Biophotonics
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Module 05: LASERs for Biophotonics
Lecture 24: In Vivo Photoexcitation

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Welcome, I hope at least some of you are still with me, if you are with me I admire your courage and ask you to come with me into this wonderful experience that we are having while discussing biophotonics.

Now, thus far we have understood a bit about what lasers are, what are their properties, what they can do, the laser light, the intense light from laser can generate some very weird and very new phenomena, we want to see in this chapter and the subsequent chapter where exactly we would like to utilize them. So, today's topic it will be In Vivo Photoexcitation, in vivo photoexcitation.

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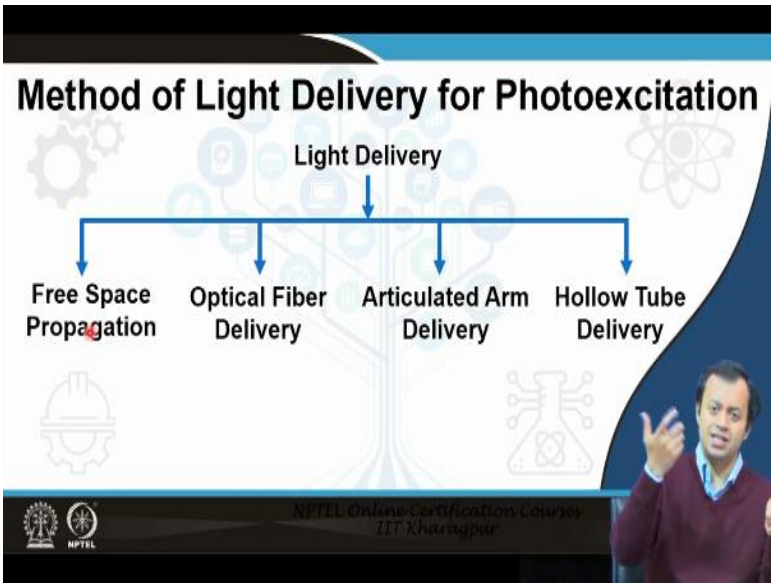

So, let us see what I exactly mean? It means that I want to deliver light to a specific area of the human body, I want to deliver light to a specific area of the human body to a specific areas, to a specific tissue subjected to illumination either by normal light or since this is a chapter dedicated, this is a module dedicated to laser, I want that specific area to be illuminated by laser light.

Now, there are couple of methods or more than couple of methods by which light can be delivered for excitation at the tissue level towards the tissue, towards the organ by this couple of or four different methods, there are other method, this is not an exhaustive list but these are the most common.

The first is Free Space Propagation, you switch on a light and it falls on to your body and if it is a laser it falls onto your body and then it does, it modifies or changes the biological material, in this particular case most possibly your skin, it can be your eye when it comes to retinal surgery but it can it can modify some part of your skin and thereby, you can utilize it for several dermatological procedures, tattoo removal, acne removal etcetera, etcetera. These are mostly free space propagation.

Optical Fiber Delivery, in which the light is guided through an optical fiber, I will be coming to that in detail, Articulated Arm Delivery and Hollow Tube Delivery. So, these are the four major processes in which light can be used or light could be delivered.

So, these are like the carriers, these are like the transportation medium which delivers the light at a specific organ, a specific tissue, a specific region in the body and thereby and thereby different types of effects takes place and you utilize this effects for either cure or diagnostics as such.

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So, let us see the Free Space Propagation. Free space propagation you use a laser, you use a laser, this is like a laser gun and you subject it or you shine the light into somebody, some part of the human body, case and point as I said dermatological process, this is usually the external surfaces of the body, these are usually not always the external surfaces of the body, you can point it in your mouth or mostly they use it in your laser eye surgery, cataract operation as such.

But a substantial amount of usage of free space propagation of laser light is for dermatological application where you subject it to, subject it to treat different ailments of the skin, acne removal, laser hair removal, some kind of spot removal, tattoo removal these kinds of things, the intense light from the laser interact with the tissue.

And thus far you have known what are the effect of tissue when it subjects to light, what are the effects of tissue, what are the different types of effect, coagulation, photoexcitation this, that temperature increases, etcetera. All of those things, several of those things can take place and we optimize it, we optimize it for different procedures obviously, the laser light used for hair removal will be different from the laser light used for tattoo removal or laser eye surgery, so this is free space propagation.

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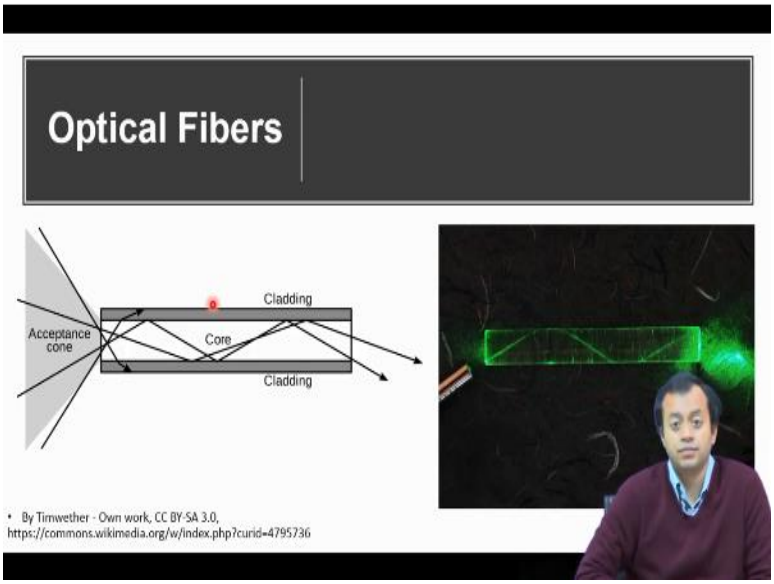

The quite interesting one are when you are using Optical Fiber. Optical fiber I think electronic students all know, physics student all know, maybe the biotechnology student know a bit but maybe you have lost touch, so I will tell you what it actually means.

So, we have optical fibers, these days optical fibers are very common, the internet service that you are having in your house or in your office, the data is carried by optical fibers, depending of course where your office and home is, but optical fiber carries this core and cladding part where the refractive index of the core area.

So, it is a tube which contains two different areas, two different zones, it is a tube, it is a tube which has two different zones, the outer zone is called the cladding and the inner core, the inner core of the tube is called core, the inner inner part of the of the tube is

called core, the inner inner tubing has a higher refractive index, the outer part has a lower refractive index.

And if you are shining light on to this tube at a specific angle, at a very very specific angle you can guide this light completely by the process of total internal reflection. I think you all have heard of total internal reflection in high school but it means that whatever light is falling onto the surface is totally reflected without anything getting refracted.

So, refraction can be considered as zero or almost zero, there are evanescence field but let us not go into that direction. Most of the light is reflected and thereby like a mirror it is guiding through the upper layer and lower layer, it will bouncing off through the upper layer and lower layer and finally reaches the outer destination.

So, this is a actual representation, you have seen a green laser and it is hitting the walls and thereby coming out of it without any or without any specific loss, the losses from optical fibers are very, very less, these days it is ridiculous 0.2 db per meter, 0.2 db per meter and people are saying even less can be achieved. So, whatever information thereby you have stored in this light, in this beam of light can be faithfully reproduced or faithfully guided towards the output.

And mostly optical fibers have used in communication for carrying laser based information but now I can use it to guide light and optical fibers that the core is very small 2 micrometer or even less, the entire thing can come within couple of millimeters or couple of centimeters, imagine, just imagine what can I do if I put a small optical fiber cable containing intense energy laser into one of the orifices of my body. Ever heard of endoscopy? I will come to that.

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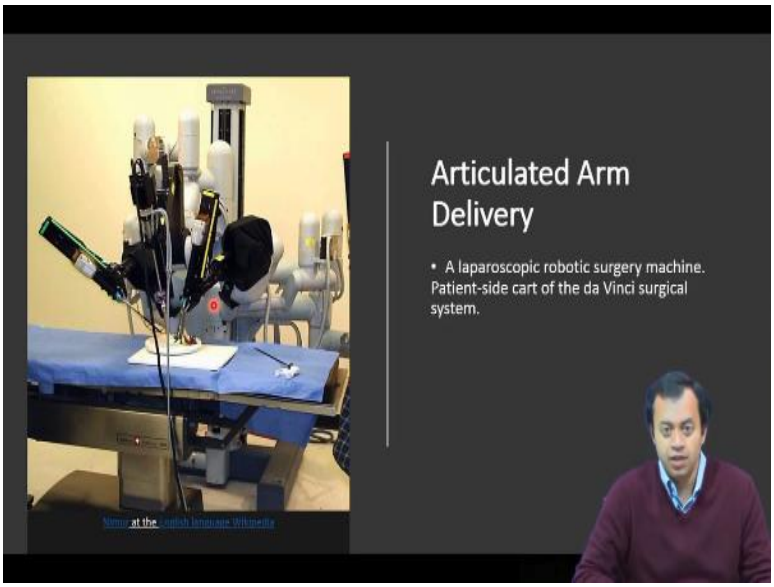

There is of course, Articulated Arm Delivery which is basically robots, these are robots which contains laser, so you must have seen assembly lines of car manufacturing units, where you know all those robotic arms does welding and cutting of metal tools. So, if you can do that there why cannot we do this here for a human being, where these robot, robotic arm are either operated virtually or they are simply automatically.

They have a program inside, human being simply sleeps there, the patient simply sleeps there and without much of a human intervention per se it does, it work, with sets of robots, articulated arm delivery, mechanical engineer students know what I mean by articulated arm.

Articulated arm they will make their own motion something which human beings fingers are not nimble enough, not strong enough to do, human beings will sit there, so this is like a robotic surgery, this is like a robotic surgery using lasers. So, that could also be done.

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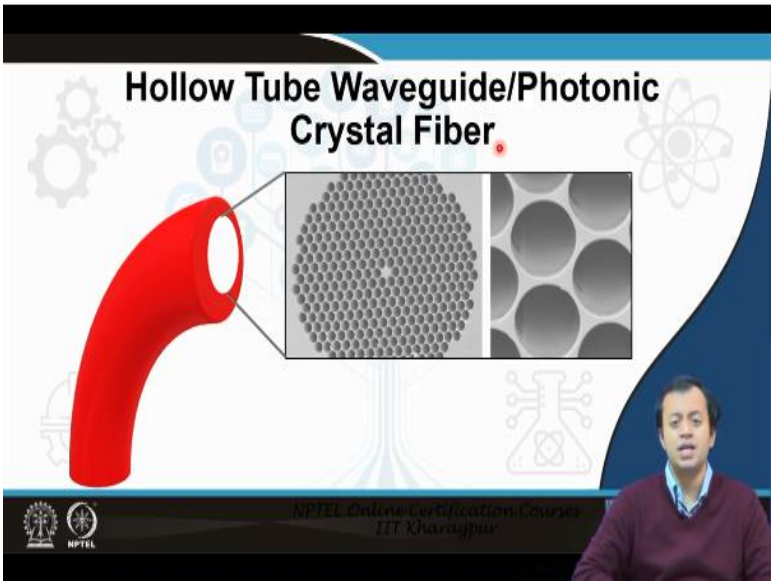

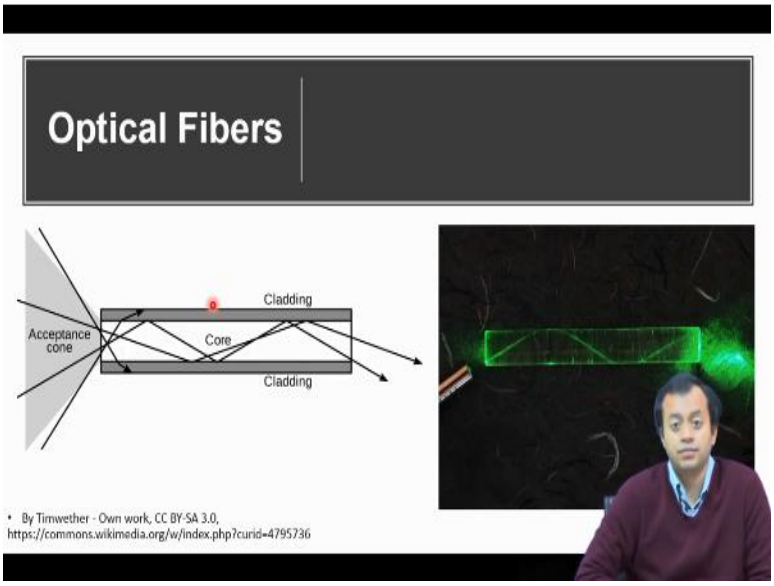

And these days we are mostly looking into Hollow Tube Waveguide or Photonic Crystal Fiber, photonic crystal fiber, so you have a fiber whose inside is hollow and either it is completely hollow or it has these kinds of honeycomb like structures where these are the holes, these are the air holes and thereby they make photonic crystal fiber. Do not worry if you do not know much about photonic crystal fiber, I will be discussing in optical biosensors what photonic crystals are, but photonic crystals are optical equivalent of semiconductors.

In semiconductors you have energy levels where electron can present, energy levels where electron cannot present, where electrons can present a conduction band, valence band, where it cannot present is the band gap. Photonic crystal produces photonic band gap, they have energy levels where photon cannot be present, there are certain energies of photons which are allowed to pass through, then certain energies of photons that are not allowed to pass through.

So, if you send a bunch of photons, multi modal, several different frequencies of laser, only one will come out of it and you are ensuring that one single type of photon is coming out of it and affecting or hitting a specific area and thereby you are seeing this. Another advantage per se is that because it has a large, because it has air gap as compared to the previous case, as compared to the previous case, this is solid, remember this is solid with a high refractive index.

Whereas these have air holes in between, these have air holes in between. It can accept somewhat under with underline, with some under that somewhat term, somewhat of a high power, high intensity of laser because in optical fiber the more intense light you make you start seeing either non-linear effect at least chi 3 comes in.

It depends on how intensely you are exciting the molecules around it at the same time it might melt because the temperature change can happen, all of those things though we say that electrons or atoms will not absorb that photon we have seen it but you never know when non-linearity kicks in that the wrong photon, any other photon can be absorbed and you do not know the afterwards effect.

Here it is air or vacuum however, you try to treat it and they can per se carry much more amount of power or much more amount of intensity but then again my experience working with photonic crystal or holy core fiber that these things are quite thin, these inner wall and they sometimes get ruptured and if they get ruptured the entire system of the photonic crystal collapses, so it depends.

Somewhat of a higher energy can be passed through hollow tube photonic crystal fiber why do we need it? Because we want to filter one single frequency of light, usually those

manufactured laser that you get from markets, though they look red or yellow or blue or green, they do not have one single wavelength, they are not specifically monochromator, they have several different wavelengths joined together with the most prominent or the centre wavelength beam around red or being around yellow or being around blue.

But usually it is not, it is not trust me, and I am talking about the normal laser that you get from any market unless you have paid millions of dollars to buy a laser, I am talking about these laser pointers that you use, the cheap lasers one that you use, the one which you get in discotheque they usually contain multiple wavelengths of light, though laser should be one photon coming up but it contains multiple wavelengths of light.

Here, here in photonic crystal you have a capacity to take that chip laser and filter one single frequency of light out and thereby try to see that one single frequency of light, what exactly it is doing to the skin or the tissue or somewhere else.

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Example, told you about endoscopy, endoscopy is very, very close to me because the first endoscope or the first process of endoscopy took place at Royal Infirmary in Glasgow, Scotland with by a person who is an alumni of the same institute which I am proud to call my alma mater University of Glasgow.

First endoscope was done by John Macintyre, Sir John Macintyre came to University of Glasgow to study electrical engineering the same thing that I did but while studying electrical engineering he changed his subject to medicine and then became a medical doctor. After becoming a medical doctor practicing in Paris and Vienna he returned back to Glasgow, started practicing in Royal Infirmary.

And he was one of the first to apply electrical engineering concepts into medicine, think about it how cool that is, yes, we have John Macintyre building and I am incredibly proud that he did this thing. So, he used a hollow tube, an endoscope, what does endoscope means? Well, endo, inside, scope, to see or to target, all of you whosoever have visited hospital know there is a different division, section for endoscope or endoscopy, what does endoscope means?

Well it is basically a tube which guides light, it is basically a tube which guides light, so you have an endoscope there is an external source of light, the light is guided through the tube, the tube is put inside some kind of orifice, says inside the mouth, the tube contains an objective, an objective lens at the very end, at the out it has, well the older one had relay lenses and you have an eyepiece by which you are seeing, your sending light and from the eyepiece you are able to see what is going on.

Now, obviously, we use laser for illumination and instead of an eyepiece here we have a video scope, a camera, that camera constantly takes picture of the light that is guided through the tube having optical fiber of very, very small diameter, say less than centimeter or less than 2 centimeter.

You can easily put inside several different human orifices with a camera or a light source attached at different ends and thereby illuminate a specific region, illuminate a specific area, this gentleman is learning how to use endoscope inside by, well he is trying to put it inside the skull, we actually do not do that but let him do whatsoever he wants, at least this is not a real person.

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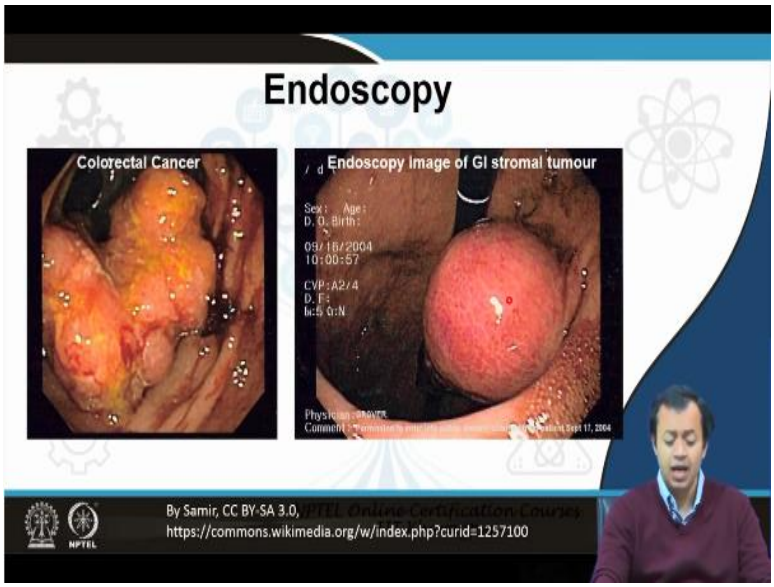

But we do endoscopy to see these different images, this person is looking at a stromal tumor, this tumor is at the gastrointestinal tract, kind of a stomach tumor type thing, not necessarily stomach it can be the entire gastrointestinal tract and colorectal cancer, it is colorectal cancer all these tumors you can now with the help of light visualize them, with the help of light visualize them.

Previously, in order to see the tonsil the doctor used to switch on torch inside our mouth and look into it, now you are sending a tube, the light is guided through the tube, these days obviously it is laser that is guided through the tube and the laser light is illuminating that area, the laser light is illuminating that area, we receive the back scattered light either through the same tube or through a Y junction tube.

So, I will show you in next few classes what exactly the tubes look like. And outside we have a camera, nowadays the cameras are pretty small with very, very powerful lenses, very powerful systems and a digital filter and what not and with the digital filtration you can get beautiful images like this, not just of this particular dimension, this particular size but you can even look into few millimeters, few micrometers, few nanometers inside for early diagnostics.

Suppose, something new or something different have only started to form, suppose a tumor has only started to build whose size is less than few micrometers, you do an endoscopy if you are able to, if the chances comes usually people will not go to doctor to do endoscopy just for the sake of it, but you know what I mean, you are able to detect it, you have the technology, thanks to biophotonics that you will be able to detect not just at this particular stage when it is like a golf ball, the tumor is like a golf ball but like a pea pod or a piece of a pea.

So, this is one of the examples that I gave you about how light could be guided at a specific area inside the human body and thereby you can use it for diagnostics. And in the next class we will see a bit more examples of lasers being guided at specific regions of the human body to both diagnosis as well as cure.

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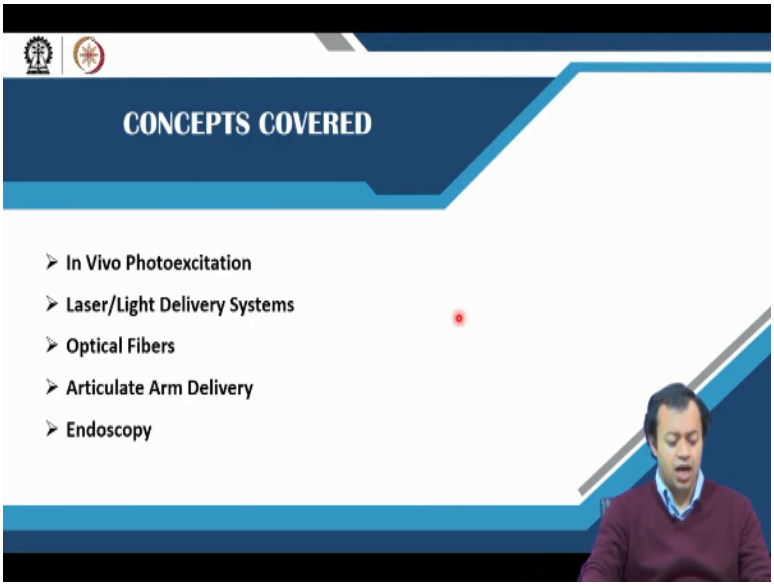

So, these are the concepts that I covered, do not worry if optical fiber the concept is still unknown we will be discussing optical fiber in the coming classes as well as photonic crystals, endoscope is the one which I actually wanted you to know.

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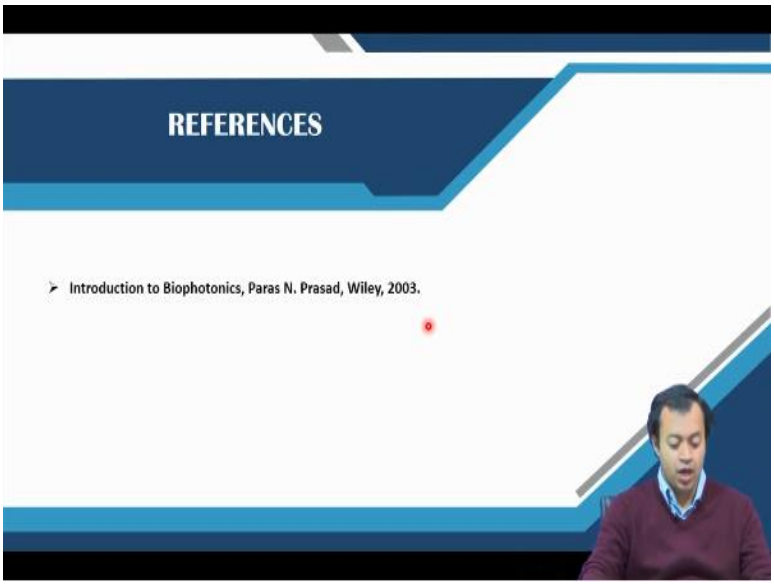

So, thank you very much.