Nanobiophotonics: Touching Our Daily Life
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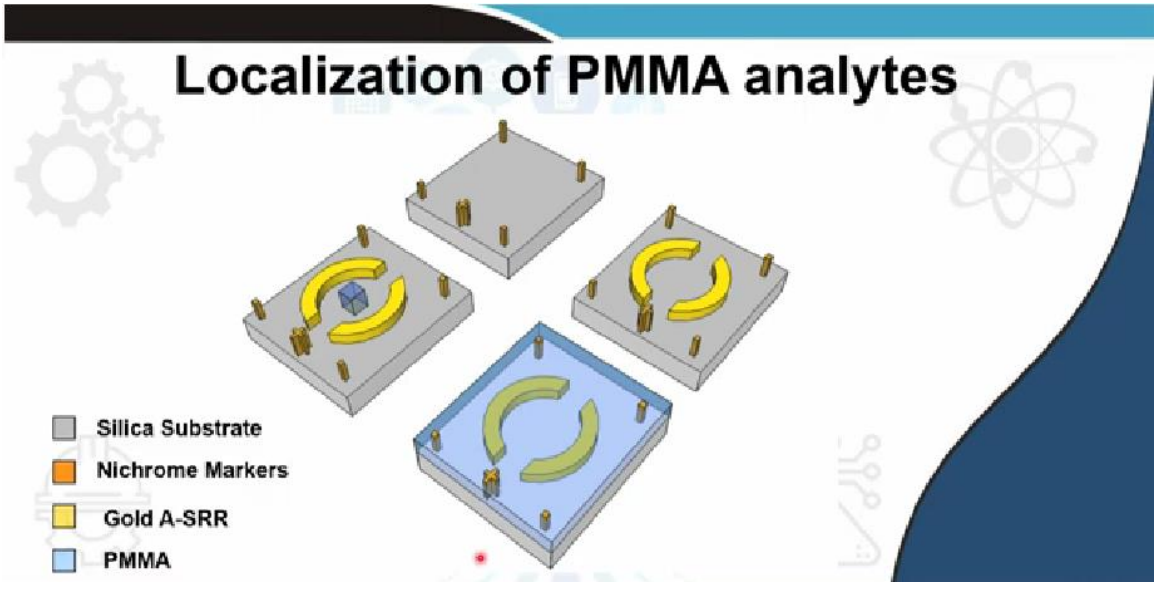
Lecture No. 38
Biosensing with Optical Nano-Antennas

Welcome back. We were previously discussing about metamaterials and those so called they are the fancy new term of the splittering resonators is nano antennas. Metamaterials which are few nanometers thin are called these these metasurfaces. So, called two-dimensional form of metamaterial is metasurfaces, but at the end of the day its metamaterial. Metasurface is just a fancy way of describing it because hardly anything is two dimensional these days it has some few nanometers thick. So, previously we have shown you how to utilize metamaterial for detecting very very thin layers of PMMA.

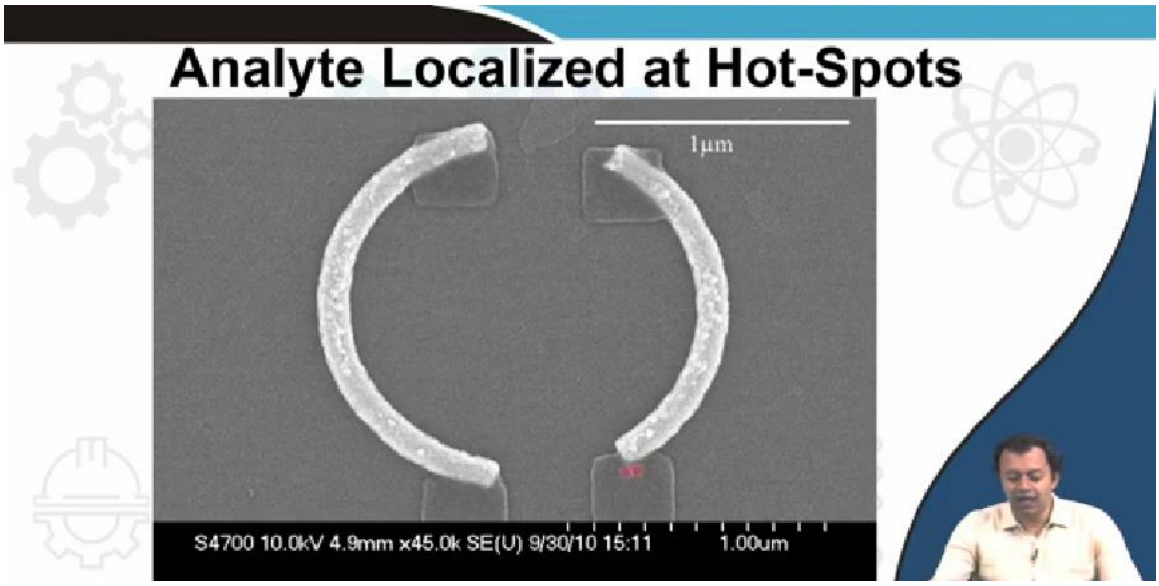
Today we will actually go and try to see if biosensing is actually possible with these so called optical nano antennas, those optical asymmetric splittering resonators. Asymmetric splittering resonators could be fancifully called as optical nano antennas. So, welcome to today's class where we will be discussing biosensing with optical nano antennas. So, I told you that these nanostructures these asymmetric splittering resonators they creates electromagnetic hotspot.



What are electromagnetic hotspots? Electromagnetic hotspots are those inhomogeneous basically heterogeneous distribution of optoelectric field. The optoelectric field are either at the end of the arcs or at the center because of the trapped mode. So, what we try to do is to see that can instead of distributing the analyte homogeneously all over the place can we actually put analyte in specific specific hotspot areas i.e. localize the polymethyl

methacrylate.

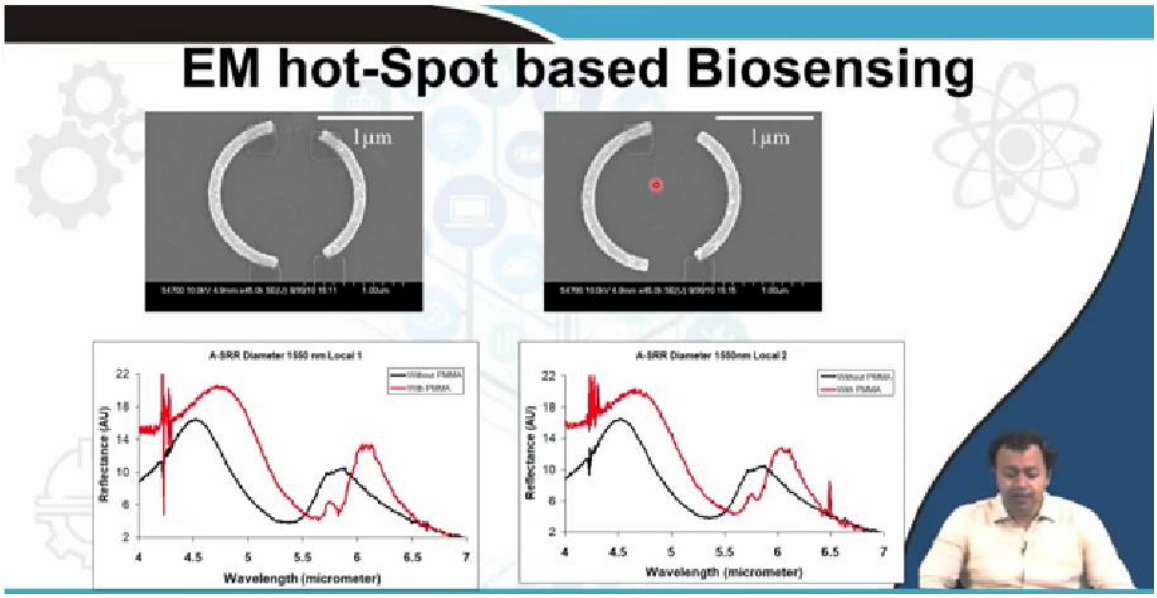
Is it at all possible to localize the analyte using nanotechnological tools polymethyl methacrylate is electron beam sensitive it is a positive E-beam resist. Is it possible to put polymethyl methacrylate at specific specific areas coinciding with the electromagnetic hotspots of splittering resonators of asymmetric splittering resonators and try to see if the sensing is even possible. You have to notice that previously the amount of analyte was huge now the amount of analyte has reduced significantly. So, that is challenging more analyte more signal yeah you reduce the amount of analyte the signal the percentage the amount it will affect the transducer will this being the transducer will also reduce yeah some amount produce a particular wavelength of light or particular electrochemical reaction or a particular electric current you reduce that amount of analyte to you know 200 times 300 times do you think the same amount of current will flow the same amount of resistance will be there the same amount of electrochemical reaction will be there the same amount of light will be reflected does not amount matters. So, this is what we wanted to test the limit of our hotspots those hotspots remember depends on epsilon c that is the refractive index of the surrounding area the surrounding medium and any small change in the refractive index 0. 01 0.1 will that be of any any any any significance or not.



So, what we did we localized I localized you can see the date how far away it is so, so far away when I was of your age blocks of poly methyl methacrylate at specific specific hotspot areas at specific specific hotspot areas of the asymmetric splitting resonator. So, this is your 1 micrometer scale and these blocks are 200 nanometers by 200 nanometers by 200 nanometer volume of poly methyl methacrylate blocks at specific specific areas of the splitting resonator. You know something funny or coincidental do you know the size

diameter of a single coronavirus how big is a coronavirus how big is the coronavirus with spikes you will be surprised to know it is exactly the same size as these blocks. So, if you could identify localized these blocks and sense them can we sense the presence of 4 coronaviruses which are exactly of the same size poly methyl methacrylate is an organic compound a virus is also an organic compound are organic assemble organic nanostructure size is same yes it replicates.

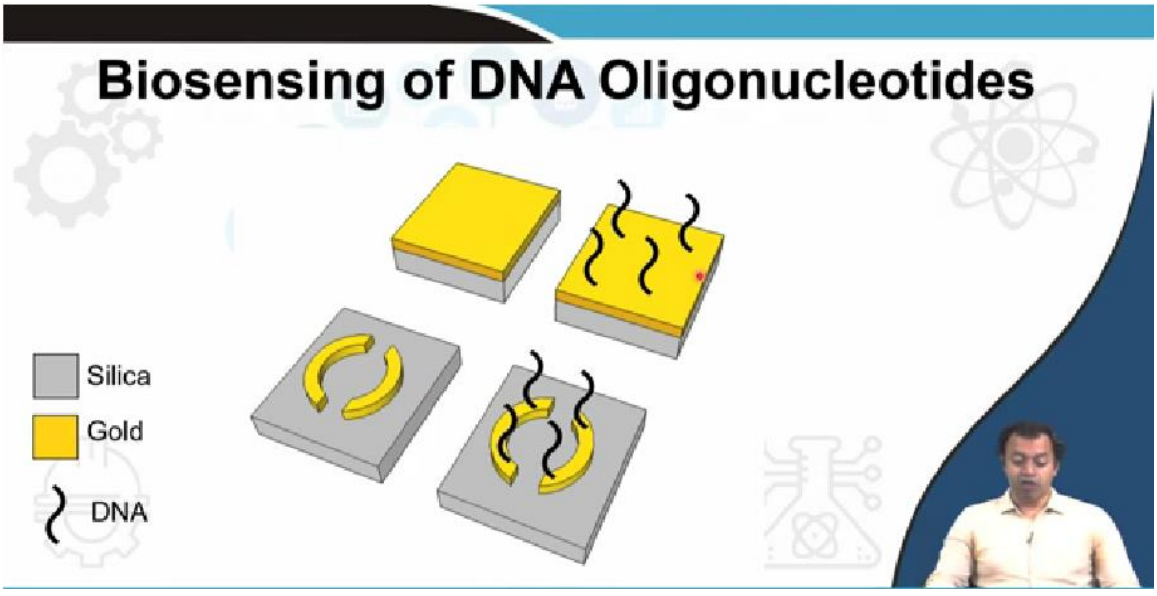
So, what, but it takes some time to replicate by that time if we are able to detect if we are able to localize we can localize you know how to localize biological materials we discussed about aptamer antibodies and what not we can localize we can simply put aptamers or antibodies in this specific specific areas which will then attach itself with the virus which will attach itself with the virion particle and then thereby there will be a change in the overall refractive index resulting in a redshift that redshift is detectable the



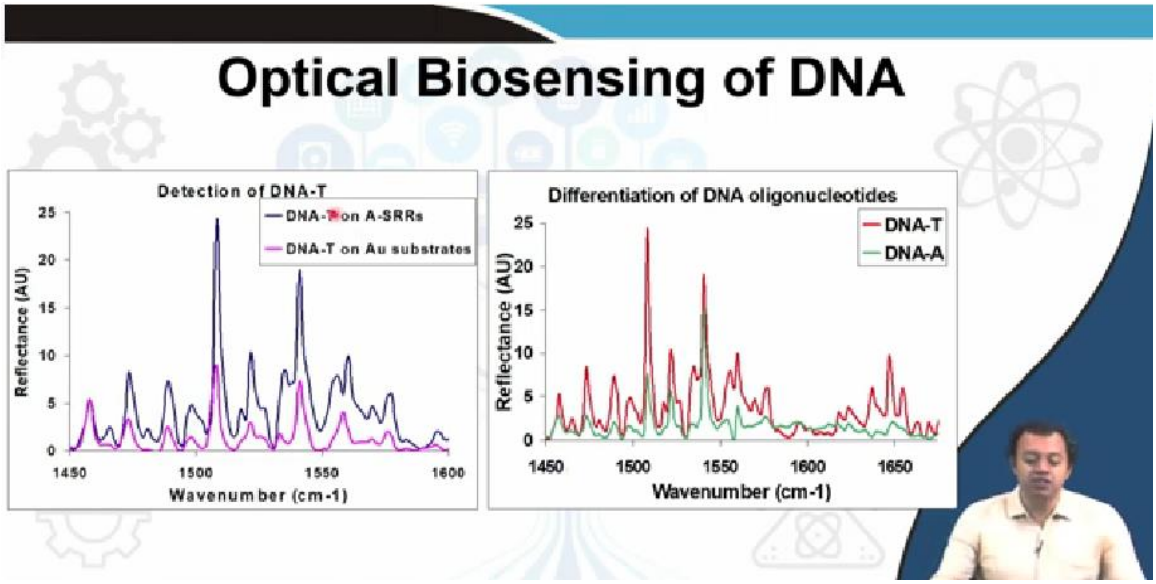
signature is still present the signature is still present albeit it has reduced significantly albeit it has reduced significantly, but the redshift is still there the signature is still there and it is still detectable from its native resonance from its native resonance it has simply reduced the previous from previous case it has it has it has reduced its sensitivity has reduced, but still still still detectable in this case there are 4 blocks in this case there are only 2 blocks of exact same size as that of a standalone virion particle as of a standalone virus. So, this is something that we directly did. So, can we now detect a single virus or couple of virus 2 or 4 or 6 and if you have detected if you have the capacity to detect just couple of virus even couple of 100 or 1000 virus at a time you can immediately take precaution that this virus have infected or started to infect then instead of quarantine entire city entire blocks entire country entire state simply you know quarantine couple of 100 people and maybe maybe the the the the spread the contagion the infection could be

protected just maybe just maybe we do not know we have to test this we have to test this and long way to go what I am telling you that the technology exist not just is exist I have used it I have created it based on existing technology and if that could be created why cannot we create a biosensor for viruses there is absolutely nothing preventing us. So, please please all of you look into these technologies and come up with interesting and nice ideas and maybe we can have a discussion together on how to detect viruses how to detect bacterias how to detect pollutants how to detect toxins in air water soil and of course, in human body. So, this is something that was quite interesting quite significant showing that yes it is possible to detect individual blocks of poly methyl methacrylate.

Poly methyl methacrylate was merely a test case we utilize it because it was available it was cheap it can be created into a thin film it is electron beam sensitive needless to say creating a virus putting it at specific places will be 1000 times more difficult, but that is that is what it is that is what life is you you go step by step you start from an easier part and then go to the difficult part moral of the story it is indeed very much possible it is indeed very much possible theoretically there is nothing that is preventing you and with tenacity with hard work yes you can come up with you know a virus detection kit in your hand which is far more accurate than the rapid antigen test rat test kit that you get. If we can detect poly methyl methacrylate what is preventing us from going from detecting DNA DNA oligonucleotides. So, we put DNA strands we try to put it in thin film of gold

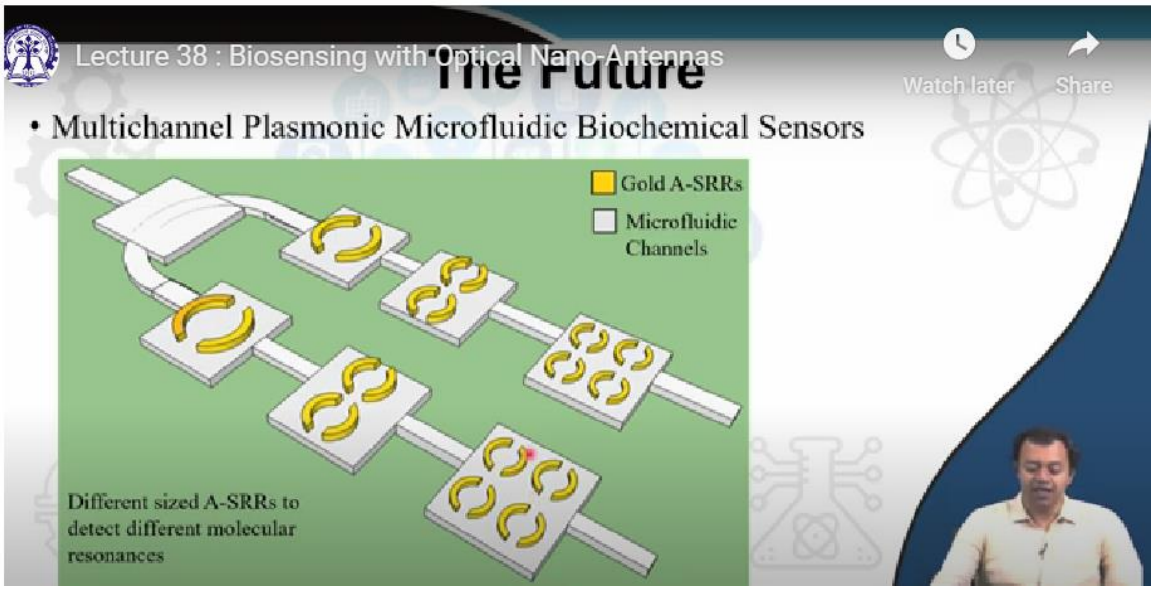


versus the asymmetric splitting resonator to see which one has a better resonance which one has a better sensitivity better resolution because people were previously using gold film-based detection they called it surface enhanced Raman spectroscopy we utilize splitting resonators as a further surface enhance Raman spectroscopy. So, DNA T means just T T T T thymine thymine thymine thymine thymine and DNA A means only



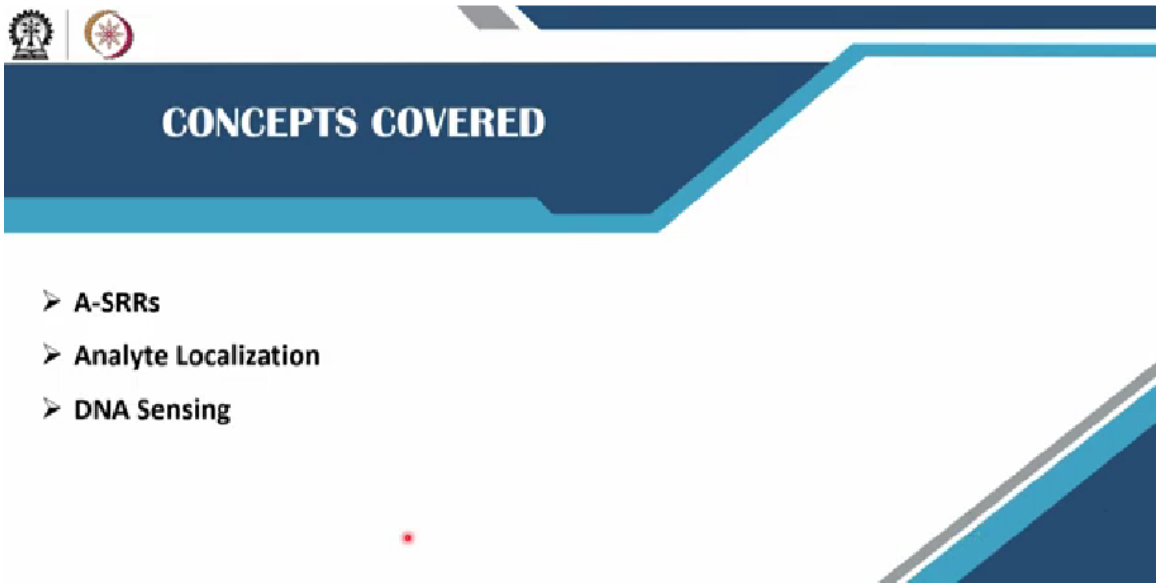
adenine adenine adenine adenine single strands of DNA only containing AAA or T T T T T this was put on top of gold substrates this was put on ASRRS the blue one you can see which one has a higher resonance the splitting resonator has its own individual resonances two peaks and one trough whereas, this will show only the plasmon resonance this will show the plasmon and they will see the magnetic resonance and it is customizable. So, you can make it match it with certain frequencies and thereby you can see the detection of asymmetric splitting resonator shows much higher sensitivity much higher reflectance much higher detection as compared to its gold counterparts whereas, you can also utilized it for differentiating differentiating between a single strand of DNA of two different pairs of bases.

So, at this present moment we are creating a database of DNA A DNA T DNA C DNA G and then we will mix them if we can mix them and figure out which one is which we have a sequencer we have a sequencer an optical sequencer which within a second will read from the reflectance from the reflectance if the DNA strand that has present how many A how many T how many C and how many G's are present that will help us immediate detection immediate genome sequencing or rapid ultrafast genome sequencing. So, all of these are presently possible using and these are all experimental result these are all experimental results these are my results I have worked on them and I have shown I am showing it to you we can do optical biosensing of nucleic acid optical biosensing of DNA. If DNA can be detected you can detect RNA if RNA can be detected you can detect protein a combination of RNA and protein or DNA and protein give a virus a combination of several of these things can give you a bacteria single bacteria you detected. The future the future lies in something like this a multichannel

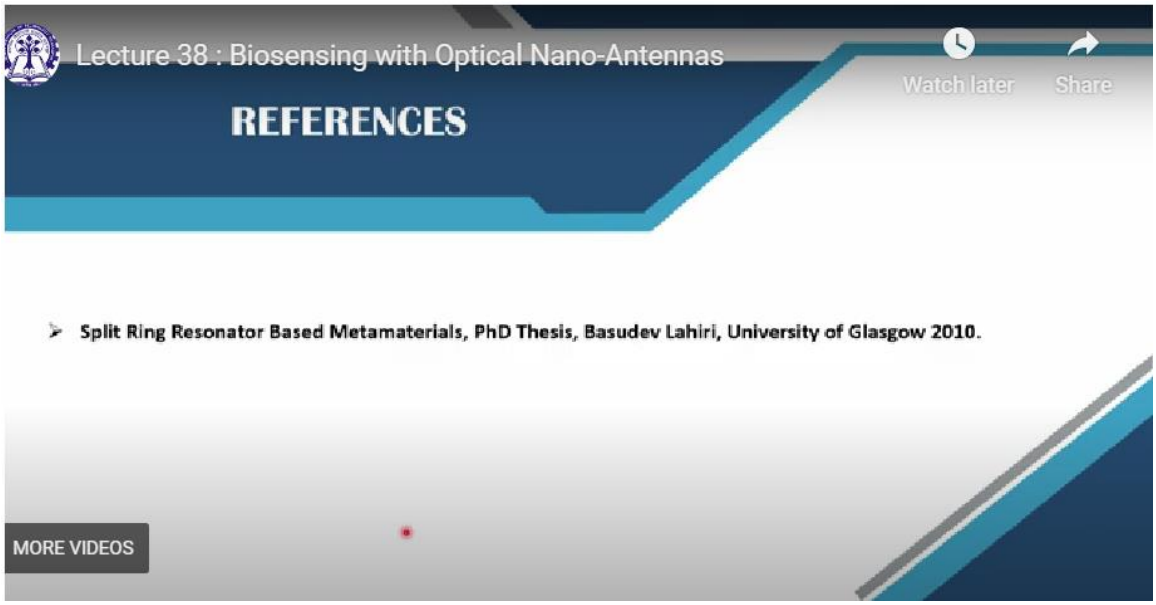


plasmonic microfluidics sensor where you have different size asymmetric splitting resonator to resonate at different frequency different frequency will be associated with different molecular vibration different molecular vibration will be associated with different individual viruses individual types of viruses you will put a oropharyngeal or nasopharyngeal swab on each of them some of them will be resonating in visible some of them will be resonating in infrared from the visible you will see a refractive index change ok first level crossed then you will go to the infrared change where you will see a particular signature coming up a particular vibrational peak coming up which we will further analyze individual peaks all of these individual peaks will represent one single virus one peak or two peak may be similar or may overlap with different types of viruses coronavirus a coronavirus b i SARS-CoV-2 SARS-CoV-1, but if you want to understand the different strains of the same SARS-CoV delta versus omicron versus the first one the first wave S 1 maybe you want to analyze all those details. So, for those you can you can you know step by step pass through all the different stages and this all these reaction happens in couple of minutes only and you have your results at hand and this is golden glass meaning it could be reused once a person's nasopharyngeal swab has been given you put it in some kind of acetone based nano structure acetone based solvent or plasma asher or something just clean it using detergent soap and it is good to go you can utilize it for another run whatsoever.

So, think about it all of those technology already exist all we need to do is think plan and utilize it from a photonic background to a biology background and that is what I am counting on you forget about the boundaries of your individual subjects just break those boundaries and think what you have previously used in electrical engineering or mechanical engineering can be utilized in gene sequencing or cancer treatment the world will be a far far better place if you simply talk to one another right.



So, these are the concept covered and these are still this is still the reference of today's



lecture and I will see you in the next class. Thank you very much.