Nanobiophotonics: Touching Our Daily Life
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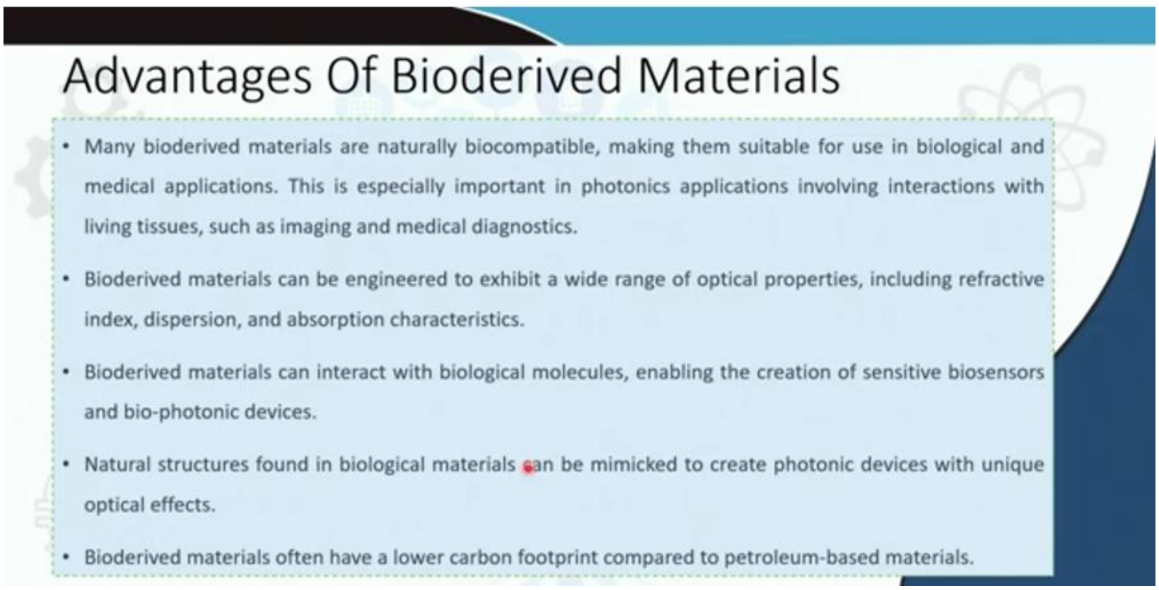
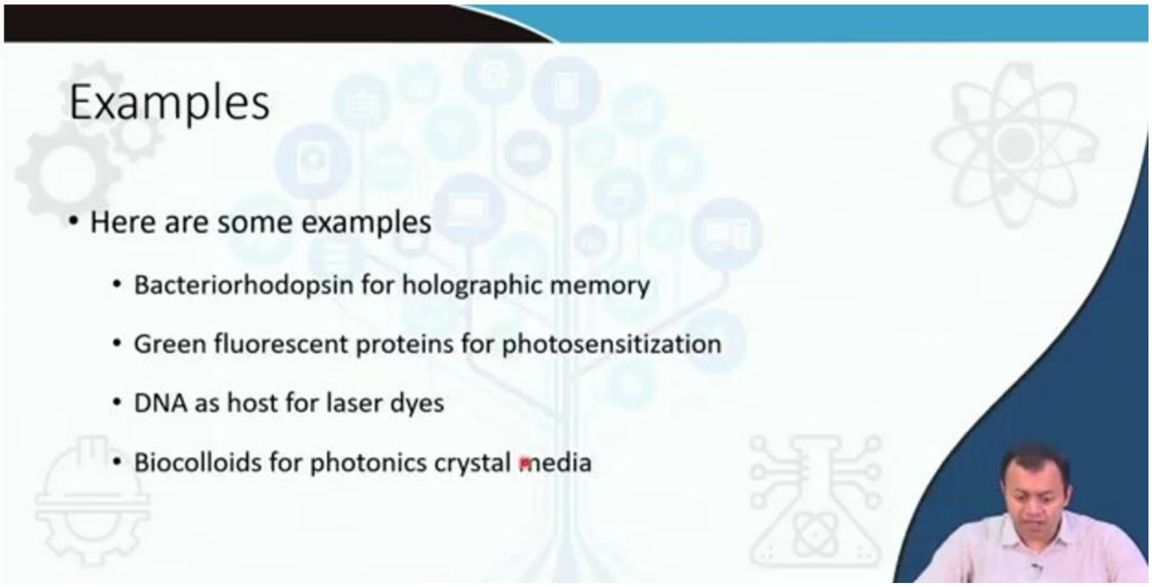
Lecture No. 57
BIODERIVED MATERIALS

Welcome back. We are still discussing about the future direction nanobiophotonics in particular and biophotonics in general will take and thus far we have discussed about biomaterials trying to explore it a bit more. So, in today's lecture let us discuss about bio derived materials, materials which are derived directly from biology. So, I have discussed a bit in the previous lecture. Let us see what are the advantages of such bio derived materials. Bio derived materials are obviously, naturally biocompatible making them suitable for use in biological and medical applications.

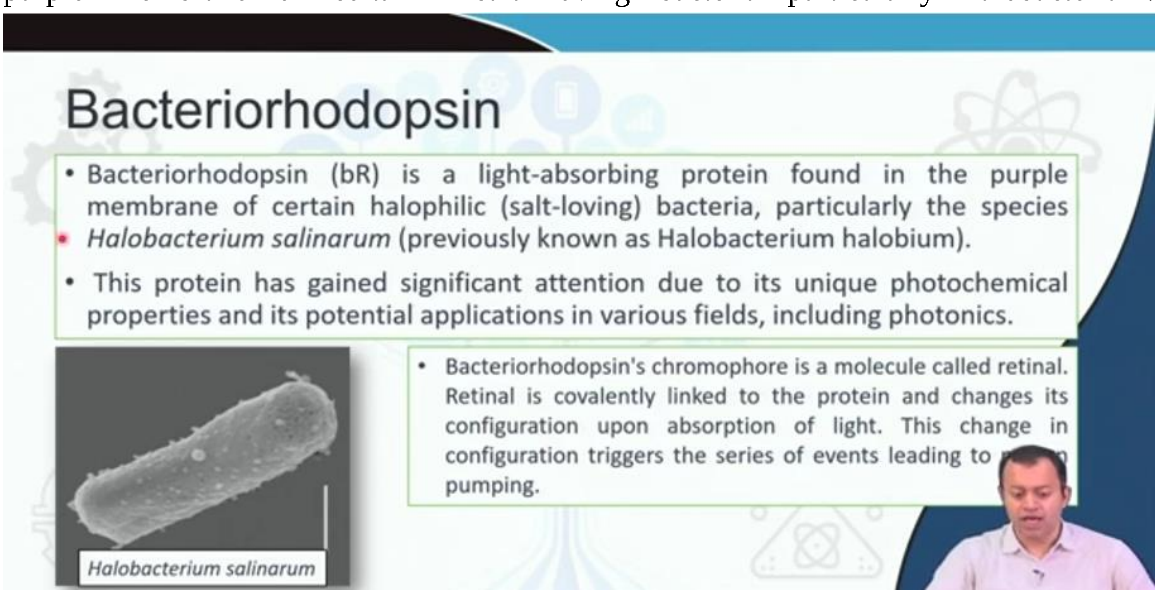


Bio derived materials can be engineered, you can engineer them, you can artificially create, you can convert them, you can modify them. Bio derived materials can interact with other biological molecules and create some sort of a chain reaction, modify them without you know completely destroying them. Natural selection found in biological material can be mimicked to create photonic device with optical unique optical effect. So, you know biological system organic systems evolve, they evolve and there is a natural selection, there is a natural bias in the different ah organism that comes out basically the so called survival of the fittest and natural selection comes into.

So, natural structures found in biological materials, they can also produce some kind of a bias towards the strong strongest structure available. So, the evolutionary principles can also be brought in of course, natural structures in biological materials can be mimicked and bio derived materials often have lower carbon footprint basically eco friendly, but fascinating aspects can come up. You derive 3 or 4 biologically inspired materials and then you find out that their interaction with light or their interaction with other biological materials, there is a preference for one particular bio derived material versus the other.



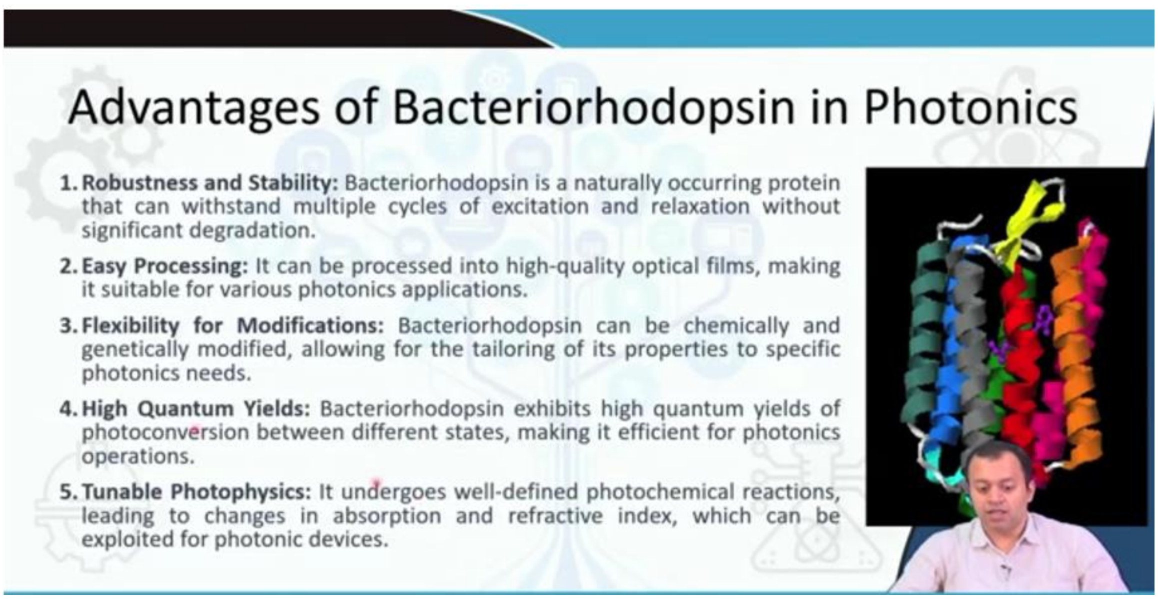
So, here are some examples bacteria rhodopsin for holographic memory, GFP for photosensitization, DNA as host of laser dyes and biocoloids we discussed this, but let us let us go little bit detail. So, bacteria rhodopsin is a light absorbing protein found in the purple membrane of certain salt loving bacteria particularly halobacterium.



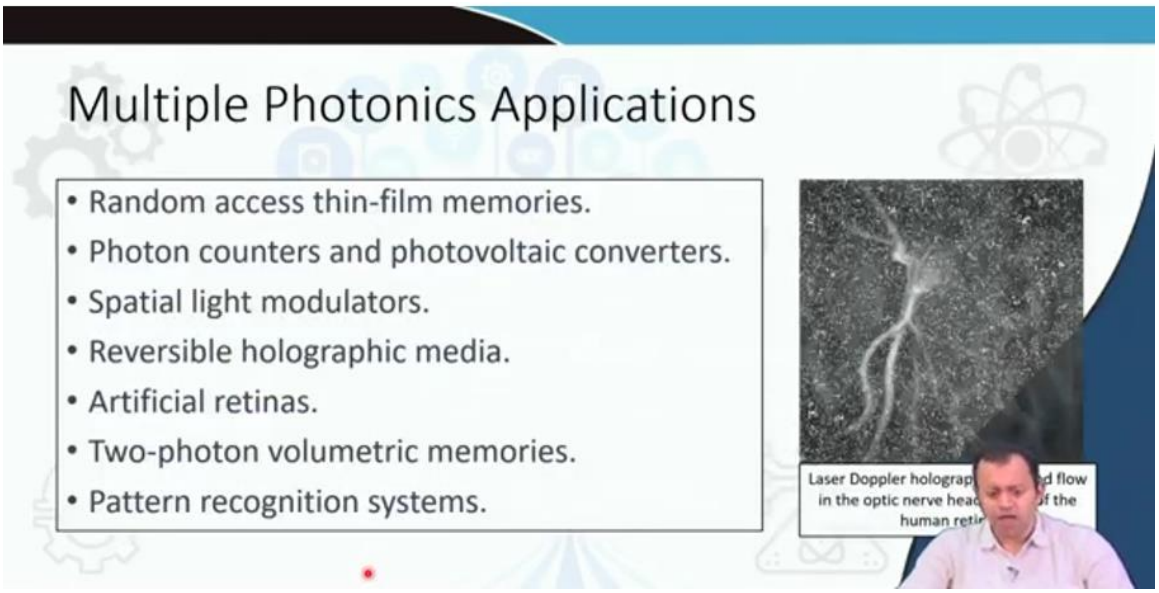
This protein has gained significant attention due to its unique photochemical properties and potential application in various field. We have discussed them in ah you know brain based imaging and what not, but these days they are using it for a holography they are using it for a holography light based memory sensing. Bacteria rhodopsin chromophore is a molecule called retinal also used in our eye for visualization. Retinal is covalently linked to the protein and changes its configuration upon absorption of light. This change in configuration triggers a series of event leading to proton pumping now think about it.

A particular material converted with covered with retinal or converted covered with bacteria rhodopsin. It is connected with particular protein. So, bacteria or retinal part of bacteria rhodopsin connected with a protein as soon as it absorbs light it kicks. It kicks the protein makes change its isomorphism from cis to trans. So, you have a thin film made up of this particular chemical retinal connected with molecule and you have then hit specific area of the thin film with specific laser and only those areas where laser has hit has a isomorphism a change in conformation of the protein rest of the area it does not right.

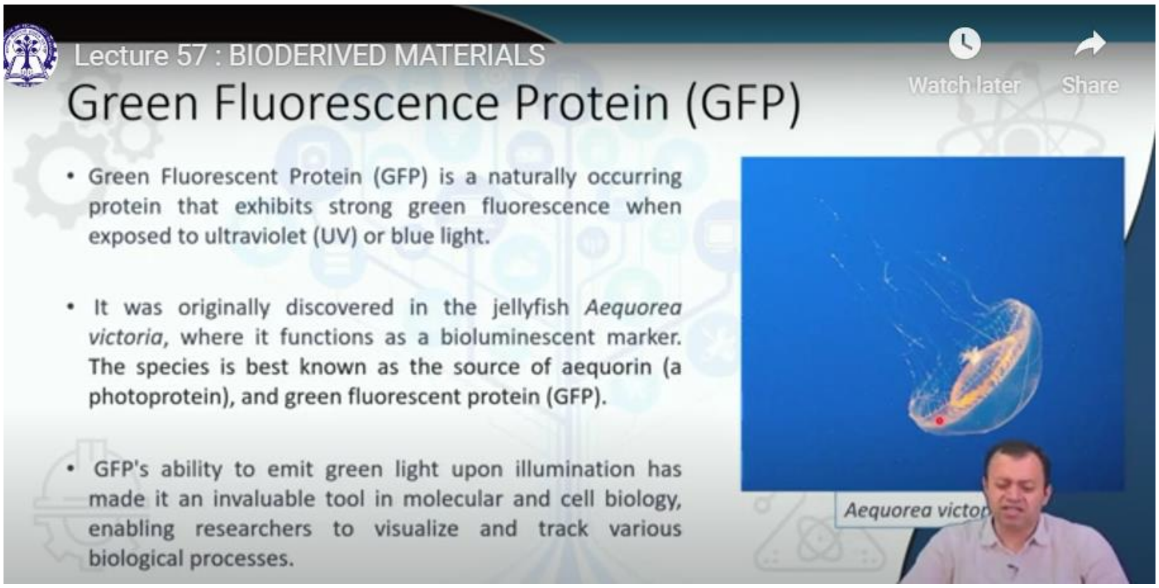
So, those areas where it has illuminated say you call it 1, those areas where it has not illuminated call it 0. So, in a thin film small area you can write 100111 etcetera can they be served this bit stream into some sort of an information some sort of a memory and after sometime you just wipe away everything you just put some kind of any potential and electric field or shine some other kind of light. So, that it resets resetting is quite easy you reset and then redo this process. So, is this some kind of a rudimentary memory that you are trying to get in a small area in a biological membrane. Remember this is biological this is not silicon out of which you will make a flip flop or a logic gate this is purely biological and you are writing the memory by light and this light will come from a laser which has been created by DNA how cool will that be the particular part of your body think about it could be used to store information biological information.



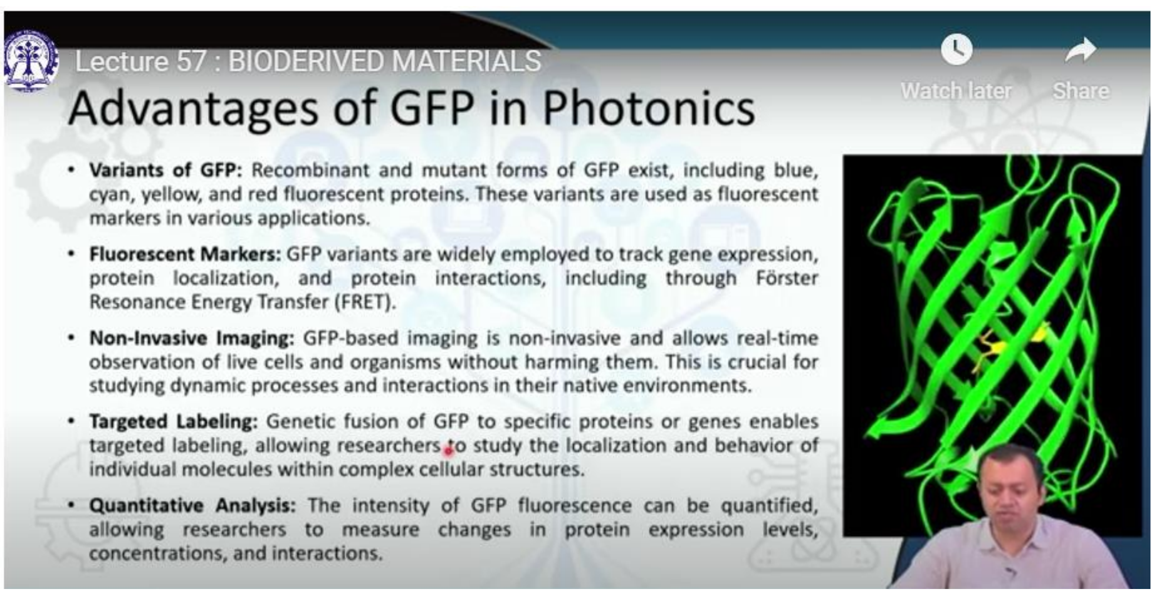
So, several advantages of bacteria rhodopsin in photonics it is robust and stable is naturally occurring protein that can withstand multiple cycles of excitation and relaxation without significant degradation. It is easy processing it can be processed into high quality optical films making it suitable for various photonic application. It is flexible bacteria rhodopsins can be chemically and genetically modified allowing it for tailoring of different types of light heating producing different types of isomorphism high quantum yield bacteria rhodopsin exhibits very high efficiency. So, how much photon results in how much amount of ah isomorphism the efficiency is pretty high ah photo conversion between different states and tunable photophysics it undergoes a well-defined photochemical reaction leading to changes in absorption and refractive index as I was saying which can be exploited for making photonic devices such as hologram such as light-based memory such as photonic crystal frequency filters optical frequency filter and what not.



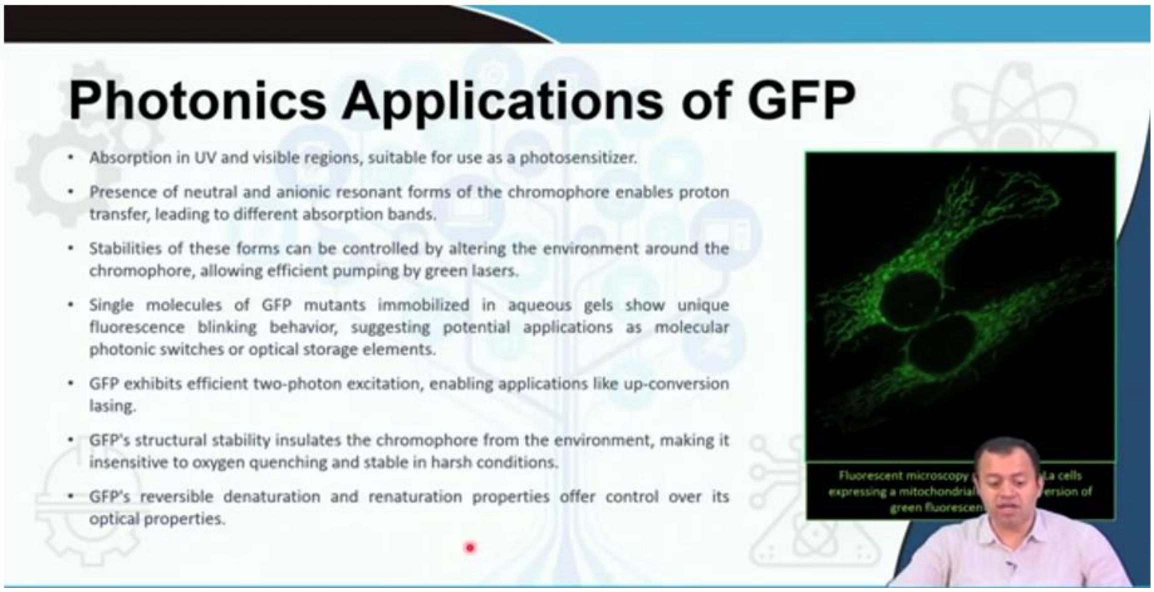
We have multiple photonics applications of them we can have random access RAM basically random-access memory thin film memories photon counters and photoholtic converters how many numbers of photons have been hitting this particular area right. How much amount of photon hits in your retina for it to convert a particular message that you see the total number of photons required you can do all these kinds of fundamental calculation because the number of photons is directly proportional to the number of isomorphism that has happened the the protein has changed its morphology. So, by looking at the amount of morphology change you can back calculate the amount of photons it has received it is reversible yeah artificial retinas that is what I was saying people who have ah you know by glau glaucoma or some other kind of retinal based disease who have who have got blinded can it be utilized and of course, these days it is quite popular to have pattern recognition system a particular biophysical photophysical photo biological activity has a particular amount of photons particular frequency particular time interval how periodic it is how different it is if you can arrange we can understand the pattern we recognize the pattern of course, using machine learning and what not you can have a fundamental knowledge you can have a fundamental knowledge of how the entire process has taken place. This is a laser Doppler holography of blood flow one behind me in the optic nerve head region of human retina.



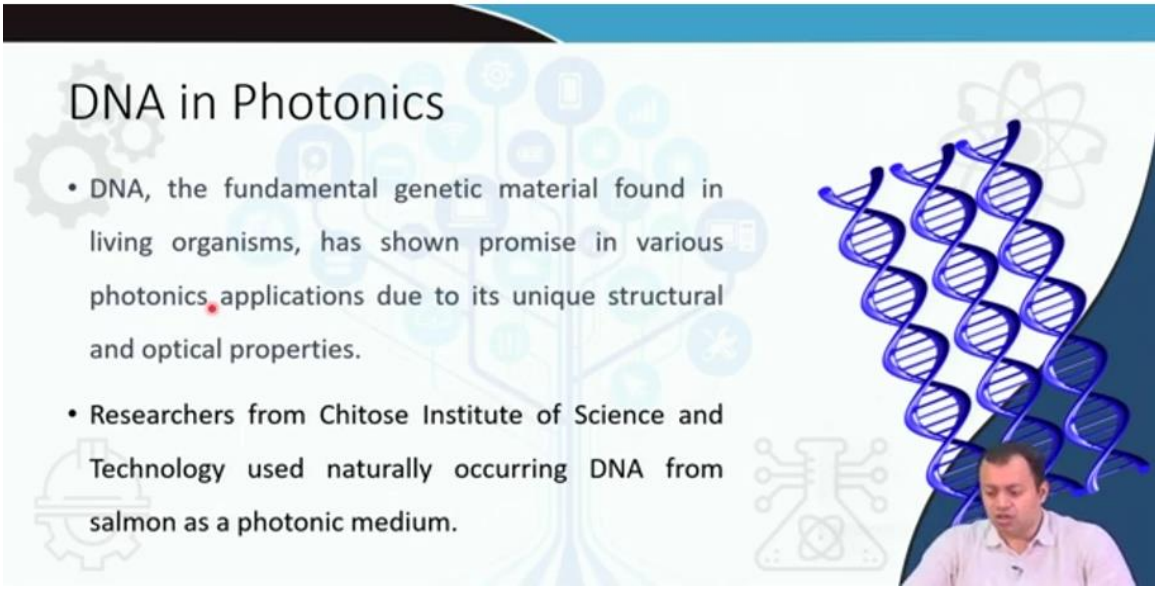
So, this is a this is just to see ah the blood flow in the optic nerve right. Of course, GFP I do not think I need to discuss this in detail we have discussed GFP in detail previously is a naturally occurring protein have a strong green fluorescence when exposed to UV light ultraviolet it was discovered in jellyfish and GFCs ability to emit green light upon illumination has made it an invaluable tool especially in fluorescence you are not using any dye you are simply um coding GFP as a gene in some kind of a ah animal and trying to see it.



There are several advantages of GFP there are different variants although GFP stands for green fluorescence protein, but now a days you can have blue cyan I do not know what cyan color is yellow and red fluorescent proteins for us it is red blue and green cyan and then mauve and purple these are here from my daughter and I have no idea what that means. And markers GFP can be used for FRET, Fruster resonance energy transfer, non-invasive imaging, targeted labeling and quantitative analysis we can utilized for protein expression level concentration and interaction.

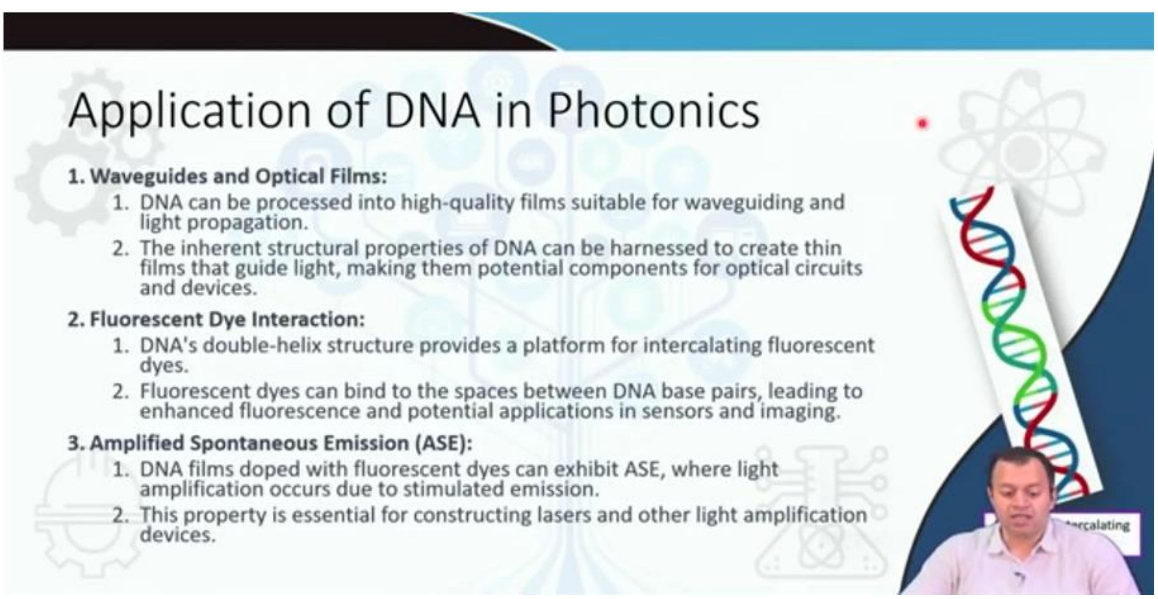


There are several photonic application absorptions of UV and visible regions suitable for photosensitization presence of neutral and anionic resonant forms the chromophores GFP structural stability insulates the chromophore from the environment like oxygen quenching this quenching is a huge problem in fluorescence a GFP reversible denaturation and renaturation properties often control over its optical properties. So, you can utilize it for ah fantastic fluorescence imaging in vivo in a dynamic process you do not have to you know kill the cell and then observe it it can evolve you put a some amount of this GFP either encoded into a living organism and then the organism grows and you constantly see the changing function of a particular ah set of proteins, particular set of ah organ, particular set of tissue, a cellular structure, morphology etcetera all changing with respect to time in a live tissue you can have a live image ah from a molecular standpoint.

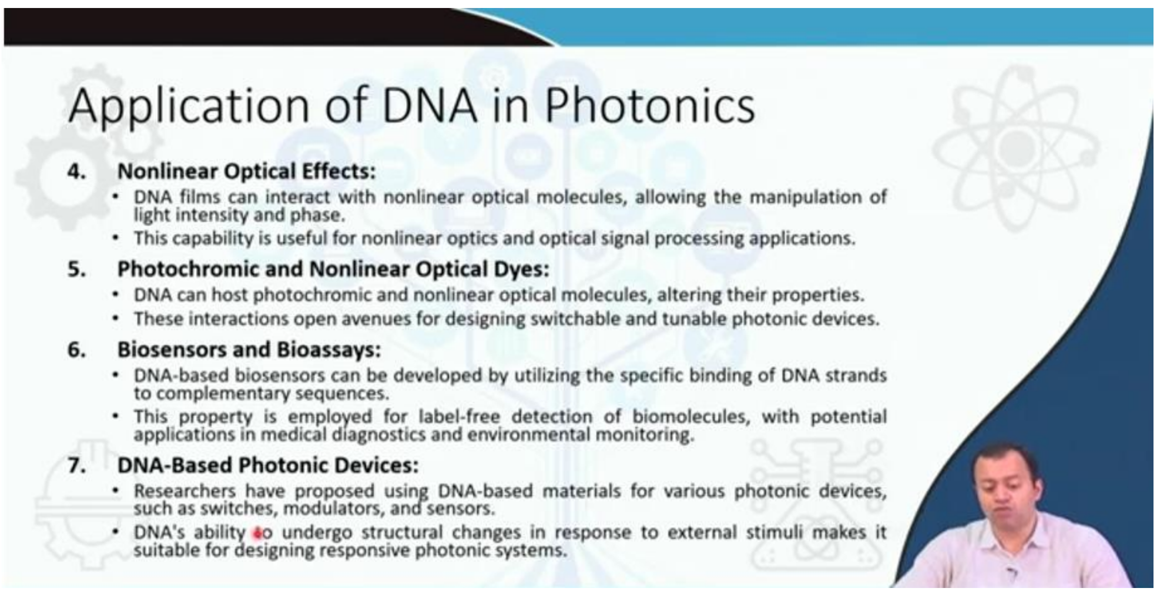


So of course, DNA in photonics this is also something that is coming up though not 100 percent that developed DNA is the fundamental genetic material and has shown promises in various photonic application researchers from ah several institute ah have naturally occurring DNA to form templates add several of them together and make thin films which can have unique electro optic property or optical property where a particular wavelength of light is allowed to pass through rest of them are all discarded you know see how beautifully naturally occurring nanostructure as well as periodic structures these are.

So, only specific photons specific energy of photons will be allowed to pass through them without getting ah destructively interfered and they could be utilized for several purposes such as making wave guides and optical films DNA can process into high quality film

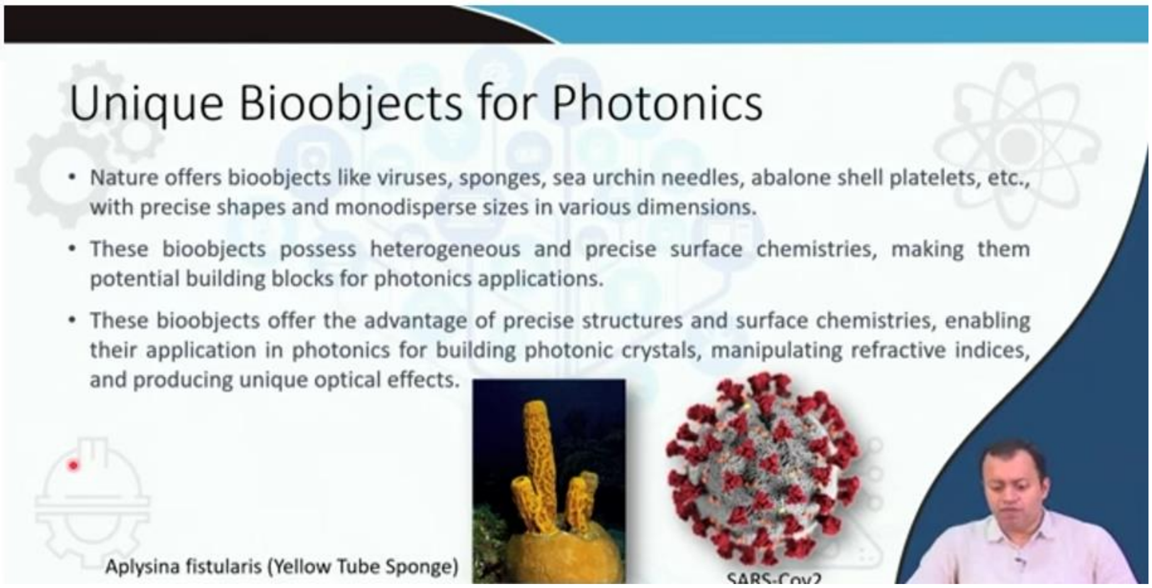


suitable for wave guiding and light propagation as I was saying the inherent structural more properties of DNA can be harnessed to create thin films that guide light making them potential component of optical circuits. Fluorescence dye interaction DNA double helix structure produce a platform for intercalating fluorescence dyes, fluorescence dyes can be bind to the space between DNA base pairs leading to enhanced. So, between base pairs you can have fluorescent dyes just in between these enhance fluorescence and potential application in sensor and imaging, amplified spontaneous emission this is where the laser is coming from DNA films dope with fluorescence dyes can exhibit amplified spontaneous emission where light amplification occurs due to stimulated emission you know it in the other way light amplification by stimulated emission of radiation LASER the properties essentially for constructing lasers and other light amplification devices. Application of DNA in photonics non-linear optical effect we discussed non-linearity photochromic and non-linear optical dyes DNA can host photochromic and non-linear optical molecules these



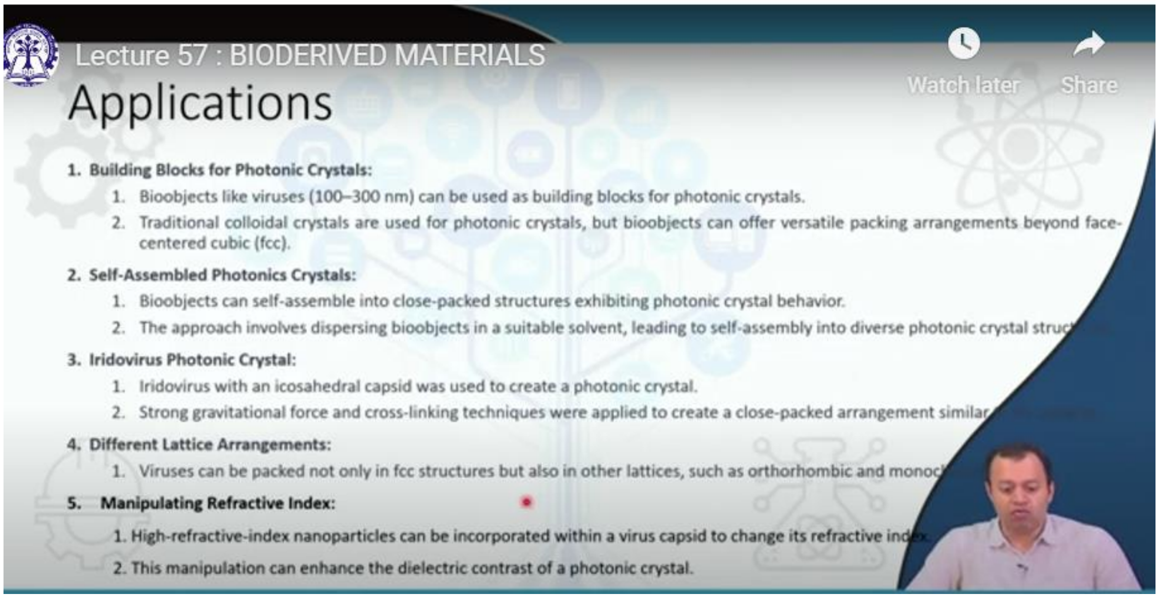
interaction often ah open avenues for designing switchable and tunable photonic devices biosensors are always there ah a single strand of DNA can be utilized as a sensor which will only attach covalently attached with its complementary pair ah if a particular virus has the complementary pair you are able to detect it if it is not attaching then it that particular virus is not present DNA based virus similar thing can be done with RNAs as well. DNA based photonic devices researchers have proposed you proposed DNA based materials for various photonic devices like switches modulators and sensors.

So, DNA based photonic devices this seventh part is something that is really cutting edge. So, see there is a natural tendency upon among you know electronics engineers as well as this ah photonic engineer these days is to convert from silicon to biological materials and especially utilize them as some sort of an implant into human bodies you already have implant pacemaker this that, but can we make it more and more biocompatible or in other words create a biological material that act as you know switches modulator sensor a part of DNA in my body is acting as a sensor glucose sensors and if it is ah it sees some sort of a disturbance it it alerts me somehow is it possible in the near future think about this.

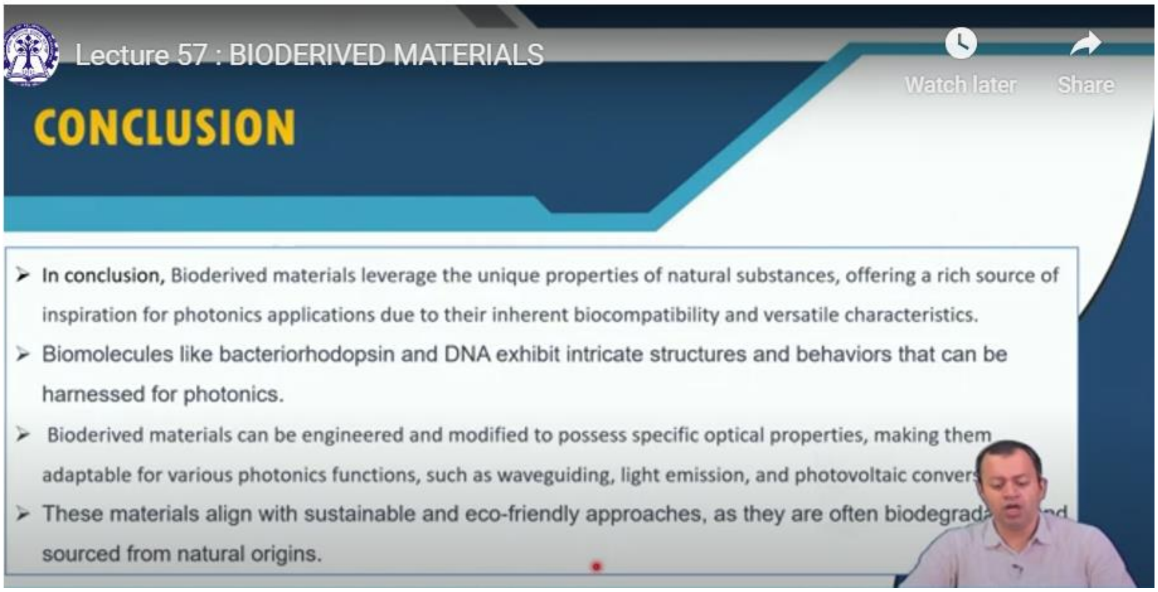


Unique bio object for photonics this is what I was telling you have seen this probably images of this this exist ah in in inside see yellow tube sponge, but many people keep this as a handicraft or decoration in their houses I have seen one of my neighbor used to have this you might have seen this, but what I am telling you is that this can be used as some sort of a template right they have a periodic structure they have a periodic structure this is also a some sort of a periodic structure either you can use it as a template or utilize this and send light into them the light you will get diffracted or interfered and that light could be utilized differently nature offers bio objects like viruses sponge sea urchins needles etcetera that has various you know periodical nano structures of various dimensions these bio object possesses heterogeneous and precise surface chemistry making them potential building block these bio objects offer the advantages of precise structural and surface chemistries manipulating the refractive indexes and produces unique optical property So, it has a unique you know periodical change in refractive index this also a periodical change in refractive index if the light is coming from this will have the red part will have a different refractive index the ash color part will have a different and again the red again different. So, relative change in refractive index this is the basic idea of photonic crystal this is exactly what is a lattice of a semiconductor is the lattice of a semiconductor and electron visiting a lattice of a semiconductor undergoes a change in periodic potential the opposite is a photon visiting a nano structure a periodic structure a periodic photonic crystal structure undergoes a change in refractive index or we call it dielectric constant n 1 n 2 n

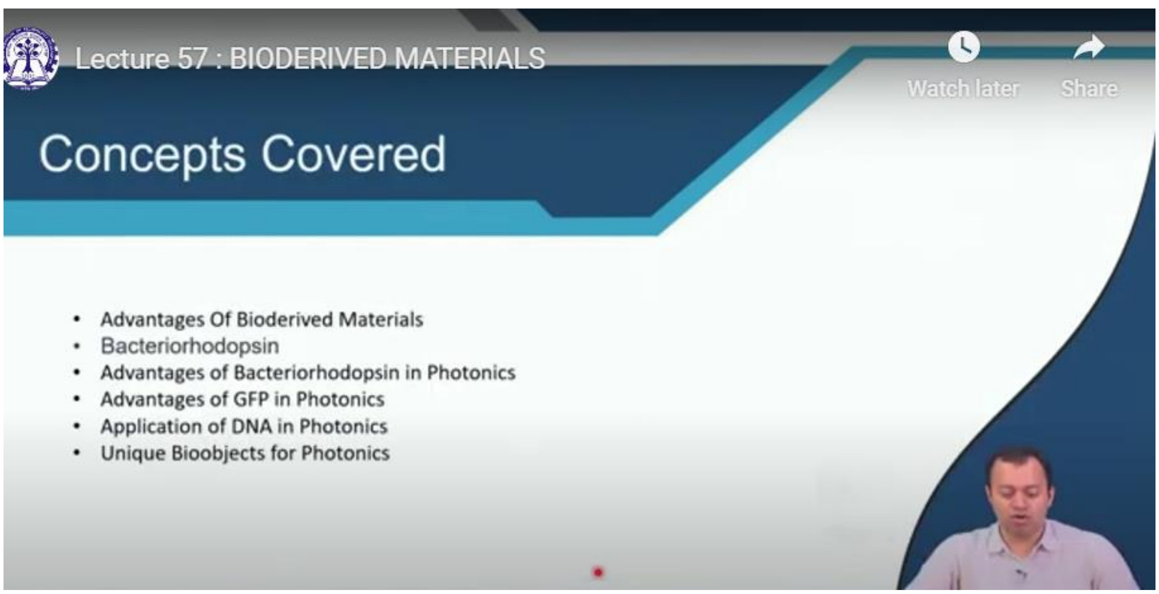
1 n 2 n 1 n 2 this is a refractive index n 1 this is a refractive index n 2 the inside is the refractive index n 1 outsides the refractive index the one which is the up part ah refractive index n 2. So, constant variation of n 1 and n 2 is equivalent to constant variation what the electron gets when it goes through a lattice periodic potential resulting in formation of band gaps valence band conduction band in this particular case the periodic refractive index change dielectric constant change of photon encounters results in formation of photonic band gaps.



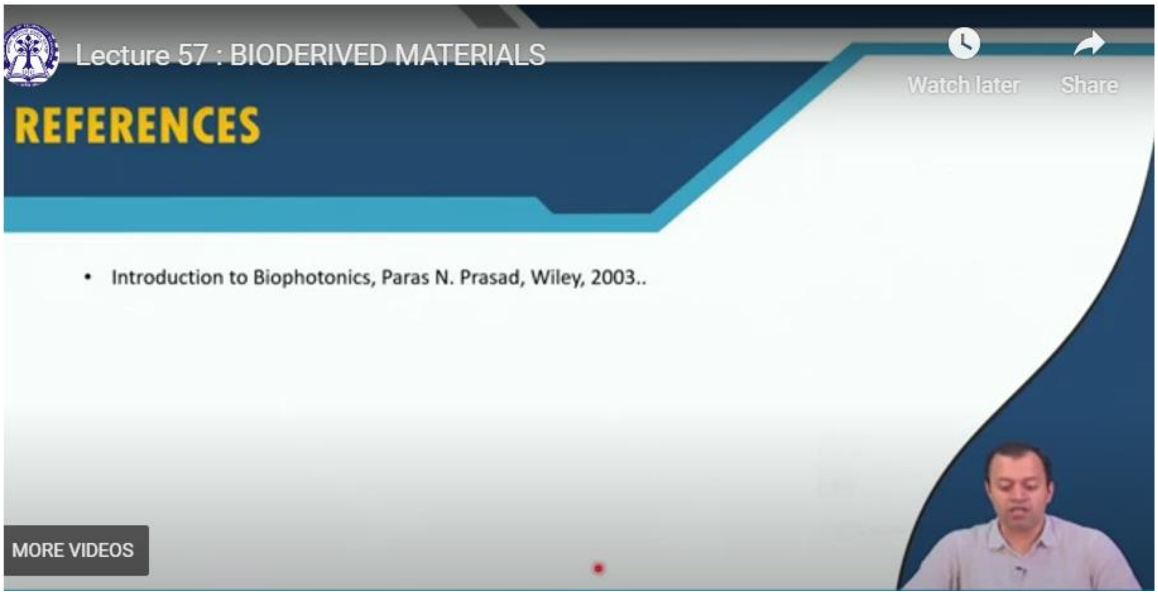
So, they could be utilized it can be used for making naturally occurring photonic crystals ah traditional colloidal crystals used for photonic crystals opals are by definition 3-dimensional photonic crystal people use opals as some kind of precious stone for the for some kind of a ring or even you will see it in in in in their necklaces. There are iridovirus photonic crystals the cap seed was used to create photonic crystal and you manipulate basically refractive indices and and create ah frequency filter devices modulator switches etcetera etcetera.



So, in conclusion bio derived materials leverage the unique properties of natural substances offer a rich source of inspiration for photonic applications biomolecules like bacteria, rhodopsin and DNA exhibit integrate structures and behaviour that can be harnessed for photonics these materials align with sustainable and eco friendly approaches and they are often biodegradable making them suitable for biomedical applications.



So, these are the concepts that I covered today and this was my reference as always and I



will see you in the next class. Thank you very much.