Lectures in LASER Physics

Dr. Mohamed Abbas Ashour

Assistant professor

Higher Institute for Optics Technology (HIOT)

Researcher at LASER Institute for Research and Applications (LIRA)

Optics, Photonics and Laser group coordinator (APS)

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mashour10@gmail.com

+201147333553

Summer School

Day Two

Day Two

Laser unique Properties

Laser resonators

CW vs Pulsed Laser

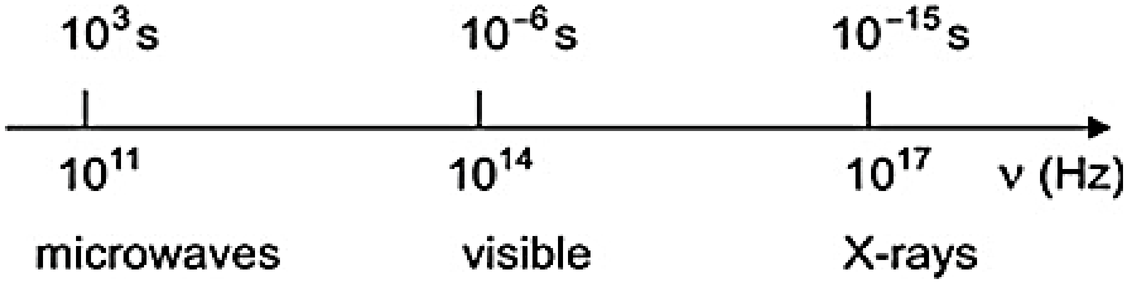
Laser Hazards & Laser Safety

Remember !!

Q1: Why no two-level Laser system?

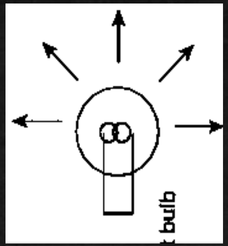
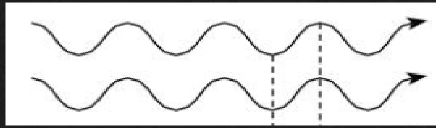
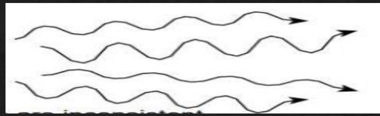
Q2: Why can't we get an X-Ray Laser?

Fig. 6.5 Natural lifetime

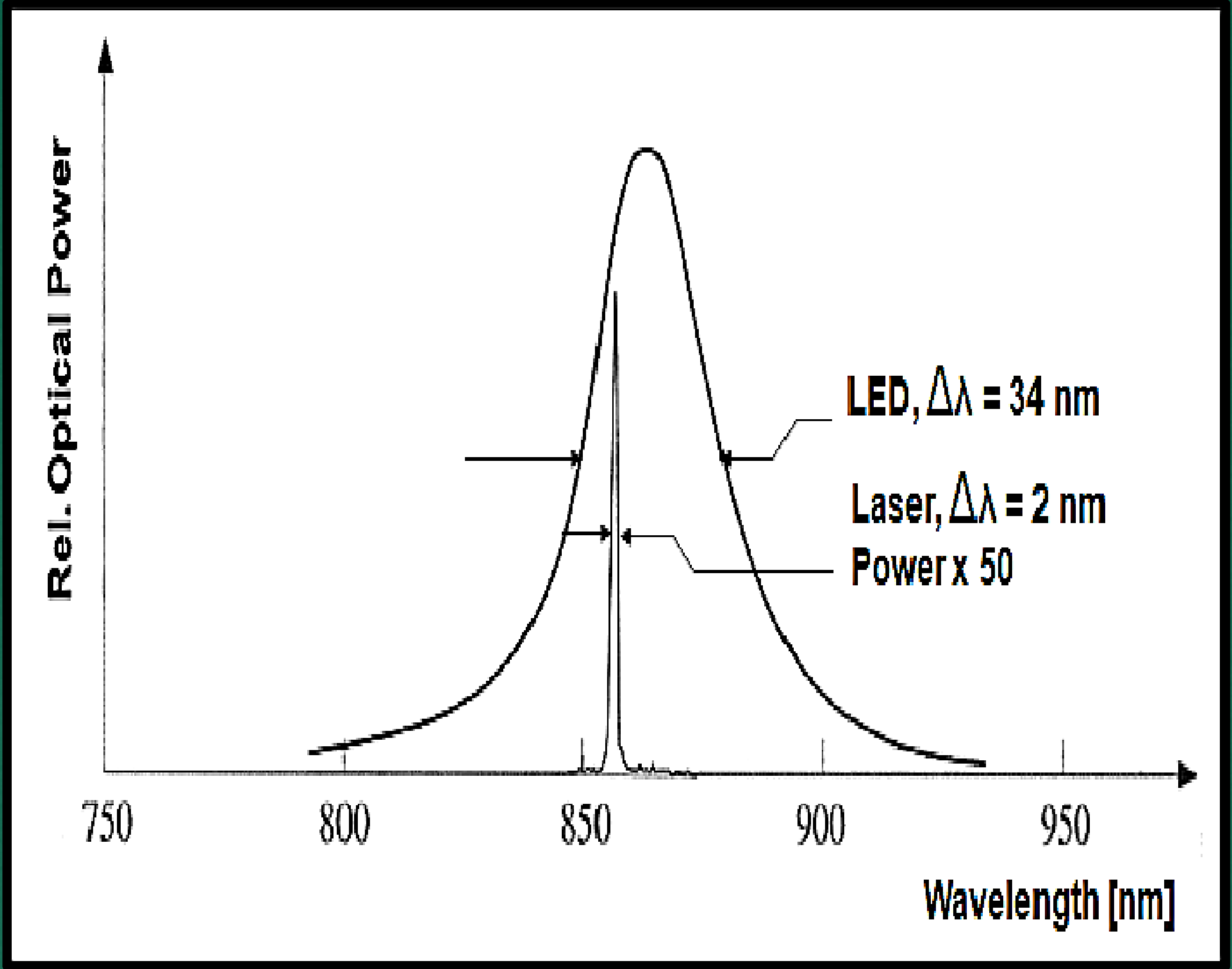


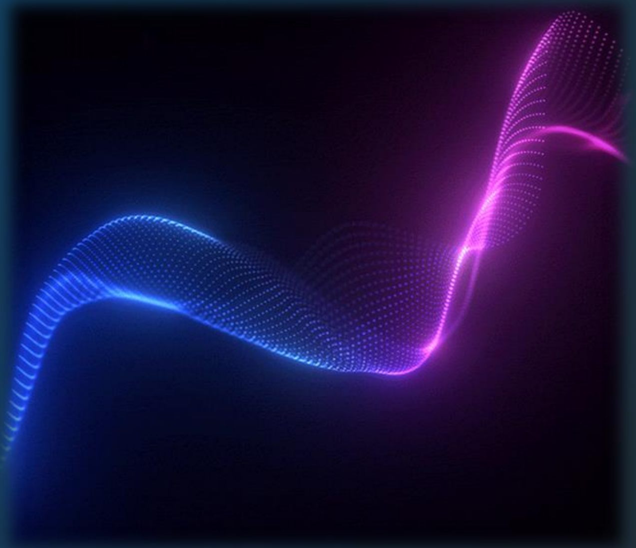
laser

Laser unique properties

	LASER Light	*Ordinary Light*
1	Monochromatic	Polychromatic
2	Directional	Divergent 
3	Coherent 	Incoherent 

Monochromaticity





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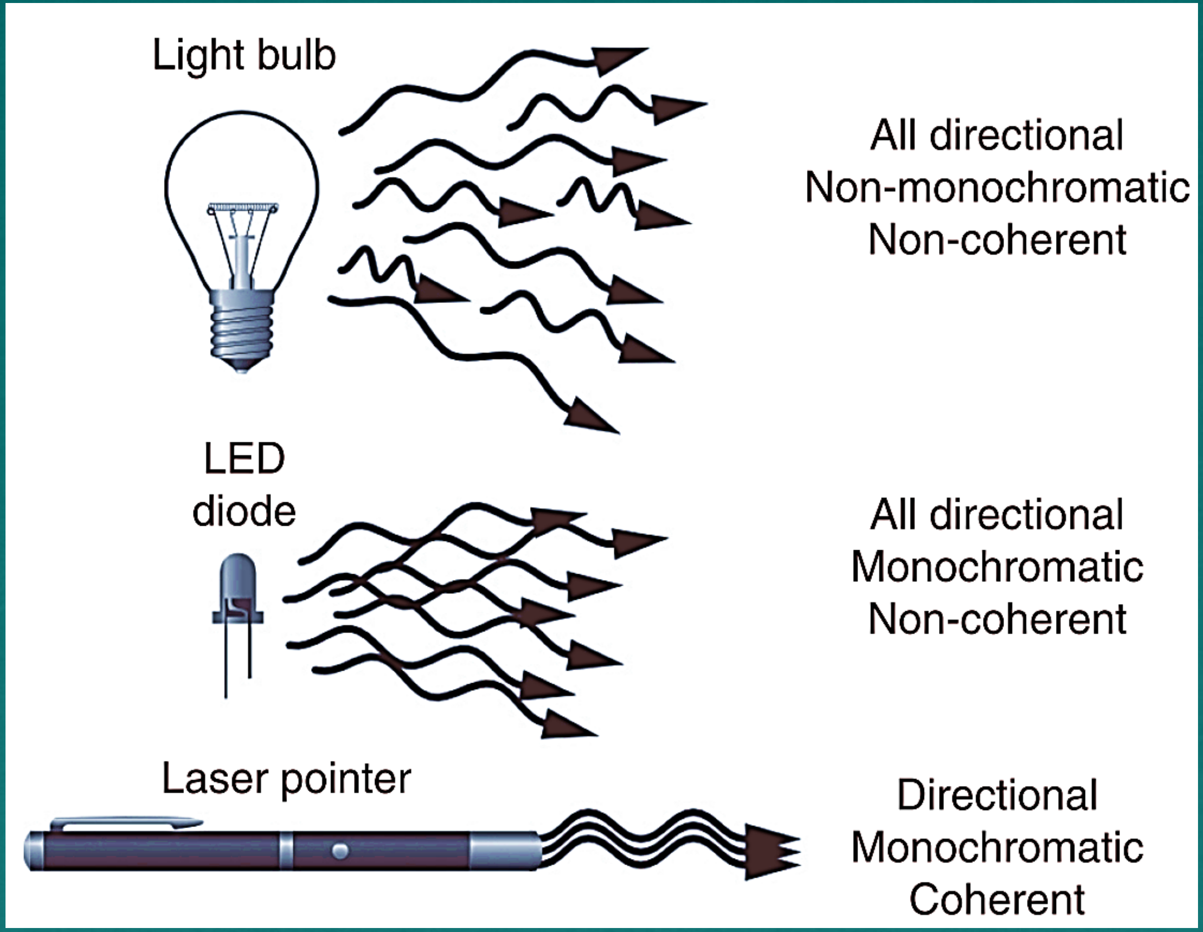
Directionality



$$\theta = 2\lambda / (\pi w_0)$$

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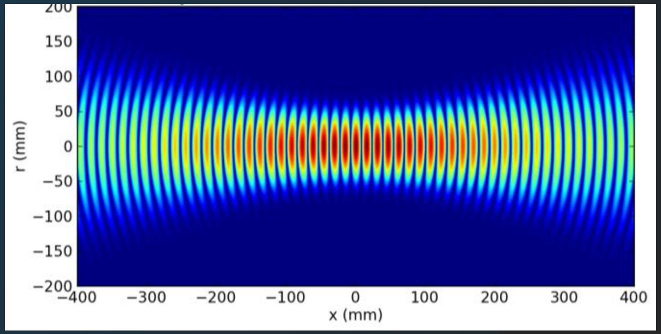
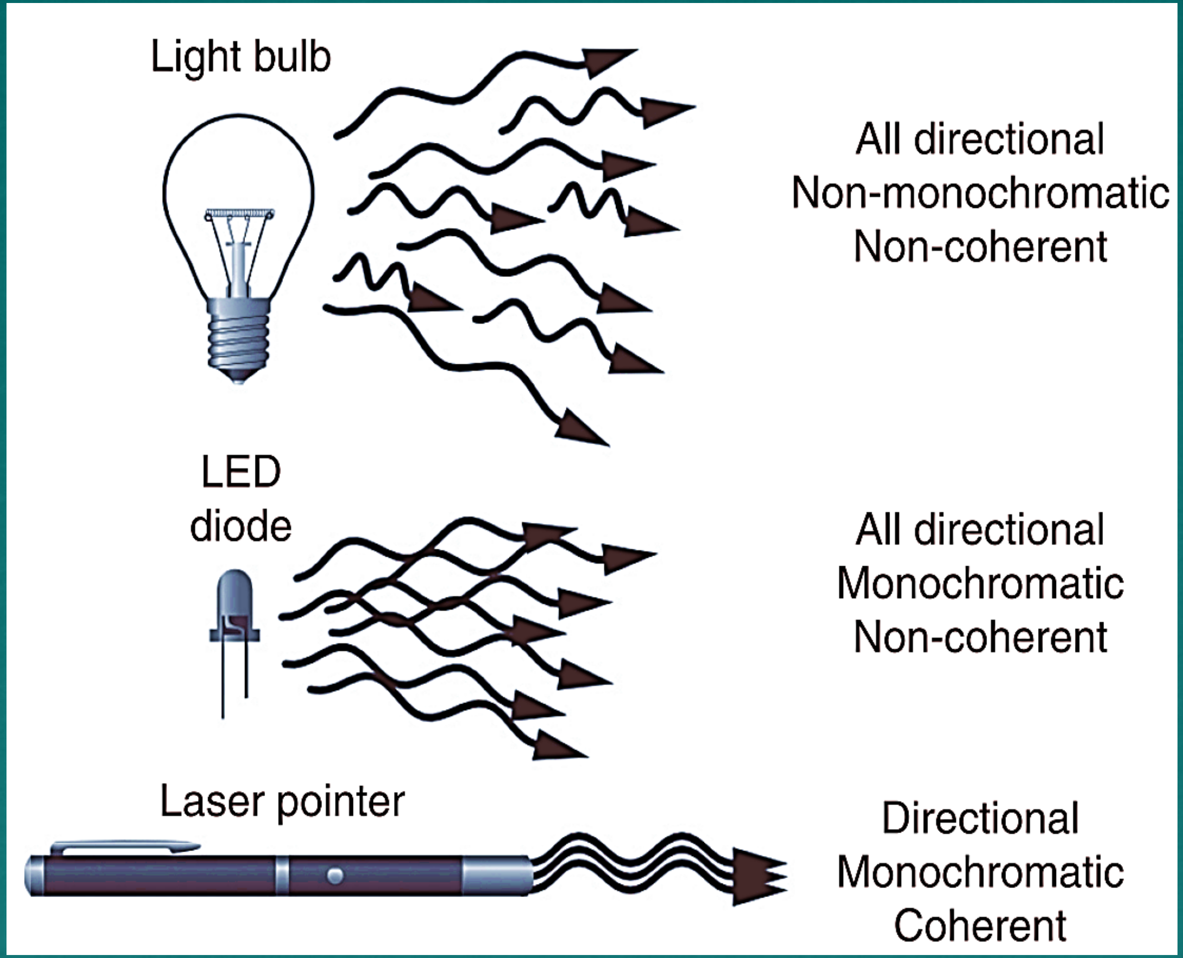


Directionality



350 – 500 mrad

150 – 200 mrad

1 – 5 mrad

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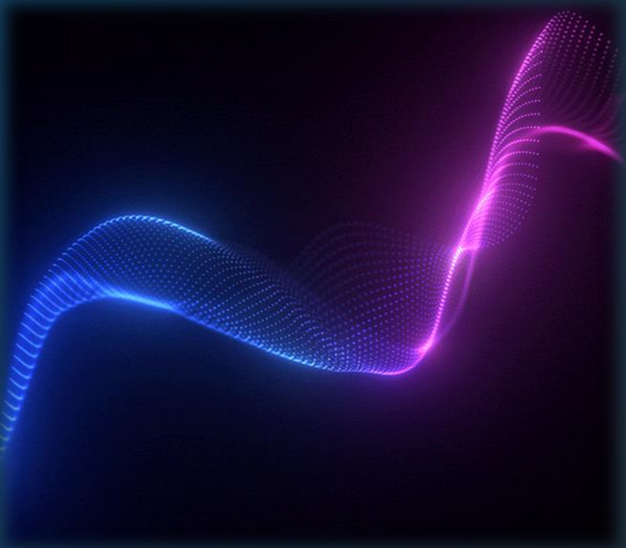
Directionality



Exercise

A laser beam (λ = 632.8 nm) having a divergence of 1 milli-radian is directed towards the moon at a distance of approximately 4×10^5 km . The beam would have spread to a diameter of……

Radius, $r = x \tan \Delta\theta$

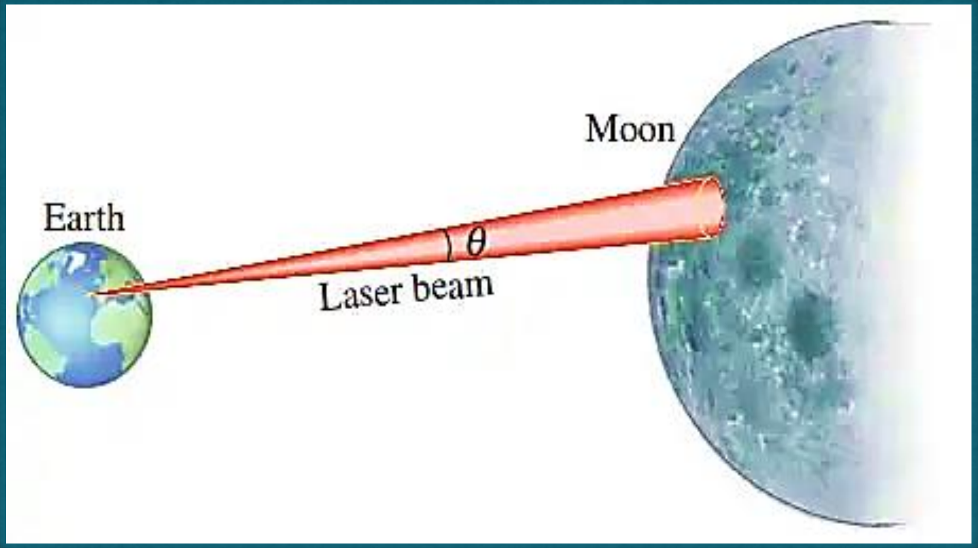
For small θ, $\tan q \simeq \theta$

$\Rightarrow r = x\Delta\theta$

$\Rightarrow r = 4 \times 10^5 \times 1 \times 10^{-3}$

$= 400$ km

So diameter, $d = 2 \times 400 = 800$ k



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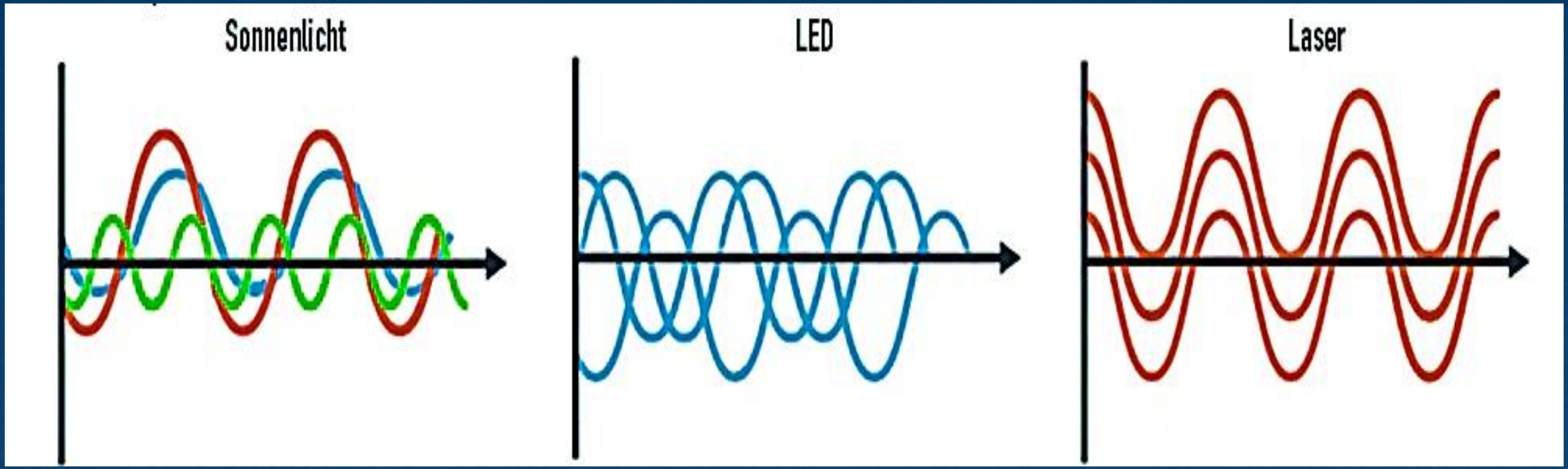
Coherence



LASER is a highly intense light source because it has very large number of Photons that are in phase

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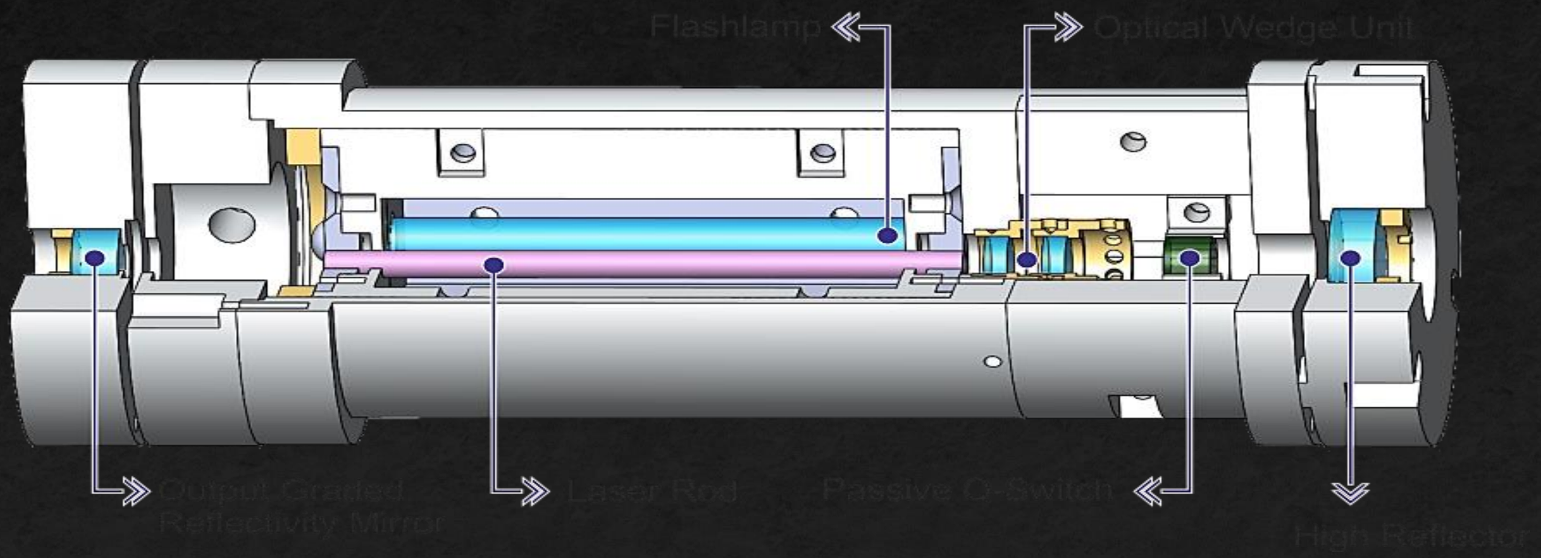
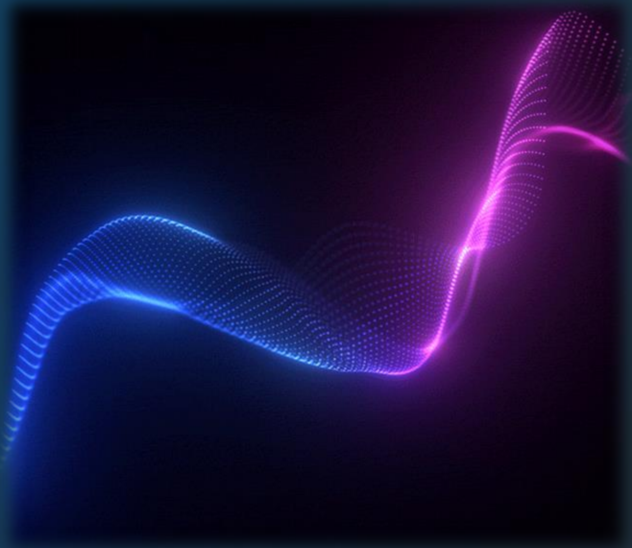
Day Two

- Laser unique Properties
- Laser resonators
- CW vs Pulsed Laser
- Laser Hazards & Laser Safety

Laser resonators

- A laser generally requires a laser resonator (or laser cavity), in which the laser radiation can circulate and pass a gain medium which compensates the optical power losses.





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Laser resonators

- The ***shape of a laser beam is determined by the resonator cavity***, a laser optical mirror, in which the laser light is amplified in a gain medium.

- Laser resonators are typically formed by using highly reflective dielectric mirrors or a monolithic crystal that utilizes total internal reflection to keep light from escaping

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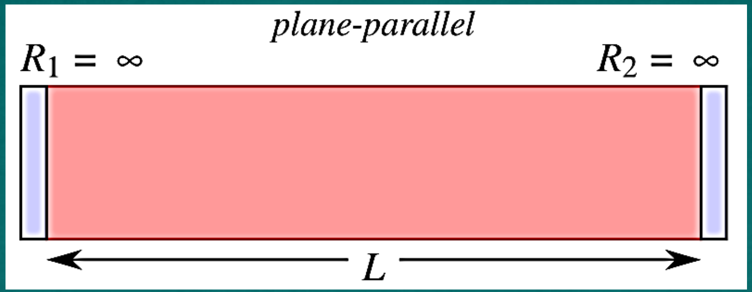
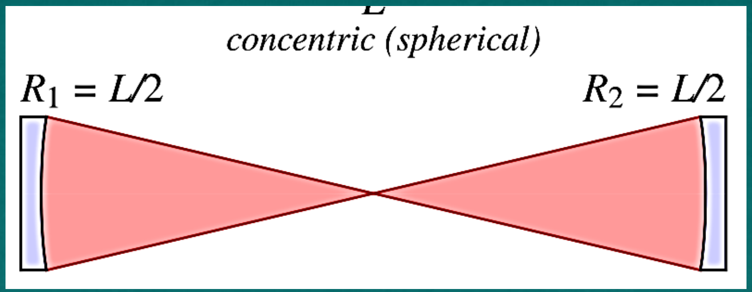
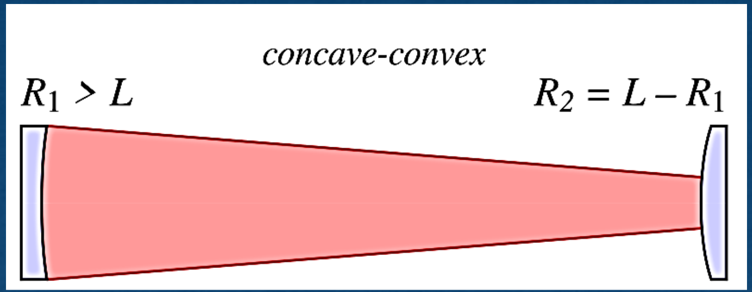
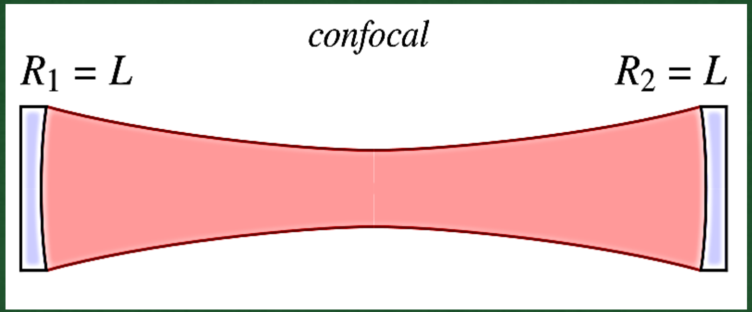
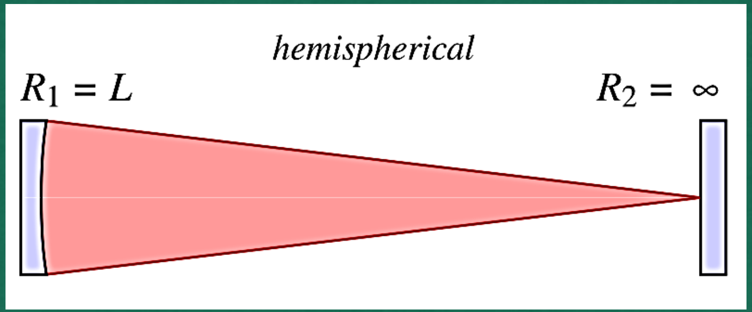
Types of Laser resonators











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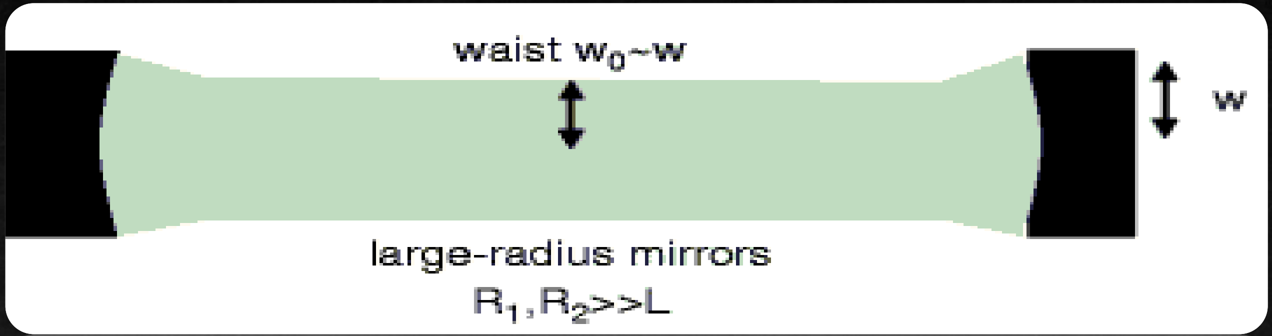
Types of Laser resonators

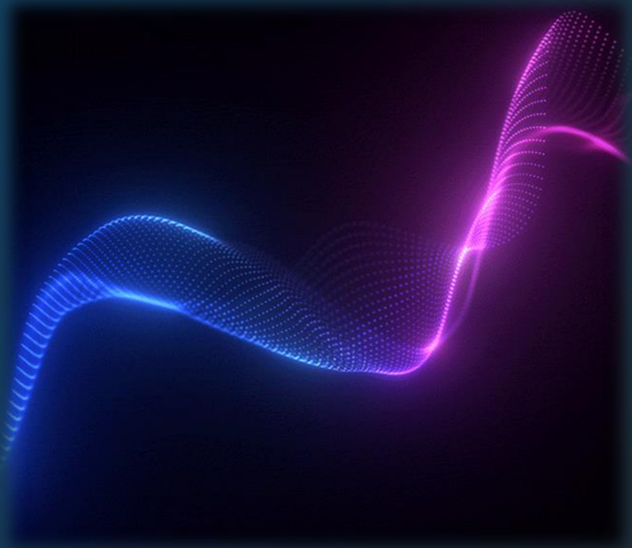
Large radii resonator



$$w_1^4 = \left(\frac{\lambda R_1}{\pi}\right)^2 \frac{R_2 - L}{R_1 - L}\left(\frac{L}{R_1 + R_2 - L}\right),$$

$$w_2^4 = \left(\frac{\lambda R_2}{\pi}\right)^2 \frac{R_1 - L}{R_2 - L}\left(\frac{L}{R_1 + R_2 - L}\right).$$

$$w_0^4 = \left(\frac{\lambda}{\pi}\right)^2 \frac{L(R_1 - L)(R_2 - L)(R_1 + R_2 - L)}{(R_1 + R_2 - 2L)^2}.$$



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Types of Laser resonators

The simplest type of laser resonator modes are Hermite-Gaussian modes, also known as transverse electromagnetic modes (TEM_{nm}), in which the electric field profile can be approximated by the product of a Gaussian function with a Hermite polynomial

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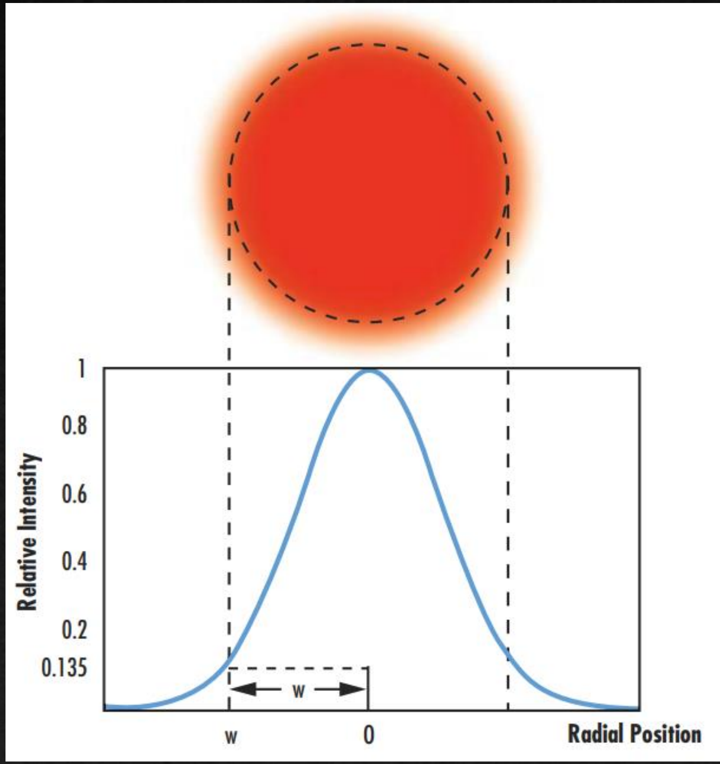
$$E_{nm}(x,y,z) = E_0 \frac{w_0}{w(z)} \cdot H_n\left(\sqrt{2}\frac{x}{w(z)}\right) \cdot \exp\left(-\frac{x^2}{w(z)^2}\right) \cdot H_m\left(\sqrt{2}\frac{y}{w(z)}\right) \cdot \exp\left(-\frac{y^2}{w(z)^2}\right) \cdot \exp\left[-i\left[kz-(1+n+m)\cdot\tan^{-1}\left(\frac{z}{z_R}\right)+\frac{k\left(x^2+y^2\right)}{2R(z)}\right]\right]$$

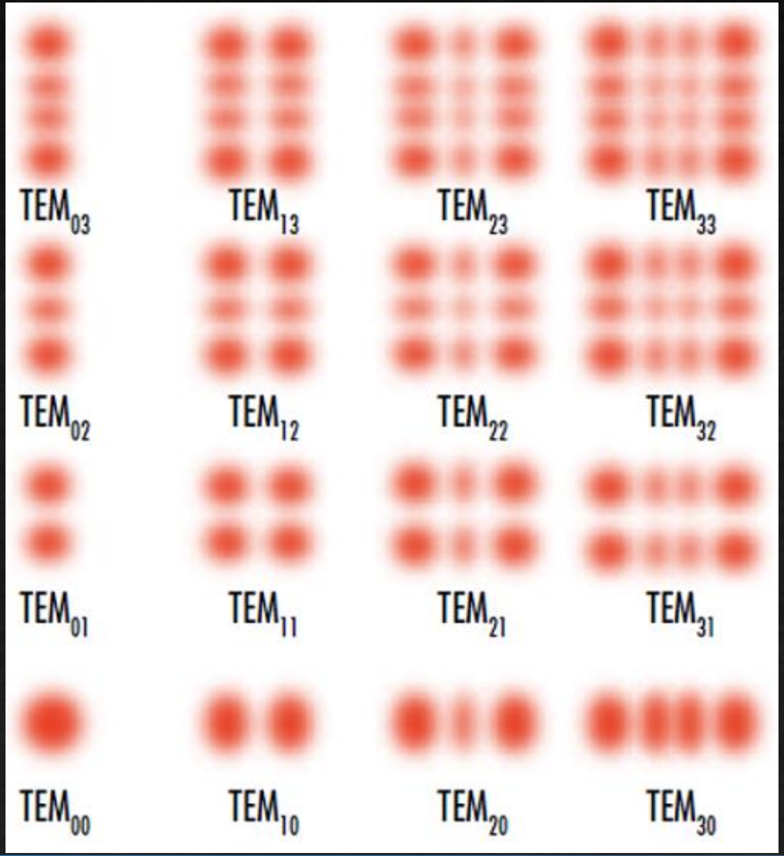
$$E_{nm}(x,y,z) = E_0 \cdot H_n \cdot H_m \frac{w_0\, x\, y}{[w(z)]^3} \cdot \exp\left[-\left(\frac{x}{w(z)}\right)^2\right] \cdot \exp\left[-\left(\frac{y}{w(z)}\right)^2\right] \cdot \exp\left[-i\left[kz-(1+n+m)\cdot\tan^{-1}\left(\frac{z}{z_R}\right)+\frac{k\left(x^2+y^2\right)}{2R(z)}\right]\right]$$

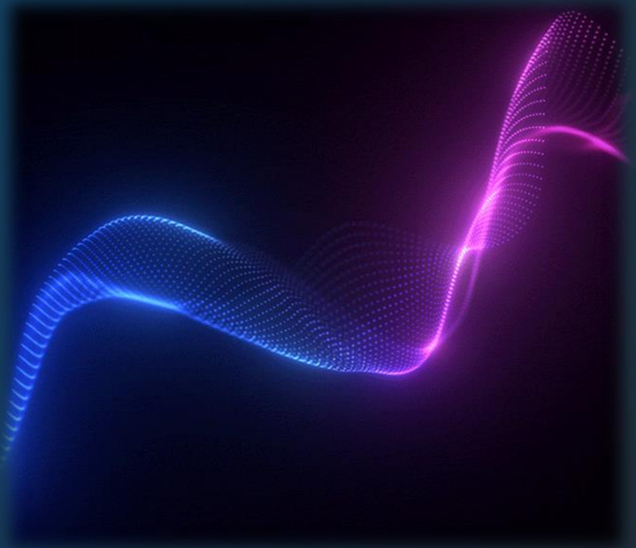
- E_0 is the field maximum
- x and y are the axes that define a cross-section of the beam
- z is the axis of propagation
- w_0 is the beam waist
- w(z) is the beam radius at a given z value
- $H_n(x)$ and $H_m(x)$ are the Hermite polynomial with the non-negative integer indices n and m
- k is the wavenumber ($k=2\pi/\lambda$)
- z_R is the Rayleigh range
- R(z) is the radius of curvature of the wavefront

Types of Laser resonators

The integers n and m define the beam shape in the x and y directions, respectively. An ideal Gaussian beam is defined by the mode TEM_{00}, which occurs when n and m are both equal to 0







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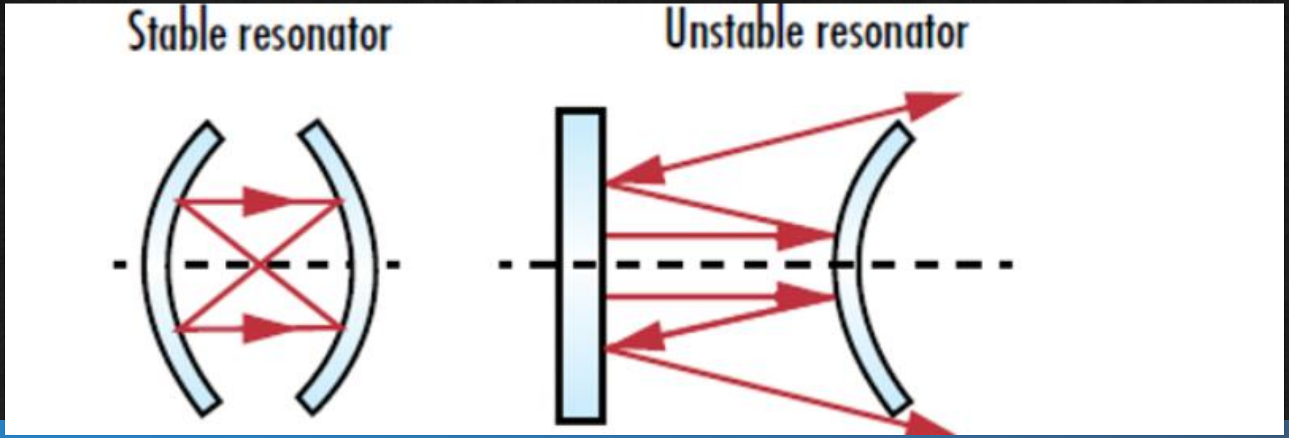
Stability of laser resonator

- Resonator cavities are "stable" if the reflected light stays inside the cavity, even as the number of reflections approaches infinity. In this instance, the only way for light to leave the cavity is through a partially reflective mirror.
- On the other hand, resonator cavities are considered "unstable" if the reflected light continuously diverges as the number of reflections approaches infinity.
- Stable resonators are often used with lasers that have powers up to 2kW to achieve high gain and improve directionality. Unstable resonators are typically used with higher power lasers to reduce the chance of damaging the reflectors



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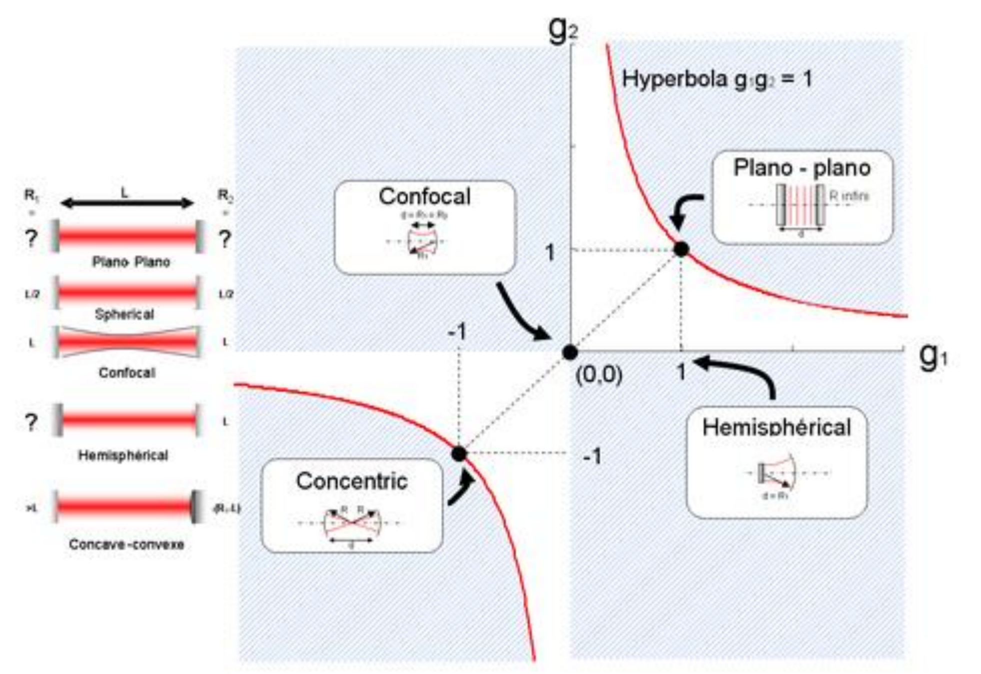
Stability of laser resonator

- Only certain ranges of values for R_1, R_2, and L produce stable resonators in which periodic refocussing of the intracavity beam is produced.
- If the cavity is unstable, the beam size will grow without limit, eventually growing larger than the size of the cavity mirrors and being lost.

$$0 \leqslant \left(1-\frac{L}{R_1}\right)\left(1-\frac{L}{R_2}\right) \leqslant 1.$$

$$g_1 = 1-\frac{L}{R_1}, \qquad g_2 = 1-\frac{L}{R_2},$$



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Day Two

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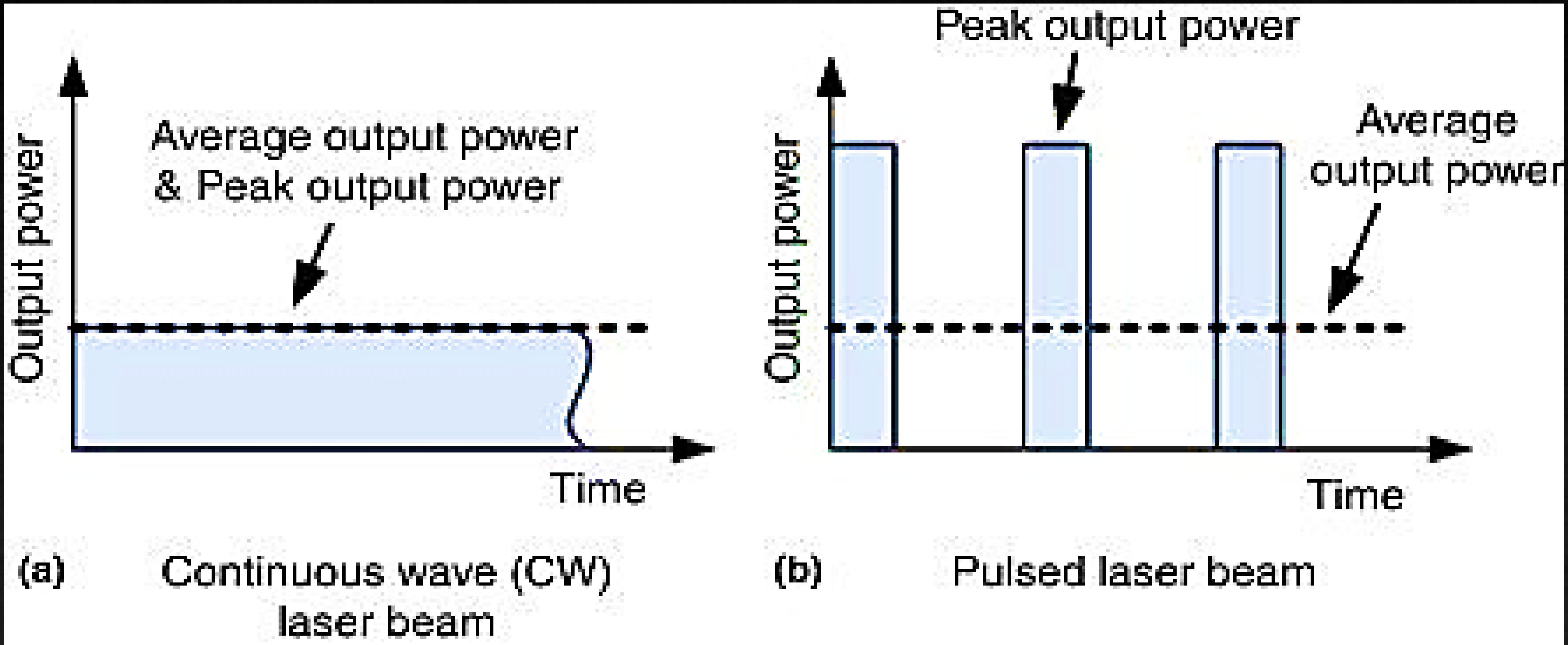
laser

CW vs Pulses Laser



Q-switched lasers → Nanosecond laser

mode-locked lasers → Femtosecond & Picosecond Laser

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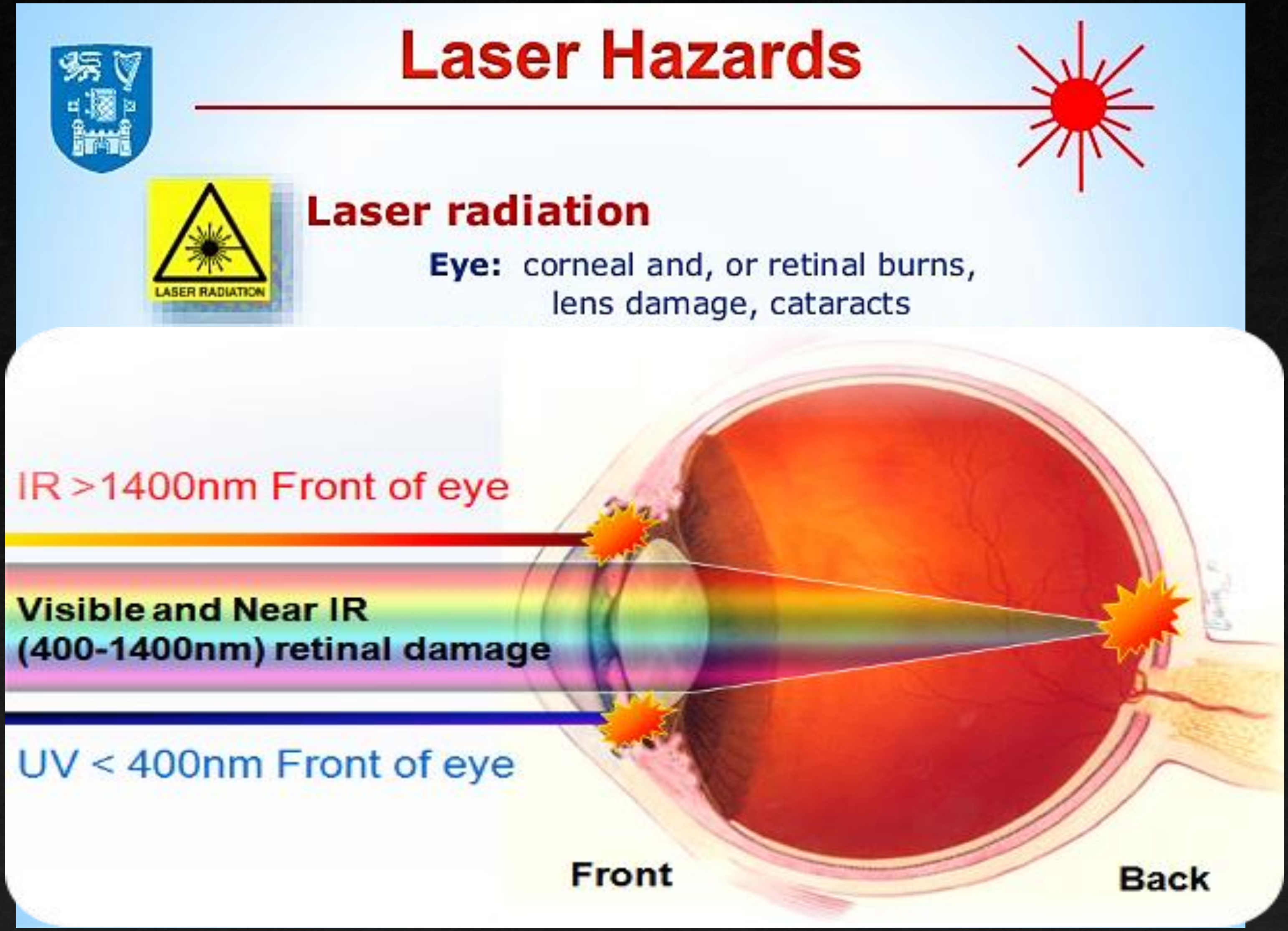
Laser Hazards & Laser Safety



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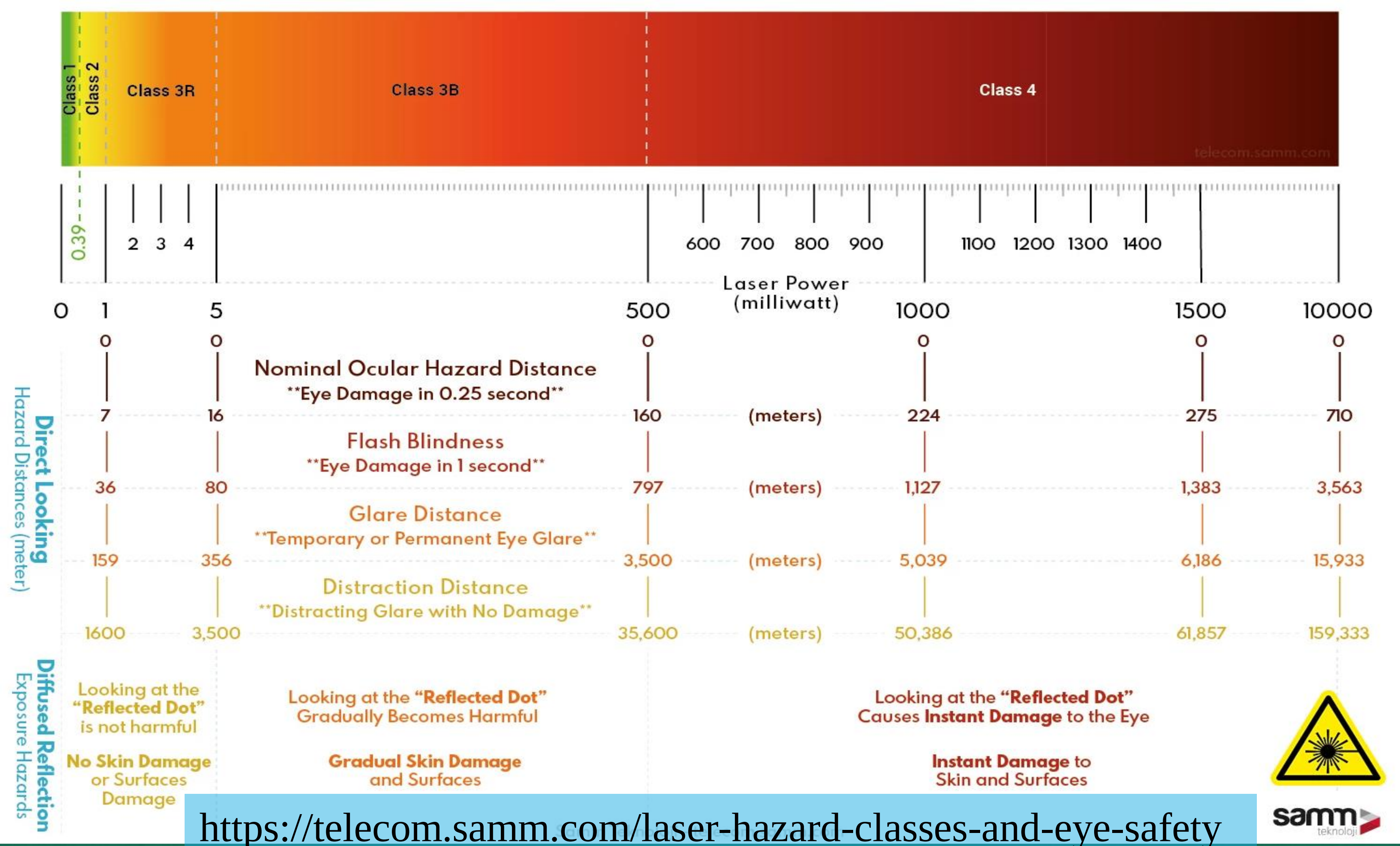
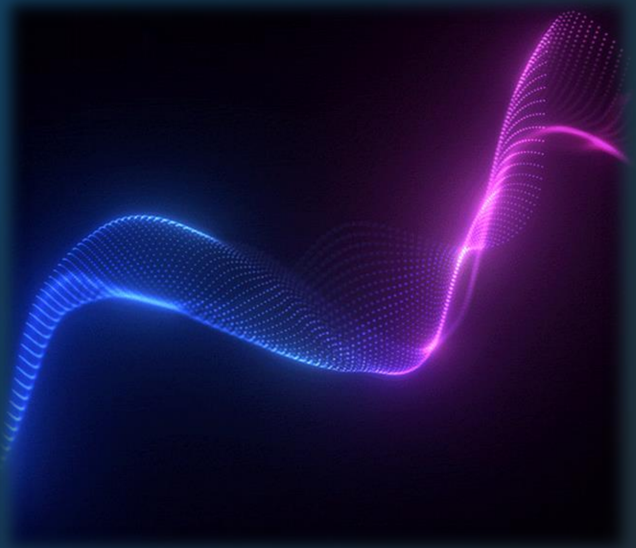
Laser Hazards & Laser Safety



https://telecom.samm.com/laser-hazard-classes-and-eye-safety



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Laser Hazards & Laser Safety

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Thank you for your time

Enjoy your day