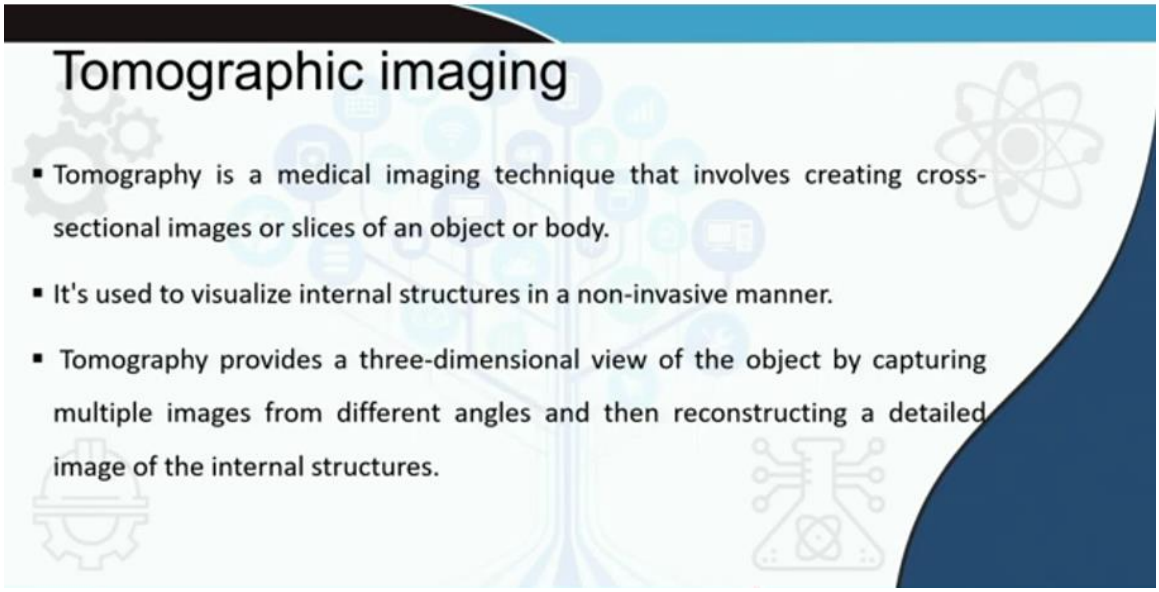
Nanobiophotonics: Touching Our Daily Life
Professor. Basudev Lahiri
Department of Electronics and Electrical Communication Engineering
Indian Institute of Technology, Kharagpur
Lecture No. 50
Tomographic technique for Brain imaging

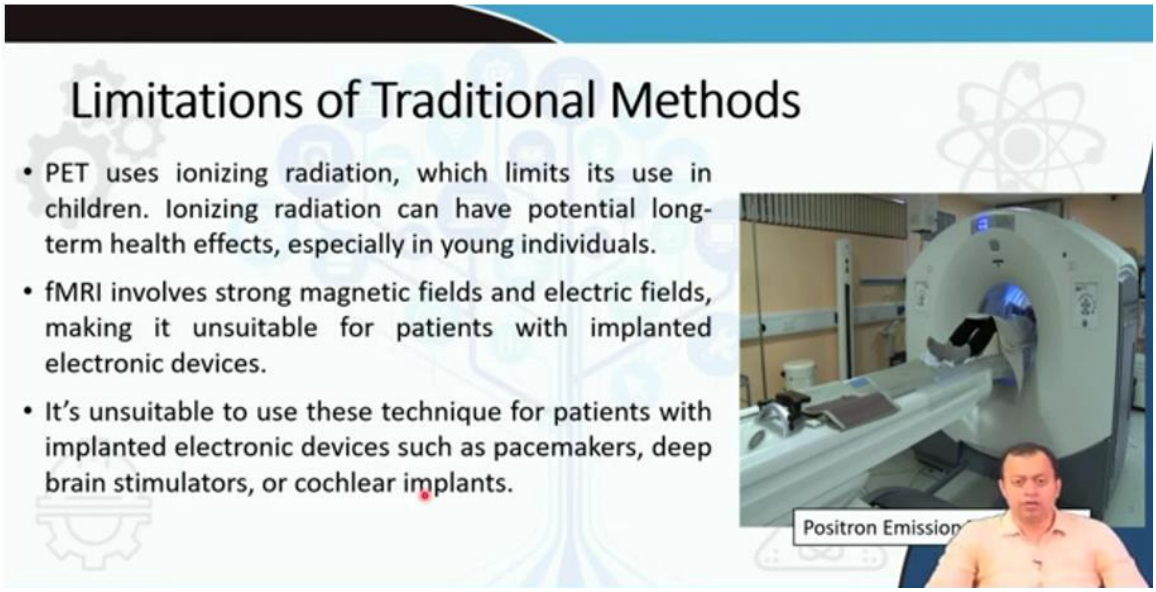
Welcome back. We are the last leg of module number 10, Introduction to Neurophotonics. Today's lecture I am going to keep it short. This will be more or less a revision and we will be discussing mostly upon about the tomography technique. We have discussed and you have learnt about optical coherence tomography. So, there is a specialized type of tomography that we use and the principles more or less will remain same.



There is slight difference between OCT, but today we are going to discuss this tomographic technique for brain imaging. So, what we actually mean is that tomography is a medical imaging technique that involves creating cross sectional images or slices or object of the body. You know CT scan, coherence tomography. Previously you used to have x-ray just in front of you and they will take an image of your skeleton, but CT scan is where the x-ray is having a 360-degree view of your entire body and thereby takes a full 360-degree x-ray image.

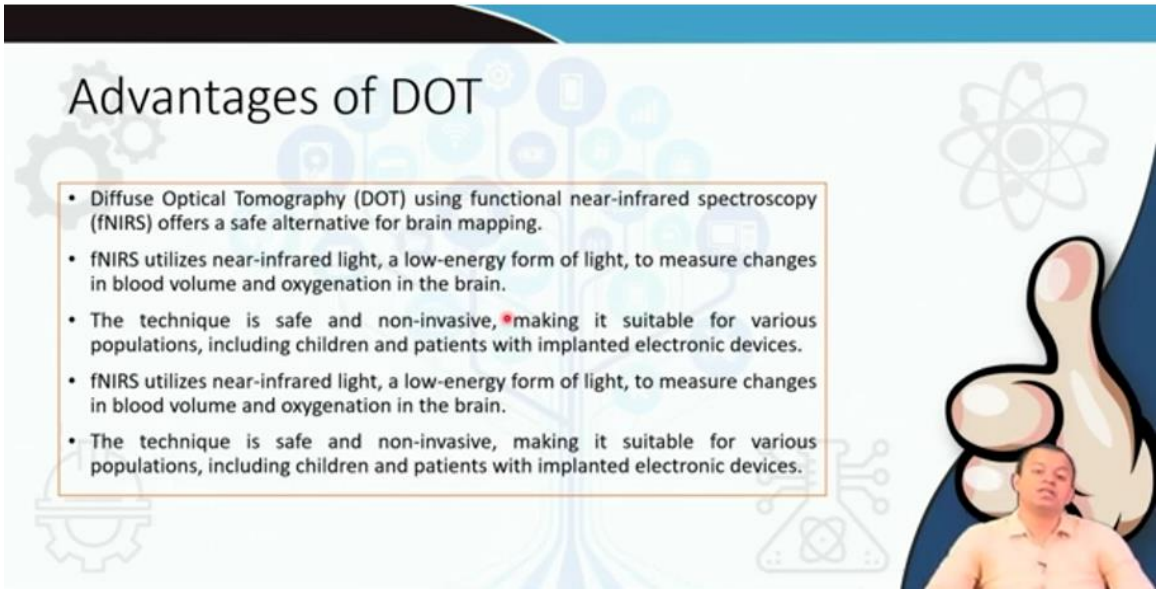
So, tomography is something similar. Well, it is CT scan, the CT, the T of CT scan stands for tomography, coherence tomography. Tomography is a medical imaging technique that involves creating cross sectional images or slices of the object or a body. So, you have the targeted object from different areas. It is used to visualize internal structure in a non-invasive manner, non-invasive manner.

Tomography provides a three-dimensional view of the object by capturing multiple images from different angles and then reconstructing a detailed image of the internal structure. So, you are having an x-ray from here, x-ray from here, x-ray from here, x-ray from here and then you know reconstruct a three-dimensional. I am used using the term x-ray because CT scan is something probably all of you have heard of, but computerized tomography, but we use something similar with brain and obviously not with x-rays. X-rays will most definitely fry up the brain. So, you use well basically the non-ionizing radiation method, the radiation that is absorbable or transmittable depending on what we are looking for.



So, the limitation of the traditional methods is simply this, positron emission tomography uses ionizing radiation which limits its use in children. Ionizing radiation can have potential long-term health effects especially in young individuals, functional MRI, magnetic resonance imaging involves strong magnetic fields and electric fields making it unsuitable for patients with implanted electronic devices. At the same time, fMRI had done not have that much of a resolution. I have been telling you they do not have this much of a resolution. This is PET, positron emission tomography where we use obviously a positron.

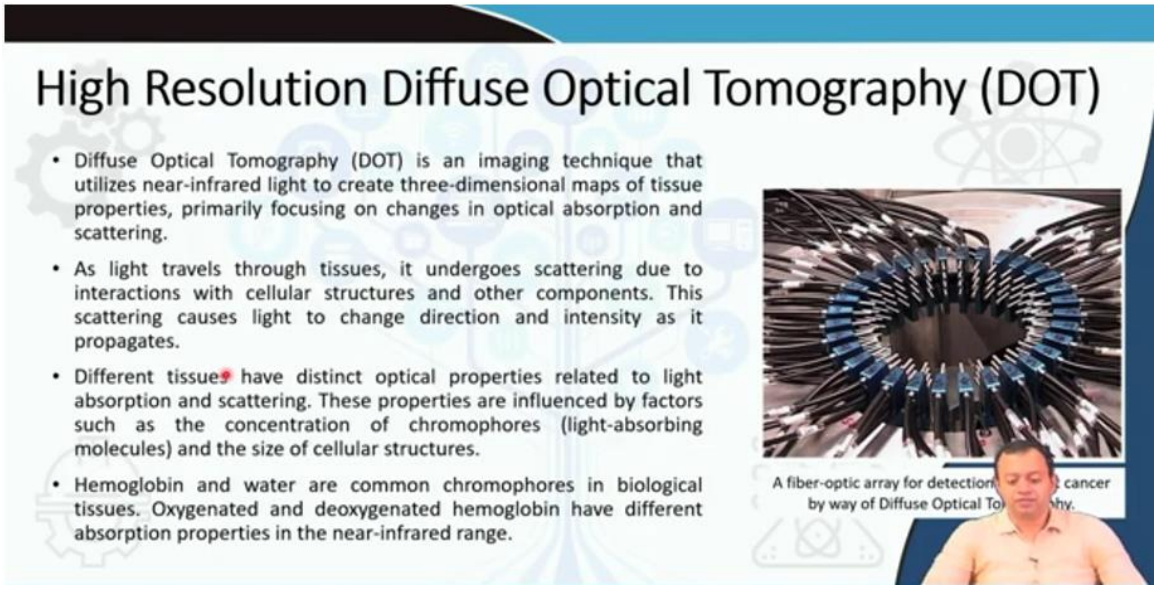
You know what a positron is medical students, you should know what a positron is. You know electron, think of a positive electron, positron. So, anyway this can have high resolution, but fMRI functional magnetic resonance imaging has low resolution and it is unsuitable to use this technique for patients with implanted electronic devices such as pacemaker, deep brain stimulators or cochlear implants even if you have a hearing aid associated with it or you know internal some hearing aids, implants are actually inside which helps if you have internal damage, then you obviously cannot use high strong magnetic and electric fields.



So, what are the advantages of DOT? DOT is a specific type of OCT, Diffused Optical Tomography or DOT imaging. DOT uses functional near-infrared spectroscopy.

We have discussed NIRS, NIRS, near-infrared spectroscopy. Here imagine the same thing NIRS at all different slices, different angles and then reconstructing it. We have discussed NIRS. So, DOT uses functional near-infrared spectroscopy. It offers a safe alternative for brain mapping.

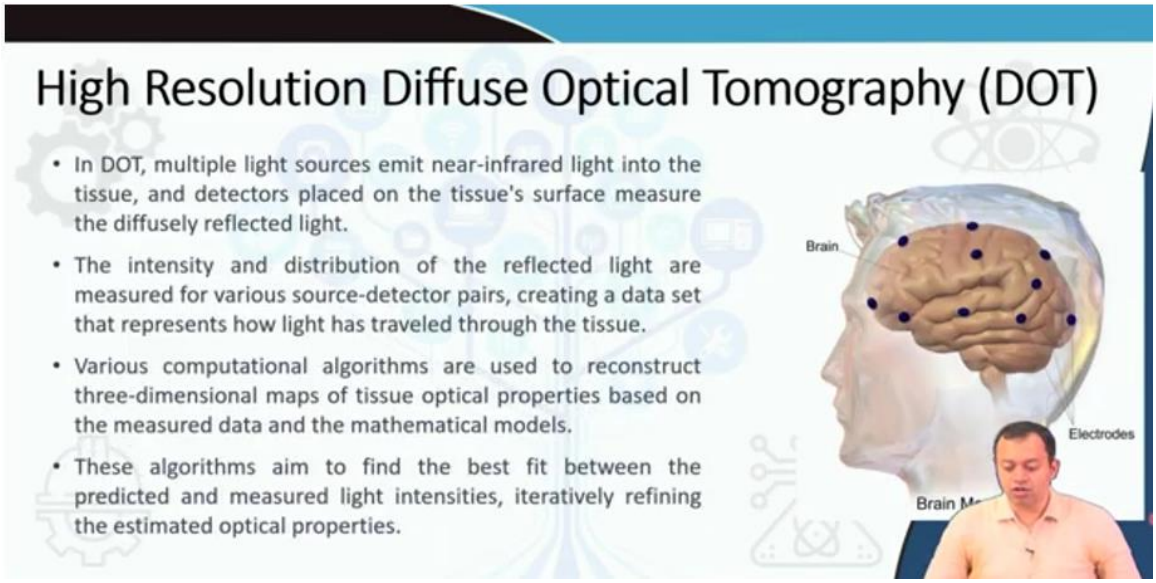
NIRS, fNIRS utilizes near-infrared light and low energy form of light to measure changes in blood volume and oxygenation of the brain. You already know this. The technique is safe and non-invasive making it suitable for various populations including children and patients with implanted electronic devices. fNIRS utilizes near-infrared light, low energy form of light and the technique is safe and non-invasive. I think he has repeated the same thing twice.



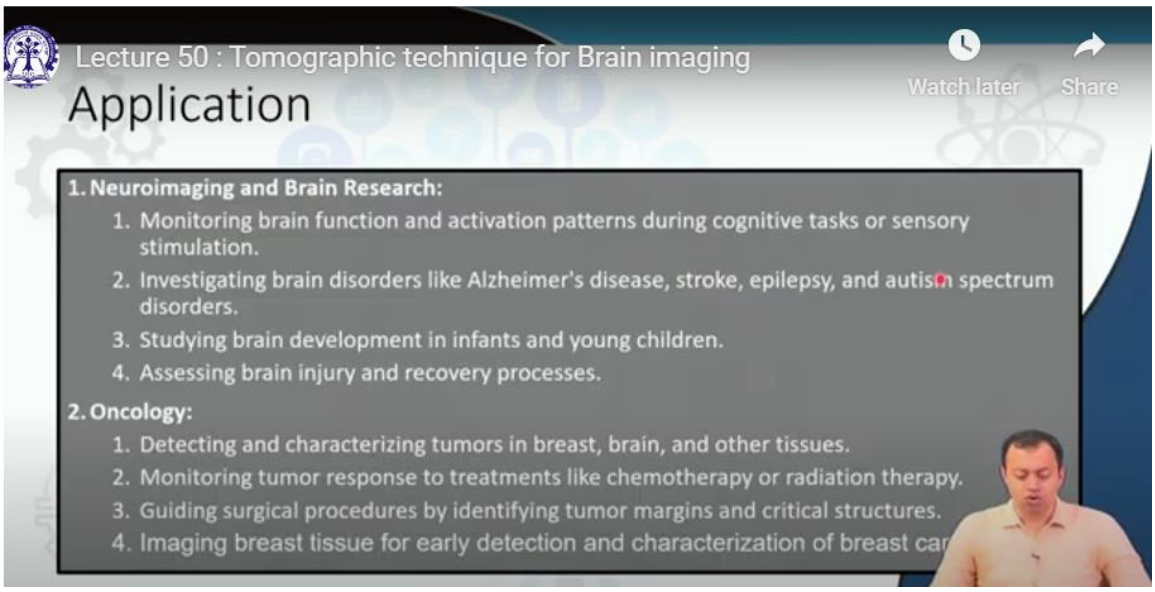
So, high resolution DOT. So, Diffused Optical Tomography is an imaging technique that utilizes NIRS. As light travels through tissue, it undergoes scattering due to interaction with cellular structure and other components. This scattering causes light to change direction and intensity as it propagates. Different tissues have distinct optical properties i.e. different tissues will scatter differently, different tissues will have because of the scattering, because of the change in refractive index, different absorption profile, the light will be, photon will be going in a different direction. And from that you can calculate, you can back calculate what type of tissue, what type of functions it is there and thereby reconstruct a three-dimensional working image of the brain while the animal or the human being is still alive. You do not open it up. So, different tissues have distinct optical properties related to light absorption and scattering. These properties are influenced by factors such as concentration of chromophores, if you have tagged it or the size of cellular structure.

Hemoglobin and water are common chromophores in biological tissues. These are endogenous or exogenous? Endogenous. Oxygenated and deoxygenated hemoglobin had different absorption properties in near infrared image and you slice it through. Yes, hemoglobin is not necessarily always going to be present inside the brain. We discussed about the blood brain barrier, but you can always use water, you can talk about cerebrospinal fluid, for spine of course, you can also use the brain fluid.

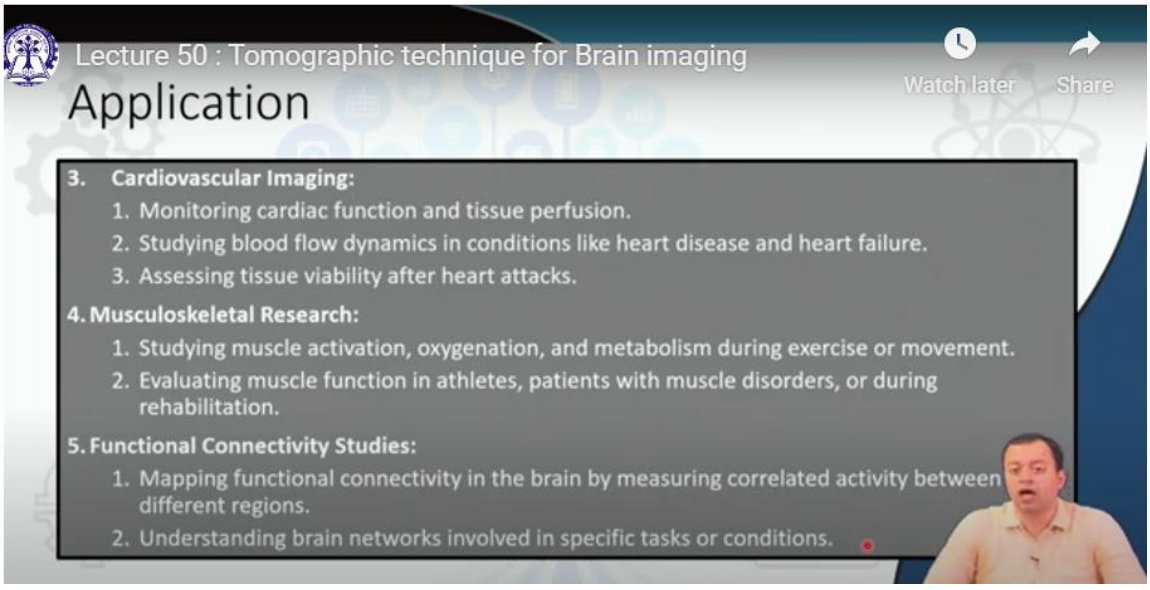
So, all of those things. So, instead of just having one direction, you send different types of NIR light and then try to reconstruct a three-dimensional image. So, this is the overall you know, a fibre optic array for detection of breast cancer, which so, dot is not specifically for brain only. This can be utilized for other type of diseases as well. Here you have you it is for breast cancer detection.



So, high resolution dot, in dot multiple light sources emit near infrared light into the tissue, multiple light sources emit near infrared light into the tissue in different direction and detector plates on the tissue surface measure the diffuse reflected light, the intensity and distribution of the reflected light are measured at various source detected pairs, various computational algorithms are used to reconstruct three-dimensional maps and these algorithm aims to find the best fit between predicted and measured light intensities, right. So, yes if near infrared spectroscopy deals mostly with hemoglobin oxygenated or non-oxygenated blood, but you can also you know tag and thereby make other fluorophores absorb a particular light which otherwise is non-absorbable by brain, but then you are also trying to look into the output, a wavelength which may or may not also be absorbed by the brain. So, overall like any other tomography, different angles, different slices, the output is also coming from different angles, you collect all of them and then you reconstruct the overall brain.

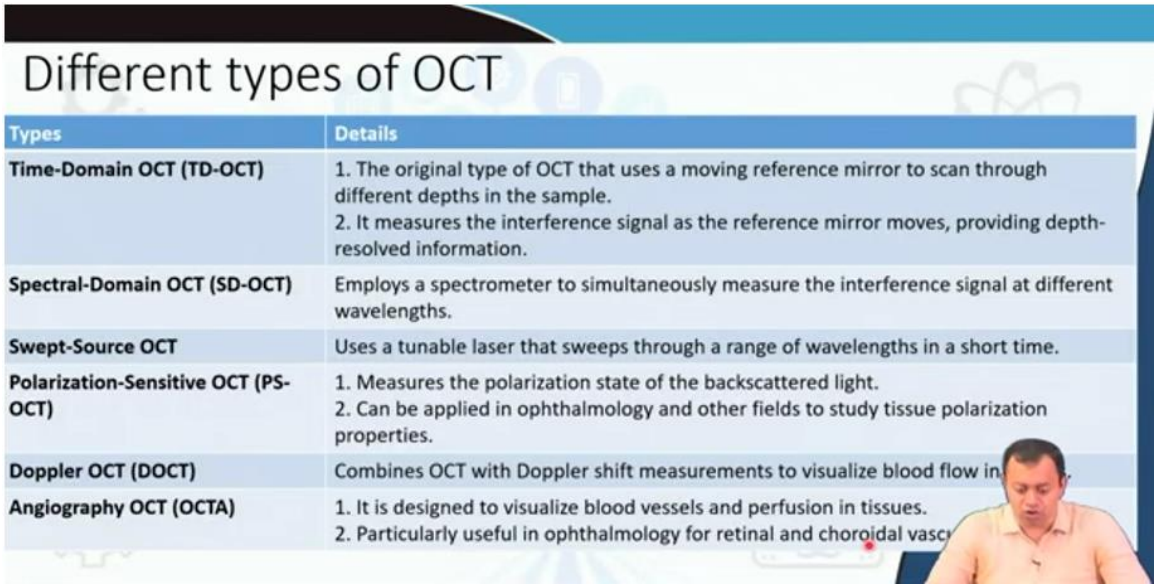


So, several application monitoring brain functions and activation patterns during cognitive task, investigating brain disorder like Alzheimer disease, studying brain development in infants and young children. It has also found application in cancer, cancer detection, oncology, detection and characterization of tumors in breast, brain and other tissue, monitoring tumor response to treatment like chemotherapy, guiding surgical procedures by identifying tumors, margins and critical structures, imaging breast tissues for early detection and characterization of breast cancer.

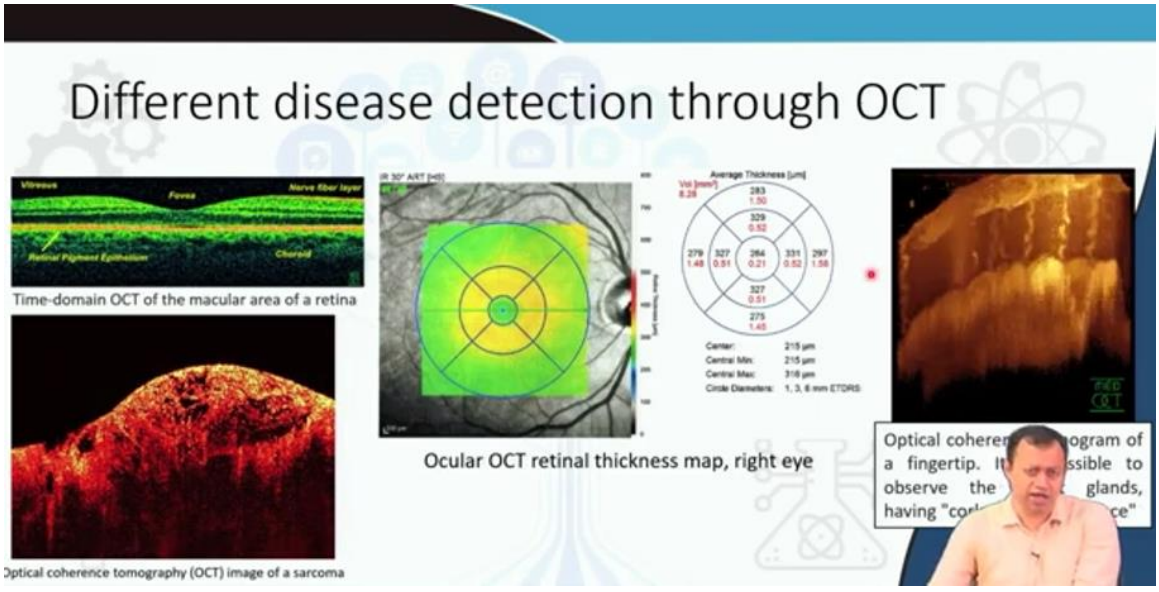


Cardiovascular imaging, musculoskeletal research, functional connectivity studies all of these have used FNIRS simply because the light is non-ionizing usually brain tissue do not absorb it. So, you can pass it through, but hemoglobin absorbs it. So, the distribution of capillary, distribution of veins, distribution of arteries, all of those things can usually be measured and a three-dimensional map could be created. Now, how is DOT, how is DOT,

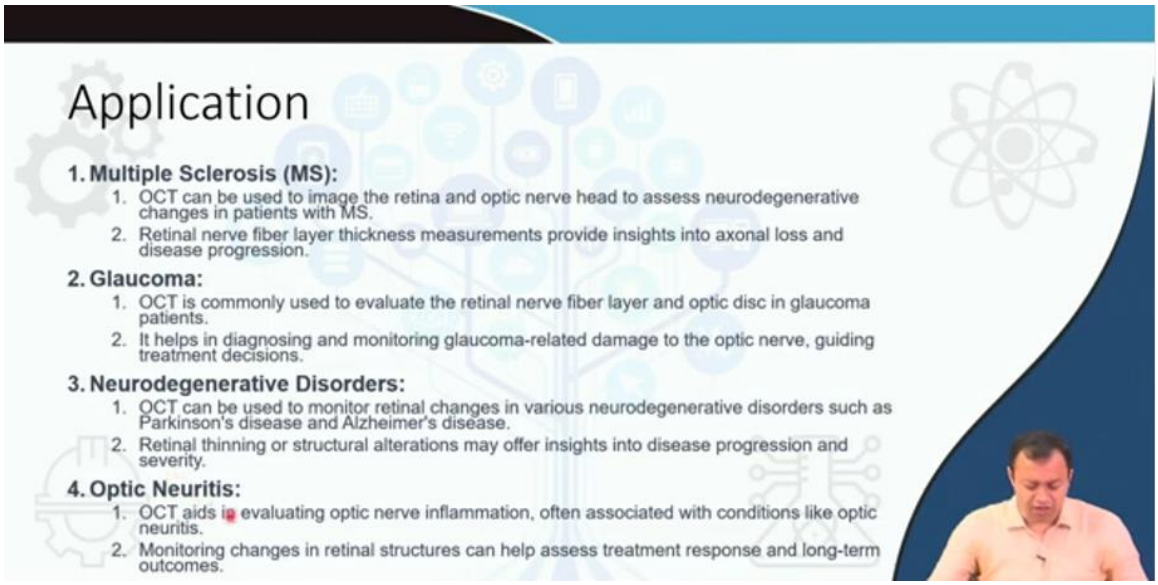
Diffused Optical Tomography different from your normal optical coherence tomography? I know this question will come. So, obviously optical coherence tomography is the overall set DOT is a subset and different types of OCT one there are several different types of OCT one of them, one of them happen to be DOT.



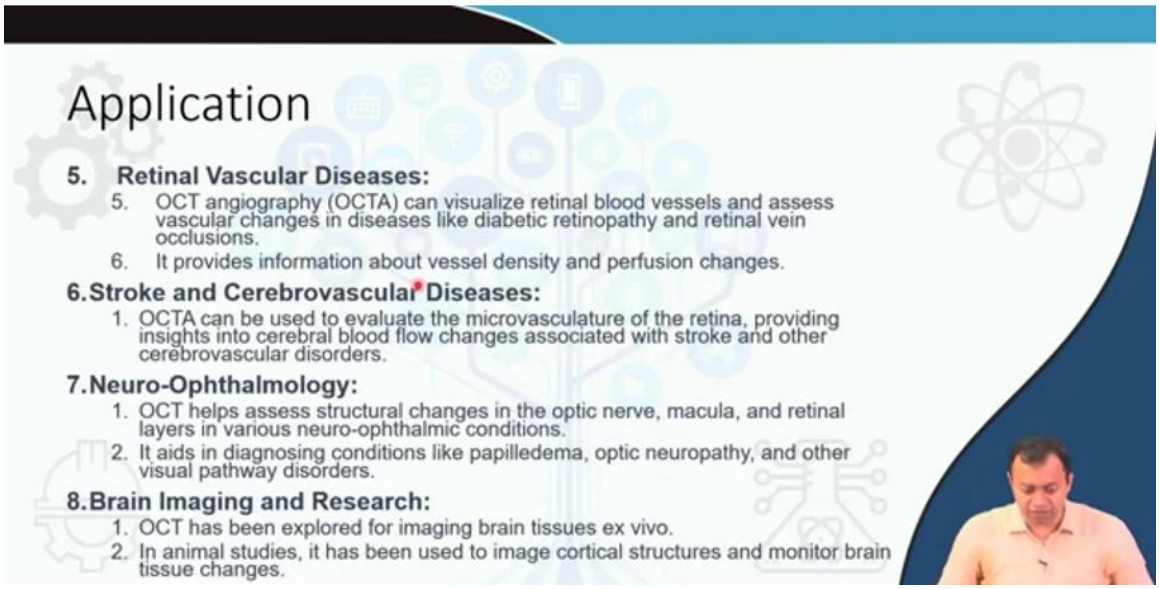
There are other DOT you know time domain OCT or spectral domain OCT or swept source OCT, Doppler OCT we have discussed this will remember the blood clot, angiography OCT it is designed to visualize blood vessels particularly used in ophthalmology, spectral domain employs a spectrometer to simultaneously measure the interference signal. So, DOT diffuse optical tomography is a part of optical coherence tomography, but optical coherence tomography and DOT has some very specific differences.



Now, this is the image that you already know I have shown you this is the OCT of the fingertip, you can see the sweat glands, the coarse screw appearances, these are the sweat glands and then this is the map of the thickness of the eye, this is of a breast cancer I think sarcoma and this is the macular area of the retina, but well OCT also has several

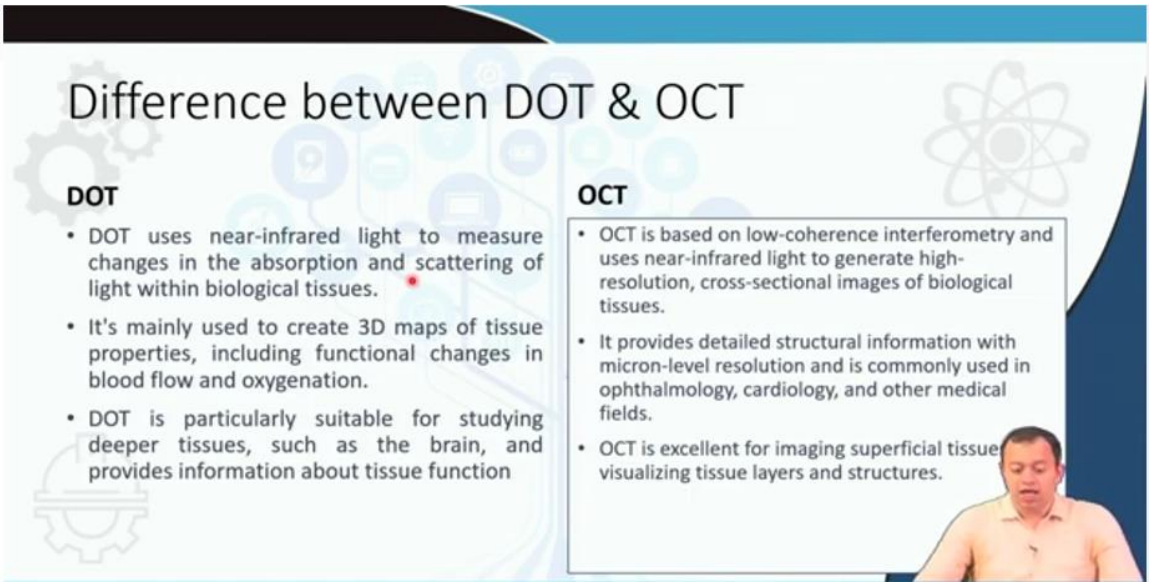


applications in like glaucoma, retinal detection, neurodegenerative diseases, optical neurotase, multiple sclerosis, MS, but let us see these are several other applications

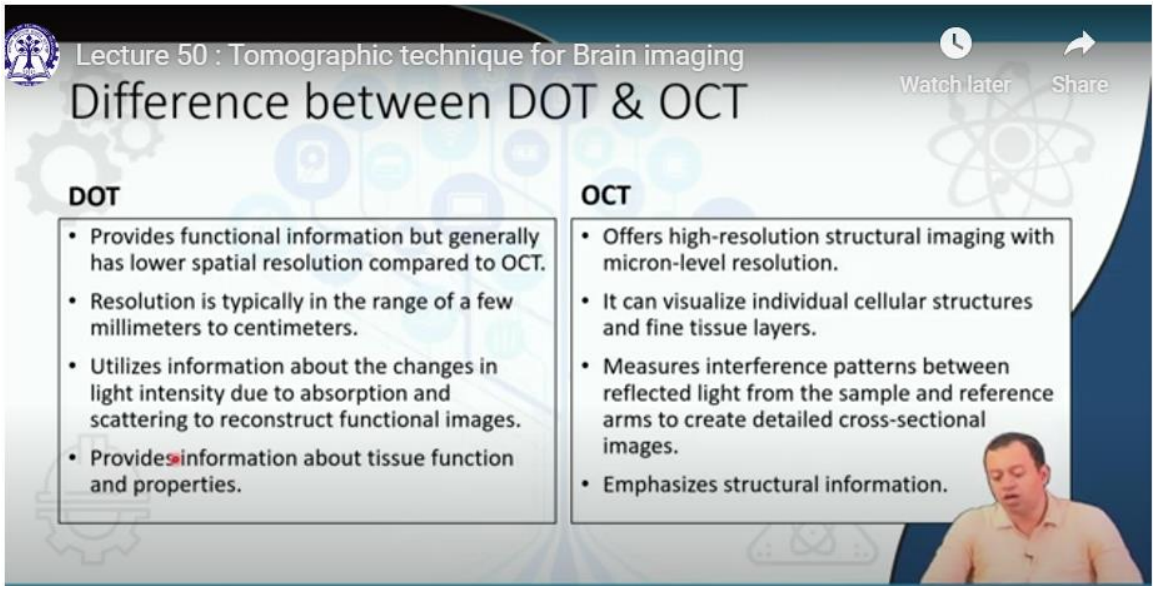


which I have given for you to read in your own spare time, but what is the difference between DOT and OCT right. DOT uses near infrared light to measure changes in the

absorption and scattering of light with biological tissues, where OCT is low coherence interferometry and uses near infrared light to generate high-resolution cross-sectional images. So, understand the difference, this near infrared is simply to penetrate through DOT mainly uses to create a 3D map of tissue properties, OCT provides detailed structural information there will be several you know overlaps of course.



OCT is excellent for imaging superficial tissues and visualizing tissue layers and structure DOT is particularly suitable for studying deeper tissue, both are similar techniques OCT is mostly the top periphery DOT is inside, but then you have seen in previous images that OCT is also giving you information from the depth of the tissue. So, for all intent and purpose DOT is a type of OCT, DOT is a type of OCT. DOT provides a functional information, but generally have lower special resolution compared to OCT absorption may occur, whereas OCT offers high resolution structural imaging,

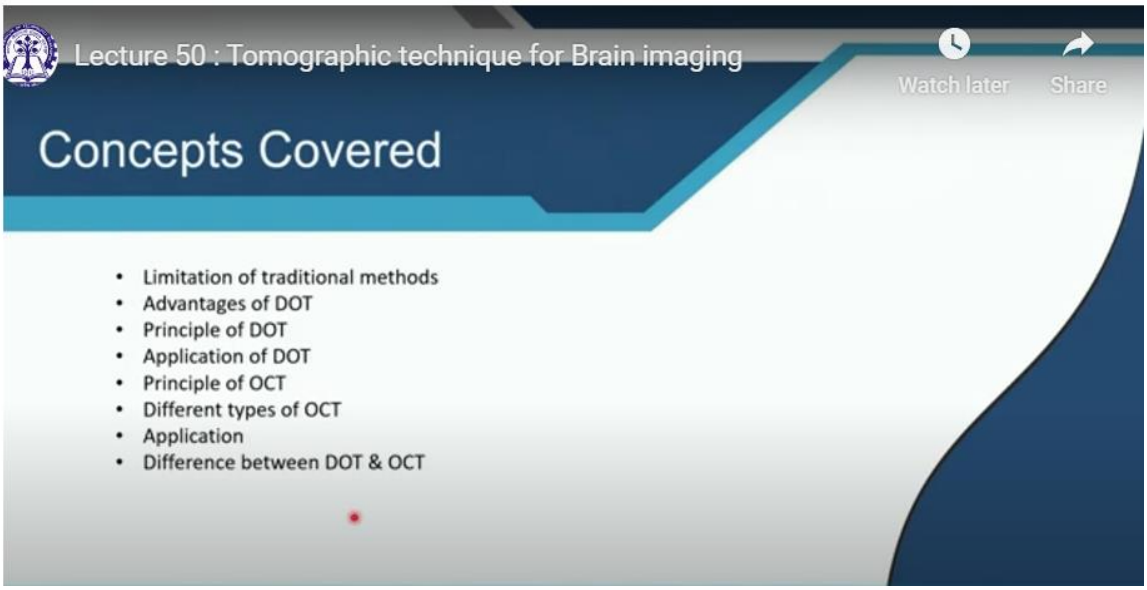


resolution is typically in the range of few millimeters to centimeters in DOT, whereas OCT can produce cellular structure with fine tissue images. ah DOT provides information about tissue function and properties, where OCT emphasize mostly on the structural part one gives you more information on the structure, but DOT which is another specialized type of OCT gives you information on the tissue function and property.

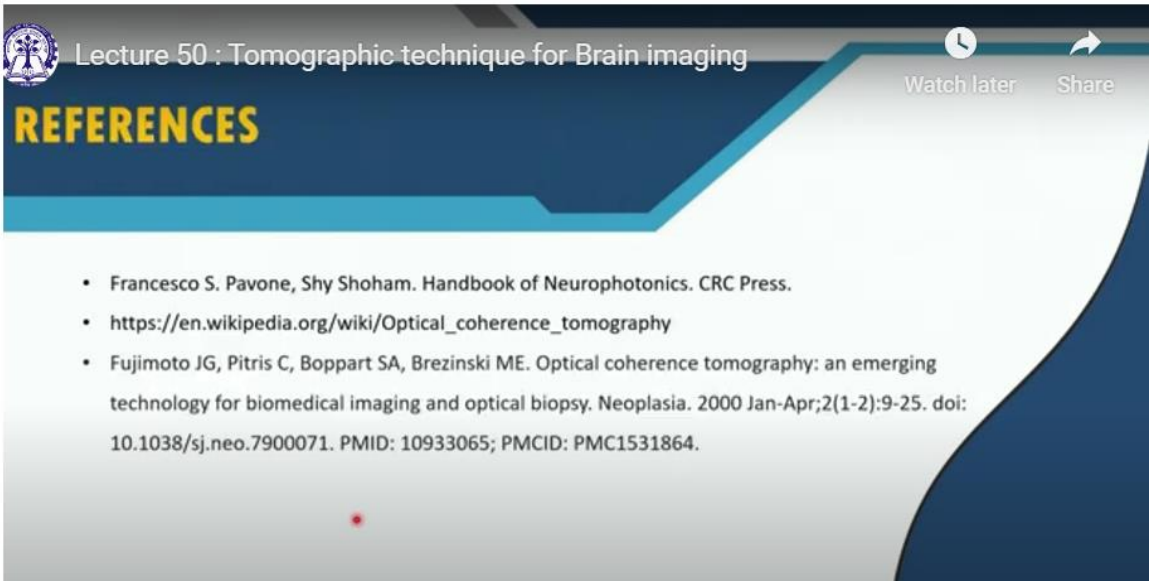
So, I think that is enough for brain imaging that we need to know there are other obviously, this is not an exhaustive list there are several other you know topics on the how to image brain.

I have tried to cover some of the main ones under no circumstances they are the most important or they produce the best results they are for the time being producing enough information. So, that we should be interested to look into it, it does not mean that any of this is best or better or it produces all are complementary to one another all are complementary to one another. And maybe in future several new types of microscopy techniques will come up which will be able which we will be able to use and detect the brain in real time i.e. how the neurons are functioning at a femtosecond picosecond pulse how each neuron is you know talking with another neuron a particular function is performed we need we we are still you know quite a far away from mapping that the functioning brain mapping that needs to be that needs to be discussed that needs to be ascertained that needs to come at a later stage.

So, DOT has the ability to penetrate deeper tissues it is less you know harmful and not just in brain it is used in ophthalmology, cardiology, dermatology, skin, heart, eyes and it it it also helps in diagnosing monitoring conditions like glaucoma problem in the eye, retinal disorder, vascular health and skin diseases.



So, these are the topics that got covered today and these are my references and thank you



very much I will see you with a new topic.