color Big B&W  
Small color Small B&W




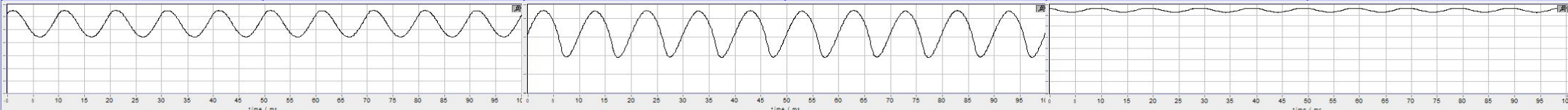



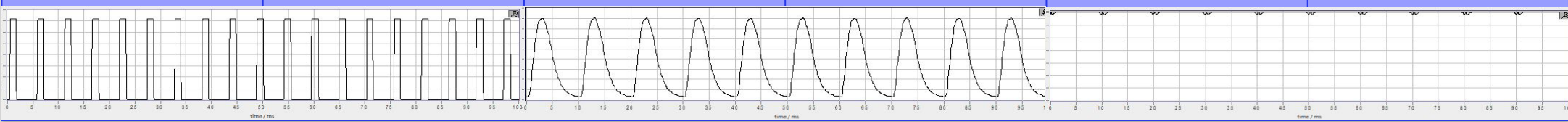
Download the label in high resolution formats  
Big color Big B&W  
Small color Small B&W

Only the 200 version is suitable for printing with the correct colour codes

integrated ballast of a particular wattage	No
Flicker metric	1,0
Stroboscopic effect metric	0,4



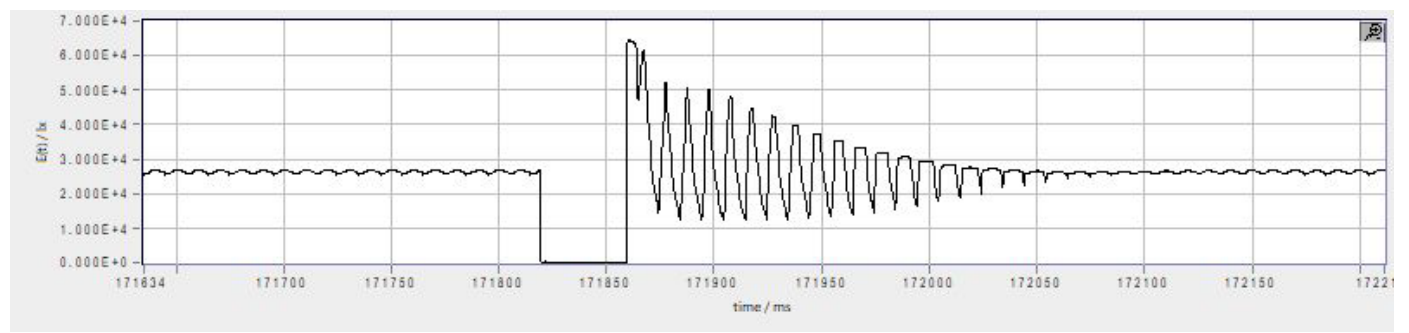
# Examples of TLM measurement results

<p>Incandescent 40 W</p> 	<p>Freq: 100 Hz SVM: 0.70 PstLM: 0.13</p> <p>MD: 19% FI: 0.06</p>	<p>Fluorescent Tube magnetic ballast</p> 	<p>Freq: 100 Hz SVM: 1.32 PstLM: 0.11</p> <p>MD: 40% FI: 0.12</p>	<p>Fluorescent Tube electronic ballast</p> 	<p>Freq: 100 Hz SVM: 0.09 PstLM: 0.03</p> <p>MD: 3% FI: 0.01</p>
					
<p>LED PWM</p> 	<p>Freq: 186 Hz SVM: 5.08 PstLM: 7.54</p> <p>MD: 100% FI: 0.75</p>	<p>LED filament bad</p> 	<p>Freq: 100 Hz SVM: 4.44 PstLM: 0.14</p> <p>MD: 100% FI: 0.35</p>	<p>LED filament good</p> 	<p>Freq: 100 Hz SVM: 0.02 PstLM: 0.04</p> <p>MD: 1.6% FI: 0.002</p>
					

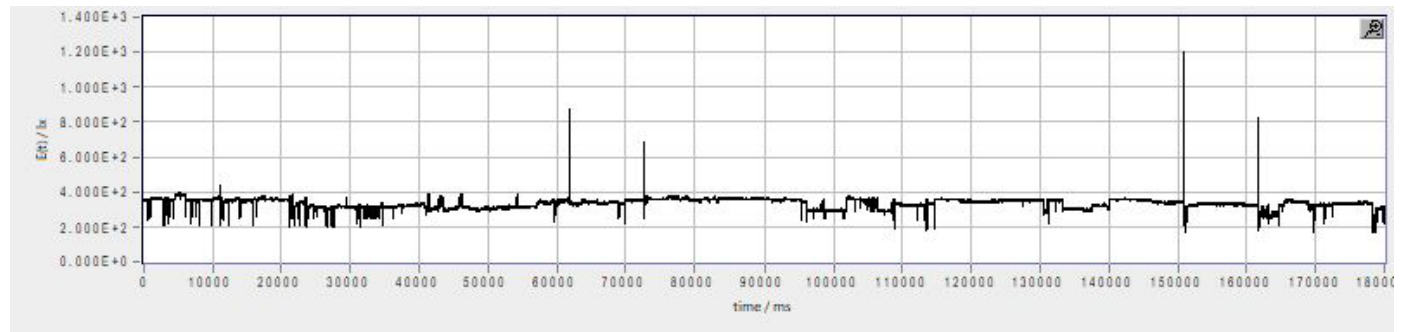
# $P_{st}^{LM}$ is a time domain measure

$P_{st}^{LM}$  gives higher readings on **non periodic** changes, such as flashes, outages and transients, compared to periodic behavior.

For periodic behavior, SVM is used, as it is a frequency domain measure.



$P_{st}^{LM} = 17$   
SVM = 0.088



$P_{st}^{LM} = 17$   
SVM = 0.013

# Demonstrations of measurements

Labarazzi

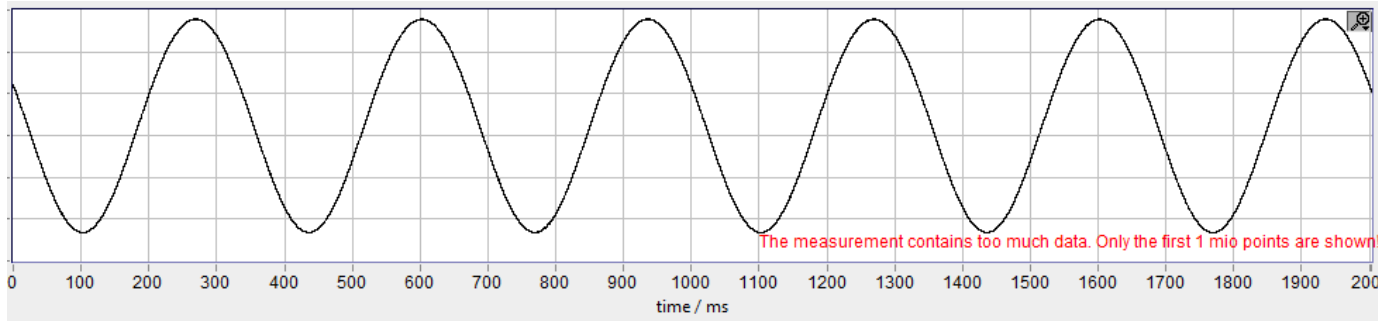


LabFlicker



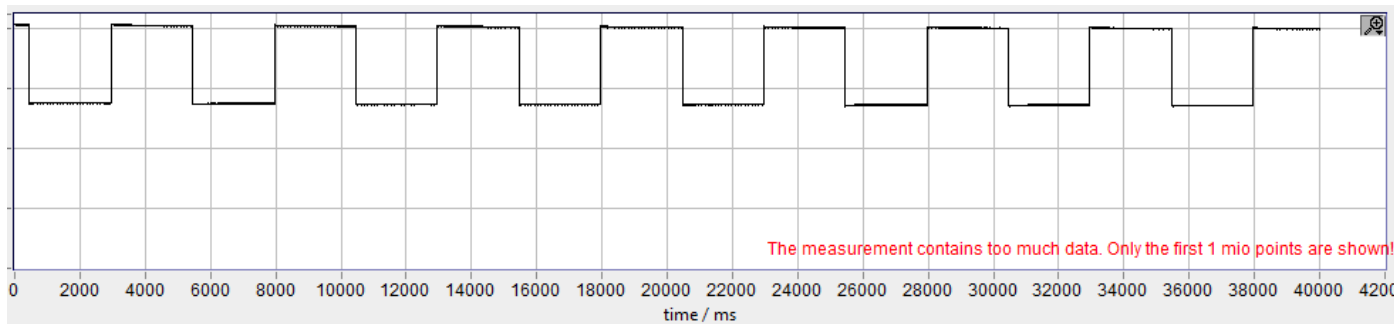
Viso Systems

# Exemple of high $P_{st}^{LM}$



Freq: 3 Hz  
SVM: 0.05  
**PstLM: 49**

MD: 80%  
FI: 0.25



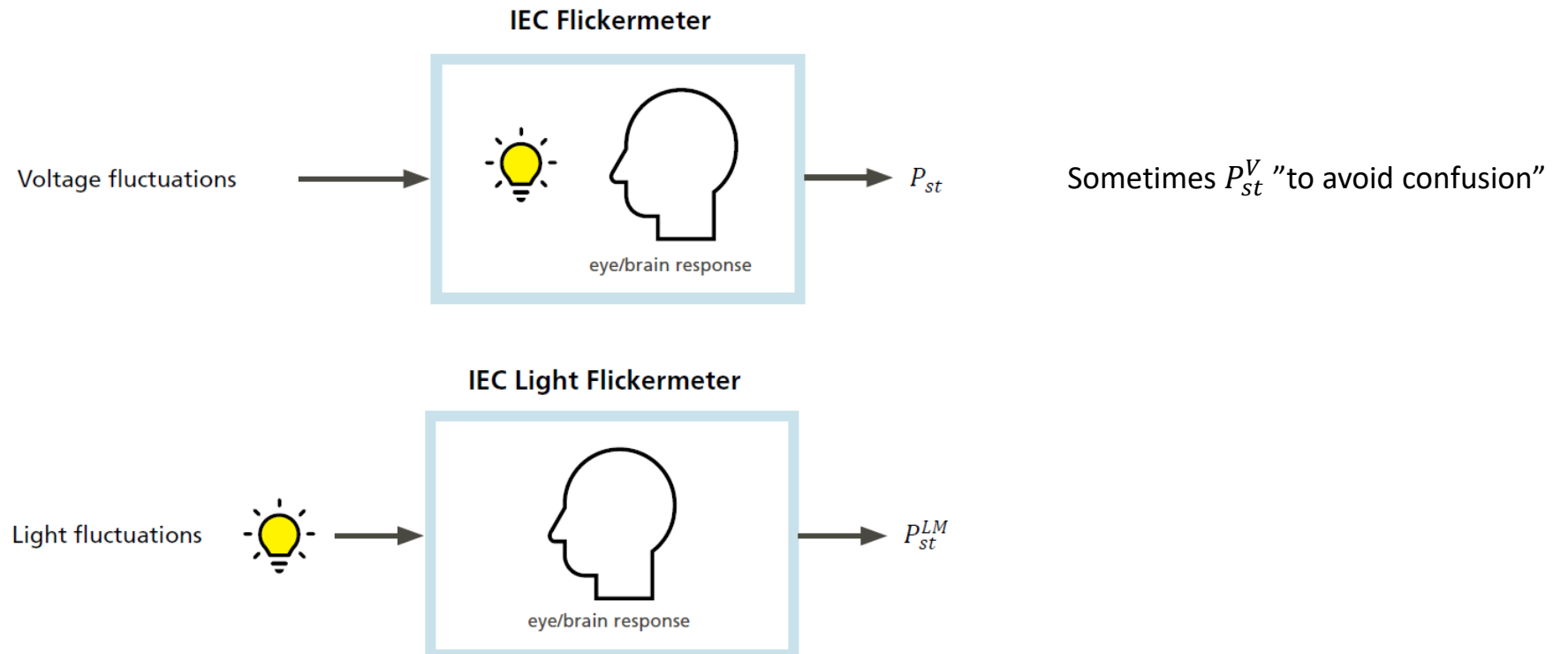
Freq: 0.2 Hz  
SVM: 0.01  
**PstLM: 14**

MD: 20%  
FI: 0.1



# Two methods – same measure

Short-term flicker indicator,  $P_{st}^{LM}$



# What you "measure" is not what you get a "measure of"

IEC Flickermeter



$P_{st}$

IEC Light Flickermeter



$P_{st}^{LM}$

Name: Short-term flicker indicator

Symbol:  $P_{st}^{LM}$

st stands for "short-term" (3 min)

LM stands for "Light Measurement"

P stands for "**Perceptability**"

or Planning levels, Pegel (German *level*), Papillotement (French *flicker*), Paracetamol

# Flicker Explained – Reports



## The medium report

### **Flicker Explained – Guide to IEC 61547 for the lighting industry**

Intended for lighting industry



## The heavy report

### **Flicker Explained – Interpretation of the Technical Report IEC 61547**

Intended for technical committees



Available at Lund University Research Portal

## The light report

### **Flicker – a technical overview**

Intended for anyone interested

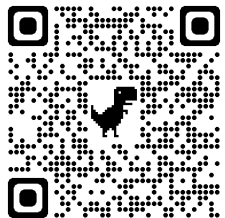


# Flicker Explained – Even more



News article on LU:

Nya rapporter för att motverka flimmer från LED-lampor

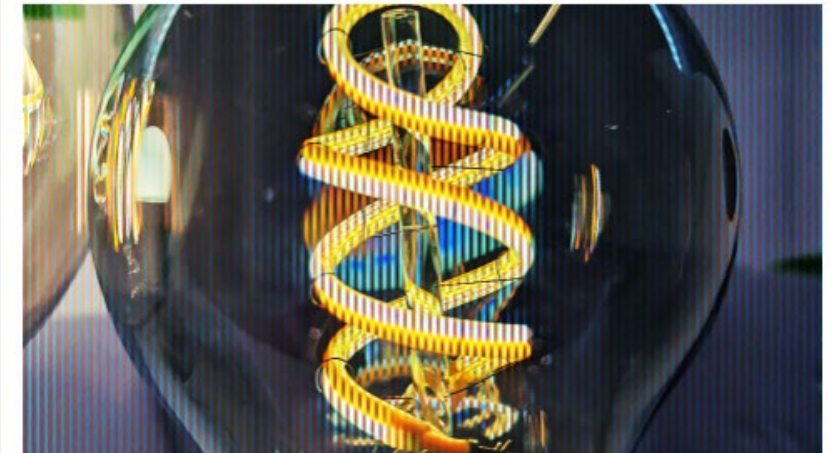


<https://youtu.be/UUW2q0vCJ6w>

Or search: Koll på flimmer lth

## Nya rapporter för att motverka flimmer från LED-lampor

Av Jessica Sellergren - publicerad 27 mars 2023



– Tidigare gav lyströret upphov till flimmerproblem. Nu är det LED-baserad belysnings teknik som behöver uppmärksammas. Det säger Johannes Lindén som är en av forskarna bakom en serie rapporter om flimmer. Foto: Johanna Rydeman

Lampans LED-teknik framhålls ofta för sina fördelar – att den är energisnål, att den håller länge och att tekniken går att styra på olika sätt. Men att LED-lampan kan ge upphov till flimmer nämns inte lika ofta. En av anledningarna är att det saknas kunskap om hur fenomenet ska mätas och hur hälsan påverkas. Det vill ljusforskarna vid LTH ändra på, och presenterar nu en serie rapporter om flimmer.

När ljuset varierar över tid uppstår effekter som vi kan se med blotta ögat – och sådana vi inte kan se. I värsta fall kan dessa ljusvariationer över tid påverka hälsan negativt, framför allt genom att orsaka huvudvärk eller migrän.

### Gränsvärden för flimmer från lampor

EU har 2021 slagit fast gränsvärden för hur mycket flimmer och stroboskopiska effekter som är tillåtet från en LED-lampa. Men kraven är svåra för belysningsindustrin att leva upp till bland annat på grund av att standarderna är otydliga.

För att öka kunskapen om flimmer och dess påverkan på människan har en serie rapporter om LED-teknik och flimmermätt nu publicerats. De ger också guidning i hur de nya riktlinjerna ska kunna följas och hur en övergång till hållbar teknik ska kunna realiseras. Rapporterna bygger på resultat från forskningsprojektet "Flicker Explained",



Johannes Lindén i Lunds universitets forskningsportal



Få koll på flimmer – Johannes Lindén tipsar:

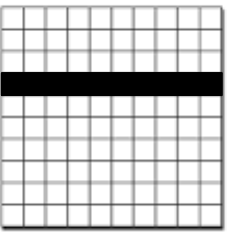


# Rolling shutter demo

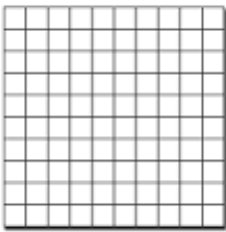


Mobile cameras use rolling shutter

Rolling Shutter



Total Shutter



"Exposure time":



52  $\mu$ s



1.5 ms



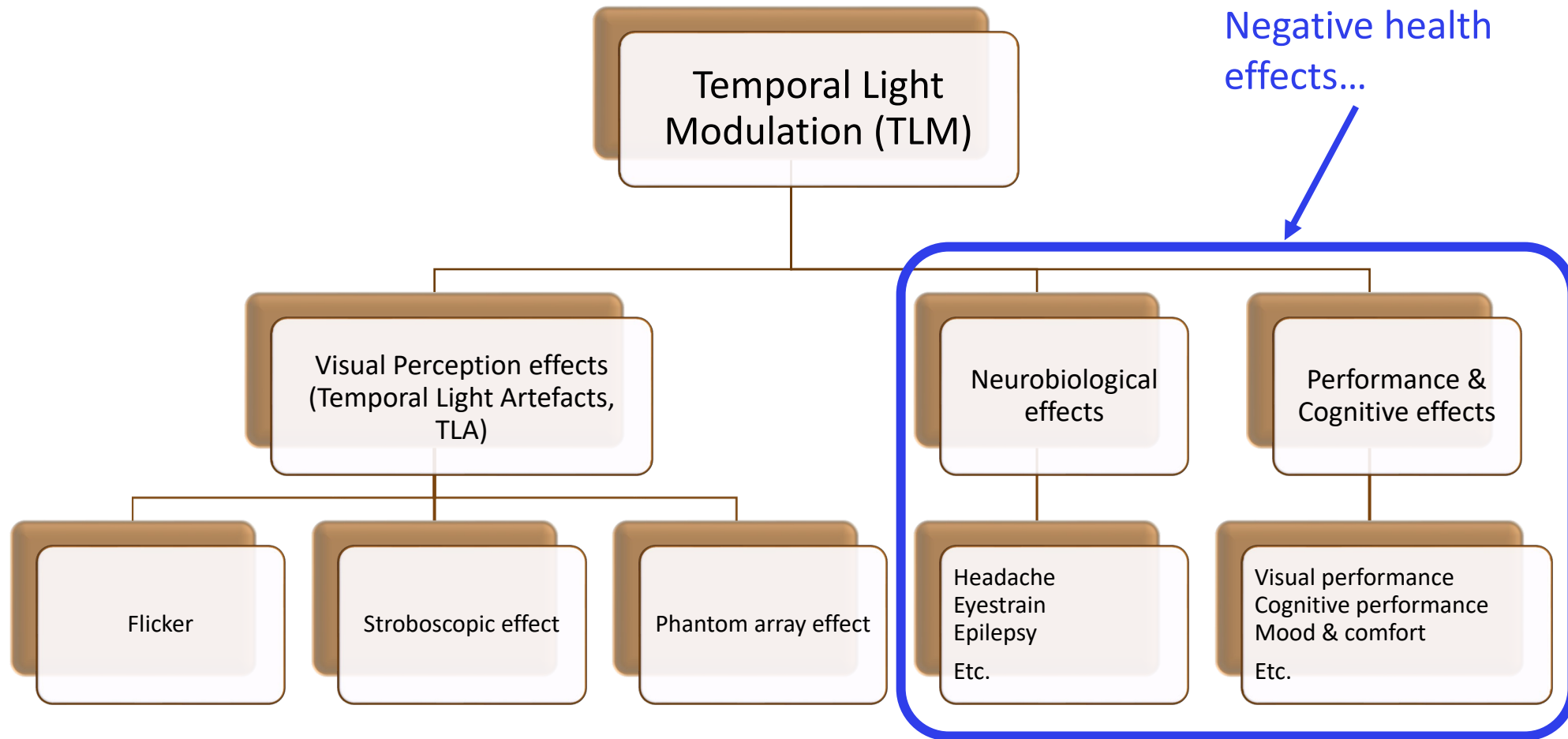
4 ms

**Conclusions:**

Mobile phone cameras

- are not good TLM measurement tools
- can serve as a first indicator
- may be able to measure frequency

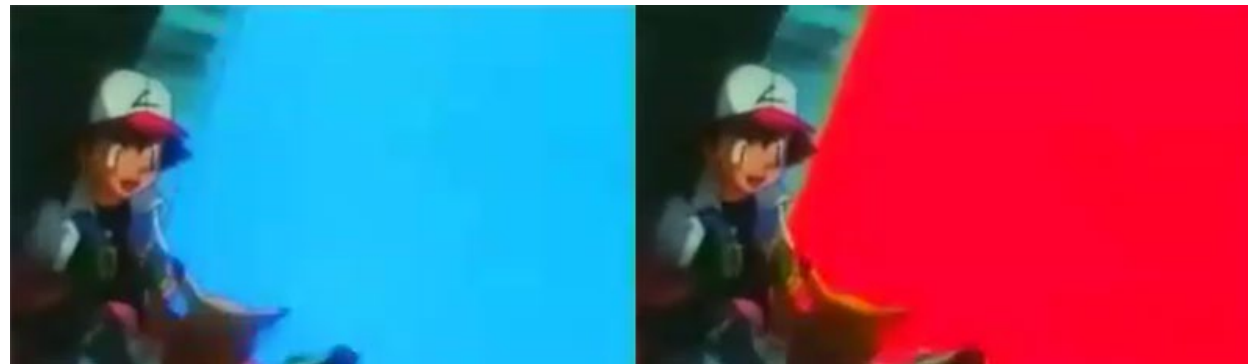
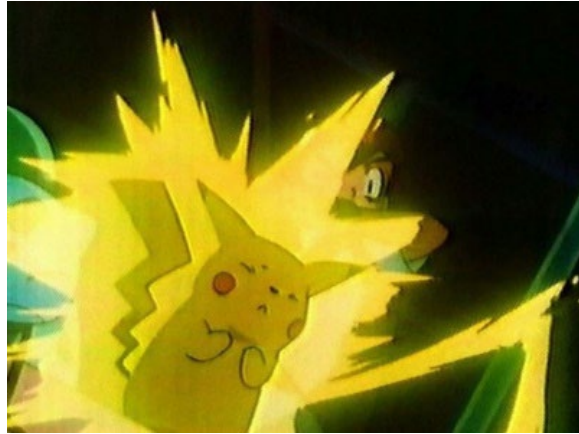
# TLM and health





# “Pokemon Incident” 1997

- 560 epileptic seizures in 4 seconds



# Resposns to TLM

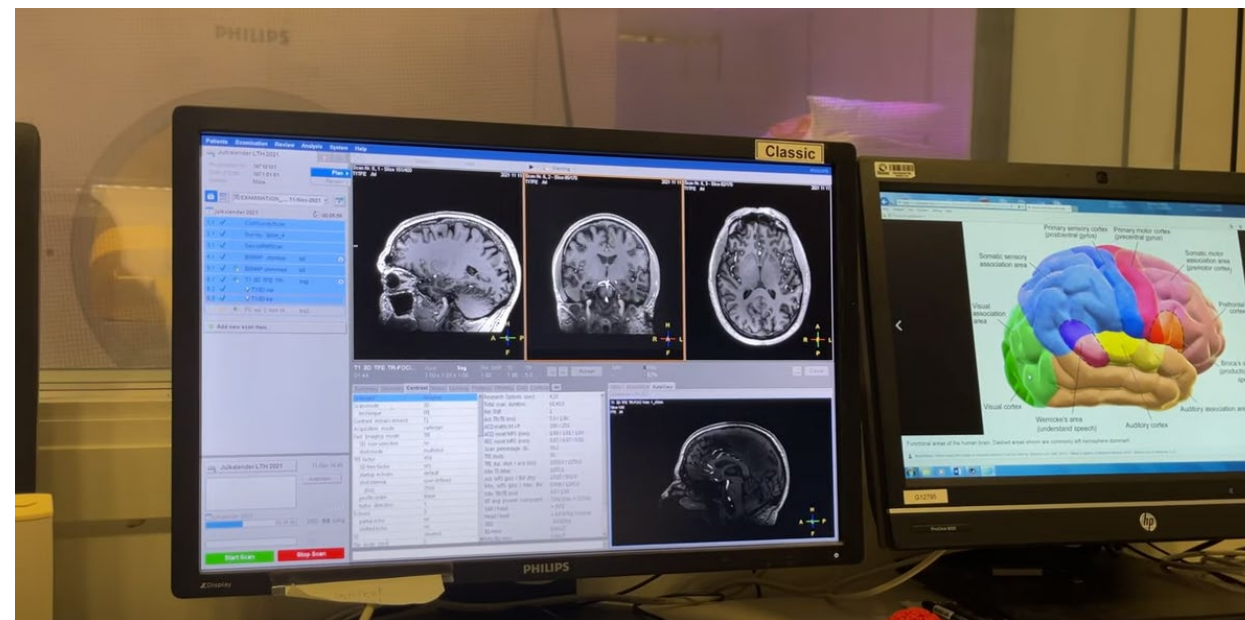
- “Pokemon Incident” of 1997:  
560 epileptical seizures due to 4s of 12.5 Hz blue-red flicker<sup>1</sup>
- Migraine and headaches<sup>2</sup>
- Photophobia<sup>2</sup>
- Hypersensitivity to electricity<sup>3</sup>
- Individuals with autism shows more negative response to TLM
- Stress
- Change in the alpha activity, EEG
- Harder for individuals with dyslexia
- Annoyance



1. Fisher et al., “Photic- and pattern-induced seizures: A review for the Epilepsy Foundation of America working group,” *Epilepsia*, vol. 46, pp. 1426–1441, Sep. 2005.
2. Wilkins, A., Veitch, J., & Lehman, B. (2010). LED lighting flicker and potential health concerns: IEEE standard PAR1789 update. In 2010 IEEE Energy Conversion Congress and Exposition, ECCE 2010 - Proceedings. <https://doi.org/10.1109/ECCE.2010.5618050>
3. Wibom, R. Nyhlén, P. Wennberg, A. (1995). “Flimmer från lysrör. En möjlig bidragande orsak till besvär vid “elöverkänslighet”, Undersökningsrapport 1995:31, Arbetslivsinstitutet, Sverige

# Pre-tests

2021 Christmas calendar episode of LTH  
5 min youtube clip (in Swedish)



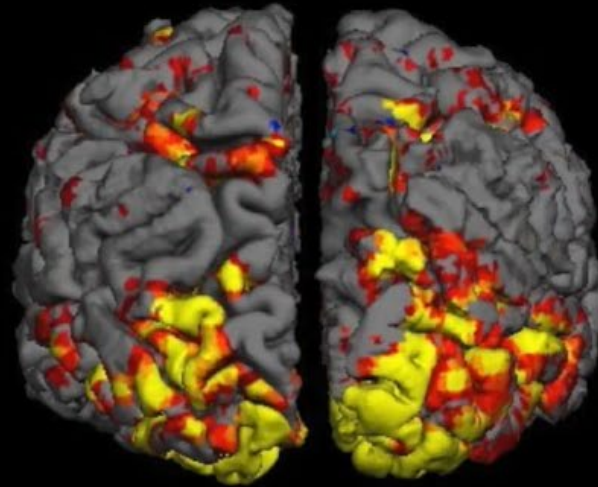
<https://youtu.be/zkY5FW00GPY>



Or search "LTH julkalender flimmer"

# Pre-tests

- ● More activity for black&white flicker
- More activity for colour flicker



**Back view of brain**  
**Visual cortex**

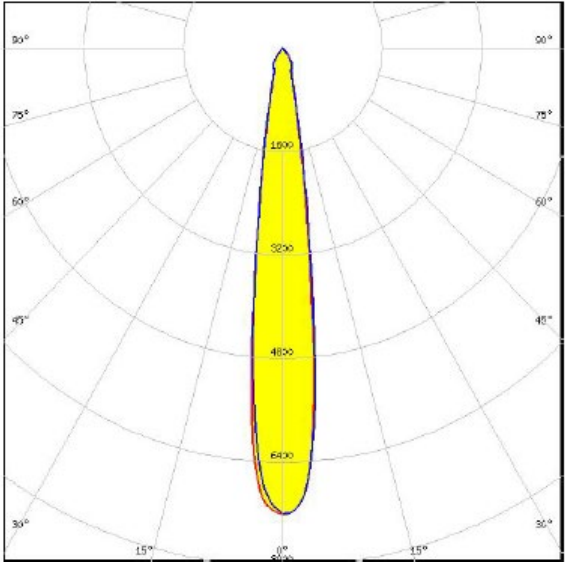
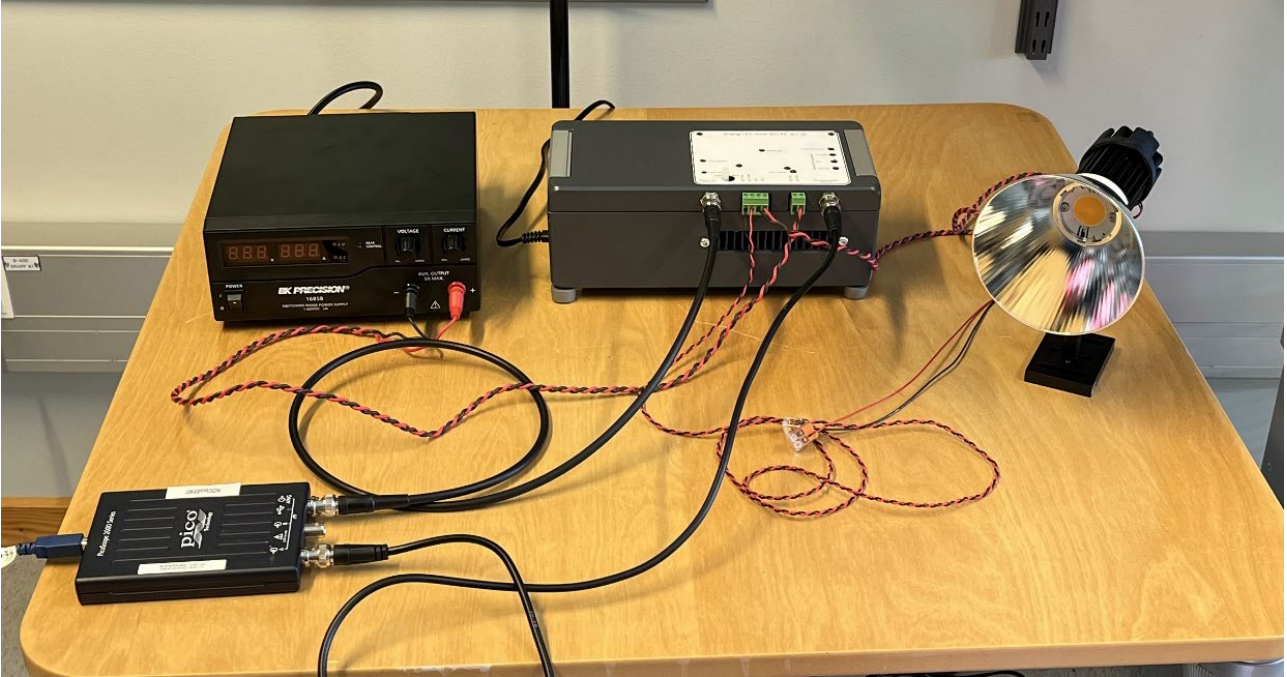
# fMRI-flicker – How flicker effects the brain

- **Project period: 2022 sept. – 2024 aug.**
- **Funded by Swedish Energy Agency**
- **Budget: 3 MSEK**
- **Multidisciplinary**
  - Visual ergonomics at Design Sciences at Lund University
  - Department of Medical Imaging and Physiology (BoF) at Skåne University Hospital
  - Department of Clinical Sciences, Lund University
  - Department of Psychology, Lund University
- **Objective:**

To investigate how light flicker of different types give rise to brain activation. The overall aim is to obtain scientific basis for formulating a measure and limit values for neurological impact on the brain, caused by light flicker.

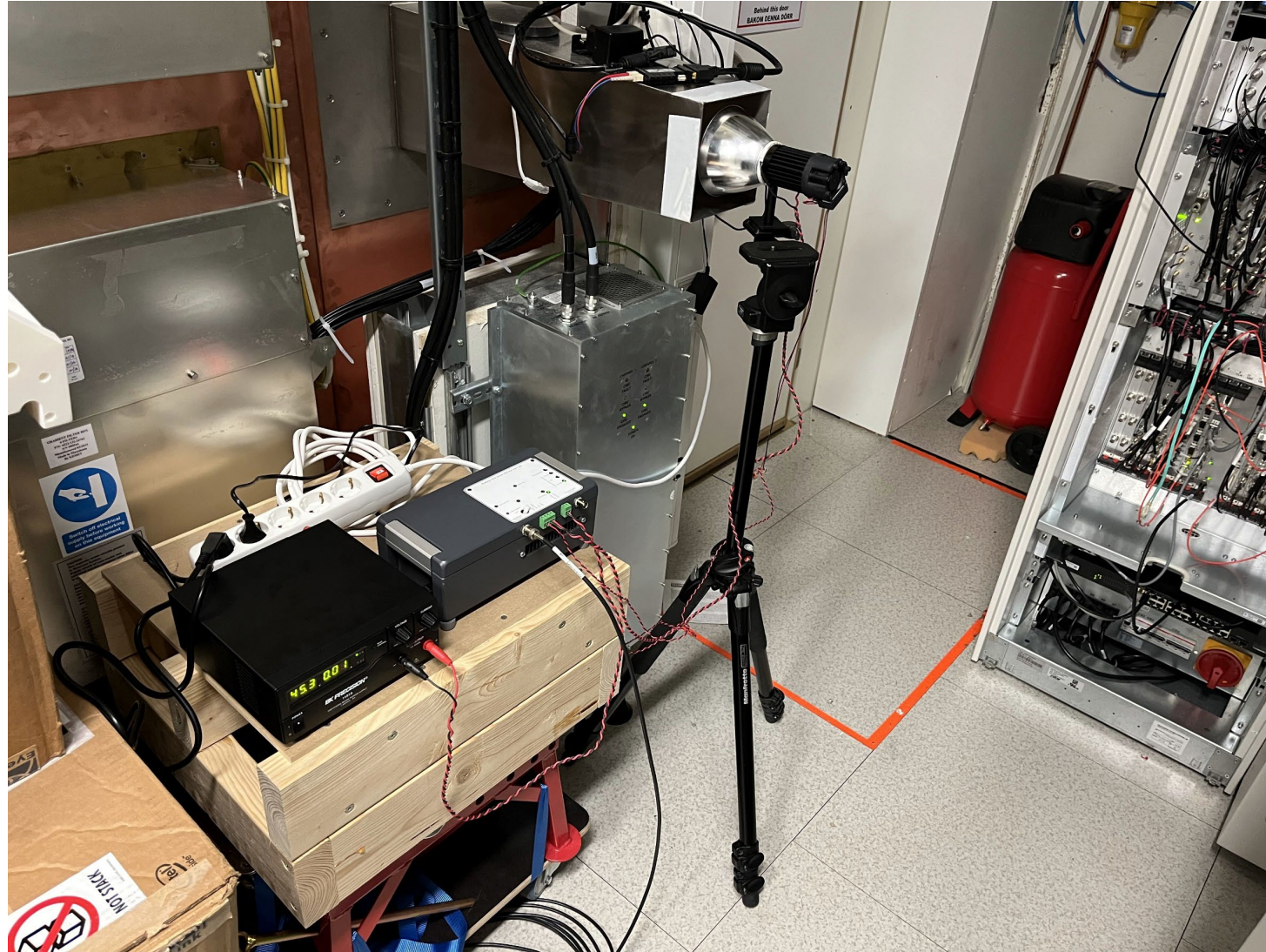


# Flickering light source

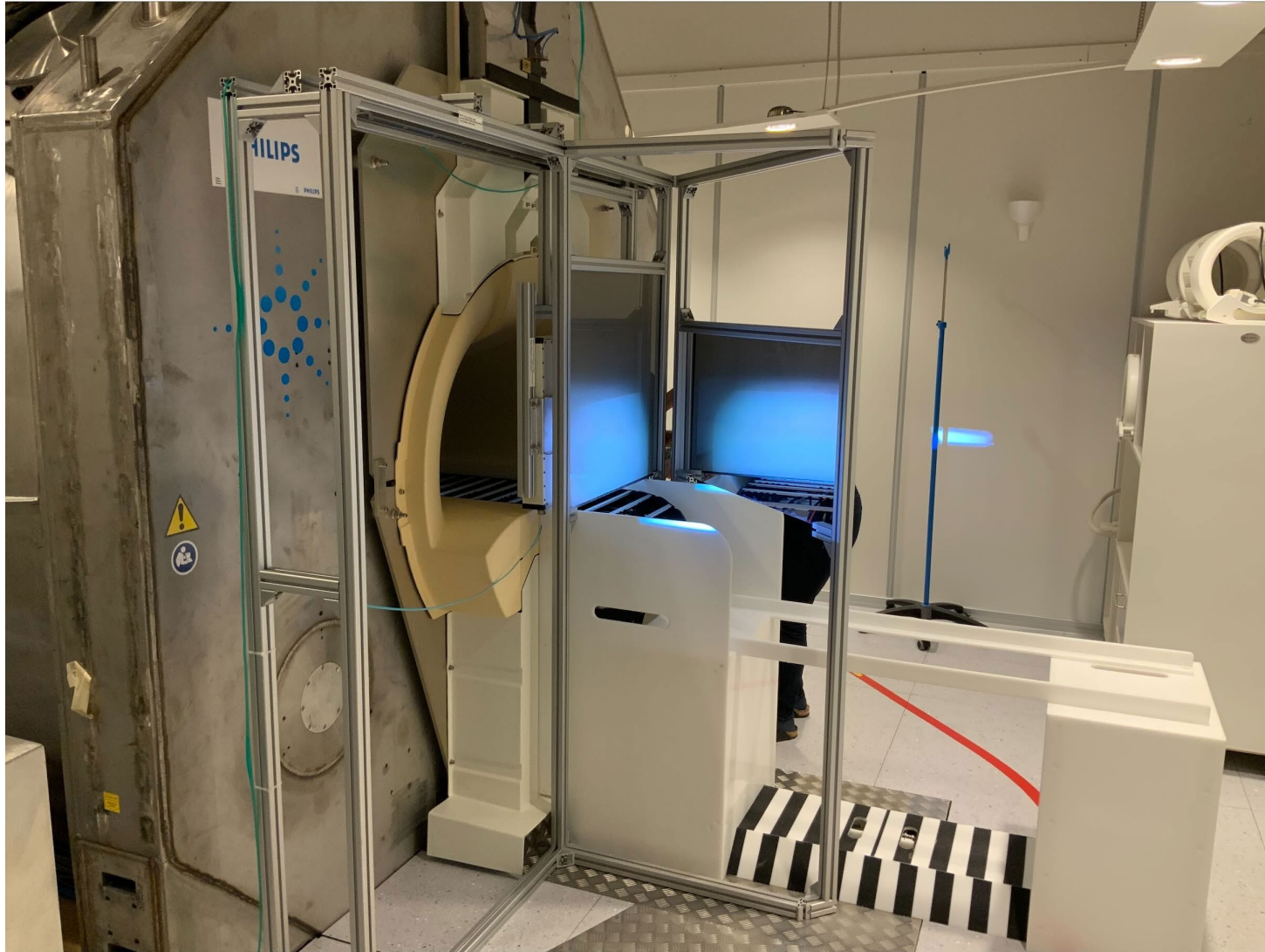




# fMRI-flicker – how flicker effects the brain

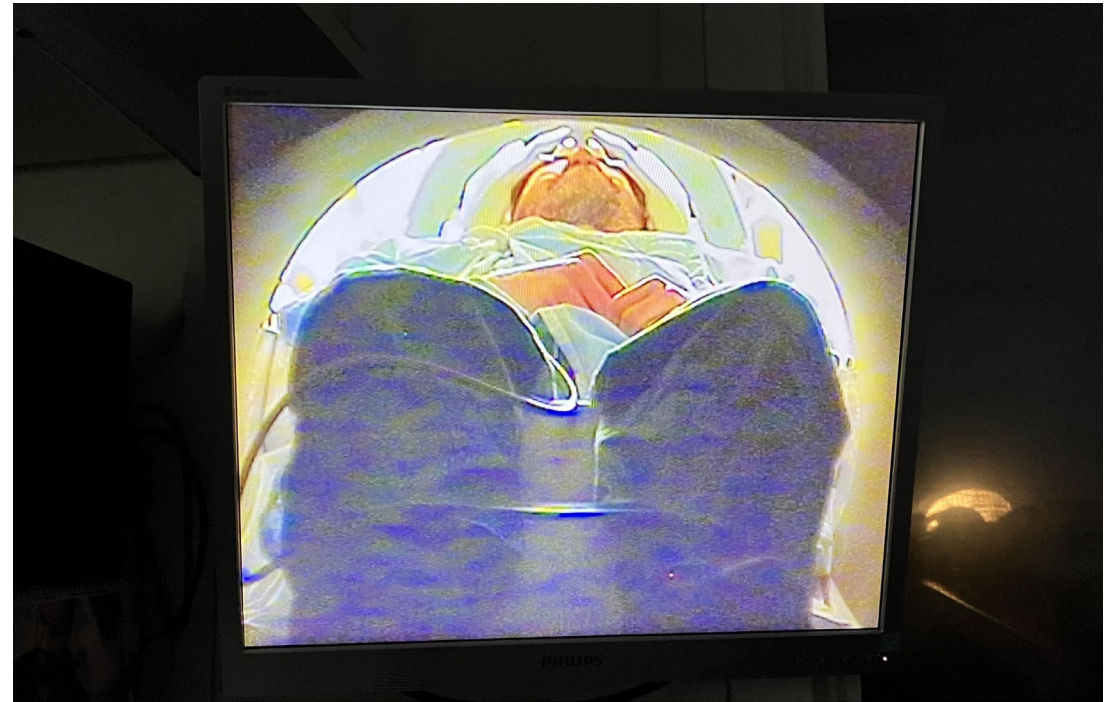


# fMRI-flicker – how flicker effects the brain





# fMRI-flicker – how flicker effects the brain



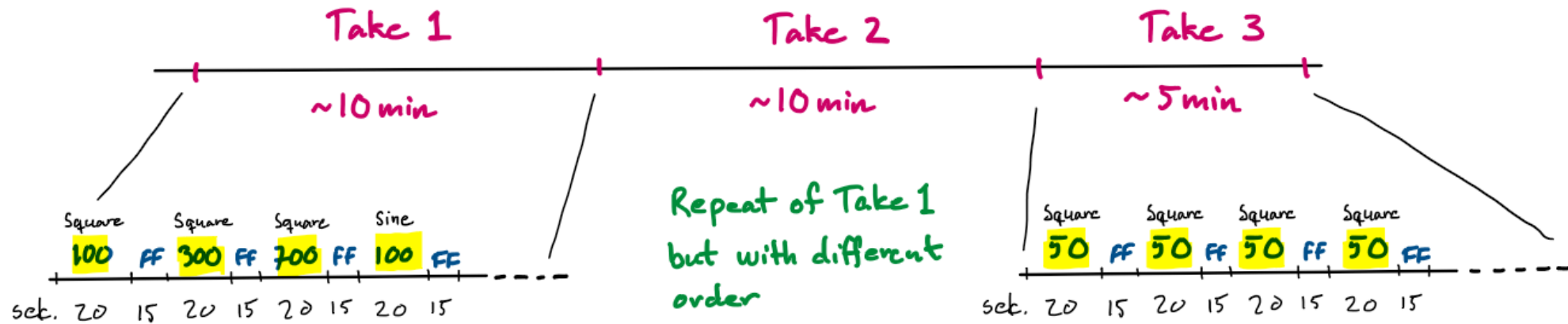
# fMRI-flicker – how flicker effects the brain





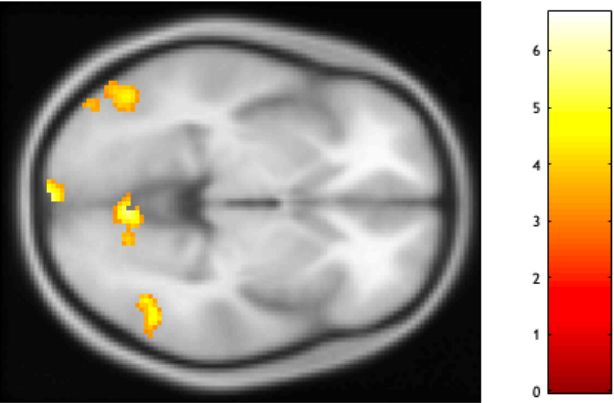
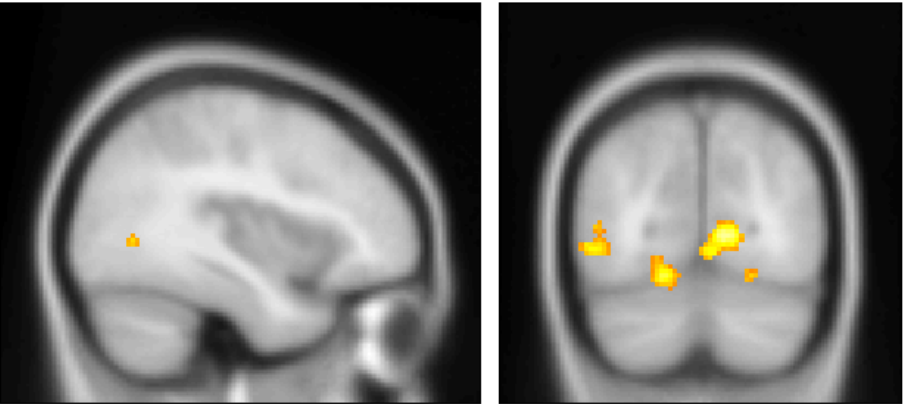
# Sketch of sequence

~ 25 min

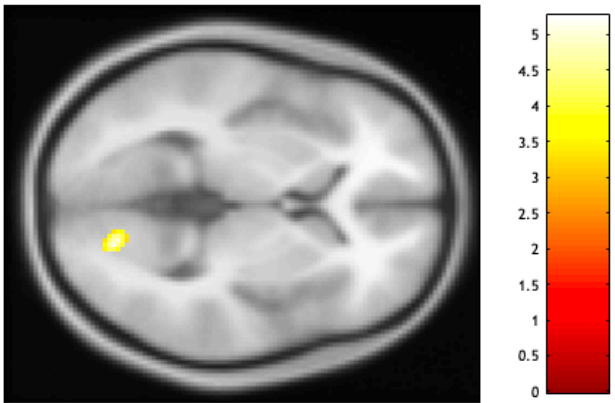
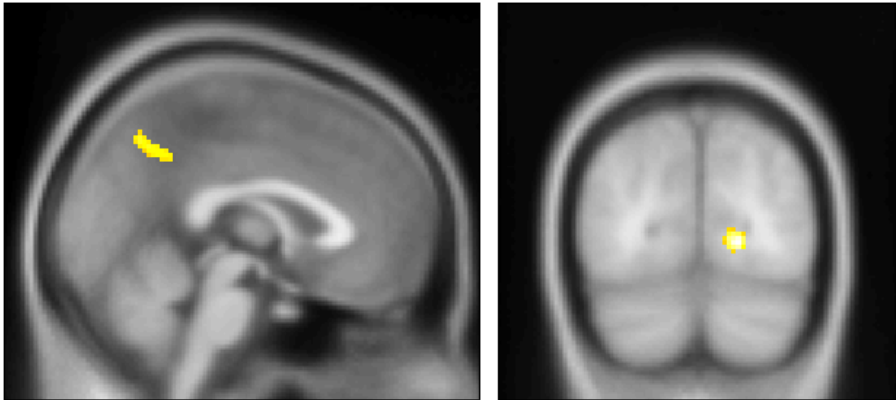


FF = Flicker Free

# First test results



50Hz vs constant baseline



100Hz vs constant baseline



# Project status

- 23 healthy subjects scanned during spring 2023
- Plan to scan ca. 35 subjects with mild migraine during autumn 2023
- Data analysis during spring 2024
- Submission of publication before summer 2024



Questions?





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*Thank you!*

*... and don't forget to get some light!*





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