Nanobiophotonics: Touching Our Daily Life
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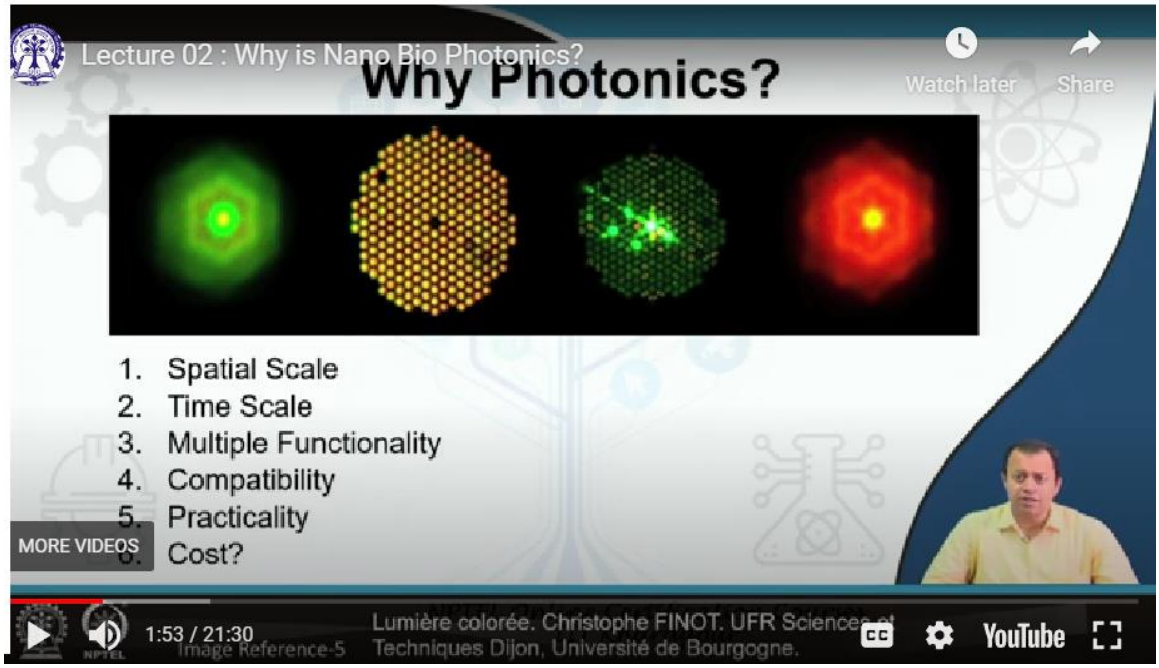
Lecture No. 02
Why is Nano Bio Photonics?

Welcome back. We were discussing about nanobiophotonics and this is lecture number 2, where we will go little bit more into the overall structure of the course as well as why there is a particular requirement for nanobiophotonics. I tried to cover little bit in the previous lecture, but let us go little bit further into where nanobiophotonics could be utilized, where exactly nanobiophotonics have its applications and how could you possibly directly benefit from it. Now before going to nanobiophotonics, let us understand why photonics is required. Why exactly is a requirement to have photonics? We could have gone for nanobioelectronic of course, we could have gone for nanobioacoustics of course, but why did we choose to go into nanobiophotonics or why particularly photonics was utilized. In the next lecture, I will be telling you a detail about what photonics is or how photonics can be utilized, but suffice is to say that light- or light-based technologies have certain advantages that electronics or acoustics cannot provide.

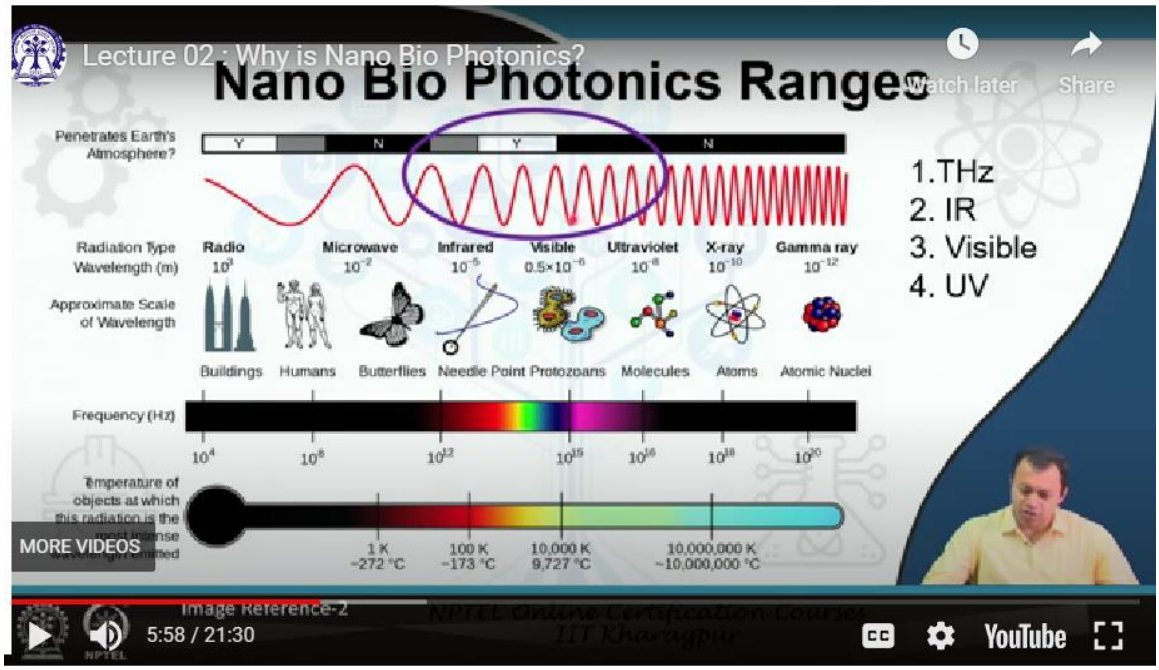


First and foremost being its scale both in space as well as time, meaning a photon particle that is light is made up of photon particles. These particles can vibrate at a frequency that is far higher than that of an electron could. Electrons obviously have mass, photons though many people claim to have 0 mass it is not absolute 0 mass, but its mass is far less than that

of an electron and it could thereby vibrate at a frequency that is far faster far higher than that of any electron could do. And thereby as the people in Bell laboratories in New Jersey United States found out that by vibrating this light particles vibrating photons, they could pack more amount of information and send them far away without them getting affected much by external factors such as temperature, heat, mag, stray noise, stray magnetic field unlike that happens in electronics.

Secondly if we are talking about light in the visible spectrum as I discussed in the previous structure, it is mostly available you can generate light at a comparatively low cost visible light comparatively low cost not necessarily always and it could be utilized for multiple functionalities. It preserves the biological integrity of the system it does not destroy it and there is other aspect that it is compatible with the human body. So, photonics has several aspects in itself that finds it suitable when you are treating diseases at sensitive areas of the human body. Say for example, you are trying to detect some kind of a tumor inside the eye obviously, you need to prove it with light rather than some kind of a chemical material or rather than some sort of a by passing electric current. Similarly, if you are trying to probe the mind probe the human brain, it is far safer to utilize certain wavelengths of light that passes through the brain than you know sending electric current or sending some kind of a chemical material inside the brain and trying to probe it right.

It might affect the entire brain and thereby defeat the purpose that you are trying to see or it can of course, manifest itself into different side effects. So, photonics has this advantage. In the next lecture we will go detail into several other aspects of photonics, but suffice is to say we choose photonics instead of electronics or acoustics, acoustics means sound because it has a size advantage. You could confine light to a very small area and usually if you are clever enough it will not be irreparably damaging that area of the biological material. So, when we are talking about nanobiophotonics range, we are mostly dealing in the visible spectrum.



In the visible spectrum with certain aspects of infrared you will see as soon as I start the spectroscopy chapter that infrared is required because molecules are more affected by infrared than necessarily by visible molecules have their motion. When infrared light comes molecules absorbs and they start vibrating at a particular frequency. These frequencies can be detected and these frequencies are specific very specific for these molecules and thereby could be utilized as a signature. So, we will utilize a little bit of infrared. You know infrared is always associated with heat.

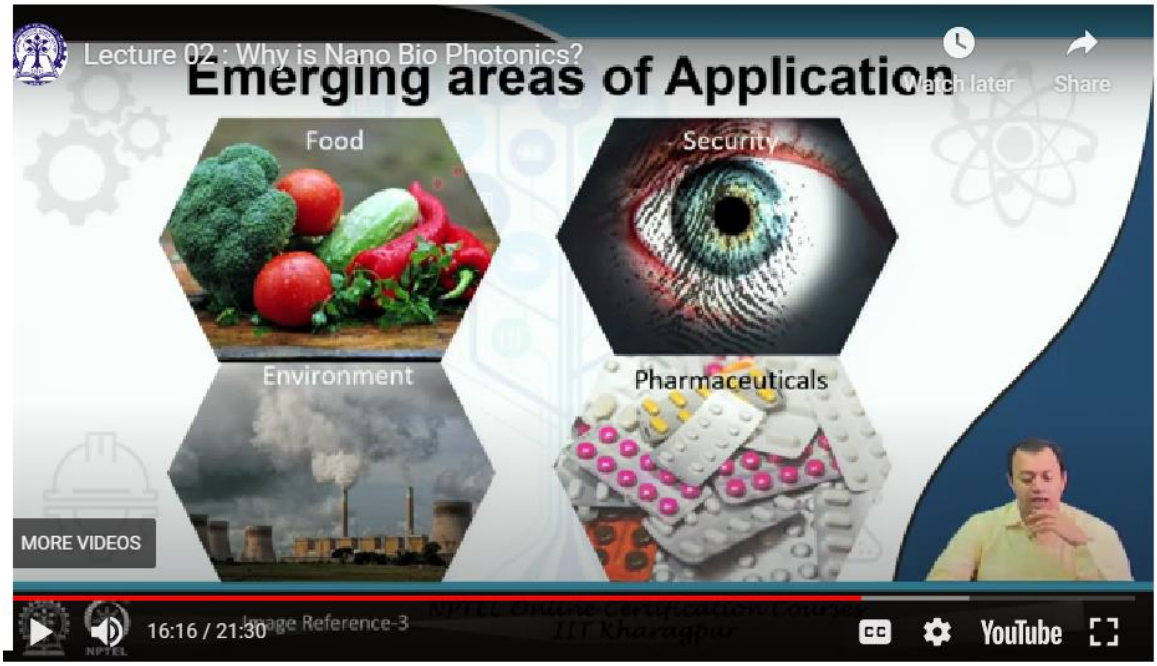
Can anyone of you tell me why is that? Why is infrared associated with heat and not visible or ultraviolet? I gave you a hint in previously, but think about it why is infrared associated with heat. Nevertheless, we will be dealing with visible spectrum mostly and to a point we will be discussing or we will be delving into ultraviolet. Though we would like to avoid ultraviolet as much as possible because they are high frequency high energy wavelengths and too much ultraviolet as you know will start damaging the cell, tissue and fragile systems like nucleic acids proteins etcetera. So ultraviolet we will try to avoid it as much as possible because at the end of the day if we claim that it has less effect or no side effect and then we you know subject it to ultraviolet ray then it defeats the purpose. You see mostly this visible spectrum helps you know cover most of the biological materials at a subcellular level at a cellular subcellular level and you can go little bit deeper as well if you are clever enough.

If you are able to break the diffraction limit light cannot be a particular wavelength of light cannot be infinitely put into an area which is smaller than its own wavelength meaning

if you are trying to resolve or trying to see a particular dot of size say 100 nanometer and you are trying to see it with a light of wavelength 400 nanometer 500 nanometer visible spectrum you will get into difficulty because there is something called diffraction limit meaning light will have difficulty in resolving materials resolving features resolving structures whose sizes are less than half of its wavelength. So 400 nanometer wavelength light will have difficulty resolving structures which are less than 200 nanometer of light it is called a diffraction limit abbe's limit abbe's diffraction limit, but using nano bio photonic technologies you can break this limit you can break ~~this diffraction~~this diffraction limit and using 400 nanometer structures 400 nanometer wavelength you ~~can go~~can go and detect say 50 nanometer structures. So, this is possibly something that photonics provides I will not be discussing about terahertz, but I decided to give terahertz anyways because microwave photonics is something that is coming up very strongly right. I am not a specialist in that or I have very little knowledge apart from the thing that it is exciting it does not excite me per se, but it might excite you thereby you should be able to you should be aware of this thing if you are excited go into ah terahertz photonics or microwave photonics this part is not going to be covered terahertz photonics will not be covered in this particular course we will be mostly dealing with number 2 and number 3 infrared and visible in order to discuss application of nano bio photonics. Now obviously, you know that ah light based therapy or light based technologies are already utilized in medicine or biological fields from a long period of time there is there is nothing particularly new in here microscopy has been going on since since 16th or 17th century fluorescence endoscopy keyhole surgery these are the keyhole surgery laser eye surgery I have discussed laser eye surgery before, but if you do not know we utilize laser eye surgery for you know correction of the eye for you know corneal correction etcetera and optical coherence tomography is utilized for non destructively imaging your retina your back of the eye.

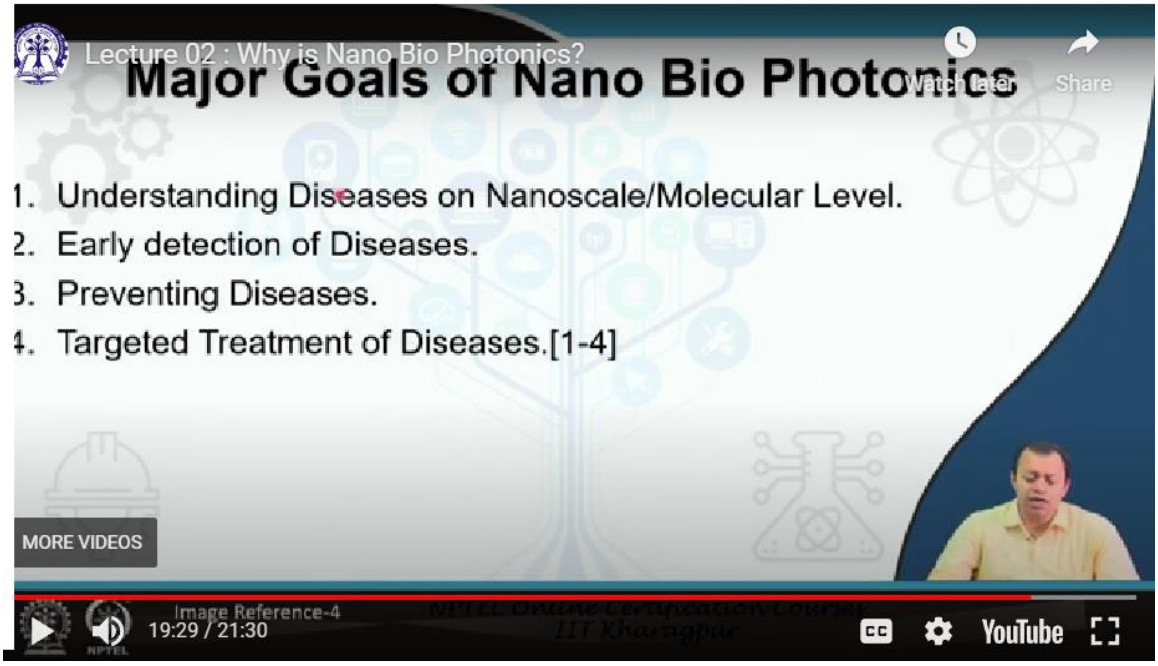
So, these technologies are already available meaning some of these technologies of bio photonics or nano bio photonics exist already in our day to day life meaning your life is more or less already affected by it you have perhaps used a pulse oximeter during the dreadful months of coronavirus pandemic to measure your blood oxygen level you might have gone through endoscopy you might have known somebody who has gone through laser eye surgery or you might yourself has gone to the eye doctor to check your eyes or retina and that person have made you sit in front of an OCT optical coherence tomography and thereby try to see the entire three dimensional view of your eyes. So, several of these technologies from nano bio photonics point of view already very much exist what we want to say is that we take it from here this is our base and we then go to the next level I would not be discussing these in here I just I am telling you that these already exist, but can we go any step further can we go any step further and perform surgery or perform some kind of a therapy or do tomography on to other areas of the body at a nano scale resolution not just looking into your eye completely or focusing on the retina, but going just inside the optical nerve can we image the optical nerve non destructively and try to see what is happening there at a cellular and sub cellular level can that be understood. So, this is our base we will take it from here meaning nano bio photonics already exist though you may not know it you have utilized nano bio photonics technologies in your life already you know pulse oximeter is an example where light is used to detect the amount of oxygen that your blood vessels or that your blood is carrying what kind of technology do you think that is it has light it has it is very small it has a processor to process and obviously, it is utilizing it is being used in your body which happens to be a biological material. So, is it not an application of nanobiophotonics you tell me is granted there are electronics aspect I am never saying that photonics means we need to divorce from electronics or we need to

divorce from acoustics it is an interdisciplinary field you will borrow a technologies from all different areas, but point that I am making here is that several of you have already utilized this technology by probably not knowing it that keeping that as base we will go one step further to see if you can utilize it to understand the human brain if you can utilize to understand genes if you can utilize to understand and cure some sort of disease manifestation. There are several other emerging areas of nano bio photonics it has not simply restricted itself to biology as I said anything that affect one field need to be affecting other fields as well nanobiophotonics is being utilized for environmental detection people are utilizing micro plastic detection in ground water as well as you know water bodies like rivers and ponds using nanobiophotonics technologies micro spectroscopy nano spectroscopy etcetera we need to detect adult transient food the micro plastics that has come up micro plastics are plastics which plastic particles whose size are you know at a micro scale level or nano scale level which usually gets passed through this garbage treatment plants the filters of the garbage treatment plants and since they are non biodegradable they stay in the environment in water bodies in fields and they finally, found themselves in drinking water facilities as well as in foods just an example and then they get deposited inside human body you drink it you eat it you inhale it and bits and bits of plastics get you know deposited in your body how do you detect it how do you prevent it from happening.



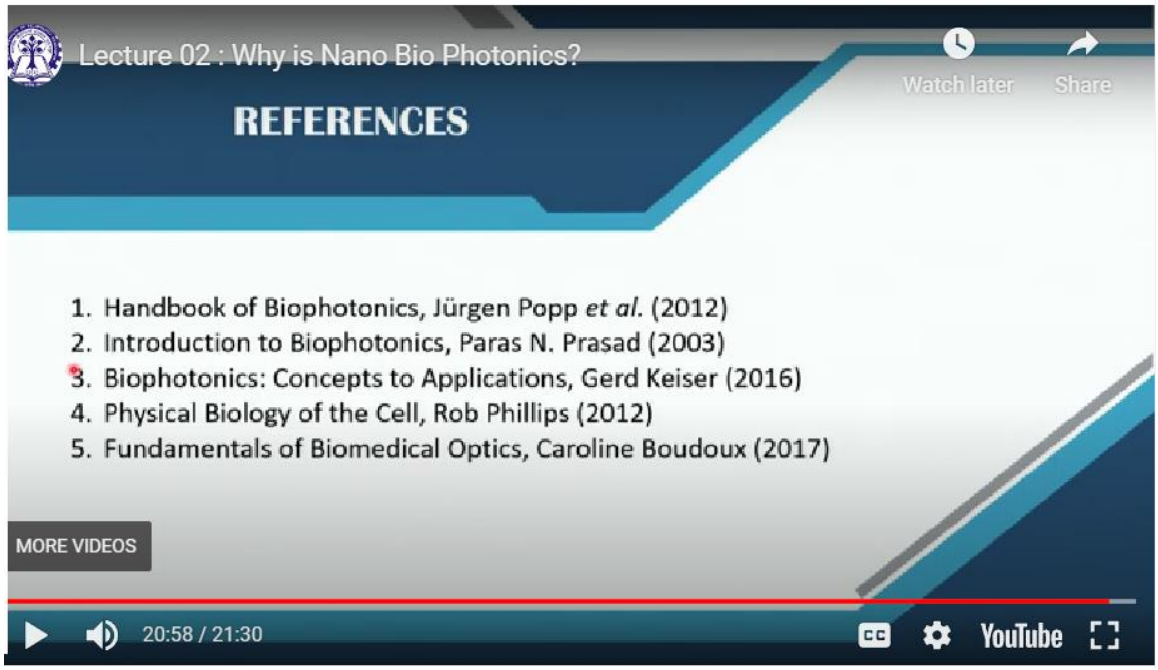
Nano bio photonics provides the technology to you know detect these amount of adult rants pollutants for example, micro plastics in environment in water bodies in air in food water etcetera similarly of course, you need to apply in security these days are quite common cyber security or secure communication all of these things are coming up though that is an area of nano photonics where secure communication is being done, but to identify a particular human being authentically nano bio photonics have a huge role to play and it

can take it to the next level you are identifying a human being not just by that persons fingerprint or that persons retinal scan, but you are trying to identify the human being at its cellular level. Now how are you going to fool or how you are going to make a copy of somebody at a cellular level right your cell is your cell my cell is my cell you cannot have anything else as such. So, you are identifying the small differences in DNA in proteins in the cellular level and thereby authenticating or validating the identity of a person. So, taking it to the next level fingerprints can already exist retinal scanner is also there, but if you want to take it to the next level from a DNA point of view identifying a person from a forensic or a security point of view nano bio photonics aspect and of course, pharmaceutical from investigating the side effects of medicine to whether the medicine is able to cure it or not and what effects it is manifesting at a subcellular level nano bio photonics can play a very strong role. So, what are the major goals of nano bio photonics we need to understand the disease at a nano scale slash molecular level we need to understand the first rule of war is to understand your enemy yes disease is the enemy if we want to cure a disease we need to understand a disease whether it is because of an external factor whether it is because of an internal factor can it be communicable does it spread from one person to another or does it localize which part of the body does it affect does it stay in that part of the body after certain time does it migrate from one area to another area how virulent is it how fatal it can cause what are the treatments required.



So, all these understanding of the disease at a molecular level can be done by this technology as I have said since it is a nano scale level you are able to detect the disease at a cellular or subcellular level at that is the earliest stage as soon as it is detected at early stage you have a better chance of you know disease outcome you have a better chance of

defeating the disease if you are able to detect it at a very early stage of course, we need to prevent from this spreading further not only we have detected it we have stopped it spread to go any further and then finally, you are going for treatment of the disease and treating the disease where exactly it has manifested targeted treatment you are not going any further than that. So, that there are no unwanted circumstances. So, these are the major goals of nanobiophotonics and we would like to see how far we have achieved and how far we need to go by utilizing these technologies.



So, this is the very basic of my introduction to nanobiophotonics I think I have given you enough introduction to what it is why it is why should you be interested where will you find it from next chapter onwards let us discuss on the manifestation of photonics manifestation of nanotechnology and the manifestation of biotechnology and how you can combine it together for achieving those goals that I have just said. I hope to see you in the next class as well.

Thank you very much.