The Blue Light Hazard – What Does it Really Mean?

Presented by:

OSA Color Technical Group

The **OSA Color Technical Group** welcomes you!

Technical Group Leadership 2019

Chair
Manuel Spitschan
University of Oxford, UK

Executive Committee
Rigmor C. Baraas
University of South-Eastern Norway

Executive Committee
Jon Y. Hardeberg
NTNU, Norway

Executive Committee
Francisco Imai
Apple Inc.

Our Technical Group at a Glance

Our Focus

- “all aspects related to the physics, physiology, and psychology of color in biological and machine vision”

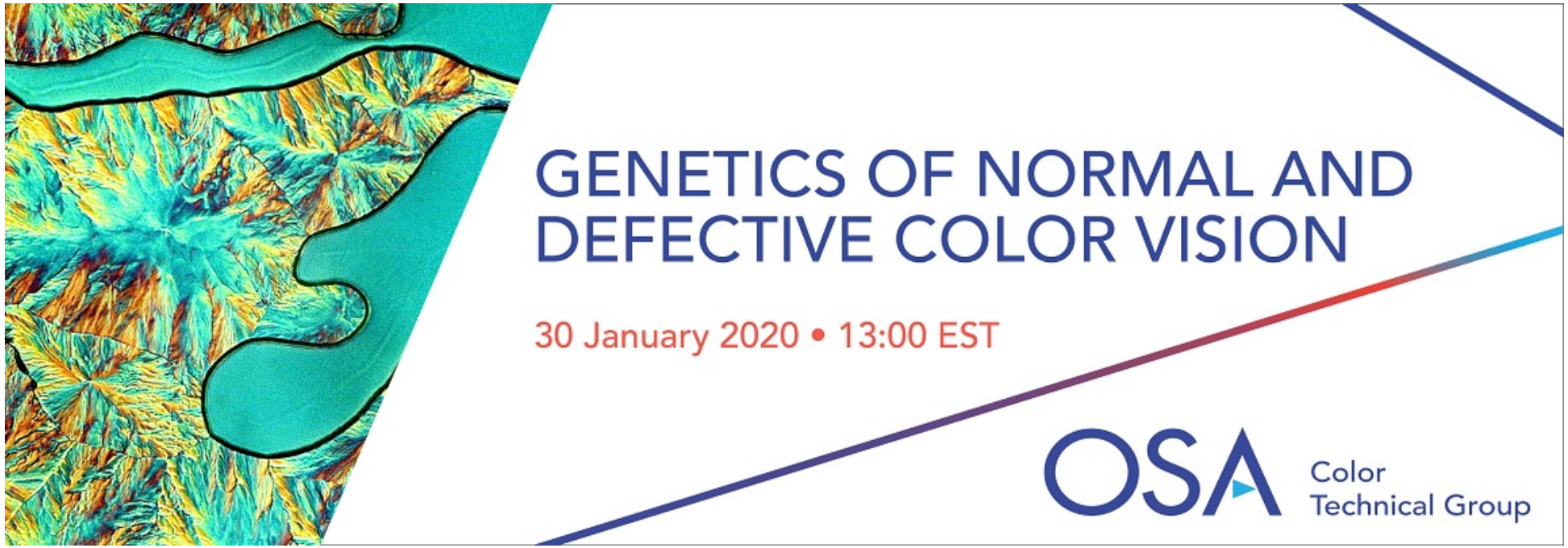
Our Mission

- To benefit *YOU*
- Webinars, social media, publications, technical events, outreach
- Interested in presenting your research? Have ideas for TG events? Contact Manuel Spitschan (Chair) at manuel.spitschan@psy.ox.ac.uk

Where To Find Us

- Website: https://www.osa.org/en-us/get_involved/technical_groups/vc/color_(vc)/
- Twitter: #OSAColorTG
- LinkedIn: https://www.linkedin.com/groups/13573604

Save the date!



Speaker: Prof. **Maureen Neitz, UW**

Host: Rigmor Baraas

Today's Webinar

Blue Light Hazard – What does it really mean?

Dr. John O'Hagan

CIE; Public Health England, UK

Speaker's Short Bio:

Heads the Laser and Optical Radiation Dosimetry Group at PHE's Centre for Radiation, Chemical and Environmental Hazards

- Visiting Fellow, Loughborough University
- CIE, Vice-President Standards

International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

The Blue Light Hazard – What does it really mean?

Professor John O'Hagan

CIE Vice-President Standards

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What is CIE?

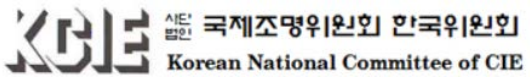
- 1900 – International Commission of Photometry
  - Itself formed from the International Gas Congress
- 1913 – International Commission on Illumination (CIE from the French “Commission Internationale de l’Eclairage”)

CIE is a technical, scientific and cultural non-profit organization

Central Bureau located in Vienna, Austria

© Google

Members of CIE (Selection)



Technical Work - Divisions

- 1 – Vision and Colour
- 2 – Physical Measurement of Light and Radiation
- 3 – Interior Environment and Lighting Design
- 4 – Transportation and Exterior Applications
- 6 – Photobiology and Photochemistry
- 8 – Image Technology

Deliverables

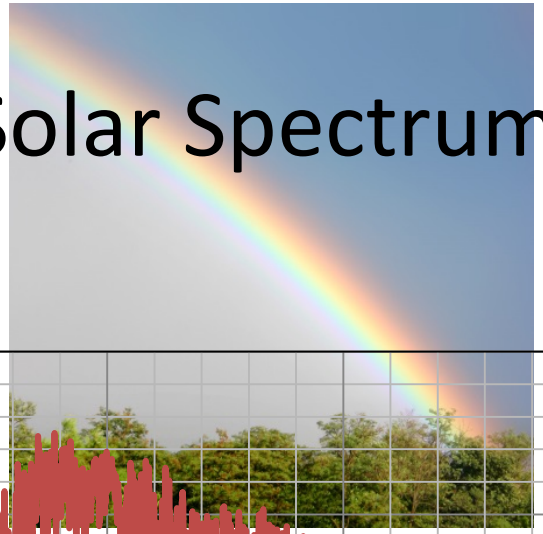
- 22 new publications in the last two years
- 12 conferences/workshops from 2015-2019

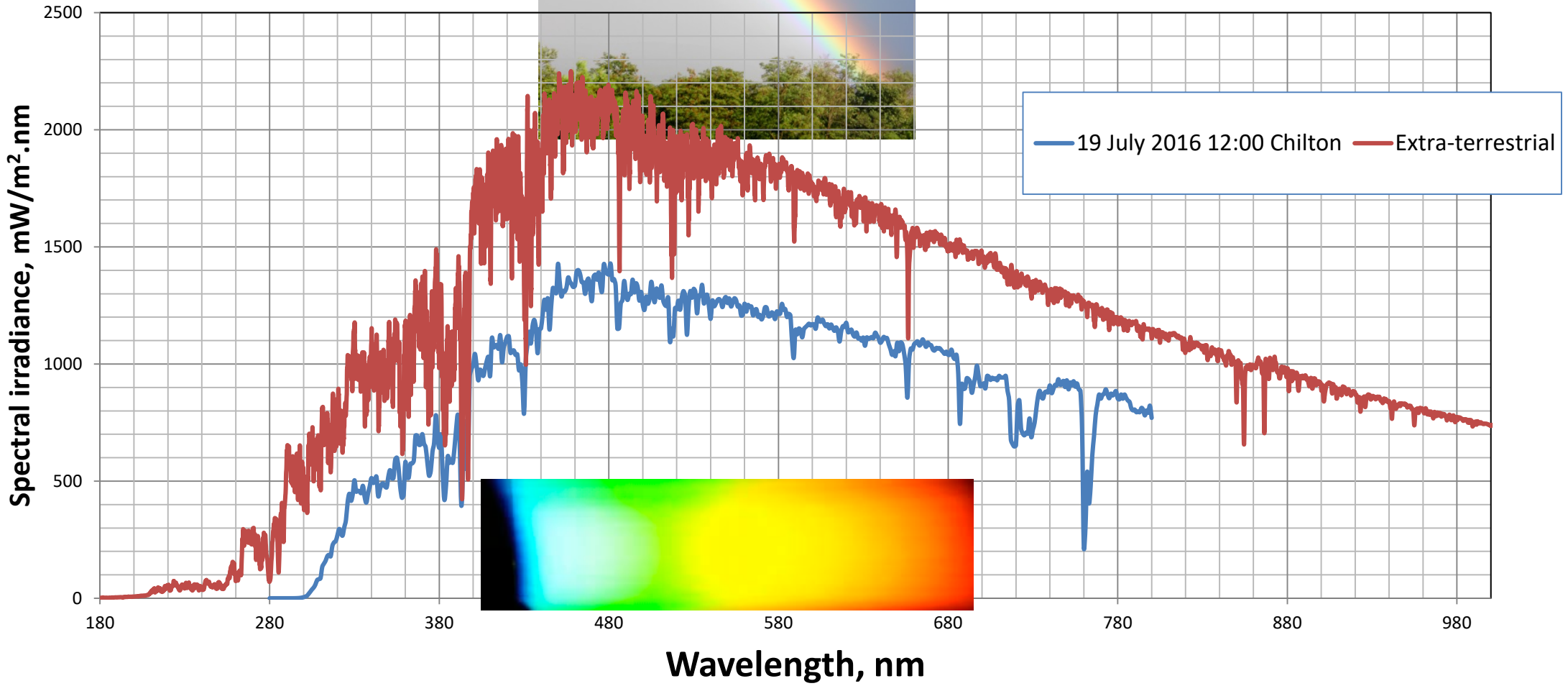
- 2 Position Statements in 2019 (http://www.cie.co.at)
  - Position Statement on the Blue Light Hazard
  - Position Statement on Non-Visual Effects of Light - Recommending Proper Light at the Proper Time, 2nd edition

Recognised by ISO as an International Standardization Organisation

- 1989, ISO formally recognized the CIE as an international standards organization
- 2019, Partner Standards Developing Organization (PSDO) Agreement signed between CIE and ISO

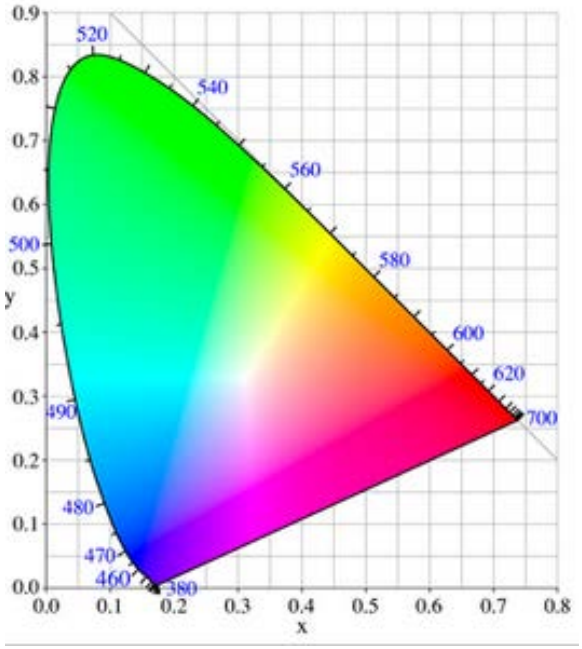
Solar Spectrum



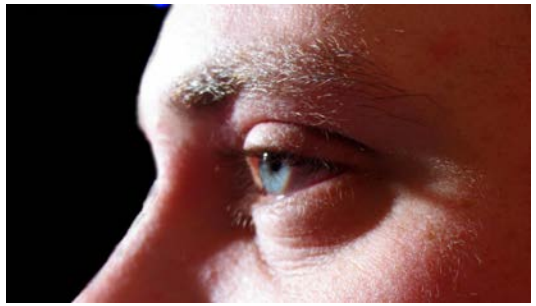


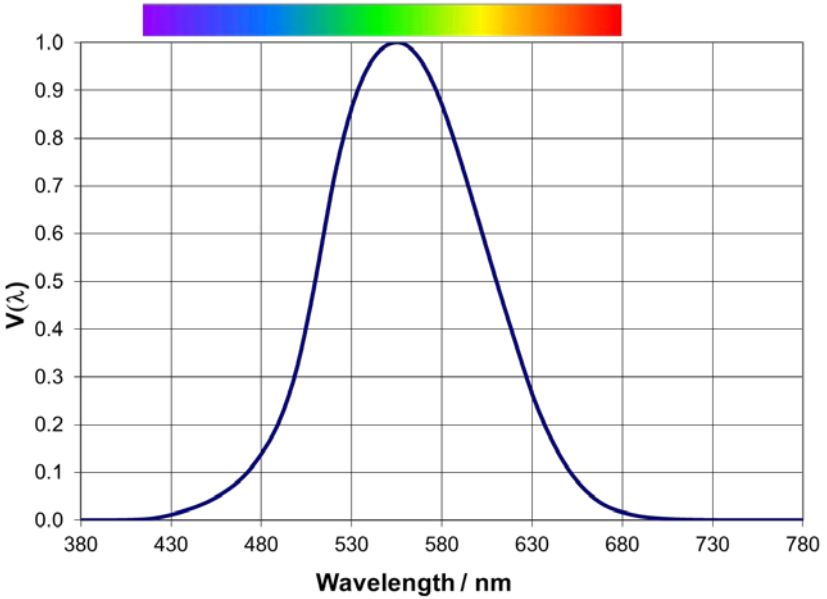
Rainbow © Met Office

What is Blue Light?



Colour Space – CIE 1931



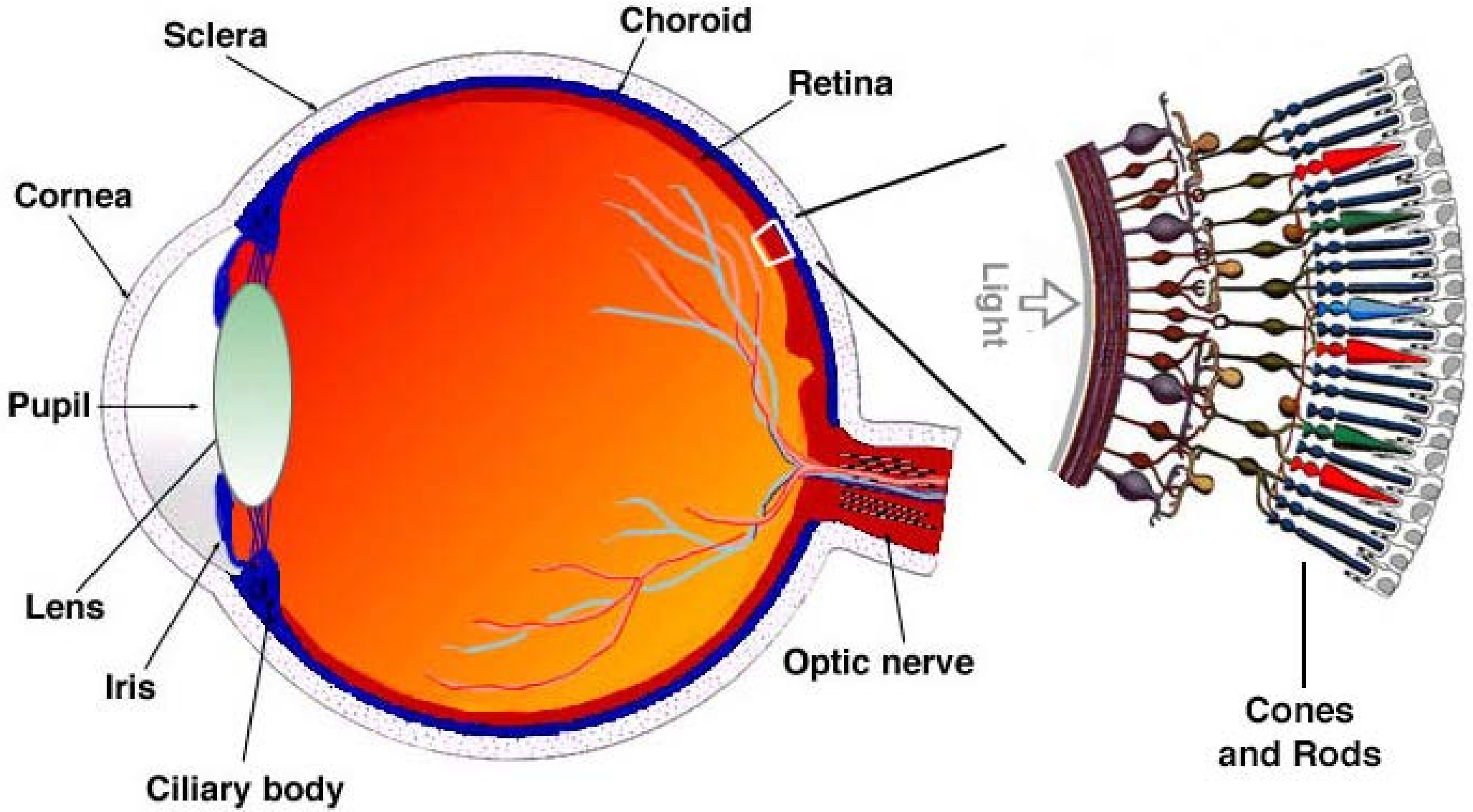


V(λ) – CIE 1924

Low Level Light

Bright Light

Too Much Light


Sclera
Choroid
Retina
Cornea
Pupil
Lens
Iris
Ciliary body
Optic nerve
Light
Cones
and Rods

“Artificial Light”

Safety concerns are not new

August 18, 1928 – Australian Magazine Advertisement

The WEEKLY TIMES August 18, 1928.

The SPIRIT of HAPPINESS

— IS EVER PRESENT IN THE WELL LIGHTED HOME

Men and women too, re-act to light as a flower turns to the sun. Aladdin is the only lamp capable of producing an artificial light of true daylight quality. Aladdin chases gloom away; floods your home with 70 candle power soft white light, makes it a home indeed. Costs little and saves that cost over and over again. Three hours light for one penny. Burns 94% air. Lights on a wick like an ordinary lamp.

No pumping, no smoke, no noise, no danger.

Old-fashioned open flame lamps, electric light and benzine-gas all contain a large percentage of rays harmful to the human eye. Scientists say Aladdin light is pure white and cannot harm the sight.

Convince yourself. Let us arrange a Free Trial through your local dealer. Write for particulars of this remarkable offer.

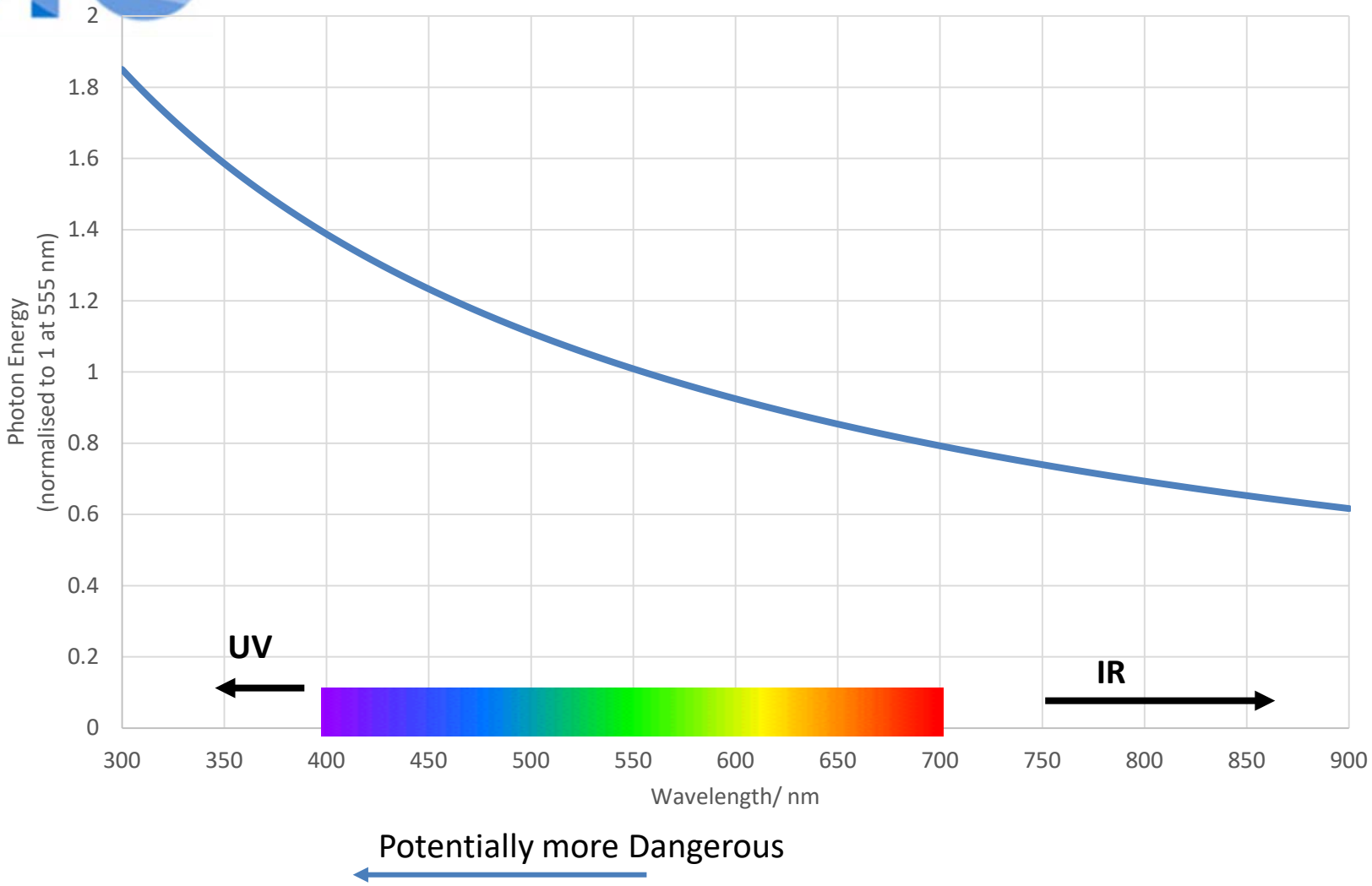
ALADDIN INDUSTRIES LTD.
504 Aladdin House,
49-53 Shepherd Street,
SYDNEY.

AN ALADDIN DEALER IN EVERY TOWN

No pumping, no smoke, no noise, no danger.

Old-fashioned open flame lamps, electric light and benzine-gas all contain a large percentage of rays harmful to the human eye. Scientists say Aladdin light is pure white and cannot harm the sight.

Photon Energy



Potentially more Dangerous

$E = hc/\lambda$

h, Planck constant ≈ 6.63×10^{-34} J.s

c, speed of light ≈ 3×10^{8} m.s^{-1}

At 555 nm, $E = 3.58 \times 10^{-19}$ J

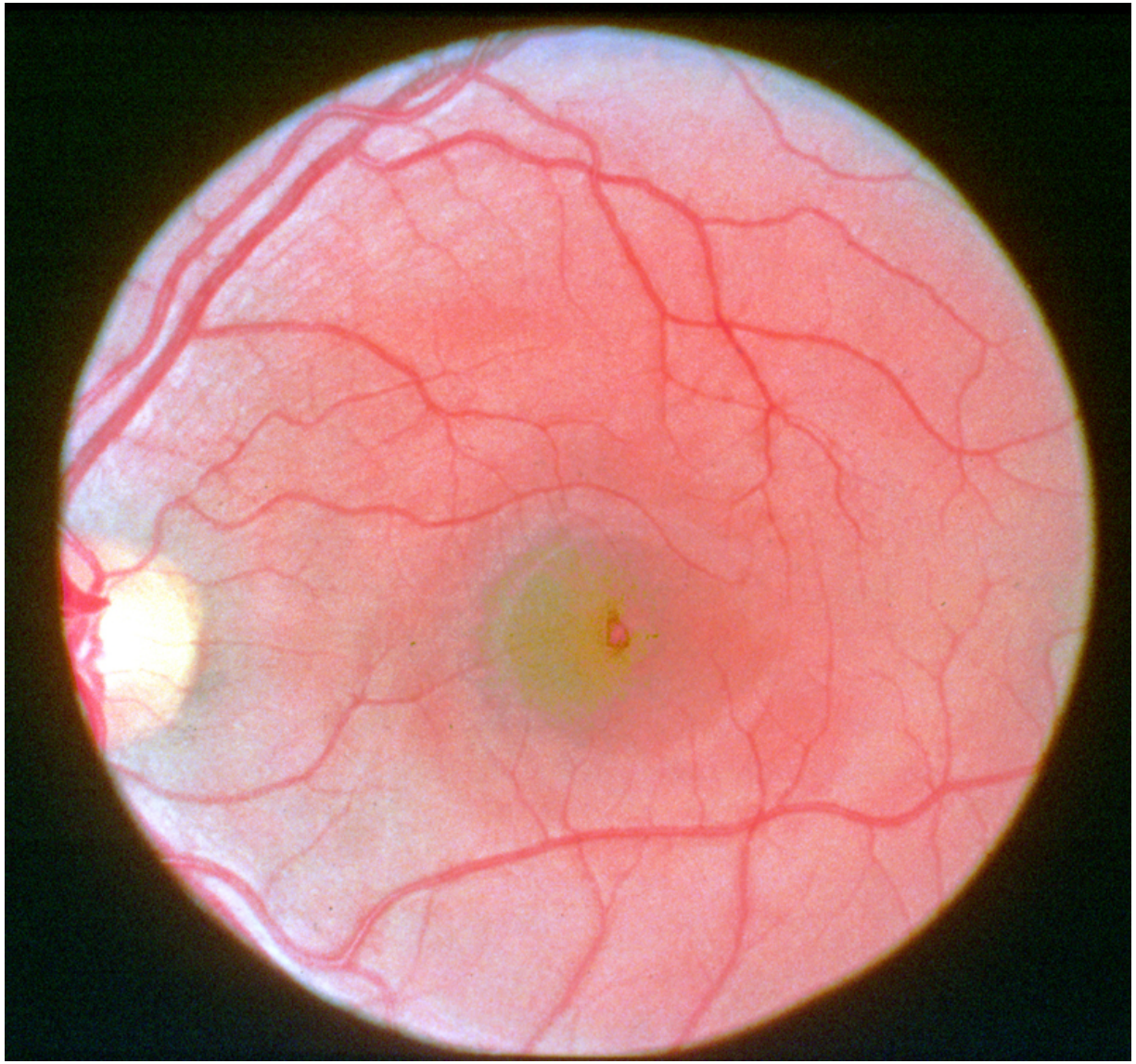
or 2.24 eV

or 216 kJ.mole^{-1}

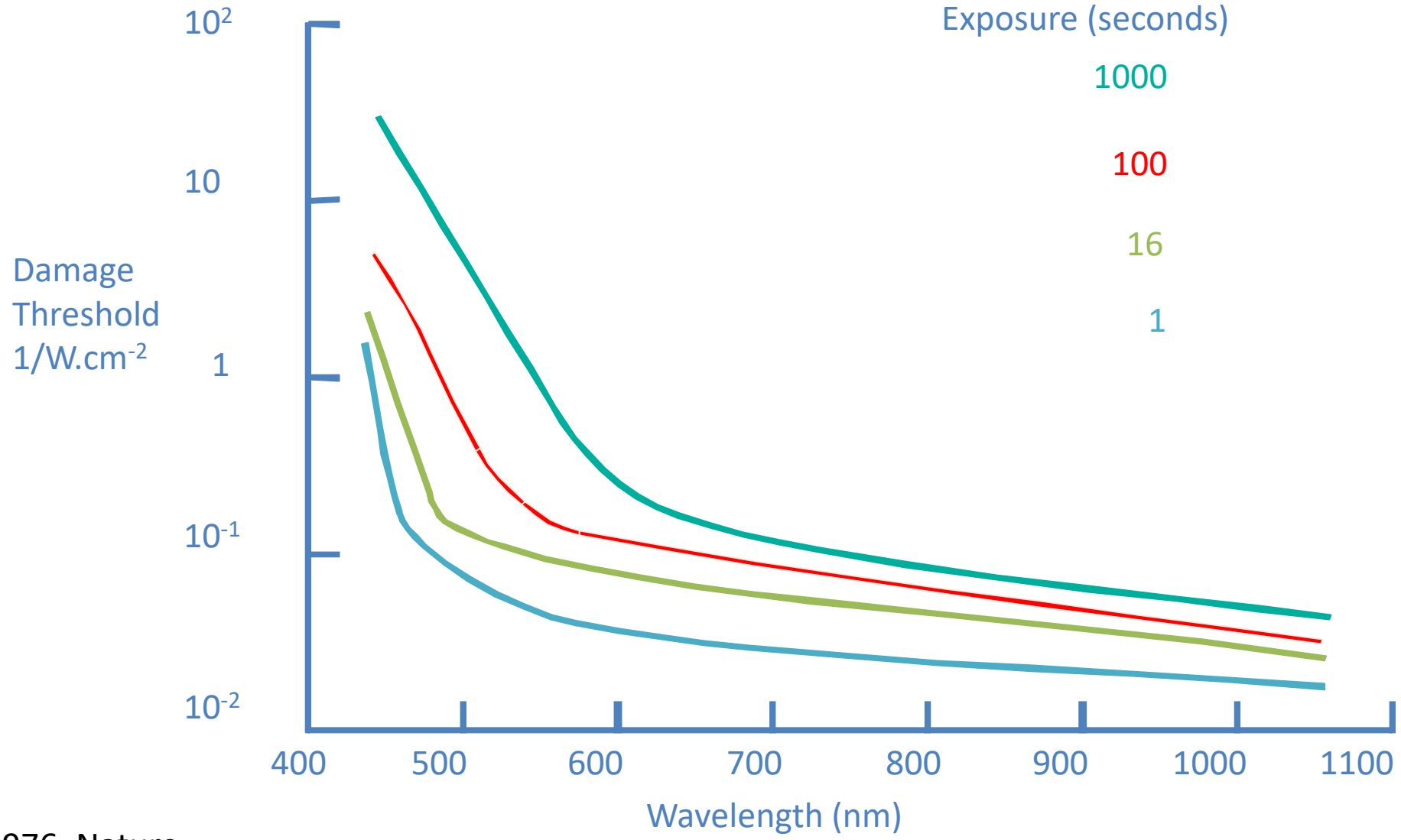
Blue Light Hazard

- Main worry is exposure of the retina
- Until 1970s main concern was thermal effects – heating retinal tissue
- William Ham and colleagues – evidence of photochemical damage

Retinal Photochemical Injury: Photic Retinitis



Sensitivity of the Retina to Photochemical Injury



Ham et al, 1976, Nature

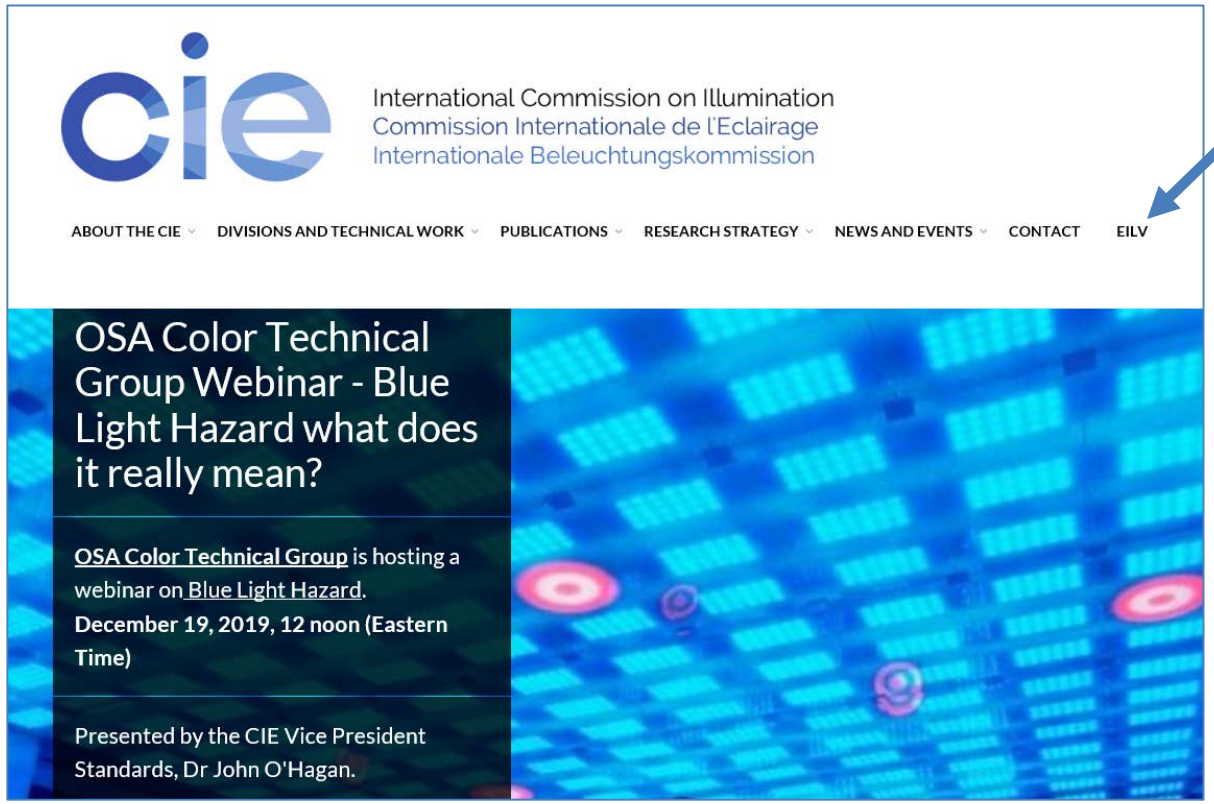
Photochemistry Principles

- A photon of light must be absorbed before producing an effect
  - Christian von Grotthus (1785-1822) and John Draper (1811-1882)
- Only one photon of light is absorbed by each molecule undergoing a photochemical reaction (within limits)
  - Johannes Stark (1874-1957) and Albert Einstein (1879-1955)
- The outcome from a photochemical reaction depends only (within limits) on the total energy absorbed (product of radiance or irradiance and time of exposure)
  - Robert Bunsen (1811-1899) and Sir Henry Roscoe (1833-1915)
- Vision is a photochemical process

Blue Light Hazard

- Type II photochemical retinal damage
- 380 nm to 550 nm
- 300 nm to 550 nm for the aphakic eye

EILV



cie.co.at

Blue Light Hazard

e-ILV CIE International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

TERMLIST INDEX TERMLIST CIE

Home

17-97 blue light hazard

potential for a photochemically induced retinal injury resulting from optical radiation exposure at wavelengths primarily between 400 nm and 500 nm

NOTE 1 This damage mechanism dominates over the thermal damage mechanism for exposure durations exceeding 10 s.

NOTE 2 The action spectrum extends into the UV-A for persons without a normal UV-A absorbing lens.

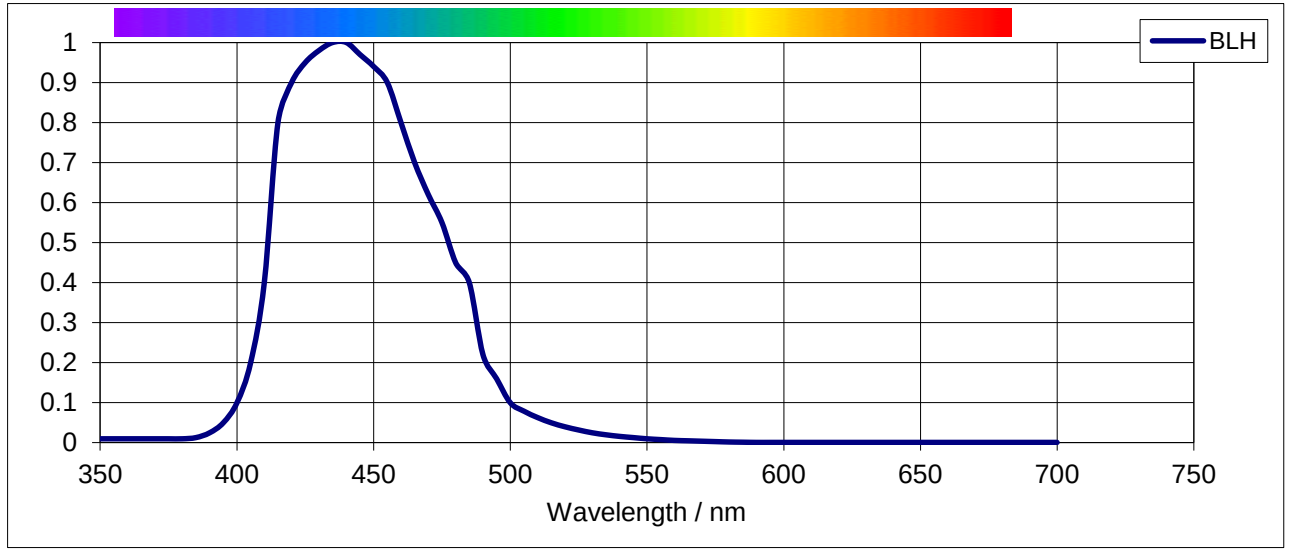
Abbreviation: "BLH"

Blue Light Retinal Lesions

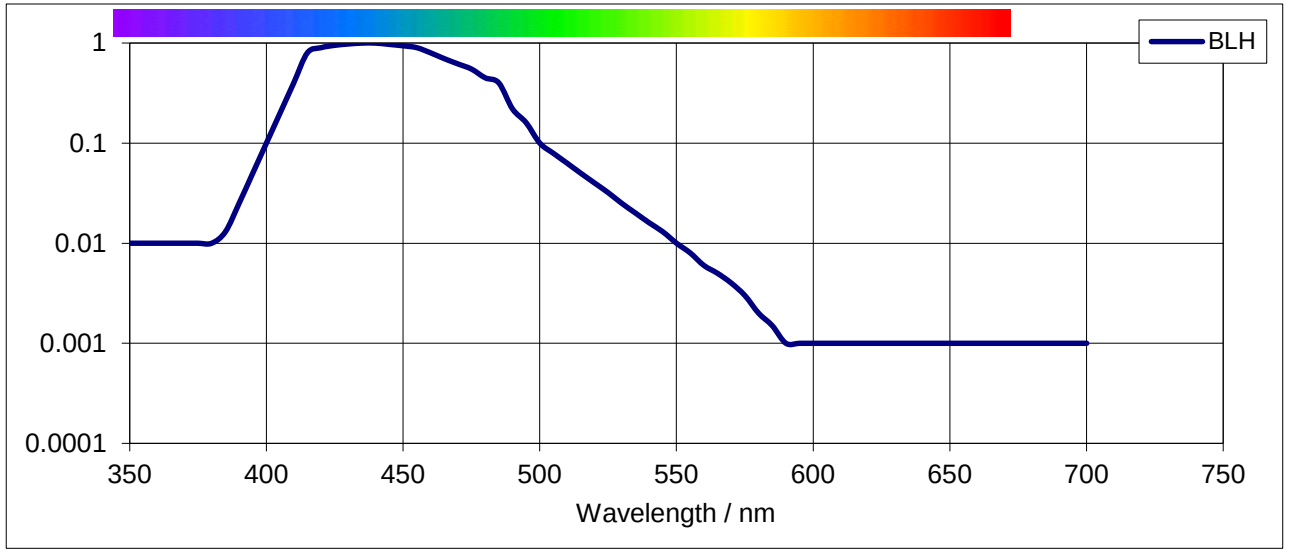
- The photochemical reaction initiates a chain of biological reactions centred on the retinal pigment epithelium
- Time to onset: A noticeable reaction is generally delayed for more than 12 hours after exposure, the peak of reaction is usually observed at 24-48 hours post exposure
- Occurrence: lasers, accidental (or deliberate) observations of the sun and arc welding.

Wavelength-Dependence of Blue Light Hazard

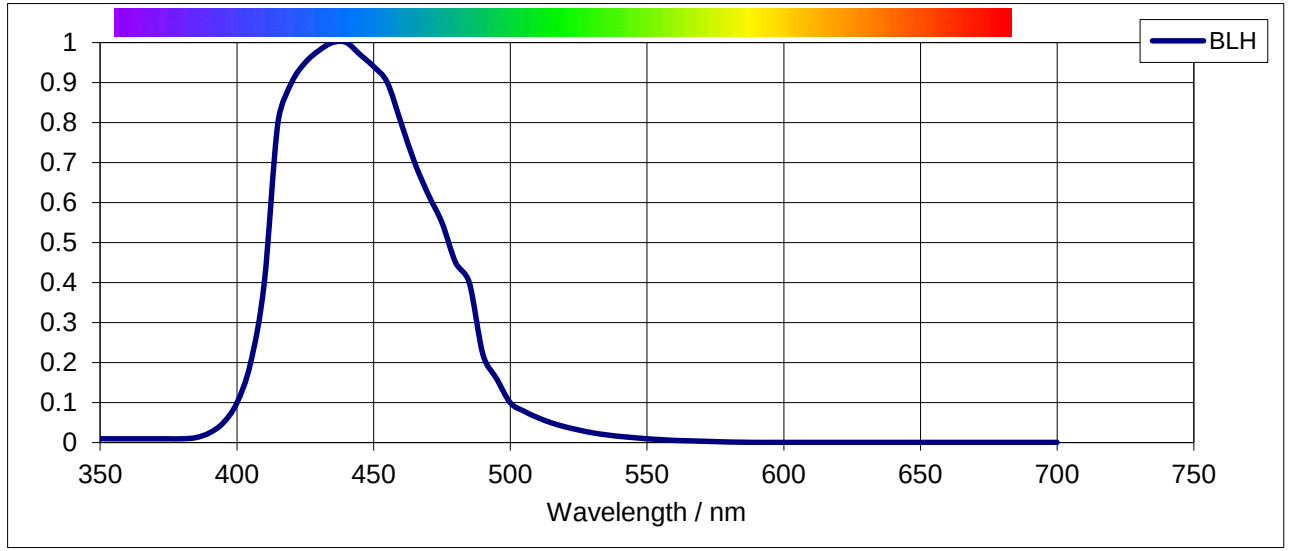
Linear scale

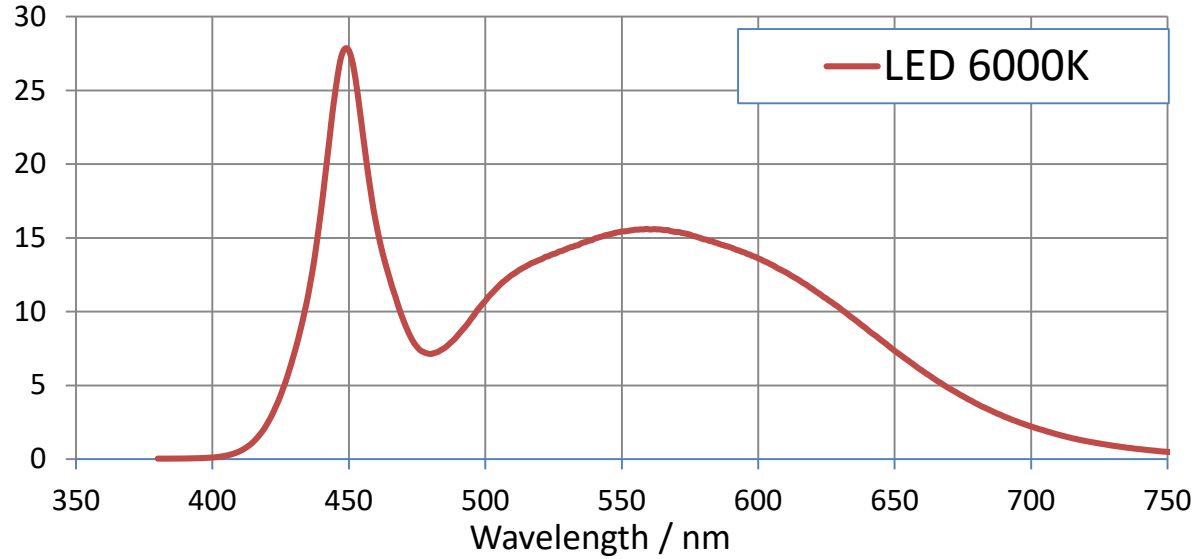


Log scale



Wavelength-Dependence of Blue Light Hazard

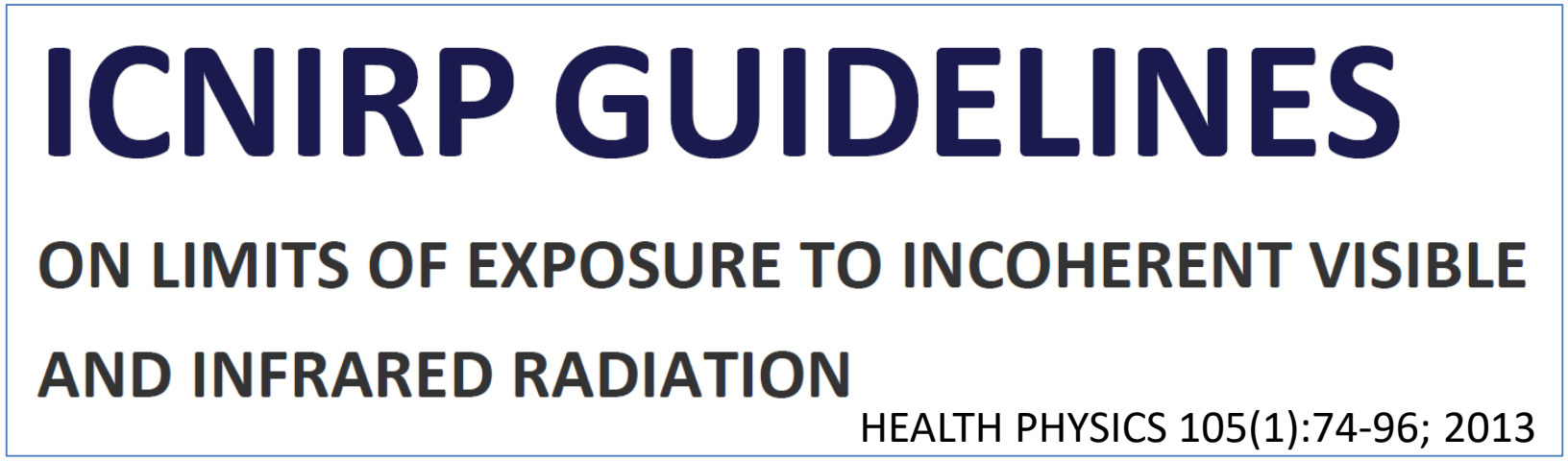




Guidelines on Exposure Limits

ICNIRP
INTERNATIONAL COMMISSION ON
NON-IONIZING RADIATION PROTECTION

As an independent organization, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) provides scientific advice and guidance on the health and environmental effects of non-ionizing radiation (NIR) to protect people and the environment from detrimental NIR exposure.



Free to download from www.icnirp.org

ICNIRP Guidelines on Exposure Limits

$$L_B \cdot t = \sum_{300}^{700} \sum_{t} L_\lambda(\lambda,t) \cdot B(\lambda) \cdot \Delta t \cdot \Delta\lambda \leq 10^6 \quad \text{J·m}^{-2}\text{·sr}^{-1}$$

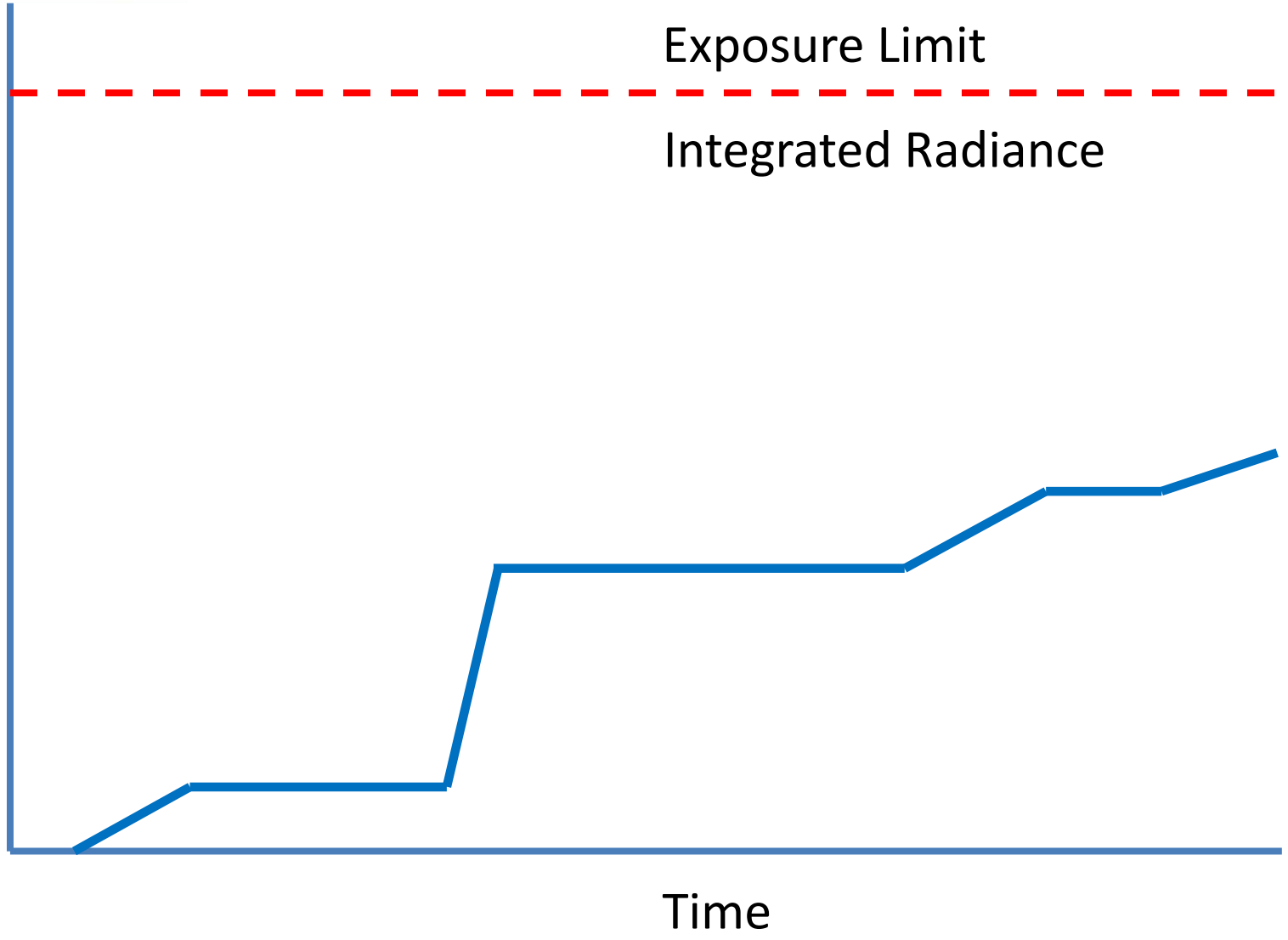
$\leq$ 10,000 seconds

$$L_B = 100 \text{ W.m}^{-2}\text{.sr}^{-1}$$

> 10,000 seconds

L_B is the effective blue light radiance
$B(\lambda)$ is the blue light hazard weighting function

Blue Light Hazard – Time weighted average



ICNIRP Guidelines on Exposure Limits

Table 5.

Exposure duration (seconds)	Acceptance averaging angle γ_{ph}(radians)
$t < 100\ s$	0.011
$100 \leq t < 10{,}000$ s	$0.0011 \cdot t^{0.5}$
$t > 10{,}000$ s	0.110

Note: t must be input in seconds to calculate γ_{ph} in radians

ICNIRP Guidelines on Exposure Limits

For sources that subtend an angle less than the acceptance angle, γ_{ph}

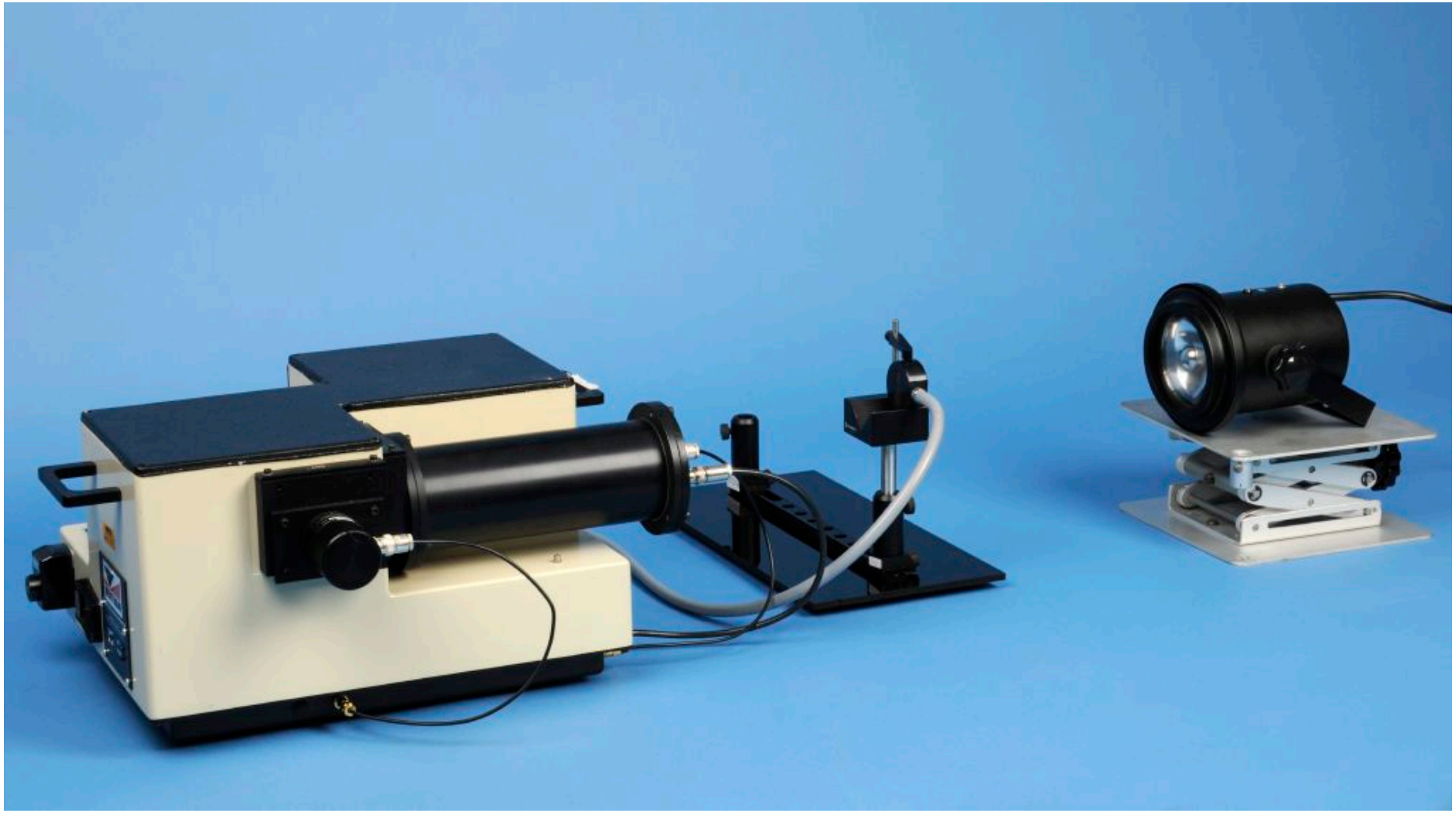
Limits can be expressed in terms of radiant exposure or irradiance:

For $0.25 \leq t < 100$ s, $\Omega = \pi \times \gamma_{ph}^2/4 \approx 1 \times 10^{-4}$ sr

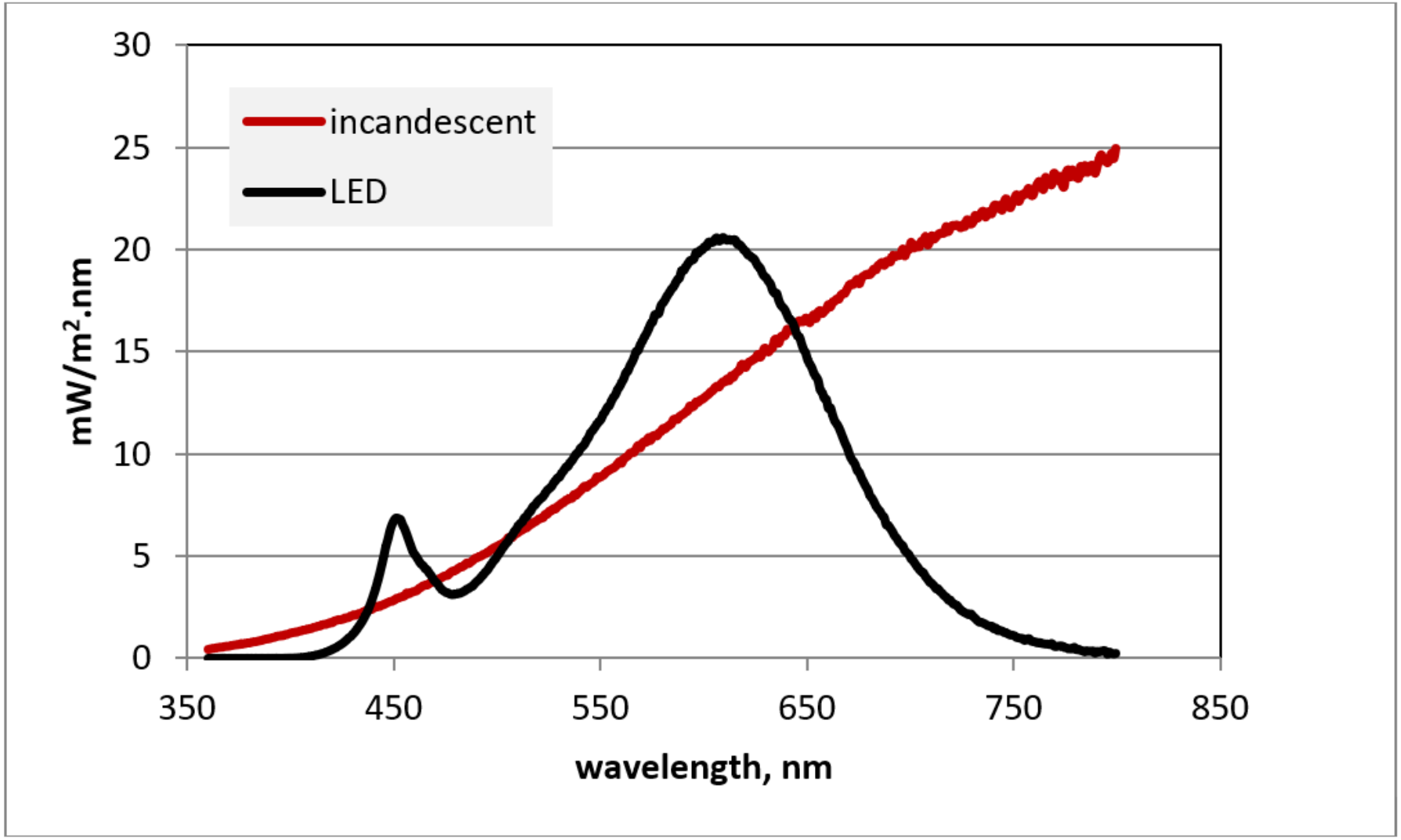
Therefore, radiant exposure limit = 1×10^6 J.m^{-1}.sr^{-1} x 1×10^{-4} sr
= 100 J.m^{-2}

Similarly, for $100 \leq t < 30{,}000$ s, irradiance limit is 1 W.m^{-2}

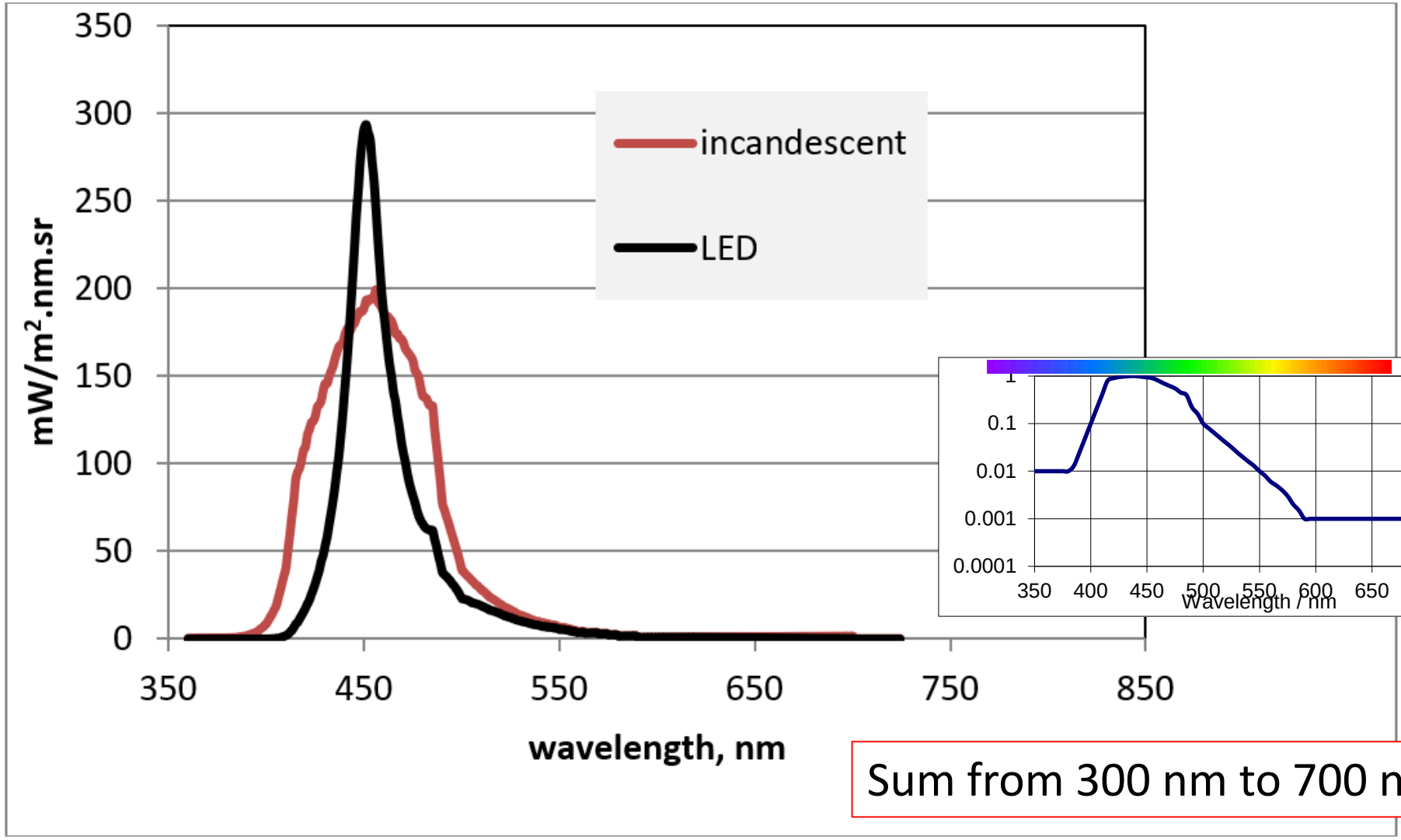
Spectral Measurements



Incandescent vs LED Lamp



Incandescent vs LED Lamp weighted for BLH



Sum from 300 nm to 700 nm

Comparison of Lamps

Accessible emission: lighting					
	Luminance cd/m^2	% ICNIRP Trigger Level	BL weighted radiance, $W/m^2.sr$	% of ICNIRP EL	Hazard ratio, W/lm
LED1	78525	785%	20.6	20.6%	2.62E-04
LED2	44149	441%	10.1	10.1%	2.28E-04
Inc	51207	512%	14.0	14.0%	2.74E-04
CFL	44556	446%	12.9	12.9%	2.91E-04
600 panel	3492	35%	1.7	1.7%	4.97E-04

ICNIRP Trigger Level: 10^4 cd/m^2

Eye (2016) 30, 230–233

Are the exposure limits exceeded in normal life?

Photobiological Risk Classification of Lamps and Lamp Systems—History and Rationale
David H. Sliney, Rolf Bergman & John O'Hagan

LEUKOS, 12:4, 213-234
DOI: 10.1080/15502724.2016.1145551

Common Sense

Colin Smith, Creative Commons Licence

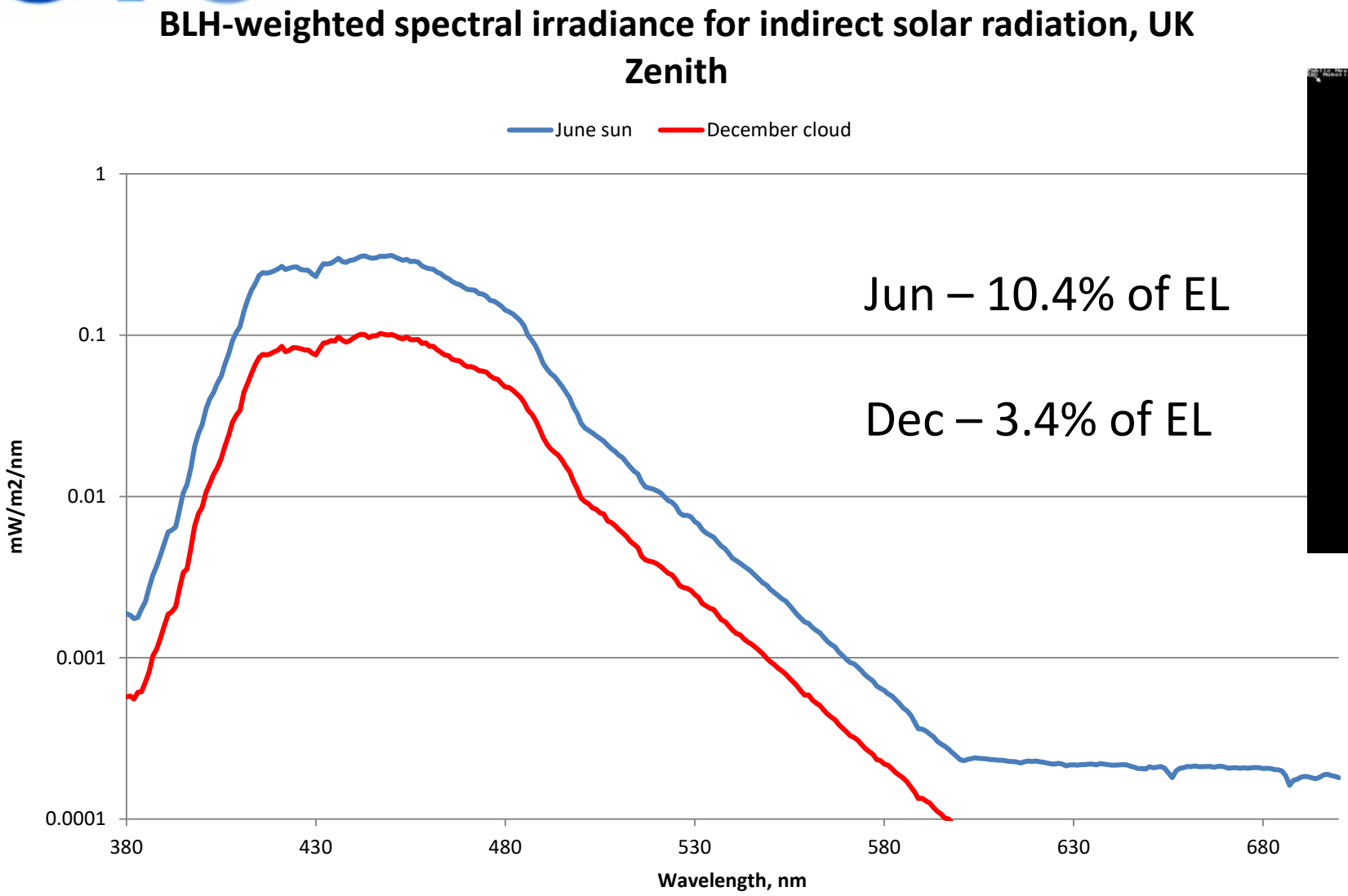
"The man on the Clapham Omnibus"

Lamps

Standard

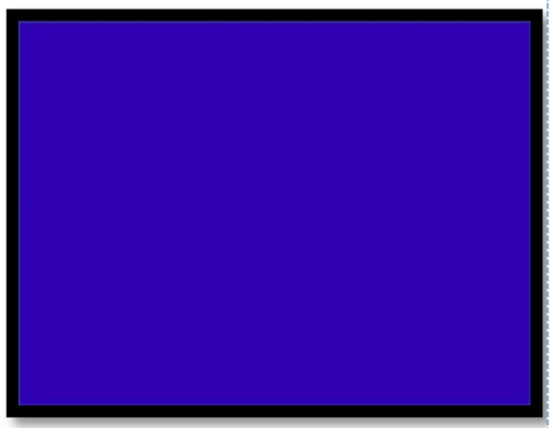
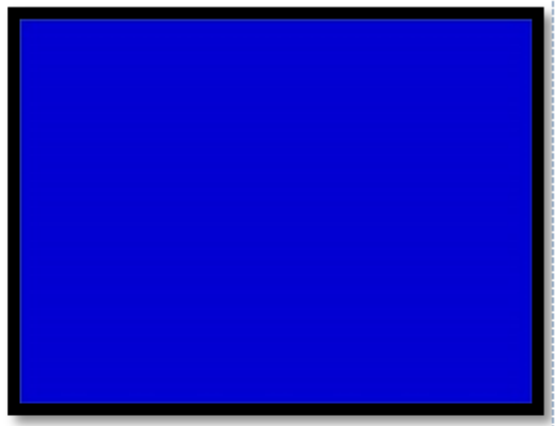
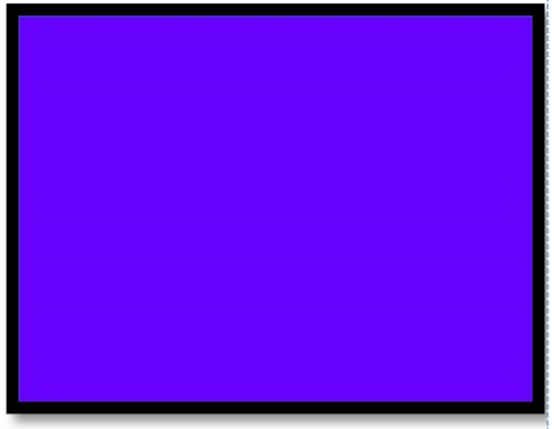
- Photobiological safety of lamps and lamp systems
  - IEC 62471:2006/CIE S 009:2002
- Risk Groups
  - Exempt, RG1, RG2, RG3 (RG3 is the only one we worry about)
  - Assessment conditions for lamps
    - 200 mm or 500 lux for GLS
- Currently being revised

Comparison June/December, UK



Devices we stare at

Screen colours

		
S1: R255, G255, B255	S2: R48, G0, B179	S3: R0, G0, B210
		
S4: R0, G100, B100	S5: R102, G0, B255	S6: R142, G201, B230

Computer Screens – full white image

Accessible emission full white screen: monitors					
	Luminance cd/m^2	% of ICNIRP Trigger Level	BL weighted radiance, $W/m^2.sr$	% of ICNIRP EL	Hazard ratio, W/lm
1	126	1.26%	0.11	0.11%	8.86E-04
24	70.51	0.71%	0.054	0.05%	7.69E-04

Eye (2016) 30, 230–233

Laptop Screens – full white image

Accessible emission full white screen: laptops					
	Luminance cd/m^2	% of ICNIRP Trigger Level	BL weighted radiance, $W/m^2.sr$	% of ICNIRP EL	Hazard ratio, W/lm
9	152.1	1.52%	0.13	0.13%	8.64E-04
10	62.8	0.63%	0.048	0.05%	7.68E-04
11	100.8	1.0%	0.084	0.08%	8.32E-04
12	87.3	0.87%	0.072	0.07%	8.22E-04
14	148.0	1.48%	0.12	0.12%	8.37E-04
15	137.2	1.37%	0.11	0.11%	8.38E-04
20	104.4	1.04%	0.082	0.08%	7.89E-04
22	184.4	1.84%	0.15	0.15%	8.37E-04
23	196.9	1.97%	0.17	0.17%	8.61E-04

Eye (2016) 30, 230–233

Tablet Screens – full white image

Accessible emission full white screen: tablets					
	Luminance cd/m^2	% of ICNIRP Trigger Level	BL weighted radiance, W/m^2.sr	% of ICNIRP EL	Hazard ratio, W/lm
3	174.9	1.75%	0.15	0.15%	8.68E-04
4	93.8	0.94%	0.084	0.08%	8.91E-04
5	63.2	0.63%	0.053	0.05%	8.46E-04
6	42.9	0.43%	0.034	0.03%	7.82E-04
7	142.3	1.42%	0.131	0.13%	9.17E-04
17	238.3	2.38%	0.214	0.21%	8.98E-04
18	140.3	1.40%	0.12	0.12%	8.77E-04
19	191.1	1.91%	0.176	0.18%	9.20E-04
26	202.5	2.02%	0.180	0.18%	8.90E-04

Eye (2016) 30, 230–233

Smartphones – full white image

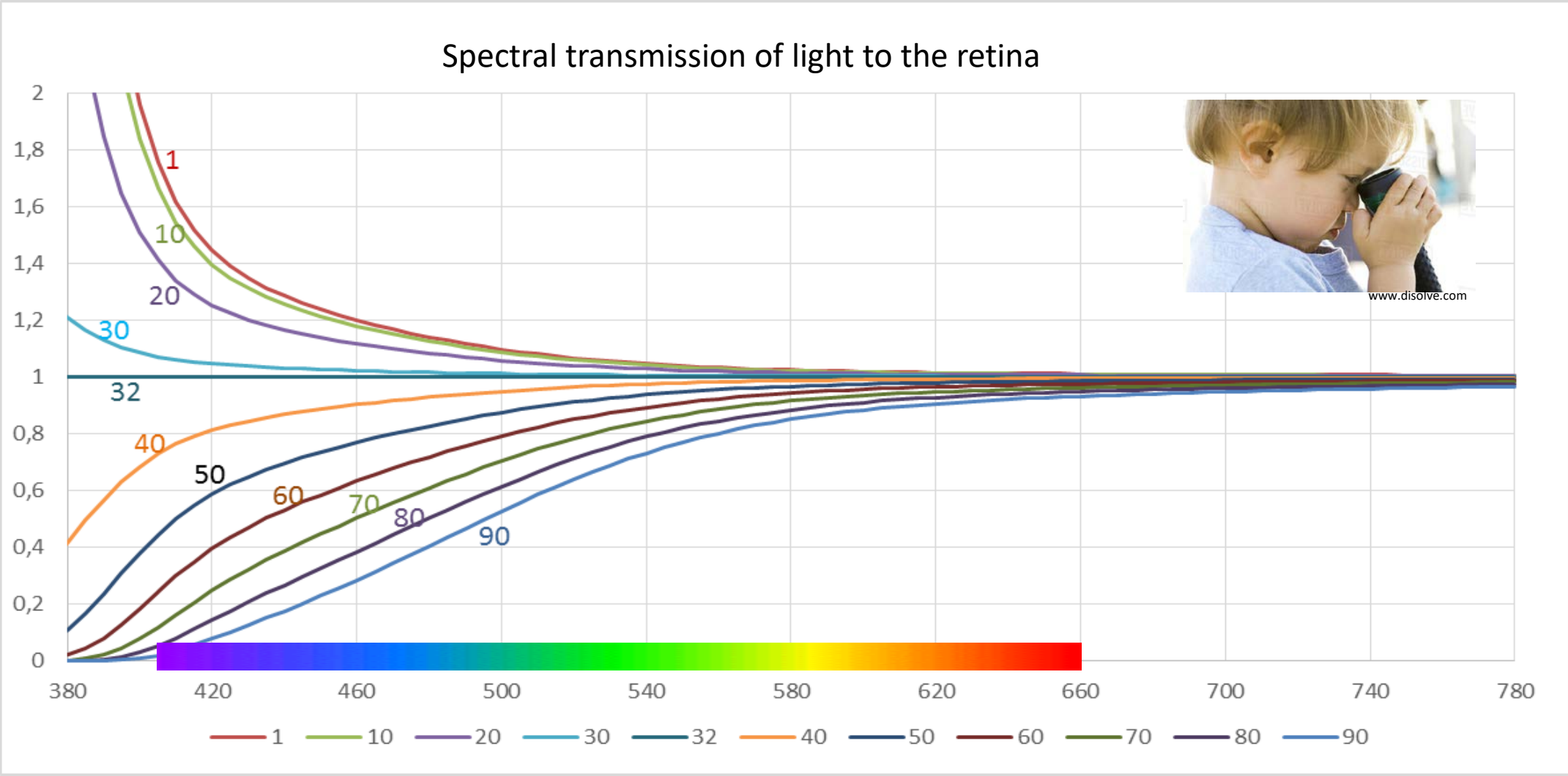
Accessible emission full white screen: smartphones					
	Luminance cd/m^2	% of ICNIRP Trigger Level	BL weighted radiance, $W/m^2.sr$	% of ICNIRP EL	Hazard ratio, W/lm
2	294.4	2.94%	0.28	0.28%	9.43E-04
8	177.5	1.78%	0.15	0.15%	8.61E-04
13	366.5	3.66%	0.31	0.31%	8.56E-04
16	408.5	4.08%	0.38	0.38%	9.36E-04
25	214.6	2.15%	0.19	0.19%	8.82E-04

Eye (2016) 30, 230–233

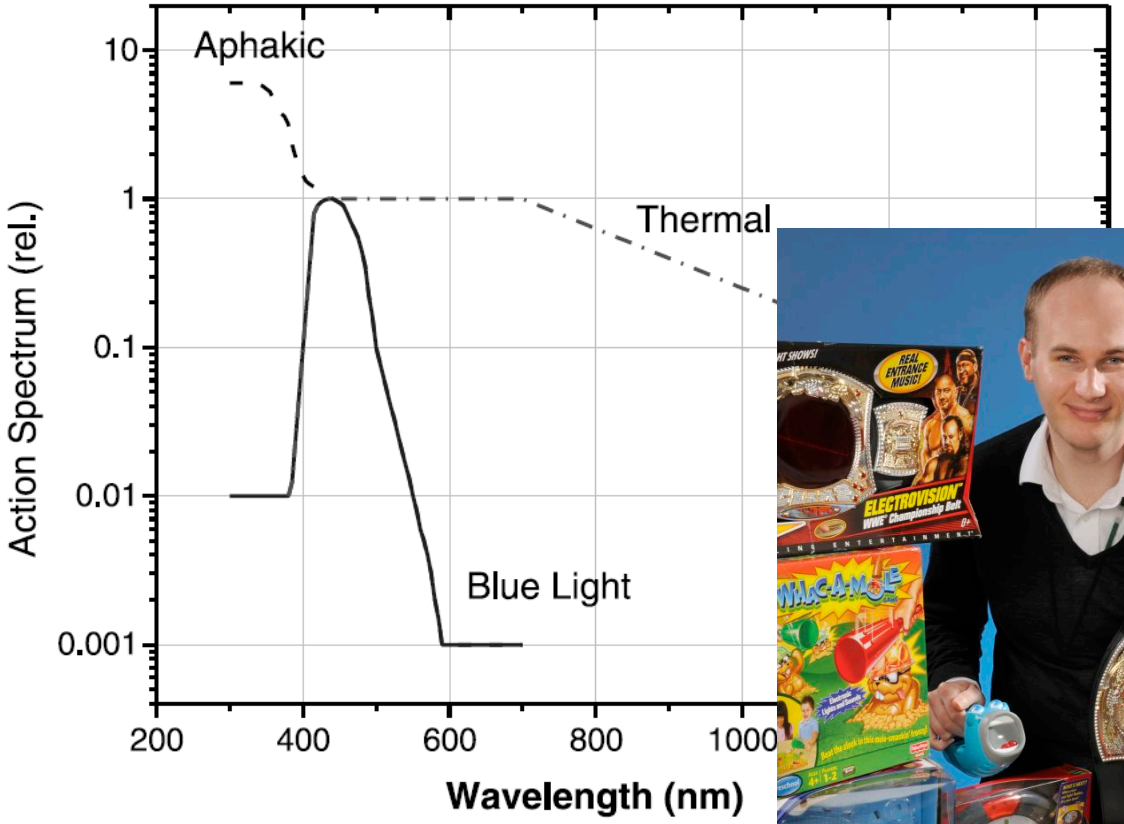
LED Street Lights

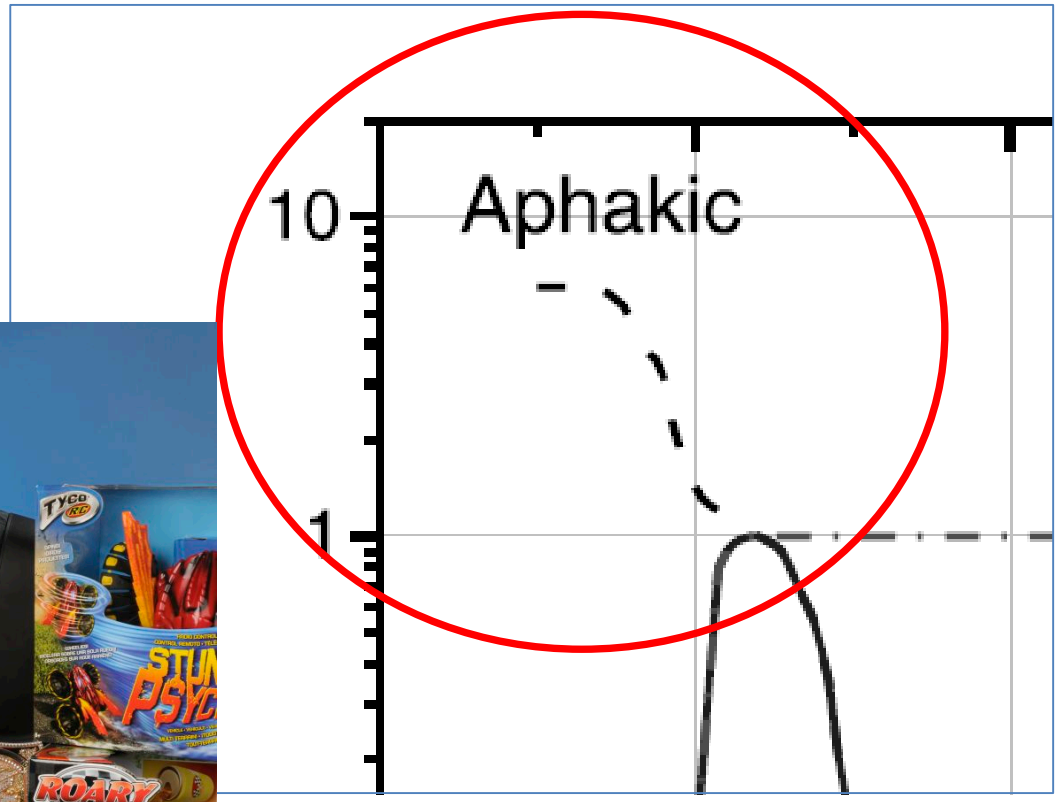
© Daily Mail

Impact of Age



Young Children





We don’t like bright light in our eyes

© Ant Jordan

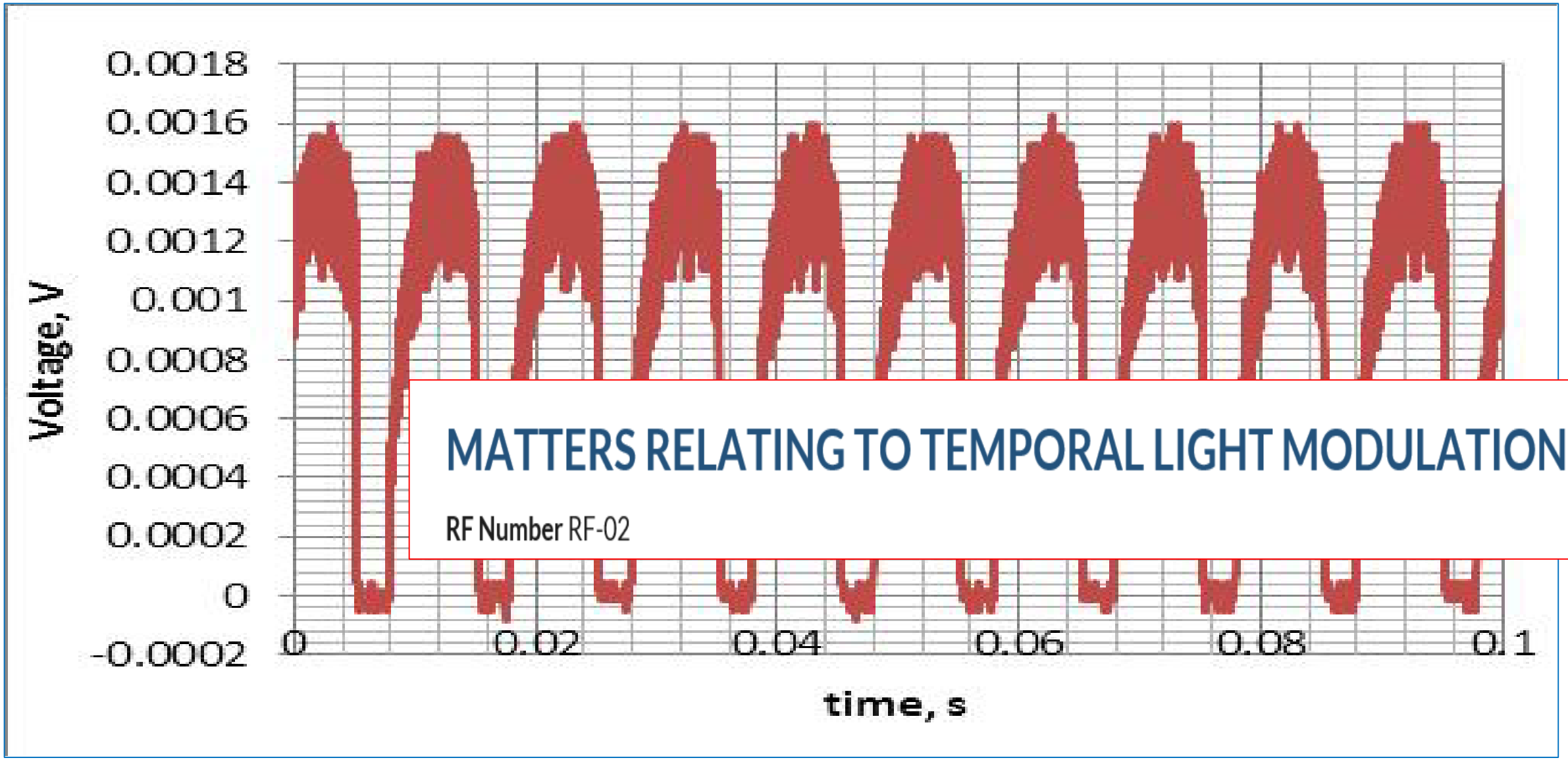
Macular Degeneration

Several epidemiological studies reveal a link between exposure to sunlight and the risk of age-related macular degeneration, but scientific consensus has not yet been established – especially at the levels of sunlight most of us experience.

www.wikipedia.com

Other Concerns with Lighting

LED – Light output vs Time




24-Hour Clock
by GreatGadgets

zzzZZz

International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

CIE Position Statement on the Blue Light Hazard

April, 2019

There have been a number of reports in the media about the risk to human health following exposure to light from sources such as light emitting diodes (LEDs), referring to the term "blue light hazard" (BLH). This term has been inaccurately used to represent the risk of actual eye damage and the influence on general well-being.

www.cie.co.at

International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

CIE Position Statement on Non-Visual Effects of Light

RECOMMENDING PROPER LIGHT AT THE PROPER TIME

2nd Edition[1]

October 3, 2019

THANK YOU FOR LISTENING

ciecb@cie.co.at