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ILSC® 2025

Conference Proceedings

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Schulmeister K., Rauter P.

Comparison of retinal thermal injury thresholds with Class 1 AELs as function of exposure duration

International Laser Safety Conference, ILSC 2025, USA, Paper #L0902

Published online by the Laser Institute of America, 2025, Orlando, Florida, USA

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Comparison of Retinal Thermal Injury Thresholds with Class 1 AELs as Function of Exposure Duration

Karl Schulmeister, Patrick Rauter
Seibersdorf Laboratories, Austria

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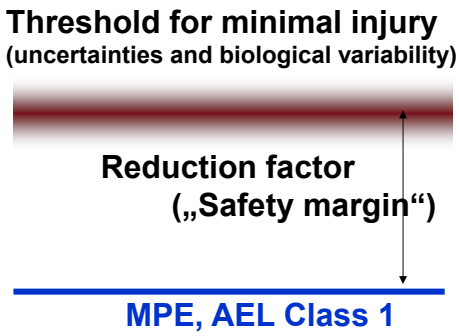
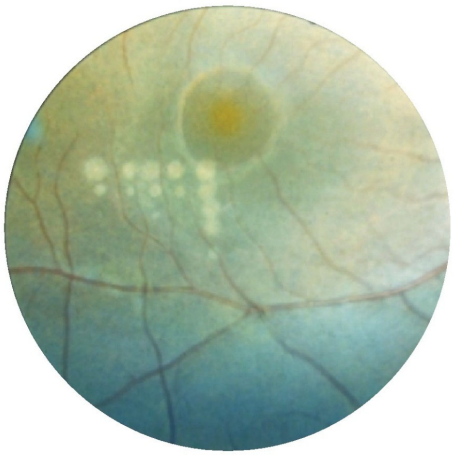
Retinal thermal AEL (MPE)

ANSI Z136.1 (since 2014)
ICNIRP 2013
IEC 60825-1:2014

Single Pulses, Dependences:

- Wavelength (530 nm, 1060 nm)
- Pulse duration
- Retinal irradiance profile (Top Hat diameter → α)





Reduction factor:

- varies due to simplification of exposure limits
- should consider uncertainty of data

Computer Model

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Seibersdorf Laboratories computer model to calculate thresholds for retinal injury (JLA 2017)

Validated against Non-Human Primate data
Validated against ex-plant (fresh cow-eyes)

Model data and ex-plant: basis for $\alpha_{max}(t)$ update 2014

Applicable for thermal damage, **t ≥ ~100 µs**

Data shown for 1 µs also to show trend, but NHP thresholds are lower (micro-cavitation)

Interpretation:

- Optimised for ED50 (variability: actual threshold could be a bit lower)
- Predictions have uncertainties: maximum factor 1.8 model too high

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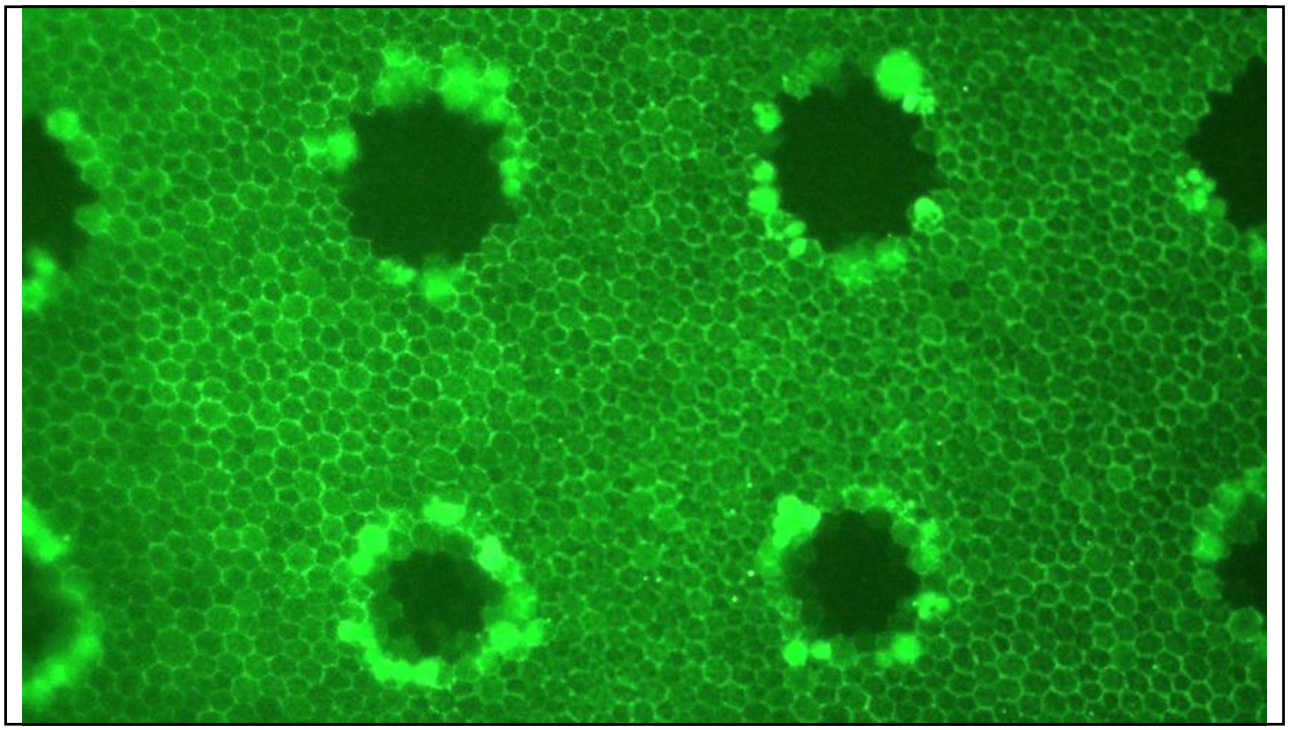
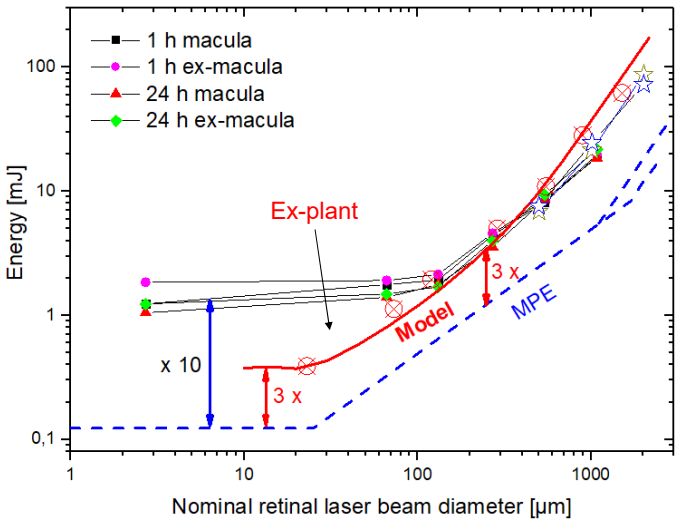


„Safety Factor“ *NOT* generally 10!

NHP: Lund et al. (2007) **100 ms, 514 nm**



Adopted from:

REVIEW OF THRESHOLDS AND RECOMMENDATIONS FOR REVISED EXPOSURE LIMITS FOR LASER AND OPTICAL RADIATION FOR THERMALLY INDUCED RETINAL INJURY

Karl Schulmeister,* Bruce E. Stuck,† David J. Lund,† and David H. Sliney‡

Health Physics Vol. 100 (2011)

Angular subtense of retinal image α
Top hat profile

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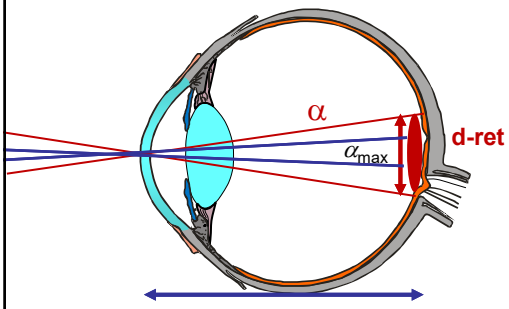
d-ret = α · 17 mm

Human adult eye



Air-filled eye: 17 mm

Injury thresholds THR: intraocular power **IOP** = total power in eye

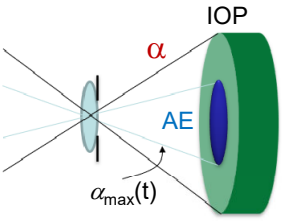
IEC 60825-1: compare AE ↔ AEL

AE: power within $\alpha_{max}(t)$

If $\alpha > \alpha_{max}(t)$:

AEL: $C_6 = \alpha_{max} / \alpha_{max}$

Scaling Factor = IOP/AE



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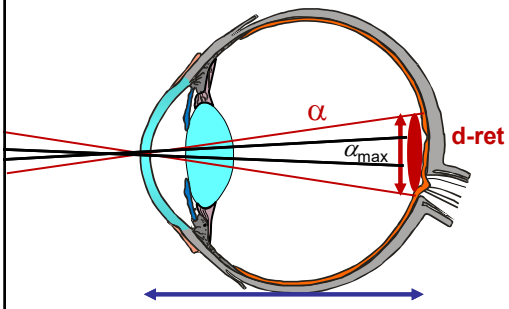


Air-filled eye: 17 mm

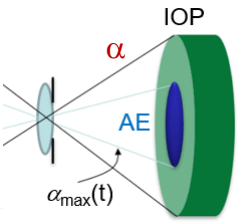
If $\alpha \le \alpha_{max}(t)$: AE = IOP $C_6 = \alpha / \alpha_{min}$

If $\alpha > \alpha_{max}(t)$: Scaling Factor = IOP/AE

$$C_{6-scaled} = \frac{\alpha_{max}}{\alpha_{min}} \cdot scaling\ factor$$

$$C_{6-scaled} = \frac{\alpha_{max}}{\alpha_{min}} \cdot \frac{\alpha^2}{\alpha_{max}^2} = \frac{\alpha^2}{\alpha_{min} \cdot \alpha_{max}}$$

Compare AEL-scaled with THR (both in terms of „power into eye“)



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$$AEL[\mathrm{J}] = 7\times10^{-4}\cdot C_{6-\mathrm{scaled}}\cdot t^{0.75} \quad \text{for } t \text{ from 5 µs to } T_2$$

If $\alpha > \alpha_{\max}(t)$: $C_{6-scaled} = \dfrac{\alpha^2}{\alpha_{\min}\cdot\alpha_{\max}}$

$$\alpha_{\max}(t) = 200\cdot\sqrt{t} \quad \text{for } t \text{ from 625µs to 0.25s}$$

$$AEL = 7\times10^{-4}\cdot\frac{\alpha^2}{\alpha_{\min}\cdot200\cdot t^{0.5}}\cdot t^{0.75} = 7\times10^{-4}\cdot\frac{\alpha^2}{\alpha_{\min}\cdot200}\cdot t^{0.25}$$

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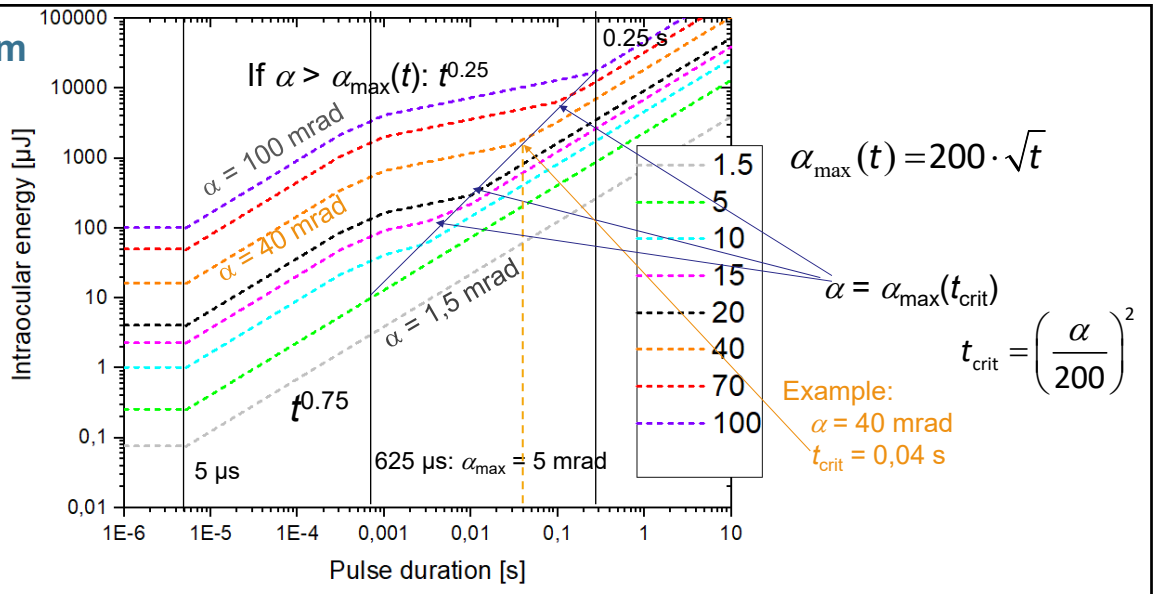
532 nm



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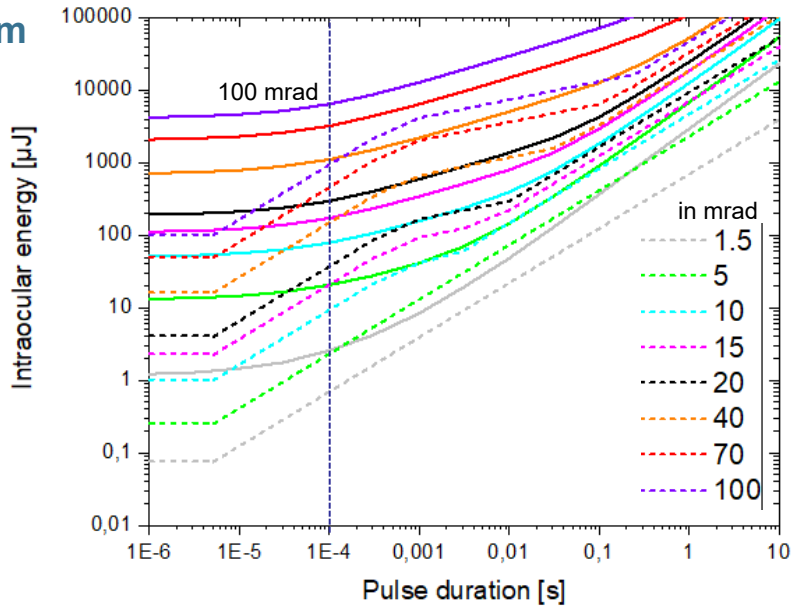
532 nm



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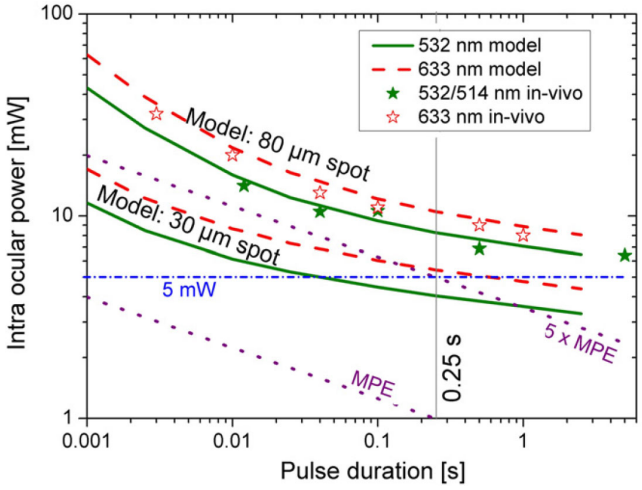
Model for „minimum spot size“: 30 µm

Probably over-restrictive

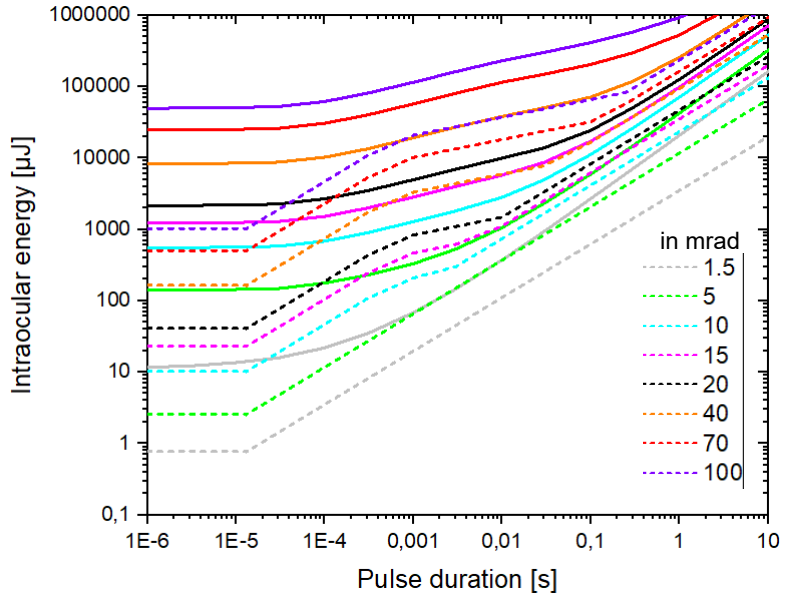
The risk of retinal injury from Class 2 and visible Class 3R lasers, including medical laser aiming beams

Karl Schulmeister*, Mathieu Jean

Medical Laser Appl Vol. 25 (2010)



1060 nm



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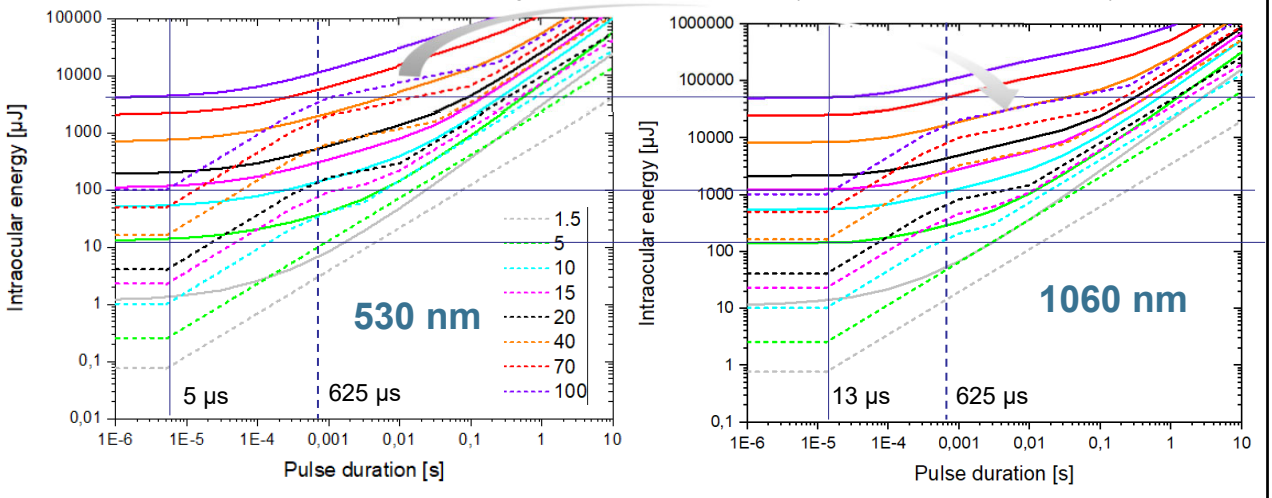
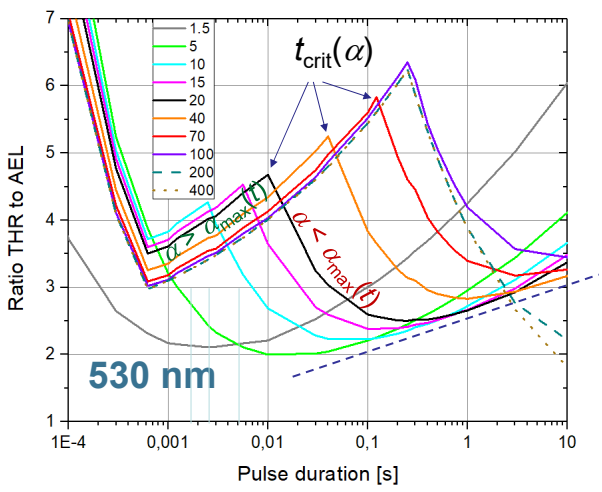
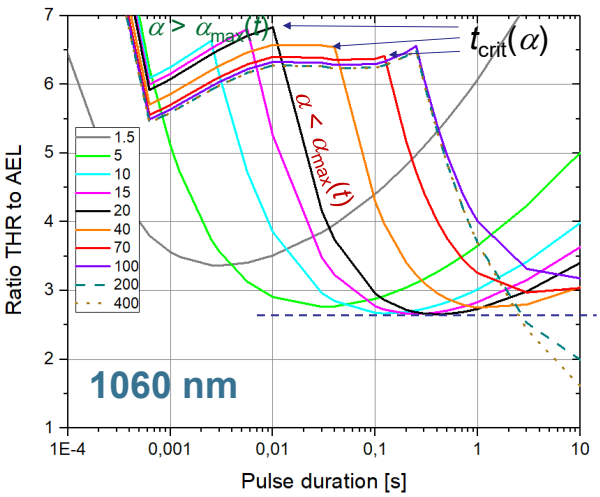
In this regime, 1060 nm AEL lower (less than factor 10 difference)



Factor 10 not only AEL but also thresholds!





- No constant margin
- MPE, AEL: simplification!

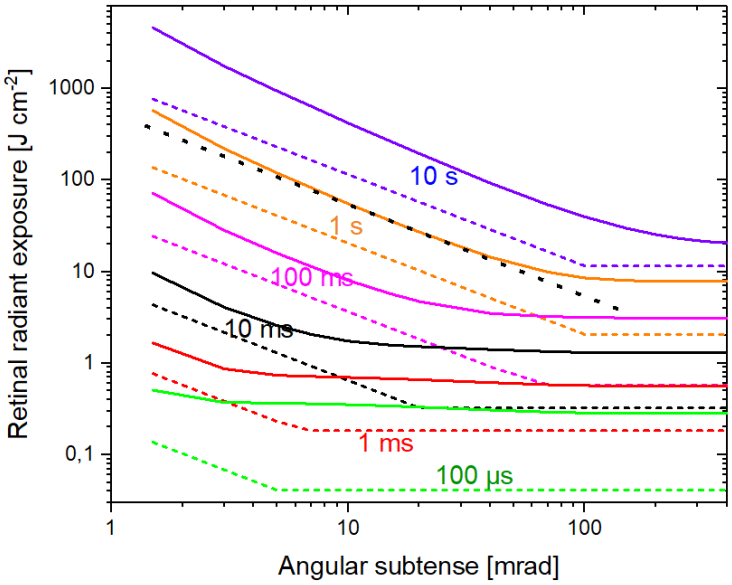
- Margin as small as 2

- *Uncertainty in model…*

- Need to consider α-dependence
- Different α-dependence for w.l.

530 nm

H-ret = IOE / area-retina



- No room for further reduction of margin (C_5=1 problematic)

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- Changing MPE has to be done with great care…
- …considering ALL data and dependencies

- MPE must not be too high!
- MPE should not be lowered (unless necessary, not lower than now)!

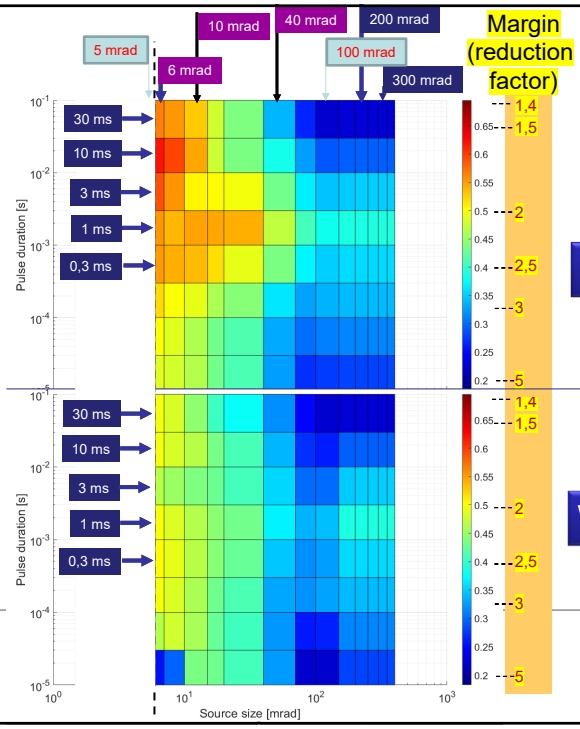
- Making it „better“ might make it more complex!
- Simple → over-restrictive!

- **Is it necessary to change?**
- **Current C_5 also works for non-constant pulse trains!**

250 ms
530 nm

Frequencies varied

About 5000 thresholds



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$C_5 = 1$ Rule 1, Rule 2

With $C_5 < 1$ Rule 1
Rule 2
Rule 3