Al-Mustaqbal University

College of Engineering & Technology

Biomedical Engineering Department

Subject Name: Medical Lasers in Engineering

Third Class, Second Semester

Subject Code: [MU0113207]

Academic Year: 2024-2025

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Lecture No.:-5

Lecture Title: [Types of Lasers2]

Repetitively Pulsed Lasers

Figure (2) illustrates the output power of a repetitively pulsed laser as a function of time. The quantities Pmax, Δt1/2, and E are as defined previously. Pavg is the average power of the laser. The pulse repetition time (PRT) is the time interval between similar points on two consecutive laser pulses.

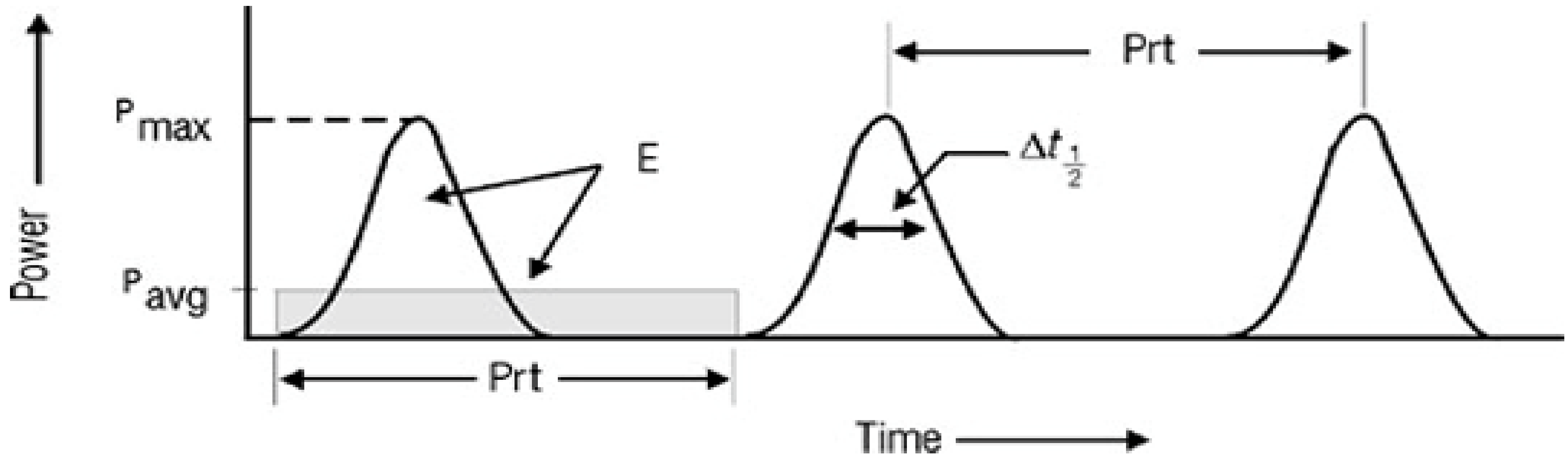

Figure (2): Repetitively pulsed laser

The pulse repetition rate is the number of pulses per second and is related to pulse repetition time by Equation 3:

$$PRR = 1 / PRT \qquad (3)$$

Where; PRR = Pulse repetition rate.

The shaded area in Figure (2) represents the product of the average power and the pulse repetition time. This area is the same as that of one of the laser pulses; therefore, Equation 4 can be used to determine the energy of a single pulse in a repetitively pulsed laser.

$$E = (Pavg)(PRT) \qquad (4)$$

Example: A Q-switched Nd:YAG laser produces 5000 pulses per second at an average power of 20 W. Find the energy of a single pulse.

Answer: $E = 4\ mJ$

The “duty cycle” of a repetitively pulsed laser is defined as the ratio of the time the laser is ON to the time the laser is OFF. The ratio is usually expressed as a percentage. Thus, a 10% duty cycle means that the laser is on for 10% of that period, while a 90% duty cycle means the laser is on for 90% of that period. Quantitatively, the duty cycle is equal to the ratio of pulse duration (Δt1/2) to pulse repetition time (PRT), thus is given by Equation 5:

$$DC = \Delta t_{1/2} / PRT \quad (5)$$

Where; DC = Duty cycle. From Equation 4;

$$PRT = \frac{E}{P_{avg}}$$

From Equation 1;

$$\Delta t_{1/2} = \frac{E}{P_{max}}$$

Substitution of these values into Equation 5 yields Equation 6

$$DC = \frac{(\frac{E}{P_{max}})}{(\frac{E}{P_{avg}})}$$

$$DC = \frac{P_{avg}}{P_{max}} \quad (6)$$

Example: A repetitively pulsed CO2 laser has an average power of 100 W, a pulse duration of 0.5 ms, and a pulse repetition of 500/sec. Find the; duty cycle and maximum power. Answer: $\boldsymbol{DC = 0.25}$ **,** $\mathrm{P}max = 400\ W$

Laser classifications:

The most popular classification of lasers is based on whether the gain medium is a gas, liquid, or solid.

Gas: e.g., HeNe laser, excimer laser, CO2 laser.

Liquid: e.g., dye laser.

Solid: e.g., Nd:YAG laser, Nd:glass, Ti:sapphire laser.

Diode (semiconductor) laser.

Summary of

some common lasers

Laser	Pulsed or CW*	Tuneable	Emission wavelengths
HeNe	CW	No	632.8 nm (1.15 µm)
Ar ion	CW	No	351, 455, 458, 466, 477, 488, 497, 502, 515, 529 nm
N_2	P	No	337 nm
Excimer	P	No**	190 – 350 nm
CO_2	Both	Yes	10.6, 9.6 µm**
Dye lasers	Both	Yes	365 – 930 nm
Nd:YAG	Both	No	1064 nm (532, 355, & 266 nm)***
Alexandrite	P	Yes	720 – 800 nm
Ti:sapphire	CW	Yes	670 – 1100 nm
Diode lasers	Both	Yes	UV to mid-IR

* Typical mode of operation

** Tuneable over a narrow range (or depending on particular laser)

*** 2nd, 3rd etc. harmonics

Solid State Laser

Solid-state lasers are lasers in which active ions in crystal or glass host materials are optically pumped to create a population inversion (in other words, the solid state laser uses a solid crystalline material as the lasing medium and is usually optically pumped). The flexibility of solid-state lasers stems from the fact that;

• The size and shape of the active material can be chosen to achieve a particular performance.

• Different active materials can be selected with different gain, energy storage, and wavelength properties.

• Output energy can be increased by adding amplifiers.

A large number of passive and active components are available to shape the spectral, temporal and spatial profile of the output beam.

Figure (3) shows a basic setup of solid state laser

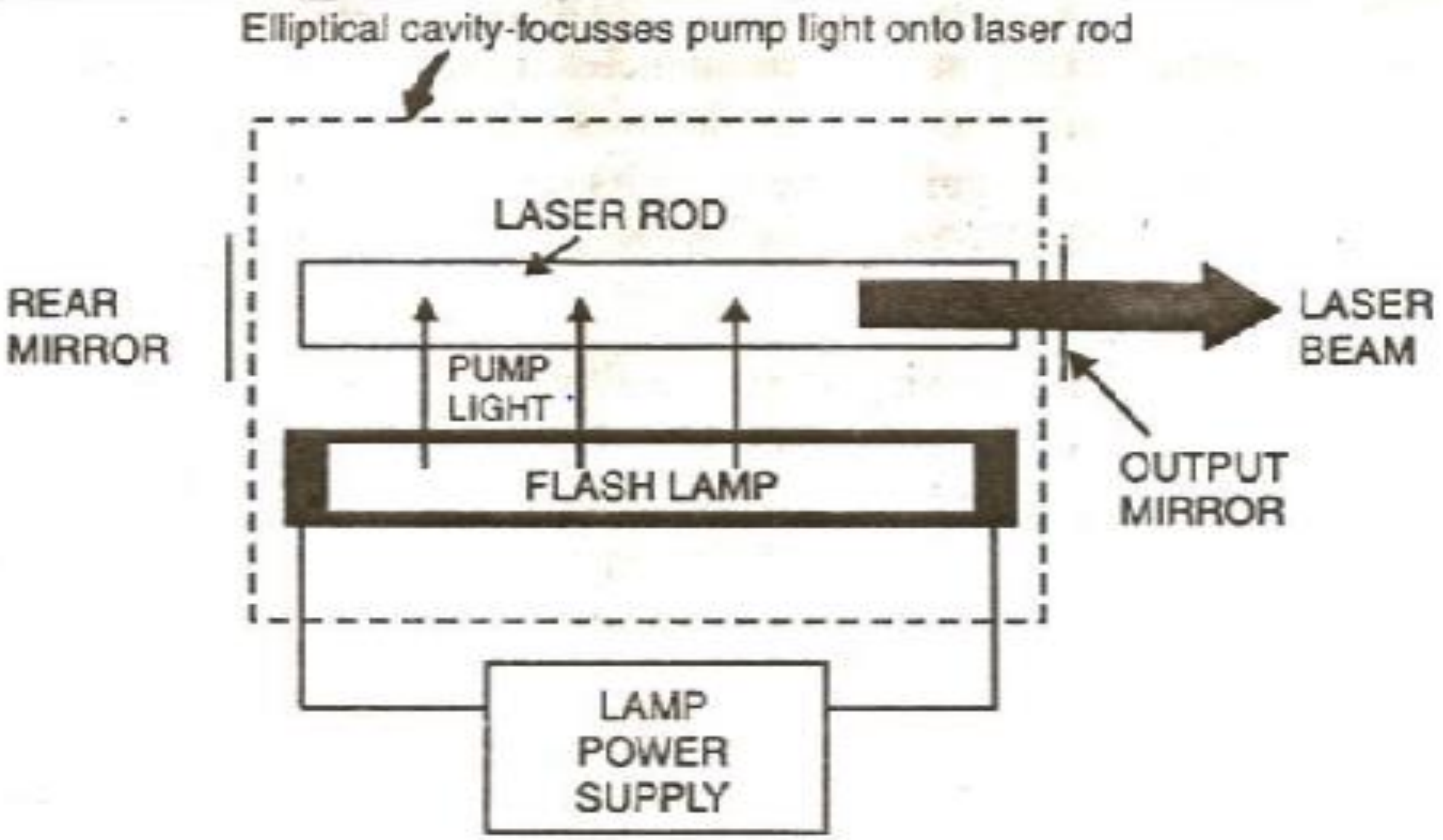

Figure (3): Schematic solid-state laser

The atoms in a solid are close to each other, and the interaction between neighbors is strong. Thus, the absorption and emission spectrum ranges in solids are much wider than those of gasses. Wide absorption spectrum allows pumping of the active medium with a "conventional" light source, which has a wide emission spectrum.

In Optical Pumping the active medium is excited by illuminating it with external electromagnetic source. The photons from the external source are absorbed by the material of the active medium, thus transferring energy to its molecules. Two types of electromagnetic sources are used in optical pumping:

- Source of wide band electromagnetic spectrum such as; Flash lamps, Incandescent lamps, Arc lamps, etc.
- Source of narrow band electromagnetic spectrum.

- Structure of the active medium in solid state laser The active medium in solid state lasers is a medium of one solid material, in which impurity ions of another material are scattered. These impurity ions are replacing atoms of the solid background, and the energy levels which participate in the lasing process are those of the ions of impurity.
- The solid background influence on the energy level structure is minor. Thus, the same impurity ion embedded in different host material will emit at very close wavelengths. The optical properties of the laser are dictated mostly by the impurity ion. On the other end, the physical properties of the active medium such as thermal conductivity, thermal expansion, are determined by the solid host.
- Thus, the solid host determine the maximum power levels which can be emitted from the laser.

Optically Pumped Solid-State Lasers

The active medium in these lasers is a crystal or glass. The shape of the active medium is usually a rod with circular or square cross section. The pumped beam usually enter the active medium via its surface area along the rod, while the laser radiation is emitted through the ends of the rod. The pump lamps for pulsed lasers are usually Xenon (or Krypton) flash lamps, in which a low pressure gas is contained within quartz tube. The pump lamps for continuous lasers are usually Halogen lamps, or high-pressure Mercury discharge lamps.

Examples of solid-state laser

- Ruby laser: the first laser.
- Nd:YAG & Nd:Glass lasers.
- Alexandrite laser.
- Ti: Sapphire laser.
- Fiber lasers (Erbium in a glass host).