Experimental Methods in Fluid Mechanics
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Lecture No. 32
Use of PIV Contd

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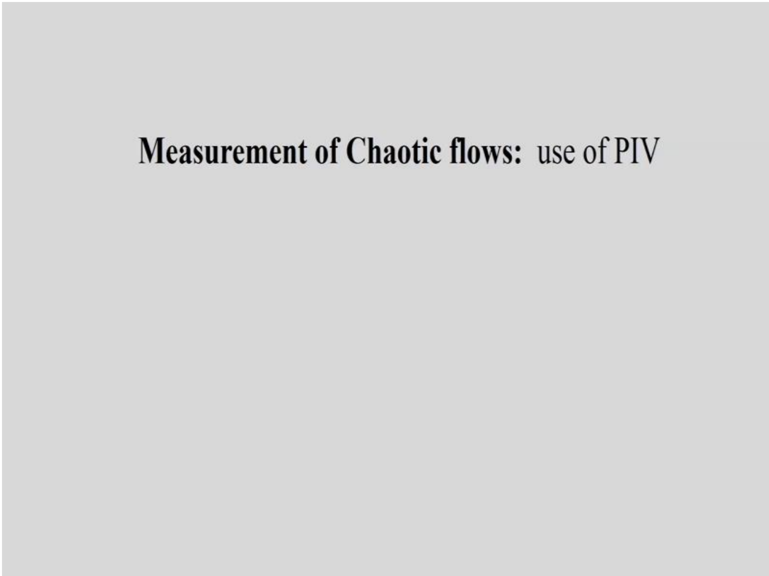

Good morning, I was discussing about the basic principle of PIV in the context of chaotic flow measurement and we have discussed about you know a few important aspects which are related to the PIV. Now in continuation of that today we will discuss the remaining other aspects which are required to understand to get the output from the PIV measurement technique.

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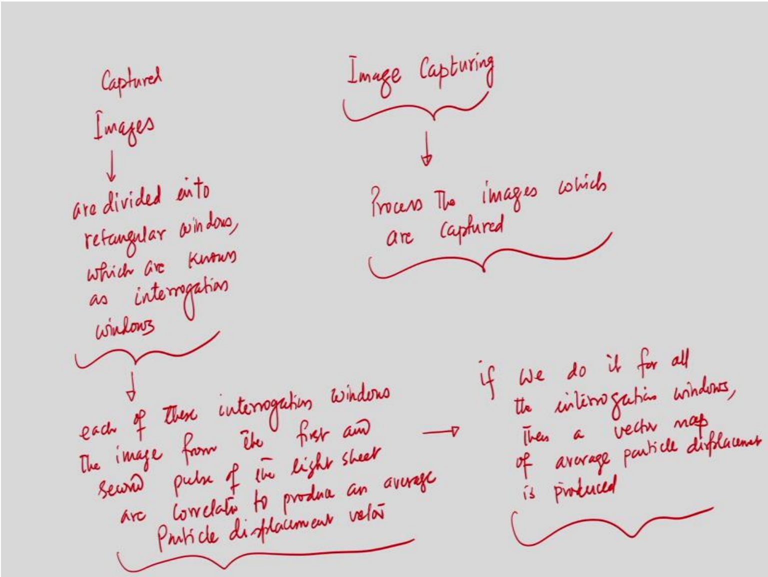

So, if we can recall that we have discussed about the image capturing. So, image capturing and then from image capturing another module will be to processing of the, to process the images which are captured. So, this is another important aspect, if we can recall correctly that in the last class we have discussed that the, you know images, the camera images are divided into rectangular windows and these windows are known as the interrogation windows.

So, if we try to write the camera so the images are divided, captured images are divided into rectangular windows, rectangular regions, rectangular zones and these rectangular regions or windows are an windows which are known as interrogation windows. And then, so that means interrogation windows and each of these interrogation windows, the images which are captured from the first and second pulse of the light sheet are now correlated to form of a vector of the or to form average displacement vector.

So, that means, the next is that is the, each of these, interrogation windows, the image from the first and second pulse of the light sheet are correlated to produce or to form average particle displacement vectors that means, camera will capture image. Now the images which are captured by the camera will be now processed to give the output, you know that, you know I can say the output in terms of the velocity of the fluid that is what we are looking for.

So, this is the particle displacement vector. So, if we do it for all the images captured. So, that means next step is for we do it for all the interrogation windows then, so if we do it for all the interrogation windows we will get then a map I can say vector map of average particle displacement is formed or produced right? So that means, if we do it for all the interrogation windows, we will see to the schematic diagram, what is interrogation windows?

What is the image which is captured by the camera? So, then we can produce a vector map of all the vector map of average particle displacement is produced. Now, we know the time between two consecutive images captured by the camera. So, if we divided the particle displacement vector by the, you know, particle displacement vector by this time then we will get.

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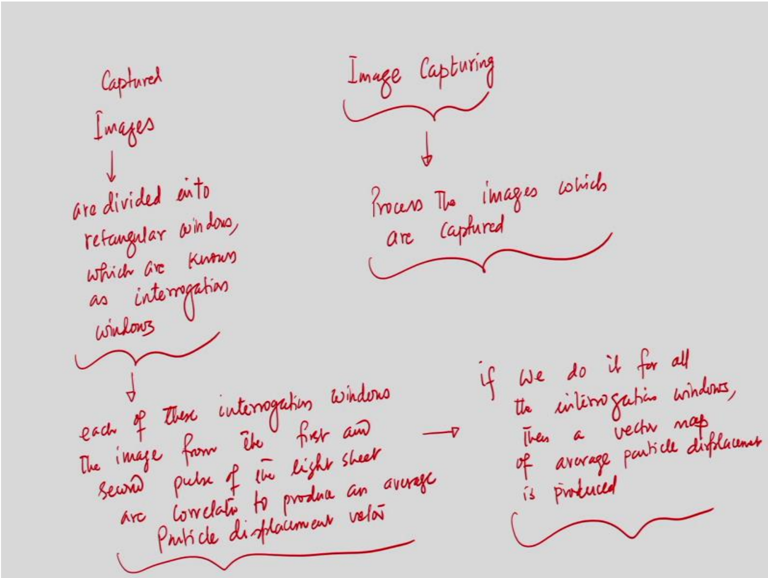

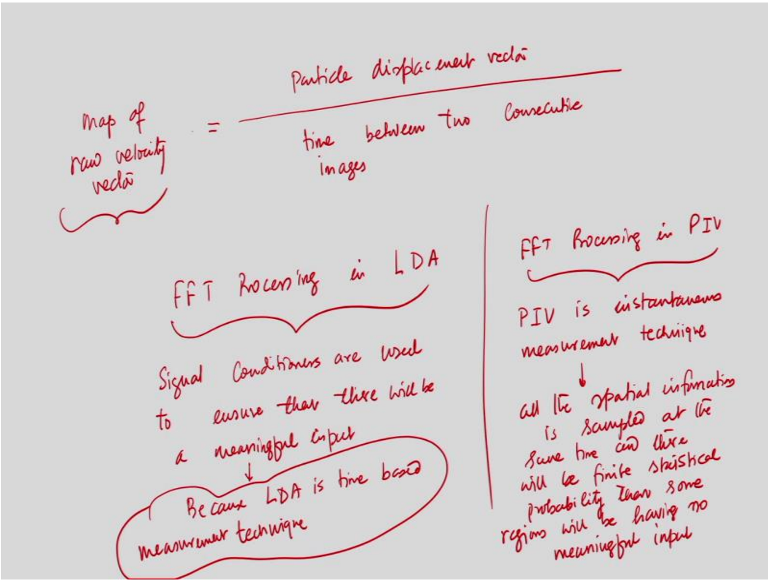

So if we go to the next slide. So, that means, this particle displacement vector and we also know the time between two consecutive images. Then, so, if we divided by this that means, then we can produce map of raw velocity vectors that is what. That means you need to corelate. So the velocity vector that we are getting, if we go to the previous slide that to produce a displacement vector that means, each of these interrogation windows, for each of these interrogation windows, the images from the first and second pulse of the laser sheet are now correlated to provide the average displacement vector.

So, this average displacement vector if we divided by the time which we know because that is captured, that these two images are captured by the camera will get the map raw velocity vector that means, you need to correlate. So, to speed up the correlation, FFT processing is done. So, this correlation is important for this particular technique and to speed up the correlation FFT processing is done.

Now, question is with the FFT processing, there is an important point that I should mention that will always get an output whether the input is meaningful or not. And one conceptual difference between the FFT processing in the Particle Image Velocimetry and FFT processing in Laser Doppler Anemometry that is what we have discussed in one of my last lectures that you know FFT processing in like a Laser Doppler Anemometry will give.

So, I am writing, FFT processing in LDA, Laser Doppler Anemometry. And if we try to compare FFT processing, in PIV, Particle Image Velocimetry. So, as I said, one important point to mention that for the FFT processing will always get an output whether the input is meaningful or not. See if we do that for the LDA analysis.

One important thing is that LDA analysis, if we do the FFT analysis for the Laser Doppler Anemometry, if we do the FFT analysis, this signal conditioners are used to ensure a meaningful, signal conditionals are used to ensure that there will be or there is will be a meaningful input. This is quite obvious because LDA is time-based technique. So, this is quite obvious because LDA is time-based technique. I can write time-based measurement technique.

So, this is quite obvious that if we do the FFT analysis for the LDA we will get a meaningful input. And this is quite obvious because LDA itself is the measurement technique which is time based, but if we do it for PIV, PIV on the other hand is instantaneous measurement technique. And hence all the spatial information, all this spatial information is sampled at the same time and if we do it there is a finite statistical probability that there will be some reason. And for some reasons where there will be no input.

So, this is an instantaneous measurement technique and, in this technique, what is done, all the spatial information is sample at the same time and there will be you now finite statistical probability that a few or that some reasons will be having no meaningful, no meaningful input. So, this is the conceptual difference between LDA and FFT. I was thinking to discuss this aspect in this context, so this is the fundamental, rather conceptual difference between LDA and PIV.

LDA is a time-based measurement technique and as a result of which signal conditional are essentially used to ensure that there will be a meaningful input, but for FFT analyses of FFT processing of the PIV, Particularly Image Velocimetry that is instantaneous measurement technique.

And in this technique, what is done all the special you know informations, spatial information is sample at a time and at this, at the time and there will be finite statistical probability that some results will be having no meaningful input. That means, why I am going to discuss this issue, that means, if we know a priori that if we do the FFT analysis of PIV. Then there will be some output for no meaningful input that means we need to validate the PIV analysis that is important question.

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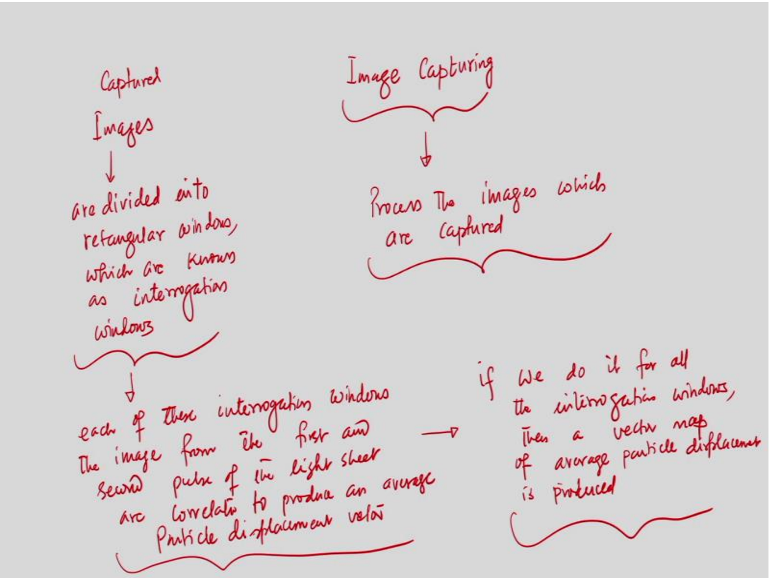

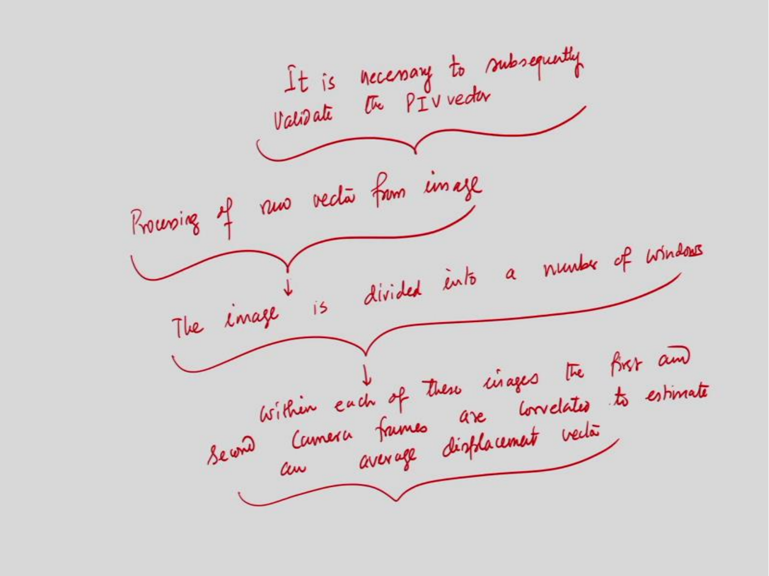

Therefore, from this analysis, we can write it is necessary to subsequently validate the PIV vector. So, this is very important. Now, next is our, next part will be to discuss. So, our next part will be to discuss the processing, the raw vector using the image that is what I was discussing. So, processing of image. So, but till now we have discuss that images are obtained from the camera and the you know the captured images are...

If I go to the previous slide that captured images are divided into rectangular windows and which are known as interrogation windows. And we have seen that captured images are correlated to the raw vector and that is done using two different methods. So, that means the correlation of, that means correlation what is done to convert image into the raw vector that is done using two different methods.

So, what I am writing now, the images are correlated. I can say images, which are, you know, divided. So, I am writing the image is divided into a number of windows that is what I have written. Next is, next is within each of these images the first and second camera frames correlated to estimate an average displacement vector.

That is what I was discussing in the last slide, vector. So, this is the processing of raw vector from the image that is the images, the image is divided into a number of windows and that is what we have discussed many times that these windows are called as the interrogation windows.

This interrogation windows within each of these interrogation windows, I mean, we are getting a number of interrogation windows and within each of the images the first and second camera frames are correlated to estimate an average displacement vector. So, from these at least we can see that this technique does not record to track the, track each and every particle.

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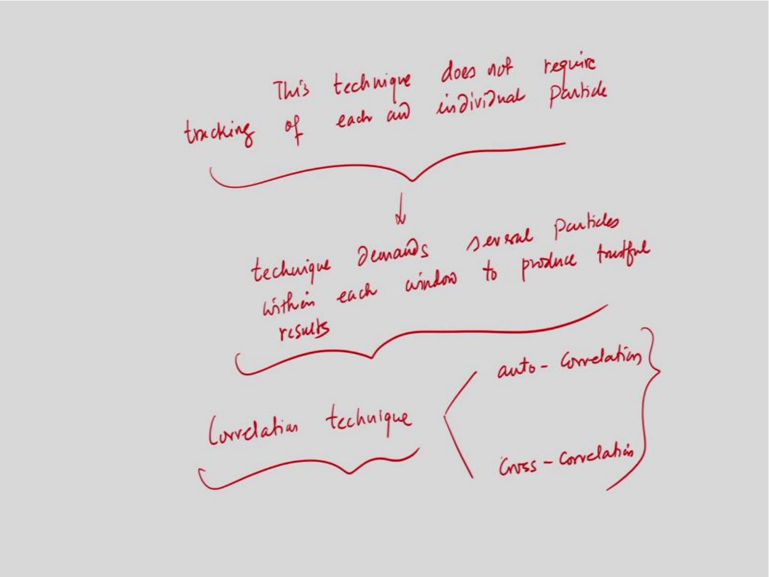

So, that means, if we go to the next slide, so, this technique does not require tracking of each individual particle right. So, that means we are focusing our attention on a zone not on the individual particle, if we, but at the same time we are having another problem. So that means we do not record to track the individual particle but at the same time we are having another problem that this technic you know, demands several particles within each window to produce trustful results.

So, this is another important problem that means, although we are not required to track individual particle, but at the same time, this technique demands that the several particles within each window, the several particles would be considered within each window essentially to produce the trustful results.

So now question is, these images are correlated to the raw vector, from the image which you have, which are captured by the camera will be now correlated to the raw vector. And you know the time and if we divided this raw vector by the time, we will get the speed of the particle and that is nothing, but the speed of the flow velocity.

Now, the two different correlation techniques are used that is what. So, the correlation technique, there are two different you know techniques are used one is known as you know autocorrelation and second one is the cross correlation. In most of the PIV analysis, this cross-correlation algorithm used.

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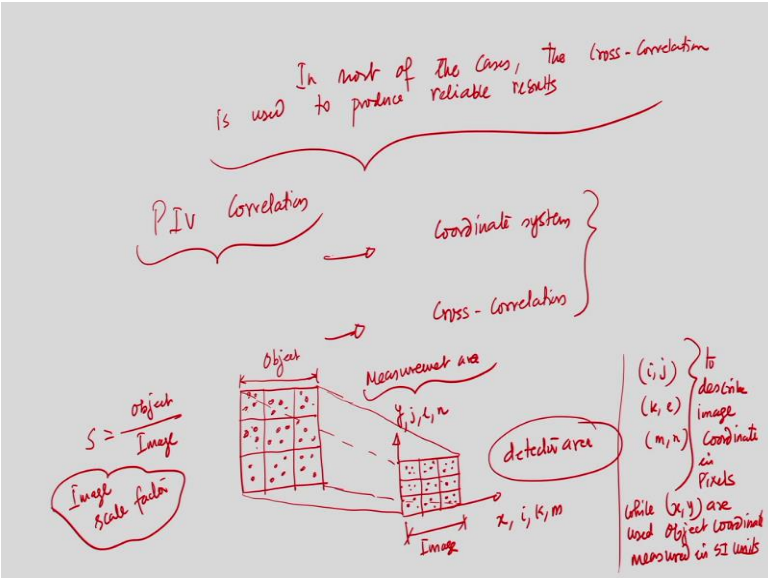

So, I am writing in most of the cases cross-correlation is used to produce reliable results. So, we will discuss the cross-correlation algorithm which is used to produce the trustful result. Now, to discuss about the PIV correlation, first we need to discuss about the coordinate system. And then second, we need to discuss about the cross-correlation. So, what is coordinate system?

As I said that in most of the cases of PIV analysis, the cross-correlation algorithm is used to produce the, you know reliable results. And hence, we will discuss the cross-correlation algorithm here, but for the PIV correlation these two important parts are there that is the coordinate system and second is the cross-correlation. So, if we try to now, say this is.

So, what is coordinate system and why it is important at least we should know and for that, I will try to discuss through a schematic depiction. So, particles are there, what is done? So, this is object. Now, this is image, so we are capturing image. And this is, so we are talking about two-dimensional X, this is Y. I am writing Y and this is image. So, this is detector area, this is measurement area.

So, this is measurement area object, we are focusing light on that, we are capturing using camera that is the detector area. Now, we know that S is the object by image. What is S? So S is object by image and S is that is image scale factor, image scale factor that is imaged by object. So, we are illuminating the object area, measurement area, we are capturing using camera that is the detected area.

Now coordinate system here we had having two you know, say we are using following symbols, that is, I comma J, K comma L and M, N. So, these are used to describe image coordinate in pixels. While X comma Y are used for object coordinates, for object coordinate measured in SI units. So, that means X and Y are the object coordinates which are measured in SI unit.

While I comma J that is the symbols are used in this schematic that very important I, I, K, M, J, L, N. So, the I comma J, K comma L and M comma N these are the symbols are used to describe the image coordinate in the pixel. So, this is what is done in the micro PIV analysis. So, camera is captured, image is captured by the camera and this image, object by image that is the image scale factor that is very important at least for this analysis.

So, next I will try to briefly discuss about the cross-correlation, right. So, before I know move to discuss about the cross-correlation at least, we should know about the coordinate system little bit more.

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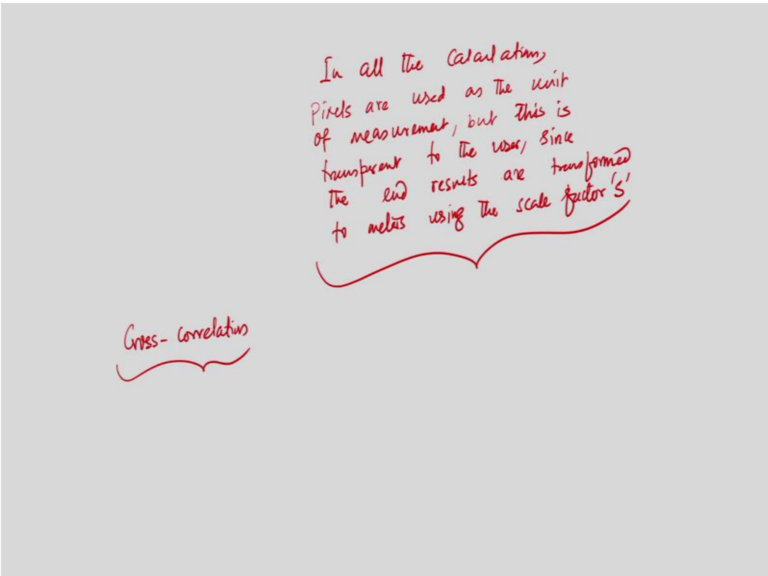

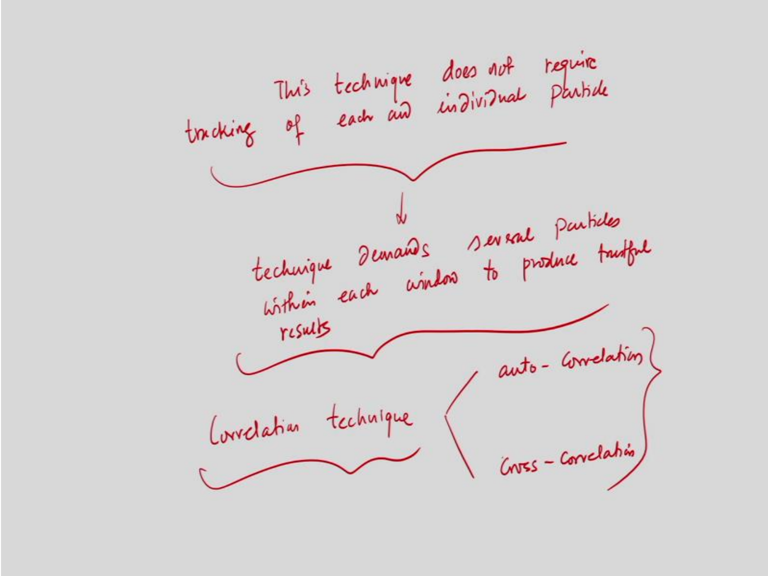

That means this in all the calculation pixels are used as the unit of measurements and but this is transparent to the user. Since the end results that is very important the end results are transformed to meters using the scale factor S. That means, all the calculation pixels are used as the unit of measurement, but this is transparent to the user since the end results are transformed to meter using the object to image scale factor that is S.

So, next we will briefly discuss about the cross-correlation. At least we have understood that in the context of chaotic flows. In fact, if we need to know the flow, if you need to know the flow velocities in the turbulent flow environment or if we try to characterize the flow even, even in the domain of laminar flow, if you try to validate, I mean as that is what I was, you know, you know discussing that the this PIV technique does not record tracking of each and individual particle, but at least it records several particles within each window to produce you know, trustful result.

And it is also important that this technique should be I mean the measurement obtained using these techniques will be validated. So, if we use PIV to measure the turbulent flow characteristics, that is the turbulence corrected, fluctuating components, the three-dimensional velocity field. Then at least before we go to obtain the, before we go to use this technique for this turbulent flow environment, at least we will try to validate the method using a laminar flow.

So, we know that the velocity (())(33:18) is perfectly parabolic if we talk about flow between two parallel plates in the laminate region. So, I mean fully developed flow. So, if we try to characterize the fully developed flow between two parallel plates, if we know the experimentally and that is experimentally proven profile, and if we try to validate that profile using the PIV analysis, then we can benchmark.

So, knowing that the, knowing that this technique can reproduce the result, which is experimentally proven, in the context of fully developed flow between two parallel plates, then we can go for the measurement using this technique for the turbulent flow region. So, it is at least we know, at least understood from this discussion that this technique, which is not really invasive, we do not record to probe, we do not record to insert any probe in the flow field.

But at least using light, light is an essential component for this measurement, but at least using a few particles which are seeded to the flow, we will discuss in detail that the particle should have a few important characteristics. So, by using only a few particles, we can characterize the flow field even if it is the, you know, chaotic, even if it is the region of a turbulent flow. So, question is this technique is having a few advantages feature that means it does not disturb the flow field.

Although a few particles are seeded, but these particles are neutrally buoyant, that we will discuss. Only using light source by illuminating a particular zone, we can correlate the velocity of the particle. As I said that in this technique, essentially we measure the velocity of the particle. So, in PIV analysis, we measure velocity of the fluid, but, the velocity of, the flow velocity is related to the velocity of the particle which are measured.

So, we can measure the velocity of the particle from there we are trying, we can corelate. So, what will be the velocity of the fluid? In fact, we assume that the fluid velocity should be the velocity of the particle and that is what this analyse, the basic principle of this analysis is. Now, the cross-correlation algorithm is also an important part. Rather I can say an important you know component of this measurement technique.

So, we will discuss this, but in this course, it is important to know that PIV is also another important measurement technique, which is used to measure flow parameters in a region, where the flow field is highly chaotic. And that is what we have understood the basic principle by which we can correlate the velocity, even in the turbulent flow region.

But we will discuss the cross-correlation algorithm and as I said that in most of the cases cross-correlation algorithm use instead of the auto correlation, we also need to discuss why auto correlations are not used. And if we do not use auto correlation of course, we will be using the cross-correlation.

Then the basic, at least a few will try to give a brief overview of this cross-correlation algorithm. And from there we will try to find, try to see by how we can really obtain the velocity field using by measuring the images. So those part I will be discussing in the next class. So with this, I stopped my discussion today. Thank you.