Biophotonics
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Lecture 60
Summary & Revisiting Few Topics

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Welcome. We are at the very end. And today I do not have any new topic because everything that I had to cover in this particular course I trust I have covered it. So, I will return to some of my old slides that I started when I was discussing the introduction part and try to tell you that where, how far we have come, what we have started with and where we have come. So, this is not part of any module. This is my last lecture and I have tried to summarize and try to revisit few additional topics.

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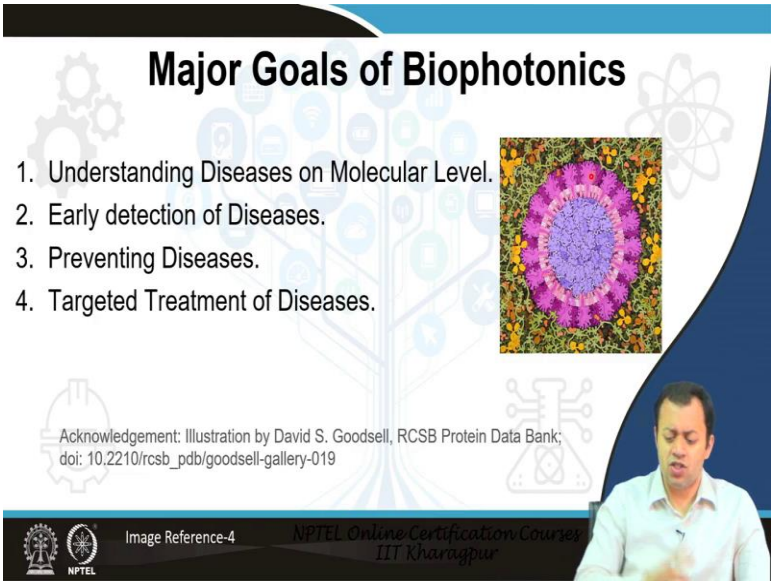

So, what were the major goals, what was the output that we were looking for, what were the outcome that we wanted to get from biophotonics. So, the biophotonics, as you know, that we wanted to understand a disease on a molecular level. We wanted to understand what is happening at a cellular level, a molecular level for a particular disease. What physical changes are taking place. We want to detect is as early as possible and we obviously want to prevent it. So, we want to image, diagnose, as well as provide some kind of therapeutic intervention.

We obviously want a targeted treatment of disease. We want to specifically locate a bad cell, bad organelle, a specific virus, a specific pathogen and thereby go and destroy it specifically without harming any other area. Remember, photodynamic therapy, photothermal therapy, hair removal using laser. So, we were very, very specific. We are targeting specific area. So, you must remember what this image was. If not, then go back to the earlier slides.

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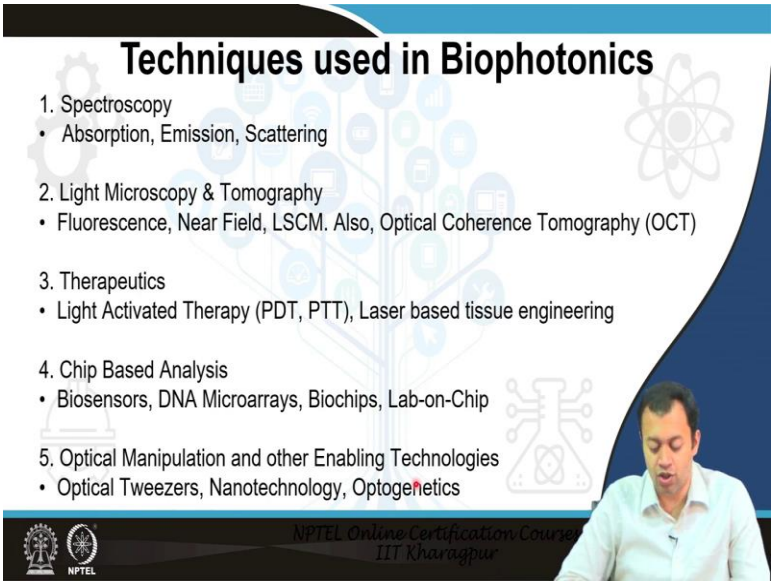

So, what are the different techniques? What are the different techniques we used in biophotonics? Try to see how many of them have been covered. How many of them you remember me covering you? How many of them you can tell me? There are different types of spectroscopy, absorption spectroscopy, molecular as well as electronic, vibrational as well as electronic spectroscopy. We have absorption, we have emission, and we have scattering. Different types of spectroscopy we discussed.

We discussed UV visible spectroscopy. We discussed FTIR, infrared spectroscopy. We also discussed a little bit of NIRS, near-infrared, which the devices more or less same. We also discussed Raman. We also discussed how the polarization of the molecule changes. So, spectroscopy we used in biophotonics and by this time you should have some understanding of spectroscopy.

We discussed different types of microscopy. Fluorescence, a large part of me giving you the lecture was on fluorescence. You know the singlet state, the triplet states, what kind of quenching takes place in fluorescence. Near-field, how can we break the diffraction limit? What is the diffraction limit of light? How do we break it? How do we bring it so close and illuminate it? Laser scanning, confocal microscopy, what is scanning, what is confocal microscopy? I hope you remember what all of these are.

And of course, we discussed optical coherence tomography. Optical coherence tomography is slightly different from microscopy. So, I have separated it. OCT, we discussed OCT. We discussed OCT of the eye. We discussed OCT of the brain. Several other areas, optical coherence tomography is being used. So, these were more or less detection or imaging.

Then there was therapeutics, we discussed about photodynamic therapy, photothermal therapy, where some kind of chromophore is being used. Light was getting there. The chromophore was activating. It was reacting, it was producing a triplet state and that triplet state was reacting with oxygen and the water nearby and producing reactive oxygen species that was eating up the bad tumor. Photothermal therapy, mostly heat is generated.

And we discussed in detail about the laser-based tissue engineering. Here we discussed the different topics. Specific areas of the laser, specific frequency, specific pulses are being absorbed by specific tissues, specific areas of the tissue and thereby, you either break it down or you coagulate and join them together. So, different types of tissue engineering were done by direct insertion of laser. Photoablation all those things we have discussed.

We also discussed about the cheapest analysis which includes biosensors. We discussed a large amount of biosensors of with me covering my own work metamaterials, fiber optics were also used, DNA microarrays we have used, biochips and lab-on-chip I touched upon it a little bit. You can go further. Lab-on-chip is also coming up, which includes all those microelectromechanical systems and a very complicated circuitry into a chip. Biochip or gene chip is something that came out of DNA microarray. So, that has also been done.

And of course, other enabling technologies, which includes optical tweezers, nanotechnology. By this time, you should know how a silicon wafer or gallium arsenide wafer is created, extracted and how we draw or write or print patterns in it. So, both how to make it, how to make a lamp or how to make a substrate, how to make a wafer you know. Remember, molecular beam epitaxy and how we can make patterns, how can make it into an IC, integrated circuit, chip, by this time you should know because I have covered it.

And of course, we discussed a little bit about optogenetics very, very little I know. So, that is a glimpse of something that I wanted to give it to you. Maybe in part two of this course, if there is a part two, I am not saying that there is any, if in future there is a part two of advanced

biophotonics, which I may or may not take maybe more part of optogenetics and neurophotonics will be added, but that is something which is far away in the future. So, do not hold your breath.

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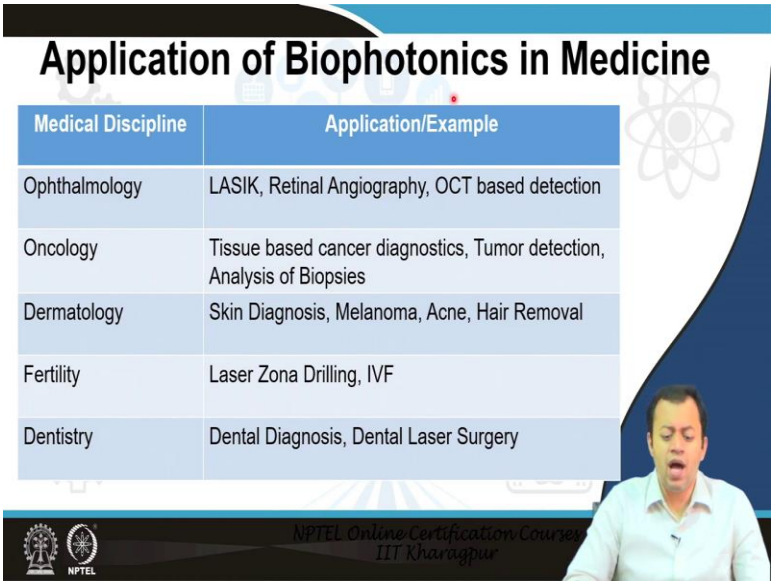

So, what are the different applications of these techniques? We discussed about LASIK eye surgery. Remember, how excimer lasers, how UV lasers were made to create a flap in your eye and the cornea straightened up so that the focal length goes further into the retina. We discussed this, retinal angiography and optical coherence tomography-based detection. These parts were more or less discussed. So, I am just copy pasting this slide from my introduction. I want to know how many of this were discussed.

Angiography where blood vessels inside the eye were taken care of using optical fiber, just like you do angioplasty in heart. Oncology, tissue-based cancer diagnostics, this was something, tumor detection and optical biopsies we touched upon some of them. In dermatology, of course, skin diagnostics, melanoma, hair removal, we did discuss several of these. Fertility, IVF and laser zona drilling, remember this was part of the optical tweezer course, optical tweezer chapter. So, this part was discussed. And a little bit of dental diagnostics, dental surgery we covered in our biophotonics course. So, that more or less covers it.

Now, before I go, for the past few days or past few weeks, most student have asked me a very common question. I have found this question coming up over and over and several of you are asking is that is there any, what are the research groups where can I work on biophotonics?

Several of you, undergraduate, postgraduate or PhDs aspiring to be PhDs or postdocs have asked me like this is an interesting subject, I want to do research or I want to do summer internship or I want to work in this area, what are the different research groups, where can I work? So, I thought that maybe it will be beneficial for at least some of you to tell me, for me to tell you some of the research groups, some of the places where significant amount of research on biophotonics is going on. Maybe it will help.

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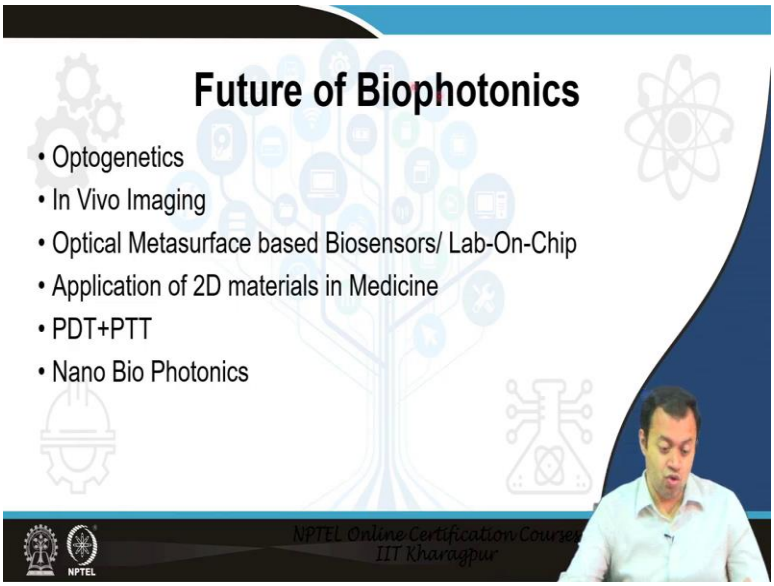

So, before that, let me just tell you what are the future of biophotonics, where the most important research is going. Optogenetics is a bourgeoning field, in-vivo imaging. So, you can read it at your own leisure. I know I have spoiled it. You want to go to the main research groups. But read. These are something which I strongly suggest you to read about. 2D materials are coming up. These are the future. But which are the research groups who are working strongly in biophotonics research.

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So, I have two slides. One for biophotonics research group abroad, outside India, and the next slide will be inside India. So, disclaimer, I do not know any one of them personally. This is not a merit list. I am not saying this person is at a rank at this, that person is not at a rank. They are, this is not an exhaustive list. This is only few of the lists that or few of the groups that I followed because I like. This will give you a start. If you are looking for places to go and work on biophotonics, this is a random collection in no particular order of some research groups abroad which perform very good biophotonics research. Not that I am recommending them. Not that they require any recommendation from me, per se. It should be the other way around. They should be recommending me rather than me doing that, but you get the point.

I have constantly followed Professor Fujimoto's group at MIT. There are excellent research going on in with Professor Howard's group at Notre Dame. I collaborate with few of these people somewhere here and there at different stages of collaboration, whatever collaboration actually means. So, they are some very, very excellent groups, few of those excellent groups. There are several other groups that I have not mentioned. So, at your leisure time, go visit some of their websites and try to see what kind of papers they have published, like the work that was going on at NIST. NIST is where I have also worked, Leibniz University, Hannover. Japan, they have this biophotonics research group.

Apart from this there are incredibly good work being done in University of Heidelberg, then obviously Kirchhoff's Institute in Germany, Stanford. So, the point being here is if you are trying to look for work in this area, do not always search for biophotonics. Expand your search and look for say biomedical engineering or bioimaging or bionanophotonics or like use these keywords.

These few names will help you. These few names will give you a start and from that you can then diversify and look into different other areas apart from biophotonics, but somewhat may be related, which you might be feeling interested to go and work or go and collaborate or go and communicate with them. So, these are some of the research groups, world leading research groups abroad.

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And then the there are several research groups in India. I get this question all the time. Where in India can I work on biophotonics? So, there is a uber fantastic lab in TIFR, Tata Institute of Fundamental Research of Professor Sudipta Maiti's biophotonics lab and top-notch work is going on in this lab. So, no doubt about it. I mean, I am very thoroughly impressed by the, just look at the type of publication this group is doing tremendous, tremendous work.

There is S.P. Singh's group at IIT Dharwad, this gentleman has worked at MIT. Nirmal Ghosh in IISER, Kolkata, Professor Sudipta Maiti at IIT Kanpur, probably some of you know she also is quite active in NPTEL and her work is tremendous to say the least. And then there are several

laboratories where more than one professor, more than one researcher, more than one scientist work. So, it is not run by a specific person. So, like Biophotonics Lab in IIT Madras or Center for Biophotonics at Manipal Academy or the Biophotonics Laboratory at the National Center for Earth Science Studies, Kerala, there is Raja Ramanna Advanced Center, RRCAT, I think, Raja Ramanna Centre for Advanced Technology that work on biophotonics.

So, if you want to go and look into these works, by all means, please, please do so. Look some of the work that they are doing. But I would strongly suggest to expand your keywords. Just do not stick to biophotonics. Look for bioimaging, biomechanical studies, photothermal therapy, neuroimaging, optogenetics. So, expand it. Expand it and I think you will get more and more hits. These are again not an exhaustive list. Those of you who I have not mentioned it does not mean anything is just space and time that this is something that I came across.

I do not know frankly speaking, personally any of them and this is not an endorsement or an advertisement from my side. Not that they require any endorsement or advertisement from me to begin with, but you get the point. You have to contact these people if you are interested. So, and depending on your performance, your work you might get.

And obviously last but not the least we have our own group at IIT Kharagpur. This is in conjunction with the Advanced Photonic Laboratory of Professor Shailendra Kumar Varshney of Electronics Engineering Department. We have some nice tools like microscope enabled FTIR spectrometer. We also have an AFMIR, atomic force microscopy infrared spectroscopy machine. We have several different pulsed laser source and fume hood cabinets.

So, there are several researchers working in our research group as well. It is just that if you want to get connected or work in several of these institutes, since they are central government and quite reputed institute, you have to go through some rigorous entry tests. So, their competitive exams that you need to pass to get into that.

I get emails like I want to do PhD under you. I get emails from students all the time. I want to do PhD under you. I want to you to supervise me. That is all fine and good, but that comes at a later stage. First you have to pass the exam, the Indian exam of GATE or NET or other such entrance examination and only when you have qualified after clearing this entrance examination, then only somebody, some professor can make some sort of a judgment call regarding whether to

supervise you or not. So, there is initial rigorous competitive exam process before you are actually allowed to work in any of these laboratories. So, be aware of that. Let us there be no false hope.

So, I hope that basically covers some of your queries, some of your points. I learned quite a lot from teaching you this particular course. There were several times I fumbled, I made some mistakes. And to the best of my knowledge, they were not deliberate and they were not something catastrophic. But if they are, then I most definitely apologize. I hope I was able to explain or give some sort of information to you and make few of you curious. Few of you are now willing to look into the other sides. Few electronics engineers or physics people are willing to look into medicine or biology in a very, very serious manner.

Similarly, perhaps few life science students, medical doctors, medical practitioners are now looking into photonics, now looking into physics, trying to see that these new technologies where they can apply it to serve better their own medical practice. So, that was overall the aim that I came up with that this bridge between physicists and physicians needs to be broken on, this bridge needs to be built, beg your pardon, this bridge has to be built that these two groups of people need to communicate among each other only for the betterment of humankind. I hope some of you are interested. It was a pleasure for my site to teach you this. And I wish each one of you all the very best for your future. Thank you. Thank you very much.