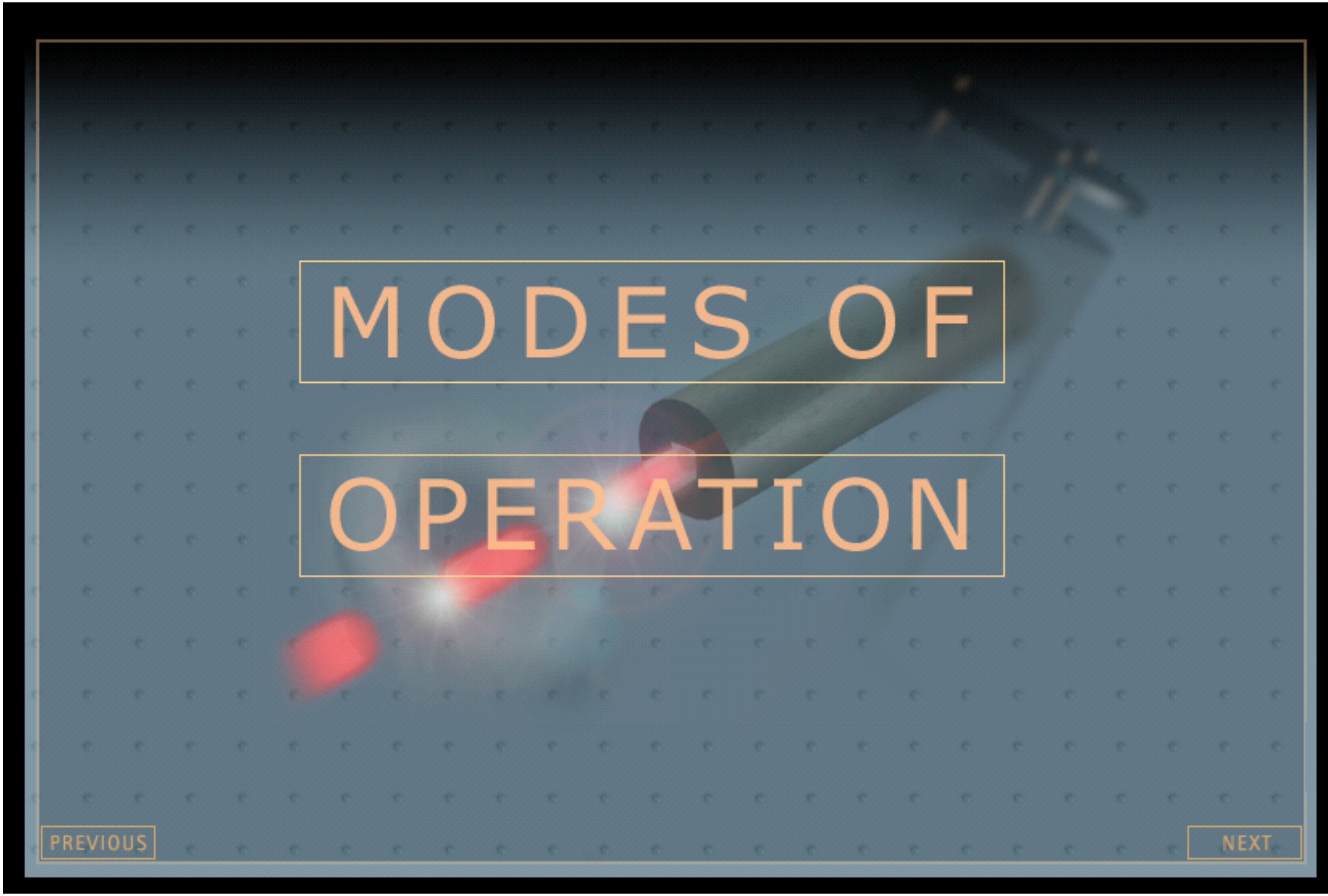

MODES OF
OPERATION
PREVIOUS
NEXT

The choice of laser mode depends on the desired result.

Due to physical and technical reasons some lasers can only emit short pulses of radiation, others emit continuously.
These modes of operation are described by the terms [pulsed] laser and [continuous wave] laser.
While a pulsed laser cannot emit a continuous wave, it is possible to have a cw-laser emit light pulses by mechanically or electrically chopping the beam and/or creating [super pulses].

The laser of [choice] is determined by the desired effect.

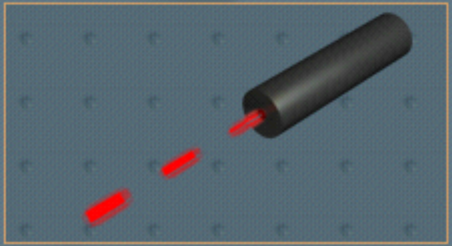
PREVIOUS
NEXT

The choice of laser mode depends on the desired result.

The duration of those pulses varies for each laser and depends on physical principles of operation such as Q-switching and mode-locking.

Due to physical a
pulses of radiati
These modes of c
[continuous wave] laser.
While a pulsed laser cannot emit a continuous wave, it is possible to have a cw-laser emit light pulses by mechanically or electrically chopping the beam and/or creating [super pulses].

The laser of [choice] is determined by the desired effect.



PREVIOUS

NEXT

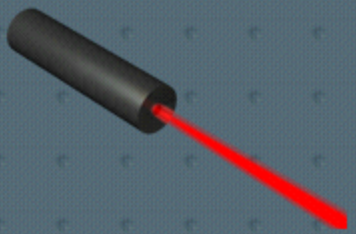
The choice of laser mode depends on the desired result.

Due to physical and technical reasons some lasers can only emit short pulses of radiation, others emit continuously.
These modes of operation are described by the terms [pulsed] laser and

Many lasers emit a truly continuous wave and are therefore termed cw-lasers.

inuous wave, it is possible to
chanically or electrically
chopping the beam and/or creating [super pulses].

The laser of [choice] is determined by the desired effect.



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The choice of laser mode depends on the desired result.

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pulses of rad
These modes … ser and
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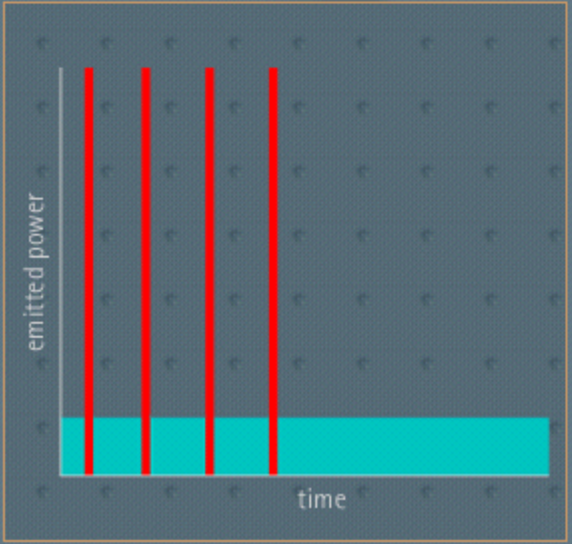
Typical medical lasers include:

alexandrite laser:		pulsed
ArF excimer laser:		pulsed
argon ion laser:	cw	
CO_2 laser:	cw	
Er:YAG laser:		pulsed
dye laser:	cw	pulsed
gold vapor laser:		pulsed
HeNe laser:	cw	
Ho:YAG laser:		pulsed
krypton ion laser:	cw	
KrF excimer laser:		pulsed
KTP laser:	cw	pulsed
copper vapor laser:		pulsed
laser diodes:	cw	
Nd:YAG laser:	cw	pulsed
ruby laser:		pulsed
Ti:sapphire laser:	cw	pulsed
XeCl excimer laser:		pulsed
XeF excimer laser:		pulsed

A pulsed laser's emission is defined by the pulse duration and pulse interval.

A physical unit which describes the operation of a pulsed laser is the [pulse-repetition rate]. [Pulse duration] and [pulse interva ls] are also characteristic properties.



PREVIOUS

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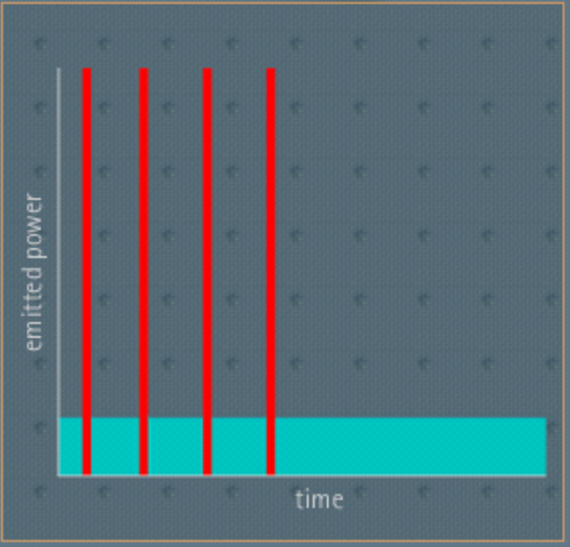
A pulsed laser's emission is defined by the pulse duration and pulse interval.

A physical unit which describes the operation of

1 Hertz (Hz) is the unit of repetition rate. A pulse-repetition rate of 1 Hz is equivalent to the emission of one pulse per second. Some lasers operating in pulsed mode are capable of emitting several thousands of pulses per second. Pulse-repetition rates vary over many [orders of magnitude].



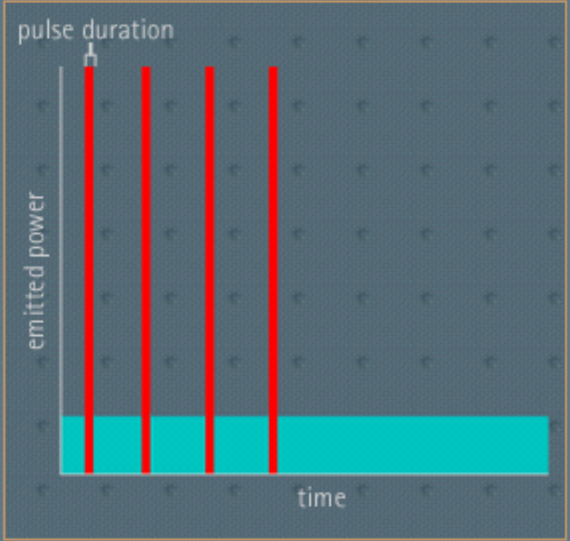
PREVIOUS

NEXT

A pulsed laser's emission is defined by the pulse duration and pulse interval.

A physical unit which describes the operation of a pulsed laser is the [pulse-repetition rate].
also

The pulses often last for only a small [fraction] of a second.
The pulse duration depends on the method of pulse generation and [varies] within a broad range.



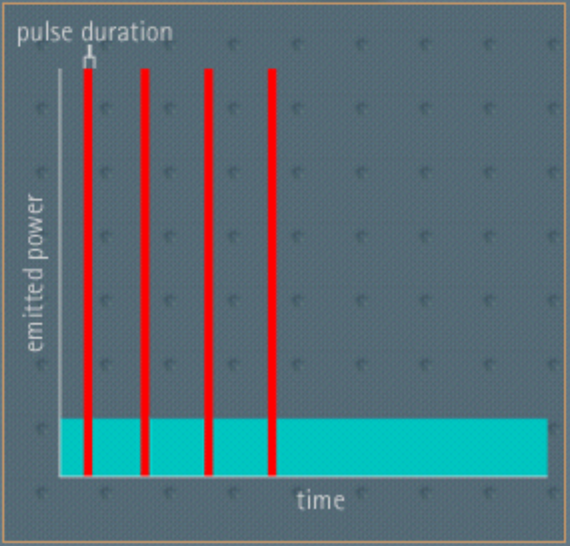
PREVIOUS

NEXT

A pulsed laser's emission is defined by the pulse duration and pulse interval.

1 millisecond (ms)	= 0 001 s
1 microsecond (µm)	= 0.000 001 s
1 nanosecond (ns)	= 0.000 000 001 s
1 picosecond (ps)	= 0.000 000 000 001 s
1 femtosecond (fs)	= 0.000 000 000 000 001 s

The pulse duration depends on the method of pulse generation and [varies] within a broad range.



PREVIOUS

NEXT

A pulsed laser's emission is defined by the pulse duration and pulse interval.

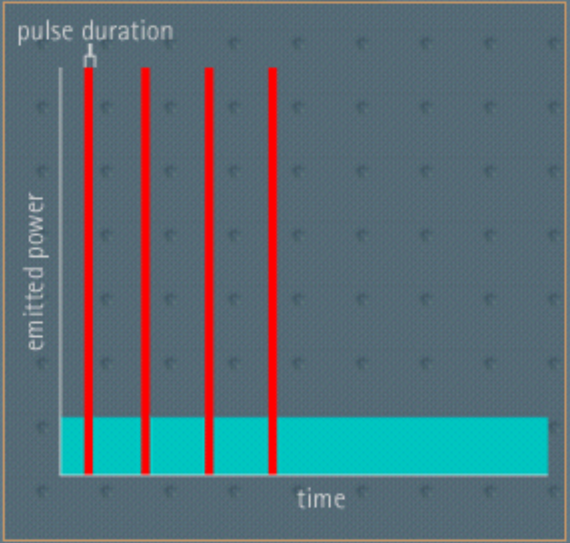
A physical unit which describes the operation of a pulsed laser is the [pulse-repetition rate].

also

The pulses often last for only a small [fraction] of a second.

The pulse duration depends on the method

pulse type	typical pulse duration		
chopped	1 s ...	1 ms	(1 s ... 0.001 s)
super pulse	1 ms ...	1 µs	(0.001 s ... 0.000 000 1 s)
Q-switched	1 µs ...	1 ns	(0.000 000 1 s ... 0.000 000 001 s)
mode-locked	1 ns ...	1 ps	(0.000 000 001 s ... 0.000 000 000 001 s)



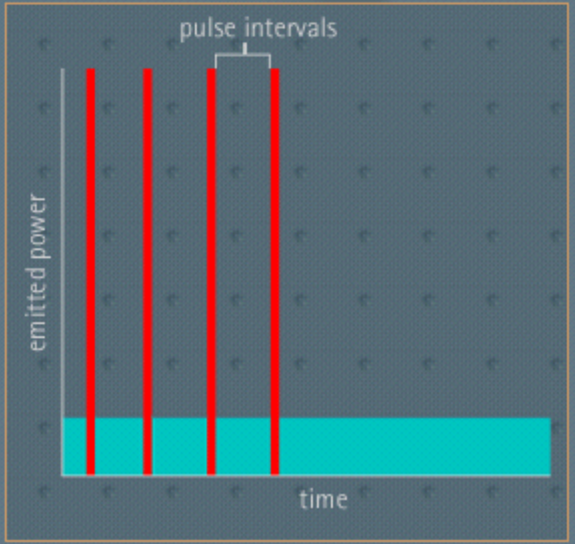
PREVIOUS

NEXT

A pulsed laser's emission is defined by the pulse duration and pulse interval.

A physical unit w
a pulsed laser is
[Pulse duration]
characteristic properties.

The intervals between individual pulses are usually much longer than the pulses themselves.



PREVIOUS

NEXT

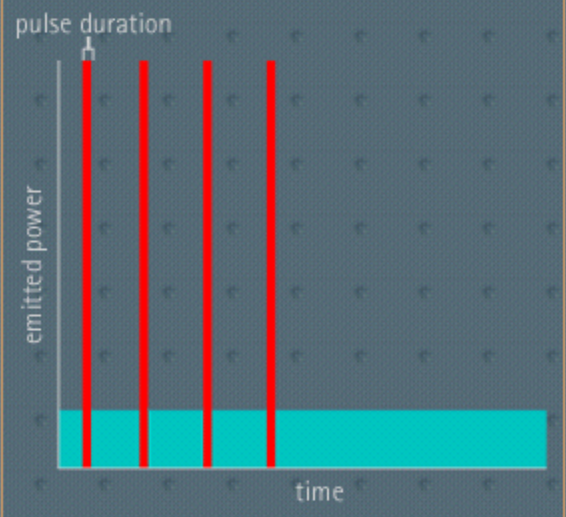
The peak power can exceed the average power by many orders of magnitude.

The radiation emitted by a laser is characterized by its wavelength and its [power].

While the [average power] of a pulsed laser is usually low, the [peak power] which is achieved in short single pulses can be much higher.

For a pulsed laser system the [energy] of a pulse is therefore more significant than the average power.

The shorter the time interval in which a certain energy is emitted the higher the [peak power].



PREVIOUS

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The peak power can exceed the average power by many orders of magnitude.

The radiation emitt
its wavelength and

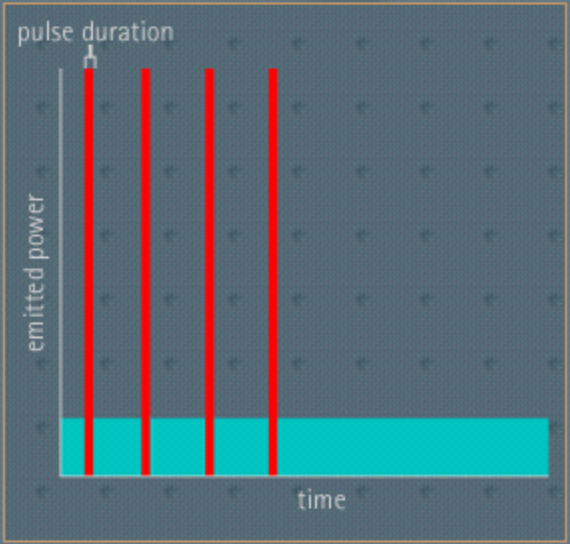
While the [average
usually low, the [pe
short single pulses

Power is measured in Watts (W).

1 kilowatt (kW)	=	1 000 W
1 megawatt (MW)	=	1 000 000 W
1 gigawatt (GW)	=	1 000 000 000 W
1 milliwatt (mW)	=	0.001 W
1 microwatt (µW)	=	0.000 001 W

For a pulsed laser system the [energy] of a pulse is therefore more significant than the average power.

The shorter the time interval in which a certain energy is emitted the higher the [peak power].



PREVIOUS

NEXT

The peak power can exceed the average power by many orders of magnitude.

The radiation emitted by a laser is characterized by its wavelength and its [power].

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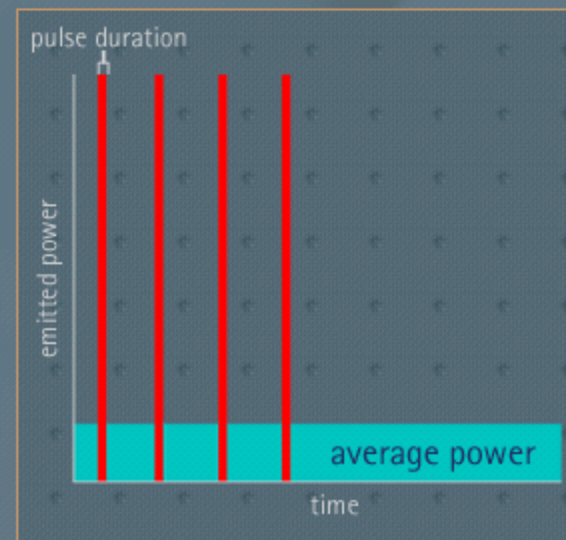
For a pulsed laser the average power does not contain information about the peak power unless the pulse duration is known.

For a pulsed laser system the [energy] of a pulse is therefore more significant than the average power.

The shorter the time interval in which a certain energy is emitted the higher the [peak power].



PREVIOUS NEXT

The peak power can exceed the average power by many orders of magnitude.

The radiation emitted by a laser is characterized by its wavelength and its [power].

While t
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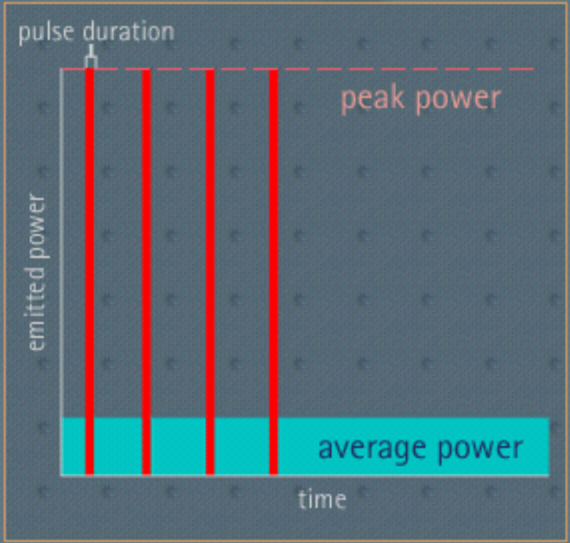
The peak power is defined as the maximum power achievable in a single pulse.

For a pulsed laser system the [energy] of a pulse is therefore more significant than the average power.

The shorter the time interval in which a certain energy is emitted the higher the [peak power].



PREVIOUS

NEXT

The peak power can exceed the average power by many orders of magnitude.

The radiation emitted by a laser is characterized by its wavelength and its [power].

While the [average power] of a pulsed laser is usually low, the [peak power] which is achieved in short single pulses can be much higher.

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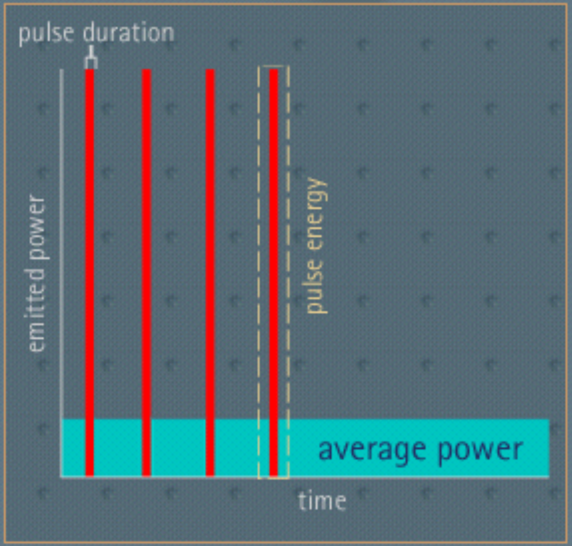
energy is

The energy of a pulse is equivalent to the power which is emitted over a certain period of time. Energy is measured in Joules (J) and varies by many [orders of magnitude].
1 Joule = 1 Watt x 1 second (1 J = 1 Ws)



PREVIOUS NEXT

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While the [average power] of a pulsed laser is usually low, the [peak power] which is achieved in short single pulses can be much higher.

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The energy of a pulse is equivalent to the power which is emitted over a certain period of time.
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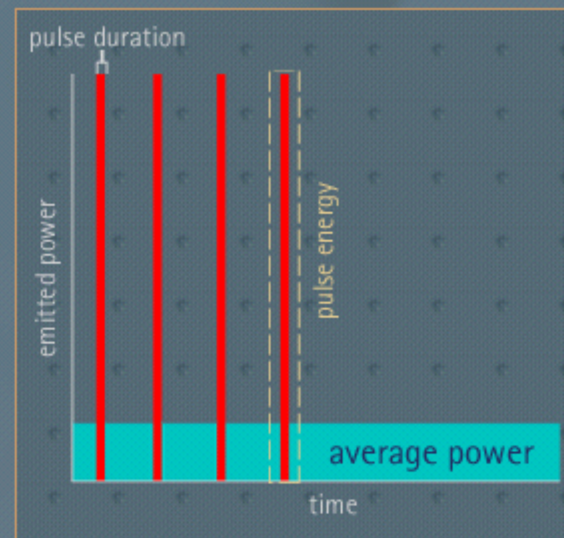
1 millijoule (mJ)	= 0.001 J
1 microjoule (µJ)	= 0.000 001 J
1 nanojoule (nJ)	= 0.000 000 001 J
1 kilojoule (kJ)	= 1 000 J



PREVIOUS NEXT

The peak power can exceed the average power by many orders of magnitude.

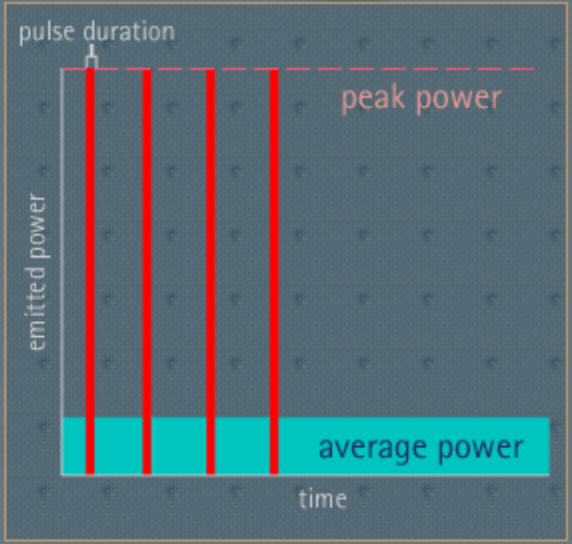
The radiation emitted by a laser is characterized by its wavelength and its [power].

While the [average power] of a pulsed laser is usually low, the [peak power] which is achieved in short single pulses can be much higher.

For a pulsed laser system the [energy] of a pulse is therefore more significant than the average power.

The shorte
energy is

Assuming that the same amount of energy were emitted in shorter and shorter pulses the peak power would increase more and more.



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Examples

A light bulb consumes an electrical input power of 60 Watts (W). 60 Watts consumed in 1 second is equivalent to an energy of 60 Wattseconds (Ws) which is the same as 60 Joules (J).
Continuous use of 60 Watts over a period of 1 hour (3600 seconds) is equivalent to an energy of 216 000 Wattseconds (Ws) which is the same as 216 000 Joules (216 kJ).

Operating an electric oven (average power 2 kW) over a period of 1 hour (3600 seconds) is equivalent to the consumption of 2 kilowatthours (2 kWh = 7200 kWs) which is the same as 7200 kJ or 7.2 megajoules (MJ).

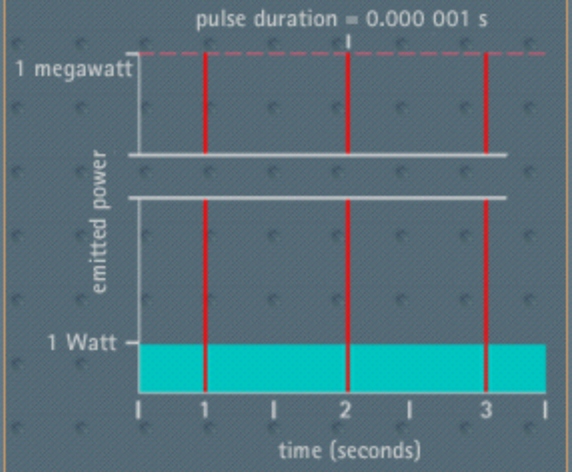
An Ar^+ laser emits an average power of 5 Watts (W). 5 Watts emitted in 1 second is equivalent to an energy of 5 Wattseconds (Ws) which is the same as 5 Joules (J).
Continuous emission of 5 Watts over a period of 1 hour (3600 seconds) is equivalent to an energy of 18 000 Wattseconds (Ws) which is the same as 18 000 Joules (18 kJ).

Power

The average output power of a pulsed laser is calculated by multiplying pulse energy by pulse-repetion rate.

If a pulsed laser emits an energy of 1 Joule at a pulse-repetition rate of 1 pulse per second (1 Hz), the average power is 1 Joule per second (J/s) = 1 Watt . For a pulse-repetition rate of 2 Hz, the corresponding average output power would be 2 Watts.
The average output power does not depend on the pulse duration.

The peak output power is [calculated] by deviding the energy per pulse by the pulse duration.



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Power

The average output power of a pulsed laser is calculated by multiplying pulse energy by pulse-repetion rate.

If a pulsed laser emits an energy of 1 Joule at a pulse-repetition rate of 1 pulse per second (1 Hz), the
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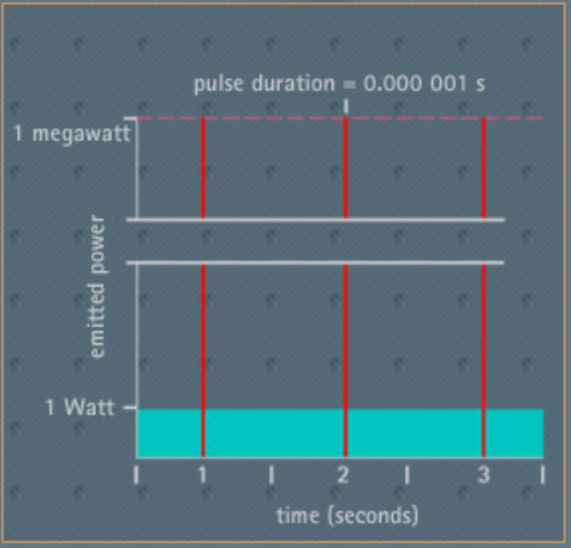
Thus, the peak power of the above laser may be much higher than its average power if the energy is emitted in a very short pulse.

A pulse duration of 1 microsecond (0.000 001 s) corresponds to a peak output power of 1 000 000 W (1 megawatt), a pulse duration of 1 nanosecond (0.000 000 001 s) corresponds to a peak output power of 1 000 000 000 W (1 gigawatt).
The shorter the pulse, the higher the peak power.

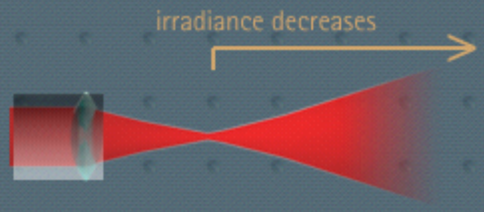


PREVIOUS NEXT

The beam concentration has its maximum at the focal point.

How a laser affects a tissue sample depends – apart from wavelength, power and exposure duration- on the [size] of the irradiated spot.

When a laser beam strikes a surface, the effects are determined by the [irradiance] or the [radiant exposure]. Both decrease with increasing distance between the laser and the irradiated tissue, as the beam spreads with increasing distance from the focal zone.



The beam concentration has its maximum at the focal point.

The smaller the irradiated area, the stronger the effect.
The maximum effect is achieved in the focal zone.

m of the irradiated spot.

When a laser beam strikes a surface, the effects are determined by the [irradiance] or the [radiant exposure]. Both decrease with increasing distance between the laser and the irradiated tissue, as the beam spreads with increasing distance from the focal zone.

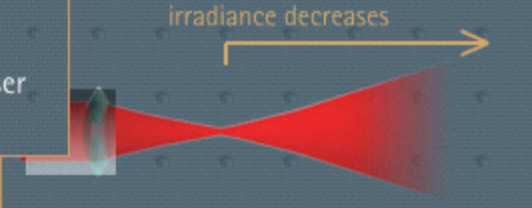
PREVIOUS NEXT

The beam concentration has its maximum at the focal point.

How a laser affects a tissue sample depends – apart from

The irradiance corresponds to the power that is deposited in a unit surface area. It is measured in Watts per square centimeter (W/cm^2). The irradiance is the relevant unit when describing cw-laser beams interacting with tissue.

Both decrease with increasing distance between the laser and the irradiated tissue, as the beam spreads with increasing distance from the focal zone.



PREVIOUS

NEXT

The beam concentration has its maximum at the focal point.

How a laser affects a tissue sample depends – apart from wavelength, power and exposure duration– on the [size] of the irradiated spot.

When a laser beam strikes a surface, the effects are

The radiant exposure corresponds to the energy that is deposited in a unit surface area. It is measured in Joules per square centimeter (J/cm^2). The radiant exposure is the relevant unit when describing pulsed lasers interacting with tissue.

PREVIOUS

NEXT

What is your estimate?

An Ar^+ laser emits a constant power of 1.5 W. The beam is focused onto a circle-shaped area measuring 2 mm in diameter. (this corresponds to an area of 0.03 cm^2)
How high is the irradiance in that area ?

[1.5 W/m^2] [approx. 5000 W/m^2] [approx. 50 000 W/m^2] [approx. 500 000 W/m^2]

What is your estimate?

An Ar^+ laser emits a constant power of 1.5 W. The beam is focused onto a circle-shaped area measuring 2 mm in diameter. (this corresponds to an area of 0.03 cm^2)
How high is the irradiance in that area ?

[1.5 W/m^2] [approx. 5000 W/m^2] [appro

Correct ! 1.5 W are focused onto an area of only 0.03 cm^2, the irradiance amounts to 48 W/cm^2 (480 kW/m^2).

PREVIOUS NEXT