2nd ArPS Summer School on Advanced Physics, Zewail City

Arps arps arps

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)

26 - 08 - 2024

mashour10@gmail.com

+201147333553

PAGE 31

School Summe









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	10 ³ s	10 ⁻⁶ s	10 ⁻¹⁵ s
		I	
	10 ¹¹	10 ¹⁴	10 ¹⁷ v (Hz)
	microwaves	visible	X-rays





Monochromaticity



Directionality



All directional Non-monochromatic Non-coherent

> All directional Monochromatic Non-coherent

> Directional Monochromatic Coherent

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



Directionality



350 – 500 mrad

150 – 200 mrad

<u>1 – 5 mrad</u>

Directionality

Exercise

A laser beam (λ = 632.8 nm) having a divergence of 1 milliradian is directed towards the moon at a distance of approximately 4 \times 10⁵ 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 kmSo diameter, $d = 2 \times 400 = 800 \text{ k}$







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







CW vs Pulsed Laser



Laser Hazards & Laser Safety

• 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.





• 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





PAGE 44

Types of Laser resonators

Large radii resonator





LASER

PAGE 45

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

$$egin{split} E_{nm}(x,y,z) &= E_0 rac{w_0}{w(z)} \, \cdot \, H_n\left(\sqrt{2}rac{x}{w(z)}
ight) \ & \cdot \exp\left(-rac{x^2}{w(z)^2}
ight) \, \cdot \, H_m\left(\sqrt{2}rac{y}{w(z)}
ight) \cdot \exp\left(-rac{y^2}{u(z)^2}
ight) \ & \cdot \, \exp\left[-i\left[kz-(1+n+m)\cdot an^{-1}\left(rac{z}{z_R}
ight)+rac{k\left(x^2+y^2
ight)}{2R(z)}
ight]
ight] \end{split}$$

$$egin{split} E_{nm}(x,y,z) = E_0 \cdot H_n \cdot H_m rac{w_0\,x\,y}{\left[w(z)
ight]^3} \cdot \exp\left[-\left(rac{x}{w(z)}
ight)^2
ight] \cdot \exp\left[-\left(rac{y}{w(z)}
ight)^2
ight] \ & \cdot \exp\left[-i\left[kz-(1+n+m)\cdot an^{-1}\left(rac{z}{z_R}
ight)+rac{k\left(x^2+y^2
ight)}{2R(z)}
ight]
ight] \end{split}$$

- E₀ is the field maximum
- x and y are the axes that define a cross-section of the beam
- z is the axis of propagation
- w₀ 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







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





Stability of laser resonator

- Only certain ranges of values for R₁, R₂, 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.

$$0 \leqslant \left(1 - rac{L}{R_1}
ight) \left(1 - rac{L}{R_2}
ight) \leqslant 1.$$

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





Laser unique Properties

Laser resonators

CW Y

CW vs Pulsed Laser



Laser Hazards & Laser Safety

CW vs Pulses Laser



Q-switched lasers \rightarrow Nanosecond laser

laser

mode-locked lasers \rightarrow Femtosecond & Picosecond Laser



Laser unique Properties

Laser resonators



CW vs Pulsed Laser



Laser Hazards & Laser Safety

Laser Hazards & Laser Safety





Laser radiation

Eye: corneal and, or retinal burns, lens damage, cataracts

IR >1400nm Front of eye

Visible and Near IR (400-1400nm) retinal damage

UV < 400nm Front of eye

Front

Back



Laser Hazards & Laser Safety

	Class 2 Class 3B Class 3B	Class 3B			Class 4	télecom.t	amm.com
	60 2 3 4		6	00 700 800 90	0 100 1200	1300 1400	
(0 1 5	i	500	(milliwatt)	1000	1500	10000
Direct Looking Hazard Distances (meter)	o c	Nominal Ocular Hazard Distance **Eye Damage in 0.25 second**	o 		o 	o 	o
	7 16	Flash Blindness **Eye Damage in 1 second**	160	(meters)	224	275	710
	150 25	Glare Distance **Temporary or Permanent Eye Glare**	2500	(meters)	5.039	4,196	15 022
	1600 3.5	Distraction Distance **Distracting Glare with No Damage**	35,600	(motors)	50 386	61 857	150 333
Diffused Reflect Exposure Haza	Looking at the "Reflected Dot" is not harmful	Looking at the " Reflected Dot" Gradually Becomes Harmful		C	Looking at the "Reflec auses Instant Damage	ted Dot" to the Eye	
	No Skin Damage or Surfaces	Gradual Skin Damage and Surfaces			Instant Damag Skin and Surfa	e to ces	
rds	Damage h	ttps://telecom.samm.com	n/lase	er-hazard-c	lasses-and-	eye-safety	Samp be

(meter)



Laser Hazards & Laser Safety



CLASS 3B LASER CONTROLLED AREA

AVOID DIRECT EYE EXPOSURE

LASER SAFETY EYEWEAR REQUIRED

Thank you for your time

Enjoy your day