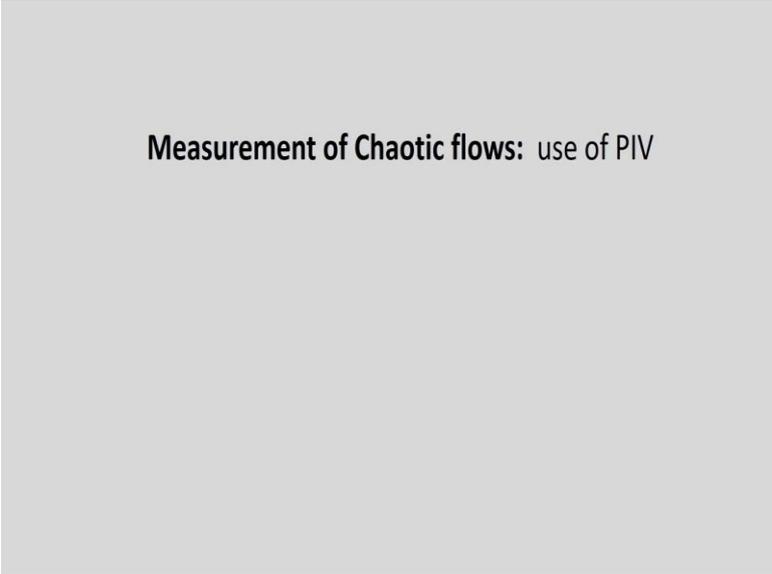**Experimental Methods in Fluid Mechanics**
Professor Pranab Kumar Mondal
Department of Mechanical Engineering
Indian Institute of Technology, Guwahati
Lecture No. 31
Use of PIV

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Measurement of Chaotic flows: use of PIV

Good afternoon, we will discuss today about the, you know, measurement of chaotic flows using PIV. So, in this module we will discuss about different aspects of PIV, what is PIV and then we will try to, you know, give a brief overview of this instrument to be precise the I can say operational the other working principle of the PIV.

So, when we talk about the chaotic flows, in fact, if we try to recall that in my last lecture, we have discussed about the measurement of flow parameters in the turbulent flow environment that means, I mean if the, in a flow parameters, flow properties and the, you know, to precise flow velocity, which is not having uniform throughout these, uniform value, uniform magnitude in the field.

So, I mean, we have discussed that the flow velocity which is having two different components in the turbulent flow environment, one is the average one, another is the fluctuating. Now, fluctuating part or fluctuating component. So, if we are interested in measuring the chaotic flows, then we have seen that either we can use measuring hot wire anemometer in that case we need to insert a probe and using two or three different wires at a time at a given point, we can calculate the different components at that particular instant of time and at that particular point.

We have also discussed about that the, you know, placing of a probe in a flow field leads to the local disturbances. Then the user or the experimentalist who is using these, who is using this probe to measure the flow of, you know, parameters to characterize the flow he or she may not come up with the correct result because of this local disturbance.

Now, to circumvent that problem associated with the measurement of, you know, flow characters using probes, another new technique came into the picture and that technique relies on the optical method that means, we are using light source, we are, we have seen you know from last class that what we do, we use a light source and we try to you know illuminate a particular zone, particular portion of the flow field, which is the zone of our interest and from there, we can you know, calculate, we can predict the, you know, either quantitative as well or the qualitative estimate that which we are interested in.

That means, either we can calculate the qualitative, you know, we can predict the quality picture of the flow field or we can quantify, we can you know calculate the quantitative value of the flow parameters and this qualitative as well as qualitative measurement is possible using this optical image based technique. In continuation of that, in this module we will try to discuss about the measurement technique using PIV.

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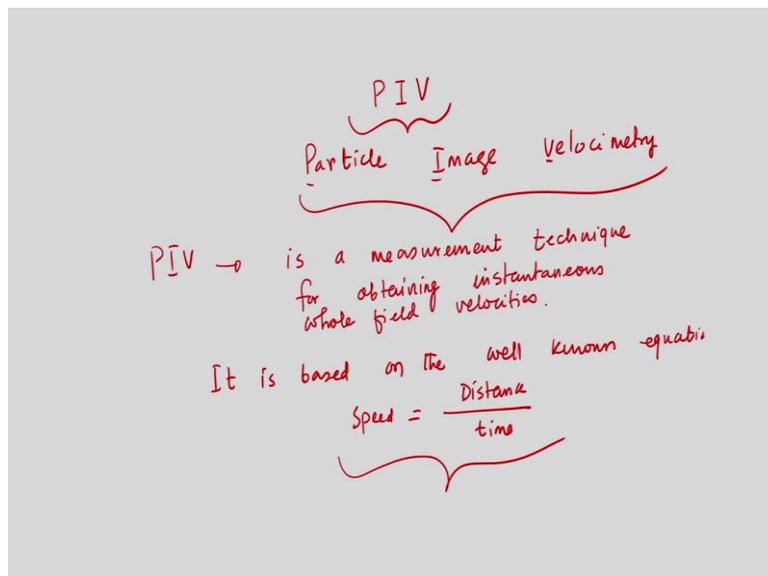
So, what is PIV? Before we go to discuss, before we go to briefly you know, discuss about the you know, I can say basic principle of PIV, we need to know what is PIV? So, this PIV is Particle Image Velocimetry. So, this, this is a PIV, from the name itself, at least we can understand that this technique, this method relies on the seeding of a few particles. That

means we need to, you know insert a few particles in the flow domain, flow field. Maybe it is I know boundary layer flow or it may be the flow between of flow in a confined domain.

So, the Particle Image Velocimetry that is PIV is nothing but the imaging of the, you know particle instead of, I mean so, basically if we are looking for the velocity of the fluid flow velocity, what we are doing essentially we are trying to calculate the velocity of the particle which are seeded in the flow. So, this method, this technique relies on seeding the particles you know, which are very important.

So, the Particle Image Velocimetry that means, we are using light source to illuminate a particular zone of the field and we have we need to insert a few particles and the particles should have a few important, you know, I can say characteristics and that we should discuss those, I mean those characteristic feature of the particle and particle by measuring the, by measuring the displacement of the particle in the flow field, we will try to quantify the velocity of the flow.

So, basically what is done that this Particle Image Velocimetry technique that is PIV, this PIV I can say is a measurement technique for obtaining instantaneous, you know, I can say whole field velocities. So, even this method is very popular nowadays, this method will have a few, you know, disadvantages features that we will discuss, but what we can say now, that the method is used to measure the instantaneous whole field velocities, which is important for the turbulent flow.

That means, turbulence that is there, we need to measure the fluctuating part of the velocities that means, at a particular time in a given space, what are the different components that is it is not a laminar flow, flow field is, I mean velocities or streamlines are not in a perfectly parallel, it is a chaotic moment. And we need to obtain the information about the flow field, whole field at you know whole field velocities.

So, the PIV is a measurement technique for obtaining the instantaneous whole field velocities. If we try to recall that in the context of you know measurement of chaotic flows using LDA that we have discussed in the last class. LDA is another important method in which we are also getting qualitative as well as quantity measurement of the, you know, flow field using light.

Even for the LDA you know, that is Laser Doppler Anemometry measurement technique, we need to have a few, you know see at seeding particles. So, similar to that what we have seen

in the context of LDA, in this particular method as well, we are, you know; I mean, we are interested in measuring the instantaneous whole field velocities by seeding new particles. So, the particles will be seeded in the flow, in a flow field.

So, this is the PIV technique. Now, this technique it is based on well-known equation that is speed equal to distance by time. So, that means, the particle will move from one location to another location in the flow field because there is a continuous you know flow, if we can somehow track the particle in a given location.

And if we know the time at that, you know point and if we try to capture the same particles in a, in different location and if we know the time taken by the particle to traverse that particular distance, we can obtain the speed of the particle. As I said few minutes back that PIV measurement is essentially measurement of the velocity of a particle that is called Particle Image Velocimetry.

So, by knowing the velocity of the particle here, you know, predicting the velocity of the fluid, so the speed is nothing but distance by time and that is used again in this method to calculate, to predict the velocity of the fluid. So, now we will discuss a few important points. So, when we talk about Particle Image Velocimetry or PIV in short, there are two different parts.

First one is the you know, setup and the working principle of their setup. And then finally, another important module of this measurement technique is the imaging. That means, if we just go to the previous slide, where we have retained Particle Image Velocimetry. So, that means, we need to capture image of the particle and from the analysis of the image we can correlate what will be the velocity of the particle.

So, there are two important thoughts associated with this measurement technique. First part is the construction of the system and the functionalities of different parts associated with the system. And then second part is the image analysis, which is very important. So, today we will try to discuss about the basic principle, focusing the function of different parts associated with the system. And then we will move to see the analysis of the images which are captured from the setup.
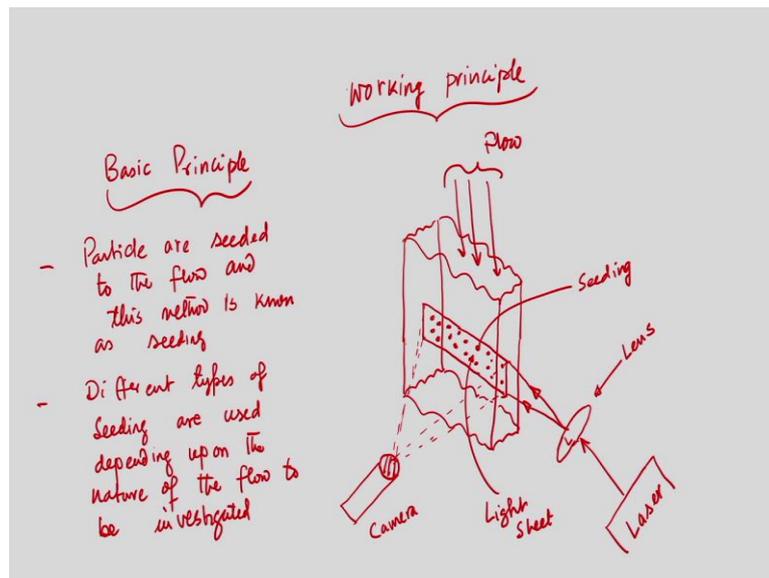
So, the first part is the you know, working principle and to, I will write you know, important points which are you know, which we need to know in the, to know the which are, which you need to know about the PIV principle. Now, before I go to discuss about the important points, what we need to do? We need to know the schematic. So, I mean what we need to know the different parts associated with the system.

So, now, I will try to you know, depict the schematic diagram of a particular PIV system. So, if we take to now write that will have, so this is say we have flow from the top. So, this is the flow direction. So, liquid or any particular fluid is flowing from the top and this is the confined domain through which the fluid is flowing. Now, what we can do, you can, we can illuminate a particular portion, say this is the portion we are trying to illuminate and we have seeded particle like this.

The number of particles will be seeded in a particular flow configuration that will depends on so many factors, on many factors. So, this is the confined domain, liquid or any fluid is allowed to flow from the top to the bottom, and I mean the liquid is flowing or fluid is flowing. And we are focusing our attention on a particular zone in the flow field. And we can see that the fluid is now shown that you know fluid is now seeded with the particles.

So that can be seen. Now, importantly, if we can illuminate that particular portion. So, we are trying to illuminate this portion using laser. So, this is lens L and light is falling on the you know lens using a laser source, from a laser source. So, this is laser source from which light is coming, you know the beam is taken through a lens to split into two different parts. So, that

we can protect, we can focus our attention on a particular zone and that is what is seen from the schematic.

And what is done the particles are that is what I was telling. The object is we have now illuminated a zone in the flow field using this laser source. What do we need to do next? We need to capture the image of the particles and then only we can correlate what will be the velocity of the fluid by you know, calculating the velocity of the particle through different you know, numerical techniques.

So, what do we, what do we need to do next that means, in this setup, the setup is not complete until we are now inserting, we are now installing another important part or we are now in until we are integrating another important part with the system that means, we need to have one camera and which will, you know, capture the image. So, one camera will be there and that will be captured, this is the camera and this is the light seat right and these small, small particles are the seeding, seeded particles.

So, these are seeding. So, from this schematic at least it is clear that this system is very simple, this system is a very simple system in which we have one light source, laser, one lens, then one camera. So, when any particular fluid is flowing through a confined domain. Now, through a confined pathway, we need to illuminate the fluid, illuminate a particular zone within this flow field.

And if we illuminate it, we can see that the fluid is now seeded with the particles, the particles are seeded in the flow. Now, the zone which you are illuminating using the light will be captured by the via camera. So, this is what is the working you know basic principle. So, now, I will try to write the basic principle. I will try to write and that will help you to you know, understand even in a later stage that the light will be used to illuminate a particular portion, particular zone of the flow field.

Wherein, we have seeding particle and that particular zone that I have marked by the light sheet that means, as light sheet a particular zone is illuminated. And that will be recorded by a camera and the camera will be located right angled you know, to the incoming light source, at right angle to the incoming light source. So, basic principle is that, first one is that seeding, so particles are seeded to the flow and this method is known as seeding.

Different types of seeding are used and that is depending upon the nature of routine investigated. So, this is the basic you know preliminary thing, we need to add a few particles

to the flow and this process or method is known as seeding. Different types of seeding are used depending upon the type of or nature of flow to be investigated, depending upon whether the liquid is you know density, liquid density, liquid viscosity and so many other things. So, depending upon the flow of to be investigated, different types of seedings are used fine.

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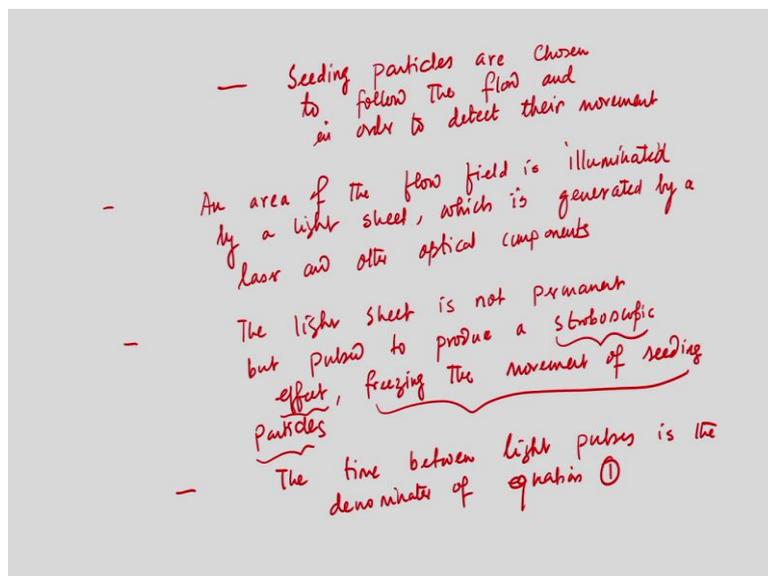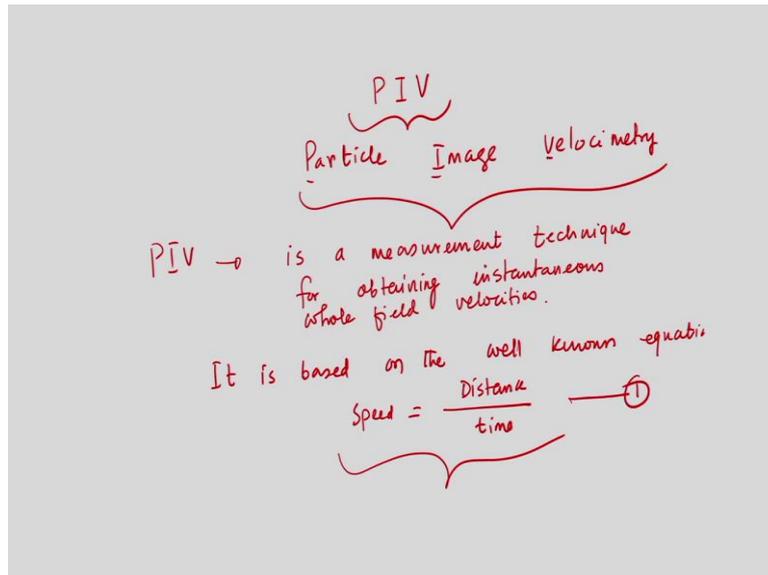
Next important point is that, although I will discuss in detail, but at least for this you know for the time being the seeding particle are chosen to follow the flow and in order to which is very important and in order to detect their moment right. So, this is important. Next is a few important. So, this is, so, today what we are trying? We are trying to know all the basic

principle and then knowing the basic principle in an next we will try to know the image processing that is another important part with this, of this technique. So, this is important.

Next is what we can see? An area of the flow field is illuminated by lights sheet and which is generated, which is generated by laser source, laser and other optical component. So this, so an area flow field is illuminated by lights sheet which is generated by laser and other optical components that is what we have seen. So, we need a laser source, we need lens and different other accessories those could not show in this schematic fine.

So, this is important. Now important is the light sheet is not permanent but false to produce a stroboscopic effect. What is that I will discuss and freezing the movement of the seeding particles. The time between light pulse, between light pulses is the denominator of equation one. So, if we now go back to the previous slide, this equation is one that means a time which is there in the denominator that is nothing but that time between two laser pulse, light pulse now two light pulses.

So, this stroboscopic effect that is very important we have written that moving object can be represented by a. So, I have written the word stroboscopic effect and also the fizzing the movement of a seeding particles. So, that is why the light pulse is not permanent, but it is pulse to produced. So, that means, the stroboscopic effect that means, the continuous or the moving object is represented by a short series of samples.

So, that means, it is not continuous, we can the moving object can be represented by a series of short instantaneous movement. So, it is not a continuous movement. So, moving inter movement can be splitted into a number of short small, small movement and that is nothing but the stroboscopic effect. So, this is we have understood.
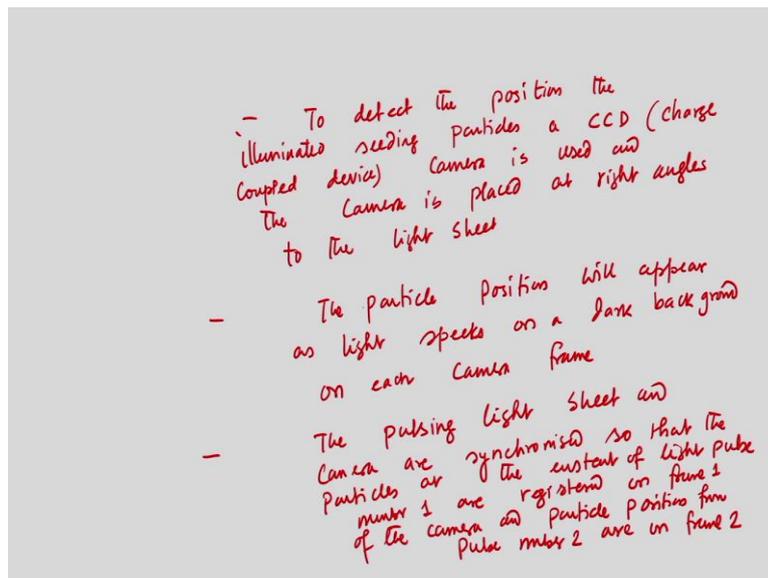
Next is, next important is that now we have to detect and for to detect the illuminated, the position of the, you know, illuminated particle are CCD camera that is known as charged coupled device, charge charge, coupled device, CCD camera is used and the cameras place that is very important, camera is placed at right angles to the lights sheet, to the incoming light or to the lights sheet right.

So, we have one camera that is what we have seen in the schematic and the camera is placed at right angles to the light sheet and this is CCD camera. Now the camera is you know is placed only to detect the position of the illuminated seeding particle. The next is the particles, particle position will appear as light specks on a dark background on each camera frame, right? So, the particle position will appear in the lights specks on a dark background on each camera frame.

So next what we will do, the pulsating lights sheet or the pulsing lights sheet and camera are synchronized so that the particle at the instant of light pulse number one are registered on frame one of the camera. And particle position from pulse number two are on frame two, this is important to know. That means the pulsing lights sheet and camera and synchronized, so that it is pulsing and camera also. So, the camera you know the, so that the particles at the instant light pulse number one are registered on camera frame number one.

And pulse number two camera frame number two, this was not, you know, this was not possible in older generation of CCD where you know, we had to capture all the, position on a given, on a same frame, but this is not the case with the present is CCD camera. So, now we

have understood that, since the particle positions is a pulse you know that is called stroboscopic effect that is what we have discussed.

So, we will have the continuous movement with a short number of instantaneous movement. So, we have a pulsing, so the pulsing lights sheet and camera are synchronized in such a way that the, you know, particles at an instant of light pulse one will be captured or will be registered on camera frame number one, on frame number one of the camera. And the particles position at you know pulse number two that means the next pulse will be registered in frame number two of the same camera.

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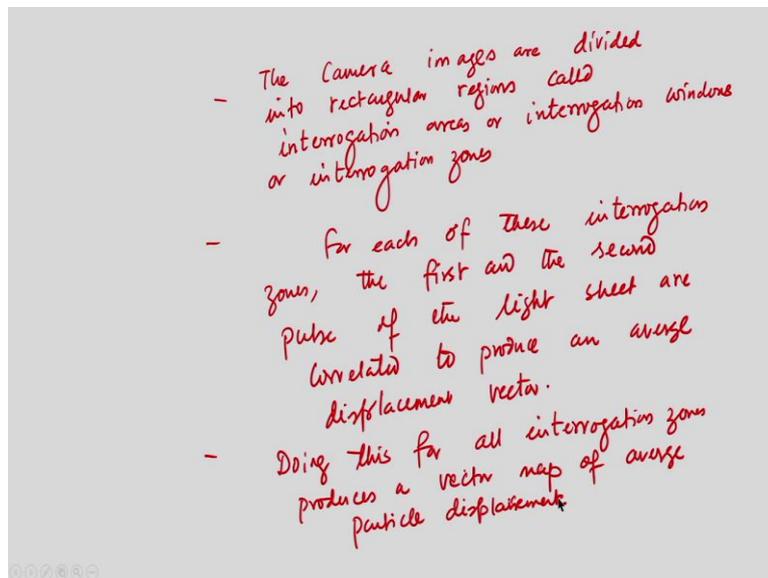
So, next is that the camera image we have captured. So, the camera images are divided into rectangular regions called interrogation areas or interrogation windows or integration zones. So, that means, the camera images are divided to rectangular region which is called, known as what is called interrogation areas or interrogation zones or the interrogation windows. And next is for each of this interrogation windows or zones the first and the second pulse of the light sheet are correlated to produce an average displacement vector.

So that means for each of these interrogation zones, the first and the second pulse of the light sheet are correlated to produce an average displacement vector, average displacement, you know, vectors. And doing this for all interrogation zones produces a vector map, vector map of average particle displacement right? So, doing this for all interrogation zones produces a vector map of average particle displacement. Now, if we divide this average particle

displacement by that time between twos you know consecutive pulse, the two consecutive light pulses, we will get the speed of the particle.

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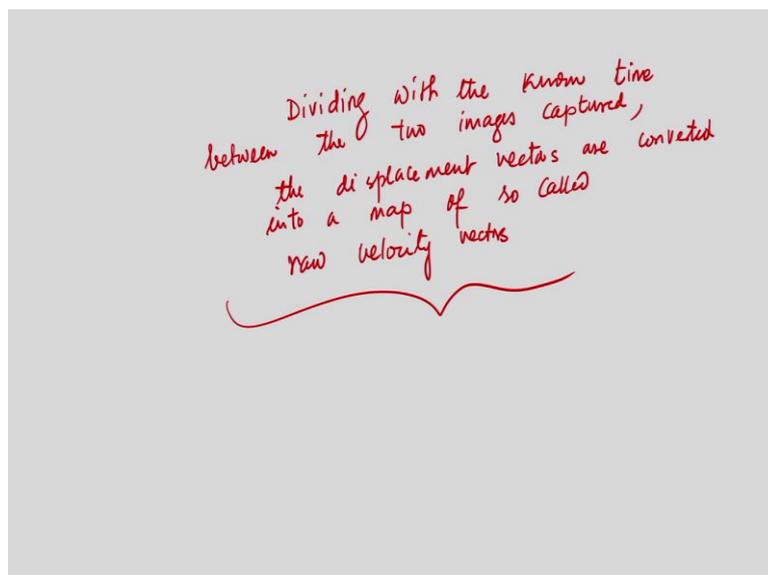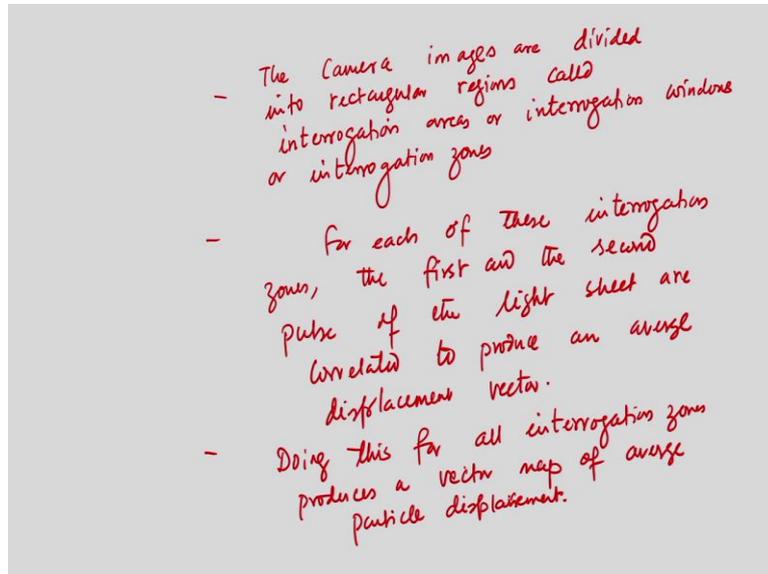
So, next I am writing that dividing, dividing with the known time between the two images captured, captured the displacement vectors are converted, converted into a map so-called map of so-called raw velocity vectors. So, what we have discussed today is that by knowing the displacement vector and if we divided that, you know displacement by the non-time, we can divide into the non-time the two images, between the two images captured the displacement vectors are converted, this is converted into a map of so-called raw velocity vectors.

So, what we have understood is that we have captured two images and we know the particles location, when they have captured in a particular frame and we know the you know and that is known as correlation. So, we are also capturing the particle position in the second frame and we can correlate this particles, by this we can correlate the average displacement that is dividing. So, if we go to the previous slide, I have written that average particle displacement that we have, that we are doing.

So, that that means, knowing the average displacement if we divide the known time, we will get the displacement vector and that vector displacement vector will be converted into the map of so-called raw velocity vector. So, now question is they are important question that I would like to discuss that now we know their average displacement, and we know the time between the displacement then from there, we can calculate the speed using equation one.

Now, we will discuss their critical issues that what we have understood till now, that next what is the image processing and that is very important to correlate the, you know, velocity of the particle. And from there we will try to quantify the velocity of the fluid. So, the next issue is that images which are captured in different frames, we will be now correlated to obtain the speed of the particle and knowing the speed of the particle, we can calculate the velocity of the fluid and of course, instantaneous velocity at that particular point of time.

Now, so, this correlation and image processing is an important task with this measurement technique, and we need to know several important issues which are related with this correlation, as well as the, you know, measurement of the fluid velocity. And those aspects we will be discussing in the next class. So, this I stopped my discussion today. Thank you.