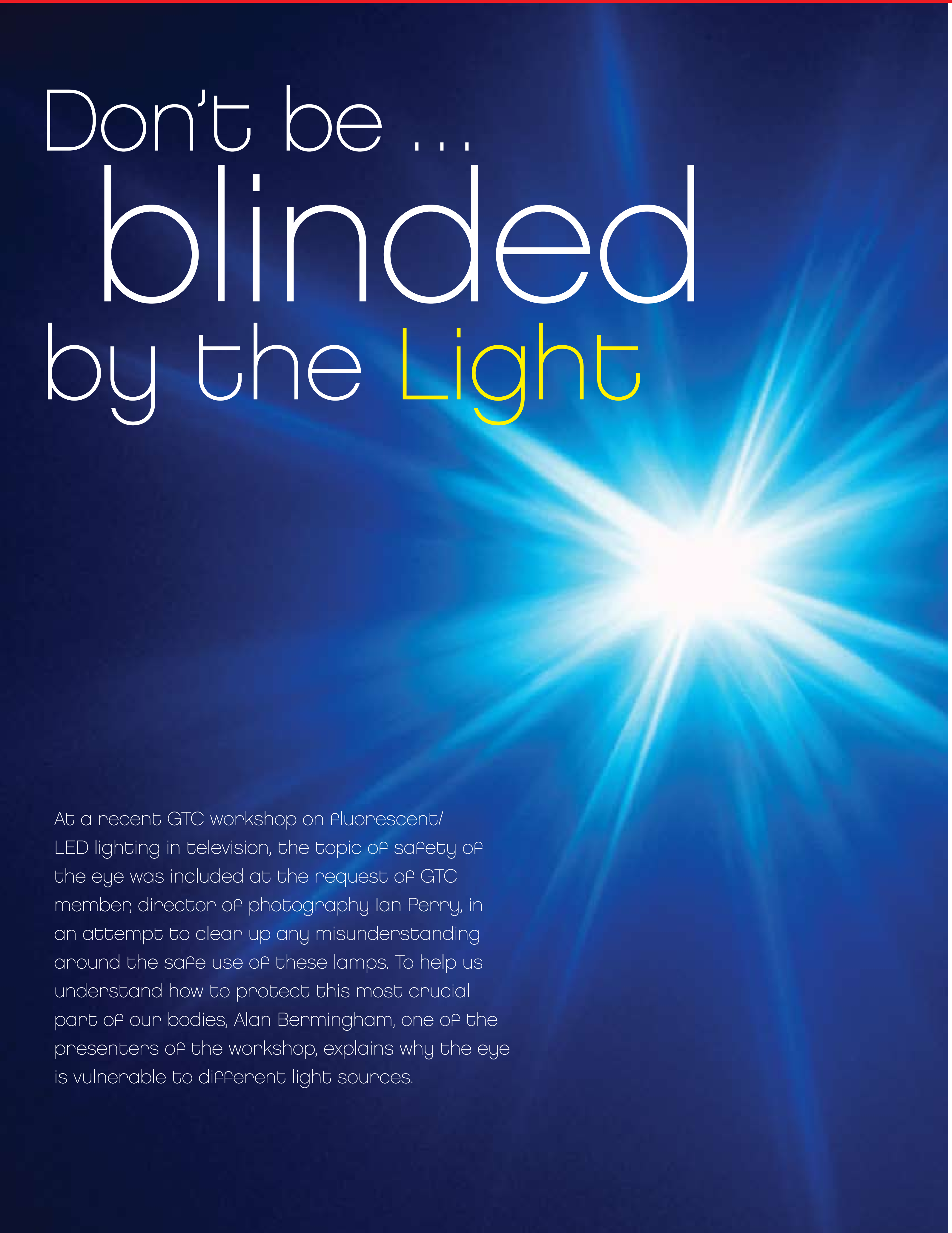
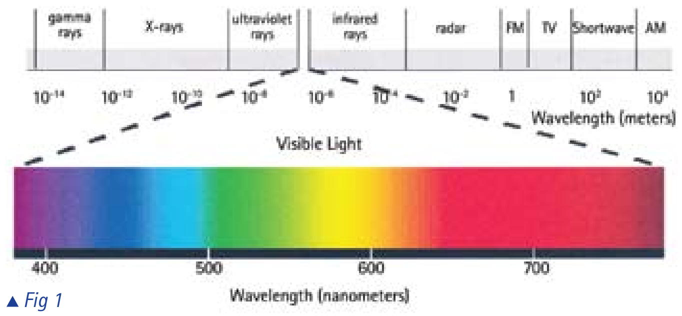


Don't be ... blinded by the Light

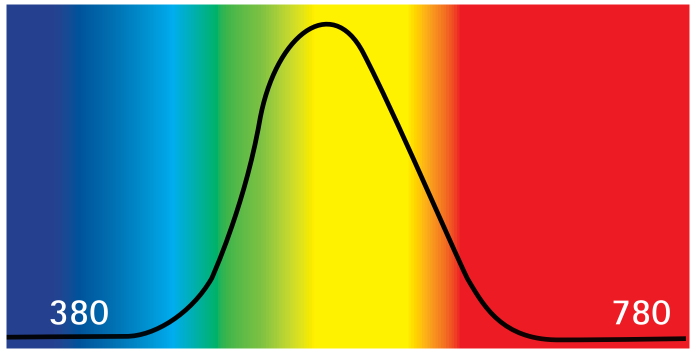
At a recent GTC workshop on fluorescent/LED lighting in television, the topic of safety of the eye was included at the request of GTC member, director of photography Ian Perry, in an attempt to clear up any misunderstanding around the safe use of these lamps. To help us understand how to protect this most crucial part of our bodies, Alan Bermingham, one of the presenters of the workshop, explains why the eye is vulnerable to different light sources.

Anyone involved with any kind of lighting should be aware of the potential dangers associated with electromagnetic radiation and human sight. Figure 1 shows the electromagnetic spectrum ('radio' waves).



▲ *Fig 1*

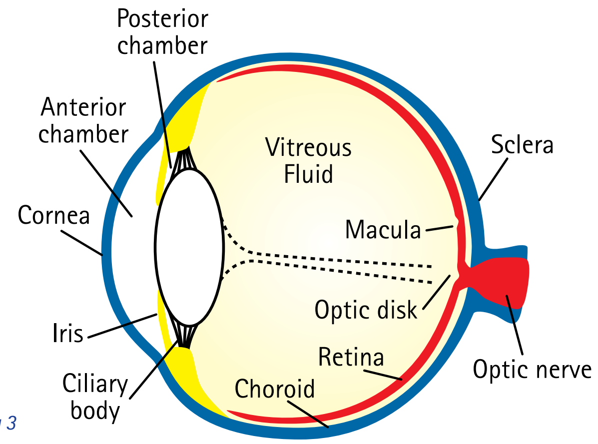
Within this spectrum is a small band of wavelengths which are visible to the human eye. The average response of the human eye is called the *photopic curve* (*Fig 2*).



▲ *Fig 2* The CIE Photopic Curve

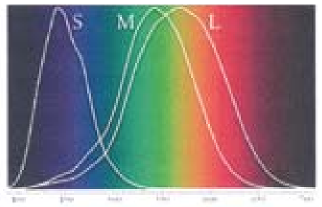
Some facts about the eye

- The retina receives an image of around 200 degrees, with increasing resolution towards the centre of vision (macula) (*Fig 3*).



▲ *Fig 3*

- The image falls on photosensitive cells called rods and cones. The rods are very light-sensitive but low in resolution and colour sensitivity, while the *cones* are low in light sensitivity but very high in resolution and rich in red, green and blue colour receptors. (*Fig 4*). In the macular area, the cones are much finer and very tightly packed, which gives incredible resolution. Any damage to this part of the retina is very serious. About 65% of the cones are red-sensitive, 33% green-sensitive, leaving only 2% blue-sensitive. However, the actual sensitivity of the 'blue' cones is very high compared to the others.



Responses normalised for:

S – Short wavelengths – Blue
M – Medium wavelengths – Green
L – Long wavelengths – Red

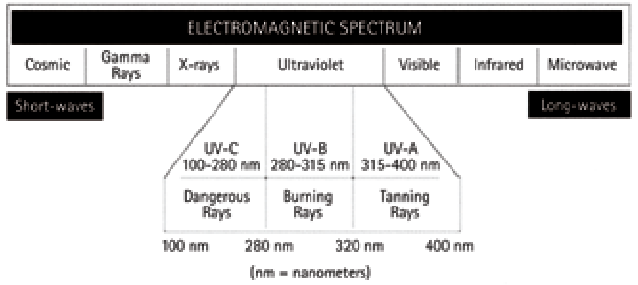
▲ *Fig 4*

- The *iris* prevents damage to the retina by controlling light entering the eye, and is mainly controlled by information from the 'blue' cones (via the brain). There is a limit to how 'small' the iris can close though, hence the discomfort felt in very bright light, and the inability of the eye to completely protect itself.
- Permanent damage of differing sorts can be sustained from ultraviolet radiation, infrared radiation and visible light as shown in the table below.

UV-B/C	inflammation of the cornea
UV-A	photochemical – cataract, clouding of lens
Visible	photochemical – damage to retina; retinal burn
780–1400nm near IR	cataract; retinal burn

Ultraviolet radiation (UV)

UV radiation from the sun is classified as UVA, UVB and UVC according to wavelength.



▲ *Fig 5*

Shorter wavelengths have greater energy and can result in the greatest harm. The ozone layer absorbs the UVC radiation and some 10% of the UVB but all the UVA reaches Earth.

You should be aware that sea, sand and snow can all reflect UV – sea up to 25%, sand 20% and snow 80%. **Maximum unprotected eye exposure to UV should be 2 hours for snow and 6 hours for sand.**

While some UV radiation is required for good health, an excess can be harmful. Too much exposure to UV can:

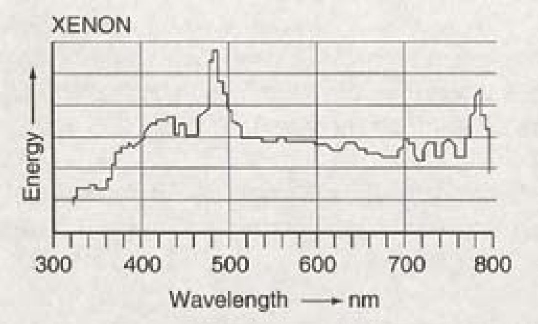
- accelerate the ageing process in the eye
- accelerate the formation of cataracts (clouding of the lens)
- cause a form of sunburn of the cornea (snow blindness, photokeratitis)
- cause sunburn
- cause skin cancer

It is the UVA that causes tanning and cataracts, while the UVB is responsible for cataracts and skin cancers.

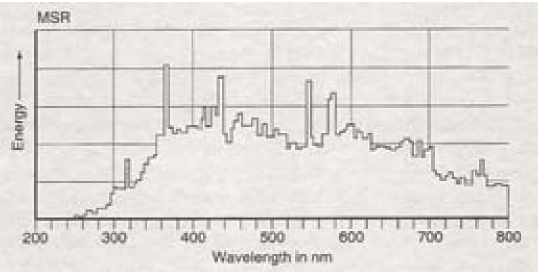
Man-made UV dangers also exist, namely:

- Carbon arcs
- Xenon arcs
- Metal halide lamps
- Welding equipment
- UV health lamps

For xenon and MSR sources the radiation can be outside the visible 400–700nm zone (*Figs 6 and 7*).

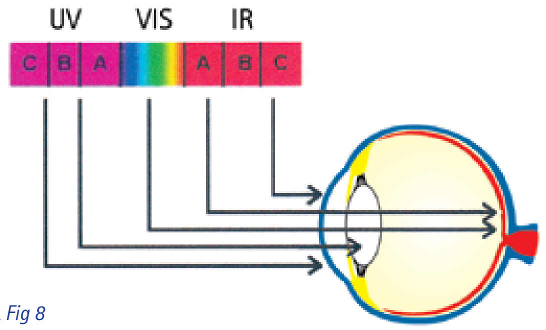


▲ *Fig 6*



▲ *Fig 7*

Eye damage from light reaching the retina



▲ *Fig 8*

In the figure above (*Fig 8*), note that the transmission of the lens and cornea is from 380nm to 1400nm i.e. it includes the near infrared. The cornea absorbs UV, preventing it reaching the retina.

If the light transmitted to the retina is too intense it can cause:

- flash blindness
- photochemical reaction
- retinal burn

Flash blindness is the reaction of the retina to a short-term flash of light of extremely high intensity. It is caused by the bleaching (oversaturation) of the retinal pigment. As the pigment returns to normal, so does the sight.

In daylight, the constricted pupil of the eye will reduce the amount of light entering the eye. At night, the open pupil will allow more light to enter the eye, so the effect is greater and lasts longer.

Photochemical reaction occurs with exposure to intense visible light which damages the ability of light-sensitive rod and cone cells to respond to visual stimuli. This results in loss of sight which may be temporary or permanent.

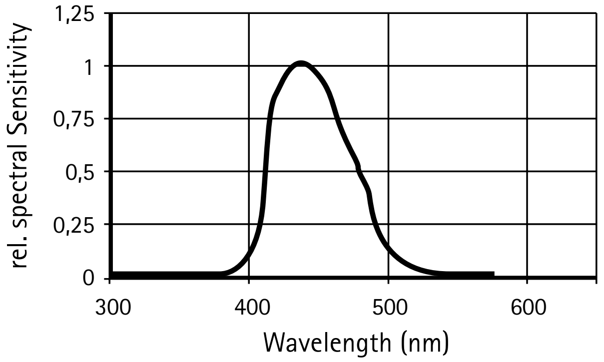
Retinal burn may accompany the photochemical reaction above when a person looks repeatedly, or for a long period of time, at the sun. The high level of visible light and near infrared radiation causes heating and 'cooks' the tissue of the retina. This thermal injury destroys the rod and cones creating a blind area. There is no feeling of pain and this injury is irreversible.

The part of the eye providing the most acute vision is the *fovea centralis* (the centre of the *macula lutea*). This is the central 3–4% of the retina. If a retinal burn occurs in this area it will *instantly* result in the loss of the ability to see fine detail. Lasers provide a very narrow parallel beam of light which when focused onto the retina produces enough heat to sustain a retinal burn. A one-watt laser beam, focused to a small spot can produce temperatures higher than the sun. **Never point a laser at someone's eyes and never look directly into a laser.**

Blue light hazard (photoretinitis)

This is photochemical damage from exposure to medium to intense strength visible radiation for more than 10 seconds. The damage is irreversible and can lead to blindness.

The graph below shows the sensitivity of the eye to blue light hazard (*Fig 9*).



▲ *Fig 9*

Blue light hazard is defined as the potential for a photochemical-induced retinal injury from radiation between 400 and 500nm.

High energy visible light (380 to 530nm) has been implicated as a cause for *age-related macular degeneration* (reduction in ability to see fine detail).

Normally, when the photoreceptors in the retina absorb visible light, the cells bleach and become useless until they recover through a photochemical process called the visual cycle. Absorption of blue light has been shown to cause a reversal of the process where cells become unbleached and responsive again to light before they are ready. This may cause irreversible changes induced by prolonged exposure to moderate levels of short wavelength light (violet/blue).

Melanin, the substance which gives eyes their colour, protects the macula by trapping light rays. People with blue eyes/fair skin have less melanin in their irises and are therefore at greater risk.

Damage depends on:

- Wavelength (shorter wavelengths – greater damage)
- Intensity/area of light source
- Length of exposure
- Distance from the light source

In recent years, the efficacy of LEDs has improved dramatically resulting in very high output LEDs i.e. the potential for very bright compact sources.

Be especially aware of:

- New high output blue and white LEDs
- Infrared LEDs
- UV LEDs

Some 'white' LEDs use a UV LED to excite a phosphor to produce white, similar to the fluorescent lamp. There is concern over possible UV leakage. **It is recommended to avoid the potential hazard of an artist looking into an intense LED by using a diffusion filter on the light source. If you are concerned about UV radiation from any of your light sources you can also use a Rosco UV filter.**

Fact File

Alan Bermingham, former Senior Lecturer in Technical Operations at BBC Wood Norton, and former Head of Lighting at Television South West, now operates as International TV Training and Consultancy. He is the author of the Focal Press publication *Location Lighting for TV.*