Optical Engineering
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Lecture – 31
Interferometry basics

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Good morning after a long gap. So, while it feels like a long gap to me, but you still have your classes though I think they were not many classes right you had quite a few holidays in between. So, we get back to light to Optical Engineering and we start a new topic today, we are going to look at interference and since its a course on optical engineering we are not going to spend too much time on interference itself, but we kind of almost immediately go into the application of interference which is Interferometry ok.

So, I have some pictures up here, some beautiful pictures up here right; one is of and some oil spill on the road you see that quite commonly and the other is of a soap bubble. You see these kinds of images I mean I am sure you can tell me hundreds of other examples where you have noticed or seen such images I hope because if you have not; that means, you are not being very observant at all.

And why do we see these, what is the reason that you see these nice patterns and you see these variations in color? Well really it is because of the phenomenon of interference, you cannot explain these images if you stick to your ray optics picture of light your geometric optics picture of light these are only explained when you go to the wave phenomena ok. So, as I said in this course our goal is to get you up to speed as quickly as possible in the application part. So, I will do a very quick introduction to interference and then we will start looking at how and why it's useful where you can use it ok.

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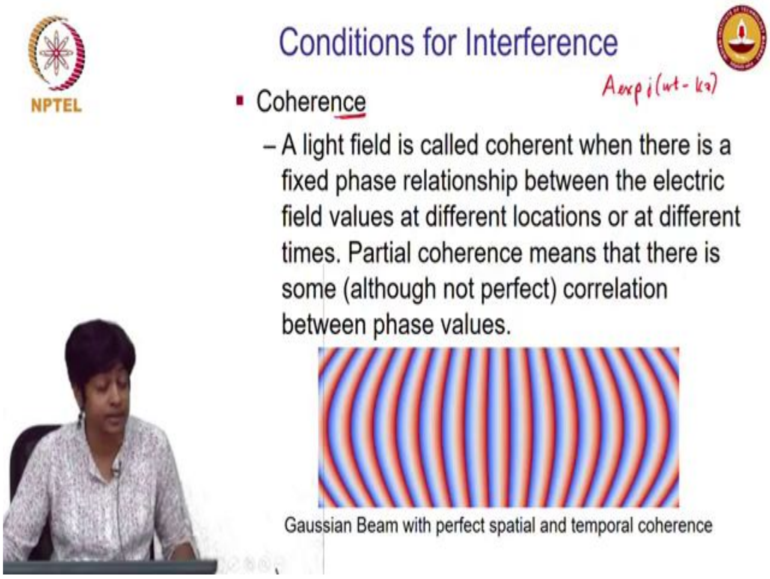

So, in order to see interference some conditions have to be met, we see we do see these patterns often, but you do not see these patterns always. So, some conditions have to be met and one important condition that has to be met is that the light that is interfering has to be coherent ok.

So, coherence you are not going to see interference if you do not have coherence ok. So, what do we mean by coherence? Right. Now, if you think about it the pattern you saw is showing you where one beam some let us take a simple case where you have two beams of light and we say they are interfering, you get this kind of fringe pattern even what I showed on the previous slide. We see some regions in the previous slide. Maybe I can just go back.

If you see this image over here you have one region which is all blue another region which is all magenta another region which is all one particular color. That means, some condition is satisfied in that region for that wavelength and that is why that wavelength becomes visible to us and its that condition that is not satisfied for the other wavelengths in that region.

So, you can think of this interference pattern like a map. Right, you have these maps which show you regions that connect points of same pressure or same you know you have isotherm points of same temperature. Well the interference pattern is nothing, but a map of that nature. What is it connecting points of the same, what do you know, can you think of? So, what isotherm is a graph that shows you the points of the same temperature right.

Student: Same wavelength wave (Refer Time: 04:13).

So, no it is not the same wavelength, it is the same phase right in other words same optical path length right. So, wherever and we will see these conditions, but if you think of the interference pattern as nothing, but an iso optical path length, its connecting regions of the same path length. And wherever there is a same path length, where is that going to happen if you assume that this film has the same path? So, let us say you have some film of some varying thickness and that is its uniform refractive index. So, it has the same refractive index throughout let us say.

Whenever the path length difference matches some condition for one wavelength that wavelength is going to be predominant and this gets clearer as we go along. But think of the interference pattern as nothing, but connecting points with a graph that connects the points with the same optical path length or the same phase ok. So, in order now, so now, I have connected interference to phase, but if I want them to have the same phase, if I want to see an interference pattern that phase relationship between the beams that are interfering that must have some stability to it.

So, think about phase itself just from the point of view forget interference just think about phase itself. If I say a wave has a particular phase behavior or a phase structure to it, we are able to write out an expression for a wave. So, if you look at an expression for a wave we can say it has a certain amplitude and then it has $exp(j\omega t - k_z)$ let us say right oh sorry I am not I do not write the j over there. So, it is s $exp(j\omega t)$ when I yeah that is all right ok. So, what do we mean here? I have a certain phase that allows me to predict how the wave is going to behave.

So, I know what the phase of the wave is, what the amplitude of the wave is at some position z at some point in time t this relationship if the wave obeys this relationship it means I can predict what is the expression for the wave after some times z after sorry after some time t at some other locations z right. The fact that I can write out an expression like this and this expression will hold true for all time t and for all z means, my wave is behaving in a consistent way.

And really coherence is talking about how consistent, we blindly write out this mathematical expression and we have always written it down. But you could actually ask when I write out this expression for a wave does this mean for all time whether I put it equal to 3 picosecond or t equal to 10 to the power 12 seconds or hours or minutes, will this expression hold true always and it turns out it may not.

Now, the expression may hold true, but these relationships ω and k oh sorry these terms ω and k they do not actually stay constant ok. So, coherence is the way to study what is the stability of this wave, with what accuracy can I predict something about the wave if I know everything about the wave at some time t and at some positions z. So, you say it's coherent when you have a fixed phase relationship between the electric field at some position at some time and the electric field at another position at another time ok. If you have such a wave we call it coherent.

Now, no wave will have a fixed relationship for infinite time and infinite positioned locations. So, the degree of coherence depends on how far you can go away and still say the wave at this far distance or the wave that is much delayed is still correlated to the wave I have measured at this place at this time. If the correlation is lost very quickly we will say that this light has poor coherence, if the correlation lasts for a long time over long distance then we say that this has a strong coherence. So, you can have a degree of coherence.

Now, it should be clear or maybe it's not that clear, but if I take a source like a white light source from a tube light and I take a laser and if I were to compare the coherence of these two sources, they do not have the same degree of coherence. So, if I want to do an interference experiment, can I do it with a white light source with the tube light? Do you think? Someone says yes and they are right you can. There is coherence. Can you do it as easily as you do it with the laser? The answer is no because a laser has a very high degree of coherence, a white light source has a very low degree of coherence.

So, setting up an experiment with the laser is easier than setting it up with the white light source, but it's not impossible ok. And we will see what would be the differences between these two sources and why sometimes. So, you might say, so we will never interfere through the white light source. Sometimes you choose a white light source because the ease with which you get fringes with a highly coherence source can sometimes be a problem for you; you do not want to have so much information and you are getting information.

So, sometimes a white light source is chosen if you have specific systems where the source has poor coherence on purpose. So, this is an image of by now you should know this is how a Gaussian will the wave fronts of a Gaussian beam as its propagating and as its propagating through its waste ok. So, you have the plain wave nature in the middle and then as it propagates outward from that. This is how a beam would look if it had perfect spatial and temporal coherence.

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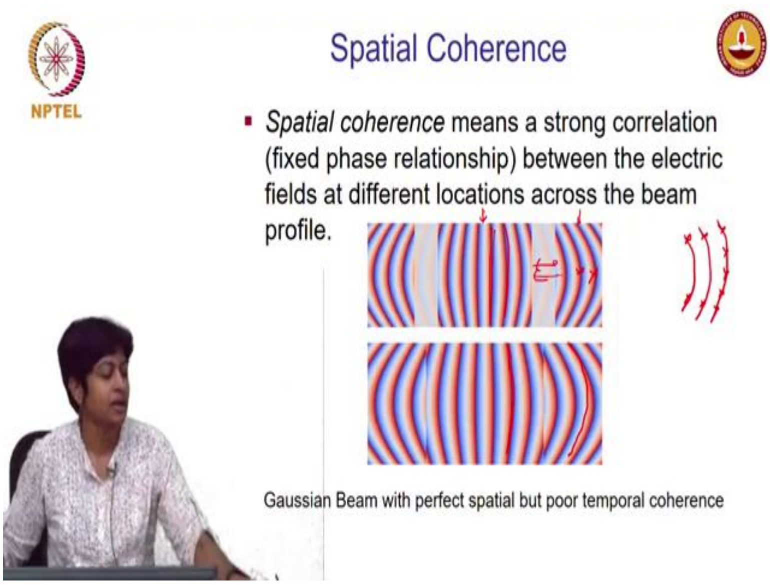

But let us say that the beam had very good spatial coherence and poor temporal coherence. So, what does that mean? So, we can talk about coherence as being the relationship between the phase at some point of time and space with respect to the phase at another point of time and space. In spatial coherence we are saying just look at the wavefront. What is the relationship at different locations on the wavefront? So, it is on the same wavefront.

So, you are not talking about different instances of time and that is why we refer to this as spatial coherence and you can see here that it's the way this image has been drawn, we have anywhere here the relationship is good. So, anywhere on the wavefront the relationship is good, but if I know the phase here I know the phase here, I cannot definitely predict the phase here because there is a gap over here something has happened to disturb the beam, yes.

Student: Where you know (Refer Time: 13:00) is not clear on the beam.

Sorry ok. Maybe I use a mouse, can you see the mouse movement?

Student: Right.

Right. So, basically what I am saying is if these are your wave fronts if I know the information here if I have a source with good spatial coherence; that means, I know what it will be here on the same wave front right. So, I know everywhere if in fact, when we define wave front we say these are the surfaces of constant phase.

So, ideally if I know the phase at some point on the wave front I am saying everywhere on the wave front that is what the phase will be, but a beam with poor coherence the phase can actually gets slightly altered you can think of it as; it has an aberration it does not have the phase it ought to have.

So, although I know the phase somewhere here it ought to have the same phase somewhere else on the wave front, but because the source has poor spatial coherence it may not be ok. In other words if it has good spatial coherence I know that the phase everywhere on this wave front will have the same value because every wave front has the same phase right ok. What is lacking here is temporal coherence.

So, we are saying this is a source which has high spatial coherence; that means, everywhere on a wave front I can tell what the phase is, but I cannot predict the phase at some later time. And so if you look at the earlier image this is how I expect my Gaussian beam to look.

So, if I know the waste is here then just using my Gaussian beam expressions I know that if it travels a certain distance z, I can choose what that value of z is. I say this is what the field is now because I know exactly how the phase has changed. The change is caused only by the optical path length travelled by that beam.

But now in this beam with poor spatial coherence sorry with good spatial coherence and poor temporal coherence I cannot predict what the wave will look like at some later point of time. You can see something has happened in this region over here which means this does not necessarily have the same phase relationship it ought to have had, if this was a perfect beam with perfect coherence ok.

So, the easiest way to think about it is that spatial coherence means you have a source where different points on the wave front will be well correlated with each other, but not correlated to a point at a later time.

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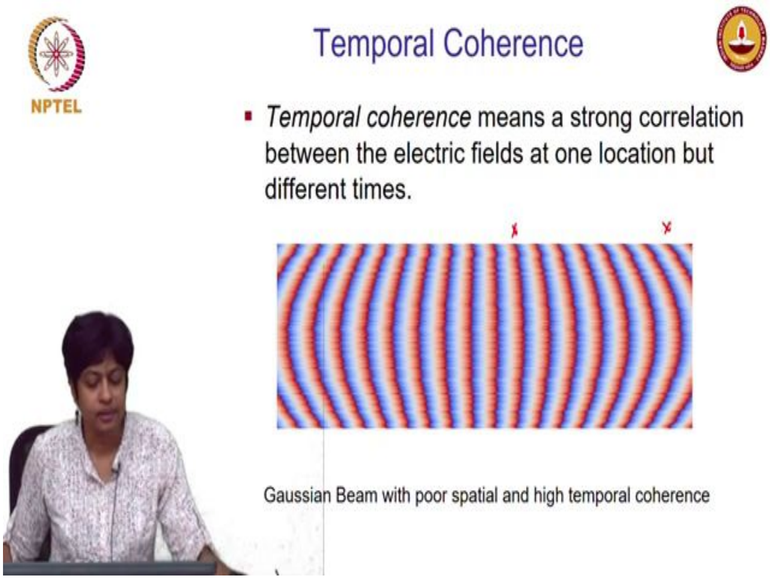

As you should imagine temporal coherence is just the opposite. So, if you move from one point to another point on the wave front there are some errors there, but if you move from one point to a later point of time that relationship holds true as it would for the ideal case.

So, you can see here we have tried to depict that here by saying the wave fronts are not smooth now its like there is some error in them, but from one point let us say I am from this point and I want to predict what is happening at this point, I will be able to predict accurately ok. So, temporal coherence; temporal coherence means then you have a strong relationship between electric fields at one point of time and a later point of time or another point of time ok.

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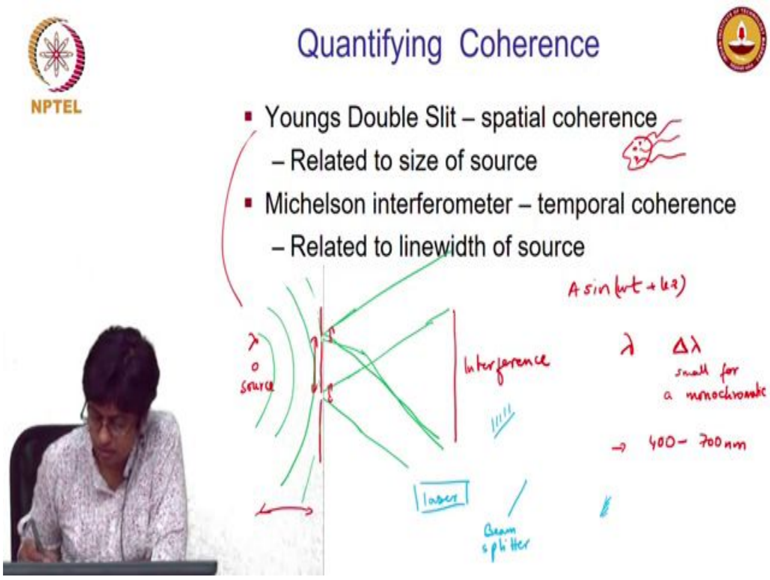

How do we study these? If I want to look at a source and find out does this source have good spatial coherence good temporal coherence and what in fact, affects the spatial and temporal coherence of a source.

Now, our ideal sources are always point sources. If you had an ideal source; that means, you had a source that was infinitesimal in size it would then have perfect spatial coherence, why? Because the source is so small you consider that only one wave is emitted from that source. Where does the origin of the lack of spatial coherence arise? You think of a source and you say that the source is actually this big, it contains many emitters.

So, every emitter is sending out one wavelength of light and the moment I have a number of wavelengths coming from various emitters they now are slightly different from each other right. So, when can I perfectly predict a wave? If I know everything about a wave at one point of time and one position, when can I always predict where that wave will be or what the amplitude and phase of that wave will be? If I have a sine wave or a cosine wave right.

So, if I say my field is $Asin(\omega t + kz)$ A, this is the ideal case I can always perfectly predict you give me the position and time information of this wave I will then be able to predict what its amplitude is at any time at any position right.

When you have a source that is not a point source it means you have a number of emitters and each emitter is emitting a perfect sine wave, but now these different sine waves need not all be in phase to start with they may be emitting at slightly different times. So, while each of them is a perfect sine wave the combination of them is not all a bunch of waves in phase. The phase difference may be small, but there is a difference you have to understand that light is very very sensitive to small changes in phase.

So, sometimes when we do derivations we say let us assume there is a change in some parameter and it's a small change and therefore, we neglect that change. In the case of light if you say wrote out an expression for the electric field whether I write A sin omega t or A sin phi or A exponential j phi, if I said I am making measurements on phase and amplitude and the accuracy with which I make the measurements is not very good in the amplitude. So, maybe I have a plus minus 5 percent error even a plus minus 10 percent error in the amplitude that might be quite acceptable.

But, if I say there is an error in phase 10% is totally unacceptable because the way light the change in this expression for even a small change in phase is very very large ok. So, changes in phase effect light are very strong. So, if I have a source that is a distributed source; that means, it is not just one emitter emitting one perfect sinusoidal wave, but a number of emitters each emitting one perfect sinusoidal wave. But since they are not all emit they do not start in phase they have a phase difference between them and that is what is going to relate to the overall coherence of your source.

So, how do we study spatial coherence? Well you might have done these experiments in I do not know school or lab even a physics lab, we want to study spatial coherence. So, we want to study how well correlated is one point of the wave front with another point on the wave front. So, you can do a Young's double slit. So, you have your source and you have two slits ok.

So, now, let us say light is being emitted by this source and the say. So, you have the wave front over here right now and from one wave front you have light coming from this point of the wave front and from this point of the wave front and then this travels a sorry straight line. And in this region there is an overlap between these two wave fronts of both.

So, you have generated two sources. Those two sources came from the same wave front from one source and now the interference you observe in this region can be used to analyze the spatial coherence quality of this source right. Of course, it depends on various things, it will depend on this distance, it will depend on this gap, it will depend on the width of these slits depend on the wavelength and it I say lambda, but of course, whenever we say lambda of a source it does not mean that the source has only one wavelength ok.

Now, sources that have poor spatial coherence. So, with any source I will say I may say that the wavelength of the source is 633 nms, but associated with that source will be a bandwidth delta lambda. Now, for a monochromatic source; that means, and the fact that I called it a monochromatic source means that delta lambda is small and we will put some numbers to that as we go along ok.

So, delta lambda small for a monochromatic source. In fact, delta lambda for a white light source can stretch anything from 400 to 700 nanometers. So, you can be talking about 300 nanometer $\Delta\lambda$ for a white light source and that is a source with poor spatial coherence. So, you know now that a monochromatic source has to be much less than $\Delta\lambda$ the spectral width has to be much less than 300 nanometers in order to have good spatial coherence.

How do I study temporal coherence? Well this particular setup of the Young's double slit allowed us to make two sources out of the same wave front. So, somehow I need to now take my original source and create two sources again, but not from the same wave front because I do not want to study spatial coherence anymore. But from a wave one two waves one of which has traveled a longer time or a longer distance therefore, than the other one ok.

So, what is common there are multitude of interferometers and interferometer is a device that generates two or more beams that you will bring together and interfere and thereby extract some information from it. So, the way in which you generate those beams defines what type of interferometer it is ok.

So, a very common interferometer is the Michelson interferometer and in the Michelson interferometer again you have a source, so it is used. So, let us say you have a laser you have a beam splitter ok. So, no guesses, no marks for guessing what it does. And then you will have another mirror and then let me remove this ok.

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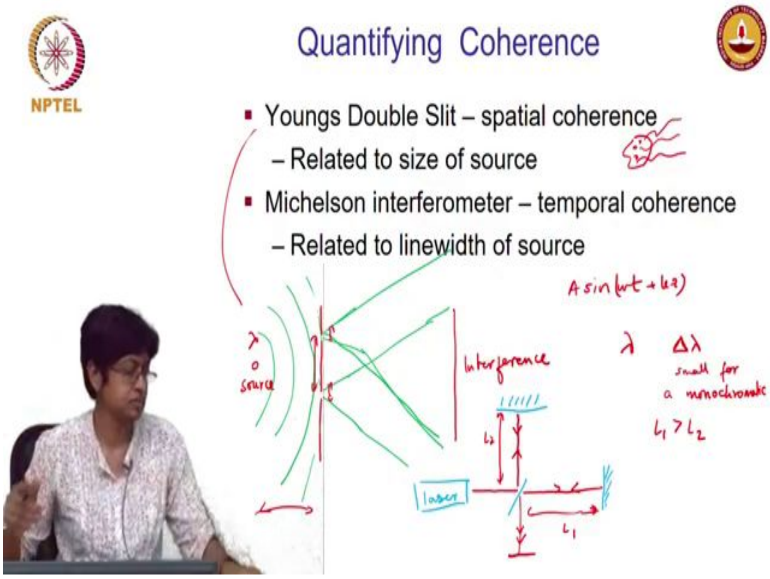

So, now what happens? Light from the laser hits this beam splitter. You can choose the ratio that you split, but typically let us say 50% of that light goes to this mirror. I have not drawn this correctly and the other 50% will go to the other mirror. So, some light has traveled here to reflect this mirror and I have drawn a general case over here, but in particular for the Michelson you would really want this mirror to be at 90^{θ} to the. so that you have normal incidence basically.

So, this configuration allows the light that is incident to hit the mirror at normal incidence. So, it travels back you would again have this mirror. So, that the second beam also hits at normal incidence and it travels back and both these beams now will come through here ok. Now, I drew the mirror stilted because if you really want to see the fringes you need to have a slight tilt between the beams.

So, I have drawn lines. The red lines indicate the path that light is taking, but actually I might have an expanded beam, so that I can see the fringes we will. We will come back to the Michelson interferometer in more detail. What is the point or the difference between the Young's double slit?

In the Young's double slit the slits ensured that you made two sources out of the same wave front and then you looked at the interference pattern of the two waves coming from these sources and therefore, that interference pattern would tell you about the spatial coherence of the source. In the Michelson the two beams now travel different paths and I have on purpose drawn one length as much longer.

So, let us say this is L_1 and this is L_2 and I have drawn L_1 greater than L_2. So, one beam is traveling a greater distance. So, if I look at an interference pattern here its as if I am interfering a wave with a wave that has traveled longer and comes a delayed version of that wave right. So, now when I look at the interference that interference will tell me how well does it happen; how well does the interference happen for a wave that is delayed. So, I could consider changing the length L_1 and maybe initially L_1 is equal to L_1 and I have a very good interference pattern then I slightly L_1 and I still have a good interference pattern.

But as I go on L_1 I can see the quality of that interference pattern goes on decreasing and at some point I may not see interference anymore if I go beyond the temporal coherence of that source. So, I hope you can see the difference between these two types of interferometers; one is both are interferometers both are creating two sources out of a single source. One allows you to study spatial coherence, one allows you to study temporal coherence.

Now, the spatial coherence I told you is already related to the size of the source because I can consider a source that is spread in size having many emitters. But even a source that has small even that has many emitters and they are not all emitting at the same time and therefore, I can relate all the different emitters to the temporal coherence. So, we relate the spatial coherence to the size of the source and the spread of the emitters and we relate the temporal coherence again to the different emitters, but to the fact to the specific fact that they have a large line width.

So, typically a source with poor spatial coherence will usually also have poor temporal coherence ok, its quite hard to achieve a source with good spatial, and sorry what did I say? If you have good spatial coherence it does not necessarily mean that you will have good temporal coherence, but if you have a source with poor spatial coherence it is quite impossible to have very good temporal coherence if you have poor spatial.

So, most likely you also have poor temporal coherence because you have these number of emitters and they will be out of sync both spatially as well as temporally in most cases ok. You can have a source with very good spatial coherence, but the temporal coherence may be poor ok.

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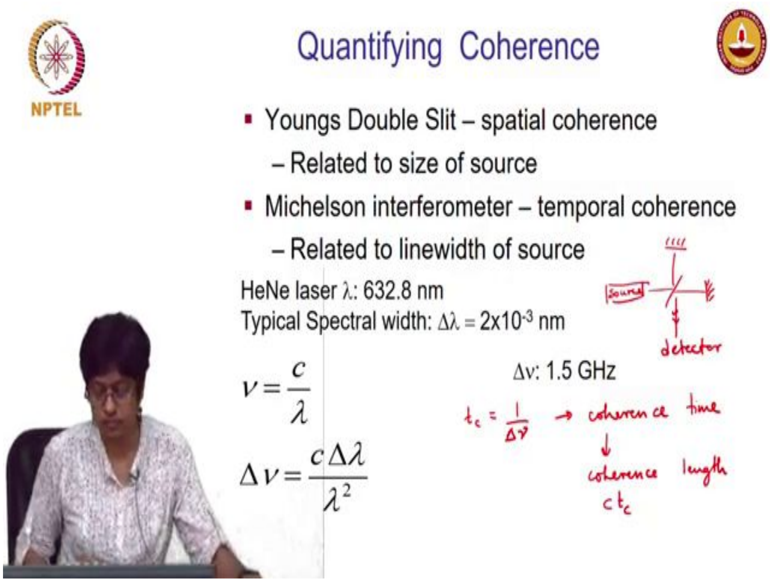

So, how do I actually relate these parameters now to and quantify the coherence? So, let us look at the case of the temporal coherence. So, we now know that the frequency of the source nu is equal to c by lambda let us assume that light is traveling in free space ok. So, the velocity is 3 to 10 power 8 meters per second.

Now, let us take a typical lab source, say source is a helium neon laser its wavelength is 632.8 nanometer, so its in the red and its spectral width; that means, a spread. So, we say this we call this a monochromatic source, but it does not mean it has just one wavelength. It is always a spread and the spread here is 2 into 10 power minus 3 nanometers.

So, if you compare this with the wavelength it seems fairly small right the wavelength is 632 nanometers and this is 10 power minus 3 nanometers its orders of magnitude smaller than the wavelength. And that is why we say this is a monochromatic source because the spread is so small compared to the wavelength.

If I differentiate this expression, so that I get I am able to relate the spread in frequency to the spread in wavelength you will get delta nu is equal to c I am not worried about the minus sign here because I am own and I am worried about the range of values we are not worried about the signs delta nu. So, this spread delta lambda relates to the spread in frequency by this relationship. So, I have done nothing, but a derivation of nu is equal to c by lambda. Now, for this wavelength with lambda 632 nanometers and $\Delta\lambda$ and the order of 10^{-3nm} you can calculate delta nu is 1.5 GHz.

So, what does this $\Delta\lambda$ tell us, what do you think it tells us? I have been doing all the talking here now you do some talking. What do you think this delta nu tells? Remember why we start looking at all of this. We are trying to understand temporal coherence right and what is coherence? Coherence is the correlation between the electric field and we are talking about temporal coherence. So, we are saying it's a correlation of the field at some time with the field at a later time right, I want to know how long does it stay correlated right.

So, what do you think this Δnu relates to? What could it relate to? I have almost given you the answer you have to just paraphrase what I have said and give it back to. And here I was thinking long break everyone will come to class brimming with enthusiasm and energy and be bouncing up and down to give us answers.

Student: One one point (Refer Time: 35:34).

I cannot hear you Hari, you will have to talk louder.

Student: 1 by delta nu (Refer Time: 35:40).

Exactly. So, he says on 1e by Δnu this is a time that tells you the time for which this source is correlated ok. So, this in fact, is nothing, but the coherence time of this source. Now, go back to your Michelson interferometer. Remember you had a source beam splitter mirror and then you looked at these beams here on a detector right. How would you study or how would you relate this coherence time concept to be used in this interferometer? Where does time play a role in this interferometer? I said we use Michelson to study temporal coherence. So, how do I; how do I study time in this interferometer?

Student: Let one beam travel positive.

Exactly. So, I am going to study time by saying let one beam travel one distance let another beam travel another distance it takes a different path; that means, it traveled over a different time right and then I am looking at the interference right. So, I can always relate this coherence time to a coherence length ok. What will that relationship be? It's going to be nothing, but the velocity with which the light is traveling and in this case we assume its air it could be some other medium, but if we say its air and let us say we say coherence time is t_c, then I will say the coherence time is nothing, but ct_c.

And in the case of the interferometer that tells me if the path length difference between these two arms exceeds the path length difference associated with this length I will not see interference, does it make sense? Even if I say this is a coherent source it again I am stressing on the point I said right at the beginning that does not mean I can take a laser beam, split it into two beams and then let those beams travel any different path length. And say they are two laser beams they came from the same source if I overlay one over the other I will see interference.

Only if certain conditions are met will you see interference and specifically only if the path length difference between those beams is less than the coherence length of that source will you see interference.

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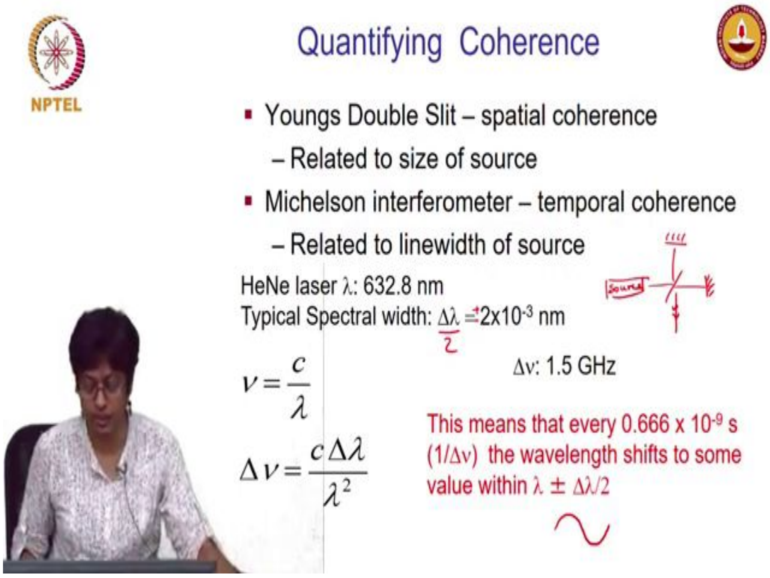

So, let me erase this. So, that you can see this ok. So, if you look at the numbers for this particular source we already said $\frac{1}{\Delta nu}$ is the coherence time and if your $\Delta nu = 1.5\ GHz$; that means, one over Δnu is in the order of point 10 to the power minus 9 seconds that is the coherence time. Now, just because light happens to travel really fast, it means that you get coherent lengths which are still practical right.

Because you are seeing you are not seeing that its 1 second in in in a time of 1 second they are correlated you are seeing in a time of 0.666666 to the 10 to the power minus 9 seconds they stay correlated, but light can travel quite good distance in that time and that allows interferometers to become useful to us ok. What happens after this time after this 0.6 into 10 power minus 9 seconds? That source now starts emitting at a different lambda.

What lambda? Its not emitting at 400 nanometers, not emitting at 1000 nanometers, its emitting at some value of lambda which will lie plus minus this value by 2 or from 632 nanometers. So, I will still say oh this source is emitting 632.8 nanometers, but really its emitting any wavelength plus minus this $\Delta\lambda/2$ from 632 nanometers ok. That means, a wavelength is changing and every time the wavelength changes I have one particular wavelength, I have drawn only one wavelength, but if I had a sinusoidal wave with this wavelength I could draw this out to infinity it would never change.

The point is that after this 10 power minus 9 seconds there is a slight change in wavelength which means the phase relationship is now no longer predictable or rather its only predictable with this accuracy ok. Any questions? No ok.

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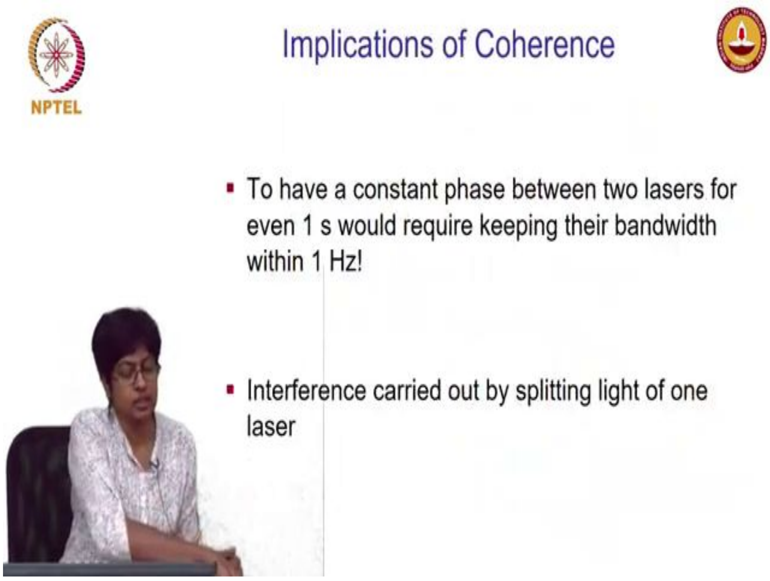

So, the implications of coherence is if I were to take two different lasers you know why do not I ever do interference with two different lasers? I would have to keep their phase relationship. So, accurate because each laser individually you saw what is happening, if I took two different lasers and I wanted to ensure they were phase correlated the kind of accuracy I would need is till date not achievable ok.

And therefore, you always do interference by taking a single laser source and splitting it and even there you have some constraints on when you will see interference depending on the bandwidth a spectral bandwidth of your source and of course, the size of your source. But in most of the applications that we will look at we will be talking about lasers and so we will assume then that the source has very good spatial coherence and the temple temporal coherence is limited by the bandwidth ok.

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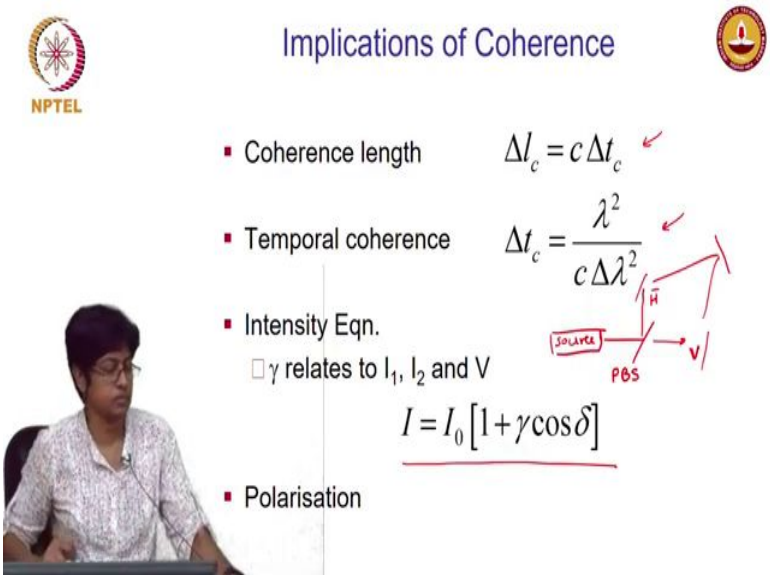

So, just to put down some of those equations again we talked about the temporal coherence and how you can relate that to the coherence length. So, temporal coherence is nothing, but that one over delta nu. So, that is this relationship we relate it to a length, so how much does light travel in that time. And, if we take two beams and take the interference of those two beams and we will do that derivation now you will get an interference equation of this kind here.

So, this is an equation where you have interfered with two beams and we will see what each of these parameters mean. One thing I have not mentioned, but you need to take into account I have just been talking about correlating an electric field at one point of space and time to an electric field at another point of space and time, but what needs to be taken into account is the polarization of these two beams need to be identical ok. So, what is polarization?

Student: Orientation of the electric field.

It is the orientation of the electric field ok. So, if I took one source and I split it and let us say I split it with a polarizing beam splitter. So, it's not just a beam splitter that splits amplitude, but it takes the polarization of that beam and splits it in to. So, I can always write polarization as a sum of say horizontal polarization and vertical polarization. So, let us say I have oriented my source in such a way that both these polarizations are incident on this beam splitter and then I send one see the horizontal in this direction and the vertical in this direction ok.

And now I interfere with this, I have mirrors to redirect these this is not a Michelson this is a different kind of setup and there is an interference here. I will not see anything the same source; the path length difference is 0 perfectly matched, but the polarizations are orthogonal. In order for two beams to interact with each other the electric fields must either have the same polarization or there must be some overlap between the two polarization states ok.

So, the assumption that I am going to make throughout the rest of this course is we are dealing with beams that have the same polarization ok. You can have interesting applications where something changes polarization partly and you use interference to measure that ok. So, I am not saying that we never worry about you worrying about polarization, but in this course we will assume that we have beams of the same polarization that are interfering ok.

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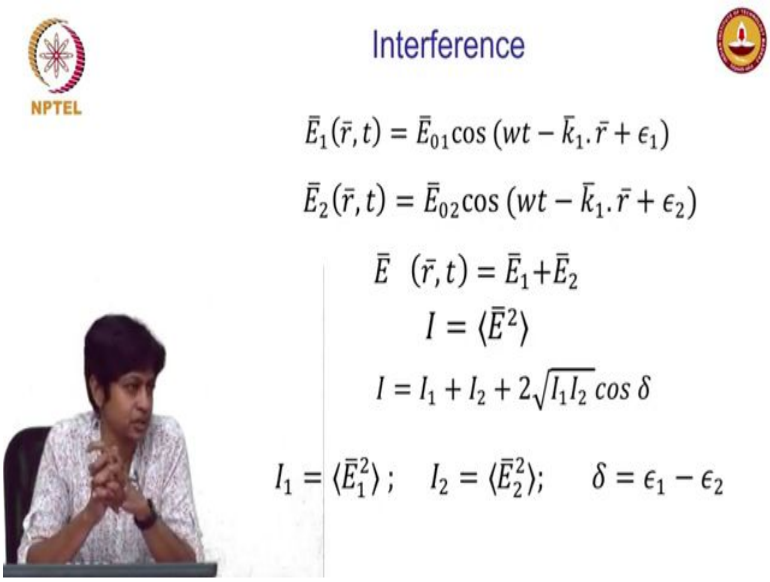

So, the last part of this class then let us just look at how we get this interference equation. So, I can write out the electric field, we are always going to use the electric field ok. So, I going to write out the electric field for one wave, so these are the two waves that are generated from one source. So, this is the electric field of one wave this is its amplitude they are from the same source. So, the omega and k in terms of the lambdas it's going to be the same right because it's the same frequency.

This is the phase of this beam determined by the path it has traveled, this is the phase of the second beam determined by the path that it has traveled. Now, when I say path; that means, we are taking into account the distance it has traveled as well as, the same question that I asked you again and again in every topic the distance as well as the, its distance the only thing that matters?

Student: Refractive index.

The refractive index. So, I could have one I could split these two beams and one beam could be traveling through water and one beam could be traveling through air. One beam could be traveling through a medium whose refractive index I want to find out and another beam is traveling through air ok. And generally in an interferometer you will refer to one beam as a reference, it's there to cause the interference and the other beam is somehow going to acquire the information. So, it's maybe reflecting a sample, its passing through a sample or its path is seeing a pressure change, its path is seeing a temperature change that one path sees the change that you want to measure ok.

So, you usually will say you have a reference beam and an object beam because one beam we consider is an object it contains information ok. So, I have my two beams here they each have different phases and different amplitudes depending on how they have been split and maybe one has reflected off a sample and that may have very much weaker amplitude. The interference is nothing, but taking the sum of these fields and squaring this to get the intensity. Excuse me.

So, if I do that I am going to end up with this relationship where I1 is nothing, but E_1^2, I 2 is nothing, but E_1^2 and this cos term is the E_1, E_2 s dot product right between because these are vector fields ok. So, the term of interest to me is this cosine term because this Δ is what contains the phase difference between these two waves and that is how I am going to extract information ok. So, is this expression clear to you? Ok. What are the assumptions we have made here? We have assumed that E_1 and E_1 have the same polarization these two fields ok.

And we have also assumed that this perfect spatial coherence, we are only using the temporal coherence of this source in order to and we will see how where you might ask where does temporal coherence come explicitly in this and we will look at that ok. So, I think yeah.

So, I will end today's class with this. So, in today's class we have started on a new topic on interference. It's a wave phenomenon and we looked very briefly at the most important condition that allows us to observe coherence that is sorry to observe interference and that is coherence ok.

So, we looked at spatial coherence, temporal coherence and we looked at the interferometers that allow us to study these types of coherence and we have ended now with an expression for two beam interference and we see that it contains three terms. The first term is nothing, but the intensity of one of the interfering beams, the second term is nothing, but the intensity of the second interfering beam by themselves gives us no special information.

But the third term contains or is a function of the phase difference between these two beams and we are going to see in further classes how we can use that to extract useful information ok. So, we meet tomorrow.