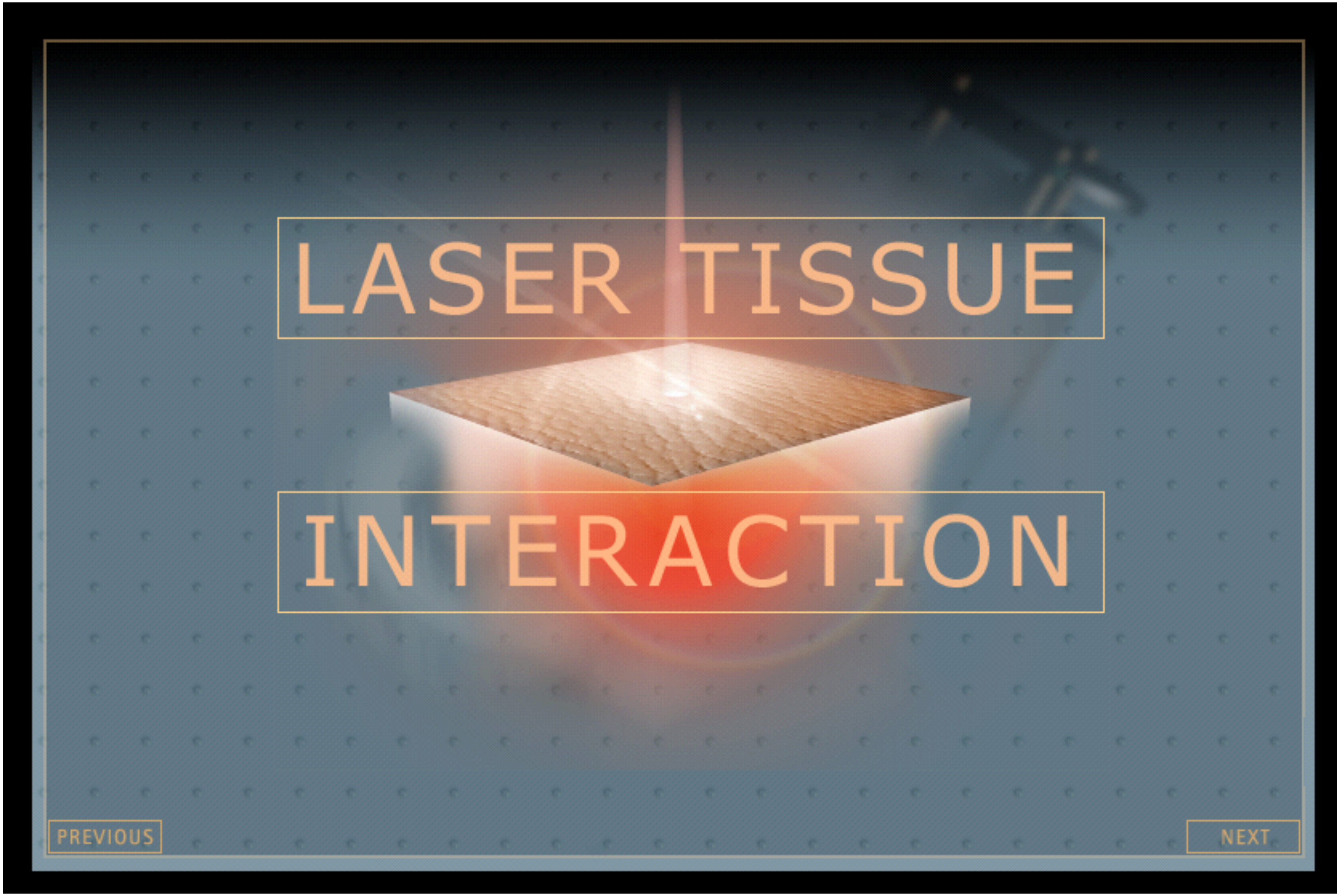
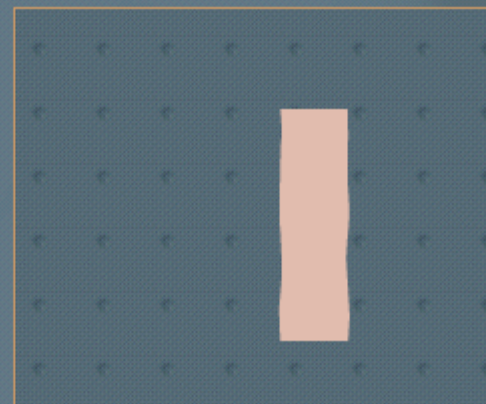

LASER TISSUE
INTERACTION
PREVIOUS
NEXT

Different types of tissue have different optical properties.

When electromagnetic radiation irradiates biological tissue, the optical properties of that tissue result in absorption, transmission, reflection or scattering of that radiation.

The wavelength of the radiation and the composition of the tissue are the main factors which determine the fractions of [absorbed], [transmitted], [reflected] and [scattered] radiation.



PREVIOUS

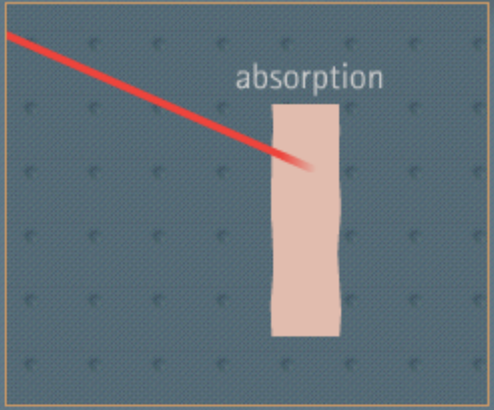
NEXT

Different types of tissue have different optical properties.

When electromagnetic radiation irradiates biological tissue, the optical properties of that tissue result in absorption, transmission,

[scattered] radiation.

Absorption means that the energy of the radiation is received and transformed by the tissue. Different tissues absorb different wavelengths of the electromagnetic spectrum.



PREVIOUS

NEXT

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When electromagnetic radiation irradiates biological tissue, the optical properties of that tissue result in absorption, transmission, reflection or scattering of that radiation.

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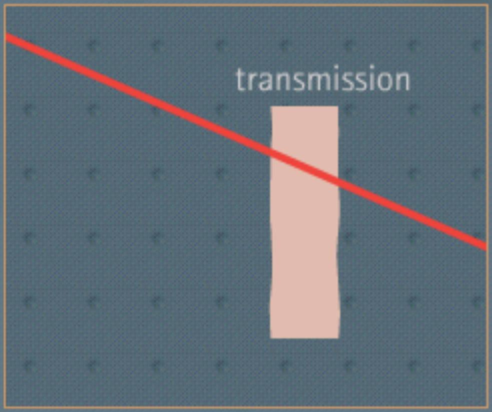
Transmission means that the radiation can pass through the tissue. Different tissues transmit different wavelengths of the electromagnetic spectrum.



PREVIOUS

NEXT

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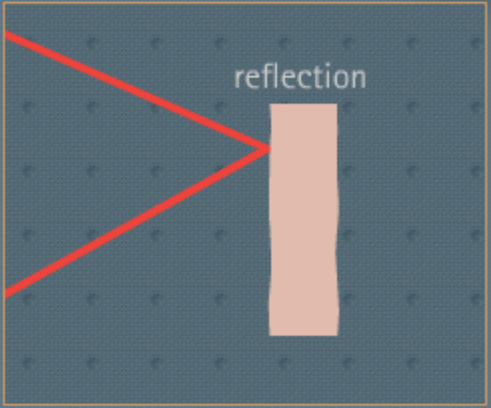
If radiation is neither transmitted nor absorbed it is scattered or reflected, i.e., deviated following its incidence on a surface.



PREVIOUS

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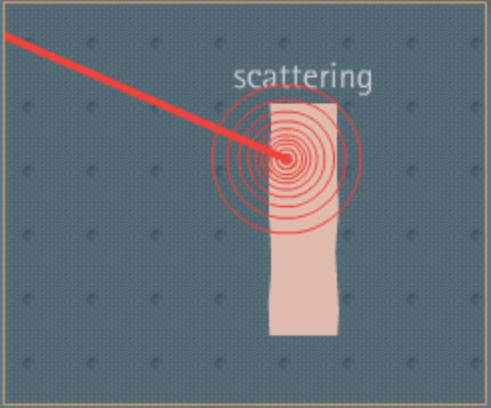
An incident electromagnetic wave is often scattered, i.e., the direction changes before it is finally transmitted, absorbed or reflected. Thus, radiation reflected from tissue originates from the respective surface as well as from scattering by underlying layers.



Absorption leads to an increase in tissue temperature.

If a tissue absorbs radiation, energy is actually absorbed. Each type of tissue has [characteristic properties] of absorption which determine the fraction of the optical spectrum absorbed.

Absorption leads to a localized temperature [increase] in the tissue. This thermal energy spreads into neighboring regions by a process known as [heat conduction]. The thermal conductivity of the tissue determines how fast this transport takes place.

PREVIOUS NEXT

Absorption leads to an increase in tissue temperature.

If a tissue abso
absorbed. Each
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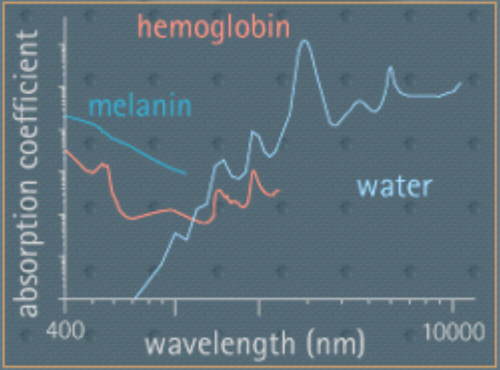
absorbed.

Since many tissues consist mainly of water, their absorption properties for infrared wavelengths are dominated by the optical properties of water. At shorter wavelengths, the absorption process is dominated by the optical properties of melanin and hemoglobin.



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The temperature rise depends on the amount of energy absorbed before cooling takes place. Very low irradiances cause little change. The circulation of blood has a cooling effect.

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PREVIOUS NEXT

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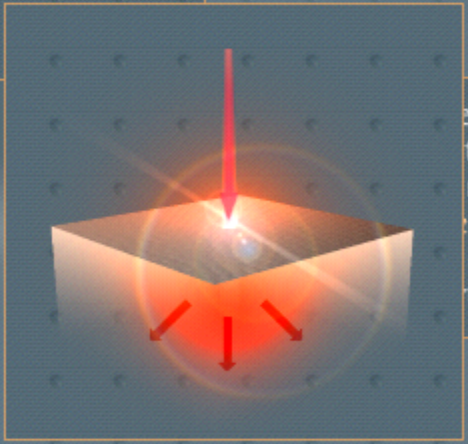

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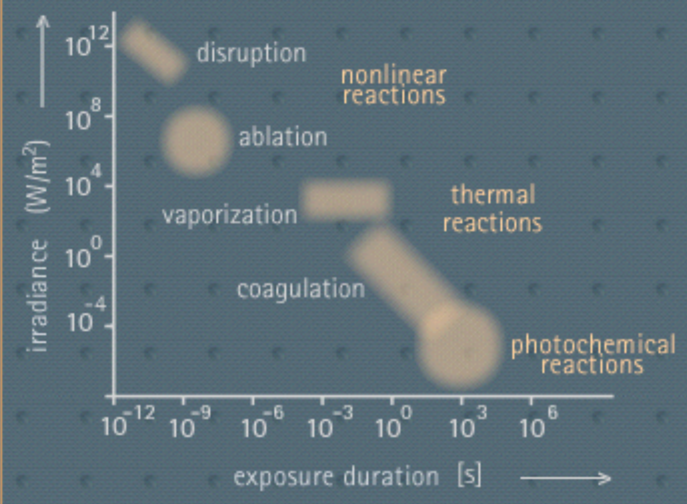
The absorption process depends on irradiance and wavelength.

The irradiance determines how the tissue reacts to the irradiation.
At low irradiances, [photochemical reactions] will dominate at shorter wavelengths.

With increasing irradiance [thermal reactions] dominate. Limited thermal conductivity may affect the deposition of energy into neighboring tissue thus leading to significant rises of local temperature, and [permanent] changes of tissue structure can occur.

Very high irradiances may induce [nonlinear reactions].



The absorption process depends on irradiance and wavelength.

Photochemical is a term assigned to describe chemical reactions induced by exposure to visible light and ultraviolet radiation. A typical example is the process of seeing: a transformation of molecules in the retina after exposure to light.

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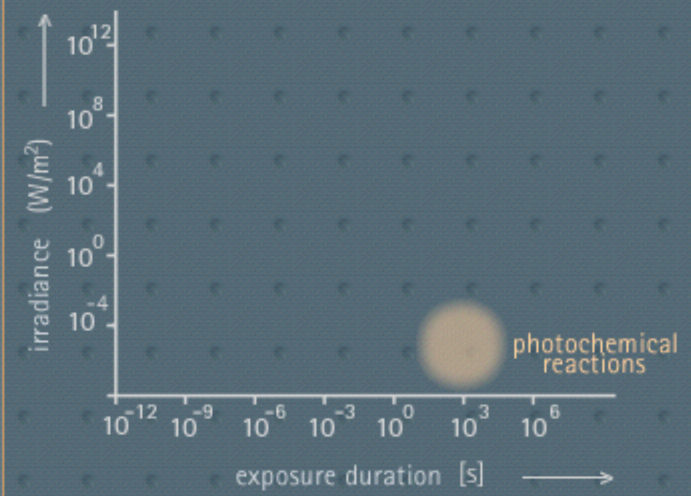

PREVIOUS NEXT

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At low irradiances, [photochemical reactions] will dominate at shorter wavelengths.

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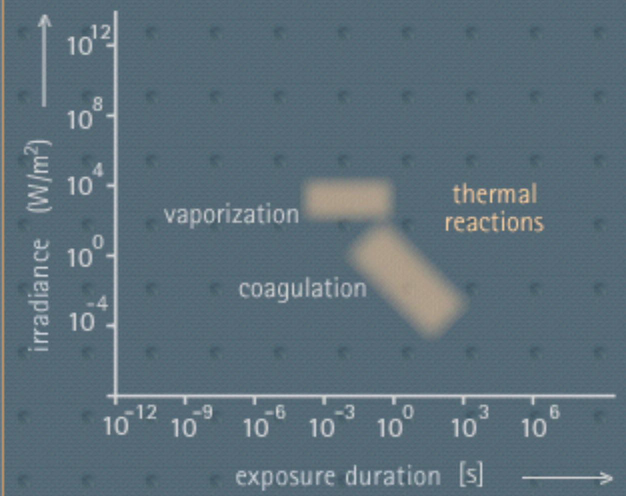

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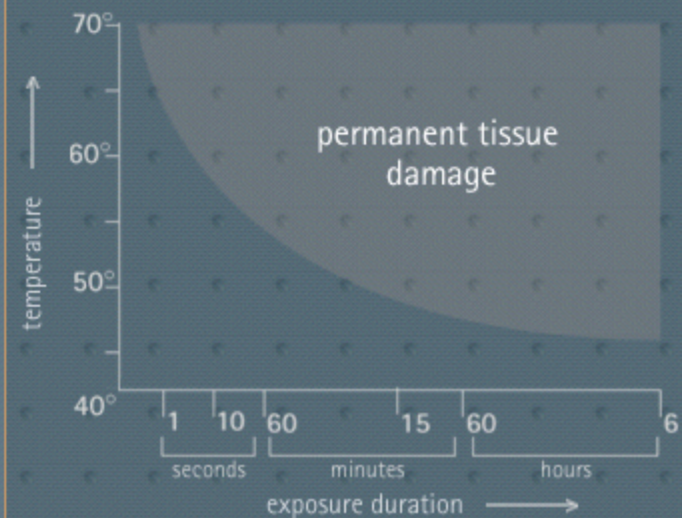
[nonlinear reactions].

There are two critical factors for the alteration of tissue structures: the exposure duration and the maximum temperature. The lower the temperature rises, the longer the tissue survives without any permanent change. Irreversible changes happen when tissue is exposed to temperatures beyond a critical temperature for a sufficient time



PREVIOUS

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Very
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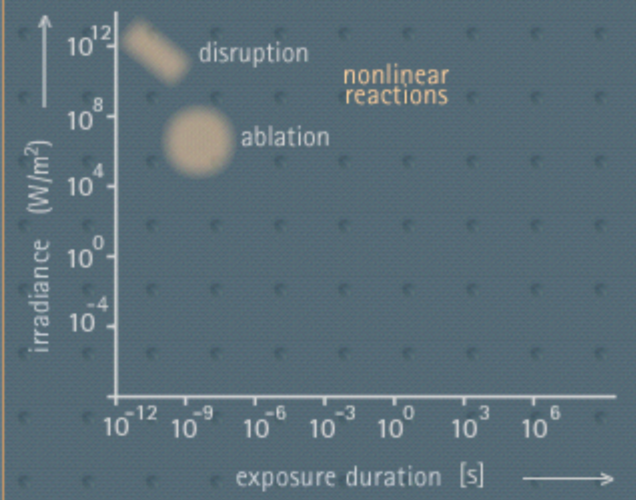
Very high irradiance can prevent tissues from conducting absorbed energy into neighboring regions. Rapid intense temperature rises can induce explosive forces that lead to an instant removal of affected tissue.



PREVIOUS

NEXT

High irradiance can alter tissues.

If the tissue exceeds a certain temperature its structure changes irreversibly. Depending on the exposure duration and the power deposited in the tissue, the following reactions can take place:

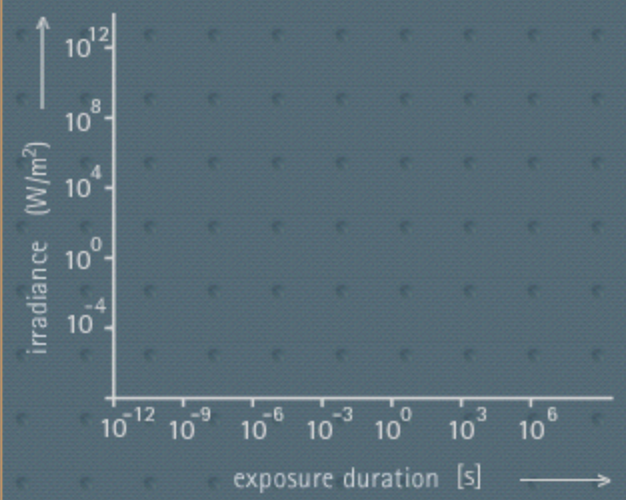
[coagulation]

[carbonization]

[vaporization]

[ablation]

[disruption]



PREVIOUS

NEXT

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If the tissue exceeds a certain temperature its structure changes irreversibly. Depending on the ex
tis

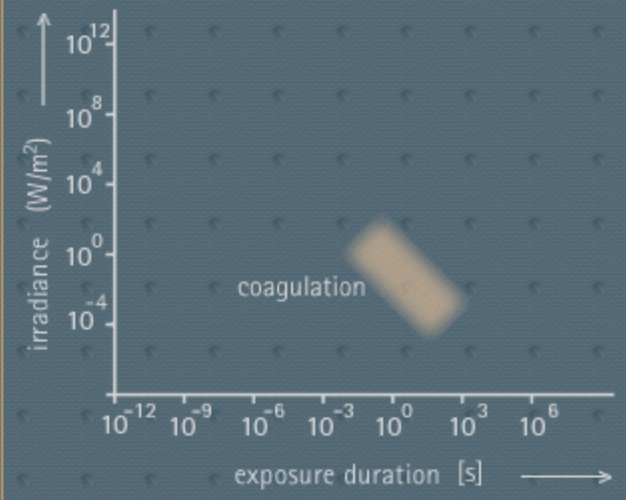
Heating tissue to temperatures between 60 and 100 °C results in its denaturation. Coagulation is frequently used to seal blood vessels.

[carbonization]

[vaporization]

[ablation]

[disruption]



PREVIOUS

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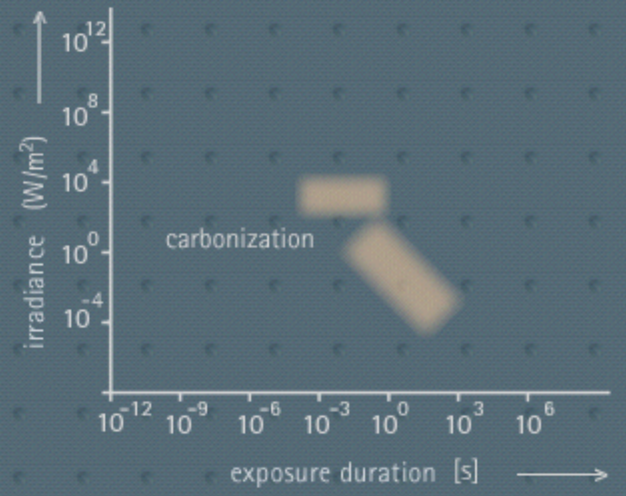
When the temperature rises, tissue dehydrates and eventually gets carbonized. Carbonized tissue has a very low thermal conductivity leading to strongly rising temperatures.

[vaporization]

[ablation]

[disruption]



PREVIOUS

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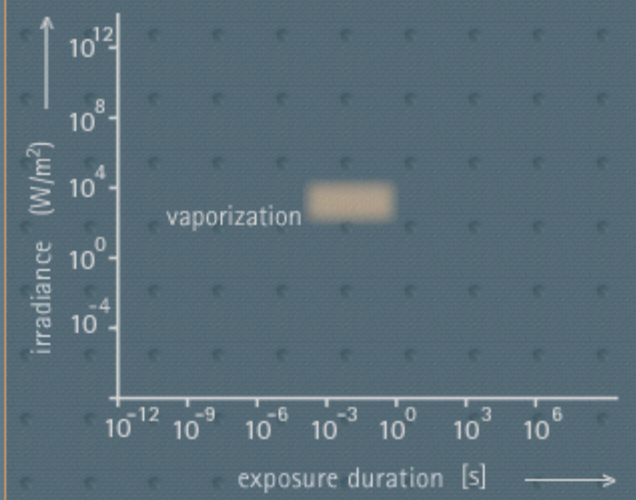
[coagulation]

Low thermal conductivity results in high tissue temperatures which lead to vaporization of water and a removal of microscopic tissue particles.

[ablation]

[disruption]



PREVIOUS

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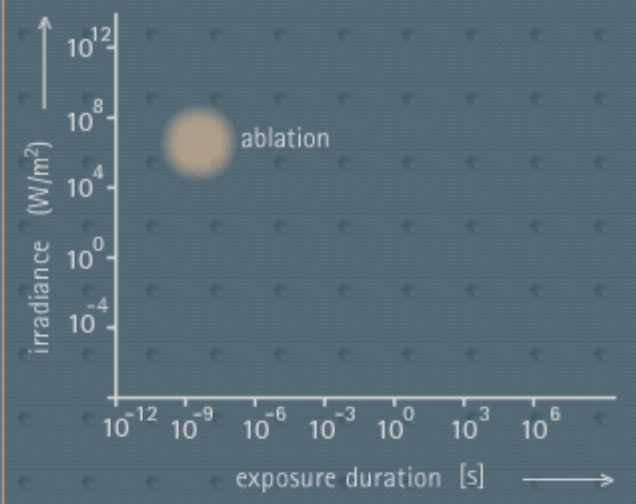
Very fast energy deposition and temperature rises prevent sufficient transport of heat into neighboring tissue. Very high local temperatures create an explosive force that drives tissue particles off the surface. Ablation is achieved when applying very short and intense laser pulses.

[disruption]



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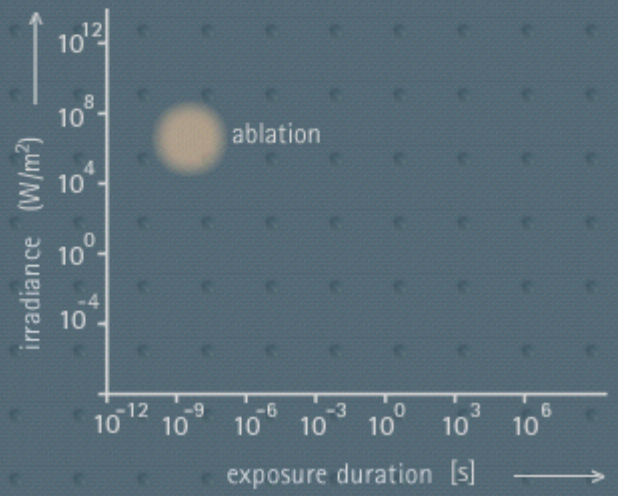


PREVIOUS

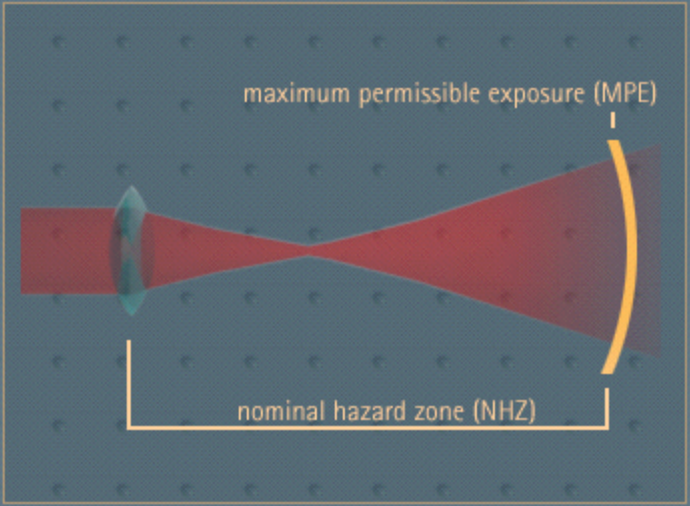
NEXT

The hazard zone is defined by biological limits.

Tissue gets damaged when a certain irradiance is exceeded. This situation can be described by defining a limit: the maximum permissible exposure or [MPE].

Damage does not occur as long as the irradiance does not exceed the MPE.

The irradiance decreases for increasing distances between the laser and the irradiated tissue allowing for a definition of a [hazard zone].



PREVIOUS NEXT

The hazard zone is defined by biological limits.

Maximum permissible exposure limits are different for the eyes and skin in the retinal hazard region. Due to characteristic absorption and thermal properties of tissue such limits are defined according to exposure duration and wavelength.

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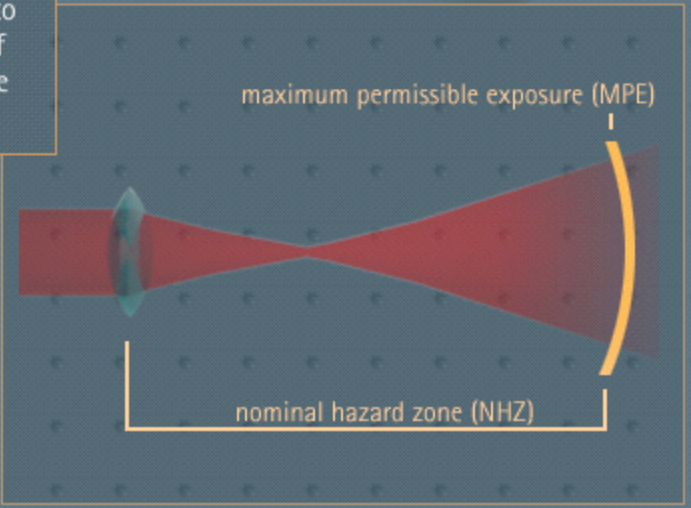

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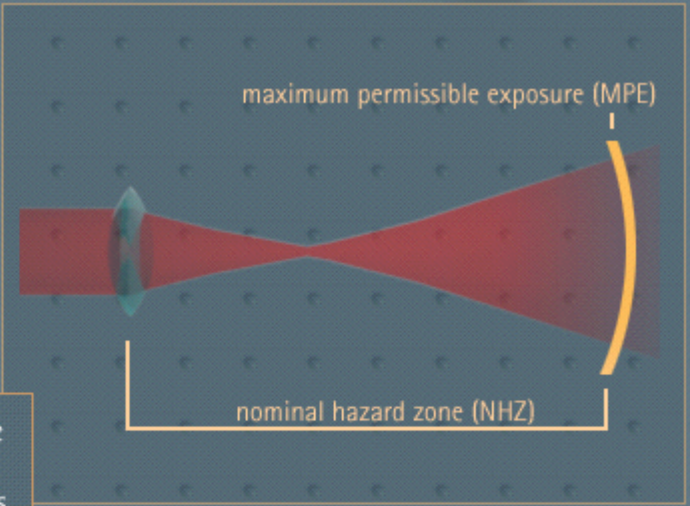
The term NHZ (nominal hazard zone) is assigned to the area where the MPE is exceeded. Since laser radiation can be reflected from surfaces, the NHZ includes areas behind and beside a laser.



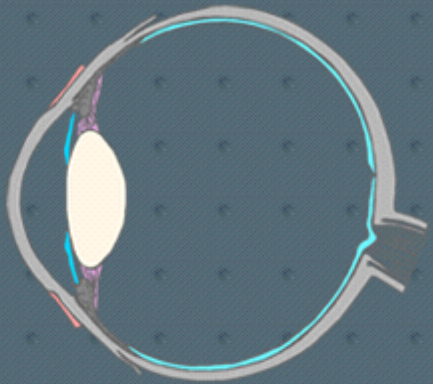
PREVIOUS NEXT

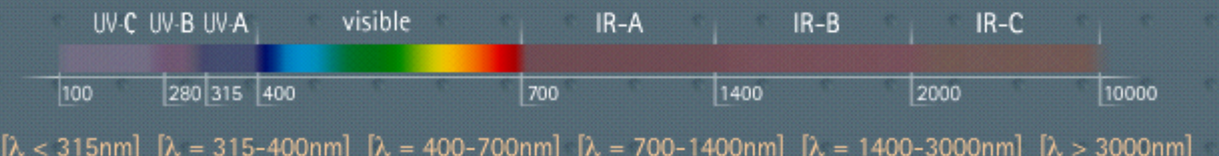
Different wavelengths are absorbed in different parts of the eye.

Different wavelengths are absorbed in different parts of the eye.

The absorbing tissue can be damaged if the irradiance exceeds certain limits.

Permanent vision loss may result.





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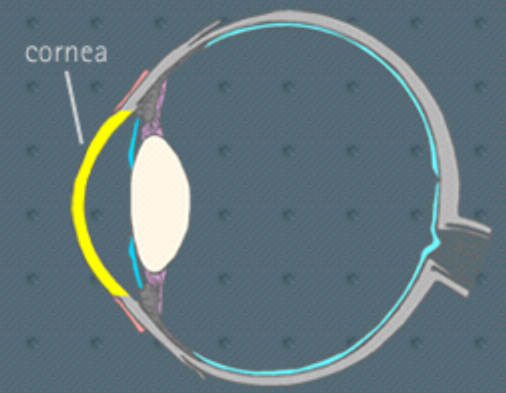

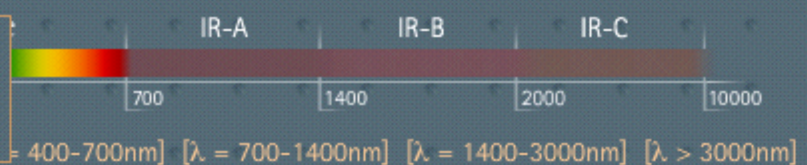

Short wave ultraviolet radiation (UV-B, UV-C) is absorbed predominantly in the cornea; UV-B also reaches the eye lens.

PREVIOUS

NEXT

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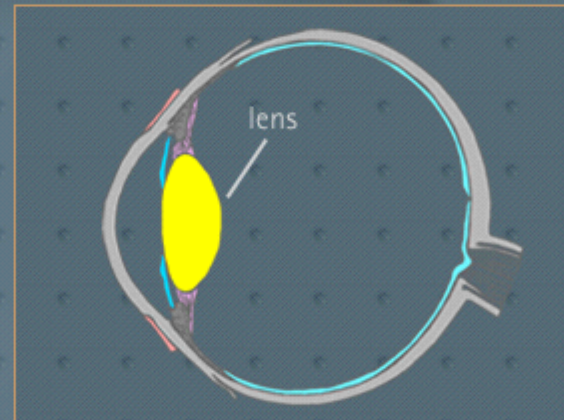

…nm] [λ = 700-1400nm] [λ = 1400-3000nm] [λ > 3000nm]

Near ultraviolet radiation (UV-A) is absorbed principally in the lens which causes it to fluoresce. Very high doses can cause corneal and lenticular opacities.

PREVIOUS

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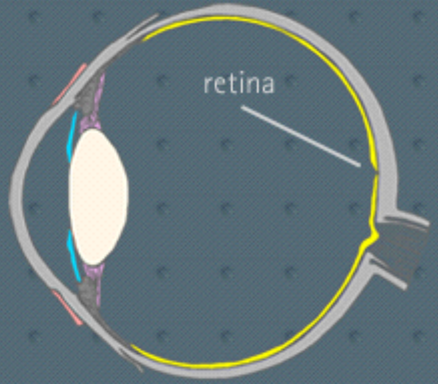
The absorbing tissue can be damaged if the irradiance exceeds certain limits.

Permanent vision loss may result.



Visible light is transmitted by the cornea, lens and vitreous body and is focused onto the retina. The beam diameter becomes very small and the irradiance in the focal zone increases dramatically.

700-1400nm] [λ = 1400-3000nm] [λ > 3000nm]

PREVIOUS

NEXT

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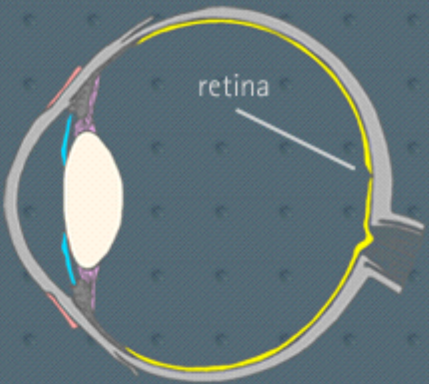
Permanent vision loss may result.



Wavelengths between 700 and 1400 nm are invisible but are still transmitted by the cornea, lens and vitreous body through to the retina. Although these wavelengths are not focused as sharply on the retina, the retinal irradiances nevertheless get very high.

PREVIOUS

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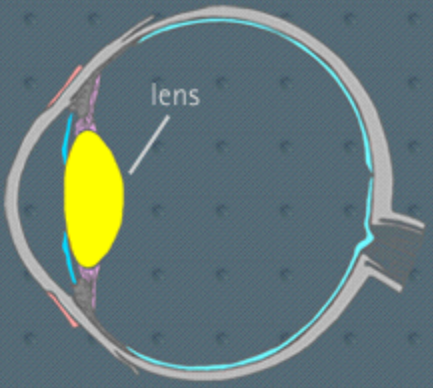
The absorbing tissue can be damaged if the irradiance exceeds certain limits.

Permanent vision loss may result.



[λ < 315nm] [λ = 315-400nm] [λ = 400-700nm] [λ = 700-14

Wavelengths between 1400 and approximately 3000 nm are not transmitted through to the retina but are absorbed in the cornea and the front parts of the eye.

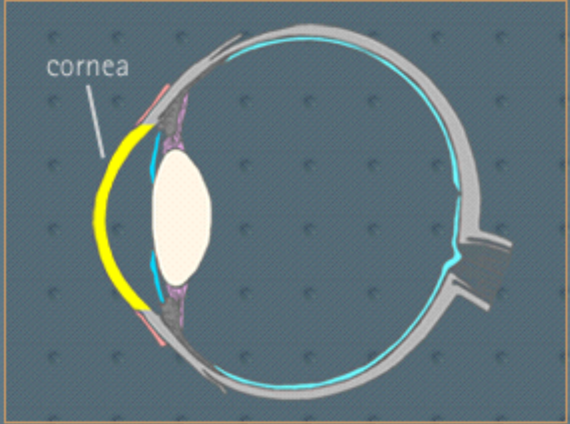
PREVIOUS NEXT

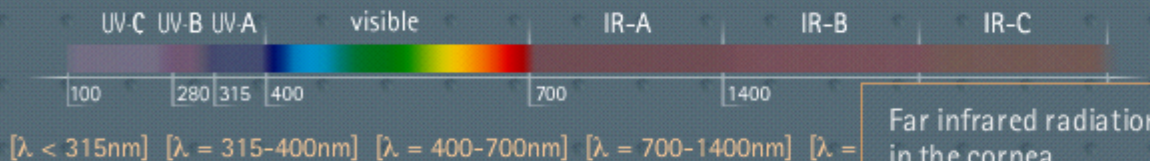
Different wavelengths are absorbed in different parts of the eye.

Different wavelengths are absorbed in different parts of the eye.

The absorbing tissue can be damaged if the irradiance exceeds certain limits.

Permanent vision loss may result.





Far infrared radiation is absorbed in the cornea.

PREVIOUS

NEXT

The irradiance on the retina can reach very high values!

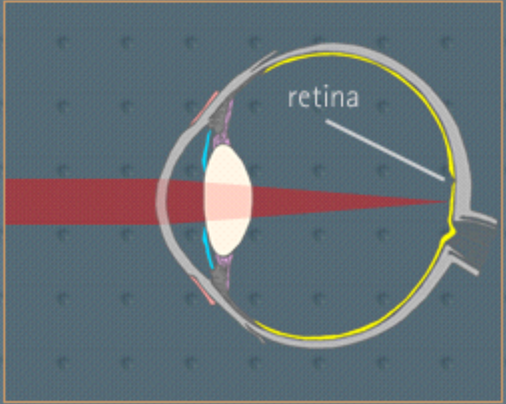
Example:

Imagine a laser beam with a diameter of 7 mm and a power of 1 milliwatt (mW). Passing through the pupil (which has a diameter of up to 7 mm), the beam is focused onto the retina with the focal zone measuring about 10 - 20 micrometers (µm) across. The beam diameter decreases by a factor of 350-700.

The irradiance is 2.5 mW/cm^2 on the cornea.

On the retina the irradiance amounts to about 300 to 1200 W/cm^2.

Thus, the irradiance increases by a factor of more than 100 000 !



PREVIOUS

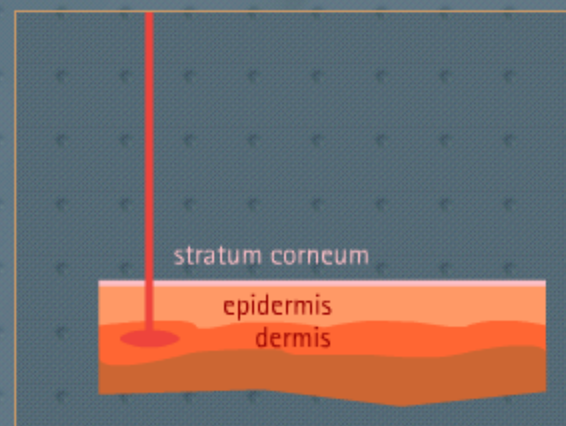
NEXT

Different wavelengths penetrate into different skin layers.

Different wavelengths are absorbed in different skin layers.

Red light and near infrared radiation penetrate deeply into the skin.

Laser radiation can cause serious skin damage.



PREVIOUS

NEXT

Different wavelengths penetrate into different skin layers.

Short ultraviolet wavelengths (UV-C) are mainly absorbed in the stratum corneum but can also reach the epidermis.

[λ < 280nm] [λ = 280-400nm] [λ = 400-1400] [λ > 1400nm]

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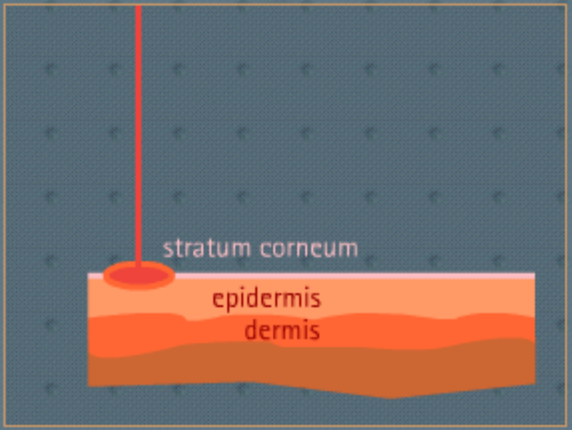

PREVIOUS NEXT

Different wavelengths penetrate into different skin layers.

Ultraviolet radiation with longer wavelengths (UV-B, UV-A) is mainly absorbed in the epidermis but can also reach the dermis.

[λ < 280nm] [λ = 280-400nm] [λ = 400-1400] [λ > 1400nm]

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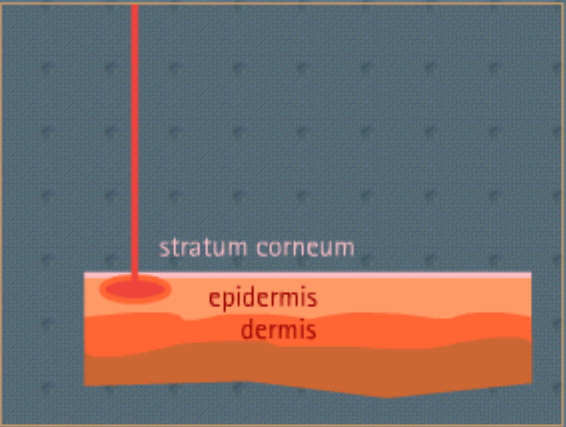

PREVIOUS

NEXT

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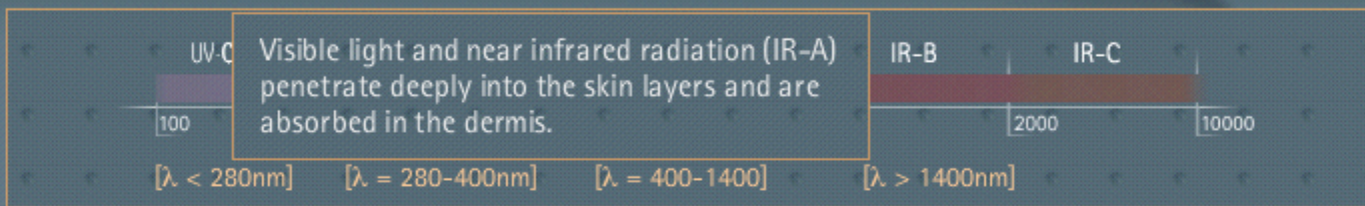

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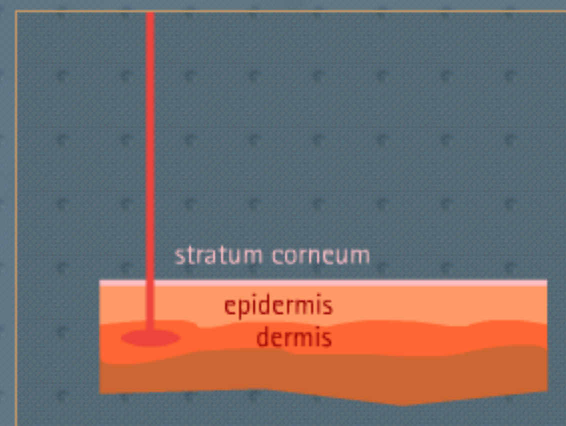


PREVIOUS NEXT

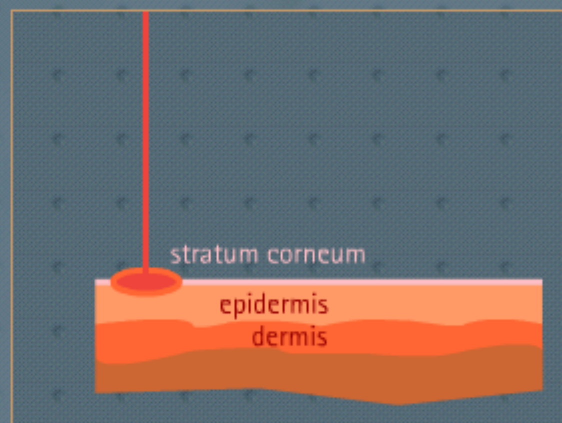
Different wavelengths penetrate into different skin layers.

Long infrared wavelengths (IR-B, IR-C) are absorbed in the skin surface.

Different wavelengths are absorbed in different skin layers.

Red light and near infrared radiation penetrate deeply into the skin.

Laser radiation can cause serious skin damage.



PREVIOUS

NEXT

Different laser parameters cause different results.

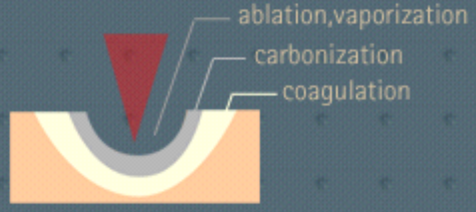
The choice of wavelength, irradiance, pulse duration and pulse-repetition rate will determine the structure and extent of tissue damage.

At the target site, tissue reaction corresponds to the amount of energy absorbed.

Therefore, different layers of tissue may react in different ways: while the tissue surface may be vaporized, neighboring tissue may become coagulated.

Pulsed lasers and cw-lasers will affect tissue differently due to different durations of exposure as well as corresponding peak power.

continous wave laser



pulsed laser

PREVIOUS

NEXT