

Nanobiophotonics: Touching Our Daily Life
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Lecture No. 35
Laser Tissue Contouring

Welcome back. We are at the last lecture of module number 7 that is Lasers for Biophotonics and in today's lecture I will be talking about laser tissue contouring. In the previous lecture we have seen how light can be used to excite a medicine that medicine then reacts with oxygen and hydrogen etcetera to create the chemical processes. Here there is no intermediary such as the medicine here the laser light is directly affecting the tissue. In the previous case we tried to see that the laser light is transparent to the tissue 650 to 1350 nanometer something is the biological transparency window. Here we are doing just the opposite we want the tissue to absorb light, we want the tissue to absorb the laser and thereby it modify property either it burn down or it welds together just like you know welding you can cut metal using same source of light, same you know gas flame at the same time you can combine them you can weld them together you can join them together by using the gas flame.

We are trying to do the same thing with lasers certain times we cut it through certain times we join it through sometime we evaporate say water vapor from skin area as you will see and thereby this is a direct application this is a direct application of laser on to the body without without any other medicine directly involved. This work was indirect application of laser, laser was used to excite a medicine the medicine was doing its work here it is just the laser and the body the medicine part can come afterwards to heal to patch to cool down to shoot down those areas.

Ophthalmic Applications

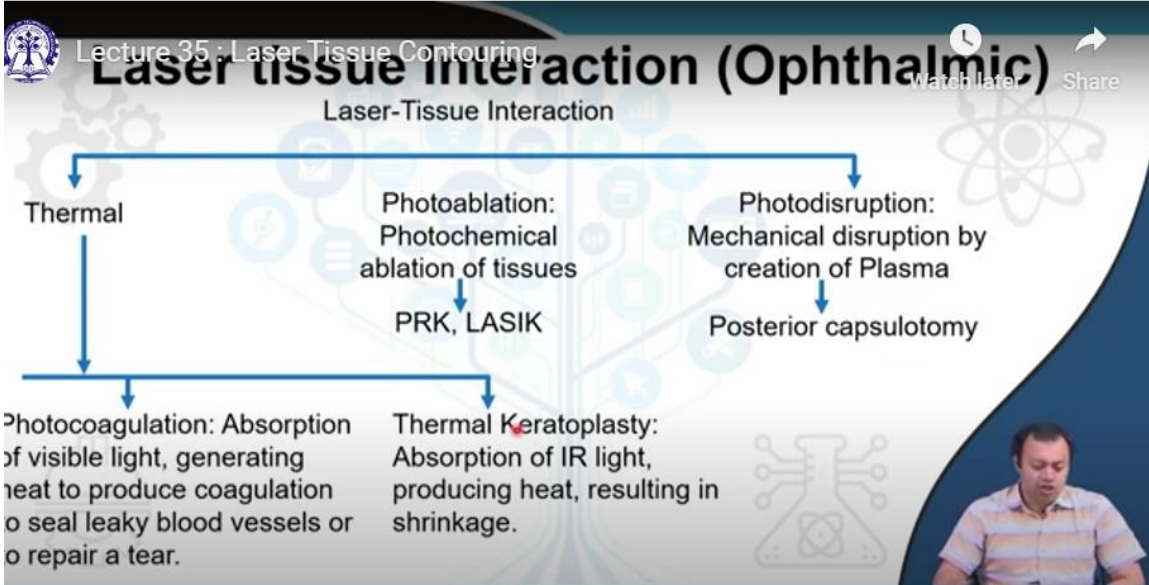
1. Use of Visible or Near Visible Lasers to treat Retinal Diseases or Glaucoma
 - (a) Diabetic Retinopathy
 - (b) Retinal Blood Occlusion
 - (c) Age related Macular Degeneration
 - (d) Retinal Tears
 - (d) Glaucoma
2. Use of Nonvisible Lasers for Refractive Surgery to reshape Cornea for Vision Correction

Mainly Correction of Myopia (near-sightedness) using

 - (a) Photorefractive Keratectomy (PRK)
 - (b) Laser-assisted sub-epithelial Keratectomy (LASEK)
 - (c) Laser *in-situ* Keratomileusis (LASIK)

So, the first and foremost application which all of you have heard of is ophthalmic eye-based operations where laser light have been used. So, the first one is use of visible or near visible laser to treat retinal diseases or glaucoma you know the retina either gets detached retinal tear or glaucoma some kind of tumor based things some some generation of certain tissues inside the back of the eye that is glaucoma, but most importantly I think almost all of you have heard of the use of non visible lasers for refractive eye surgery to reshape the cornea.

So, it is mostly for near sightedness and all of you have heard of this even if you do not know the full form LASIK eye surgery laser in situ keratotomy or LASIK laser assisted sub epithelial keratotomy PRK which is photo refractive keratotomy. I think you already know somebody in your friends or family or relative who have gone through cataract operation who have done cataract operation or laser eye surgery to rectify their eyes at an old age. So, using light on to your eye for correction refractive surgery is pretty common.

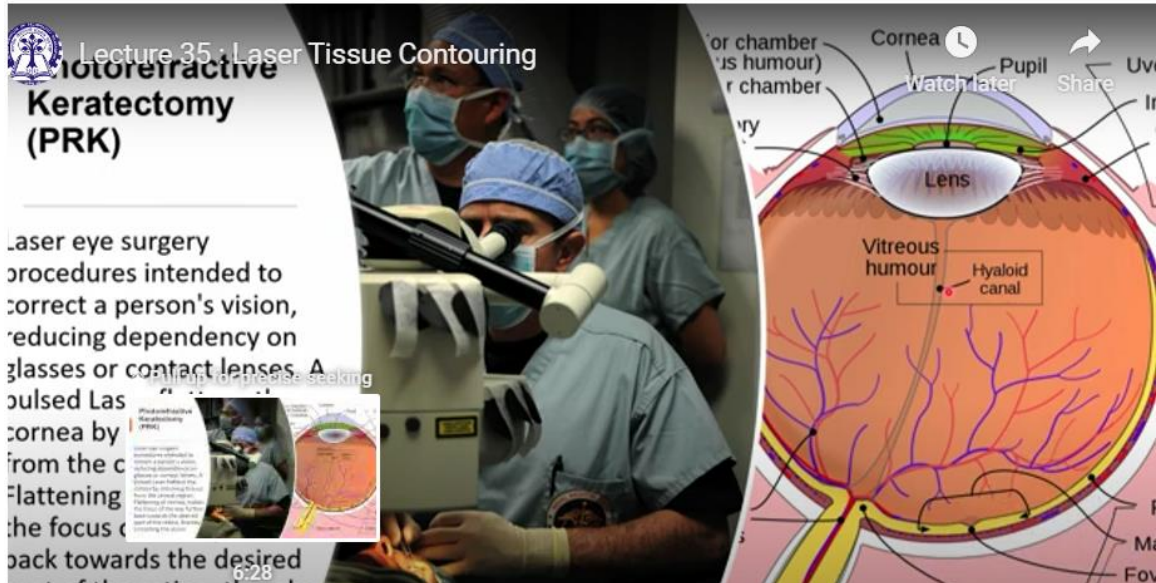


So, from an ophthalmic point of view from the eye point of view the laser tissue interaction what exactly takes place either it is thermal. So, photo coagulation absorption of visible light generating heat to produce coagulation to seal leaky blood vessels or to repair a tear this is basically welding yeah two metal disjoint at joint together using those gas flame you have seen this happening at street corners garage and places like that.

So, it is exactly the same thing where a tear or a leaky blood vessels is being melted, but only slightly only slightly so that they fuse together. The two metals separated they are melted together to so that they fuse together the heat has to be controlled so that they do not fall apart. Similarly, it is the same thing, but in a much much more precise manner where there is either a blood vessel rupture or a retina has been torn apart or something like that by sending you know thermal heat by by sending heat you just join them together. Thermal keratoplasty which is absorption of infrared light producing heat resulting in shrinkage. Something has swollen up you have sent heat to it and it has now reduced in size it has now reduced in size water vapour etcetera has been eliminated etcetera.

Photo ablation where photochemical ablation of tissues where some kind of chemical reaction takes place upon absorption of light this PRK LASIK is this photochemical ablation of tissues. Photo disruption as I said mechanical disruption by creation of plasma we excite a very very local area inside the eye region of the eye a very very local area. The electrons present in those compounds of that local area of the eye gets very excited they either ran away the molecule become ionized resulting the electromagnetic field creates plasma very fast very energetic, but very very localized area that results in destruction of certain areas where say additional tumor or something else have formed and that could simply be burnt away. So, what exactly is the PRK laser eye surgery. So, this is the patient and you see the doctor is looking at the eye through this and how much these

these these these doctors have to be skillful looking at this they have to do the operation here.

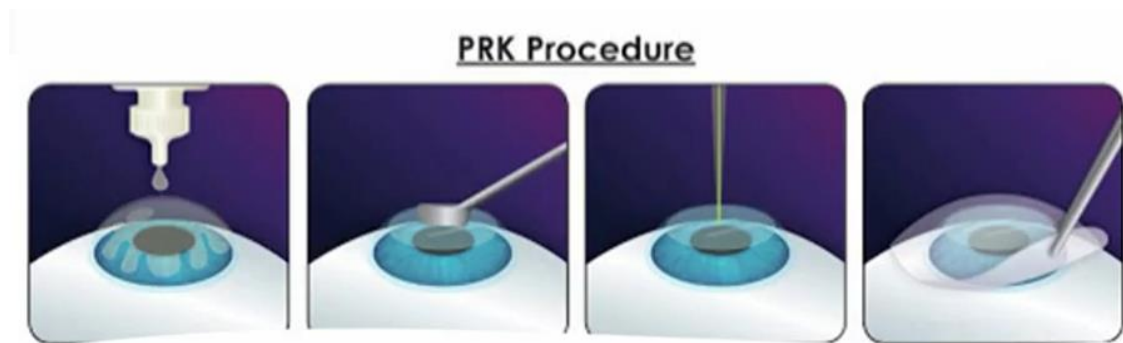


Try to write something in your take a pen and paper and try to write something by not looking at the paper look somewhere else and try to write and then see how well you have written it. This doctor is looking into it, but through a microscope which is falling into this eye and they are performing the operation performing the operation. So, this is the human eye I think I will be describing it. So, this is the lens this is the cornea the upper part of the outermost part of the eye light falls through cornea the cornea allows people expands or dilates the amount of light to go through it falls onto the lens the lens then focuses the light onto the retina this part is retina. The retina has rod cells and cones which are light sensitive their electric polarization changes upon absorption of light this change in electrical current is then passed through the optic nerve which goes inside your optical cortex which goes inside the optical cortex which is at the back of the head and thereby you interpret light resulting in vision.

So, basically you are able to see because light falls onto your eyes focused by the lens pass through the retina, retina converts light signal into electrical signal electromagnetic signal this electrical signals are then interpreted by a part of your body part of your brain the optical cortex and you are able to see this world. So, what happens this cornea this outer part of your eye as the as people age I am giving you one specific example one specific example this cornea right curves this cornea curves thereby thereby the focus of the lens gets disrupted yeah all the light that falls onto the lens has to be focused, but the filter the cornea if it has got you know changed its focal length per say if it has changed its focal length then the lens cannot focus all of its light onto the retina. So, what you do in this photo refractive keratotomy PRK laser eye surgery a pulsed laser flattens the cornea by removing tissue from the central region as you age more and more tissue gets generated

onto the cornea and it curves. So, you remove certain tissue from the central region thereby the cornea fixes up thereby the overall the focal length everything changes and now makes the focus of the eye further back towards the desired spot of the retina thereby correcting the vision with a curved cornea the light that was getting focused by the lens was coming here was coming here, but your retina is here there is any light that falls on non retinal places will not be interpreted will not be seen. So, thereby you are either losing your eyesight or you are seeing blurry you are having blurry vision.

So, what they do is that they flatten this cornea which has been curved by accumulation of certain tissues they just open it up they just flattens it up. So, that the light gets focused further back further back into the retinal area and thereby the vision is restored.



Photorefractive Keratectomy (PRK)

In PRK, the epithelial (outer) layer of cornea is removed by a mechanical (soft brush) or chemical (alcohol) or by a laser beam. Another laser beam is then used to ablate and reshape the cornea. A soft contact lens is used as a bandage and is placed over the eye to help the epithelial layer grow back.

Generally, takes 3-5 days.

So, the PRK procedure you need to know may be some of your relative has already gone through the outer layer of the cornea is removed by a either a soft brush some sort of alcohol is being put and it has been it is it is usually removed or a chemical by soft brush or removed by another laser or by a laser beam another laser beam is then used to ablate and reshape the cornea another laser beam is then put inside the cornea to to to to flatten it up and then finally, a soft contact lens is used as a bandage you put a bandage and it placed over the eye to help the epithelial layer grow back right. Upper part of your cornea is simply brushed or dissolved using alcohol and then in that thinner area you deposit huge amount of laser substantial amount of laser appropriate amount of laser flattening the cornea in the process and the area that has been removed that needs to regrow and you put a bandage on top you put a bandage on top you must have seen you know people after refractive eye surgery have have bandaged part of their eye and then it needs to be removed and then some kind of droplets or medicine has to be injected. So, it is generally taking 3

to

5

days.

This is PRK photorefractive keratectomy.

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Laser *in situ* Keratomileusis (LASIK)



In LASIK, the ophthalmologist creates a hinged flap of the cornea, approximately 125 μ m in thickness, using a specialized cutting blade mounted on a vacuum device. The cutting tool known as microkeratome, is then removed, thereby exposing the underlying corneal tissue to ultraviolet ablation of desired degree. Finally, the corneal flap is returned to its original position.

The diagram shows a cross-section of a human eye. A blue, semi-transparent, hinged flap of the cornea is being lifted away from the underlying tissue. The flap is held in place by a small red dot, representing a hinge. The underlying tissue is shown in a lighter blue color, and the entire eye is depicted in a stylized, semi-transparent manner.

The other one is lussic surgery laser in situ where as you can see from the cartoon the ophthalmologists create a hinge flap. So, instead of removing that particular area they just pay make a hinge it is not simply removed like a lid like a lid you must have drank soft drinks from can portion is simply flipped off it is not completely removed like using alcohol or chemical it simply cut open and then another laser goes inside another laser is being gone inside to flatten this curve and once your work is done the original lid is closed. The original lid is closed back the corneal flap is returned to its original position this does not require the body to regrow cornea, but simply to heal the area lussic is much more common and the duration is also quite less.

PRK vs LASIK

Laser Technique	PRK	LASIK
Pain	Moderate to Severe	Minimal, if any
Recovery of vision	2-4 weeks	1-2 days
Stability of vision	1-3 months	1 week to 1 month
Contact Lens	First 4-7 days	Usually not required
Return to work	Usually a week, may take longer	2-3 days

So, PRK versus lussic as you can see the pain is quite high moderate to severe would you like to use alcohol on your eye to remove upper part of it whereas, laser light can simply perforated pain will also be there people claim minimal pain, but I think you should ask somebody you you know who have gone through eye surgery to see how much pain has been used I think the most of the pain is by when they inject the anesthesia near your eye to see how it works.

The recovery of course, in PRK is higher 2 to 4 weeks whereas, in 1 to 2 day here you just cut a part and try to heal it here you removed it. So, body needs to regrow stability of vision is 1 week to 1 month these days yeah it is less than a week. Contact lens is required at the beginning for PRK whereas, in lussic usually it is not required and you can return back to your normal life return to work usually within a week a month with lussic 2 to 3 days is something that is recommended by who not by me the Royal College of Ophthalmologist this is the data that I have taken directly from them at London a patient's guide to xima laser refractive surgery this is taken directly from them. So, if you ask me where did I get this data how do I recommend people who have gone through lussic eye surgery to return to work after 2 to 3 days it is not my data it is from the Royal College of Ophthalmologist at London up to you whether you want to accept them or not or you want to take further rest after getting the surgery done.



Femtosecond Laser Surgery

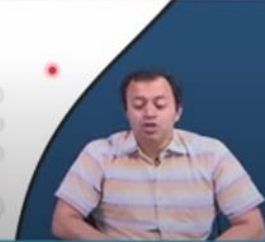
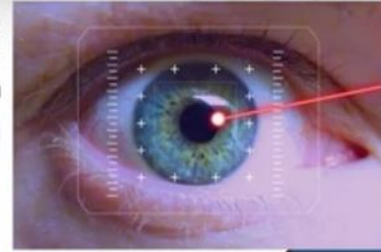


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There are several advantages offered by ultra-short pulses. The cuts and ablations could be made more precisely, with very little collateral damage. The mechanism of laser-tissue interaction in ultra-short laser pulses are different from photothermal and photoablation methods, generally associated with other lasers used for tissue contouring or ablation. The high peak power of ultra-short pulses results in Photodisruption, involving laser induced optical breakdown with the creation of avalanche ionization to produce hot **microplasma**. The microplasma expands with supersonic velocity, displacing (ablating or cutting) surrounding tissues. Since the displacement is adiabatic (i.e., it occurs on a time scale shorter compared to local thermal diffusion time), the effect of local ablation or cutting is spatially confined and any spread due to thermal damage is also confined.



There is also this new thing coming up which is femto laser surgery femtosecond laser surgery here what happens is that ultra short pulses are being injected inside the eye these pulses exist for femtosecond 10 to the power minus 15 second. So, think about this if you take a metal rod and heat a particular corner it takes some time for the heat to travel from one area to the end of the corner right 1 second 2 second 3 second, but if you are able to hit a particular area for 10 to the power minus 15 second and then gone heat will not travel to other area whatever is happening is localized at that area right it has to be localized a huge amount of light has come just for a femtosecond ultra short pulses existing for 10 to the power minus 15 second. So, what happens is that they do not produce heat or some kind of you know melting or cutting etcetera the high peak power of ultra short pulses results in photo disruption involving laser induced optical breakdown with the creation of avalanche ionization process I told you the area become ionized the electron absorbed that laser light at that specific area get excited runs away produce ionization of the molecule and produced hot micro plasma hot electromagnetic wave because of the running away of the electron charge particles produce oscillating charge particles produce electromagnetic waves this micro plasma is this electromagnetic wave hot micro plasma the micro plasma expands with supersonic velocity displacing surrounding tissue since the displacement is it occurs at a time scale shorter compared to the local thermal diffusion the effect of local absorption of cutting is spatially confined and any spread due to thermal damage is also confined. So, you excite ultra short pulses of light at a very localized area whatever is happening is happening in the localized area plasma can be produced and that can destroy the nearby area, but heat is not going out. So, a particular tumor or particular tissue-based area the local spots can be destroyed, but the heat will not spread far away and thereby melt your entire eye lots of work is being done the idea is to control idea is to control how long you will put this pulse for at what duration what is the repetition rate. So, one second 10 to the power minus 15 second it exists next

pulse

after

what

duration.

So, what is the gap between first pulse to next pulse. So, that this micro plasma is created, but it is strong enough to destroy the nearby area, but not strong enough to go very far and destroy everything plus how the heat is to be controlled all of those things are to be done using femto laser surgery the more technologically advanced we are getting the more control we are getting in femto laser surgery. And this is the future of laser eye surgery cataract eye surgery where before the heat expansion could happen before the thermal coefficient could come into effect before the heat could produce it is the pulse is already extinguished. So, like this like this by the time local effect has happened and it has reduced down without causing any heat per say thereby the damage to any surrounding area area where you do not want the heat to go is minimum.



Dermatological Applications

- Involves the highly localized destruction of light absorbing “targets” in skin, with minimal damage to the surrounding tissue.
- An appropriate wavelength, exposure duration, and sufficient fluence are necessary. The target should absorb most wavelengths resulting in inducing a photochemical process.
- The exposure duration should be shorter than or equal to the thermal relaxation time of the targets.



So, there are of course, several dermatological applications where you directly apply laser to localized destruction of light absorbing targets in skin at appropriate wavelength exposure duration the sufficient fluency and necessary previously was I now I am giving an example of the skin the exposure duration should be shorter than the thermal relaxation of time.

Lecture 35 : Laser Tissue Contouring

Human Skin

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The human skin is the outer covering of the body and is the largest organ of the integumentary system. The skin has up to seven layers of ectodermal tissue and guards the underlying muscles, bones, ligaments and internal organs.

Labels in diagram: sweat pore, hair shaft, Meissner's corpuscle (tactile corpuscle), epidermis, stratum corneum, pigment layer, stratum germinativum: stratum spinosum, stratum basale, dermal papilla, dermis, retractor pili muscle, sebaceous gland, Pacinian corpuscle, hair follicle, papilla of hair, nerve fiber, hypodermis, fascia, artery, vein, lymph vessel, Ruffini corpuscle, sweat gland.

MORE VIDEOS

So, basically the human skin is the outer covering body you shine light on several of these areas underlying muscles bones and you can change the.

Lecture 35 : Laser Tissue Contouring

Examples. Skin Port Wine Stain

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Targeted chromophore is **oxyhemoglobin**. Laser is absorbed by hemoglobin and converted to heat, which damages the endothelium. This is followed by thrombosis (blockage of blood vessel) As removal of abnormal venules occurs, the lesion regresses into more normally colored skin area.

port-wine stain (*nevus flammeus*) is a discoloration of the human skin caused by a vascular anomaly. A port-wine stain is a capillary malformation, seen at birth. Port-wine stains persist throughout life. The area of skin affected grows in proportion to general growth.

So, probably you have seen these kinds of do you know who this gentleman is this gentleman is credited for ending the cold war between America and the Soviet Russia he was the last president of Soviet Union Mikhail Gorbachev. So, they have this port wine stain type you know birthmarks where this is the abnormal growth of blood vessels blood vessels go with a particular pattern, but sometimes they grow in areas where they are not supposed to be and they expand as the human body grows. So, if this was the size in if this was the size in the child said as the child grows to become an adult the pattern the spot also grows with it a port wine stain is a discoloration of human skin caused by vascular anomaly wrong blood vessels are growing a port wine stain is capillary malformation seen

at birth port wine stain purses throughout life the area of skin affected grows in proportion to the general growth. So, so, so what you can do you can directly shine light onto it and cut off these blood vessels and thereby remove the area.

So, targeted chromophore is oxyhemoglobin laser is absorbed by hemoglobin and converted to heat which damages the endothelium endothelium is the under most part this is followed by thrombosis blockage of blood vessels endothelium is the lining bigger part lining of the blood vessels this is followed by thrombosis as removal of abnormal venules occurs the lesion regresses into more normally coloured skin area. Basically, these capillaries are starved of oxygen you basically cut them off the endothelium the out inner lining of the blood vessels are damaged. So, blood vessels got damaged blood will not flow a blood will not flow it will not remain the other thing is tattoo removal.

So, you know tattoos where the tattoo granules the ink particles go you know some place here the top most is the epidermal the epidermis layer. So, it goes slightly below your epidermis.

So, this is the region where the tattoo ink goes through quite painful and it does draw blood at certain cases. So, that is the idea if it had been on the top surface you could wash away or after several you know washing this can gets removed, but if the tattoo ink is seeped inside the epidermis not this far, but inside the epidermis then it could be it would remain it would permanent, but then you decide to remove tattoo for certain reason. So, here the chromophore is melanin laser causes extremely rapid heating of melanin and tattoo pigment granules this fractures the submicrometer particles and kills the cells that contain them. So, if you have deposited your tattoo ink at the sub epithelial area. So, that it stays you then go for burning those cells and the pigment granules and after several

setting you can have using this particular laser these are the specification how long it will remain what is its power capacity what are its wavelength you can remove them.

So, direct application of laser light in human body. Skin resurfacing has become very

Skin Resurfacing



Targeted chromophore is **Water**. A superficial layer skin is ablated in wrinkle removal. Laser deposits energy in the upper (1-20 μ m) skin, due to strong absorption of energy by water. This leaves \sim 1mm of thermal damage and hemostasis. Also used for treatment of warts, acnes and other benign epidermal lesions.

very common part of cosmetic surgery where some amount of typical laser light is targeted at different areas of the skin it is there to absorb water, water gets absorbed it becomes more stretched out it is not swollen it is not stretched out it is used for wrinkle remover laser deposits energy in the upper skin due to strong absorption energy by water this leaves 1 millimeter of thermal damage 1 millimeter of skin is actually damaged the water is removed the skin is damaged and so called skin rejuvenation treatment takes part also this warts, acne's and other benign epidermal lesions are to be removed. No medicine you are simply applying laser light to certain part of the skin to make it look younger and fresh these are the overall specification of the type of laser comes and last, but not the least is the hair removal.

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Hair Removal

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Targeted chromophore is **follicular melanin**. Selective photo thermolysis of the hair follicles is achieved without damaging the skin. Also, it is currently debatable if the hair removal achieved is permanent.

So, I told you this is the overall schematic of the skin tissue you have hair coming out of it from hair follicle and then there is the upper layer and then there is nerve and sweat glands and what not the laser targets the bottom of the hair follicle laser targets the bottom of the hair follicle and results in the hair to be simply. So, this is the root this is the hair this is connected with the root of the well it is it is root which is the hair follicle you have damaged it laser light has been sent to this hair follicle area this this this this this root part papilla of hair which has absorbed the light and it has either it has destroyed itself.

So, resulting if you destroy the root of a plant the plant itself falls. So, the root is excited by light and the hair is removed this is becoming extremely popular these days not just urban areas, but in rural areas as well not just simply in women, but men as well who have taken this and this is supposedly better than waxing or shaving especially into your private regions. So, this has become extremely popular targeted chromophores follicular melanin selective photo thermolysis of the hair follicle is achieved without damaging the skin. So, you need to have specific specific wavelength of light that is targeting just the root of the hair and is not damaging any other part of the skin which usually shaving or waxing does and however, it is currently debatable if the hair removal achieved is permanent or not right. Several laser based hair removal stores have come up in urban areas where they claim to be permanent hair removal.

However, that is debatable nothing could be permanently remove hair to the best of my knowledge and if you are involved in getting these kind of cosmetic surgeries this kind of not surgery cosmetic treatments like laser based hair removal or skin resurfacing I would strongly ask you to do it from an authorized genuine source rather than you know quacks or corner shops or places that claim to have you know miraculous results have been achieved go and do it with licensed medical practitioners. There are people or visit some

hospital ask the advice of a physician they can advise you to certain different clinics which are government registered which have medical licenses. So, try and do that because several of the times whatever claim is being made with a light-based treatment are not true.



Lecture 35 : Laser Tissue Contouring

CONCEPTS COVERED

- Ophthalmic applications of Laser tissue engineering
- PRK
- LASIK
- Femtolasersurgery
- Other Applications

So, with this these are the specification of the so, called the diode being the laser being used with this I come to the end of this module I have covered these types of concepts PRK elastic other applications have been dealt with and these are my references.



REFERENCES

- A Patients' Guide to Excimer Laser Refractive Surgery, The Royal College of Ophthalmologists, 18 Stephenson Way, London NW1 2HD, United Kingdom
- Introduction to Biophotonics, Paras N. Prasad, Wiley 2003.

So, thank you very much.