Experimental Stress Analysis – An Overview

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Lecture – 3.5
Introduction to Hologram Interferometry

In the last lecture, I explain what is the fundamental difference between normal photography and holography? In normal photography, you record only intensity information; in holography you record intensity as well as the phase information. The phase information is recorded in the form of interference fringes. We also saw the difference what a normal negative looks like. How does a hologram look like? A normal negative you can make coat what is recorded with visual inspection.

On the other hand, when you go to a hologram you see interference pattern. You do not see anything beyond that and you need to have a separate optical arrangement to reconstruct only, then you can see the hologram and one of the very common application of hologram is on holograms stickers. You all are familiar where, what you find is if to testify the genuineness of the product, almost every product you name in they have a hologram sticker.

The reason is holograms are difficult to record, but easy to reproduce and this helps you to make it as a sticker and only the manufacturer, genuine manufacturer will have the original for him to use it as a sticker. So, it acts like a security device, but what we find is from a stress analysis point of view, we are not interested in only the use of holograms stickers. We want to get quantitative information. For quantitative information what you have to do? You have to go in for hologram interferometry.

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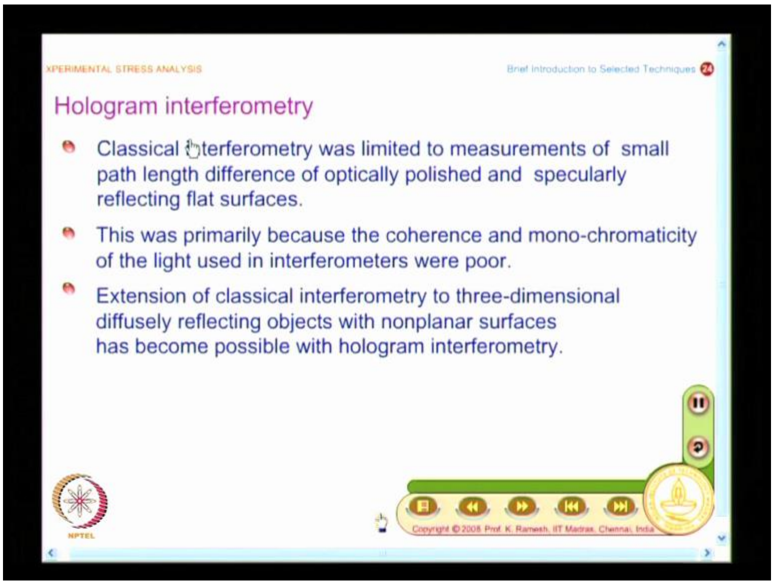

Let us look at what is hologram interferometry. So, what you find here is you know you will have to look at that, what is the difference between classical interferometry, and hologram interferometry. In your schools, I am sure you must have done the exercise on newton rings where, you essentially use optically polished surfaces and find out unevenness by interferometry technique.

So, classical interferometry was limited to measurements of small path length differences of optically polished and specularly reflecting flat surfaces. So, the key point here is, you are looking at flat surfaces they were polished and you are also confining your attention to small path difference. So, even a mercury arc lamp is sufficient to reveal that kind of information and in fact, when holography was developed in 1948, Gabor had only mercury arc lamp. So, the technology was not sufficient to explode the full potential of holography at that time. It is only after lasers where invented and were available for common views; the interferometric techniques had a boost.

What we look at as hologram interferometry? What you find here is and what we find here is the earlier mercury arc lamp had mono-chromaticity is not to the extent like what you have in laser, and coherence as also limited. So, we were confining only to small path difference. And what happened in hologram interferometry was extension of classical interferometry to three dimensional diffusely reflecting objects, with non planar surfaces became possible.

So, we have had a quantum jump, we had a flat surfaces from flat surfaces, we could go to a three dimensional objects, and once you come to three dimensional object the path length is not small. Path length is much larger, and we are also looking at non planar surfaces. So you graduate, you graduate from simple experiments on interferometry at to go and find out what happens on a three dimensional object.

In hologram interferometry you collect so much information the processing becomes difficult. It is not that the technique is back, the technique collects so much information because you are looking at three dimensionality and all its totality. So, this was possible mainly because of lasers, lasers have helped this possibility.

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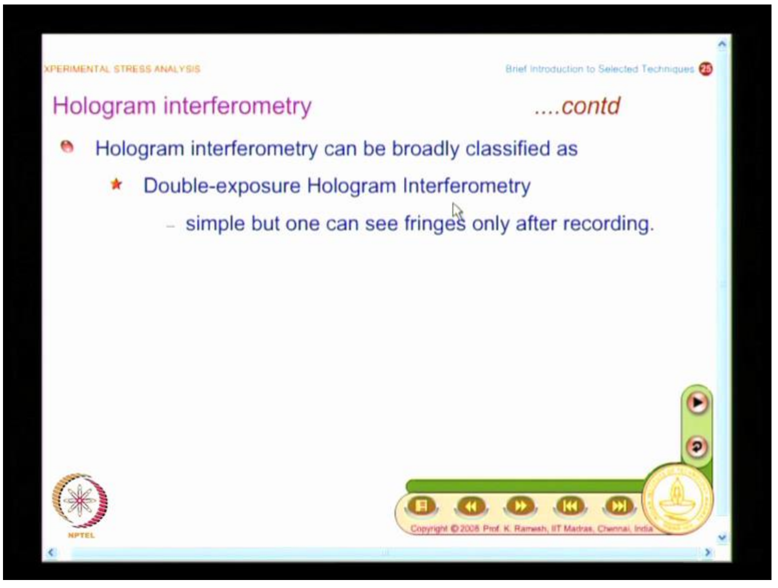

And what you have is you can classify hologram interferometry into various methods. One of the earliest to one was double exposure hologram interferometry, the name itself suggest that you are going to have two exposures, when I am going to have two exposures you will not be able to see the fringes in real time. Because you have to post process these exposures only then you will be to see the fringes in real time.

And what we saw in photoelasticity, we could see the fringes as the model was loaded, the similar thing was also there in moiré when I move the gratings relative to each other, I started seeing fringes, I did not have to have two exposures for me to see the fringes. So, what you find here is in double exposure hologram interferometry it is simple, but one can see fringes only after recording. But what you will have to understand is, in holography we talk in terms of wavelengths. So, I can measure very small displacements.

So, it is very very fine technique and later on we will also see there is also stringed vibration isolation requirement for many of these techniques, why that is so? That also will have a look at it. So, the other category see once you find a restriction you know researchers do not keep quite. Researchers find out ways by which they will circum at this limitation.

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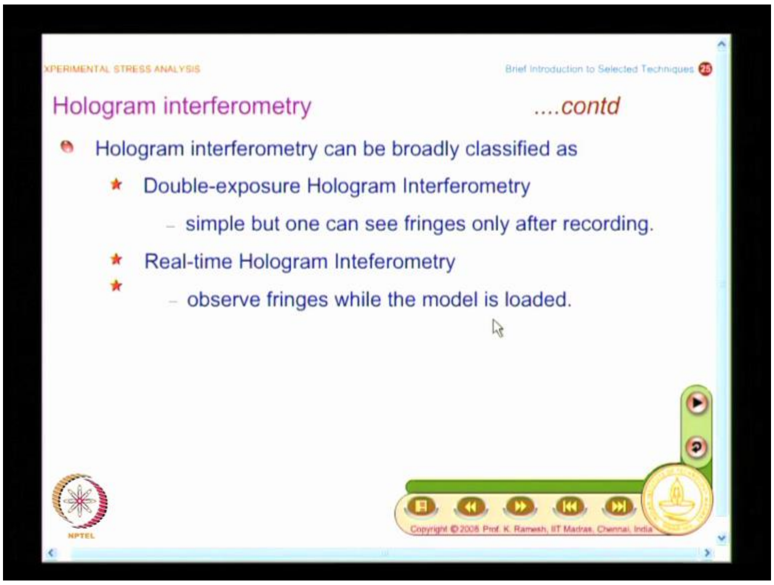

So, what you have is you graduate from double exposure hologram interferometry to real time hologram interferometry. The name itself suggests, you observe fringes while, the model is loaded. So, it is lot more convenient, real time holography is lot more convenient than double exposure hologram interferometry. But if you look at the technology you will have to be very careful in handling it, because you measure in terms of wavelengths. even small misalignments between exposures, can spoil your quality of output. So, this is very, very important.

Whenever you find a restriction researchers and scientist, work and circum and end this. So, if you have a problem do not get worried, you have a scope for research, that is how research problems are coined.

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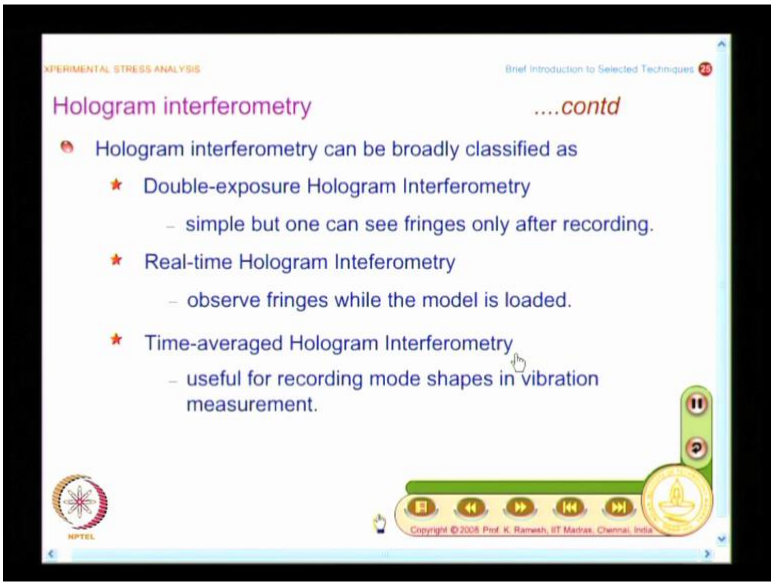

And what is another form of holography is, time average hologram interferometry. and this was useful for recording more shapes in vibration measurement. The time average itself says you are having a vibration event and then when, the model is vibrating you have to have some kind of a time post processing so that you get the information without sense of blur. And here you get Basel fringes and so on and so forth.

So, what we find here is hologram interferometry can be broadly classified into three categories; double exposure hologram interferometry, real time hologram interferometry and time averaged hologram interferometry.

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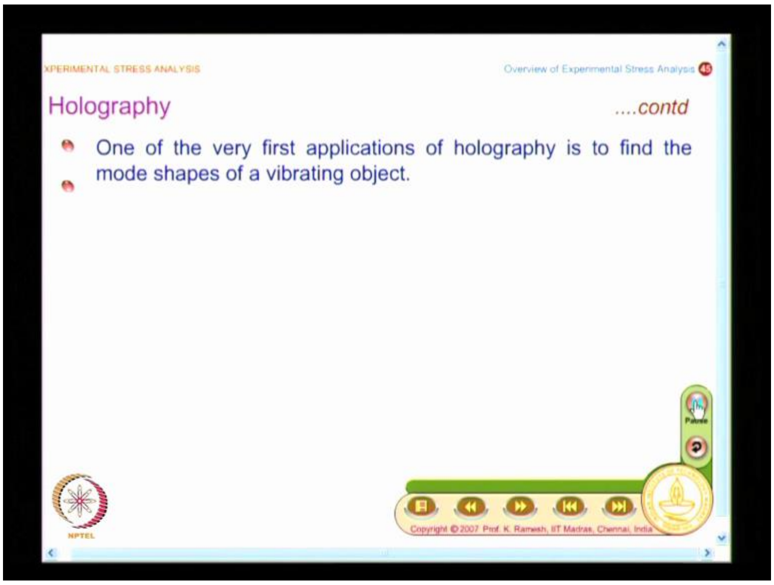

When you look at the development what do you find here is hologram interferometry is first application was, on finding out the more shapes of a vibrating object. So, if you look at one of the motivation for hologram interferometry to see as a stress analysis or displacement measurement tool. It was initially used for capturing the more shapes of turbine blades, and (Refer Time: 09:22) and others have contributed significantly in this area, and we have already seen when you say holography I look at the depth information.

And in the case of vibrating blade you essentially find out of plane displacement. So, the natural extension of technique for measuring depth information is used for finding out; out of plane displacement.

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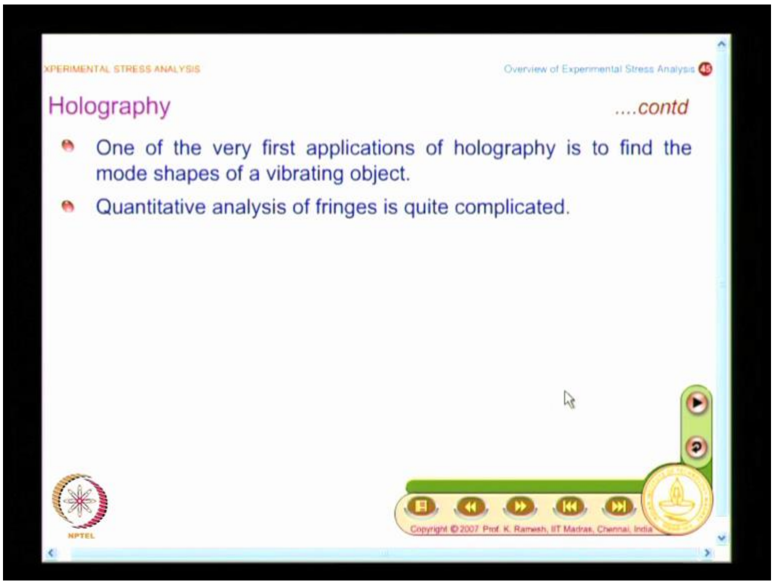

That is a natural extension of holography, but interpretation is quite complicated; why it is complicated? Quantitative analysis of fringes is quite complicated, because we record lot of information than what we can handle, because you are looking at from planar surfaces to arbitrary curved geometry and then you want to find out. So, you would essentially find out the displacement vector it will have a component of U V and W displacement.

It is not that there is deficiency in the technique; it is mainly because the information that is recorded is much more than for you to process and this we will see again and again quantitative analysis of fringe is quite complicated, we will keep looking at it as long as we look at hologram interferometry as well as specular interferometry.

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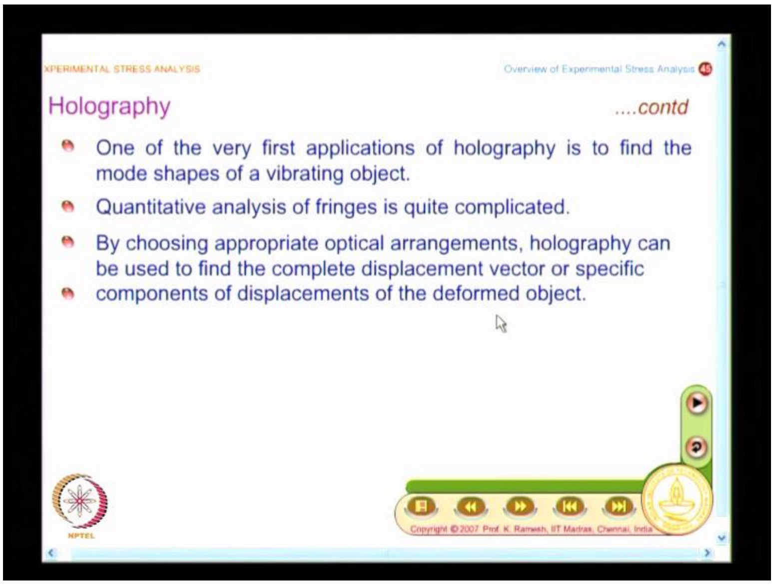

But what is the way that we can circum end this? If I choose appropriate optical arrangements, holography can be used to find the complete displacement vector or specific components of displacements of the deformed object. So, this is what I said, first identify what is the problems? Once you identify this is the problem then address it and find out what all you can modify, and then how you can use the technique. So, what you find here is I can get the complete displacement vector, more than complete displacement vector; specific components of displacements of the deformed object would be very interesting when we want to even understand analytical solution.

Suppose, I want to know what are the displacements in the case of a cantilever? I would like to see only u displacement and v displacement. So, I will have one optical arrangement to get u displacement another optical arrangement to get v displacement then I can compare it with my analytical solution and see that these two match. Whereas, in moiré you had a very simple process, where in the grating direction dictated your data interpretation. Here you have to provide some constraint on the way you do the optics and some constraint on the specimen deformation, because we are not bringing in three dimensional object and then extracting U V W, extracting only U displacement.

In a three dimensional object when it deforms you will get U V W in general. Here you take a two dimensional problem, and then deform it and extract only u displacement or v displacement as the case may be. So, you have to know while doing this experiments what are all the restrictions in the way you have to do the experiment.

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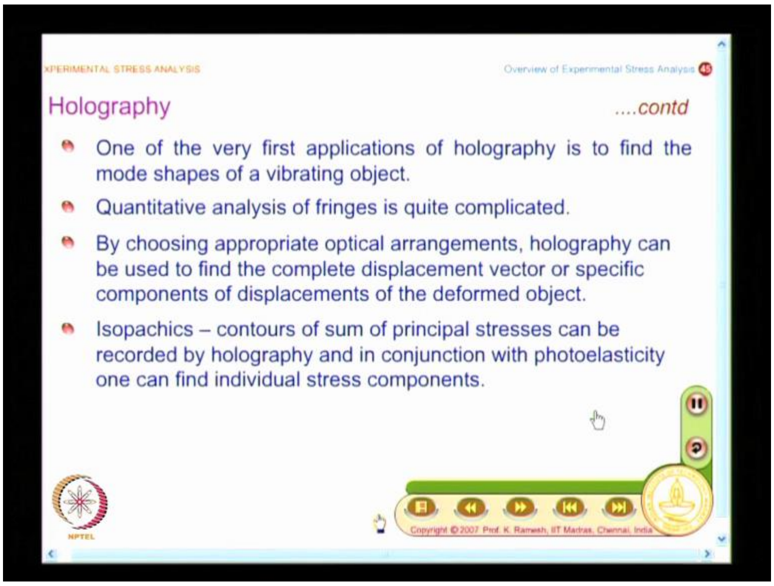

And what we have been looking at is we have also looked at how some of these techniques can be combined. Now we have looked at brittle coating can be combined with strain gauges. So, that I get information on the entire surface and also detailed precise information in regions of interest. On similar lines, I can use a variation of holography. I choose an appropriate optical arrangement, to get only the lateral displacement.

And you all know, the lateral displacement what you have as lateral displacement. if I have this as a specimen and because of Poisson effect the specimen has lateral displacement in this direction. If I look at this, that could be related to in a planar problem to sigma 1 plus sigma 2; that is how the whole thing comes. Holography essentially gives you the depth information. suppose I have this as a specimen, when I deform it; when I pull it and deform it you will have thickness variation. Thickness variation could be related to sigma 1 plus sigma 2. So, that when I record that as a whole film information, I call those contours as isopachics.

So, this is where holography comes. Holography were essentially measures the thickness information depth information can find out, here I find out the change in the depth because of in plane stress; I call those whole field contours as isopachics they are nothing, but sigma 1 plus sigma 2 contours, and what photoelasticity gives? Photoelasticity gives you sigma 1 minus sigma 2.

So, now I have, I have said individually it will give only a particular contour or a contour which has combination of stress components, but if you want to post process I can extract them individually also. So, that is what is summarized here, isopachics contours of sum of principal stresses can be recorded by holography and in conjunction with photoelasticity one can find individual stress components.

Student: Actually in holography you told about the isopachics, that is sigma 1 plus sigma 2. I did not understand the concept between how sigma 1 plus sigma 2 is the measure of the thickness?

Professor: See, in the case of photoelasticity essentially we deal with planar models and subjected to in plane loads. So, when we have that kind of situation when I have a planar model, suppose if you considered that my hand is the model then I pull it what happens is because of Poisson ratio effect the thickness changes. And if you look at the thickness change, it is proportional to minus new times sigma x plus sigma y divided by e. and sigma x plus sigma y is the first invariant. And sigma 1 plus sigma 2 is also first invariant. So, from there you get sigma 1 plus sigma 2, it is simple; it is straight forward. I get sigma 1 minus sigma 2 from photoelasticity, I combine these two and get sigma 1 and sigma 2, separately.

The basic question here is do you require individual stress components for the problems on hand? If you require it then I have go to the circus because holography is not a simply exercise, any interferometry technique it is not a simple exercise. So, this is where I said, I also showed you the picture of Athena Goddess of wisdom. So, you should be wise enough to tackle your problem, not blindly use one technique another technique collect volume of information and do not know what to do with it. So, this is where wisdom is required.

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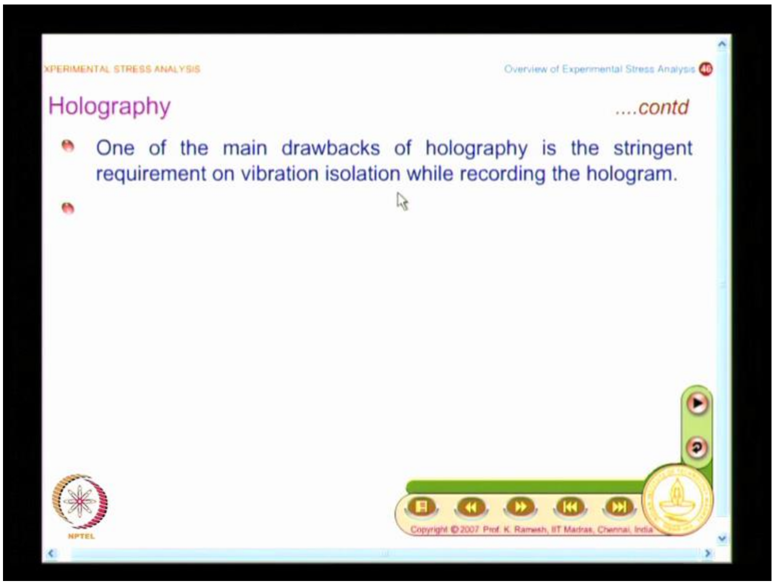

What is the restriction in holography? Holography demands vibration isolation. So, we will have to have a look at, what is the optics that I use and why it dictates, vibration isolation; if we just look at how where double expiration hologram is made, you will be able to appreciate why in holography we talk of vibration isolation. We have never spoken about vibration isolation in photoelasticity. On the other hand, I caution in moiré you will have to worry about rigid body displacement and rotation. Translation and rotation you have to worry about because that can give you spurious fringes.

So, there also the alignment becomes important. When once you come to holography you find vibration isolation, is a very very important requirement and even this you know with advancements people are coming out and making techniques, which are reasonably robust you know that is also a research is going on.

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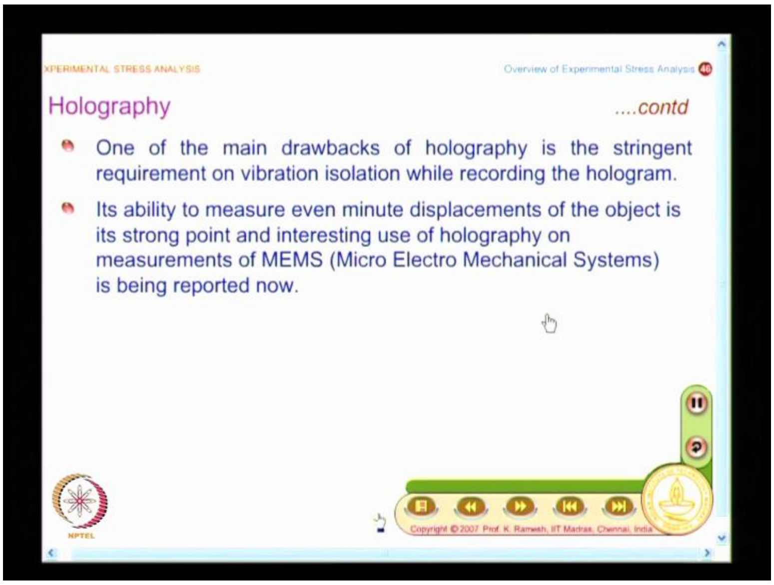

What you find is because you talk in terms of wavelengths you can record minute displacements and such tiny components as MEMS they are nothing but Micro Electro Mechanical Systems. So, you have even the actual component is very very small in size and if you want to find out the displacement on they will be much smaller than this, and because hologram or holography helps you to measure displacements of the order of wavelengths. you can measure those small quantities comfortably.

If I have a very small component, I cannot go and paste the strain gauge. That strain gauge gives me one micro strain. The strain gauge will go and rain force the small component. So, I should go for a non contact measurement. So, when I have to go for a non contact measurement holography is good. So, what you find is its ability to measure even minute displacements of the object is its strong point, and interesting use of holography on measurements of MEMS is being reported. We will also see one example in the course of the lecture.

We looked at what is holography; we focus more on holographic interferometry because holographic interferometry is necessary for you to make the displacement measurement. We graduate from planar surfaces to three dimensional objects. But when we graduate there is also a difficulty comes across because I record more information, data interpretation becomes more challenging, but for simple planar surfaces it is possible for you to do the data interpretation by appropriately constraining the model and also looking at the way the model is loaded.