Optical Engineering
Prof. Shanti Bhattacharya
Department of Electrical Engineering
Indian Institute of Technology, Madras

Lecture – 32
Interferometry basics

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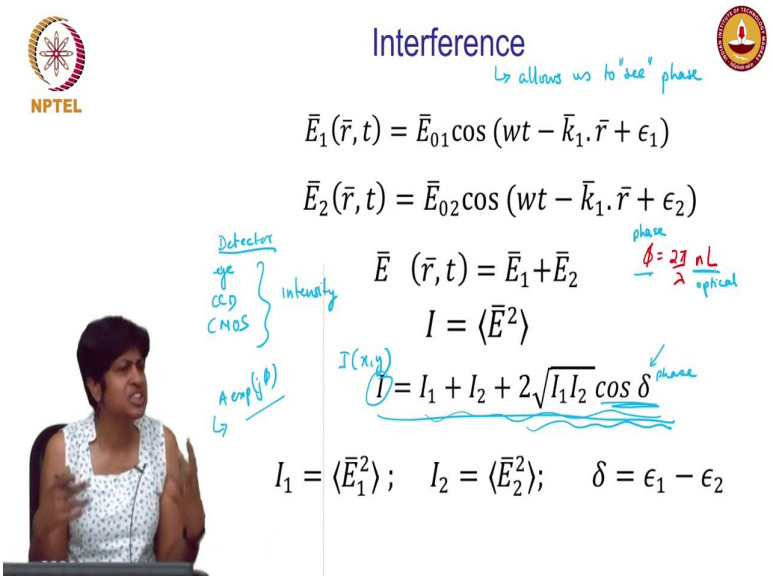

Good morning. In yesterday's class we were looking at interference and we looked at the conditions which are required to have interference, so the conditions on the source. Particularly, we looked at the coherence properties that are required. And then we said we are going to focus on sources which we assume have good spatial and temporal coherence. And arrived at an expression for the intense interference intensity, when you interfere 2 beams which have been derived from the same source ok.

And, the expression we had was this expression here where I_1 was the intensity of one of the beams that was being interfered; I_2 was the intensity of the second beam. And the third term and that is the interesting term which is also a function of both these intensities. But more importantly it has a phase factor to it and that phase is a function of the phase difference between the two beams that are participating in this interference ok. So, this Δ is nothing but

the path length difference or the phase relating to the path length difference of the two beams that are interfering. How do you think we can use this?

Why is phase important or where do we use this or where do we use interference? I started yesterday's class showing you some pictures right, we had a pattern of which you could see. If you have oil released on the road oil patch on the road you see these nice colorful fringes. So, you observe interference, but why is it useful what application do you know or what could you think of where this is useful? The measuring phase when we could potentially measure phase. And we know phase I have said this is delta relates to the phase with delta is the phase which relates to the optical path length difference where is that useful?

Student: Constructive interference, depends on personnel getting the constructive or destructive interference.

How is that useful to us? So, he is saying that you get constructive or destructive interference that is what gives you the fringe pattern right. But how useful is my question? Yes, I got a fringe pattern right. We saw that those pictures I showed you yesterday those were fringe patterns. Because the source was white light your fringe pattern was colored. You had some regions, where constructive interference happens for 1 wavelength and in other places it happens for another wavelength.

So, wherever you had constructive interference for a particular wavelength, you had a fringe of that color how is that useful? What is interfering is something, which we say it makes pretty patterns that are nice and we leave it at that. It's just something that we can admire, we can understand, we can appreciate its beauty, but there is no other purpose to it. What do you think? Ask you this question in a scientific way because if I say I want to use interference; well, inter from interference presumably I can somehow get phase. And how do I relate phase to and what could I possibly extract from that?

Student: Laconic on the refractive index of a medium. .

Pardon.

Student: Refractive index of (Refer Time: 04:25).

So, he says the refractive index of a medium and that is correct. That is one of the possible things that you can extract. What else could you extract? If you say refractive index you must immediately say something else.

Student: (Refer Time: 04:39).

Pardon.

Student: Thickness of (Refer Time: 04:41).

Thickness. So, basically phase relates to path length right, optical path length we know this we should know this very well by now right. So, if I say I have a phase $\phi = 2\pi/\lambda * nL$ it is now if somehow. So, what does interference allow me to do? It converts this phase into an intensity; that is really why the interferometer is such a powerful instrument or method of measurement. Because so, how do we; how do we see something? If I am talking about a person we use our eyes to see.

So, our eyes are our detectors. If we are running an experiment or you are using your phone you have a camera and the camera has a sensor; now whether its our sensor the retina of our eye or whether it's the sensor of a measurement system like a camera. So, a CCD sensor or a CMOS sensor, do these respond to phase or intensity or both? Does our retina respond to phase? Does a CMOS sensor respond to phase or does it respond to intensity and phase or does it respond only to intensity?

Student: Intensity.

These detectors respond only to intensity right. So, whether the detector is our eye. So, the detectors that we commonly use and; that means, our eye or a CCD or a CMOS all of these respond to intensity they do not respond to phase.

So, if I have 2 beams of equal intensity or the same intensity distribution, but they have a different face pattern over them. And I were to illuminate a CCD array with first the 1 beam and then the other I will not be able to tell the difference; as far as the sensor is concerned that is the same because the intensity distribution is the same.

If I want to see phase, I have to do something different to see phase and what do we do? We do interference that is what allows us to see phase. So, this allows us to see phase. I still do not know exactly how I am going to get the phase. I am telling you it allows us to see phase, but the CCD array is still responding to intensity.

So, if I were to have if this could be I have not I have just written I like this, but it could be a function of x y. So, it means as an intensity distribution the CCD array is measuring I of x y. So, I can say that the intensity at various positions has this value. I still have not measured the phase directly. If somehow I can use this expression I may be able to extract this delta ok.

And I am in this class going to figure out how that is possible. If I get that value of Δ then or and I have written it here as phase. So, basically this phase does not matter what parameter I use. So, this is the phase; if I measure the phase and I know the wavelength that I am working with then I can extract the optical path length right.

So, we are doing this step by step and it has to be step by step; it's not that I mean interested in measuring phase and then I put in a sense and here is the phase right. I wanted to measure phase in order to do that, I cannot even just measure intensity right; I do an interference pattern. So, that my phase of interest lies in this third term and we will see why I cannot just illuminate.

If I am going to use some indirect method by which to measure phase why can't I just take a beam which is an $exp(j\phi)$ take the square of this. So, that I get the intensity and extract phase directly from this right, but if you think about it what is the intensity of this beam? So, what is the question that I am asking you? Our goal and we will see why is to measure phase, no known detector directly measures phase.

So, we are going to measure phase through the measurement of intensity ok. Now, I am saying we need some indirect way of taking phase or extracting phase out of that intensity measurement. Why cannot I just shine the beam whose phase I want directly on to, if I have an indirect way? Why would not I just shine the beam directly and some use that indirect method and get the phase out. This what I have written over here is an amplitude: what is the

detector measuring? It's not measuring amplitude right, it's measuring intensity. What is the intensity of this expression?

Student: (Refer Time: 10:43).

I have lost the phase information right; that is why you have to carry out an interference. Because the interference gives me this expression, I have still in a sense lost the phase because what we are measuring is this, but this is a function of this. And we are going to see the way we extract it, because I have carried out an interference I am able to go and get out that delta ok. So, in order to get optical path length, I am getting phase in order to get phase I am doing interference ok.

Now, again I am saying I get optical path length; that means, I have I can if I somehow measure phase I can get the product nL; this is of course, assuming you know λ. And if I want to use this, say to measure the refractive index of some unknown medium, I then need to know the thickness of that medium.

And then I will be able to calculate what is the value of n or I might know the refractive index of that medium. And I want to find out what happens, what is the optical thickness and therefore, I would substitute n and find out n right. It is so, a powerful technique; because it's not just simply that I want to measure n or I want to measure L, but that I can use this as a sensor. Let us say there is a temperature change ok.

And let us say the temperature changes are small enough that I can make the assumption of for the particular material. I am looking at the end not changing with the temperature change, but the L changes. That means, the material expands or contracts now if I can make some assumption about n, I can from the change in the optical path length I can find out the change in L. From the change in L_1 can find out the change in the temperature or maybe the change in pressure or the change in some parameter ok.

So, I can use this as a sensor ok. So, I am interested in phase because buried in phase is information. And that is what we are always trying to do. We are trying to build a system or we are trying to build systems that we can use to extract information.