Laser and LED retina hazard assessment with an eye simulator

Arie Amitzi and Menachem Margaliot

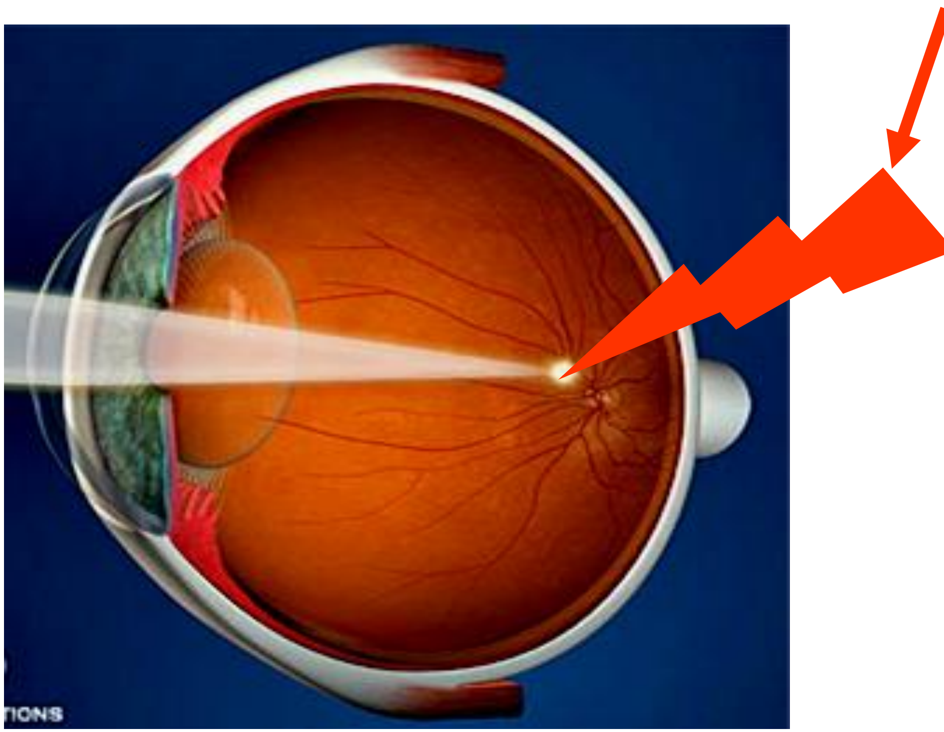
Soreq NRC

Yavne 81800, Israel

Laser radiation hazard assessment

Laser and other collimated light sources can be focused by the eye to a very small focal spot and can create a high power density on the retina

2 mW laser can create a power density of 5000 W/cm^2

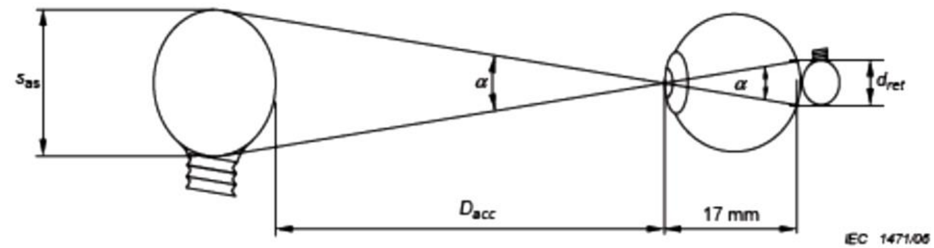


The basic hazard assessment includes

- The amount of energy per time entering the eye and absorbed by the retina
- The focal spot size on the retina

Point and extended light sources

When the angular subtense - α - is greater than 1.5 miliradians , the source is an **“extended source”**



$$\alpha = \frac{d_{retina}}{f_{eye}}$$

A point source subtends an angle to the eye of α_{min} or less:

1.5 miliradians at 400 to 1400 nm in IEC 60825-1

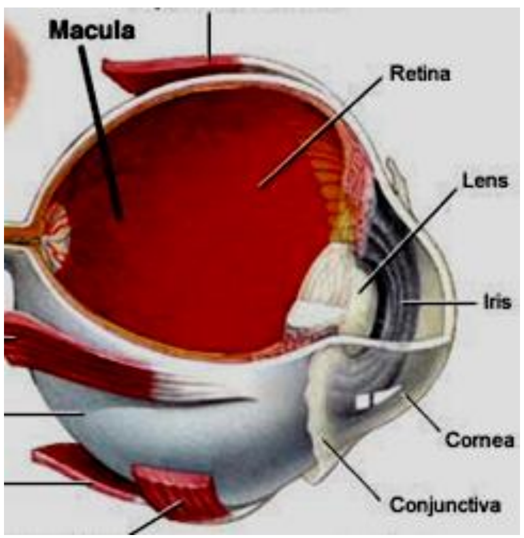
Or 1.7 miliradians at 380 to 1400 nm in IEC 62471

$$Coeficient = \frac{\alpha_{Extended}}{\alpha_{\min}} \quad (\alpha_{Extended} > \alpha_{\min})$$

Examples
- Diffuse reflection
- LED array
- Conventional frosted glass lamp

Assessment safety problems for extended sources

1. The relevant information is the actual energy distribution on the retina.
2. Theoretical analysis might be very misleading.
3. A realistic physical simulation is the optimal solution



1. The human lens consists of several fine layers of transparent tissue with different indexes of refraction
2. The variable focus length of the human eye is about 14 to 18 mm (air model)
3. The iris is the diaphragm that serves as the aperture stop

Our artificial eye measurement device

- OPHIR BeamStar® FX 66 beam profiler
- Spectral ranges 350 -1320 nm
- Pixel size 7.5 μm
- A gradual index lens with a fixed focal length of 18 mm
- A 7 mm entrance aperture
- A focusing Adjustment Mechanism
- A ±6% linearity of power and Spatial uniformity of ± 5%
- Spectral range and spectral sensitivity should be corrected in order to measure broadband light source

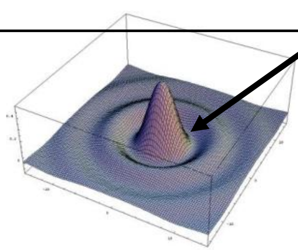
Fixed instead of variable focal length

Accommodation of the ***human eye*** to short distance is accomplished by a ***variable focal length of about 18 to 14 mm***

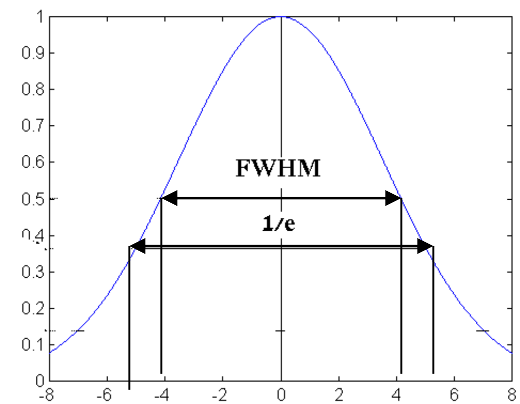
The ***diffraction limit*** d for 14 mm is smaller then 18 mm by a factor of ~0.8
By using ***FWHM*** we decrease the 1/e diameter by a factor of 0.83 (thus compensating for the fixed focal length)

That allows us to focus at a short distance and measure ***the most restrictive position*** according to the ***thin lens equation***

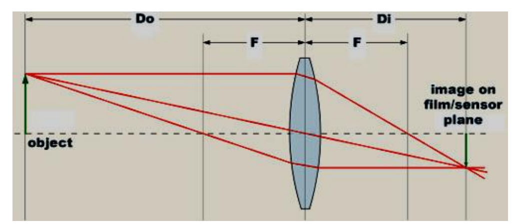
Airy disk $d = \frac{2.44\lambda f}{D}$



$$\frac{d_{FWHM}}{d_{63}} = 0.83$$



$$\frac{1}{object\ \ distance} + \frac{1}{image\ \ distance} = \frac{1}{focal\ \ length}$$

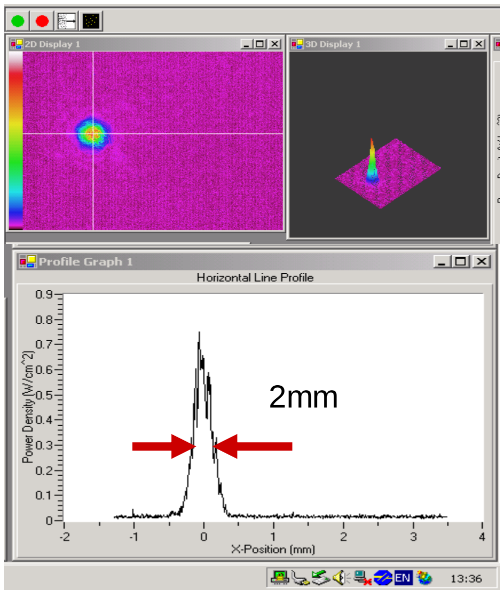


SOREQ

Examples

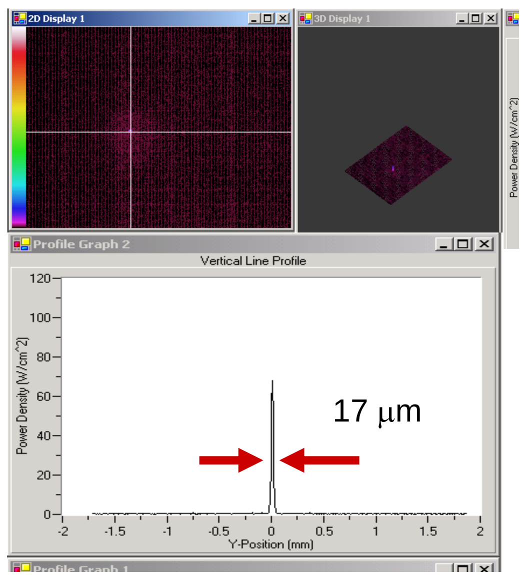
1 - Looking through X7 magnification telescope

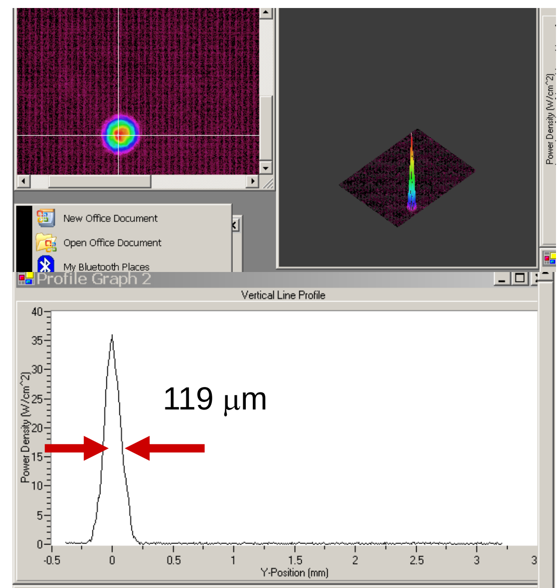
Laser through beam profiler



Laser through our eye simulator with telescope

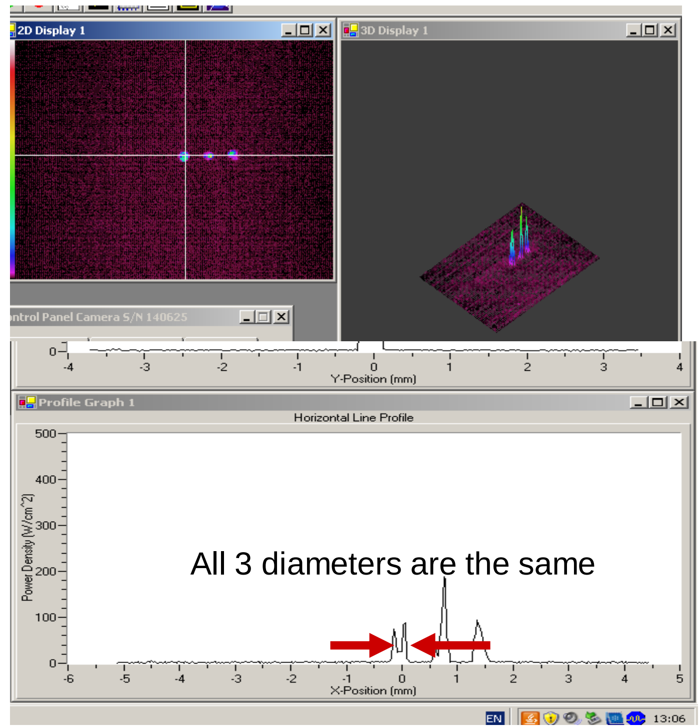
Laser through our eye simulator

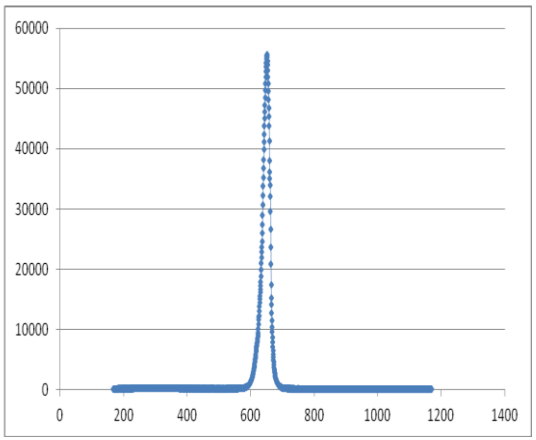




2 - Measuring 3 LEDs in a straight line form

3 LEDs through our eye simulator





We can treat this LED array as an oblong source by determining the arithmetic mean of the maximum and minimum angular dimensions of the source or using the following equation

$$LED\ \ Area = \sum Spot\ \ Size = \sum_{i}^{n} \frac{\pi}{4} d_i^{\,2}$$

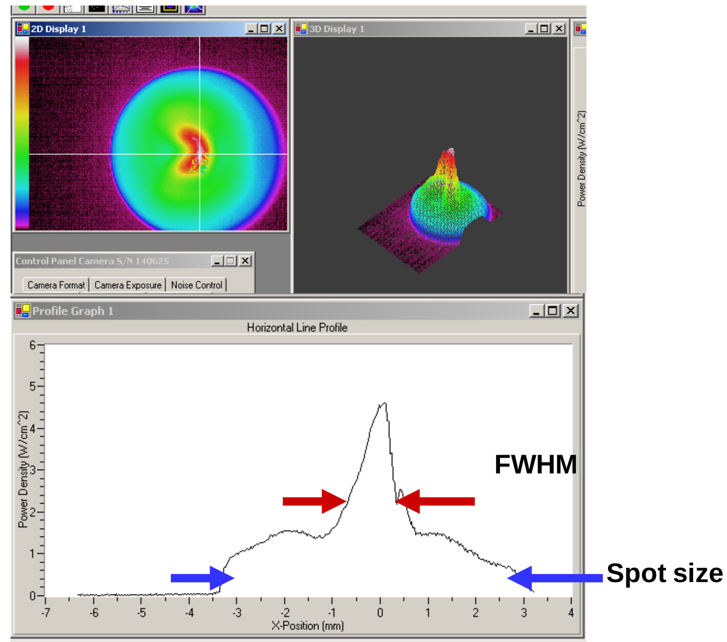
$$D_{Eq} = d\sqrt{n} \rightarrow \alpha = \frac{d\sqrt{n}}{f_{eye}}$$

3 - Measuring a bulb projector

Oblong lamp (mean dimension)
α = (length + width) / (2 x viewing distance)
α = (l+w)/2r

Circular lamp
α = lamp diameter / viewing distance
α = d/r

Lamp through our eye simulator



Because of the “hot spot”, the 50% of the peak (FWHM) criterion is much smaller than the spot size

Summary

This measurement system allows us

1. **To easily distinguish point sources from extended sources**

2. **To measure the most hazardous distance of various lasers, LED arrays and other optical sources**

3. **To use more accurate criteria for calculating the source subtense angle to the eye**

4. **To measure coherent and incoherent broadband light sources**