# Non-Ionizing Radiation Awareness

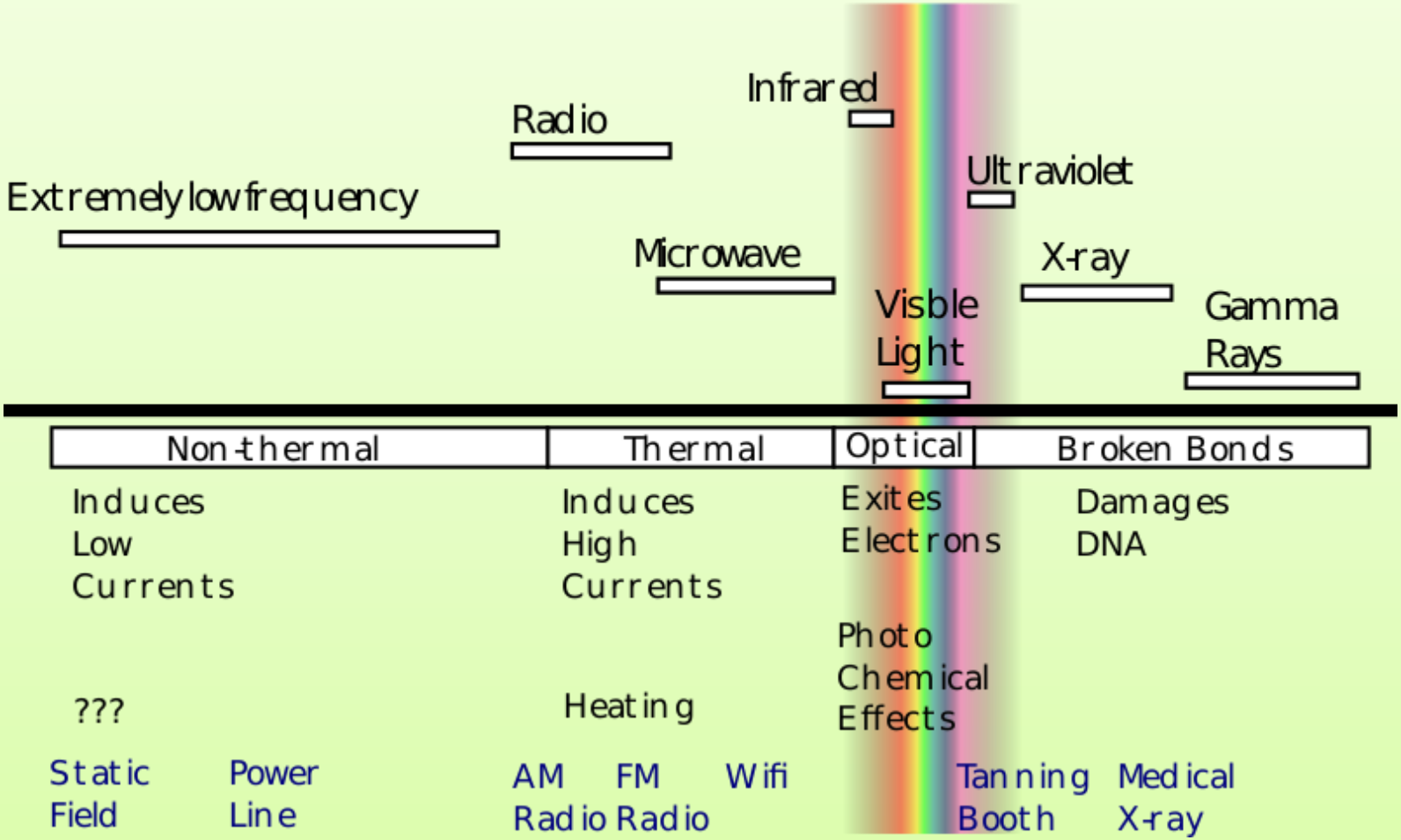
**Steve Hutchins**

DIR 2013/35 EU: EM fields, 0Hz-300GHz
DIR 2006/25 EU: AOR, λ 1mm-100nm

n.b. λ 1mm= 300GHz

This is EU law, extra local rules may be applied too.

# Non-ionising ionising



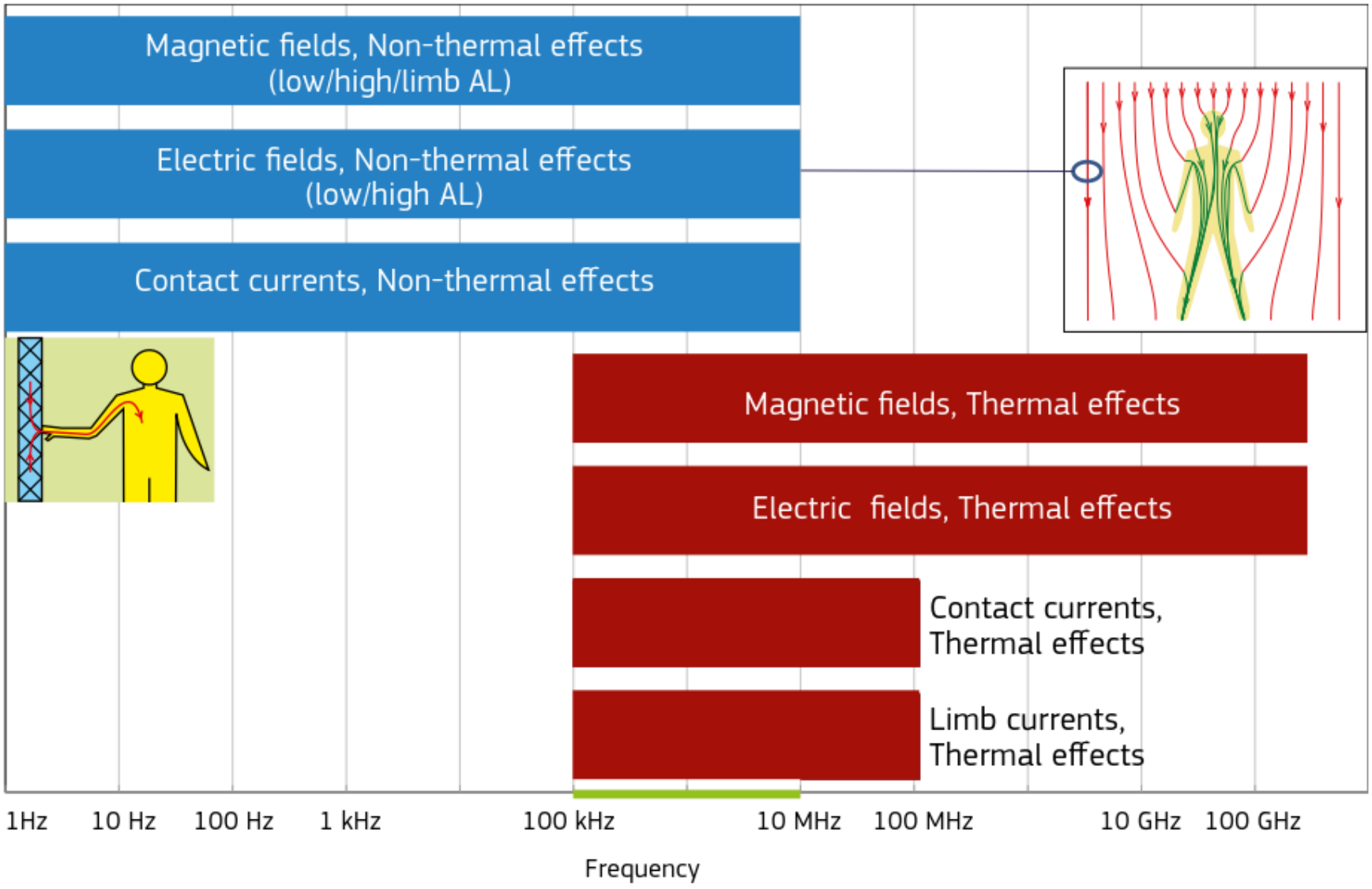
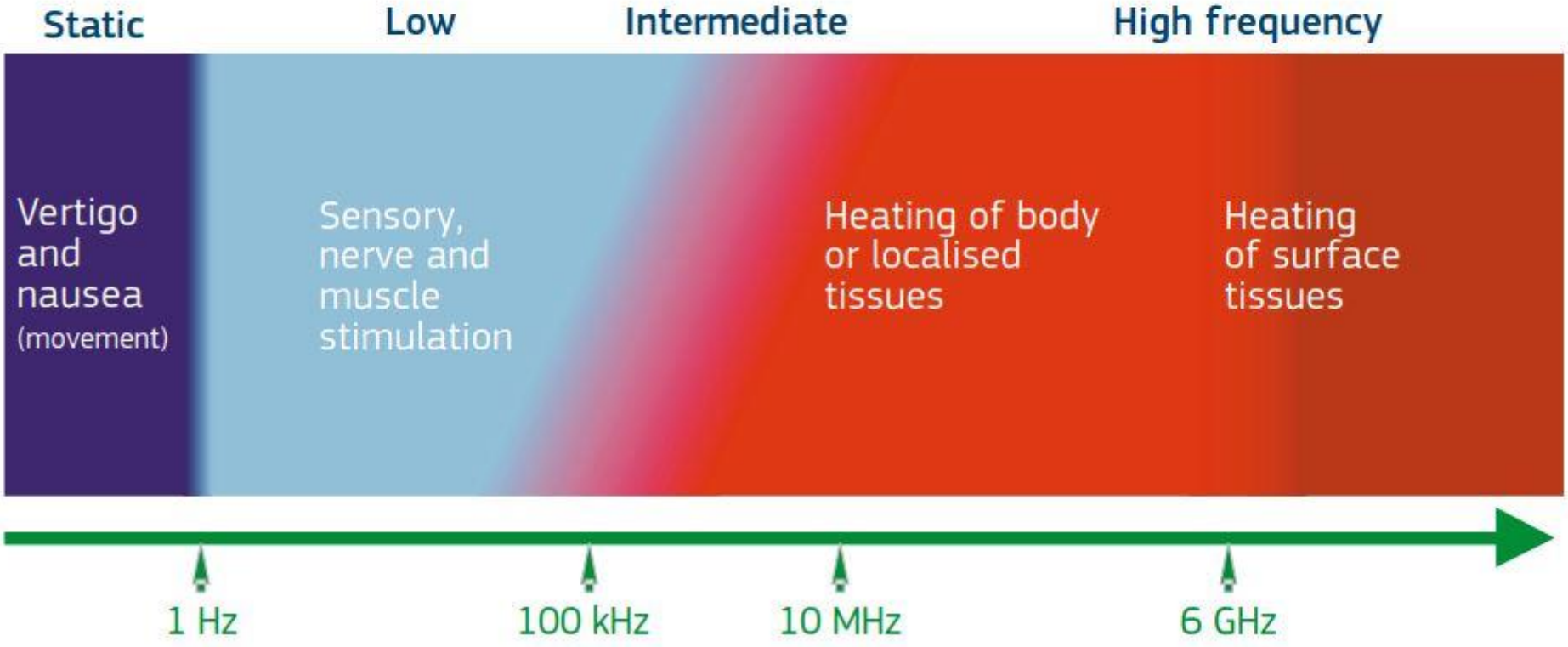

Magnetic fields, Non-thermal effects
(low/high/limb AL)
Electric fields, Non-thermal effects
(low/high AL)
Contact currents, Non-thermal effects
Magnetic fields, Thermal effects
Electric fields, Thermal effects
Contact currents,
Thermal effects
Limb currents,
Thermal effects
1Hz
10 Hz
100 Hz
1 kHz
100 kHz
10 MHz
100 MHz
10 GHz
100 GHz
Frequency

**Figure B1 — Schematic representation of principle direct effects of EMF showing the main frequency breakpoints used for the definition of exposure limit values and action levels in the EMF Directive**



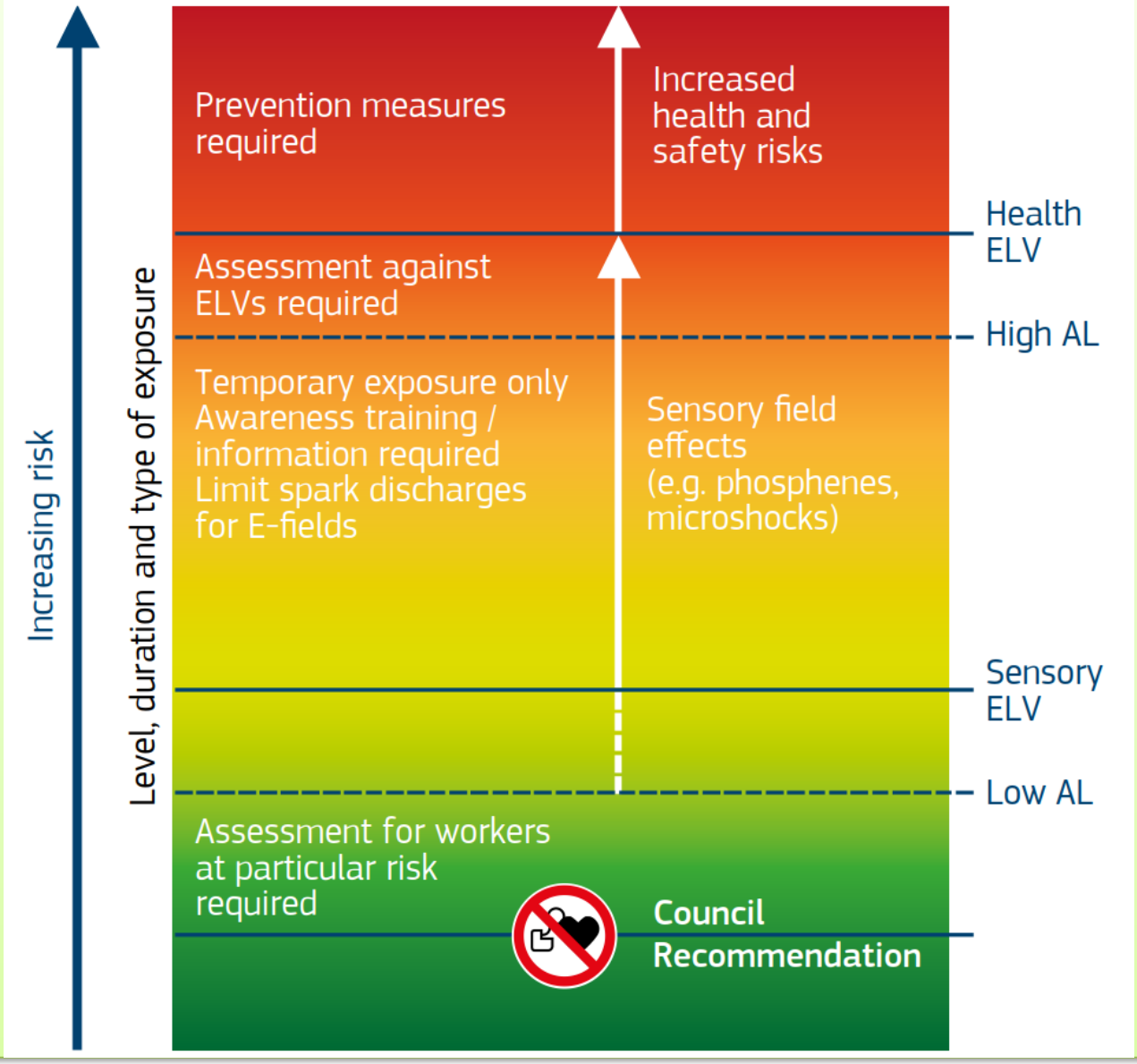

Increasing risk
Level, duration and type of exposure
Prevention measures required
Increased health and safety risks
Health ELV
Assessment against ELVs required
High AL
Temporary exposure only
Awareness training / information required
Limit spark discharges for E-fields
Sensory field effects (e.g. phosphenes, microshocks)
Sensory ELV
Low AL
Assessment for workers at particular risk required
Council Recommendation

**Table B1 — Summary of relevant health and sensory effects used to limit exposures in different frequency regions**

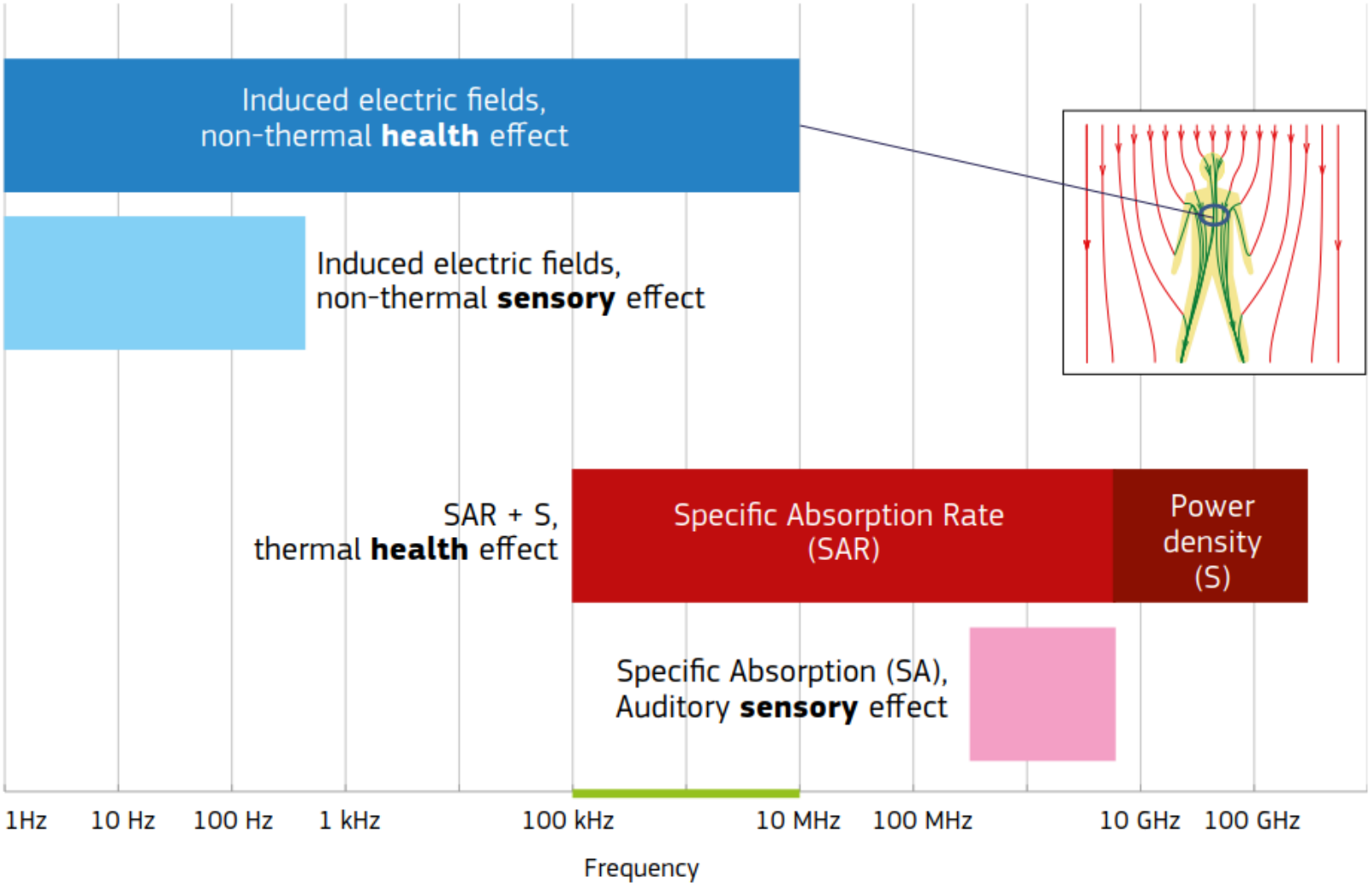
| Field and frequency | Sensory effects | Health effects |
|---|---|---|
| Static magnetic field<br>0 — 1 Hz | Vertigo, nausea, metallic taste | Altered blood flow in limbs, altered brain function;<br>Altered heart function |
| Low frequency fields<br>1 Hz -10 MHz | Phosphenes (perceived as light flashes);<br>(Minor change in brain function 1 — 400 Hz) | Tingling sensation or pain (nerve stimulation)<br>Muscle twitches<br>Disturbed heart rhythm |
| High frequency fields<br>100 kHz — 6 GHz | Microwave hearing effect (200MHz — 6.5 GHz) | Excessive whole-body or localised heating or burns |
| High frequency fields<br>6 — 300 GHz | | Localised heat damage to eyes or skin |
| NB: The effects of intermediate frequency fields (100 kHz - 10 MHz) are a combination of the effects of low frequency fields and high frequency fields. | | |

**Table 9.3 — Examples of access or other restrictions that may be required for areas where there are strong EMFs**

| Criteria | Restrictions |
|---|---|
| **Non-thermal effects**<br><br>Health effects ELV exceeded<br>High AL exceeded<br>Limb AL exceeded | No access while fields present |
| **Thermal effects**<br><br>Health effects ELV exceeded<br>Exposure AL exceeded<br>Induced limb current AL exceeded | Access restrictions to limit time averaged exposure |
| Sensory ELV exceeded temporarily<br>Low AL exceeded temporarily | Access restricted to trained workers<br>Other restrictions may apply |
| Projectile risks from strong static magnetic fields | Restrictions on ferromagnetic materials being taken into the area |
| Risks to workers at particular risk | Restrictions on access into areas with strong fields<br>Information for access to site |
| Risk of spark discharges from strong electric fields | Access restricted to trained workers |
| Risk of contact currents | Access restricted to trained workers<br>Prohibition on unnecessary conductive objects |

## Table D4 — Potential adverse biological effects, ELV and AL quantities

| Frequency | Potential Adverse Biological Effect | ELV Dose Quantity (Numerically Simulated) | AL Exposure Quantity (Typically measured) |
|---|---|---|---|
| 1 Hz to 10 MHz | Effects on central nervous system (CNS) and peripheral nervous system (PNS) | Induced electric fields in stimulated tissues in V/m | Electric field strength, magnetic flux density, induced and contact currents |
| 100 kHz to 6 GHz | Tissue heating | SAR in W/kg<br>SA in J/kg | (Electric field strength)$^2$, (magnetic flux density)$^2$, induced and contact currents |
| 6 GHz to 300 GHz | Surface heating | Power density in W/m$^2$ | (Electric field strength)$^2$, (magnetic flux density)$^2$ and power density |




Blue bars indicate non-thermal effects and red bars thermal effects.

Hazards due to effects on the body are:
induced currents, heating, burns, cell damage, cancers…

Effects are dependent on type of tissue material concerned (arms, organs, eyes..)

Exposure time, intensity and wavelengths of radiation are critical factors.

There is no simple “safe level” for the whole spectrum, or for the whole body.

All CE standard equipment -when used as intended- will not present a hazard.

***But your non-standard experiments may need to be evaluated against the following limits and any local regulations.***

## Static Magnetic Fields

Medical implants: **Action level** = 0.5mT
Magnetic objects may move independently : **Action Level** = 3mT
(tools, piercings, scaffolding….) *if source is >100mT*

**Action Level**: the employer must identify and manage the risks

Magnetic field sign, floor marking, barriers…

**Public Exposure limit** :10mT

**EFFECTS**: Dizziness, nausea: Exposure Limit Value 2T (nominal body) and 8T for limbs in controlled working conditions.

ALARA applies (as low as reasonably achievable)

## Medical Implants

Active electrical circuits:
heart, brain, medicines dosing, monitoring…

Static and RF fields may affect operation:
access to these areas is excluded. (n.b. MRI scanners, airport security…)

These areas must be indicated if over 0.5mT***!***

Passive Implants: hip replacement, pins, clips.. Follow your medical advice.

**Figure 9.7 — Standard prohibition signs often displayed in relation to EMF**

No access for people with active implanted cardiac devices

No access for people with metallic implants

# Low frequency Electro-Magnetic Fields

Induced voltages in the nervous system: Exposure Limits

**Health effects ELVs for internal electric field strength from 1 Hz to 10 MHz**

| Frequency range | Health effects ELVs |
|---|---|
| 1 Hz ≤ f < 3 kHz | 1,1 $Vm^{-1}$ (peak) |
| 3 kHz ≤ f ≤ 10 MHz | $3{,}8 \times 10^{-4}$ f $Vm^{-1}$ (peak) |

Retinal effects and brain function: Exposure limits

**Sensory effects ELVs for internal electric field strength from 1 to 400 Hz**

| Frequency range | Sensory effects ELVs |
|---|---|
| 1 ≤ f < 10 Hz | 0,7/f $Vm^{-1}$ (peak) |
| 10 ≤ f < 25 Hz | 0,07 $Vm^{-1}$ (peak) |
| 25 ≤ f ≤ 400 Hz | 0,0028 f $Vm^{-1}$ (peak) |

Low frequency Electro-Magnetic Fields

**Action Levels** for the external field:

**ALs for exposure to electric fields from 1 Hz to 10 MHz**

| Frequency range | Electric field strength Low ALs (E)[$Vm^{-1}$] (RMS) | Electric field strength High ALs (E) [$Vm^{-1}$] (RMS) |
|---|---|---|
| $1 \leq f < 25$ Hz | $2{,}0 \times 10^4$ | $2{,}0 \times 10^4$ |
| $25 \leq f < 50$ Hz | $5{,}0 \times 10^5/f$ | $2{,}0 \times 10^4$ |
| 50 Hz $\leq f <$ 1,64 kHz | $5{,}0 \times 10^5/f$ | $1{,}0 \times 10^6/f$ |
| 1,64 $\leq f <$ 3 kHz | $5{,}0 \times 10^5/f$ | $6{,}1 \times 10^2$ |
| 3 kHz $\leq f \leq$ 10 MHz | $1{,}7 \times 10^2$ | $6{,}1 \times 10^2$ |

Actions needed: to identify zone, provide training and information and record the risk assessment…

**Figure D14 — Example 2: Induced electric field distribution from exposure to a 50 Hz wire positioned near the head.**

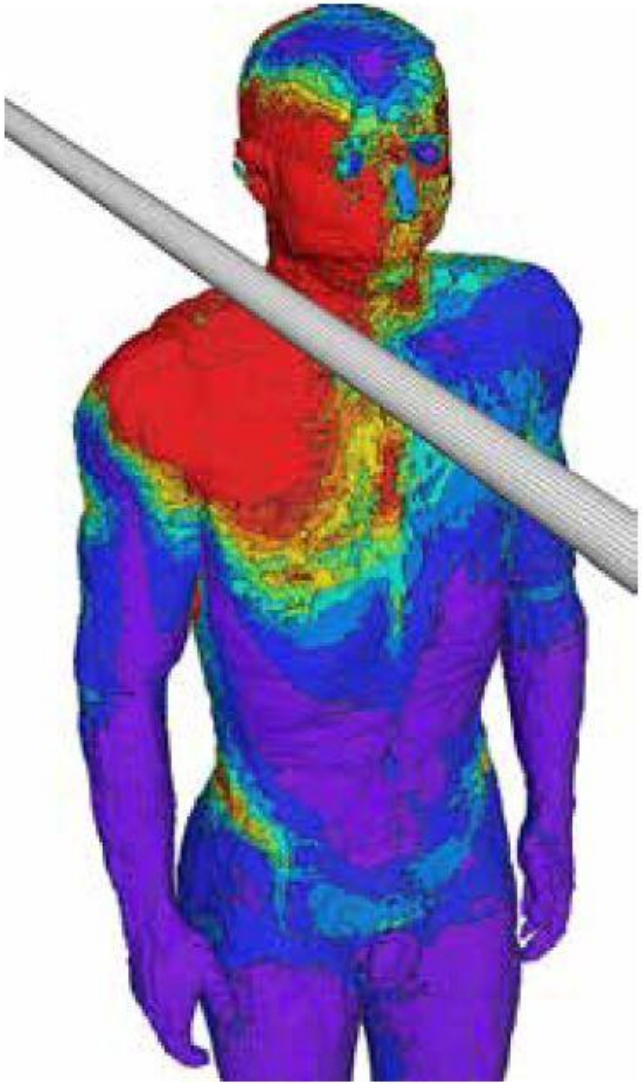
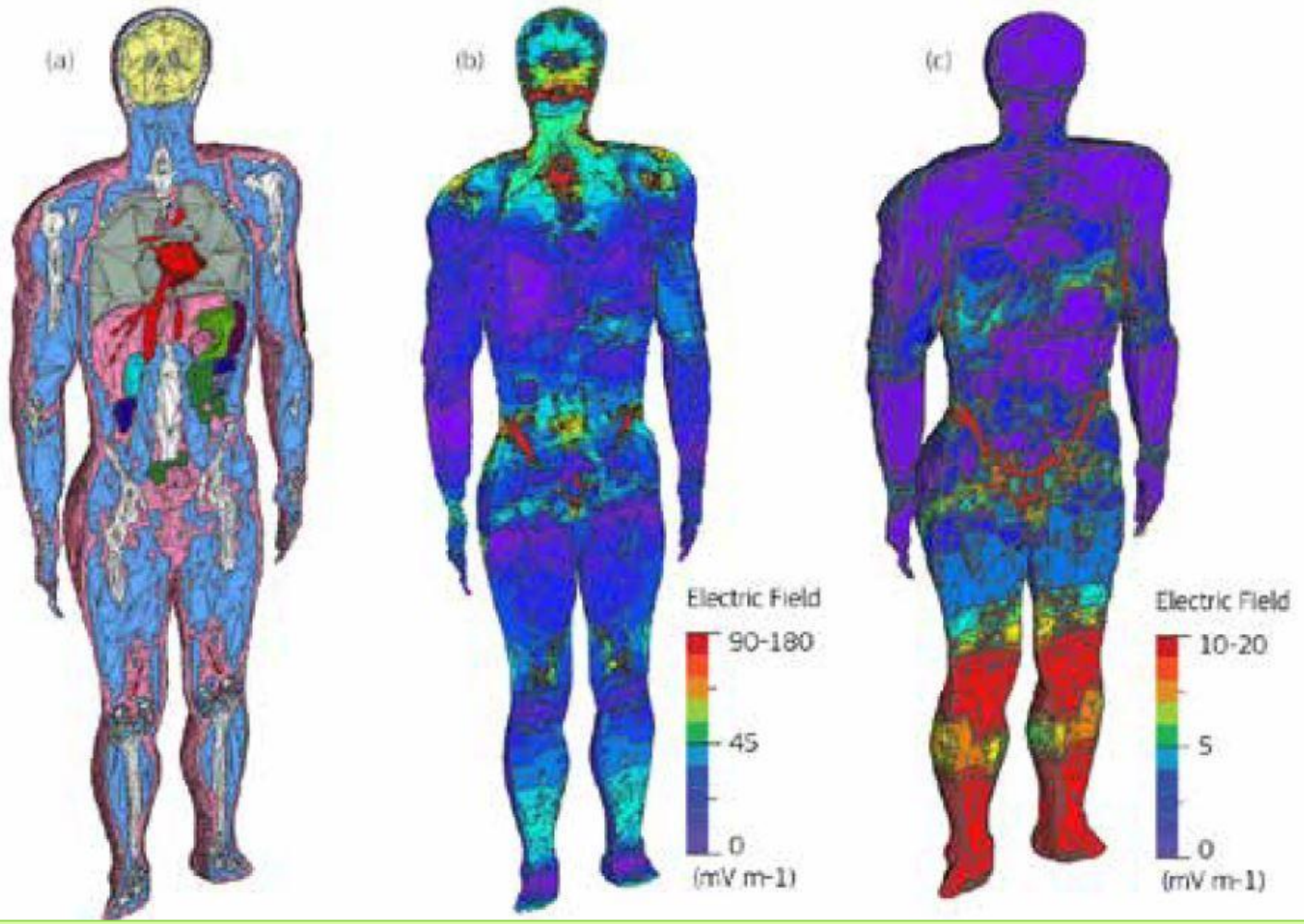


**Figure D3 — Low frequency Exposure: Cutaway images of the human body showing (a) internal organs within the body (b) internal electric fields produced from exposure to an external low frequency magnetic field and (c) internal electric fields from exposure to an external low frequency electric field**



Low frequency EM fields:

**Sources:** Power networks (50Hz and harmonics): areas would be enclosed and not accessible,
from Switching power converters/UPS (100kHz +), normally in closed cabinets, not accessible.

Electric welding, induction heating: possible local exposure.

“home made” experimental equipment? You may be working inside the equipment, electrically isolated but exposed to the fields and completely ignoring EC directives on EMC…

Sparks and heating are ignition sources: beware of flammable gasses and solvents.

Induction effects, but also shielding is possible..

Low frequency Electro-Magnetic Fields

**Action Levels** for Contact current:

**ALs for contact current $I_C$**

| Frequency | ALs ($I_C$) steady state contact current [mA] (RMS) |
|---|---|
| up to 2,5 kHz | 1,0 |
| 2,5 ≤ f < 100 kHz | 0,4 f |
| 100 ≤ f ≤ 10 000 kHz | 40 |

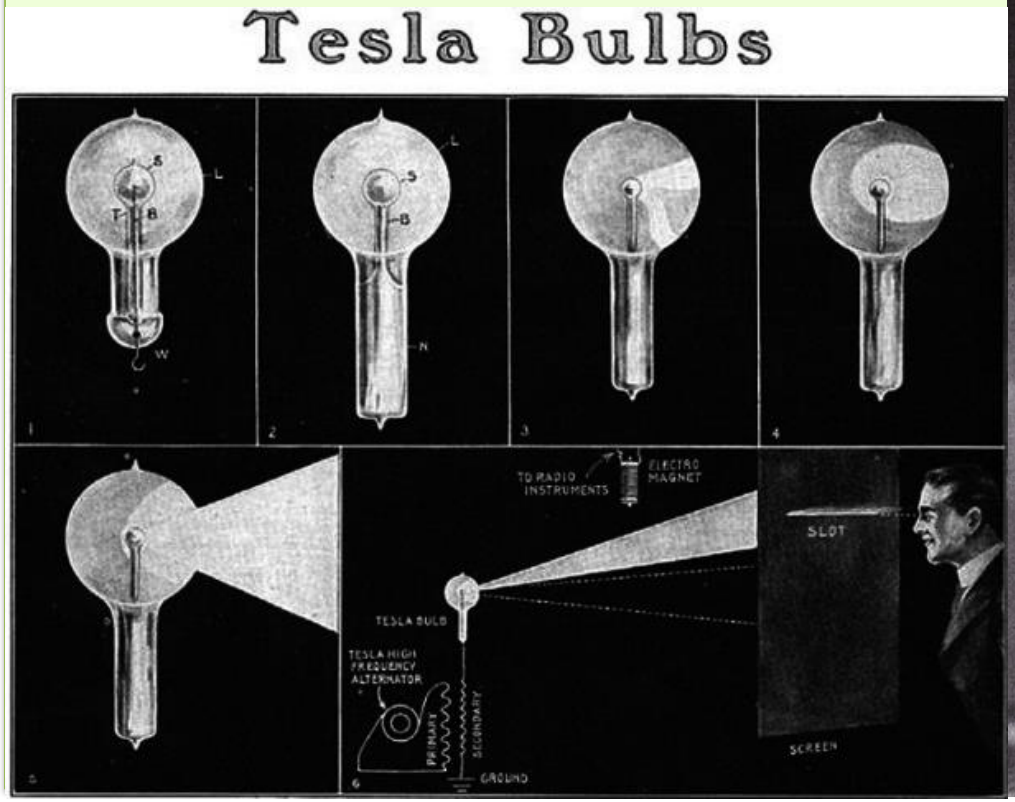
Note B3-1: f is the frequency expressed in kilohertz (kHz).

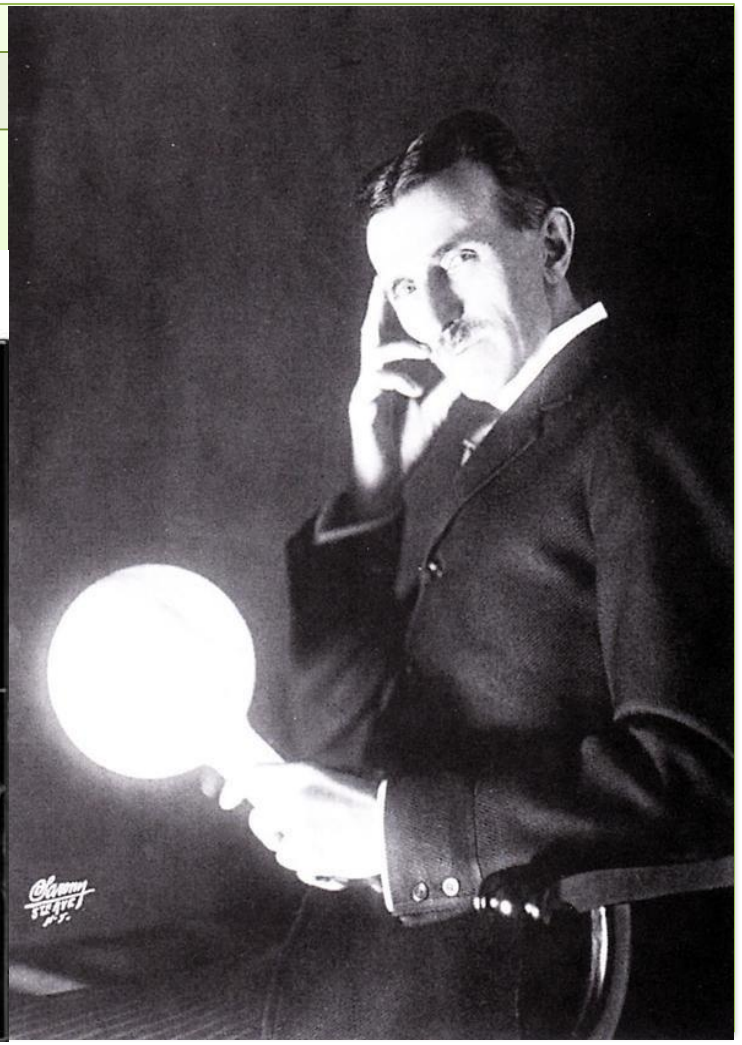
For all Low frequency E-M Fields:

Indirect effects: interference, electric shocks, sparks
Sensory effects: Nausea, vertigo, metallic taste in mouth, tingling
Contact currents: (metal object not grounded) shock or burns

Shielding is possible: Faraday Cage, best at source.

Do ***not*** do this at home….



…but Do try this….

## RF Electro-Magnetic Fields

Heating effects in tissue

**Sensory effects ELVs for exposure to electromagnetic fields from 0,3 to 6 GHz**

| Frequency range | Localised specific energy absorption (SA) |
|---|---|
| $0,3 \leq f \leq 6$ GHz | 10 $mJkg^{-1}$ |

Note A2-1: Localised SA averaging mass is 10 g of tissue.

**Health effects ELVs for exposure to electromagnetic fields from 6 to 300 GHz**

| Frequency range | Health effects ELVs related to power density |
|---|---|
| $6 \leq f \leq 300$ GHz | 50 $Wm^{-2}$ |

Above 6GHz the RF power is absorbed near the surface, so incident power density is used to define the limits.

**Figure C6 — The specific energy absorption rate (SAR) distribution in the head from exposure to a 380 MHz TETRA (Terrestrial Trunked Radio) handset**

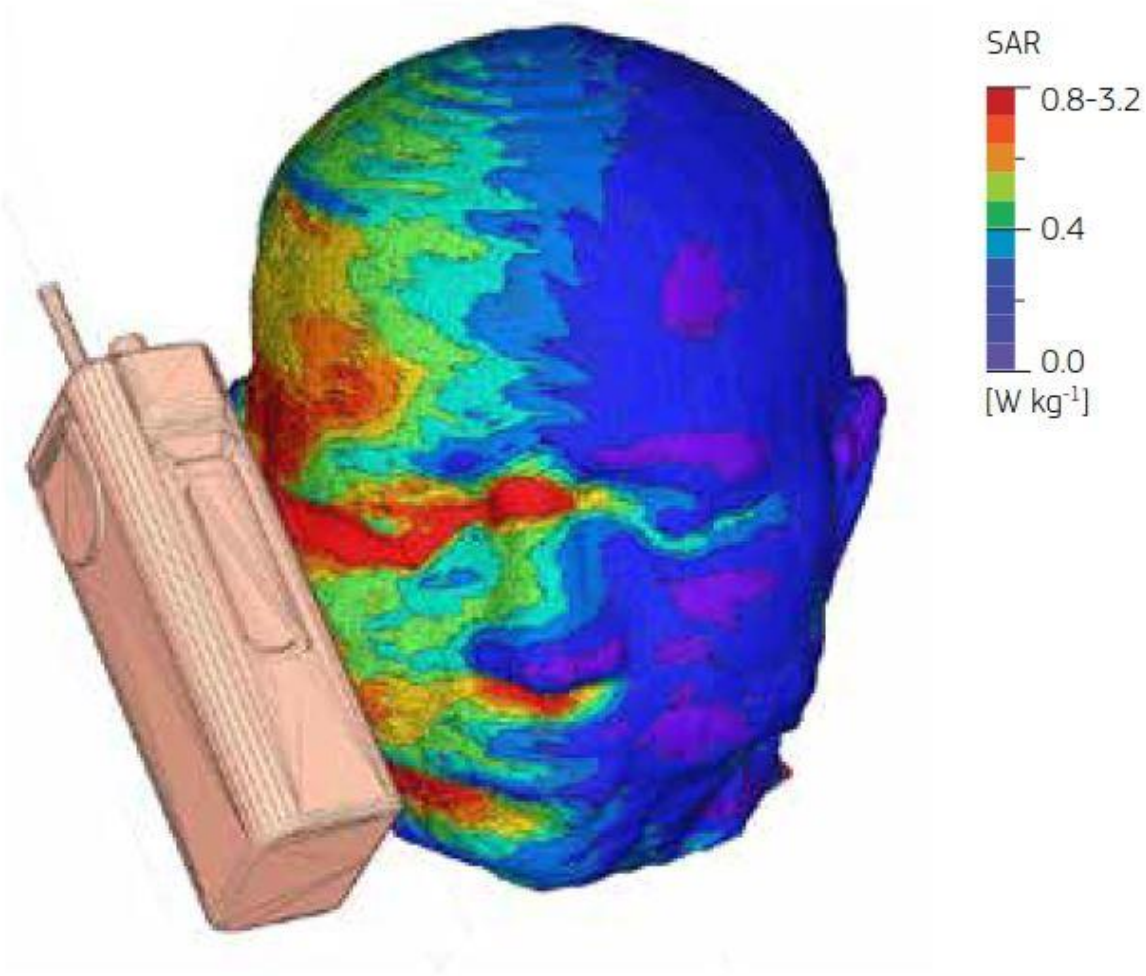
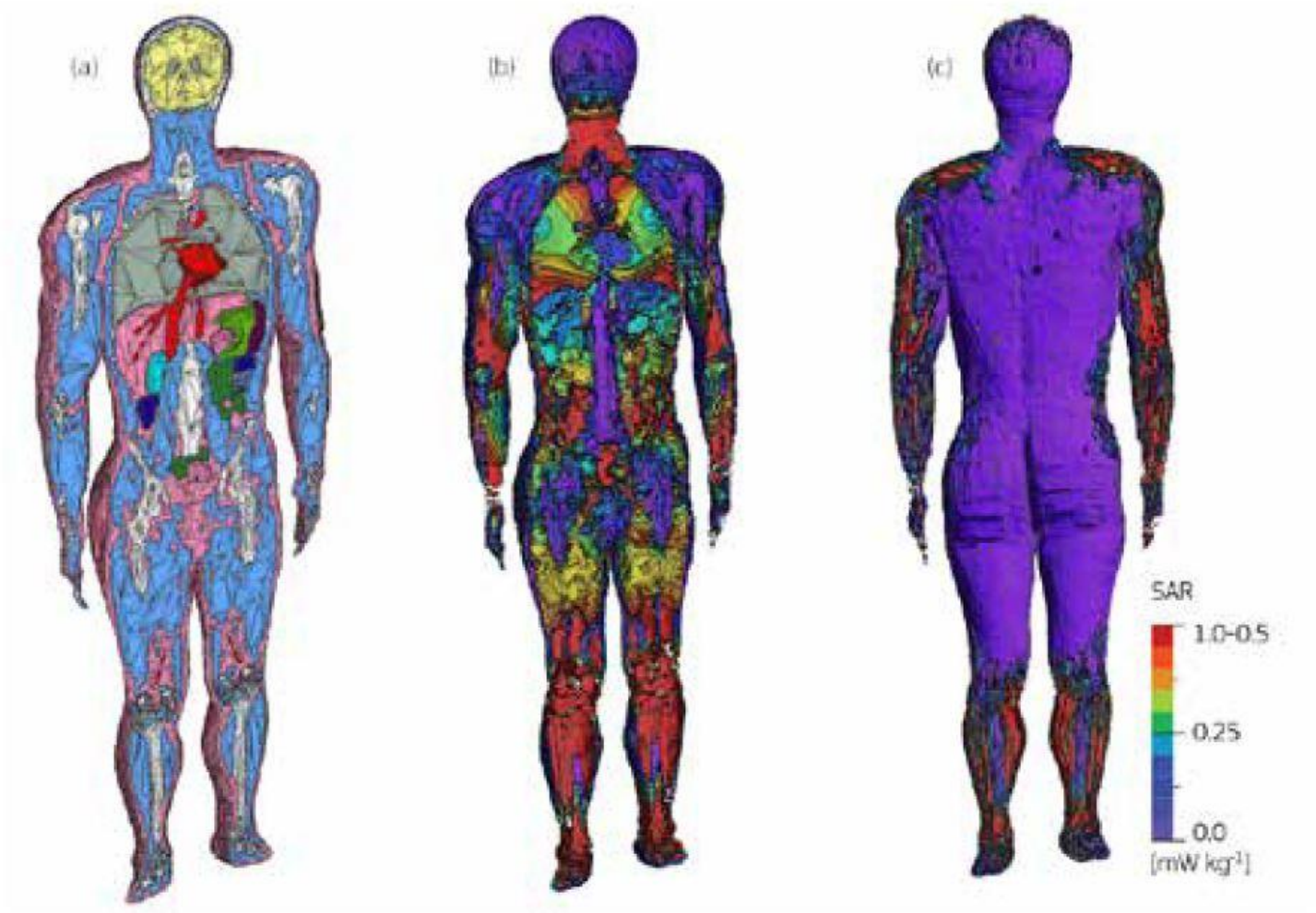


**Figure D4 — High Frequency Exposure: Cutaway images of the human body showing internal organs within the body (b) SAR produced in tissues from exposure to a 40 MHz electromagnetic field and (c) SAR produced in tissues from exposure to a 2 GHz electromagnetic field**



Radio Frequency  EM waves:

**Sources:**
Telecoms transmitters: not accessible, restricted access.
WiFi: very low level.
Mobile phone: exceeds low action level, consider not using 24/7.

"home made" experimental equipment? Have it checked.
RF connections (waveguide or coax) may have leaks if incorrectly assembled, RF leakage detectors are commercially available.

**Products - Personal & Area Monitor (Nardalert S3)**

**Nardalert S3 The world's most advanced NIR (Non-Ionizing Radiation) Monitor designed to be used as a wearable or fixed area sensor.**

*Features:*

- Specifications given based on on-body use
- Field replaceable sensor modules
- Full color LCD display
- Multi-color alarm
- USB port for data and charging
- Interchangeable lanyard or belt clip
- Comprehensive software included
- Can be deployed with NBM-580 for collecting readings from multiple Nardalert meters and probes

**SMARTS II Area Monitors**

***Measurement range***
2 MHz to 100 GHz

***Properties***

- Automatic and continuous monitoring of a given area or room
- Models available to match all available standards
- Audio and remote alarm vibrator
- Weatherproof housing available

***Applications***

From 300GHz we consider the radiation as infra red heat, absorbed near the surface.

Exposure Limit Value = 100W/$m^2$ for exposure over 1000s (corneal burns etc.)

and

20000 $t^{0.25}$ J/$m^2$ for skin burns (exposures less than 10 seconds)

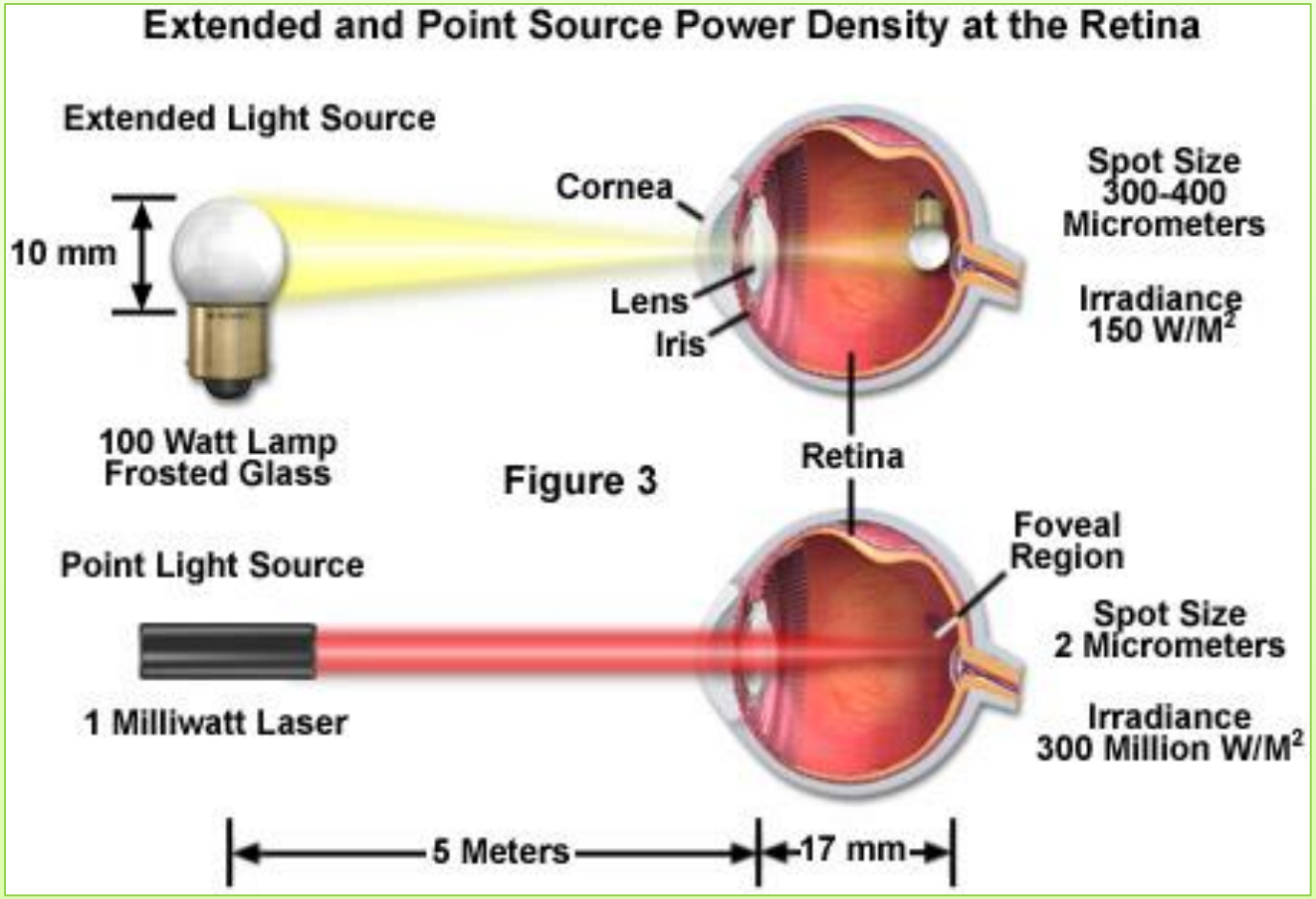
The average human body is an Infra red emitter of about 100W.

Burns would penetrate beneath the skin.

# Optical Hazards

Light can harm your eyes and skin: i.e. sunlight and bright sources

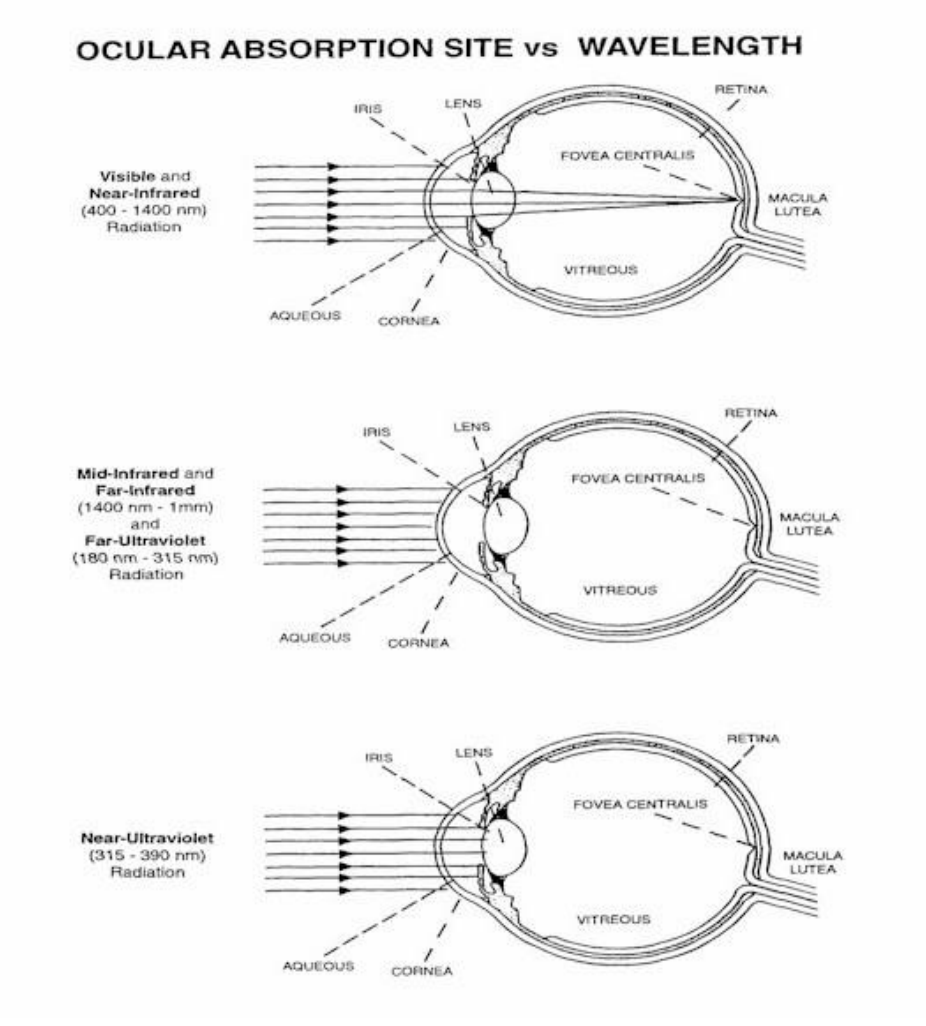
Laser beams do not follow the $1/r^2$ law : hazard over long distances



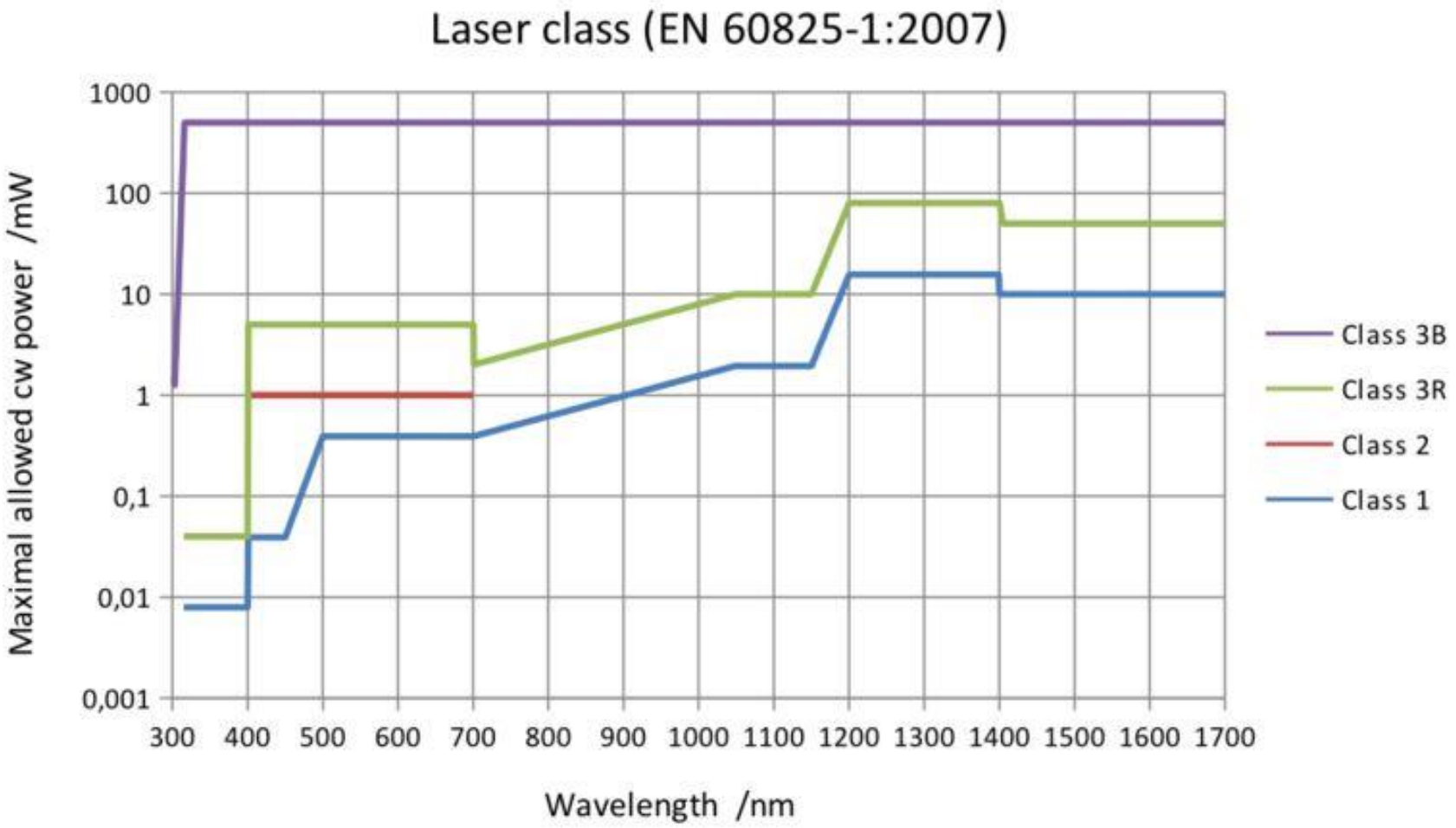
Optical Hazard depends on Wavelength, pulse duration And energy.

We calculate the energy density and apply EN207 standards to find the safety glasses for eye protection.

We calculate the maximum energy density for **skin exposure too**. This may give a safe working distance even when glasses are used.




Class 2 lasers will damage the retina if stared into.


Laser class (EN 60825-1:2007)
Maximal allowed cw power /mW
1000
100
10
1
0,1
0,01
0,001
300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700
Wavelength /nm
Class 3B
Class 3R
Class 2
Class 1

Lasers are classified and controlled by their risk level

Class 1: no hazard
Class 2: blink reflex 0.25 sec visible light only (a bit dodgy)
Class 3: training recommended, interlocks and safe area working
Class 4: training essential, risk assessment, interlocked laser area…

The classification follows the biological hazard level,

Class 4 : any laser exceeding 0.5W CW which is an ignition
and diffuse reflection hazard.

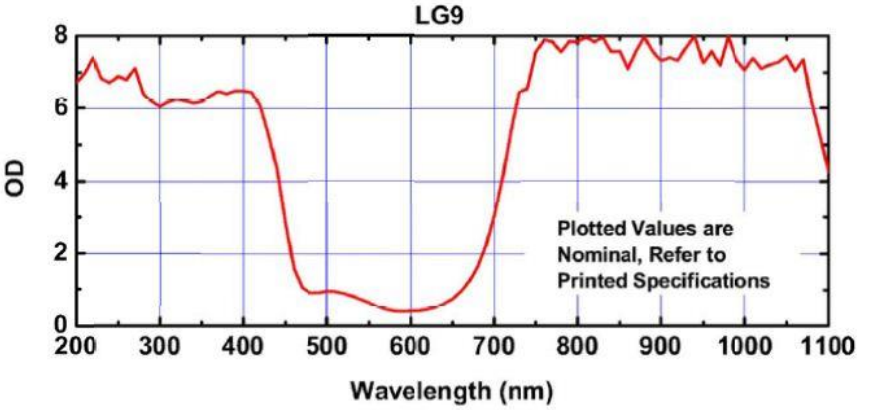

Use only if CE marked

## Specifications

| Specification | Value |
|---|---|
| Luminous Transmittance | 25% |
| Optical Density | |
| 180 - 400 nm | 6+ |
| 720 - 1090 nm | 5+ |
| 750 - 1064 nm | 7+ |

| Specification | Value |
|---|---|
| L-Rating | |
| 180 - 315 nm | D LB6 |
| 180 - 315 nm | R LB4 |
| >315 - 400 nm | DR LB4 |
| 720 - 725 nm | DM LB5 |
| 720 - 750 nm | IR LB5 |
| >725 - 1075 nm | DM LB6 |
| >750 - 1064 nm | IRM LB7 |
| >1064 - 1075 nm | IR LB5 |

## Graph




Code:
720-725 DM LB5
Wavelength in nm,
DM= CW and short pulses
LB5= EN207 coding OD5

# Non-Laser Light Sources

These sources may also cause harm to eyes and skin, there are 15 different limit curves depending on the type of damage, wave length and exposure time.

| Wavelength (nm) | | Eye | Skin |
|---|---|---|---|
| 100–280 | UVC | Photokeratitis<br>Photoconjunctivitis | Erythema<br>Skin cancer |
| 280–315 | UVB | Photokeratitis<br>Photoconjunctivitis<br>Cataracts | Erythema<br>Elastosis (photoageing)<br>Skin cancer |
| 315–400 | UVA | Photokeratitis<br>Photoconjunctivitis<br>Cataracts<br>Photoretinal damage | Erythema<br>Elastosis (photoageing)<br>Immediate Pigment Darkening<br>Skin cancer |
| 380–780 | Visible | Photoretinal damage<br>(Blue Light Hazard)<br>Retinal burn | Burn |
| 780–1 400 | IRA | Cataracts<br>Retinal burn | Burn |
| 1 400–3 000 | IRB | Cataracts | Burn |
| 3 000–$10^6$ | IRC | Corneal burn | Burn |

Seek advice! There will always be a safety responsible where you are working. EC marking = ok (DIR 2006/25 EU)

Ionizing, Photo-chemical and photo-sensitive effects.

“Ionising” is usually considered to be UV λ shorter than 380nm, where skin cancer becomes a risk.

But visible light can excite biological cells which can cause skin reactions and sensitivities. Chemicals, some medicines and plants can all cause heightened photo-sensitivity to eyes and skin.

Sound hazards.

Ultra- and Infra- sound: sonic waves beyond our hearing range

Can cause nausea, headaches and physical injury.

May be caused by machinery or air or water cooling systems where a “resonant cavity” has been created, amplifying any turbulence noise.
Infra sound may be sensed as a vibration, an ultrasound vibrating surface is painful to touch.

These can both be measured if in doubt.

Also pulsed electrical equipment: high power acoustic shock, but “low” average noise.

Free information is available from the EU in all EU languages:

**https://publications.europa.eu**

**Non-binding guide to good practice for implementing Directive 2013/35/EU Electromagnetic Fields Volume 1, Practical guide pp214**

**Non-binding guide to good practice for implementing Directive 2006/25/EC "artificial optical radiation"**

RECAP:

NIR covers a huge spectrum

Can cause a wide variety of health effects

Standard EC marked equipment is safe

Follow operating instructions

The action levels are conservative

Home-made equipment: seek to achieve EC standards.

You are responsible for others

Thank you