



University of Al-Mustaqbal
College of Science
Department of Medical Physics



AL- Mustaqpal University

Science College

Dep. Medical physics

Medical Laser Applications

Third Stage

Lec 2

***Pulsed Lasers Introduction
to
Power and Energy Calculations***

Asst. lec. Ali Salman Hamadi

1. Introduction to Pulsed Lasers

Definition and Key Characteristics

- A pulsed laser emits energy in the form of light pulses rather than a continuous beam.
- Pulse durations can range from nanoseconds (**ns**) to femtoseconds (**fs**).
- Pulsed lasers are characterized by high peak powers and are widely used in fields such as:
 - Material processing
 - Medical applications (e.g., laser surgery)
 - Scientific research (e.g., spectroscopy, time-resolved studies)

Applications in Science and Technology

- Pulsed lasers enable precise energy delivery in time-sensitive applications.
- Examples include:
 - Micromachining delicate materials.
 - Generating high-intensity electric fields for particle acceleration.
 - Studying ultrafast processes in physics and chemistry.

2. Understanding Power and Energy in Pulsed Lasers

Distinction Between (**CW**) and Pulsed Lasers

- Continuous-Wave (**CW**) Lasers: Emit a steady, continuous beam of light.
- Pulsed Lasers: Emit light in bursts, leading to significantly higher instantaneous power.

Key Terminologies

1. Pulse Energy (E): The total energy contained in a single pulse, typically measured in joules (J).
2. Peak Power (P_{peak}) : The maximum power achieved during a pulse, calculated as:

$$P_{\text{peak}} = \frac{E}{\tau_p}$$

where:

- E = Pulse energy (J)
 - τ_p = Pulse duration (s)
3. Average Power (P_{avg}) : The time-averaged power output, calculated as:

$$P_{\text{avg}} = E \times fr$$

where:

- E = Pulse energy (J)
- fr = Pulse repetition rate (Hz)

3. Mathematical Framework for Calculations

Energy Per Pulse

- The pulse energy can often be measured or derived from the laser specifications and is a fundamental quantity in calculations.

Peak Power Calculation

- Pulsed lasers often achieve very high peak powers due to the short duration of pulses.
 - For example, if a laser emits a **1mJ** pulse with a **10 ns** pulse duration, the peak power is:

$$P_{\text{peak}} = \frac{E}{\tau_p}$$

$$P_{\text{peak}} = \frac{1 \times 10^{-3}}{10 \times 10^{-9}} = 10^5 \text{ watt}$$

Average Power Calculation

- The average power is proportional to the pulse energy and repetition rate.
 - For a laser with a **1mJ** pulse energy operating at a **1kHz** repetition rate:

$$P_{\text{avg}} = E \times fr$$

$$P_{\text{avg}} = 1 \times 10^{-3} \times 10^3 = 1 \text{ watt}$$

4. Examples and Problem-Solving

Example 1: Calculating Peak Power

A pulsed laser emits light at a pulse energy of **0.5 mJ** and a pulse duration of **5 ns**. Calculate the peak power.

Solution:

$$P_{\text{peak}} = \frac{E}{\tau_p}$$

$$P_{\text{peak}} = \frac{0.5 \times 10^{-3}}{5 \times 10^{-9}} = 10^5 \text{ watt}$$

Example 2 : Calculating Average Power

A laser operates with a repetition rate of **10 kHz** and a pulse energy of **2 mJ**. Calculate the average power.

Solution:

$$P_{\text{avg}} = E \times fr$$

$$= (2 \times 10^{-3}) \times (10 \times 10^3) = 20 \text{ watt}$$

Homework / Exercises:

1. A laser emits 1 μJ pulses with a pulse duration of **1 ps** and a repetition rate of **1 MHz**. Calculate the peak power and average power.
2. Compare the peak powers of a nanosecond and femtosecond laser, each delivering the same pulse energy of **1 mJ**.

Discussion

1. What is a pulsed laser?

- A) A laser that emits a continuous beam.
- B) A laser that emits light in pulses.
- C) A laser with no energy output.
- D) A laser used only for medical applications.
- E) None of the above.

Correct Answer: B

2. Which of the following ranges can describe pulse durations in pulsed lasers?

- A) Microseconds to seconds
- B) Hours to days
- C) Nanoseconds to femtoseconds
- D) Milliseconds to minutes
- E) None of the above

Correct Answer: c

3. What is a key characteristic of pulsed lasers?

- A) Low peak power
- B) High peak power
- C) Constant beam intensity
- D) No repetition rate
- E) Weak energy delivery

Correct Answer: B

4. In which field are pulsed lasers NOT commonly used?

- A) Material processing
- B) Cooking
- C) Medical applications
- D) Scientific research
- E) Ultrafast process studies

Correct Answer: B

5. What differentiates pulsed lasers from continuous-wave lasers?

- A) Continuous-wave lasers emit light in pulses.
- B) Pulsed lasers emit a steady, continuous beam.
- C) Pulsed lasers emit light in bursts with higher peak power.
- D) Both emit light in the same manner.
- E) Pulsed lasers are always larger.

Correct Answer: c

6. What does the term "pulse energy (E)" represent?

- A) The energy in the entire laser system.
- B) The energy contained in a single pulse.
- C) The time duration of a pulse.
- D) The repetition rate of the pulses.
- E) None of the above.

Correct Answer: B

7. How is peak power (P_{peak}) calculated?

- A) $P_{\text{peak}} = E \times f_r$
- B) $P_{\text{peak}} = \tau_p / E$
- C) $P_{\text{peak}} = E \times \tau_p$
- D) $P_{\text{peak}} = E / \tau_p$
- E) None of the above

Correct Answer: D

8. What is the unit of pulse energy (E)?

- A) Watts
- B) Joules
- C) Seconds
- D) Hertz
- E) Newtons

Correct Answer: B

9. If a laser emits a pulse energy of 2 mJ and the pulse duration is 4 ns, what is the peak power?

- A) 0.5 W
- B) 50 MW
- C) 500 W
- D) 500 Kw
- E) 1 MW

Correct Answer: E

10. What is the formula for calculating average power (P_{avg})?

- A) $P_{avg} = fr / E$
- B) $P_{avg} = E \times \tau_p$
- C) $P_{avg} = E / \tau_p$
- D) $P_{avg} = E \times fr$
- E) None of the above

Correct Answer: D

11. If a laser has a pulse energy of 1 mJ and a repetition rate of 1 kHz, what is its average power?

- A) 1 W
- B) 10 W
- C) 0.1 W
- D) 100 W
- E) 0.01 W

Correct Answer: A

12. What does the term "repetition rate (fr)" represent?

- A) The total energy in a pulse.
- B) The frequency of pulses per second.
- C) The duration of a single pulse.
- D) The speed of light in the laser.
- E) None of the above.

Correct Answer: B

13. What happens to peak power as pulse duration decreases?

- A) It increases.
- B) It decreases.
- C) It remains constant.
- D) It depends on repetition rate.
- E) None of the above.

Correct Answer: A

14. Which of the following applications uses pulsed lasers?

- A) Micromachining delicate materials
- B) Boiling water
- C) Generating radio waves
- D) Long-distance communications
- E) None of the above

Correct Answer: A

15. If the pulse energy is 5 mJ and the repetition rate is 2 kHz, what is the average power?

- A) 10 W
- B) 0.01 W
- C) 1 W
- D) 100 W
- E) None of the above

Correct Answer: A

16. What is a typical repetition rate for industrial pulsed lasers?

- A) 10 Hz
- B) 10 KHz
- C) 10 GHz
- D) 1 MHz
- E) 1 Hz

Correct Answer: B

17. How is pulse duration represented in formulas?

- A) f_r
- B) τ_p
- C) E
- D) P_{avg}
- E) None of the above

Correct Answer: B

18. If P_{peak} is 50 MW and τ_p is 10 ns, what is E ?

- A) 0.5 J
- B) 5 J
- C) 0.05 J
- D) 50 J
- E) 500 J

Correct Answer: C

19. What is the unit for repetition rate (fr)?

- A) Watts
- B) Joules
- C) Seconds
- D) Hertz
- E) Volts

Correct Answer: D

20. Why are pulsed lasers preferred for ultrafast processes?

- A) High continuous power
- B) High average power
- C) High peak power and short pulse duration
- D) High energy consumption
- E) None of the above

Correct Answer: C

21. What is the average power of a laser emitting 1 mJ pulses at 5 kHz?

- A) 5 W
- B) 0.5 W
- C) 0.1 W
- D) 10 W
- E) None of the above

Correct Answer: A

22. What determines the energy per pulse in a pulsed laser?

- A) Peak power
- B) Repetition rate
- C) Average power
- D) Pulse specifications
- E) None of the above

Correct Answer: D

23. What is a typical application of pulsed lasers in medicine?

- A) Micromachining metals
- B) Generating radio waves
- C) Laser surgery
- D) Studying molecular structure
- E) None of the above

Correct Answer: C

24. If a pulse has a duration of (2 ns) and energy of (0.4 mJ) what is the peak power?

- A) 0.2 MW
- B) 2 MW
- C) 20 MW
- D) 200 MW
- E) 0.02 MW

Correct Answer: B

25. Pulsed lasers are commonly used for studying which processes?

- A) Time-resolved phenomena
- B) Long-term changes
- C) Energy loss in systems
- D) Continuous-wave modulation
- E) None of the above

Correct Answer: A