Laser in Ophthalmic Surgery

Introduction:

The introduction of lasers in Ophthalmology has had a major impact on several of the most important disorders encountered by ophthalmologists.

In 1940's, a young Ophthalmologist Myer Schwickerath considered the idea of using light to produce a thermal reaction in the retina to produce coagulation, thus originated the word photocoagulation.

In ophthalmology, various types of lasers are being applied today for either diagnostic or therapeutic purposes. In diagnostics, lasers are advantageous if conventional incoherent light sources fail. One major diagnostic tool is confocal laser microscopy which allows the detection of early stages of retinal alterations. By this means, retinal detachment and also glaucoma1 can be recognized in time to increase the probability of successful treatment. In this lecture, our interest focuses on therapeutic laser applications.

The first indications for laser treatment were given by detachments of the retina. Meanwhile, this kind of surgery has turned into a well-established tool and only represents a minor part of today' s ophthalmic laser procedures. Others are, for instance, treatment of glaucoma and cataract. And, recently, refractive corneal surgery has become a major field of research, too.

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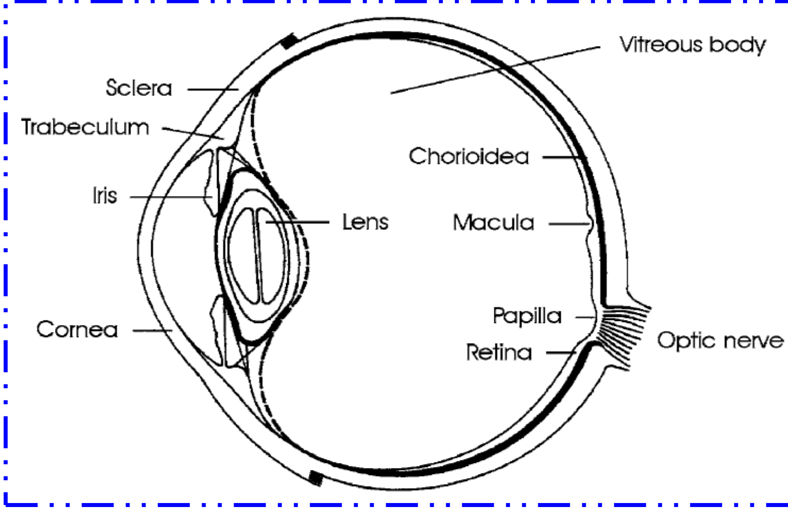
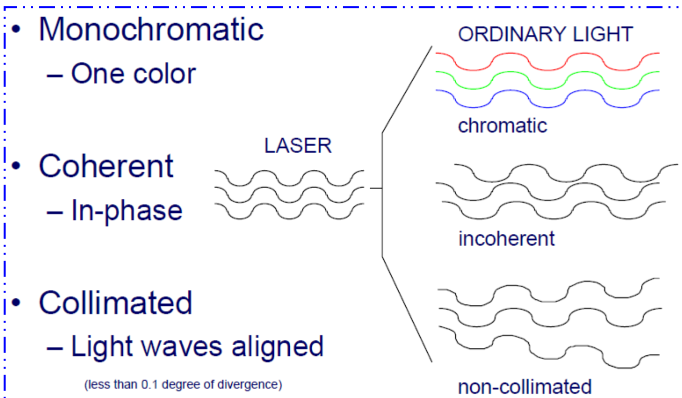
The targets of all therapeutic laser treatments of the eye can be classified into front and rear segments. The front segments consist of the *cornea, sclera, trabeculum, iris,* and *lens*. The rear segments are given by the *vitreous body* and *retina*. A schematic illustration of a human eye is shown in the next figure.



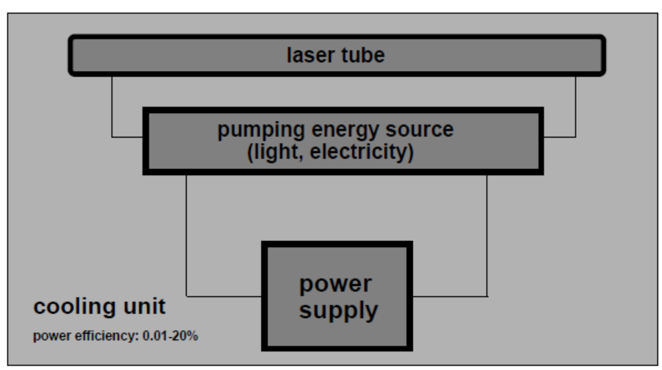
The main characteristics of LASER light

- Wavelength: Ultraviolet, Visible, and Infrared
- Power Density: Milliwatts to Kilowatts
- Duration of Pulse: Nanoseconds to Continuous
- Beam Divergence: Less than 0.1 degree
- Coherence: Millimeters to meters



Basic laser components

- Laser Tube (Laser medium + Resonating element or mirror)
- Pump or excitation sources
- Power supply
- Cooling unit (water, air)



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Laser Parameters

• Power = Number of “photons" emitted each second and is expressed in watts (W).

• Exposure time = The duration in second (sec.) the "photons" are emitted in each burn from the laser.

• Spot size = The diameter of the focused laser beam and is expressed in micron (pin). Spot size is usually fixed for treatment of a particular lesion. However, the energy (Power x Exposure time) parameters must be decreased or increased, with the decrease or increase in the spot size parameter. The spot size when focused on the retina depends on:

1) Laser Spot Magnification Factor (LSMF) of the laser lens,

2) Spot size selected in the Slit-lamp and 3) Refraction of the eye under treatment.

• Energy = Number of "photons" emitted during an exposure of any duration and is expressed in joules (J). So, Energy (Joules) = Power (Watt) x Exposure time (Second).

Laser tissue Interaction:

The interaction of a specific laser emission wavelength with various ocular tissues can be divided into five different tissue changes which are given as follows:

1. Photocoagulation therapy.

2. Photodynamic therapy.

3. Photo vaporization therapy.

4. Photo disruption therapy.

5. Photo ablative therapy.

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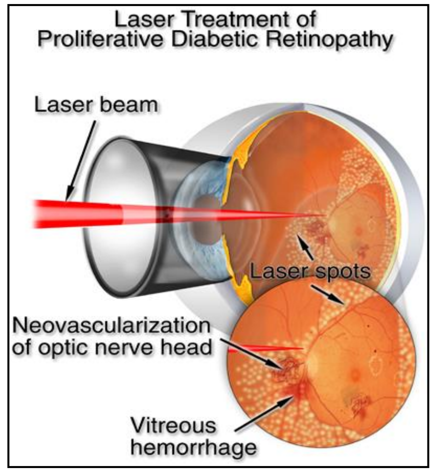
Photocoagulation Therapy: The first category of the ophthalmic tissue interaction with the laser is photocoagulation. In this, temperature of the tissue is increased from 37°C to 50°C, producing denaturation of protein (coagulation) in the region of the absorbent tissue element. This results from the conversion of light energy to heat energy. The monochromatic light from laser is absorbed by melanin, xanthophyll present in the macula and hemoglobin.



The lasers most commonly employed are:

1. Argon (488–Blue, 514.5 nm–Green)
2. Krypton (630 nm) and
3. Tunable Dye laser (488–630 nm).

When a patient is suffering from diabetic retinopathy, the concentration of oxygen in the blood is strongly reduced due to disturbances in the body. Because of the lack in oxygen, new blood vessels are formed which is called neovascularization.

Hemorrhages inside the vitreous body might then lead to severe losses in vision. In order to prevent complete blindness, the whole retina is coagulated except the fovea itself. During the treatment, between 1000 and 3000 laser spots should be placed next to each other.

Photocoagulation is used to treat Diabetic retinopathy, weak areas in the retina, new blood vessels on the retina and tumors of the eye.

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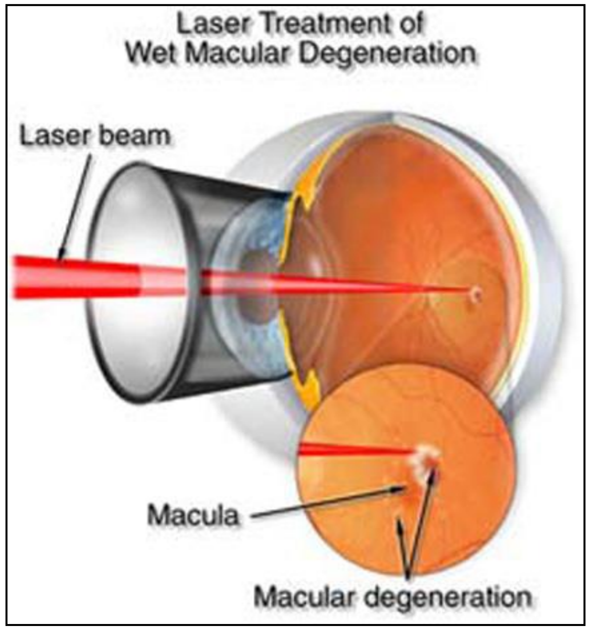
Photodynamic Therapy:

In this, the temperature rise is only about 1°C. The main lasers are the

1. The Dye laser at 630nm and
2. The Gold vapor laser at 628nm in the red portion of the spectrum.



One of the applications of the Photodynamic therapy (PDT) in the field of ophthalmology is the treatment of wet age-related macular degeneration (wet AMD).

In photodynamic therapy, a light-sensitive medicine called verteporfin (Visudyne) is injected into the bloodstream. The medicine collects in the abnormal blood vessels under the macula. Laser light is then shone into the eye, which activates the medicine and causes it to create blood clots that block the abnormal blood vessels.

Photovaporization Therapy:

In this process, the tissue absorbs the laser beam almost totally within 75–100 microns of space raising the temperature from 37°C to well above 100°C and photo vaporization takes place. The typical laser used is the carbon dioxide laser (CO_2).

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The CO_2 laser can be used to cut through skin, fasica, bone etc., without loss of blood. The carbon dioxide laser has been used in ophthalmology primarily for photovaporization and photocautery.

A great advantage of photovaporization is that it produces an almost bloodless incision by sealing blood vessels and lymphatic tissue in its path. Intravitreal photocautery has been used in treating fibrovascular fronds.

Photodisruption Therapy:

Leads to a microscopically localized temperature rise from 37°C to over 15000°C. The action of the laser depends on optical breakdown where electrons are stripped from the atoms of the target tissue and a plasma field and bubble are established, leading to a hydrodynamic and acoustic shockwave and mechanical stress factors that tear the impact tissue apart on a microscopic level.

The commonly used laser is the Nd-Yag Laser. Its main application in Ophthalmology is to cut through the remnant of a Cataract that has been surgically removed.

Photoablative Therapy:

There is no change in temperature in this method, and lasers used are all of shorter wavelengths of the UV spectrum. The lasers used are:

1. Excimer Laser (157 to 351 nm) and
2. The frequency quadrupled Nd-Yag (266nm)

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The high-energy photons of the excimer laser enable the laser beam to disrupt and break the intra-molecular bonds of tissue, which then disappear from the area of impact without the production of heat or charring. The main use in Ophthalmology is in photo refractive Keratotomy where the cornea is reshaped to reduce the myopia of a short- sighted eye.

Components of a Typical Laser System in Ophthalmology:

The following are the four major Components of a typical Laser system in Ophthalmology. They are:

1. The laser system
2. The delivery system
3. The operator room
4. The patient

The laser system is the one which is in use depends upon the particular type of laser for particular application. The type of lasers and their uses are given below:

Sl No.	Type of Laser	Application
1.	Argon, Krypton Dye lasers	Photocoagulation
2.	The Carbon dioxide laser	Cutting
3.	Nd-Yag Laser	Photo disruption
4.	Excimer Laser	Photo ablation

Most Ophthalmic lasers (except carbon dioxide laser) are delivered through an optical magnification device. The Argon, Krypton, Dye and Nd-Yag are delivered through microscope which requires no anesthesia by themselves.

However, for photocoagulation, a contact lens may need to be placed on the front of the eye and for this anesthetizing eye drops may have to be used.

In the case of the Excimer laser it is delivered through an operating microscope and requires the use of anesthetizing drops.

In addition, the Argon Laser, Diode etc., can be delivered by fiber optic cables within the eye during surgery in a procedure called Endo-photocoagulation. In all the above cases, it is important to protect the operator from the reflection of laser coming off lenses used in this procedure

The Excimer Laser:

The most common type of excimer laser uses molecularly diatomic rare-gas halides such as ArF (Argon Fluoride), KrF (Krypton Fluoride), XeF (Xenon Fluoride), XeCl (Xenon Chloride), as the active species from which the laser light is produced. In their common, unexcited form, atoms of the rare gases Ne (Xenon), Ar (Argon), Kr (Krypton), and Xe (Xenon) are inert and do not readily form molecules.

Rare gas halide molecules are held together by electrostatic forces similar to the way alkali halides (salt) molecules are formed. Rare gas halide molecules cannot be bought in bottle, but must be created in the laser vessel in-situ. It is usually done by high voltage electrical discharges in gas mixture of halogen bearing molecules and rare gas atoms.

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TABLE

Name of the Gas Mixture	Wave length (nm)	Energy/pulse (mJ)
F_2	157	40
ArF	193	500
KrF	249	1000
XeF	351 353	500
KrCl	222	100
XeCl	308	500

The above table shows the wavelength of light produced by an excimer laser depends upon the type of molecule created. It can be selected simply by changing the gas mixture originally added to the laser tube as in the left-hand column.

The pulsed energies of the light obtainable from typical commercial excimer lasers are given (Col. 3) in the above table. Nearly all the rare gas halide molecules in the vessel are excited and have energy available for extraction as ultraviolet laser photons. The wavelength of the laser light is determined by the type of molecules created and can be selected simply by changing the gas mixture originally added to the laser tube as shown in the table. Such devices can produce pulsed burst of light lasting approximately 2×10^{-8} sec at up to 500 times a second.

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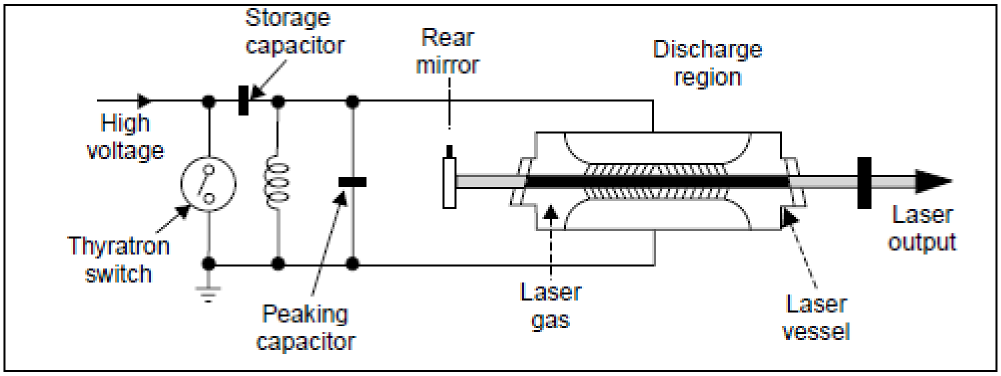

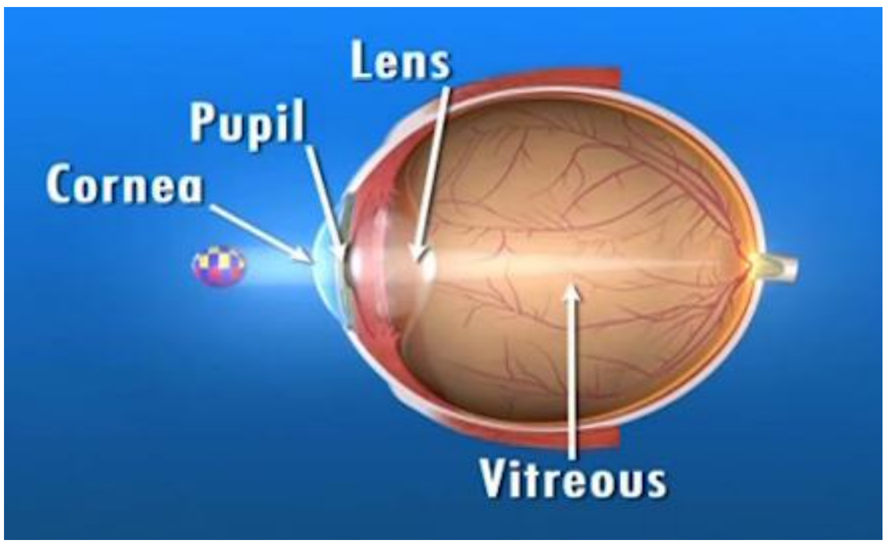

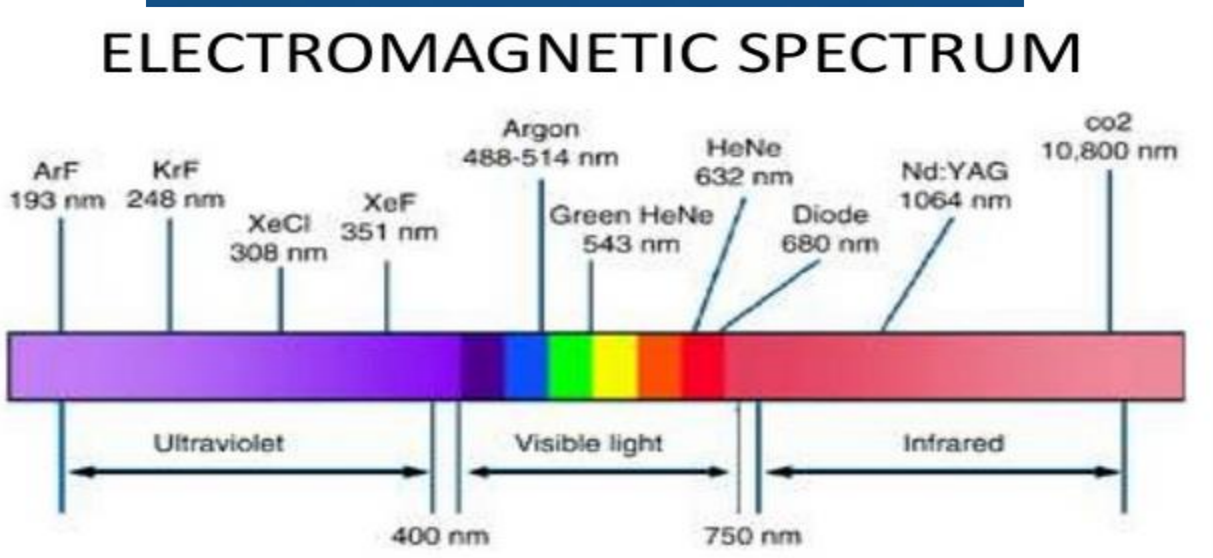

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