Nanobiophotonics: Touching Our Daily Life
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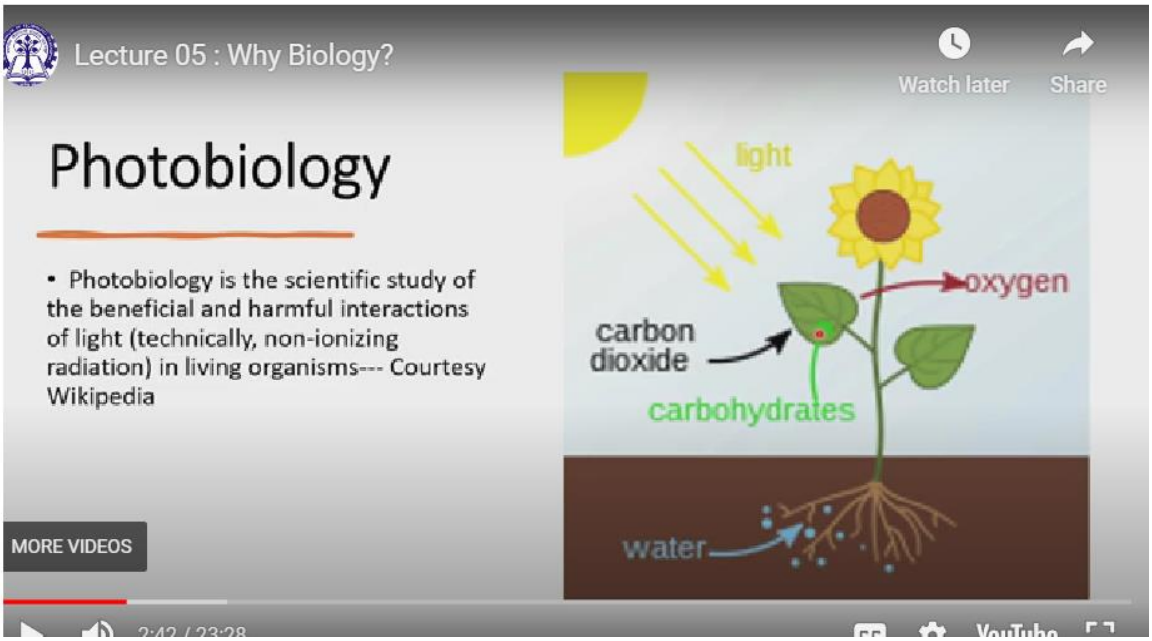
Lecture No. 05
Why Biology?

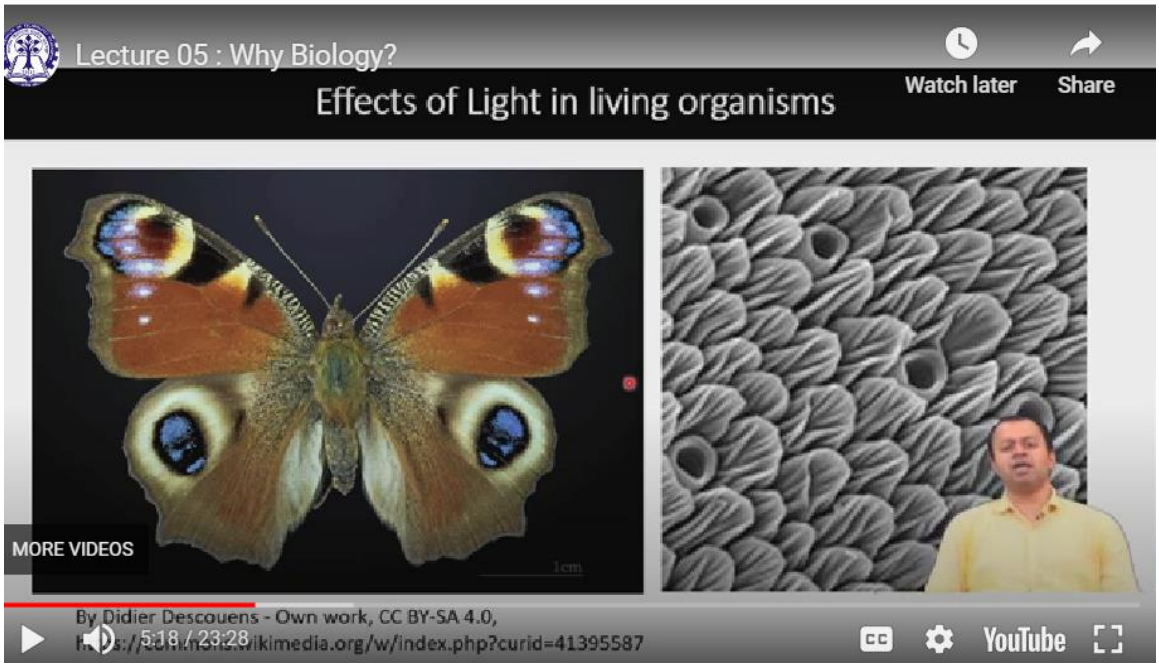
Welcome back. We are at the end of our first chapter which is Introduction to NanoBiophotonics and today I will discuss why biology? Thus far we have discussed why photonics in the previous lecture, why photonics as a technology was chosen. Now in today's lecture I will discuss why utilize photonics which has a plethora of application from communication to metallurgy to lithography to spectroscopy into biology. What is the point of utilizing light onto biological matter? Now turns out that biological matter and light have had a connection since life almost existed in this planet. Biological entities, biological material, biological organisms have had been interacting with light and the byproduct of this interaction, the output of this interaction between biological material and light have had created basically or made it sure that life sustains in this planet.

How? Well all of you have heard of this term photosynthesis. Photobiology is a specific term is a specific area and this is the best definition I found out courtesy Wikipedia yes shocking I use Wikipedia very much. Photobiology is the scientific study of the beneficial and harmful interaction of light in living organisms. Photobiology is the topic in which I want to make an example of photosynthesis.



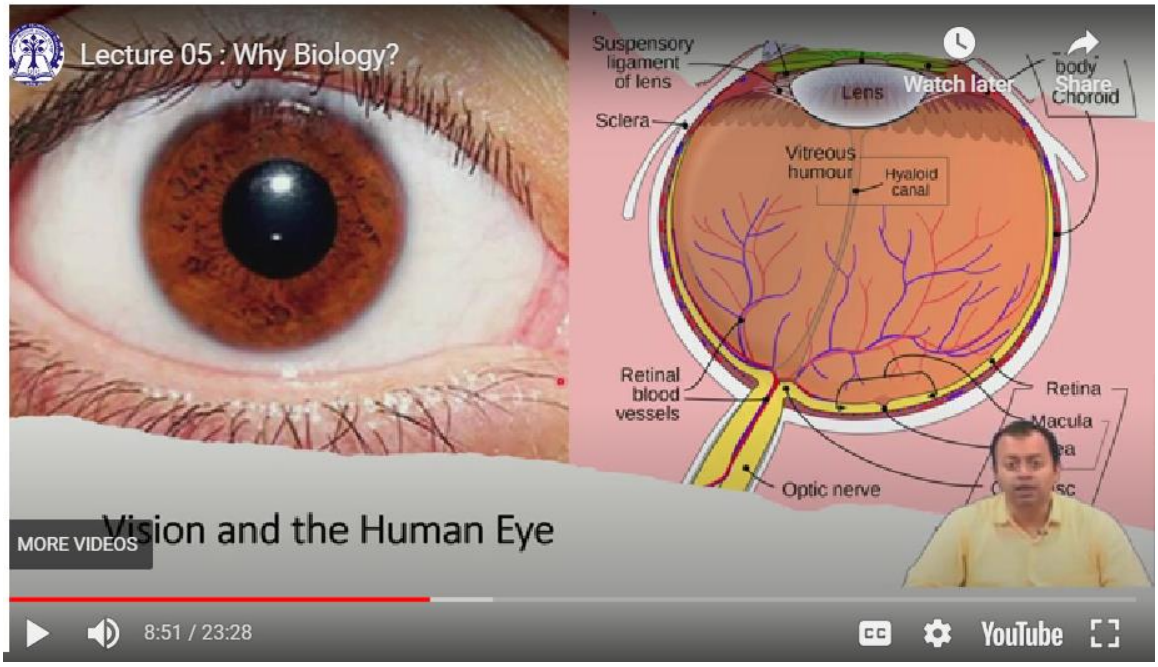
All of you have heard this or seen this or read about this in your high school where light falls into this leaf of a plant which intakes water and carbon dioxide produce glucose or carbohydrates which the which the plant use utilizes as food and the byproduct is oxygen and this oxygen is something that is sustaining life on earth. Granted there are few anaerobic bacteria that do not use oxygen, but vast majority of organisms living in this planet survive by inhaling oxygen. Now do not be fooled by this at all photosynthesis is a tremendously complicated topic. This is something that I have taken from high school because it is imprudent of me to scare you with something this early in my course. Believe you me anybody who is from a biology background knows how complex photosynthesis is there is chlorophyll a chlorophyll b all those ATP cycles this that I am not going into this, but understand that light interact with biological matter output is oxygen it is not merely enough for the light to be interacting with the biological matter as such it requires some kind of an output chemical reaction to take place and this has been happening in biology for a very long period of time as a result the topic of photo biology has come up.

You can say biophotonics to be a subset of biology subset of photo biology. Biophotonics is also a subset of photonics biophotonics is also nanobiophotonics is also a subset of nanotechnology. So, take your pick whichever background you come from you can choose. Similarly there is this thing of effect of life in light in living organism have you ever you know wondered how beautifully colored the wings of a butterfly are turns out that the reason the butterfly wings are this colorful is not because of some chemical reaction or some chemical dye, but because of the small nano structures the small holes and small antenna like structures different wavelengths of light different colors of light falls on to them they bounce among each other they interfere among each other some of them get cancelled some of them gets enhanced the overall result gives you something like this. This phenomena is called structural color, structural color, color because of the structure, color because of the nano structure not because of some chemical reaction.



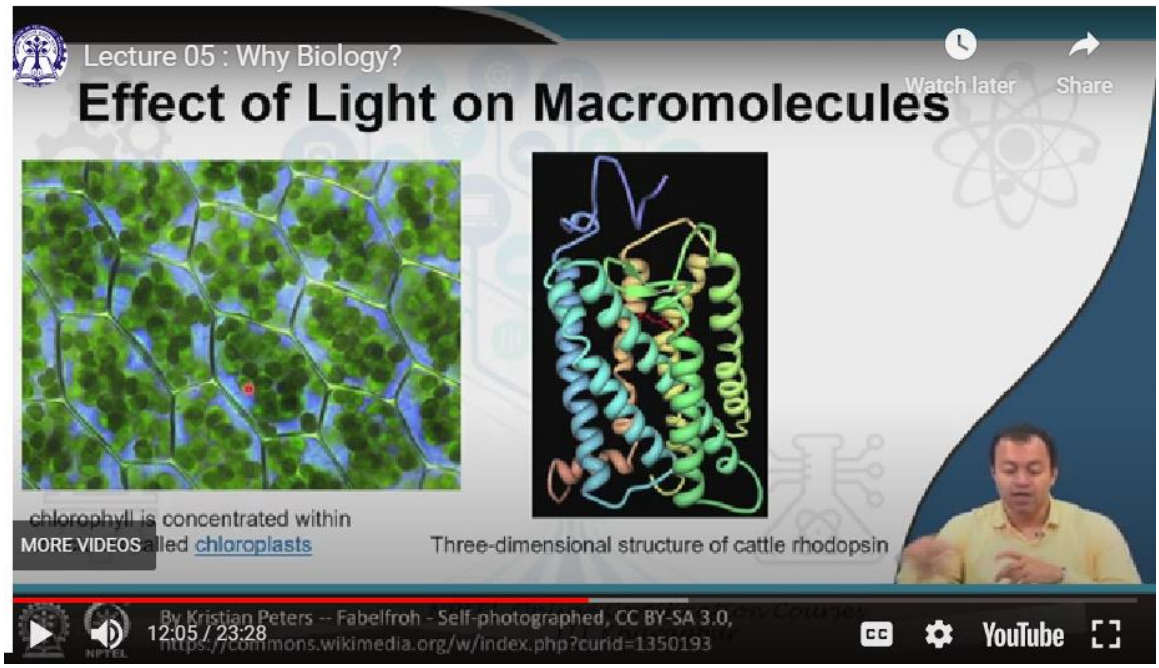
Remember as a high school student in chemistry laboratory your teacher used to give you colorless salts then on that salt you will apply certain different chemicals upon reaction with certain different chemicals the color of the salt change to something like copper blue to canary yellow to blood red and based on those colors you would use to assume or you used to diagnose or you used to tell what salt is this actually chemistry high school laboratory. So, usually color is formed by that chemical A reacts with chemical B the overall result is some sort of a color these are basically reasons why dyes have colors and these dyes are something that are utilized in textiles and apparels. Here there is no chemical reaction happening it is purely physical the structure is made in such a way the great thing is made in such a way that all the lights that fall onto it they bounce off a back the size of these structures the size of these structures are comparable to the wavelength of light. So, if the wavelength of light visible light 400 nanometer to 800 nanometer these are around same size thereby individual wavelengths individual wavelengths can be catered to these holes they can then bounce back up and down interfere diffract etcetera and the overall resultant is this there is no chance of fading away think what will happen to this if we make these kinds of nanostructures these kinds of microstructure in clothes our clothes color fade away if you put it in bright sunlight or after you know 100 and 200 washes or after few days structural color does not, but anyway that is a different topic on textile. Overall idea is nature naturally biological existing materials such as butterfly wings or photosynthesis light have been interacting with biological materials and there is an output associated with it the output is resulting in something very significant either something like life being sustained on this planet or you are simply getting amused by looking at the butterfly wings maybe you will spontaneously be write a poetry or sing songs all because of interaction of light with a living matter and its output. The output has to be significant it is simply not merely a reflection or refraction like any other matter per say it needs to

create something else like the oxygen byproduct n photosynthesis like the structural color here in butterfly wings. What do you think makes the color of the peacock feather this vibrant is it same as butterfly wings? you know peacocks right they have this peacock feathers and those those colors are beautiful what do you think is the reason for those color think about it.



Finally, what about the human eye you are watching this video using your eyes and is it not an example of light interacting with biological matter and thereby causing some sort of an output. Your eyes are like this there is this iris which opens or contracts depending on how much light has fallen onto your eye entire light falls into this lens the lens focuses this light onto your retina. I am telling you very simply very in a simplified and short manner this can go on forever the light falls onto the retina, retina has large number of rod cells and cone cells that convert this optical signal into electrical signal those electrical signals are carried through optical nerve into your cerebral cortex into your brain and your brain thereby interact brain thereby interpret the entire world around you. So, this is a biological matter which is interacting with light and based on this interaction you are able to see you are able to perceive you are able to understand the world around you. The output is understanding the output is perception the output you understand by looking at it whether it is dangerous non-dangerous edible non-edible. So, much so, thing I do not need to go on to detail of what vision can do vision is the output vision is the output that interaction of light with biological matter does. So, where exactly are those interaction taking place right it is not taking place at the bulk level, but it is taking place at a very very nano scale level for example, chlorophyll is required to convert light and carbon dioxide and water into glucose carbohydrate and oxygen these chlorophylls are concentrated within the cellular

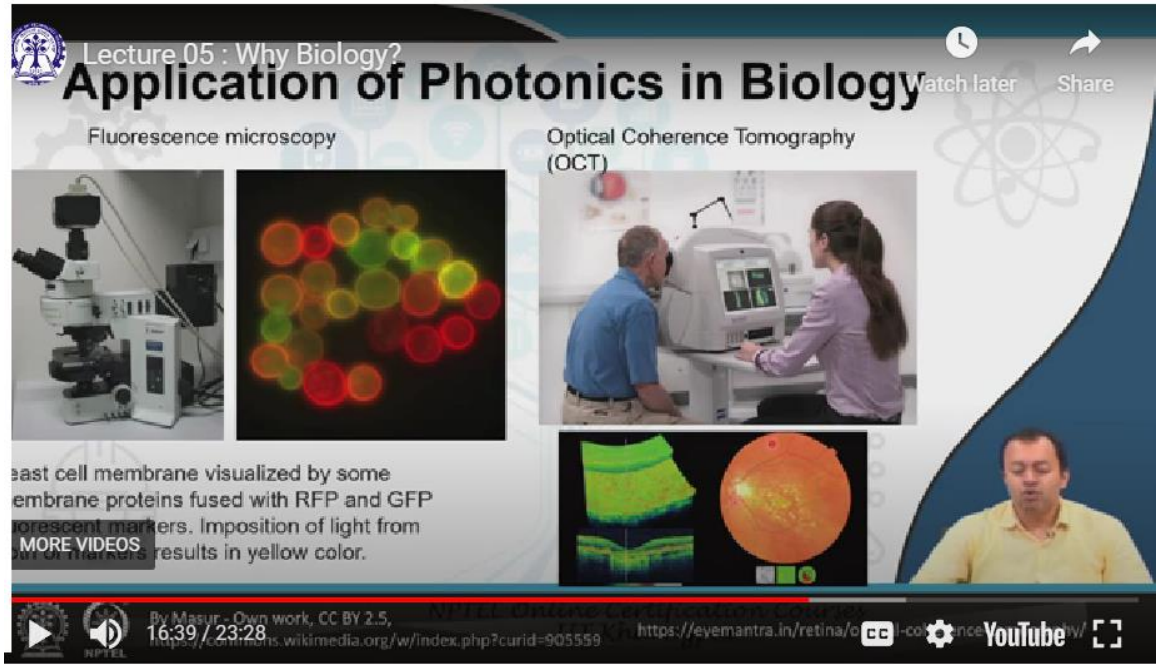
structures of plant cells called chloroplast you know there is one fundamental difference between animal cells and plant cells plant cells have this extra structure called chloroplast that contains this pigment chlorophyll this chlorophyll pigment is the one that helps in performing the chemical reaction acts as a catalyst for say in performing the chemical reaction between light carbon dioxide and water to convert it into glucose convert it into carbon dioxide and water convert it into carbohydrates and oxygen.



Similarly, the rod cells and cone cells of your of your retina present inside the retina contains this protein structure called opsin we will discuss detail of it rhodopsin is a part of it that changes its structure upon interaction of with light you know in chemistry we have this structure called cis versus trans a same chemical compound whose structure changes morphological structure changes the two types cis and trans. So, rodopsin is a chromophore is something that a rodopsin has a chromophore actually a chromophore is something that changes its physical structure upon illumination by light. So, this protein changes its structure which is present in your rods and cone cells which is present in your retina and this change in the cis versus trans the morphological structure of the protein result in changing the polarity changing the electrical connection in between those cells and this potential difference within the cells result in flow of electric current this electric current is then taken by the optical nerve into your brain. Do not worry I will discuss again this in detail this is merely the first chapter. The point that I want to make here is that the interaction of light with biological matter is not happening necessarily at the bulk level, but at a nano scale level.

So, does not flow naturally that we need to understand the interaction of light at a nano scale level and try to see if we can modify it, what technology do you think we will apply here light interacting with biological matter at a nano scale level nanobiophotonics. So,

we already have utilized several photonics space technologies as I was telling in previous previous class to understand to probe biological entities application of photonics in biology there are plethora, but let us say what about fluorescence microscopy you know fluorescence microscopy has completely changed there is a paradigm shift in how biological materials are viewed previously we used to simply stain by a dye some biological material and look them under a microscope. Now you are labeling them with some kind of a material which when absorbing light which absorbs the particular frequency of light a particular color of light emits a different color that is fluorescence microscopy and you can see something as beautiful as these are yeast cell membranes cell membranes are absorbing a particular light blue or green and they are emitting red light and thereby you are able to understand them properly. So, fluorescence microscopy is a prime example of photonics in biology microscopy fluorophore fluorescence etcetera we can able to utilize or visualize biological components like this in a beautiful manner. Secondly, another particular example is optical coherence tomography those of you who had the pleasure of visiting any big hospital especially an ophthalmologist or who have problems in their eye might have been subjected to this machine this is called optical coherence tomography in which sets of light beams falls onto your eye and it basically maps it basically maps the entire three dimension here it is given 2D, but like 3D picture image of your retina.



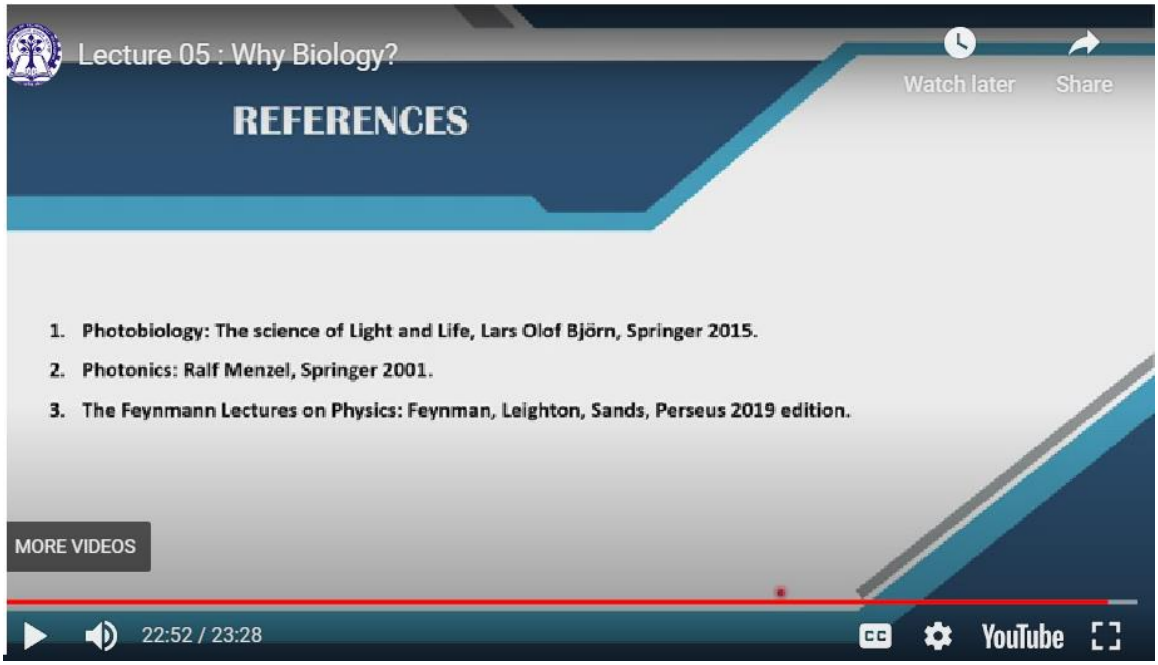
So, certain amount of light which your eyes will not absorb and thereby cause heat or damage is deliberately passed through your eyes through your iris through your lens and then a three dimensional image of your retina is created and that is mapped to see if you have a retinal damage if you have problem with the optical nerve if you have some sort of problem in the eye and this is all happening noninvasively. If you have a practical ah example if you have been in this person's position or if you have known somebody who had done OCT on their eye we will know that this is minimally invasive and completely

painless. So, what exactly is the point that I want to make here the point that I want to make here is biological substance react with light anyways they interact with light and they produce some sort of an output. Photonic technologies utilize light to probe different matters, we just simply added them together. Photonic technologies when applied in biology in medical field not only we are simply able to see or visualize we are also able to see the different modification different reaction that the biological entity will perform when subjected to a specific specific wavelength of light.

A specific wavelength of light will make your eye shut down a specific wavelength of light will make your eye not absorb it or not feel it at all thereby using a full plethora of different wavelengths of light you can understand you can observe you can modify the biological entity. Chlorophyll in chloroplast in plant cells utilizes certain wavelengths of light anyways utilize a different wavelength of light to visualize it how exactly the reaction is taking place in real time and then use multiple you know wavelengths of light simultaneously to see what exactly is going on. So, why biology because biology is right there biology is right there several things are nanoscale anyways inside it you do not have to create anything nanoscale in sophisticated laboratory you simply have to pluck the wing of a butterfly do not do it if you do not want to they are beautiful creatures, but ah there are already nanostructures available subcellular structures available within leaves within butterfly wings within your own eye that interact beautifully beautifully with a light and produces some sort of observable output. All of these things can simply be mapped using photonic technologies and you can go one step further can you modify it can you send some other kind of light can you do some laser based surgery if there is a blockage in here you have found it out by sending light which does not absorb that there is a blockage you send some sort of a laser light which is now being absorbed, but at a very very small intensity level. So, that that blockage is burnt the blockage is you know evaporated and rest remains as it is possible.

Problem with electronics is that not everything will interact with electric current do you think or do you know feel that it is feasible to use electric current to probe or to understand photosynthesis to understand how the chlorophyll is stored or would you be interested to send electric current through your retina at a very lower femtoampere or femto volt, but would you like to send electric current through your eyes. Similarly, sound i.e. acoustics well by definition sound contains much less energy than light and it is you know in a bulk form it is in a huge bulk form. So, trying to probe a eyeball or a particular neuron of your brain by sending sound waves it is quite difficult, it is quite difficult localization of sound at a particular area it is not impossible per say, but it is significantly difficult Whereas, light or laser or focused laser beams etcetera have the capacity to probe biological material at a very very small nano scale region and thereby understand how it is interacting and if it is interacting or if it is working badly how to cure it.

So, that is my overall argument of why we should be interested in learning nano bio photonic technologies.



I hope you have decided to continue this course after hearing my argument and from next class onwards we will be delving deeper on to it. As I said this was merely scratching the surface giving an interaction I have not gone detail into any topic if you are dismayed do not worry we will be taking each of those topics discussed in the previous lectures not just this one, but the previous in detail and we will take it further. I hope to see you in next class.

Thank you. Thank you very much.