Experimental Stress Analysis – An Overview
Prof. K. Ramesh
Department of Applied Mechanics
Indian Institute of Technology, Madras

Lecture – 3.4
Introduction to Holography

In the last lecture, we have looked at how to use Brittle Coating Technique in conjunction with strain gauge technique for large scale problems.

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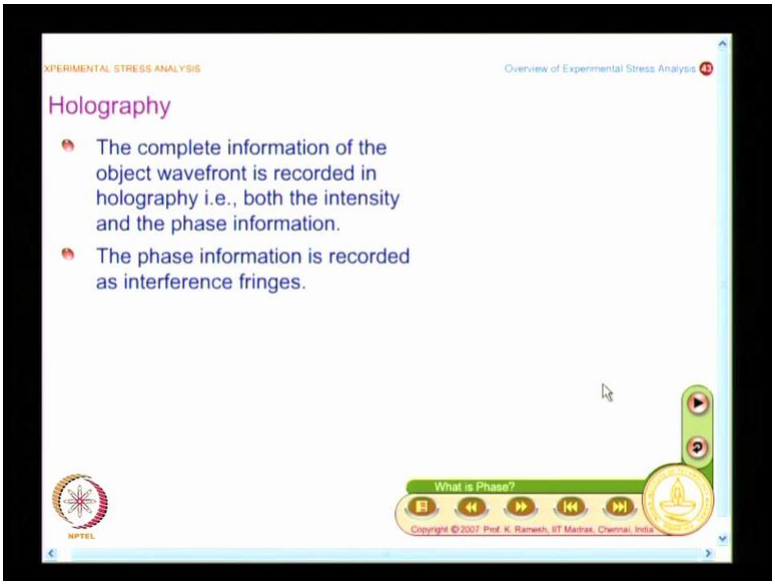

Now, we move on to the next technique Holography. And this is very similar to you know the name is very similar to photography. But what is Holography? Holography tries to provide you complete information, when you say complete information. What complete information? It tries to give you intensity and the phase information. So, we need to understand little more, when we come to Holography. And the phase information is recorded as interference fringes.

And before we get into some of these details, we will just see lasers are used in Holography. We will just look at what do we do in conventional photography and we look at what is that we do in conventional photography.

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I have the figure of photograph of Athena - Greek Goddess of Wisdom. Because I want all engineers to be wise acquiring knowledge is not sufficient to be a good engineer. You need to have practical experience knowledge combine with practical experience constitute wisdom.

So, what you see here is, you have a beautiful picture of Athena, its illumination is white light. Suppose I change the light source, what happens?

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This figure is much better, this figure is not even nice to watch and what you find here is you can see very clearly, there are specular information that is; you see dots, red dots laying on that. And this is what happens, with any laser illumination when you illuminate anything with laser. Laser is highly monochromatic and highly coherent, but you have this information available only in this fashion, and this is your positive.

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Now, lets us look at what is a negative? When I have a negative; if I look at the negative I can make out what does this negative contain? You see intensity is recorded when you have black in the original. Negative it is white. So, it allows more light and then you get that as a black in positive. So, in conventional photography, you are able to clearly, see that I record intensity I record intensity. And then you are able to see intensive variation and you are able to look at this is positive and then conjuncture what a negative could be or from negative you could see, what is the positive I have recorded. So, this is the information I want you to recognize from conventional photography.

Now we go back and then find out what Holography is all about? So, in Holography what I find is, I record both intensity and the phase information.

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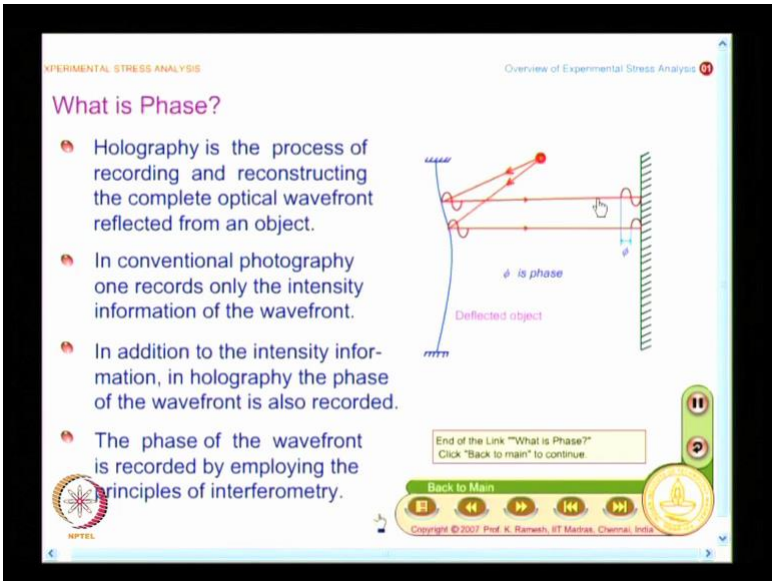

And now you have to know what is phase, what is phase you need to understand; I have a deflected object here I have a light impinges on it and reaches the model. And I would like you to have a fairly neat sketch of this, because this gives you a nutshell an understanding of what is phase? I have shown a deformed object and I have a laser source, which hits the object. The depth is different. So, when the light scattered from this reaches the screen, it reaches at different values of phase. So, the phase carries the depth information.

So, in normal photography, you do not record the phase information. You record only intensity that is what we had seen the positive and negative. The moment you come to Holography you record in addition to intensity the phase information of the reflected wavefront. So, that makes Holography different.

How this phase information is recorded? Its phase information is recorded, based on principles of interferometry and what we will see is we will see the ideas listed here. So, what we do in Holography? It is a process of recording and reconstructing the complete optical wavefront reflected from an object. When I say complete optical wavefront, I said intensity as well as phase and we have seen in conventional photography. One records only the intensity informational of the wavefront in Holography. Phase of the wavefront is also recorded, and phase of the wavefront is recorded by employing the principles of interferometry. So, that is a difference and we will go back and see how does a hologram look like and then what do you see in that.

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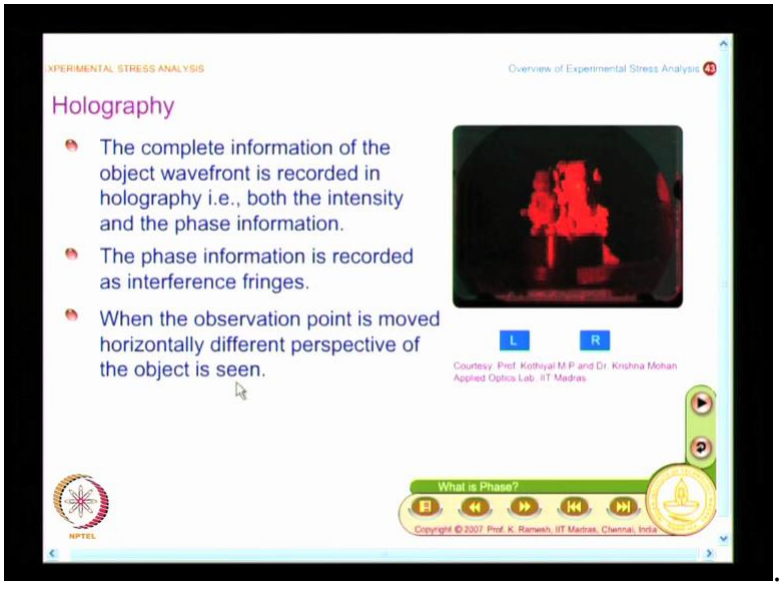

I have a Hologram here, and what is important point here is, first observation is the image is not good; as good as what I record in normal white light. But because I record the phase information, when the observation point is moved horizontally different perspective of the object is seen. So, you are able to get the three dimensional effect of

the recording. As if the model is in front of you are able to go peep, what it is? You are able to see that. I will show you that in my animation, I will also magnify this. I will show you this and this was the hologram recorded in the lab of Professor Kothiyal and Dr Krishna Mohan at Applied Optics Lab, IIT Madras.

Now, I move my head and what you see here? I see objects behind; I see this strain is behind. And you have a statue of Lord Ganesha in the front, and then I move it to the right. Then you are able to see the depth information. Are you able to see the depth information? As if the objects are kept before you. You are able to see the depth information? You are able to get different prospective, this is recorded as if you are moving the head over the region of hologram, but from my from our measurement point of view, we are not looking at only three dimensional pictures, our interest is to go in for deformation when metrology application, this is useful. Are you able to see the depth information? Are you convenience that Holography records depth? Now we go back and then see the other aspects of it.

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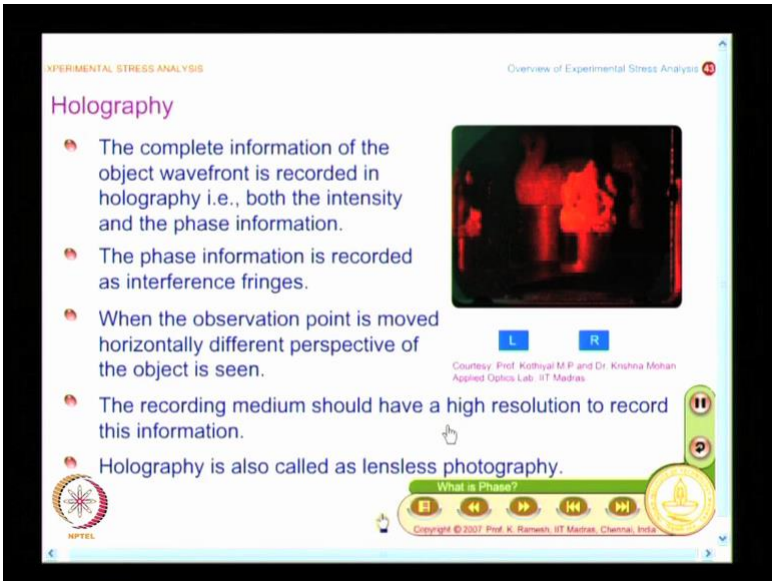

So, what I find is the recording medium should have a high resolution to record this information, because I am recording both the information of intensity and phase. So, I need to have a high resolution to record the information. Holography is also called as

lensless photography. And we have to see further, what is the implication of the use of lensless photography, and how it is recorded and traditionally they where having a very high resolution. They have holographic plates that are how they are able to record the holograms.

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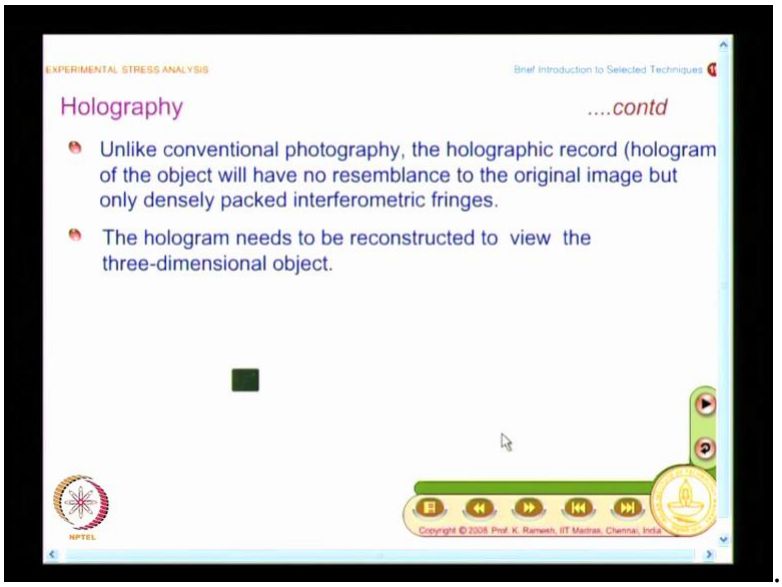

See in the case of conventional photography. The holographic record of the object will have no resemblance to the original image, but only densely packed interferometric fringes. This is my interest to show because in the case of conventional photography you look at the negative you are able to make out what is recorded on that. Suppose somebody gives you a hologram, you will not know what is that unless you reconstruct it. This is the fundamental difference. So, what you see here is the hologram needs to be reconstructed to view the three dimensional object. And for the set of Ganesha and a swan what is kept?

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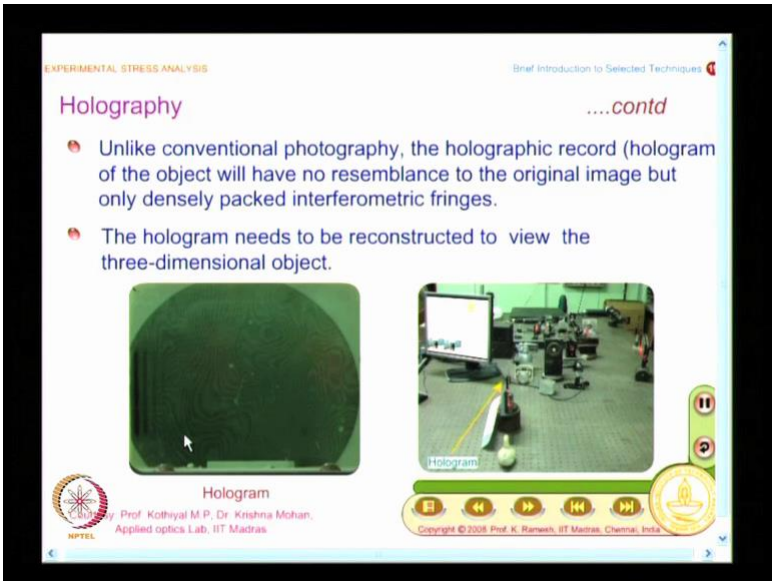

If you look at the hologram, the hologram is like this; we will see that in last and this is what I see. Do you make out anything here; you see only some funny fringes on this. So, this contains information of swan lord, Ganesha kept at different distances you are able to peep into it, and then you are able to see that. So, by looking at the hologram, with the naked eye you cannot see the picture. You need to reconstructed you need an optical arrangement to do that. And that optical arrangement is shown next, and this is what you see here. And what you have here is I have the hologram mounted I have a play of laser which falls on this, and you will have to look at this hologram and then record the three dimensional depth of the hologram. So, it is not like conventional photographic.

Conventional photograph you have a digital camera now you take a photograph instantly you see what you have recorded, but in Holography you will have to reconstruct the hologram and view it, but many will disagree with me sir we are seeing hologram day in and day out in many of our simple appliances when I buy a cassette I have a hologram printed on this, what is this hologram? Though it is not needed for you know your stress analysis or strain development displacement analysis. It is better to know have a common knowledge on what all these holograms? OK, that is what we have seen reconstruct hologram gives a nice three dimensional view.

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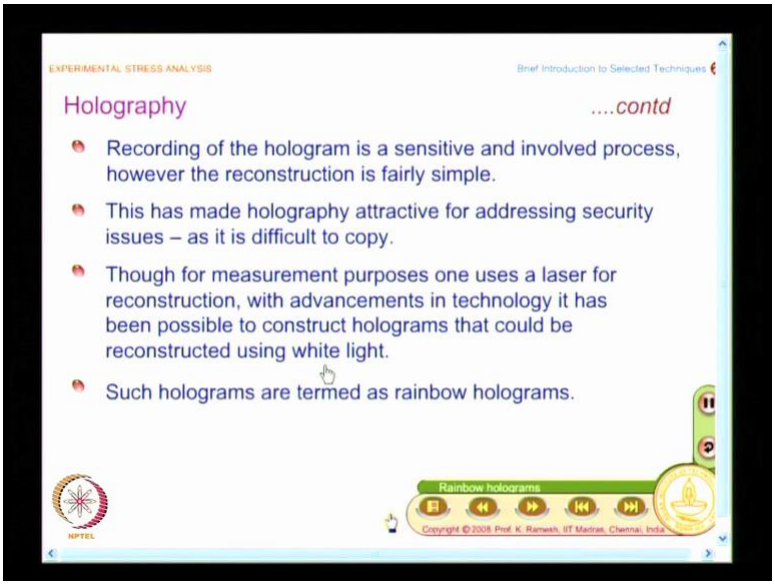

Now, what we want to see is recording the hologram is a sensitive and involved process it is not a that is why it is used for security devices; however, the reconstruction is fairly simple thought for reconstruction I need an optical arrangement to do it.

So, this has made Holography attractive for addressing security issues as it is difficult to copy that is why people use hologram stickers though for measurement purposes one uses a laser for reconstruction with advancements in technology it has been possible to construct holograms that could be reconstructed using white light. So, what you see as holographic stickers on nothing, but white light holograms there is some scarifies of quality in the process, but at the same time because holograms are difficult to make duplication is difficult. So, you are able to give a guarantee to the generous to the product if you see the hologram, given by the manufacture. And these holograms are named as rainbow holograms, and why they are called as rainbow holograms? There is a reason behind it; many times you do not know how to even look at the hologram how to look for information. And we will see what are these rainbow holograms.

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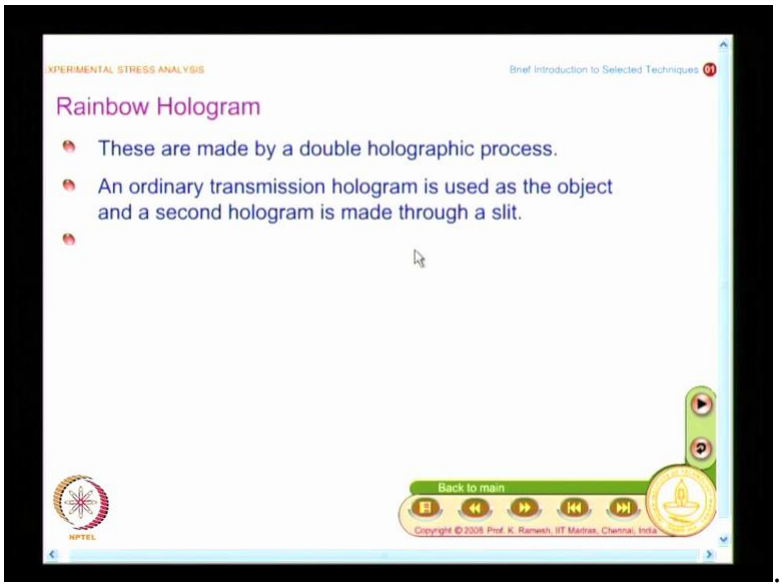

What you have here is these are made by double holographic process, an ordinary transmission hologram is used as the object and a second hologram is made through a slit; it is an optical requirement. And the focus here is I want to see the reconstruction without going into complicated optics just normal white light should be good enough, that is the purpose behind it.

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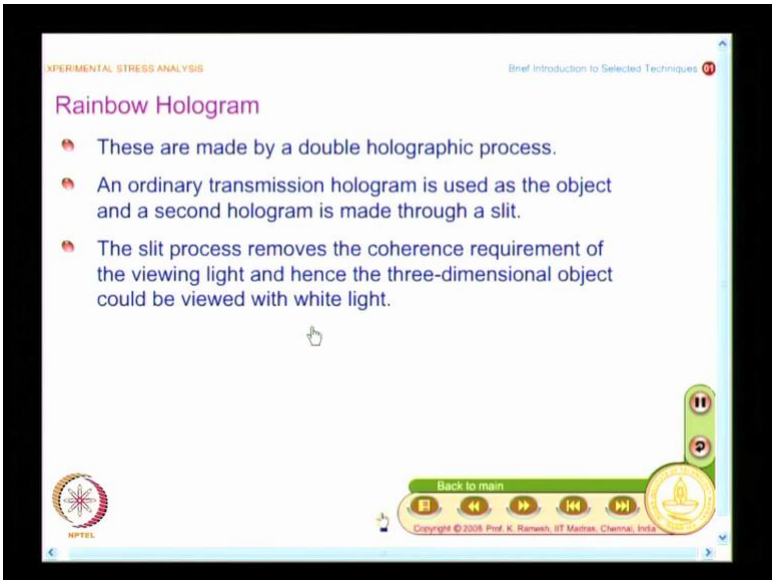

So, what you have here is the slit process removes the coherence requirement of the viewing light and hence the three dimensional object could be viewed with white light. So, that is the advantage.

So, one of the greatest application of Holography is in security which you see it has become so common place almost anything you buy it comes with the hologram sticker. And if you go back in history it was in 1983 first visa card, the dove hologram was used; I will just show you that. So, what you have here is you have a visa card dove hologram this is a dove and you could even see the color change, and what we will do is we look at another hologram which is also released during the same time. How to view a rainbow hologram? What is the difference between a conventional hologram? And this is more from of point of view of appreciating how your Holography is used in various applications.

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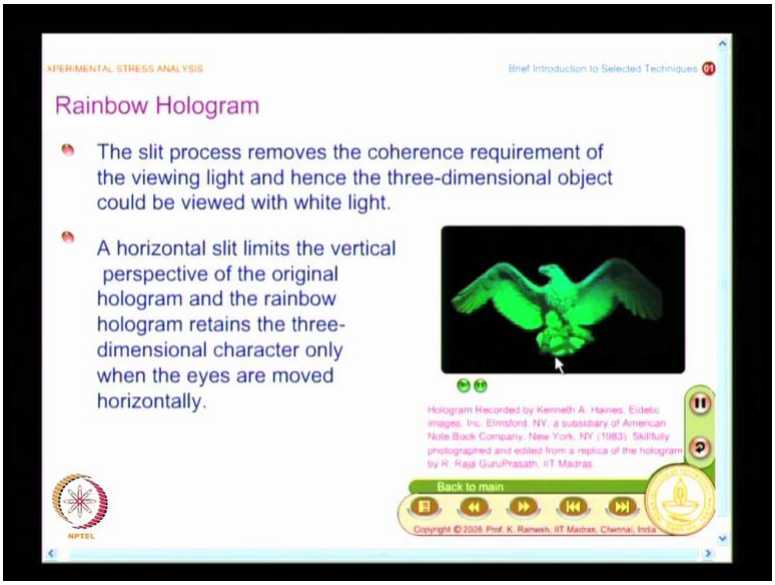

So, what you find here is I have a beautiful hologram here and we will have a magnification of this and then see the demo. And what you have here is if I move my head horizontally I will repeat it again you could see beautifully the three dimensional depth of eagle. Could you see that? I will repeat it again; you are able to see this and this hologram was recorded by Haines of Eidetic images. It was done in 1983 and this was

published on the national geographic journal as a cover page. They were popularizing holograms at that time and what you saw here as the animation, it request skill full photography to reveal and assemble them together.

See in the normal books what they will show you, if they will show one extreme view one middle view and one another view to show that it is recording the depth information, and this was done by Guruprasad, who are done it at IIT, Madras and these are assemble to give you a nice three dimensional view; but still it has not explained why it is rainbow hologram. So, you have a horizontal slit limits the vertical perspective of the original hologram and the rainbow hologram retains the three dimensional character only when the eyes are moved horizontally. When I move my eye horizontally, I have a three dimensional representation. If I move the eyes vertically, I would not have a three dimensional representation. I would have only rainbow of colors and here again recording is difficult, its recording is very difficult and that was done by my student and that is what you will see here.

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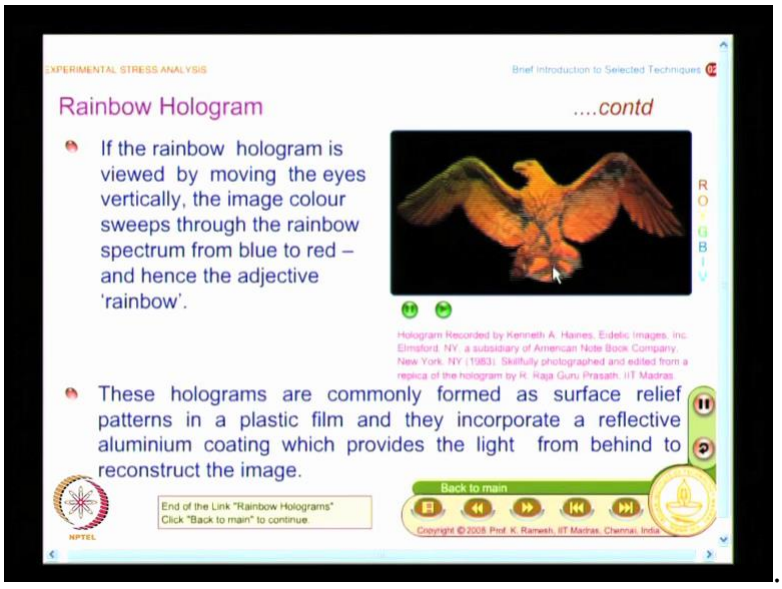

You will see beautifully the play of colors. So, I have this on the vertically movement when I do it I have play of color and this is what you see, you could see the whole eagle as green, I will move further you could see the whole eagle as red. And this is you know

this is because of the operations, if the illuminations is not already do not see this comfortably. And so what you see here is you are able to see different colors of the rainbow and able to stop only at green, I want to stop it at blue. Let me see one more I am able to stop only at my reflects are such, I am able to stop only at red or blue. I will also want to stop at blue I will try one more time; no, I am unable to do that.

So, what you find here is you have a nice hologram what you have the rainbow of colors and here because you know the images are not assemble properly you say assemblance of depth, but it is not actual depth; what you saw in the earlier one when the move the head horizontally you saw a beautiful depth here you see only colors are different. That is why it is called a rainbow hologram. And these holograms are commonly formed as surface relief patterns on a plastic film and they incorporate a reflective aluminum coating, which provides the light from behind to reconstruct the image.

So, what we saw in conventional Holography was, you need to have a laser arrangement to view the hologram; you cannot view the hologram like reading a normal negative. You need an optical arrangement to do that, but people found as advancements develop they could do away with reconstruction optics normal white light can do it. In the process your three dimensionality on both directions is lost on one direction you are able to preserve three dimensionality, on other direction you see only a play of colors. That is interesting that is very interesting. So, you have a play of colors and that is you have to verify whether it is a genuine hologram or not and these days they have multi layered holograms you will see on one layer information, another layer another information and this use of Holography is more from security point of view, less from stress analysis point of view.

So, what we will do is we will try to look at what is the use of stress analysis in the next class. And you will also have to remember Holography was invented in 1948, as recent as 1948 and the person who developed Holography or invented Holography was given a Nobel prize for it. So, it is a invention of that fundamental in nature that he got a Nobel prize, it is Dennis Gabber who got a Nobel prize in 1971 and this Holography finds numerous applications, but we will focus our attention from solid mechanics point of view, how do I find out the displacement? Primarily, it give you displacement. I spend

little time on rainbow holograms because that is what you have access to easily and you should know at least go and educate your people at home how to view an hologram. So, if you have a rainbow hologram on horizontal direction you will say you will have a three dimensional representation on the vertical scale you will see play of colors.

But now you have layered hologram. So, many varieties have come. So, many varieties even they have used color try to bring Holography in color, so many developments. So, those are all like more from marketing point of view displaces and then public use of Holography for fun we will not get into all that, we will only look at how Holography can be exploited for stress analysis.

In this lecture we have looked at the fundamental difference between normal photography and Holography. In normal photography, we record only intensive information whereas, in Holography we record both intensity as well as phase information. We have also looked at Holography using white light these are rainbow holograms and their applications for security purpose are highlighted.

Thank you.