LASER

LASERS **9**

Interaction of Radiation with Matter-Spontaneous and stimulated emissions– Einstein's A and B coefficients – Conditions for Laser action –Population inversion – Active medium – pumping schemes – Optical resonant cavity- Light Amplification-Types of lasers – Nd: YAG, CO_2 and Semiconductor lasers- homo junction & hetero junction laser.

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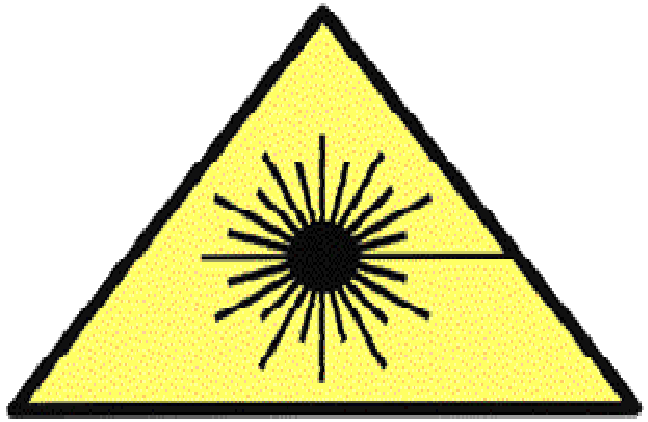
Definition & Properties of Laser Light

Acronym For:



LIGHT

AMPLIFICATION BY

STIMULATED

EMISSION OF

RADIATION

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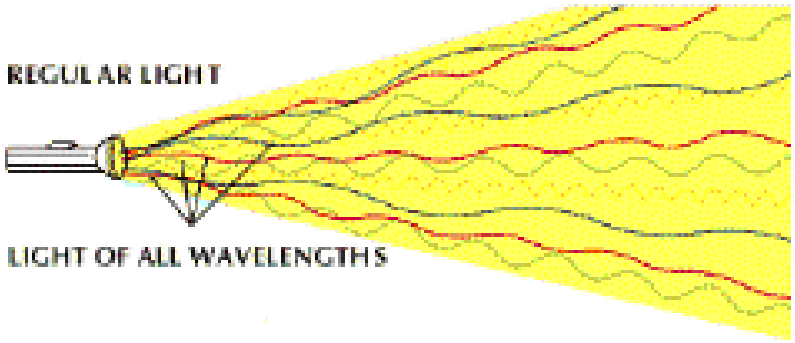
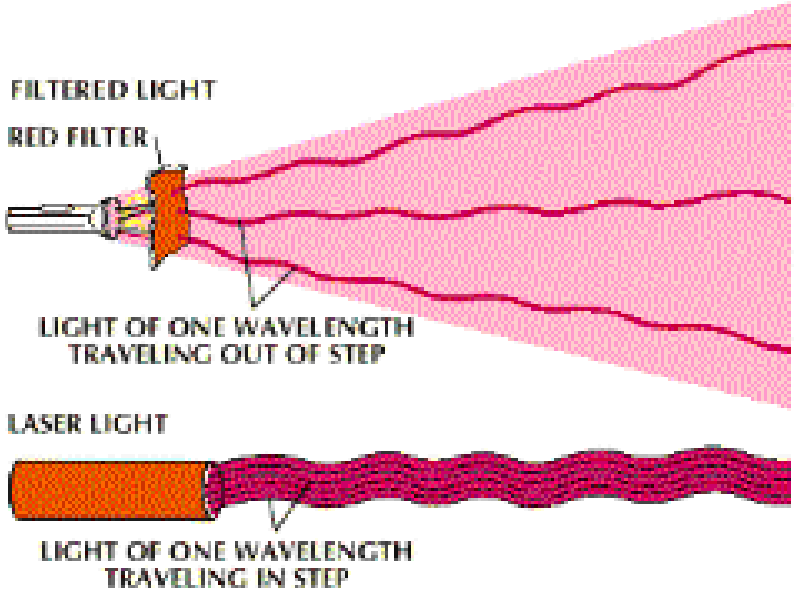
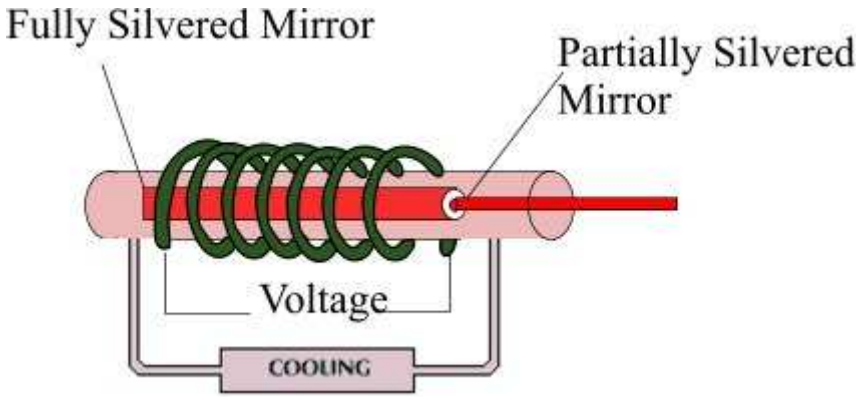
Lasers



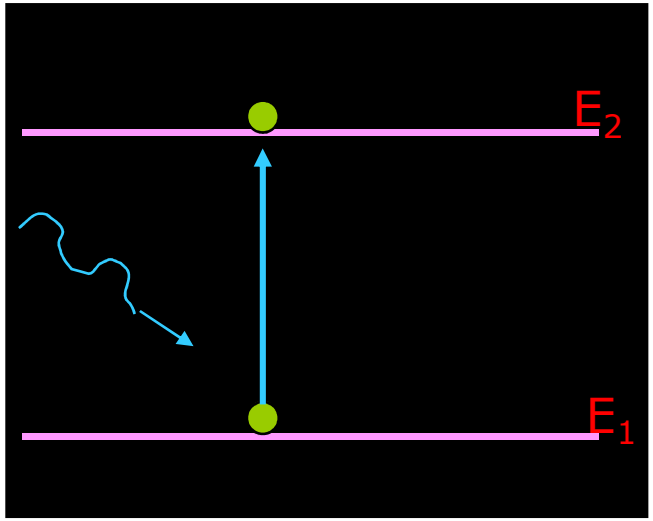
Noncoherent light



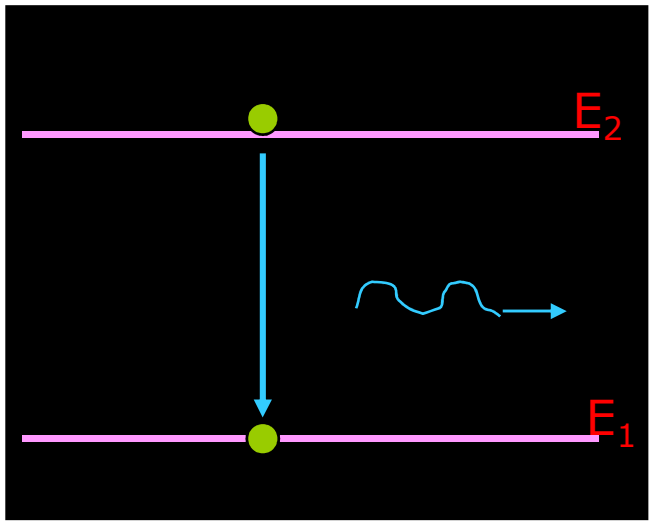


Coherent light

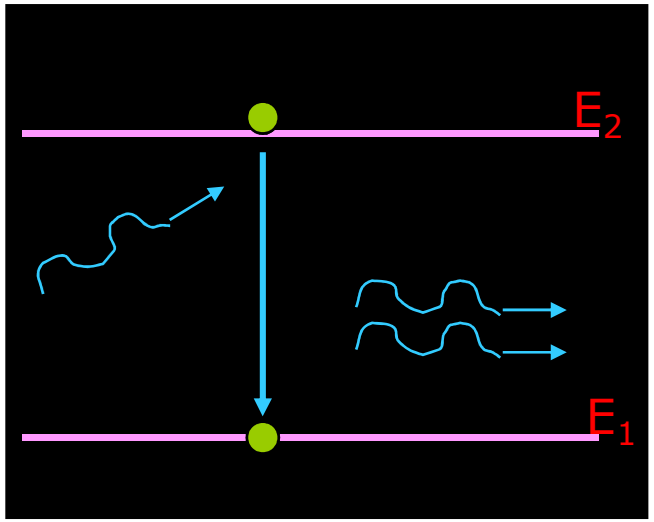
Einstein's Quantum theory of Radiation – Determination of Einstein's coefficient



Rate of stimulated absorption $R_{12} = N_1 \rho(v) B_{12}$



Rate of spontaneous Emission $R_{21} = N_2 A_{12}$



Rate of stimulated Emission $R_{21} = N_2 \rho(\nu) B_{21}$

Under equilibrium condition

Rate of absorption = rate of emission

$$B_{12}\rho(\nu)N_1 = A_{21}N_2 + N_2\rho(\nu)B_{21}$$

$$\rho(\nu) = \frac{A_{21}N_2}{B_{12}N_1 - B_{21}N_2}$$

$$\rho(\nu) = \frac{\frac{A_{21}}{B_{21}}}{\frac{B_{12}}{B_{21}}\frac{N_1}{N_2} - 1}$$

From Boltzmann distribution law $N_i = g_i N_0 \exp\left(\frac{-E_i}{kT}\right)$

$$\frac{N_1}{N_2} = \frac{g_1}{g_2}\exp\left(\frac{E_2 - E_1}{kT}\right)$$

$$E_2 - E_1 = h\nu$$

$$\frac{N_1}{N_2} = \frac{g_1}{g_2}\exp\left(\frac{h\nu}{kT}\right)$$

$$\rho(\nu) = \frac{\frac{A_{21}}{B_{21}}}{\frac{g_1 B_{12}}{g_2 B_{21}}\exp\left(\frac{h\nu}{kT}\right) - 1}$$

Plank's law of black body radiation

$$\rho(\nu) = \frac{8\pi h\nu^3}{c^3}\left(\frac{1}{\exp\left(\frac{h\nu}{kT}\right) - 1}\right)$$

$$g_1 B_{12} = g_2 B_{21}$$

$$\frac{A_{21}}{B_{21}} = \frac{8\pi h\nu^3}{c^3}$$

Properties Of Laser Light

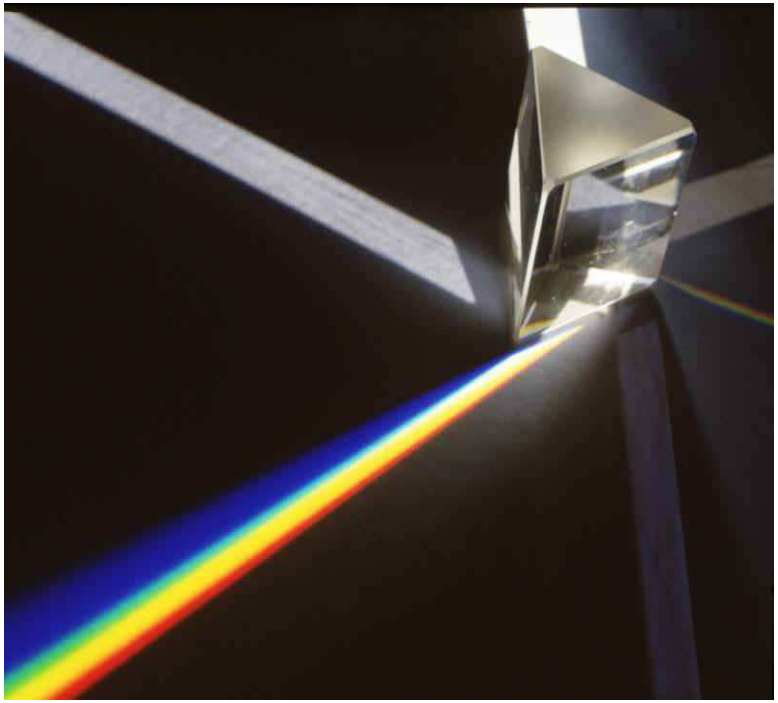
- Laser light is monochromatic, directional and coherent
- These three properties make it more of a hazard than ordinary light.
- Laser light can deposit a great deal of energy within a very small area

Properties Of Laser Light

Monochromatic

The light emitted from a laser is ***monochromatic***, it is of one wavelength (color).

In contrast, ordinary white light is a combination of many different wavelengths (colors).



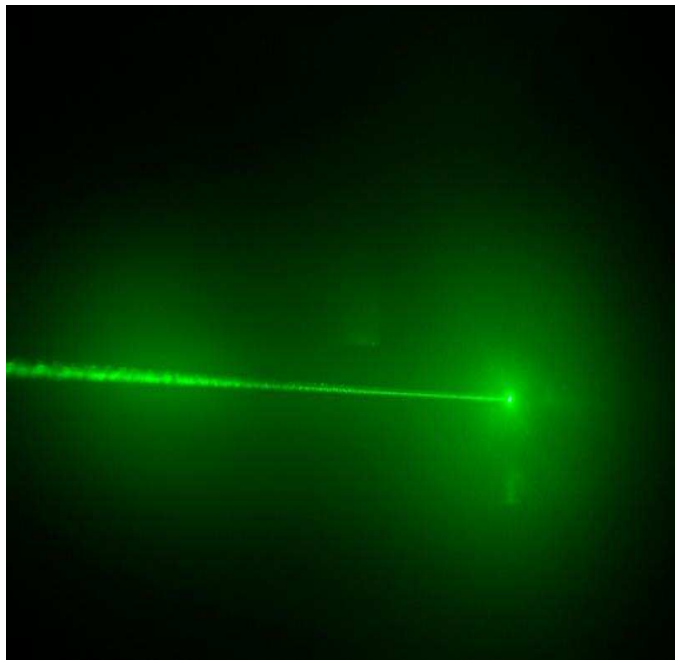
Properties Of Laser Light

Directional

Lasers emit light that is highly ***directional***.

It is emitted as a narrow beam in a specific direction.

Ordinary light (sun, light bulb, a candle), is emitted in many directions away from the source



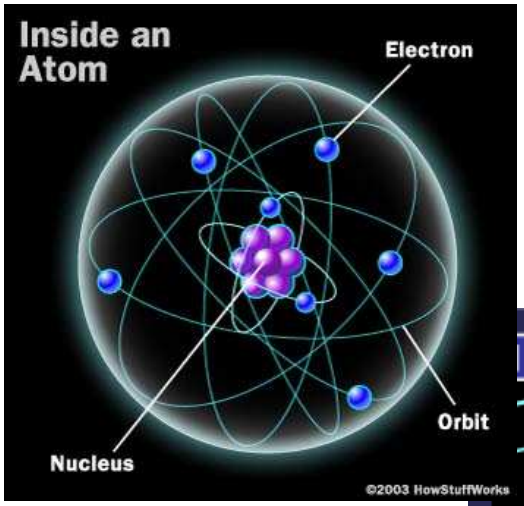
Properties Of Laser Light

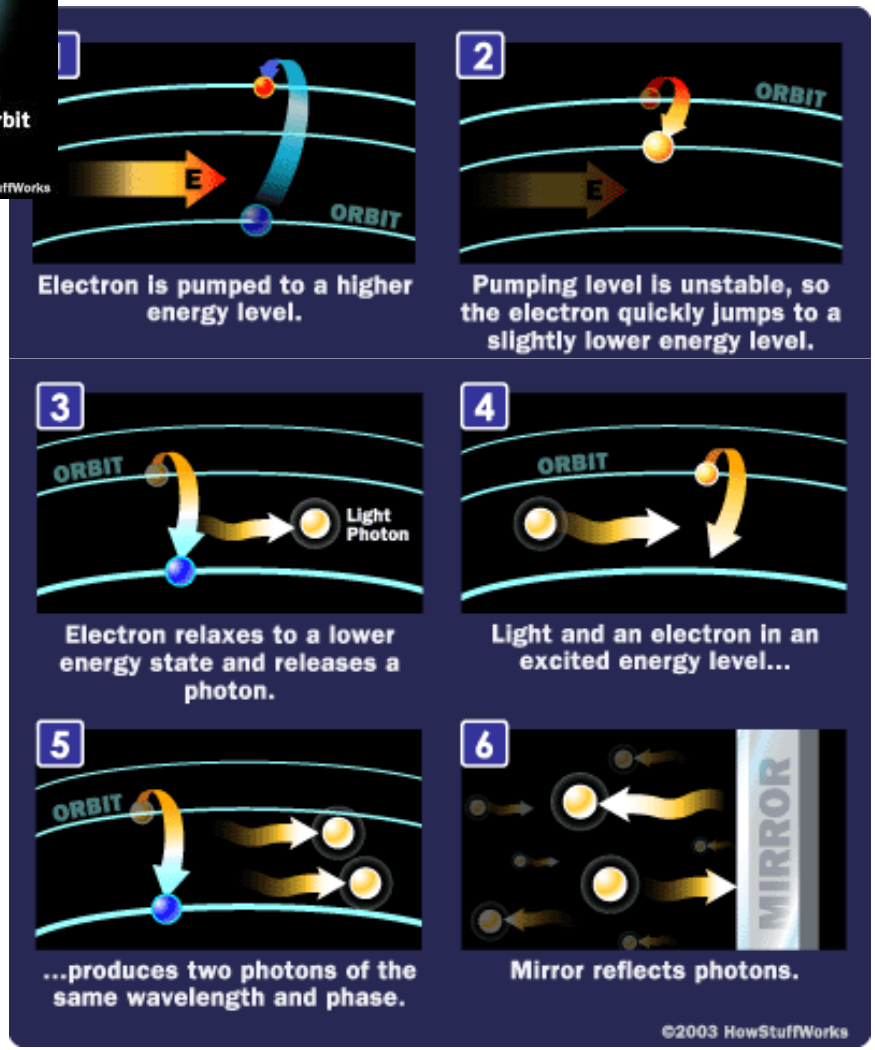
Coherent

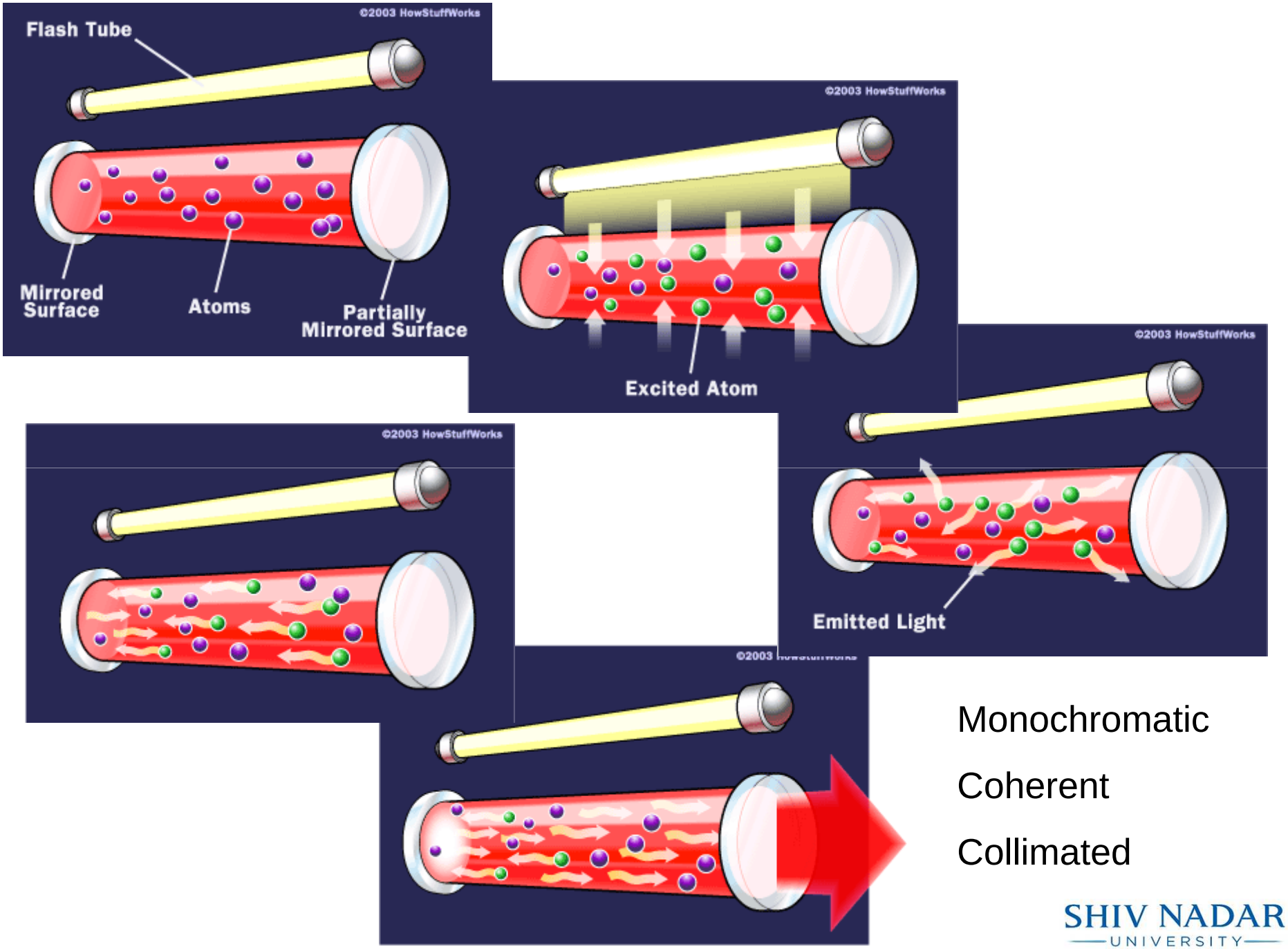
The light from a laser is ***coherent***

The wavelengths of the laser light are in phase in space and time

Laser—basics







Monochromatic

Coherent

Collimated

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Nd:YAG Laser

Type: four level solid state laser

Active medium: Yttrium aluminium Garnet

Active centre: neodymium

Pumping method: Optical pumping

Pumping source: xenon flash lamp

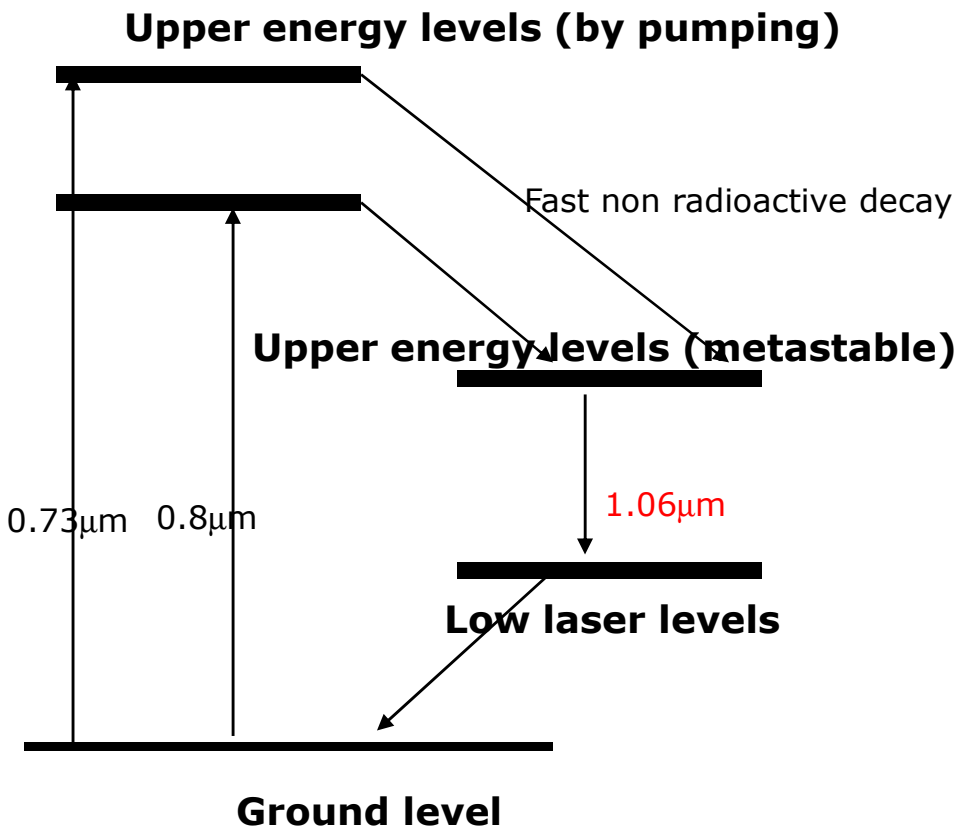
Optical resonator: ends of rods polished with silver

Power output: 100s mW

Nature of output: pulsed/Continuous

Wavelength : 1.064micrometer

Energy level diagram-Nd:YAG



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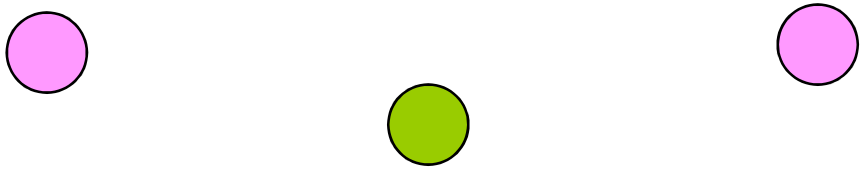
Vibration modes of CO_2 molecule

Symmetric mode (100)

Bending mode(010)



Asymmetric mode(001)

CO_2 Laser

Type: molecular laser

Active medium: Mixture of CO_2, N_2, He or water vapour

Active centre: CO_2

Pumping method: Electric discharge

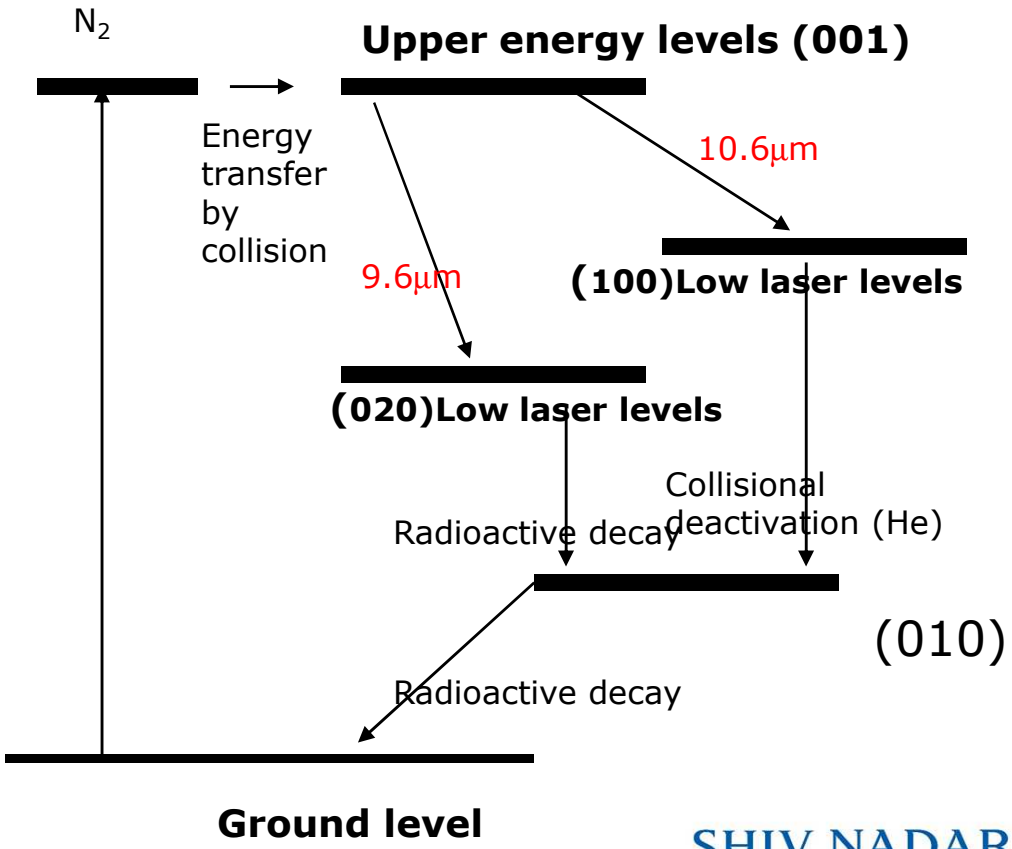
Optical resonator: concave mirror (metallic mirror of gold/silicon with aluminium)

Power output: 10KW Watts

Nature of output: pulsed/Continuous

Wavelength : 9.6/10.6micrometer

Energy level diagram-CO_2



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Semiconductor laser

Type: Solid state semiconductor

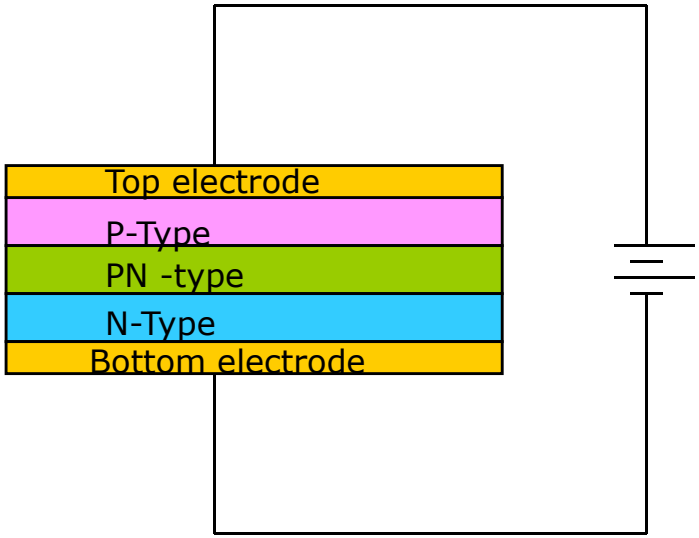
Active medium: p-n junction diode made from single crystal

Pumping method: Direct conversion method

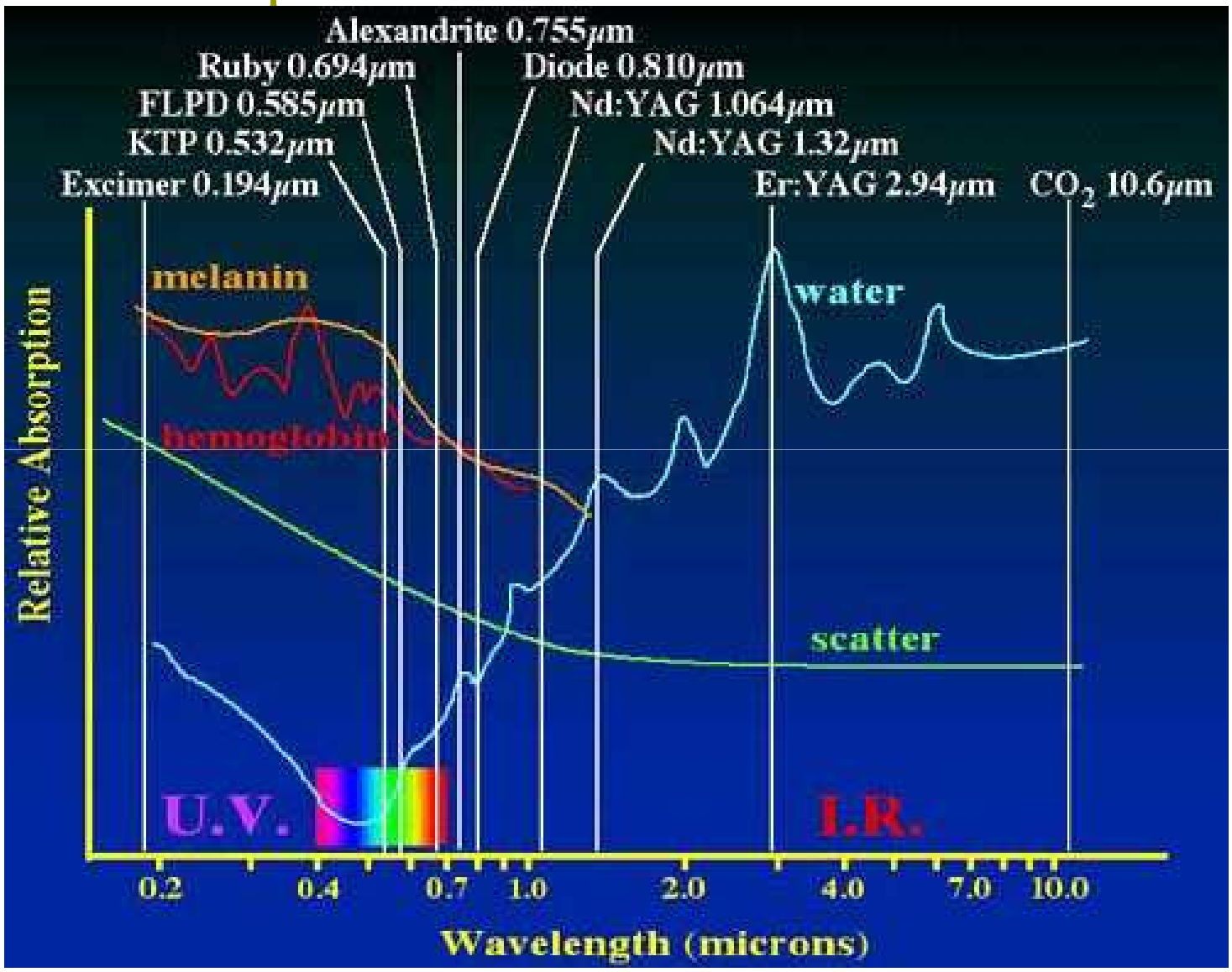
Power output: 1mW Watts

Nature of output: pulsed/Continuous

Wavelength : 8.3/8.6micrometer



Laser spectrum



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Applications of Laser

Material Processing

- Welding
- Cutting
- Drilling
- Surface hardening

Medical applications

- Ophthalmology
- Cancer treatment
- Urology
- Dermatology

Defence

- Ranging (LIDAR)
- Guide the missiles
- Disable and destroy the enemy targets

Nuclear energy

- Nuclear fusion
- Isotope separation

Optical communications

Electronic industry

- Scribing
- Soldering
- Trimming

Consumer electronic industry

Optical data storage

Holography