Experimental Stress Analysis – An Overview
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Lecture – 3.7
Introduction to Speckle Methods

Let us continue our discussion on Different Experimental Techniques.

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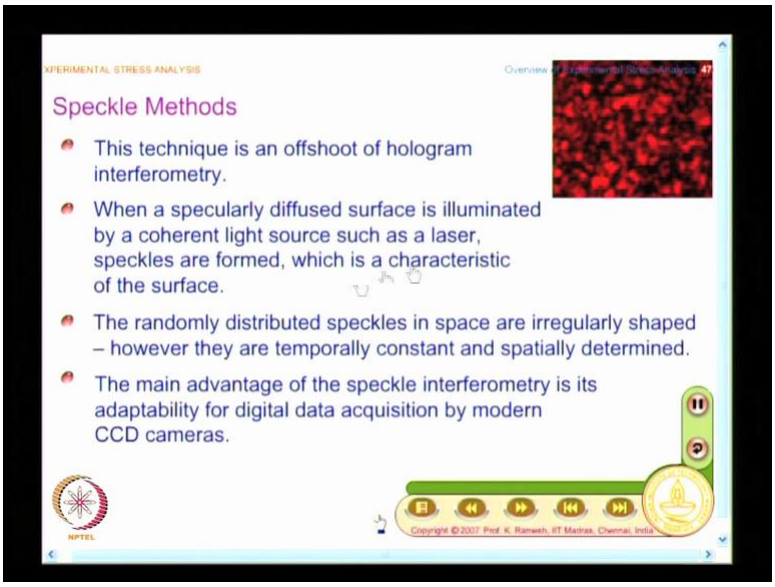

In the last lecture, we have discussed hologram interferometry. Now what we do is we move on to another technique that is Speckle Methods, and this is where it is you have a very nice illustration of the method, you just see the speckle first. And these are all the laser speckles and this is just to give you a feel of what the speckles are; I have shown this animation. And obviously, this is an offshoot of hologram interferometry and we have already seen whenever you have a coherent elimination you have formation of speckles We have seen, if I use it with white light Athena Goddess was looking nice. The moment I eliminated with laser you saws speckles on the, says, on the entire the picture and this is used as a technique to reveal displacement information.

And what you find here is the speckle distribution is random, but the advantage here is they are temporally constant and spatially determined, this we will see again and again. We will emphasis these two aspects; this is why we are able to use it as a technique. If they are totally random and changes as a function of time and space we will not have speckle interferometry. What we find here is you have randomly distributed speckles in space, they are irregularly shaped; however, they are temporally constant and spatially determined.

And why is speckle interferometry is advantageous? The main advantage of the speckle interferometry is its adaptability to digital data acquisition by modern CCD cameras. So, speckle method is an offshoot of hologram interferometry and speckles are random irregularly shaped, but they are temporally constant and spatially determined. This is a very important characteristic which we use it to our advantage.

And also you will have a lot of debate in literature between the methods will look very similar, there is a still debate whether to call it as speckle interferometry or TV holography. These kinds of discussions are going on among academic circles and then you know such discussions will continue to exist. So, we will see certain category as holography in our own judgment certain category as speckle methods. And what we need to look at is, we need to look at what this speckles are. So, what I am going to do is I am going to look at how speckles are formed and one of the important aspect in all these category is you have a formation of objective speckle.

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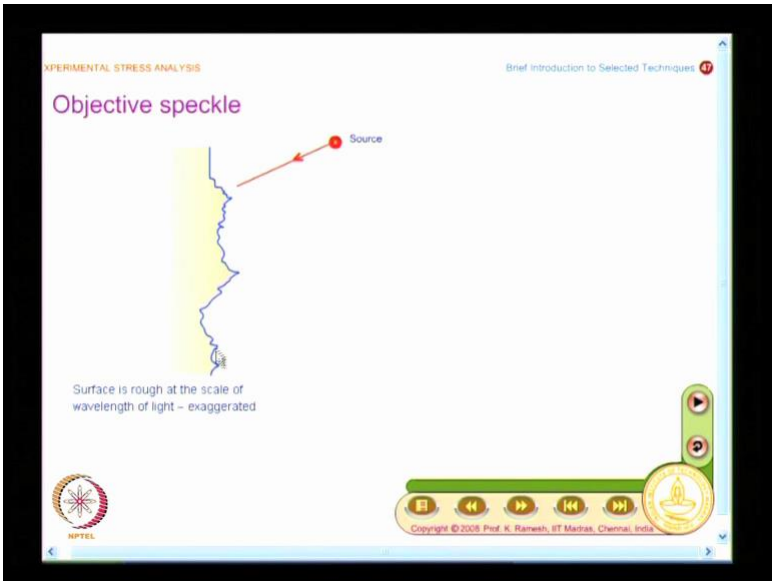

And what I want to show here is surface is rough at the scale of wavelength of light exaggerated. So, make a sketch of the surface. The surface for all practical purposes will be very smooth and straight, but if you look at the wavelength of light surface is rough at the scale of wavelength of light. So, its highly exaggerated picture, it is a very highly exaggerated picture of surface. To illustrate how speckles are formed and it is very interesting. This will be open up deeper understanding on how you have these methods.

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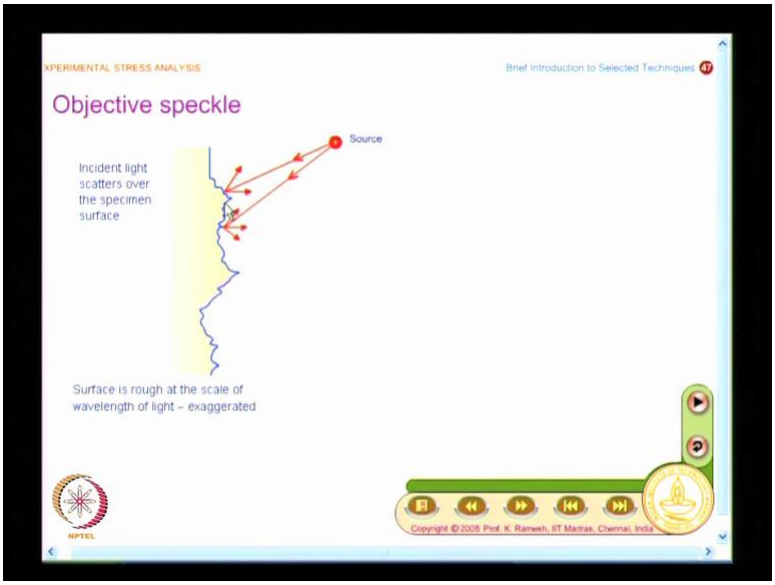

So, what I have is I have a source of light and then it is going to impinge on this. And you can observe it very carefully, that is what I said all these animations are very slow, it is not at the speed of light. So, it is just to understand the sequence of steps in the formation and let us see that.

So, what I see here is; as the light hits you have lights scattered at each of these points. So, what I have is you can also see this little enlarged instance light scatters over the specimen surface. So, when it hits the specimen the light get scattered in all direction and this you will see again, we will see the animation; the light will be hit other places on the object. What you need to notice is the light ray comes and immediately, you have scattered light and scattered light do not stay here, they travel to the screen. I have not shown that portion, I am showing the sequence of happening in stages for you to understand.

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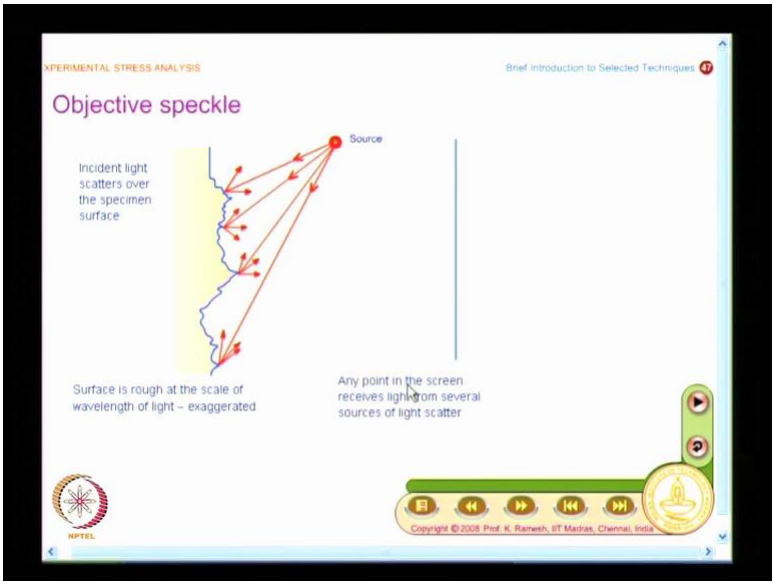

And, what I have here? The light ray comes here then you have immediately scattering of light, immediately here you have scattering of light and this is what happens.

Now, what I am going to do is I am going to put a screen, and this screen is sensitive to whatever light that falls on it or I should have a CCD camera with its lens removed, I do not have a lens in this process; I do not keep a lens here. And what will happen is; and this is what you will have to look at, see this is again a very important point. Any point in the screen receives light from several sources of light scatter; this, I want to you observe. I am looking at objectives speckle and one of the key point here is, any point in the screen; any point in the screen receives light from several sources of light scatter, and that you see the animation.

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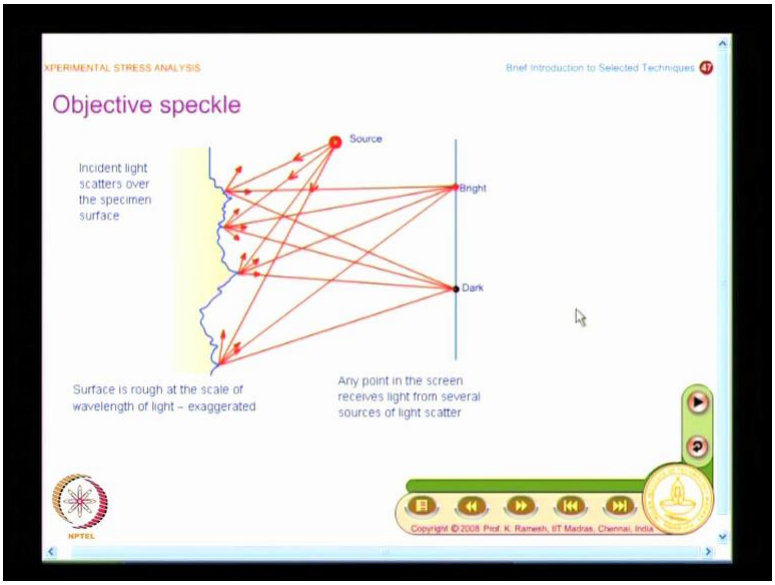

And I am looking at a point like this here so, I have a light coming from this scatter, another ray coming from this scatter, another ray coming from this scatter, another ray coming from this scatter, and it so happen, I have selected a point. So, happen that these rays do a constructive interference and I see this has a bright spot. And I take another illustrative point, where again I will have light rays from all these scattered points. This is the key point, any point in the screen receives light from several sources of light scatter is an important characteristic of objective speckle.

So, what I do is, I see the second set of rays meeting at a point and I have selected this point in such a manner for illustration that these rays interfere and gives you dark fringe, dark point. So, I have a bright point and I have a dark point. Have you been able to make a reasonable sketch of the final ray diagram of the whole thing? Because you need to have this, we have seen how this formation of lines actually happens. The light rays go and hit the model, on the surface of the model it gets scattered and from the scattered any point on the screen receives light from several points of scatter, and that is how you have to read the picture. You may finally have a picture like this, but how this picture came into exists? These are the sequence of operations, and if you want I can repeat the animation once for the clarity; you just see only animation.

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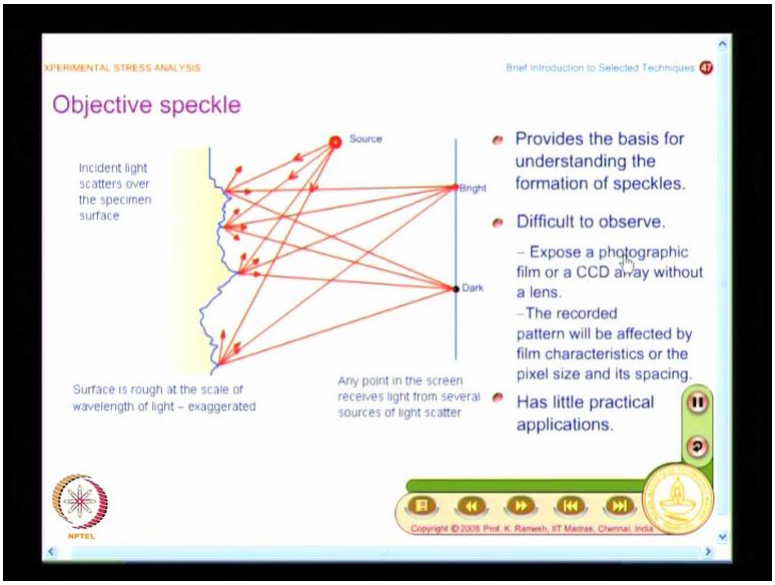

Now I have a light source, light comes and hits it; you have scattered from each of this points where it means the model. Then I put a screen, and each point on the screen receives light from several sources of scatter 1 2 3 4, for all this you get a ray, and this is a characteristic of objective speckle. I will also go and see another formation of speckle I call that as subjective speckle, it is known as subjective speckle; there the story is different.

And, what is the advantage of this? Provides the basis for understanding the formation of speckles, and it is difficult to observe. Why it is difficult to observe? All of us have an eye which has a lens, the moment I have a lens I always observed only subjective speckle; we will see that also. Because I have a lens my eyes have lens, so the moment I put a lens though I record something whatever the specular reflecting object, if I look at directly I would be recording only a subjective speckle, but only on a photographic plate or you have to take special effort to record objective speckle. So, it is difficult to observe and this is what the methodology is given, what way I can do expose a photographic film or a CCD array without a lens.

The recorded pattern will be affected by the film characteristics or the pixel size and its spacing has little practical applications. But the importance here is, it provides a basis for

understanding the formation of speckles, but it is difficult to observe. So, you need to have a photographic film exposed and that is how you have to do it and this shows how the whole speckle get formed and this shows the animation again. Because you know, if you understand this then your appreciation of speckle methods become not more clear. So, I have a dark fringe form, I have a bright fringe form, and I get light from all points of scatter and the points have summarize. One after another, you understand that it helps you to understand formation of speckles, difficult to observe and we finally say that it has little practical applications.

Now, we will see what subjective speckle is, and what we are going to look at is we will just make one small modification in this, rest of it is same. The first procedure is same. In fact, you can even have another sketch here where in you modify it, you do not have to repeat the full sketch.

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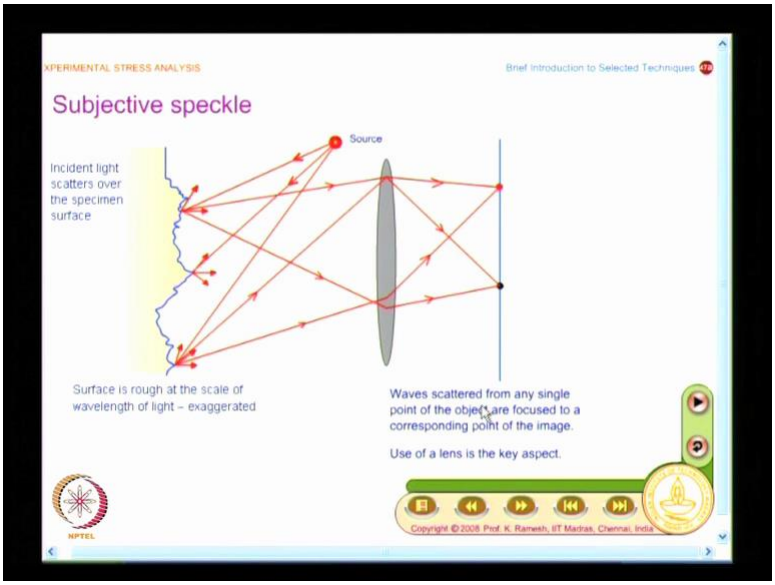

The moment I go to subjective speckle, the difference is in between the screen I put a lens, lens in the key aspect. What happens on the surface? It is same like what was seen in objective speckle, but what is recorded there is a settle but important difference. And subjective speckles are very useful, we want subjective speckle; interferometry uses only subjective speckles and we have an advantage.

And let us see how the formation of speckles here, because of the lens what happens? Because of the lens, what is the key point here is suppose I have a point on the object it is mapped on to another point on the screen; that is what the lens does. In the case of objective speckle, this point will receive from light all points of scatter because I have put a lens this will receive light from a corresponding point on the object, and in this case I have taken that, these two rays interfere in a manner that you have a dark fringe, dark point; I would not call it as a fringe, I would call it as a dark point.

Similarly, for another point if I take a; what I am going to have is, I will choose the point in a manner that there is constructive interference and I have a bright point. So, this is the fundamental difference. And what is important here is, waves scattered from any single point of the object are focused to a corresponding point of the image that is a fundamental difference between objective and subjective speckle. So, when I come to subjective speckle, use of lens is the key aspect; use of lens is the key aspect.

And let us see, now what I will say is; I said that objective speckle was difficult to observe and subjective speckle is nice to see, and if I have a film what I will have is; I will have this formed here. I have the speckle beautifully formed here.

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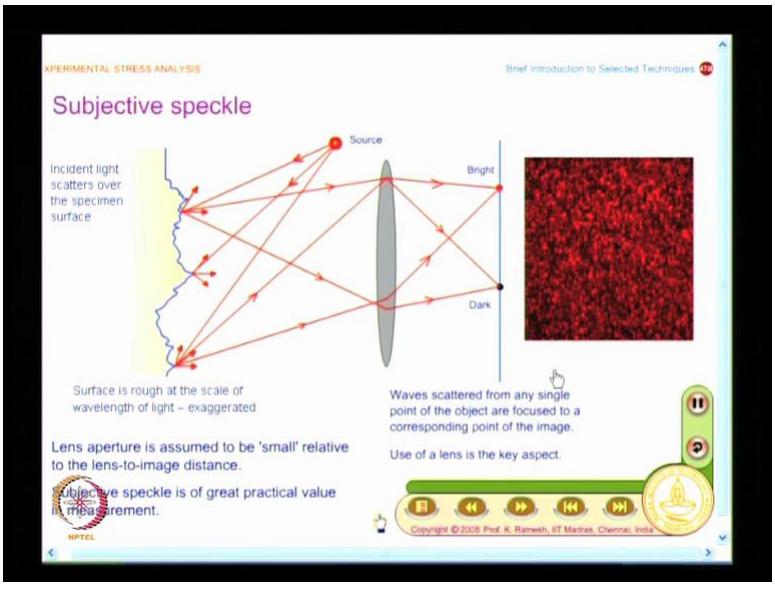

I have the speckle beautifully formed because I have a lens and we have already seen that it is temporally constant, as a function of time it does not change and specially determined. It is like a finger print. The same concept, I will again reinforce. We will have a look at this in the next slide as well.

So, the key point here is waves scattered from any single point of the object are focused to a corresponding point of the image; that is a key difference between objective and subjective speckle. So, I have a beautifully formed subjective speckle pattern. And when I go and look at the final aspects of it is like this.

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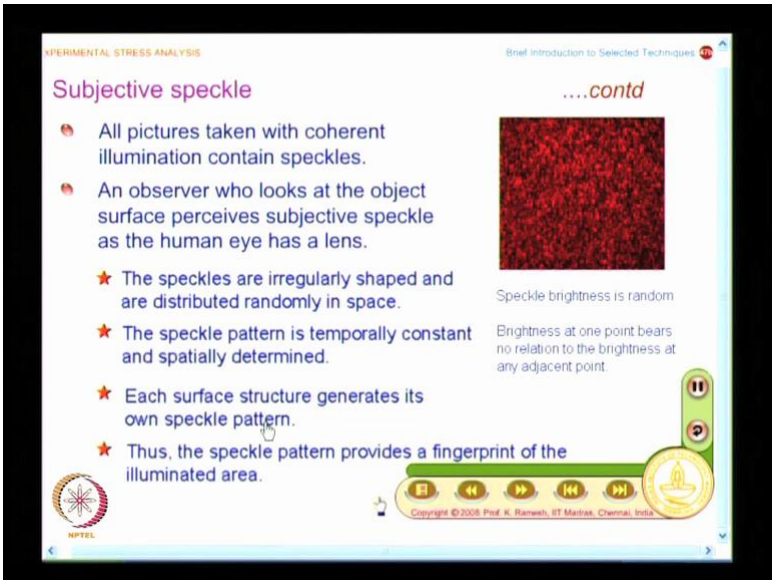

So, what we summary is here is, all pictures taken with coherent illumination contain speckles. This is a fundamental point that we have been looking at. An observer who looks at the object surface perceives subjective speckle as the human eye as a lens, that what I also mentioned it earlier. And you have this speckle and what is put here is speckle brightness is random, and what you find is brightness at one point bears no relation to the brightness at any adjacent point. So, speckle brightness is random these are all the characteristics of it, and what I find here is, it is put in a slightly different set of words; this is because you know this is very important characteristics. So, reputation is always advantageous for you to remember, the speckles are irregularly shaped and are

distributed randomly in space, temporally constant and spatially determined and also I find each surface structure generates its own speckle pattern.

Suppose, if I change the structure the speckle patterns also will be different. Thus the speckle pattern provides a fingerprint of the illuminated area. It is like a fingerprint in the case of moiré, we put a grid on it which is regular. In the case of speckle, you have the speckles formed that act like a fingerprint, and that is why we also said speckle provides you fringes which are not very smooth, we saw that when we looked at out of plain displacement of a plate clamp all around the boundary with a central load. When you have a plate all around the boundary and put a central load, when we looked at we looked at the out of plain displacement.

The experimental fringe pattern which I showed was from speckle interferometry, it was not as smooth as what I saw in photoelasticity it had only points. So, this is they are called correlation fringes, different from interferometry fringes and there is also a reason why we looked at moiré first and then look at holography and speckle interferometry. Because speckle interferometry has certain idea as share with moiré, you have a random pattern which is naturally produced because of speckle reflection.

Students: Can speckle methods be used for surface roughness measurement?

Professor: Definitely, see all these techniques, optical techniques like holography and speckle; they are all used for metrology applications. Metrology application is happening parallely and what we are interested in this course is to look at under the given application of loads what is the deformation introduce on the object, and in fact, if you look at in the future you are going to have a 3D facts; the concept there is you will have an object, you will have a facility like your microwave oven, you will have a facility you keep the object the object will rotate and you will have a light rays scanning the object and pick out the coordinate information.

And this will be available in a file, that will be transferred over internet or any type of data translate mechanism. At your end, you will have a rapid prototyping machine which will understand the signals and you will have the object on hand, when you print it you

will have the object on hand. And this is what people say that is going to be the future of manufacturing and it will also reduce your inventory and developing nations they would like to concentrate more on design and make the under developed or developing nations to do the manufacturing.

In speckles we understood that, when you have coherent elimination speckles are formed and when I say speckles, the two aspects people look at it what are known as objective speckle and subjective speckle. We saw the difference between objective and subjective speckles. And now we have to go and see what do I get in speckle interferometry and then what is the variation of speckle interferometry which is adopted to an industry which we call it as shearography and why it is advantageous to an industrial environment.

We have looked at in hologram interferometry, when you do the double exposure you have a reference beam. The necessity of a reference beam demands vibration isolation. When I come to speckle interferometry also, we will see you need a reference beam, but on the other hand when I go for shearography I do not need a reference beam. So, it is robust from industrial point of view and entity people have quickly taken this for inspecting honeycomb panels.

So, what you will have to appreciate is when you develop any of these techniques, whatever that is convenient for industrial use automatically comes out. People identify that, and that it becomes a very popular technique and people are able to use it day in and day out because the technique that you want to use should be robust, you should not be sensitive to the person who conducts the experiment. And vibration isolation, the very very key aspect and if you do not have a vibration isolation you will not be able to record holograms.

Thank you.