Paradigm Change for Optical Radiation – Temporary Blinding from Optical Radiation as Part of the Risk Assessment

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Content

1. Introduction

Exposure limits and Indirect effects

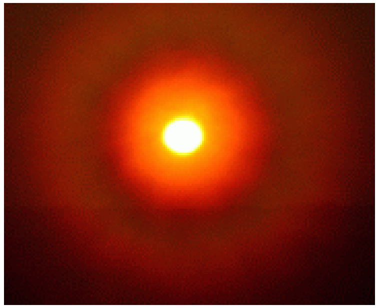
- It is stated in the European Directive on artificial optical radiation 2006/25/EC that….
- ….workers shall not be exposed above the ***exposure limit values***, which are based on various ICNIRP guidelines

Indirect effects are a new topic in risk assessment

In addition….

- … the employer shall give particular attention to ***any indirect effects*** amongst others such as ***temporary blinding*** when carrying out the risk assessment.
- **Temporary blinding is the result of a dazzling or glaring light in the visual field (“field of view”)**
- **At the very moment the database for the evaluation of adverse effects on vision caused by flash blindness and degraded color-vision is insufficient as far as new optical sources like lasers and LEDs are concerned.**

What does glare mean?



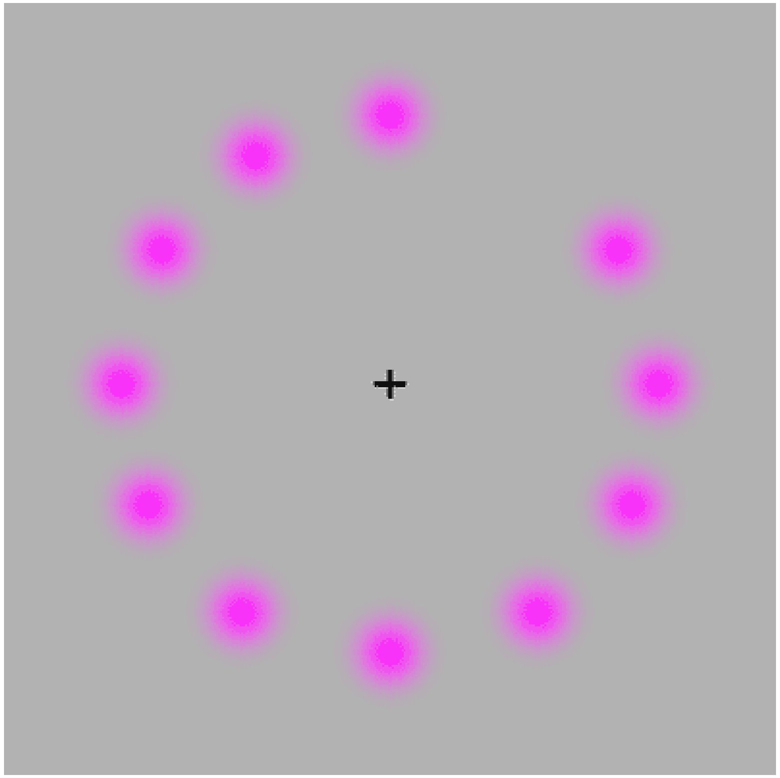
- Glare might be described as light emitting from an optical source, either a natural source like the sun or an artificial one like a lamp including an LED or a laser, with an intensity great enough to reduce a viewer's ability to see or that causes annoyance or discomfort

  ⇒ **disability and discomfort glare**

- **Glare is normally accompanied by more or less afterimages**.

What does afterimage mean?

- An afterimage is the visual impression which appears more or less immediately after the decay of the stimulation at the site where the irradiation took place.
- Parts on the retina which have been exposed by light at a sufficient level, loose its sensitivity
- Local adaptation results in various interpretations of the visual field as far as **brightness**, **hue** and **saturation** are regarded



What is already known?

- Under normal illumination conditions people can adapt to changing luminous levels and perform well
- But even with subthreshold exposure glare might impair visual functions more or less
  - dazzling effect of a bright light source in the field of view or
  - afterimage formation, which is mainly the result of photochemical changes and some neural influence from the visual cortex
- During the refractory time, an exposed individual is visually handicapped

Goal

- Determination of the degree and duration of impairment resulting from glare, dazzle, flash-blindness and afterimages:
  - **especially recovery duration of visual acuity**

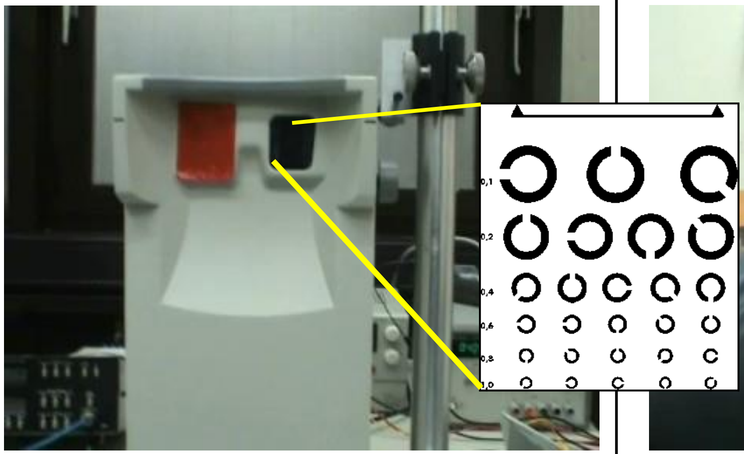
  caused by
  - a laser beam or
  - light from a lamp product like an LED
- Search for functional relations as far as
  - wavelength,
  - optical power and
  - exposure duration

  are concerned

2. Methods to determine the visual impairment

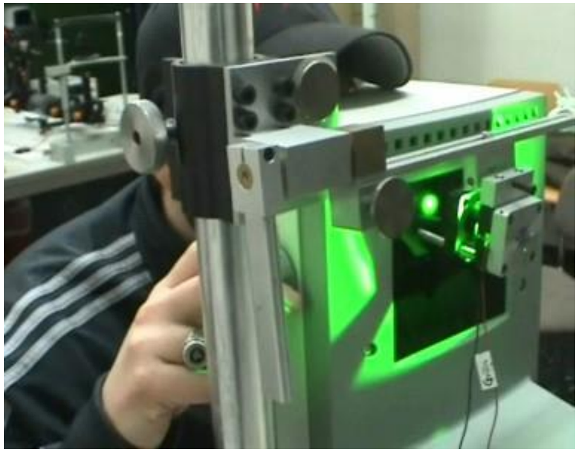
- Design and engineering of different test set-ups:
  a.) Modified binoptometer with Landolt-C rings to determine the recovery time after irradiation with a high brightness LED (HB-LED) and
  b.) Special computer monitor assisted reading test for the case of laser irradiation.

Test situation during LED exposure and visual acuity measurement



modified binoptometer

test person



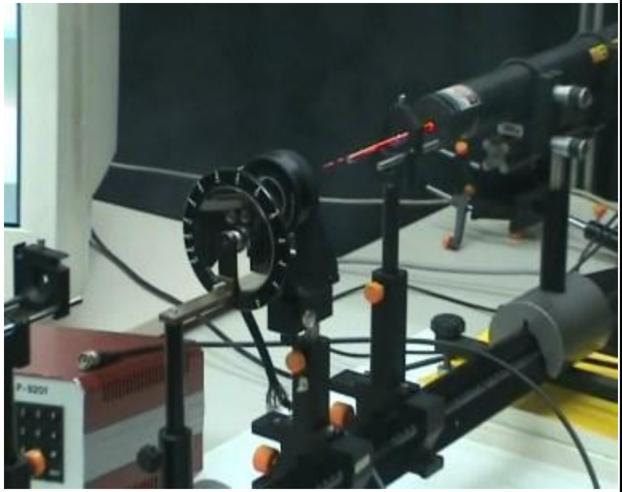
LED source in action

irradiation situation

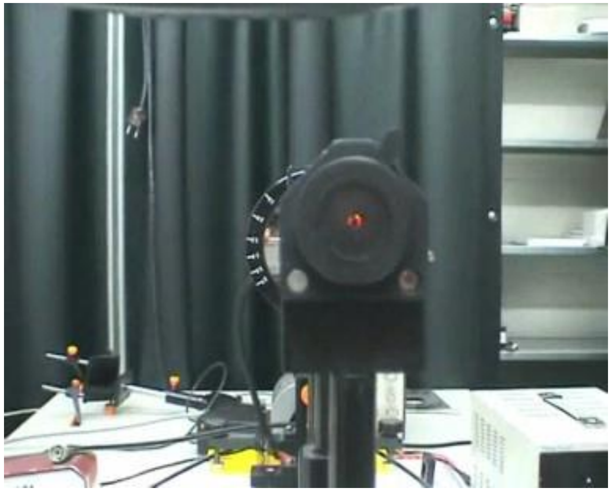
last phase of irradiation

recovery time

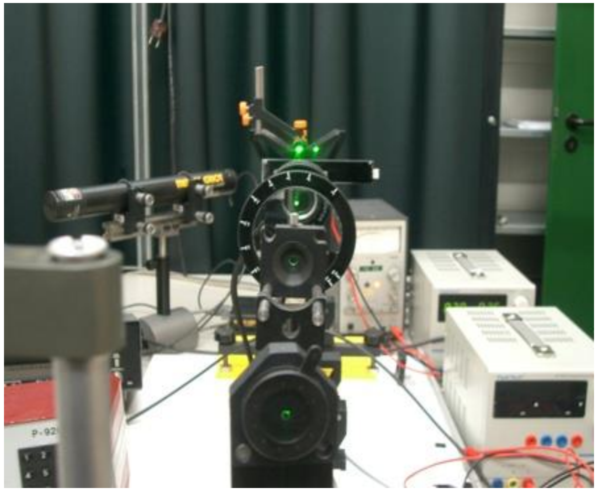
Test arrangement for laser beam exposure and reading test procedure



laser, alignment & attenuator



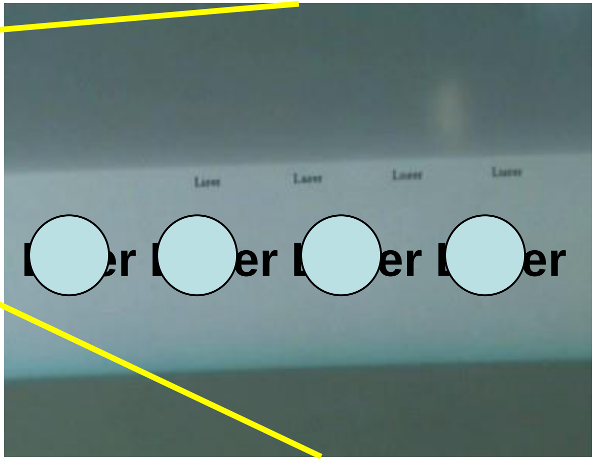
look into the laser beam (He-Ne)



neodymium vanadate laser, shutter, apertures and attenuator

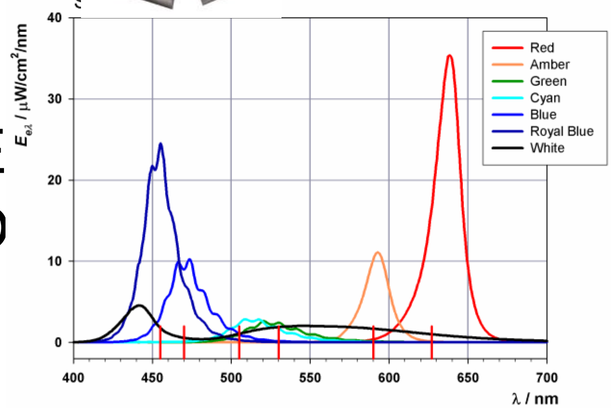
test person fixed in a chin rest and being irradiated

test person in front of the monitor



test chart with 4 words (Arial 12 pt) for reading test

Test conditions and parameters

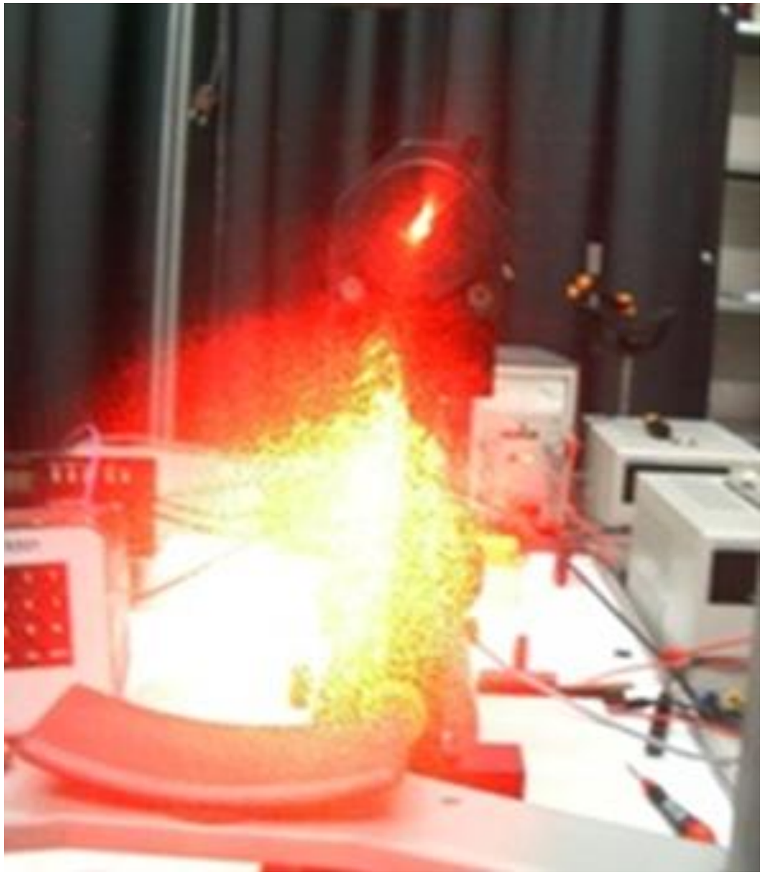
Source		Parameters		Number of trials	Sum of trials
LASER		Wavelength/nm	632.8	943	1,267
			532	324	
		Exposure duration/s	0.25, 0.5, 1, 5 and 10		
		Maximum optical power/mW	0.783		
LED	 	Colour (Wavelength/nm)	**Red (640 nm)**	735	2,824
			Green (520)	821	
			royal blue (460)	640	
			white	628	
		Exposure duration/s	0.25, 1, 5, and 10		
		Maximum optical power/mW	3		

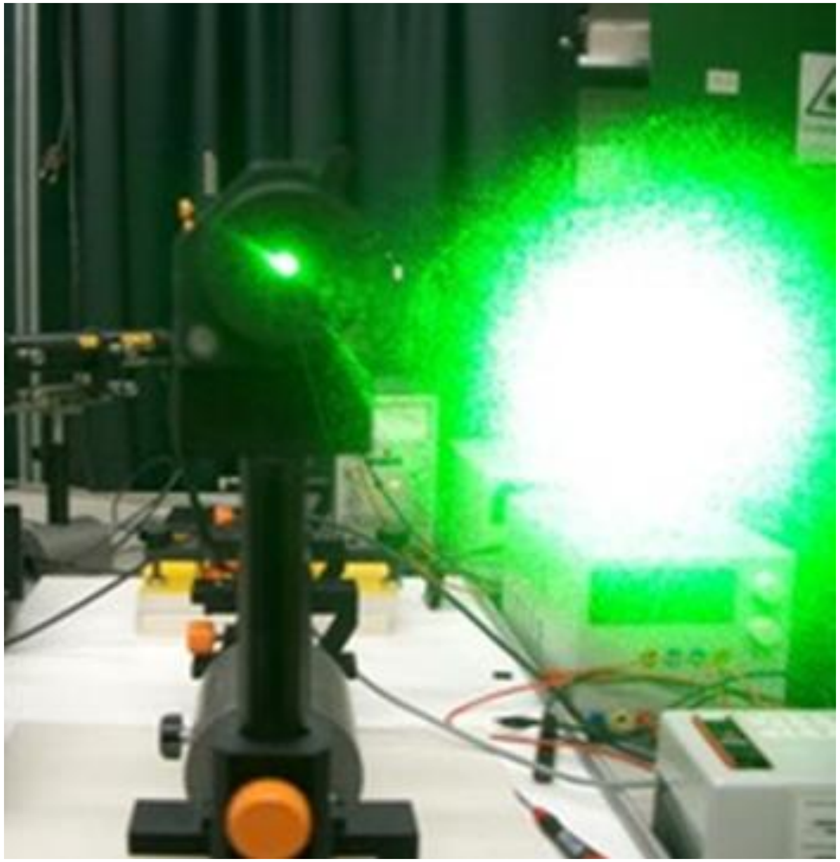
Different laser test conditions: 10
(2 wavelength and 5 exposure durations)

Total: 45 subjects, 4,091 irradiations, 26 different test conditions

Impression of dazzling light sources

- Helium-neon laser (632.8 nm), and
- Frequency-doubled Nd:Yttrium Vanadate laser (Nd:YVO_4, 532 nm)





3. Experimental results

- **LED:** **green** (0.12 mW to 1.5 mW, t_{exp} = 1 s to 8 s)
- Visual acuity recovery time t_{VA}

$$\mathbf{t_{VA}/s \approx 3.7 \cdot \ln(\mathit{energy}/\mu J) - 16.2}$$

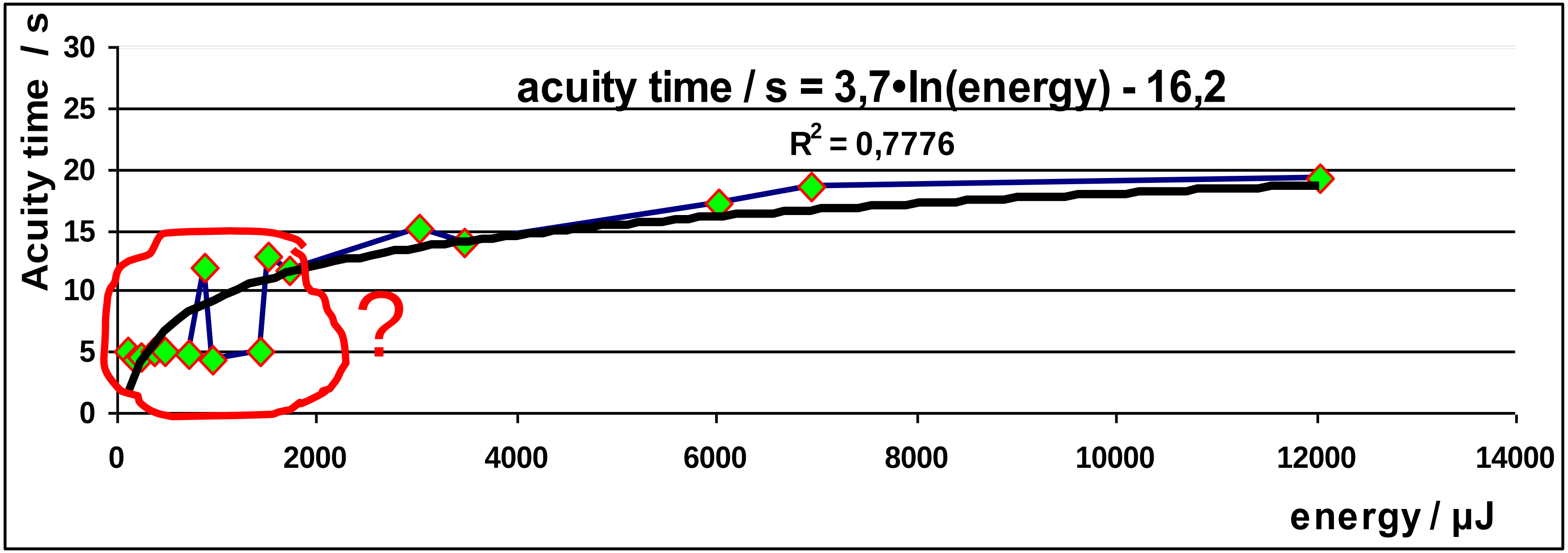
- **Laser:** **632.8 nm** (P = 10 µW to 30 µW, t_{exp} = 0.25 s to 10 s)
- Afterimage duration t_a

$$\mathbf{t_a/s \approx 50.6 \cdot \ln[(P \cdot t_{exp})/\mu J] - 13.4}$$

- Additional investigations:
  - Impairment threshold determination for other LED colours and for laser irradiation
  - Impairment with Green laser at 532 nm and
  - Comparison with values at 632.8 nm

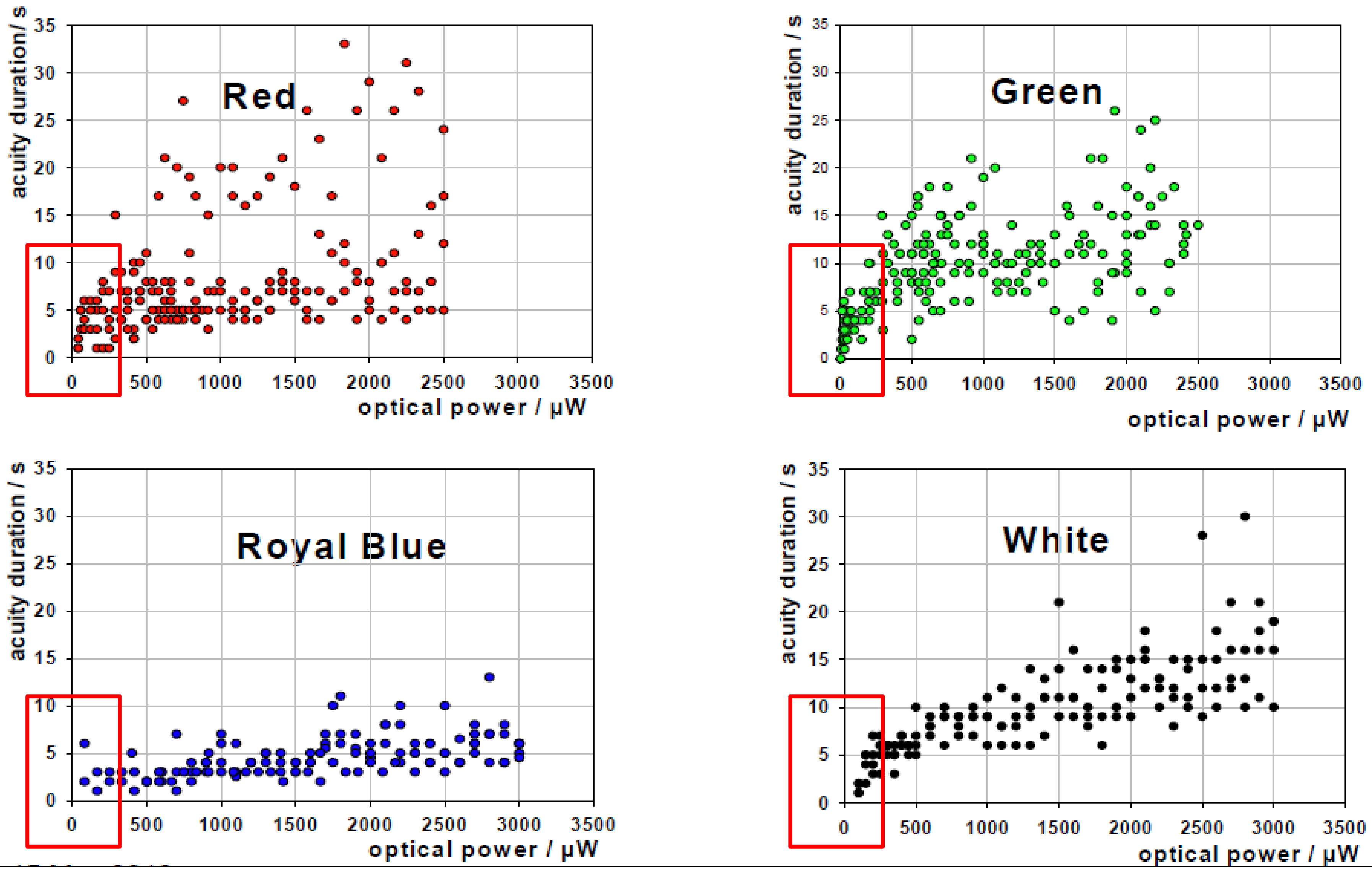
LED irradiation ("green")

First investigations: 4 test subjects, coarse trials

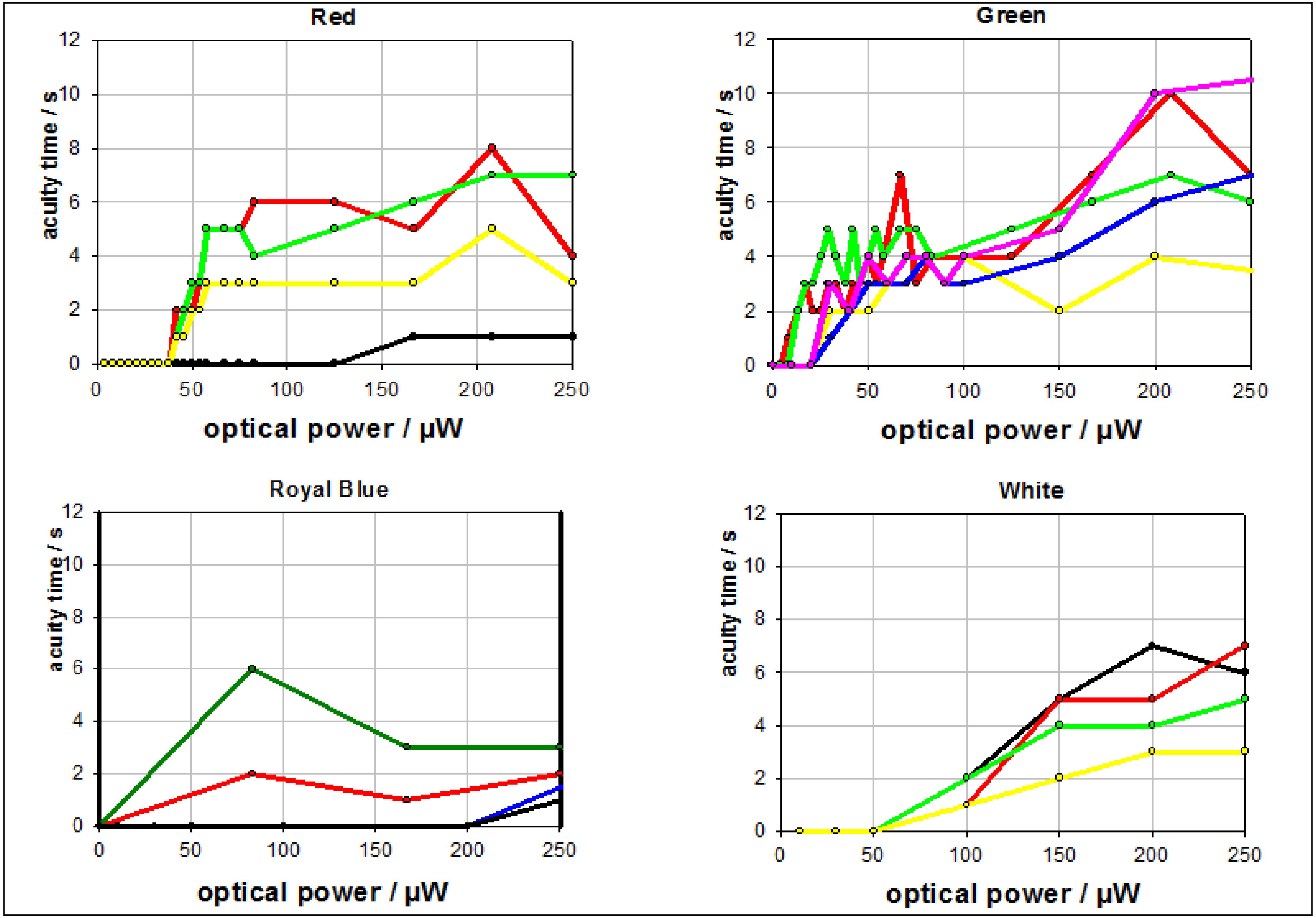


Next steps: **more volunteers**
more colors
search for threshold

HB-LEDs – exposure duration 0.25 s



HB-LEDs – exposure duration: 0.25 s –Threshold

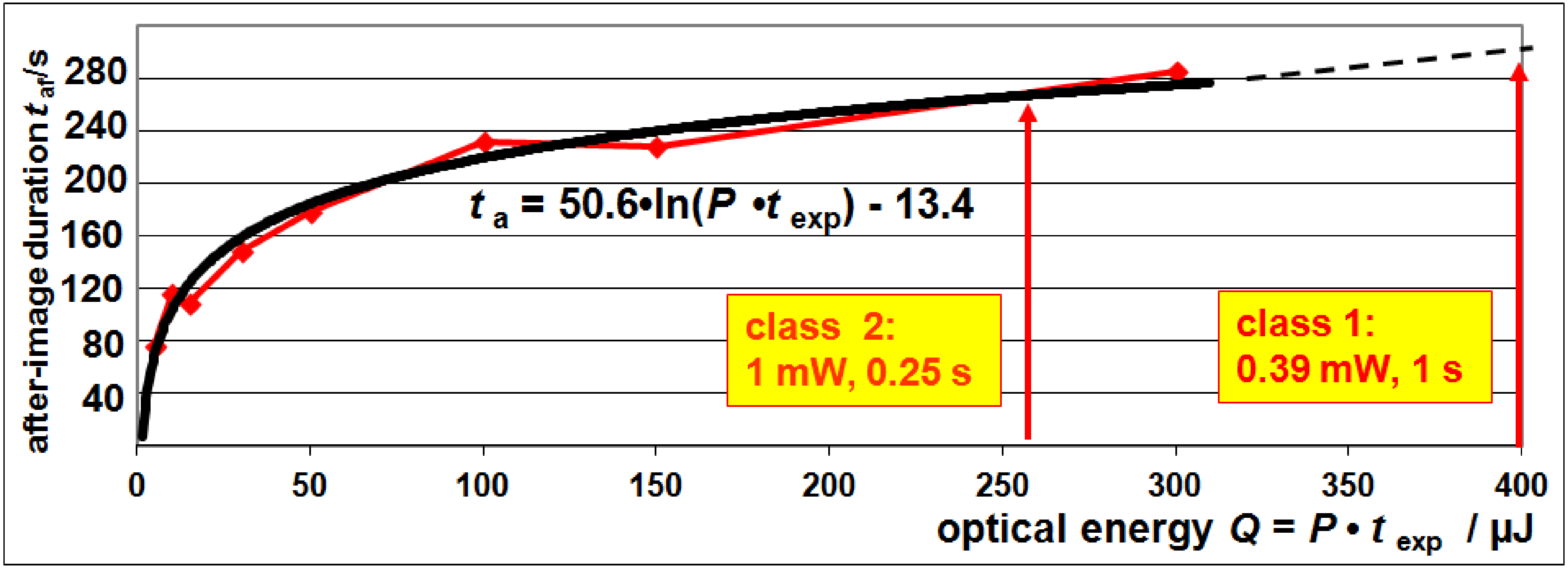


Characteristics for colored LEDs

- Relatively large spread due to individual perception,
- Rapid rise is distinguishable especially for the green LED,
- Green shows the largest impairment time, and
- White LEDs produce larger recovery times than royal blue LEDs, although in principle white LEDs contain a blue LED whose emission is converted in a special phosphor into a broadband radiation in order to result in white via additive colour mixture

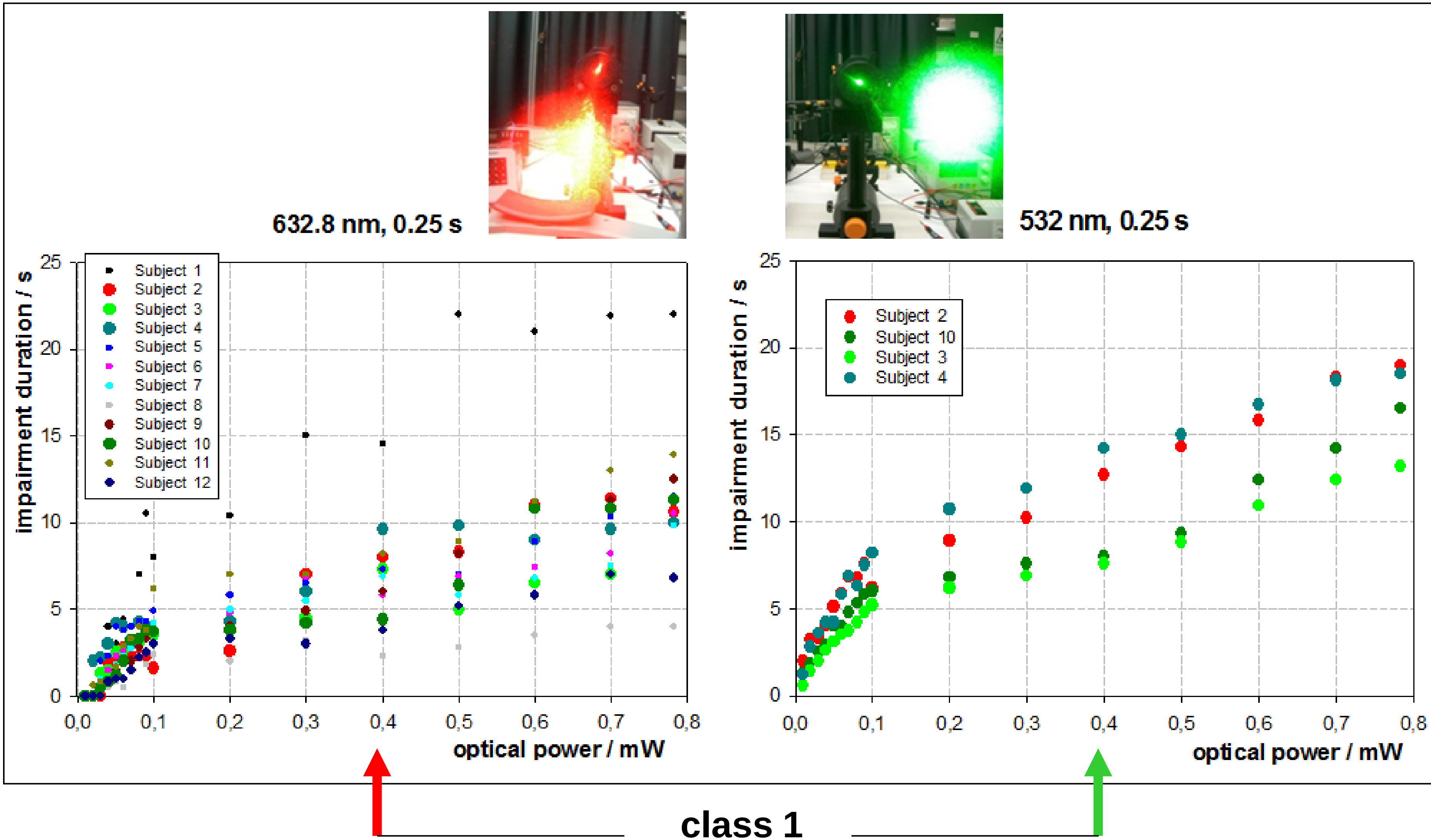
Dose relationship for laser irradiation

Laser irradiation (632.8 nm) in the Fovea (glare angle 0°)

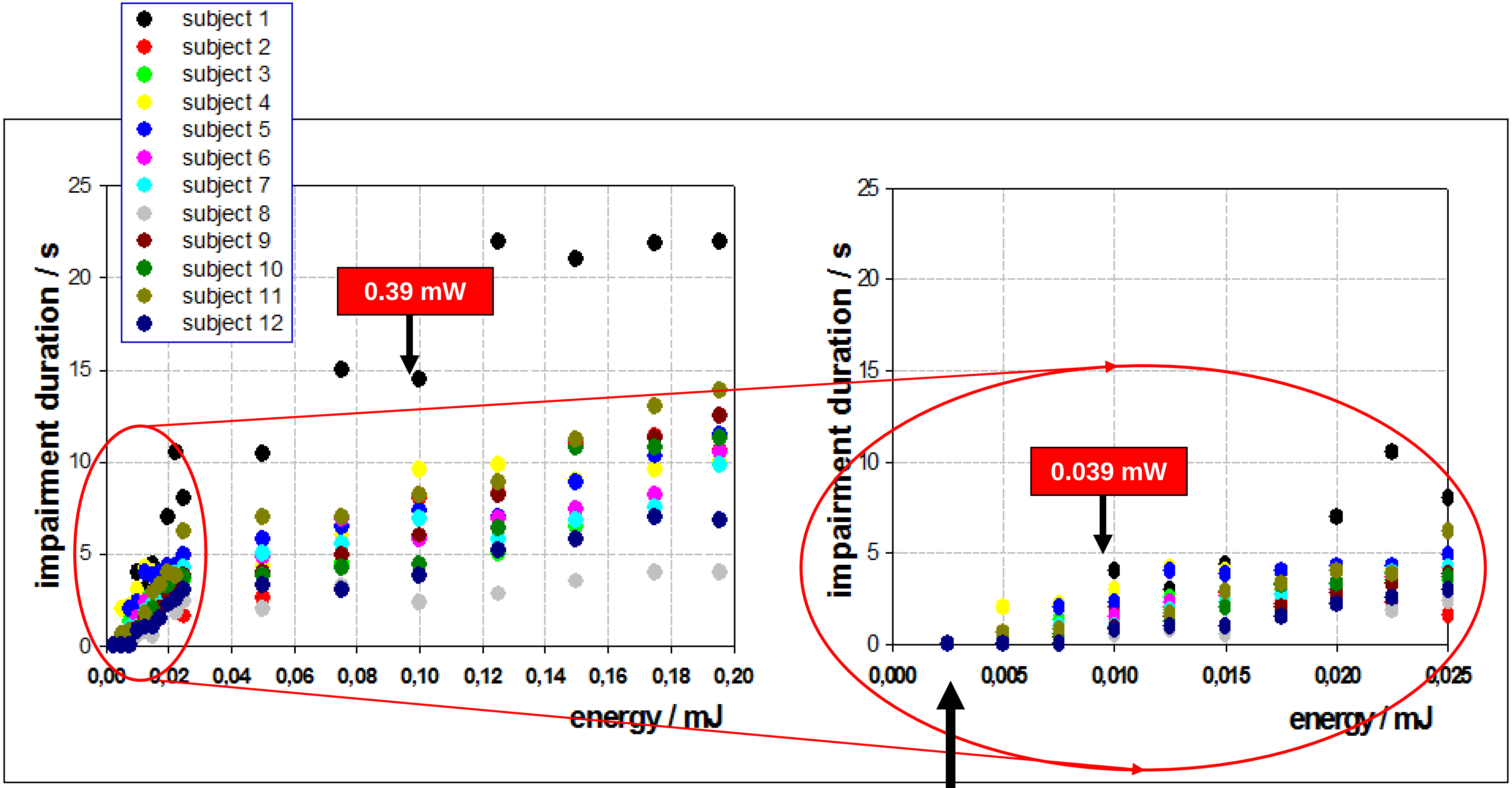


$$t_{af,fovea} = 2 \cdot \{t_{af,5°}/s \approx 25.3 \cdot \ln[(P \cdot t_{exp})/\mu J] - 6.7\} \approx 50.6 \cdot \ln[(P \cdot t_{exp})/\mu J] - 13.4$$

Red vs Green – exposure duration: 0.25 s

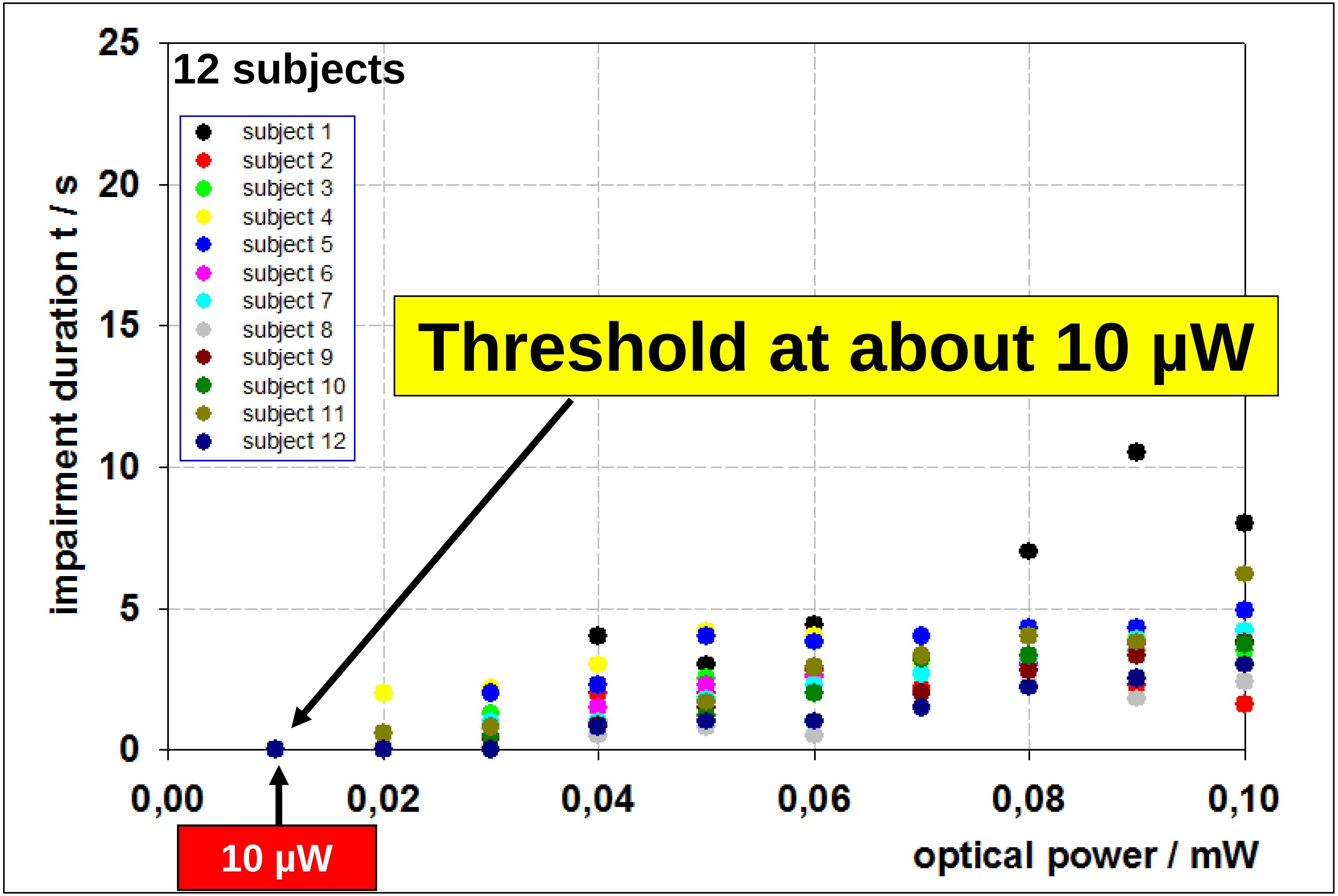


He-Ne Laser (0.25 s): Threshold behavior

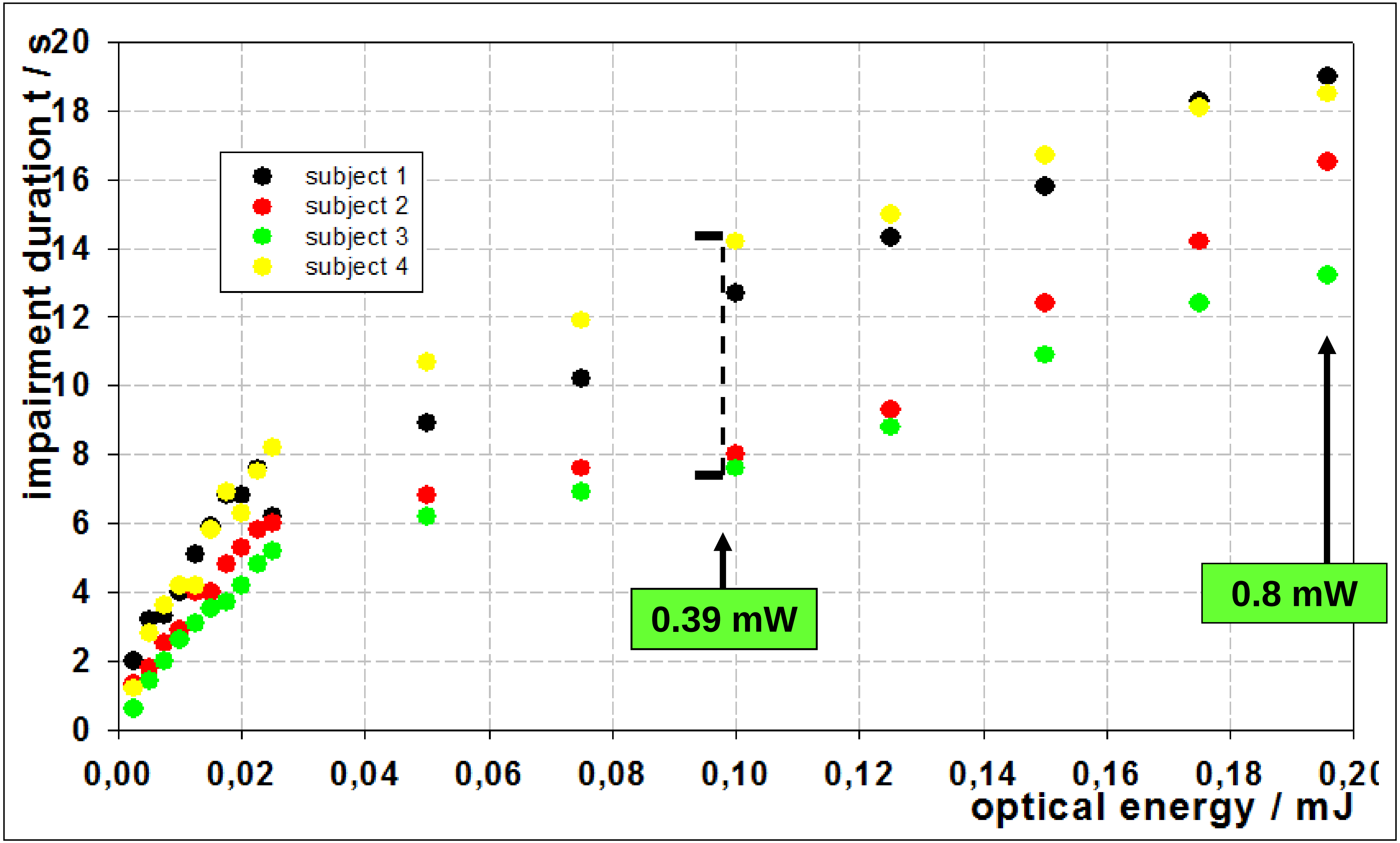


0,0025 mJ = 2.5 µJ

He-Ne Laser (0.25 s) –Threshold



SHG Nd-Laser (0.25 s): Visual acuity recovery time



Summary

- Laser and LED have been investigated as far as the capability to impair visual functions is concerned
- The respective disability threshold as a function of exposure duration has been searched
- Wavelength-dependent values have been found for both laser and LED radiation
- Individual differences in the impaired physiological visual functions do exist (up to a factor of about 8!)
- Functional relationships might be used for the derivation of protection limits as far as indirect effects like temporary blinding are concerned

... Thank you for your attention!