Minimum invasive operative treatment by laser

Laser :

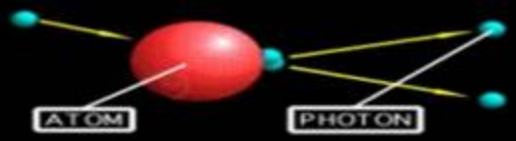
L=Light

a = amplified

s = stimulated

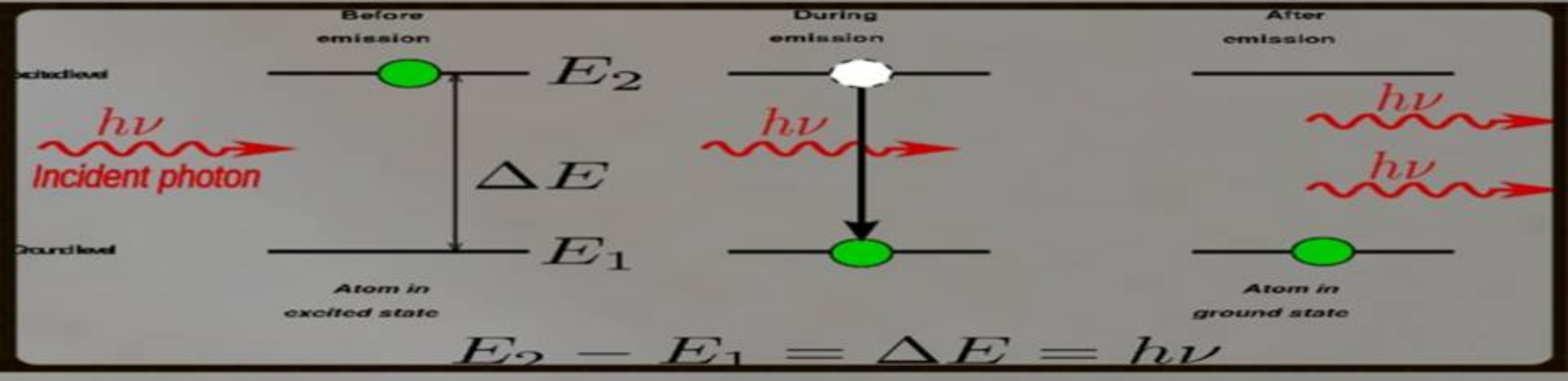
e = emition

r = radiation



S – Stimulated E-Emission

- If an atom in the excited state is struck by a photon of identical energy as the photon to be emitted, the emission could be stimulated to occur earlier than would occur spontaneously. This stimulated interaction causes two photons that are identical in frequency and wavelength to leave the atom.

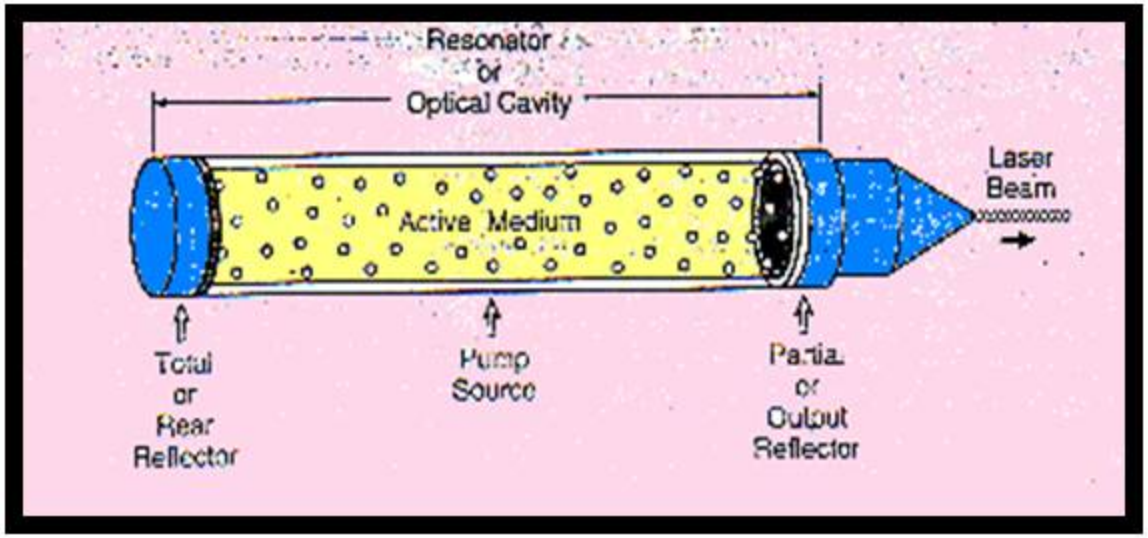


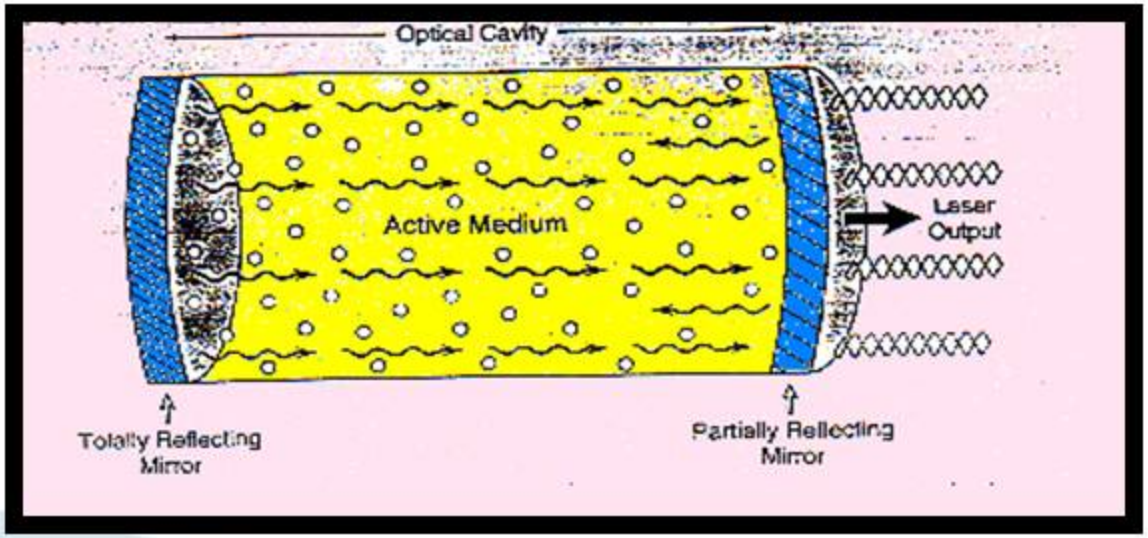
Laser apparatus:

A-Lasing media

B-Optical resonators

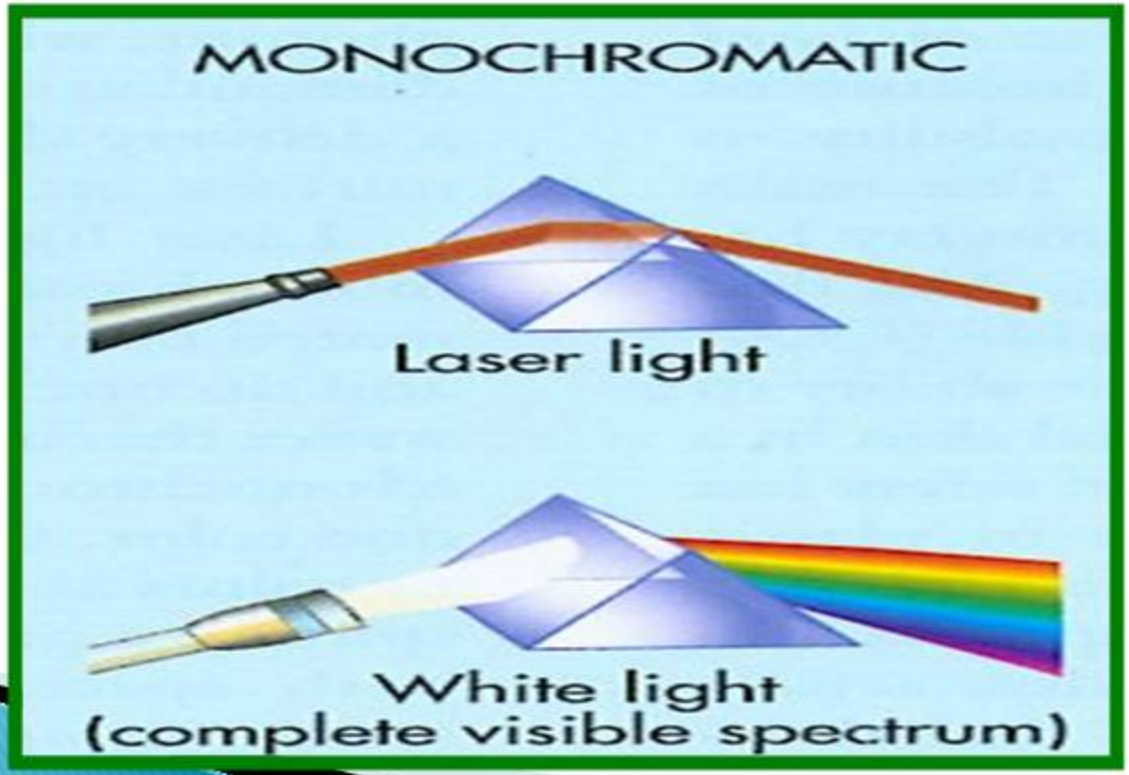
C-Energy source



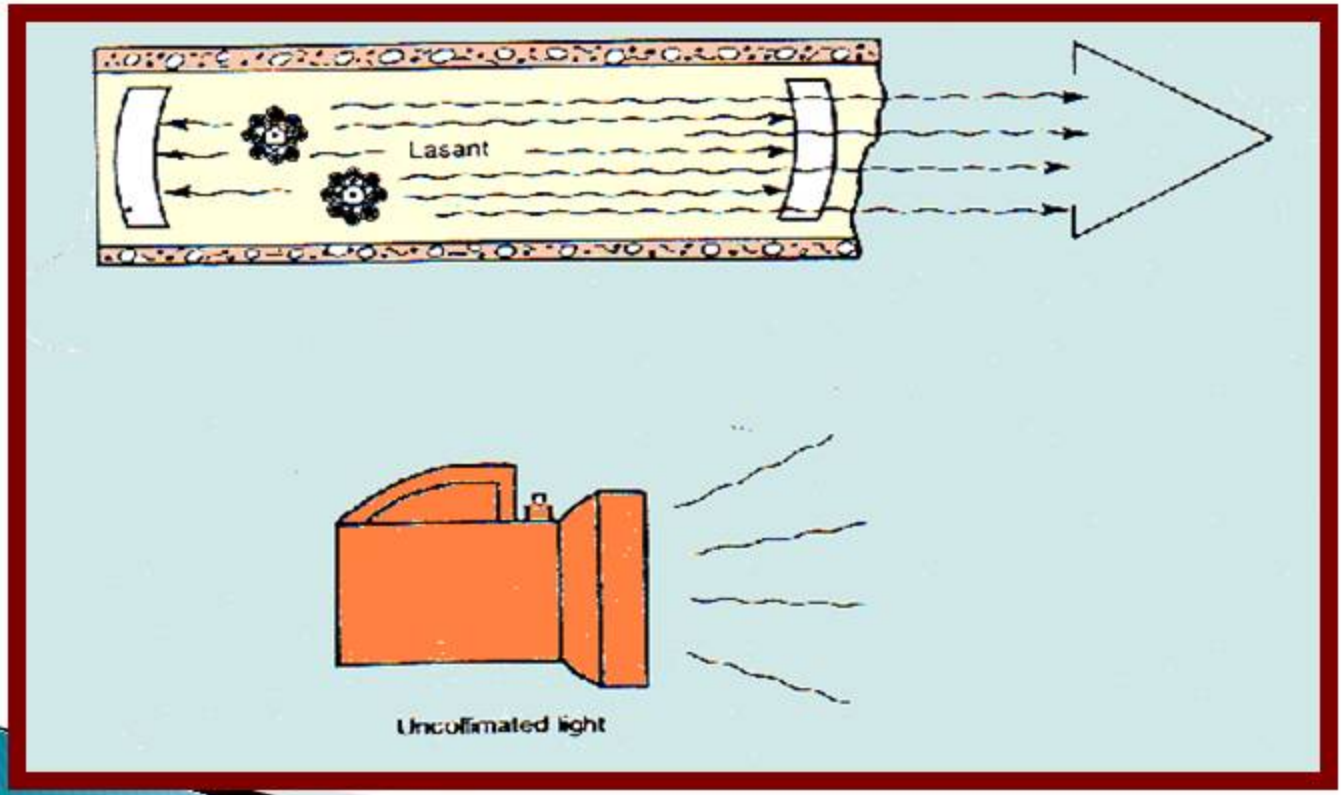


Properties of laser light:

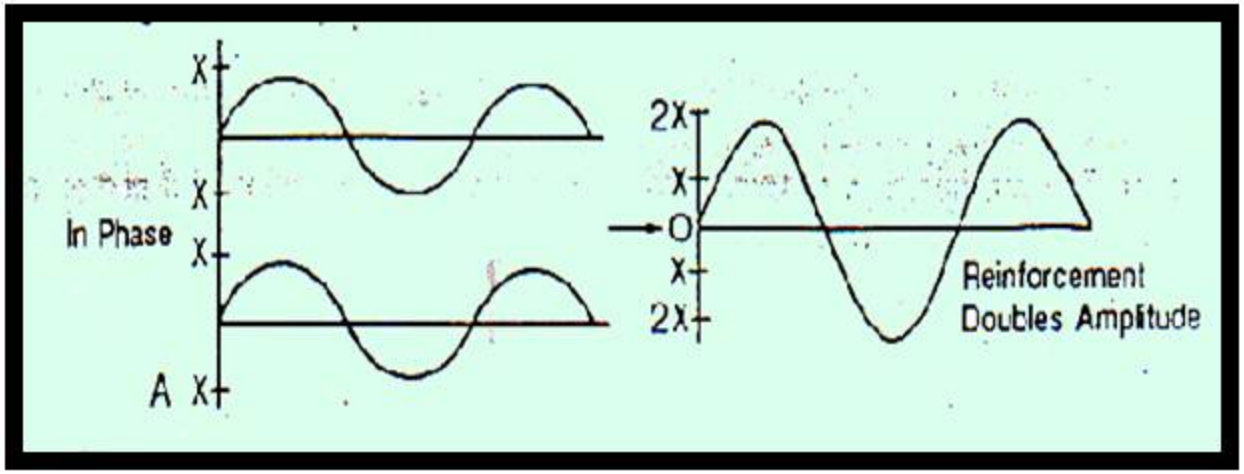
1-Monochromaticity

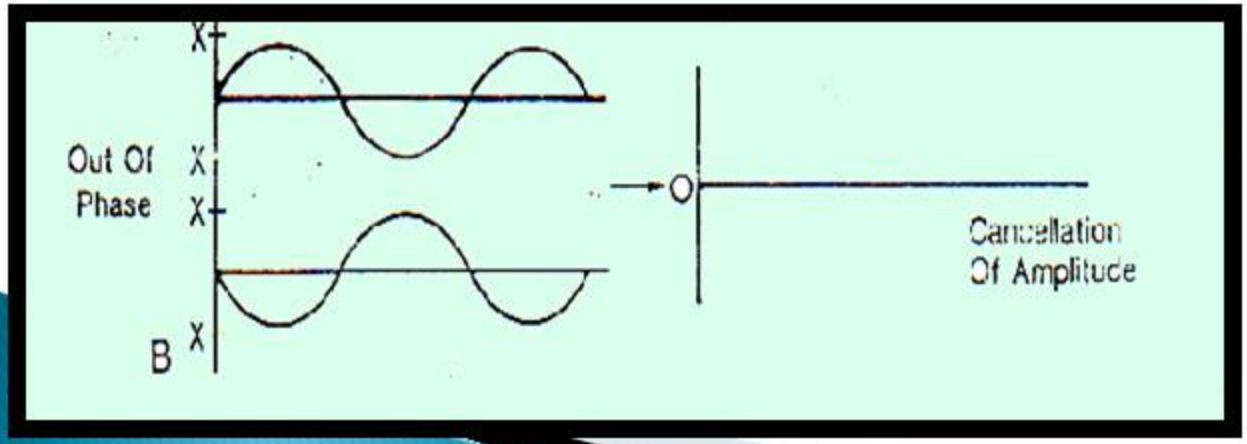


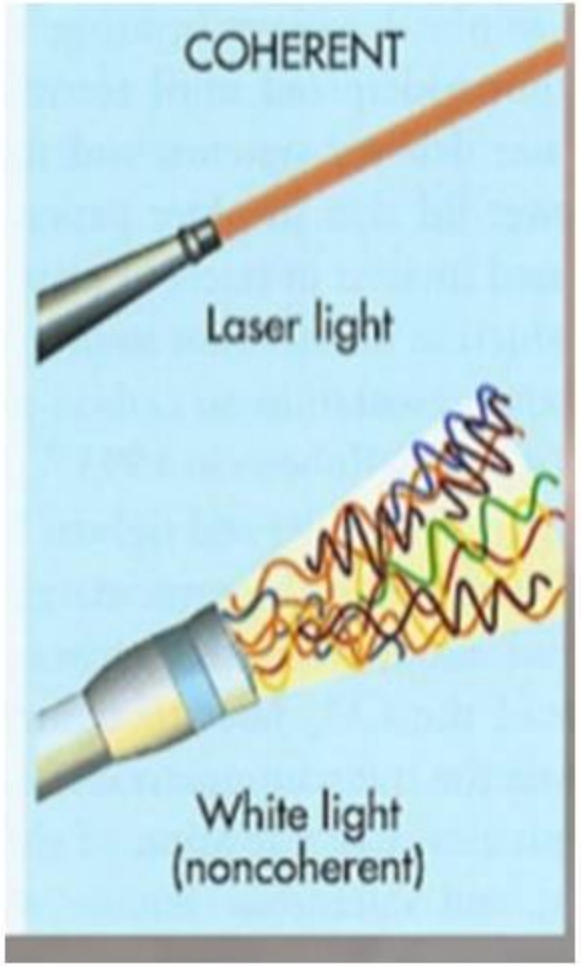
2-Directionally



3-Coherence


X
X
X
In Phase
A X
2X
X
O
X
2X
Reinforcement
Doubles Amplitude

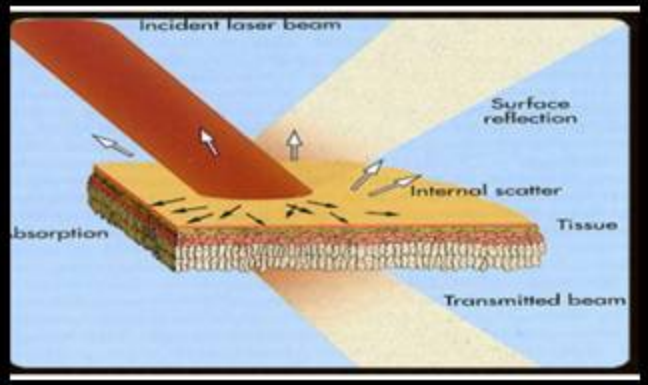

X
Out Of
Phase
X
X
B X
O
Cancellation
Of Amplitude

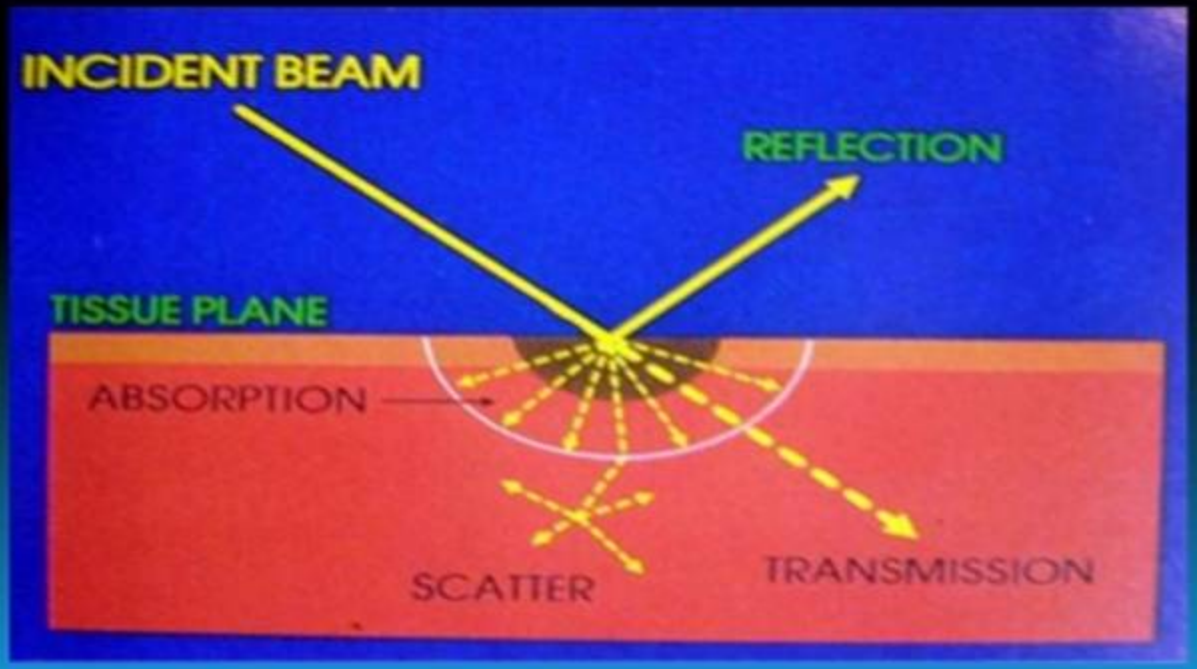

COHERENT
Laser light
White light
(noncoherent)

4-Brightness

Laser interaction with biologic tissues

- Four different interaction
  - Reflection
  - Scatter
  - Absorption
  - Transmission





(1) Photochemical (Photochemolysis):

- Fluoresce : Certain biological pigments, upon absorbing laser light, can fluoresce, which can be used for detecting teeth caries.

- Photodynamic interaction : in which a 635nm laser used to activate a dye solution of tolonium chloride placed in a carious cavity or root canal. Activation of the tolonium chloride releases oxygen species which disrupt the membranes of micro-organisms found in caries, periodontal pockets and root canals.

(2) Photothermal :

- light energy absorbed by the tissues is transformed into heat energy which then produces tissue effects as follows:

  Coagulation and haemostasis: from 60oC to 70oC

  Photopyrolysis: from 65oC to 90oC, target tissue proteins undergo permanent morphological change (protein denaturation) as result of dissociation of covalent bonds.

(3) Photovaporolysis:

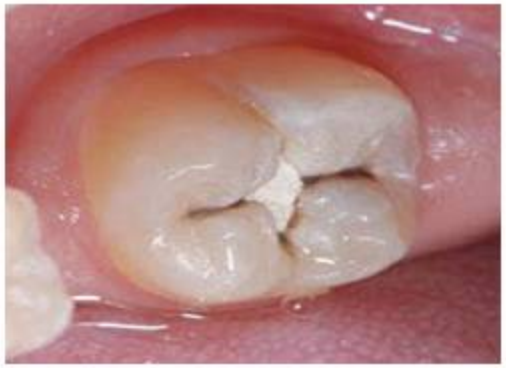
at 100oC +, inter- and intra-cellular water in soft tissue and interstitial water in hard tissue is vaporised. This destructive phase transfer results in expansive volume change, which can aid the ablative effect of the laser by dissociating large tissue elements. This will be carried onto a further phase: transfer to hydrocarbon gases and production of residual carbon (carbonization)

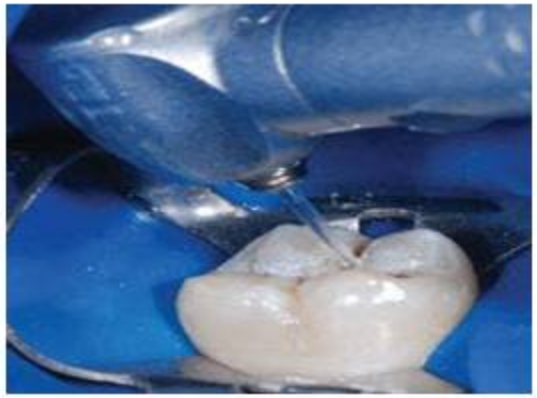
1-Selective caries removal

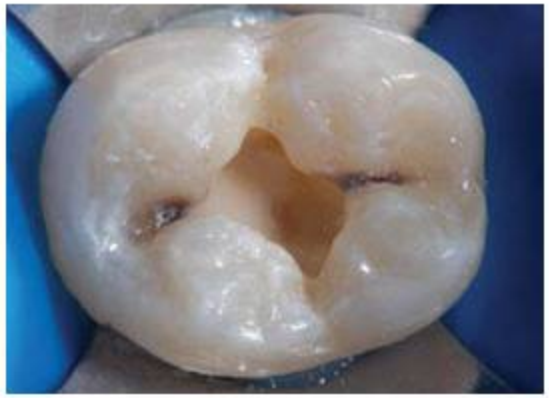
- Wavelengths close to 3000 nm, such as those emitted by the erbium lasers, are close to the main absorption peak of water and hydroxyapatite, and therefore they have been demonstrated to be effective for cutting soft and hard (enamel, dentin, and alveolar bone) tissues. The erbium lasers are Er:YAG

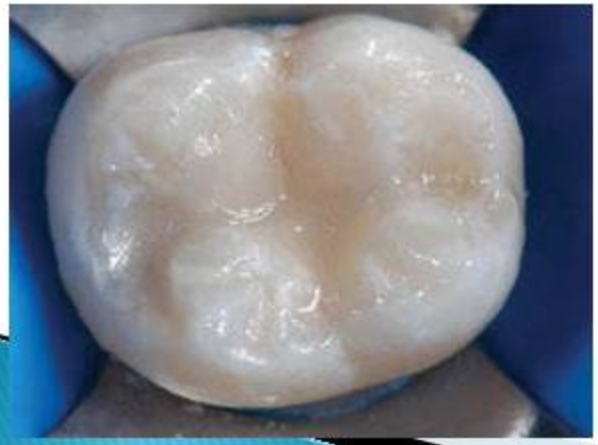
(erbium:yttrium-aluminum-garnet, 2940 nm) and Er,Cr:YSGG (erbium, chromium:yttrium-scandium-gallium-garnet, 2780 nm).(Bader and krejci 2006)

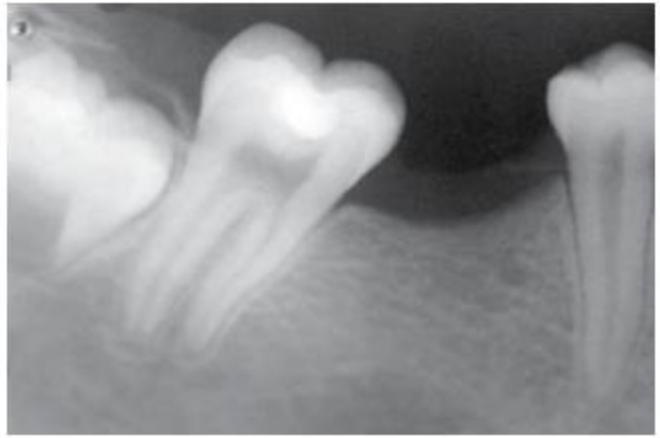
Erbium lasers (2940 nm and 2780 nm) are interesting alternatives for selective removal of carious tissue and cavity preparation.











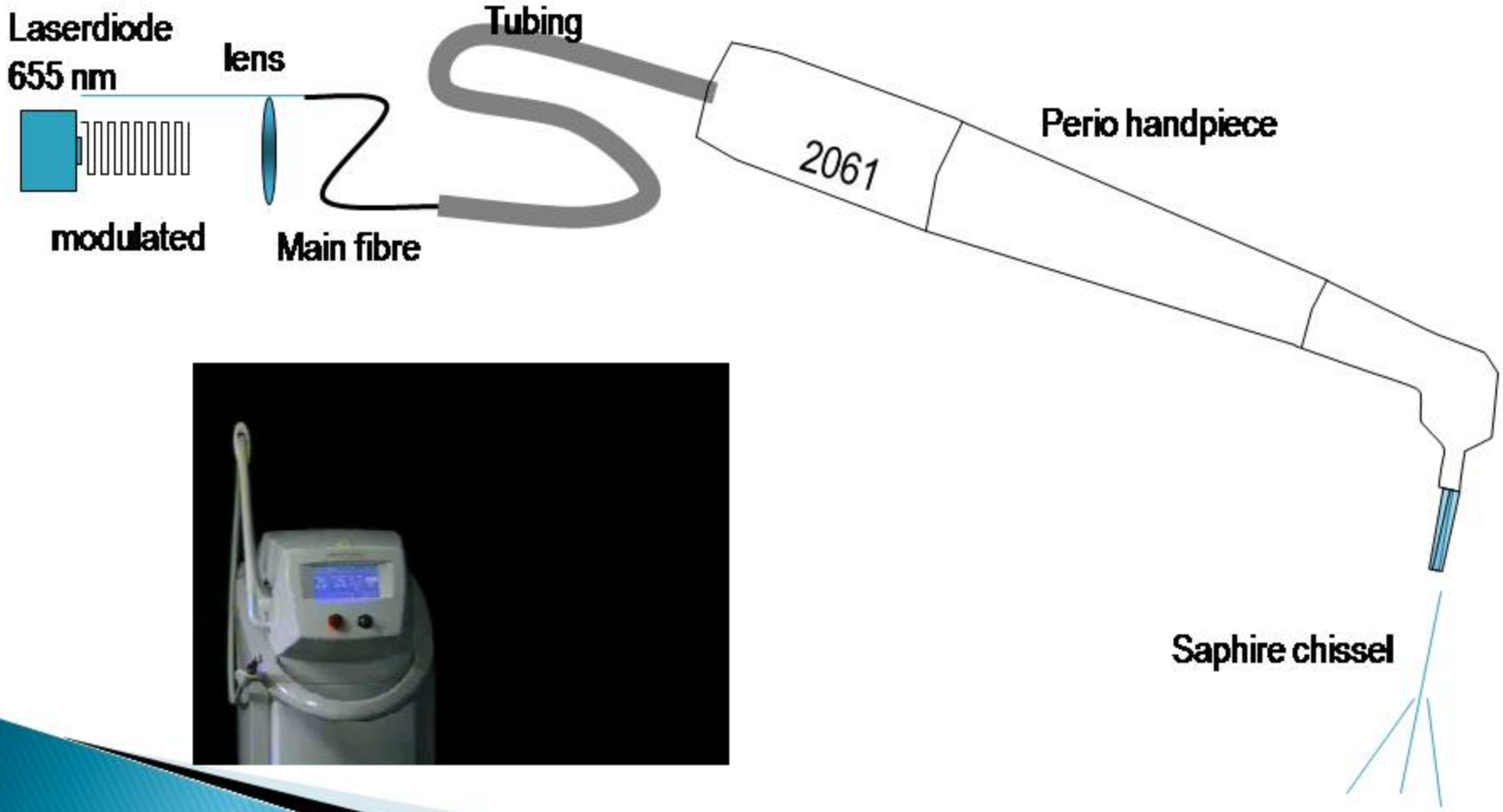
How do Er:YAG and Er,Cr:YSGG lasers remove dental hard tissue?

Thermomechanical ablation:

During this process, the infrared laser energy is absorbed by the subsurface water that is confined by the hard tissue matrix, and this quickly leads to "micro-explosions" that remove the mineralized tissue. The greatest part of the energy is absorbed by the ablation process and only a small fraction may heat the adjacent tissues. The high amount of water inside the carious tissues increases the interaction of the laser with the target tissue, leading to a selective removal of carious tissue and resulting in a more conservative cavity design.(Keller and Hibst 1998 and Ana et al 2006)

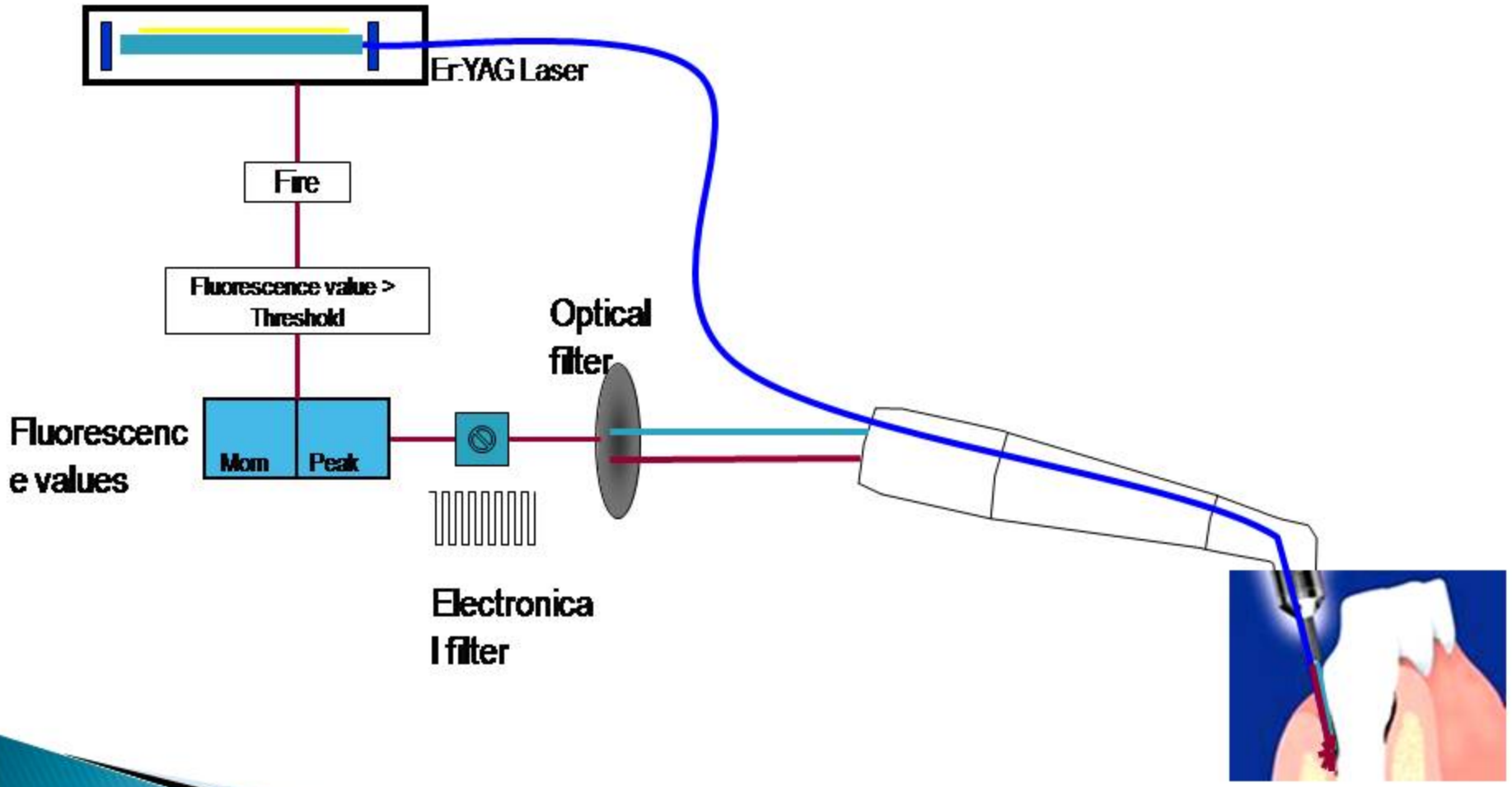
2-Feed-back system

Excitation of fluorescence



Feed-back system

Detection and ablation of calculi



3-Antimicrobial photodynamic therapy for carious tissue:

(Laser in dentistry ;Guide for clinical practice 2015)

Minimal invasive dentistry (MID) is significant change involves the principle of the maximum preservation of both healthy dental structures and structures capable of remineralization.

Photodynamic therapy (PDT) is a component of two aspects of the minimal intervention protocol for dental caries treatment (i.e. prevention and cure) because the interaction of a specific wavelengths of light with a non-toxic compound (the photosensitizer [PS]) and oxygen can result in the production of reactive species, which are capable of inducing the death of bacterial cells in dental biofilms.

based on the biological principle that the carious lesion is composed of two layers: infected and affected. The first layer is highly infected, necrotic, and irreversibly disorganized, whereas the second layer is less infected and potentially remineralizable

Antimicrobial photodynamic therapy (aPDT) is a very promising method for dentin disinfection prior to restorative procedures because, in the presence of the oxygen found in cells, the light-activated PS is capable of reacting with surrounding molecules by electron or hydrogen transfer to produce free radicals (Type I reaction). Alternatively, energy transfer to oxygen (Type II reaction) can lead to the production of singlet oxygen. These reactions will cause microbial death. One of the advantages of aPDT is that the development of resistance to it by microorganisms appears to be unlikely because singlet oxygen and free radicals interact with several different cell structures and metabolic pathways of microbial cells.

aPDT is equally effective against antimicrobial-resistant bacteria and antimicrobial-susceptible bacteria, and repeated photosensitization has not been shown to induce the selection of resistant strains.

The aPDT activity against Gram-positive/Gram-negative cariogenic bacteria (in homogeneous and mixed forms), planktonic cells, and biofilm cells has been reported for a series of PS and dosimetry parameters

The factors affecting on antimicrobial photodynamic therapy in conservative treatment.: (Laser in dentistry ;Guide for clinical practice 2015)

1-Electrical charge : cation photosensitizing agent act against gram -ve bacteria (has -ve charge membrane)

2-Type of reaction: Type I base on free radical(electron or Hydrogen) while type II base on signet oxygen

3-depth of penetration of photosensitizing agent: usually affect on external part of biofilm not inner part

4-light transmition: usually affected by light refraction and light reflection

5-Actual interaction time: for bacteria in superficial and deep regions of dentinal tubules to be sensitized by photosensitizing agent the 3-5minte is recommended

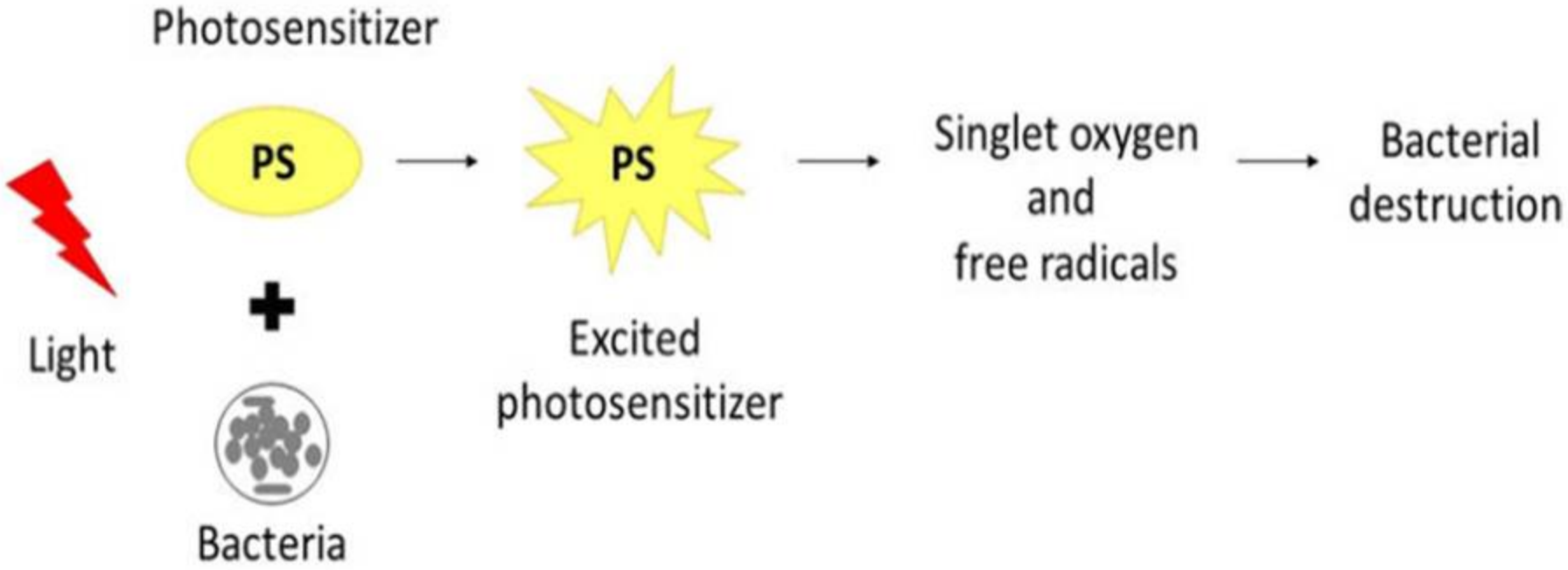
6-concentration of photosensitizing agent: High concentration my cause self quenching (optical shield phenomena) lead to decrease the light actually reaches the bacteria and reduce the generation of reactive oxygen species(thus 10-100 μg/ml is ideal concentration but 25-50μg/ml is usually used because of complexity of substrates)

7-Intensity and wave length of the light: power, type of emitter and energy density of laser used for photodynamic therapy .Red wave length shows more penetration than blue but usually both of them is favorable from antibacterial and therapeutic point of view. Energy density may induce photomodulation that effect on cell membrane and microchondia of odontoblast to form secondary dentine.

8-Contamination of photosensitizing agent with saliva or blood : this reduce photosensitizing agent activity

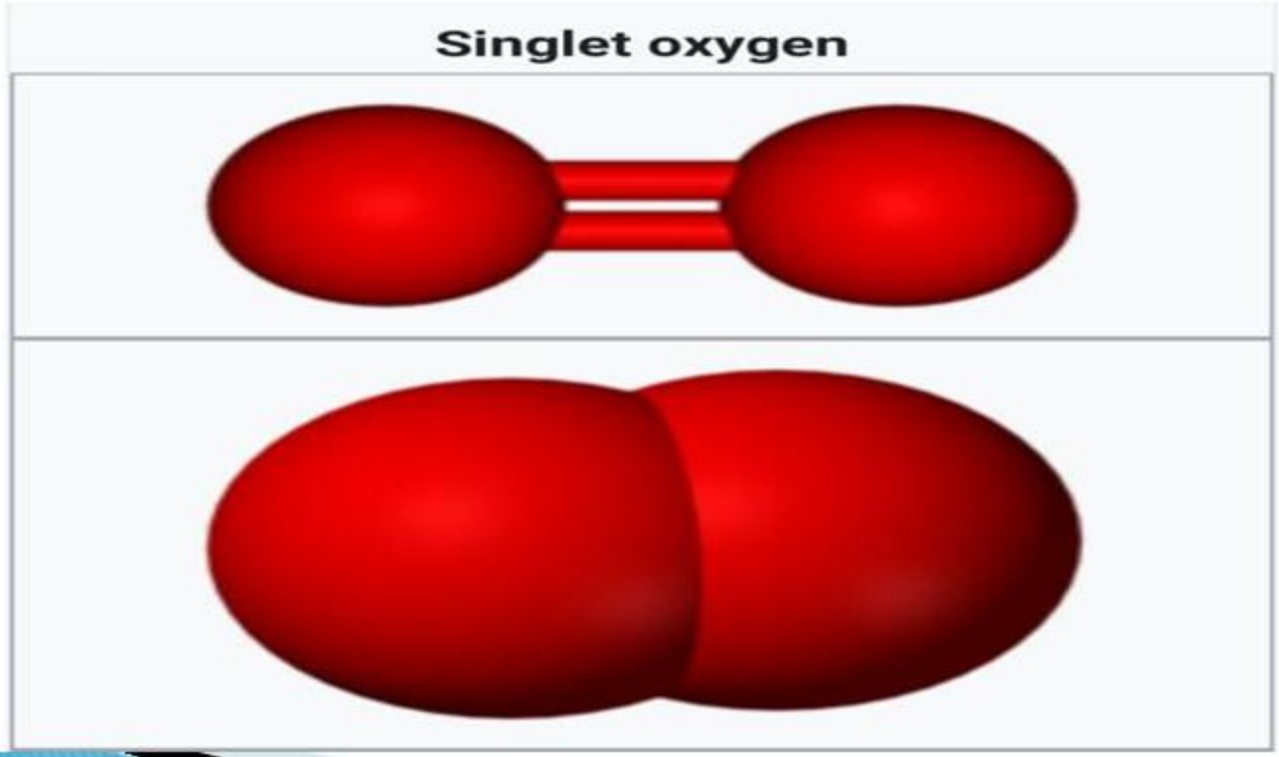
Mechanism of action of a PDT

Antimicrobial photodynamic therapy activity is based on the combination of a non-toxic PS and an appropriate wavelength of visible light, which in the presence of ambient oxygen is activated and can promote a phototoxic response. The reactive oxygen species (ROS) that are produced can cause damage of biomolecules and cause oxidation of cellular structures leading to the death of microorganisms .(Tortora and funke 2010)

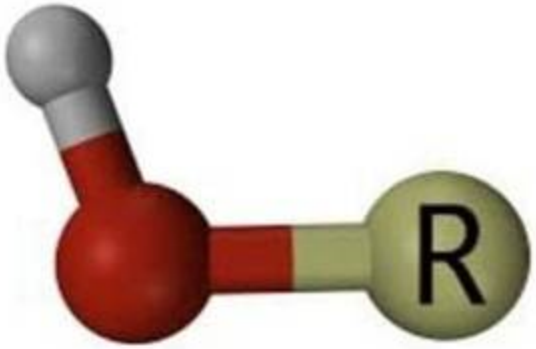


Laser Phys. Author manuscript; available in PMC 2017 December 01.

The aPDT action mechanism is briefly described by the excitation of a nontoxic light absorbing dye (PS) that forms a long-lived excited triplet state, which then transfers energy to the surrounding molecules, generally to molecular oxygen, to form highly reactive and cytotoxic ROS such as hydroxyl radicals and singlet oxygen .(Paschoal et al 2013)
Singlet oxgen, systematically named dioxygen(singlet) and dioxidene, is gaseous inorganic chemical with the formula O=O (also written as $^1[O_2]$ or $^1O_2$) .Which is in aquantum state where all electrons are spin paire. It is kinetically unstable at ambient temperature, but the rate of decay is slow (Manda et al 2009)



Singlet oxygen is a **very strong oxidant and readily oxidizes cellular components such as lipids, proteins, and nucleic acids**. Singlet oxygen can be quite long-lived in a cell and can diffuse over appreciable distances, including across cellular membranes into extracellular compartments (Manda et al., 2009).



A hydroxy or hydroxyl group is a functional group with the chemical formula **-OH** and composed of one oxygen atom covalently bonded to one hydrogen atom. In organic chemistry, alcohols and carboxylic acids contain one or more hydroxy groups.

Interaction microorganism-PS

The effectiveness of aPDT for different microorganisms depends on PS type, its concentration and the class of microorganisms (Gram-positive bacteria, Gram-negative bacteria, fungus or virus),(Huang et al 2012)

aPDT is more effective in the inactivation of Gram-positive bacteria, since the outer portion of their cell wall (composed of peptidoglycan and lipoteichoic acid) is relatively more porous, allowing PS to reach the cytoplasmic membrane.(De Melo et al 2013) .

In contrast, Gram-negative bacteria present a much more complex morphology. The outer portion of their cell wall contains negatively charged lipopolysaccharide, lipoproteins and proteins with a porin function, in addition to peptidoglycan. This structural organization forms a physical and functional barrier that hinders the incorporation of PS . (Dail et al 2009)

When these microorganisms are in the biofilm form, the photodynamic activity of PS is generally reduced, because there is a structural difference in the cell membranes of these microorganisms and the presence of other components, such as extracellular polysaccharide matrix. (Huang et al 2012)

Photosensitizers

Requirements of ideal Photosensitizers:(Laser phys. Author manuscript 2017)

1- An ideal PS should be a single pure substance stable at room temperature.

2- have minimal toxicity and only be cytotoxic in the presence of light exhibiting optimal absorption, distribution, metabolism and excretion. Ideally it should absorb light wavelengths between ~600 and 800 nm that penetrate deeply into tissue.

3- should produce singlet oxygen and other ROS.

4-should be inexpensive and commercially available in order to promote extensive utilization of treatment.

5-It should be selective for specific cells or tissues and should not be mutagenic or carcinogenic .

6- ideal PS for aPDT must also show high affinity for binding to microorganisms, require a very short drug-light interval, have a broad spectrum of antimicrobial action, low affinity for binding to mammalian cells, should be able to destroy resistant bacterial strains .

Classification of Photosensitizers:(O-Connor et al 2009)

PSs are generally classified as:

1- porphyrin-based (tetrapyrroles)

2- non-porphyrin-based.

Porphyrin-derived PSs are further classified as:

first, second or third generation PSs.

A- First generation PSs include hematoporphyrin derivative and Photofrin.

B-The second generation PSs are chemically pure compounds compared with first generation compounds (mixtures), that absorb light at a longer wavelength and cause significantly less skin photosensitization post-treatment.

C-The third generation PSs are bound to carriers such as antibodies and liposomes selective for tumor tissue .

Some types of photosensitizers

Ortho Toluidine blue (TBO): TBO has also proven very effective in killing bacteria in the oral cavity when photo-activated . Toluidine blue is an acidophilic metachromatic dye which absorbs light at 596 nm and 630 nm and that selectively stains acidic tissue components (sulfates, carboxylates, and phosphate radicals). Toluidine blue has an affinity for nucleic acids, and therefore binds to tissues with a high DNA and RNA content .(Sridharan et al 2012)

Methylene Blue dye (MB) has been used for a long time to detect pre-malignant cells and as a tissue marker in surgery. It is effective against Gram-negative bacteria because of its hydrophilicity capacity, low molecular weight, and its positively charge . The characteristic color of MB is caused by the strong absorption band at 550–700 nm region . MB may induce either the formation of hydroxyl radicals (type I) or singlet oxygen (type II) species, which extends the application of MB in PDT . The mechanism of inactivation of bacteria by MB seems to be a mixture of type I and type II processes, and the relative efficiency of each them depends on the cell type and experimental conditions . (Tardivo et al 2005)

Rose Bengal and erythrosine : are examples of xanthene dyes which are characterized by the absorption of light at wavelengths of 450–600 nm and 500–550 nm, respectively; this absorption is associated with the subsequent photochemical reactions. (Ackroyd et al 2001 and Allaker et all 2009)

Rose Bengal staining is used for the diagnosis of eye diseases, and erythrosine is used in dentistry to reveal biofilms. (Ackroyd et al 2001 and Allaker et all 2009)

Erythrosine, in particular, is ideal for use in PDT compared with other dyes, because it is approved for use in the oral cavity and does not show direct toxicity to the host tissue. Xanthene dyes have been excited with tungsten filament lamps and other light sources for the reduction of Gram-positive bacteria, Gram negative bacteria and yeasts during aPDT. (Ackroyd et al 2001 and Allaker et all 2009)

Curcumin is a yellow pigment, isolated from Curcuma longa rhizome. It is frequently used in cooking as a seasoning and has a wide range of pharmacological effects, such as anti-inflammatory action, anti-carcinogenic and anti-infective activities. It displays absorption peaks ranging from 300 to 500 nm of the visible spectrum, has a low cost, easy handling and is effective against yeasts.. However, curcumin has very limited solubility in water and the use of oils and synthetic solvents has been suggested to enable its dissolution . (Araujo et al 2012)

Light source of PDT

The first light sources used in PDT were polychromatic, non-coherent, lamps designed to emit white light and heat in most cases.

Laser light used for PDT was monochromatic, coherent radiation, and the treatment could be better defined using the optimum wavelength, a high energy density and light transmission through optical fibers .(Alvarenga et al 2015)

Another light source used is based on the LED (light emitting diode). without any increase in temperature. LEDs can be designed to emit light in the three colors of visible light (red, blue and green) and also in the near infrared region (>700 nm). (Alvarenga et al 2015)

4-Treatment of cervical lesions

Erosion

Abrasion

Abfraction


Thank you