

Advanced Measurement Techniques in Fluid Mechanics and Heat Transfer

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Week – 12

Lecture - 60

General Optics + PIV + Schlieren Demo

Hello, everyone. Welcome to this lab demonstration session for the course on optical methods for solid and fluid mechanics. In this session, I will show you different camera lenses that we have in our lab, and then I will show you different imaging parameters that you can control to get good images. So, coming to the lenses. This is a wide-angle lens with a variable focal length between 24 mm and 120 mm, which gives a large field of view, but the resolution is low. Now we have this Navitar zoom lens; it gives you very high resolution, but the field of view is small.



Sigma macro lens is a prime lens with a fixed focal length of 105 mm, and the field of view and the resolution are in between these two lenses. So, depending on the requirement, you can choose different lenses that are available in the market. Now I will move to the different imaging parameters that you can set in the camera to get the desired imaging. There are three critical parameters that decide a good imaging.

First is the exposure time. It signifies the amount of time for which the camera shutter is open. Then the second is F number. This signifies how much you want to open the aperture. Then third is ISO.

ISO signifies the sensitivity of a camera. Now these settings are common to all the cameras, even high-speed cameras, but I will show how to change these settings on a Nikon camera, and its model is the D850. And to control these parameters, you need to put your camera in manual mode and there you have a button for changing the mode. And then when M appears on the screen, it means it's in manual mode. To change the F number, there is a knob.

You can rotate this knob to control the f-number. Then, here's a knob. You can rotate this knob to change the exposure time. And then you have the ISO button. You can simultaneously press the ISO button and rotate this knob to control the ISO of your image.



Now, with the help of a demo, let's see how you can control these parameters to get the desired imaging. Here is our Nikon camera; then there is an object near the camera, and there is another object far away from the camera. As you see, this is the exposure time of 1/200 second, the F number is 5.3, and the ISO is. With these settings, you get an image that looks like this.

In this image, the front object is in focus, whereas the background is not in focus. Now,

if you want the background object to be in focus, then you can change the F number. With a higher F number, you can increase the depth of focus. In the next image, I will change one parameter while keeping the other two the same. I will change the f-number.

You see the exposure time and ISO remain the same, and the F number has increased from 5 to 36. Now you see a dark picture. Why? Because when you increase the F-number, you basically reduce the aperture. It means you have reduced the amount of light that's entering the camera. Now, to address this issue, what you can do is increase the exposure time so that a larger amount of light can enter the camera during this higher exposure duration.

Keeping the other two parameters, F number and ISO, the same, I will increase the exposure time from 1/200 second to 1/4 second. Now, you see a properly exposed image. With the front object in focus as well as the back object also in focus, what happens when you increase the exposure time even higher from 1/4 second to 2 seconds? Here, you get an overexposed, saturated image, and a lot of information has been lost from this image again. You can control the ISO to address this issue. ISO is essentially the sensitivity of the camera.



Now, if I decrease the ISO from some value, here it is 12800. I have reduced it to 1000, as you can see. It is again a good image with the front object as well as the background object in focus. So, depending on the requirement, you can control these parameters to get a good image. Here is our Nikon D850 camera.

There is one object near the camera and there is another object relatively far from the camera. The value of three different parameters can be seen at the bottom of the camera screen. The exposure time is 1/200 second. The F number is 5.3 and the ISO is 12,800.

Here, it's M, which signifies that the camera is in manual mode. Now let's click an image for this setting. And let's see how it looks. So you have an exposure time of 1/200, an f-number of 5.3, and an ISO of 12800.

For this value of parameters, the image looks like this, where you have the front object in focus, whereas the object in the background is not in focus. Now, if you want to keep your depth of focus high, it means you want to focus on both objects. Then you can increase the f-number, and both objects will be in focus because the depth of field will increase. Here I will increase the f-number to a very high value and then click another image. Now let's see how this looks.



You see a dark image. You see a dark image because when we increase the f-number, we have basically reduced the aperture. It means the amount of light that's entering the camera has been reduced. That's why we see a poorly-exposed image. To address this issue, you can increase the exposure time. Right now, the exposure time is 1/200.

Given the same F number and ISO setting, if I increase the exposure time, it means I allow more light to enter the camera, and then you can get a good image. Let's see that.

So I am increasing the exposure time to 1/4 second and clicking one image. Let's see how it looks. Now you see a properly exposed image with the foreground object as well as the background object.

Both are in focus, and the parameters are 1 by 4 seconds of exposure time. The F number is 36, and the ISO is 12800. Now what happens if you increase the exposure time even more? Let's see. So I'm making an exposure time of 2 seconds.

And then click on one image. And this is how it looks when I increase the exposure time. Since the shutter is open for a long time. The whole image is overexposed and saturated, and a lot of information has been lost from this image. To overcome this problem, you can decrease the sensor's sensitivity.

That is ISO. So keeping the other two settings the same, if I decrease the ISO, then I can again get a properly exposed image. So I am decreasing the ISO to 1,000. And then click on an image. And let's see how it looks. Now you see I have kept the exposure time fixed to 2 seconds, the f-number to 36, and the ISO decreased from 12800 to a value of 1000.

Now you can see you have a properly exposed image with both the object and the background in focus. As per the requirement, you can play with these parameters, such as exposure time, ISO, and the F number, and then you can achieve the desired imaging. All the lenses I showed earlier were spherical lenses. However, there can be cylindrical lenses that are used in, for example, particle image velocimetry, where you want to create a sheet of light from a cylindrical beam of light.

Here is one such lens. It's a plano-concave cylindrical lens, and it's mounted on a 3D-printed holder. There is a plano-concave cylindrical lens. It has a concave curvature on one plane, whereas it has no curvature on the other plane. So it converts a cylindrical beam of light into a diverging sheet of light that I will show here with the help of a laser light source. It's a green laser, and it's a 5 milliwatt laser.

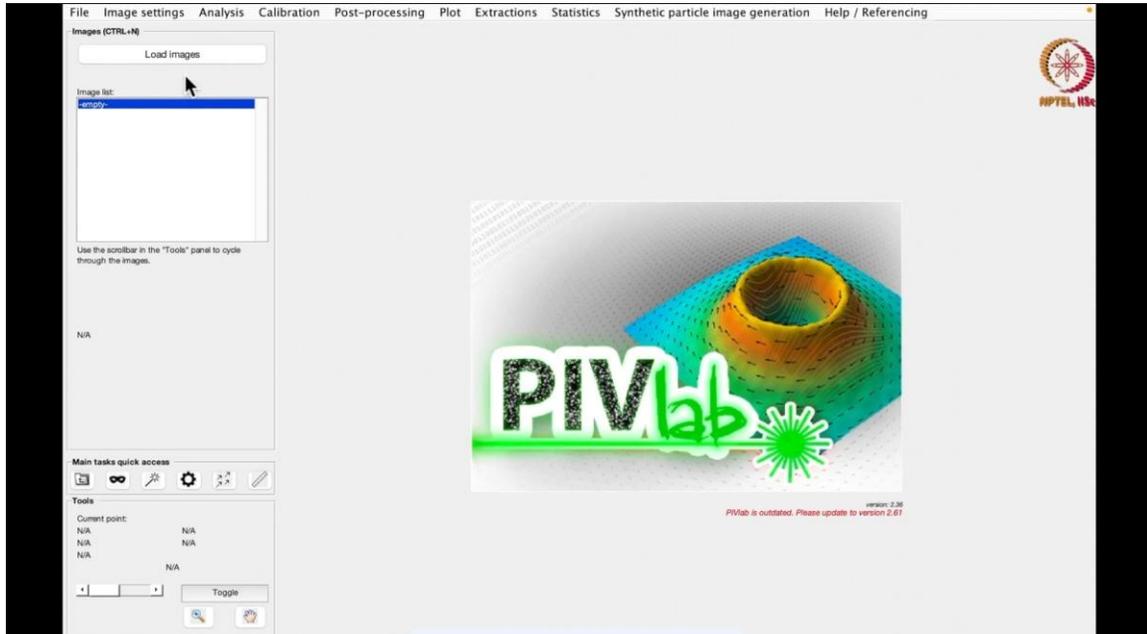


Although the power is not high, before turning it on, it's important to put on safety goggles that are rated for this particular laser. Now I'll turn on this laser, and you will see it produces a cylindrical beam of light. That appears as a circular projection on the screen. Now, when I put this cylindrical lens in front of the laser, you can see that the cylindrical beam of light has transformed into a sheet of light that appears as a line on this screen. And as I mentioned earlier, these lenses are used in particle image velocimetry where you want to create a sheet of light to illuminate the particles in a particular plane.

With this, we have come to an end of this session. Thank you. Hello everyone, welcome to this lab demonstration session on Particle Image Velocimetry, or PIV. In this session, I will show you different components that are required to do a recording of particle image velocimetry, how these components are arranged, and then later I will also show you how to take the PIV recording and analyze it using one add-on software available in MATLAB, and the name of the software is PIV Lab. So let's look at the experimental setup for PIV.

This is our specimen. It's a transparent fluid tank. I have kept water in it. It's kept on a magnetic stirrer, and there is a magnetic bead inside the water, and when I turn on this stirrer, it rotates and creates a flow field inside the water that is kept inside this tank. Now I have also added tracer particles to this water. I have used glass spheres with a size of 9

to 13 microns in diameter as the tracer particles, and these tracer particles are ordered from Sigma Aldrich.



Now, to do particle image velocimetry, you need to illuminate your plane of interest in which you want to see how tracer particles are moving. So to illuminate a particular plane, I have kept a laser here and a cylindrical lens, which I demonstrated earlier in the previous video. This cylindrical lens transforms a cylindrical beam of light into a diverging sheet of light. That sheet of light illuminates particles in a particular plane.

So let's turn on the laser. While setting up the experiment, you have to be careful, and you need to use proper laser goggles. I have already aligned it, so I am not wearing it. Now, as you can see, there is a sheet of light that is illuminating the particles in this particular plane. And then I kept the camera perpendicular to this plane. And this camera is recording the motion of the particles in that particular plane.

So let's take a sample recording. And now the camera is recording the motion of particles in this particular plane where the particles are illuminated. Okay, now we will take this recording and look at how it appears on the screen, and then I will also show how to, uh, segregate frames from this particular recording and then put them into MATLAB, and using the PIV Lab application, how you can analyze the video and get the flow field in this particular plane. Now let's open this application.

It will take some time to load. Okay. This is the window for the PIV lab application. It's

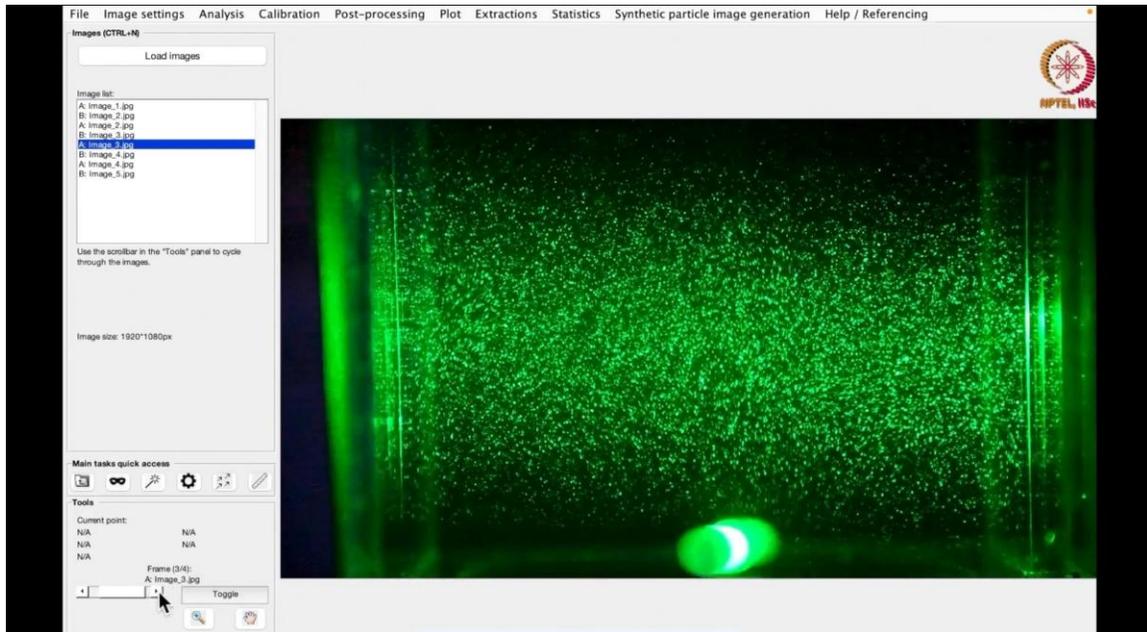
very interactive software. And there are lots of options available, but I am going to walk you through the key steps required to perform the PIV analysis. So it mainly consists of three steps. First is pre-processing, then processing, and finally post-processing.

In the pre-processing part, we perform the preliminary image processing on the PIV recording, where we eliminate noise to make it suitable for PIV analysis. And then, in the processing part, we run the cross-correlation algorithm to get the flow field. And then in the post-processing part, we filter out the spurious or erroneous vectors. Okay. So the first step is to load the images that we have extracted from the PIV recording.

So when you click on load images, you will have the option to browse the folder where you have kept the images. Then select the images, add them to the PIV lab application, and then import them. Now we have selected five frames, which will give you four pairs for PIV correlation, and you can see that here. So the first thing is the pre-processing part, where you can go to the image settings, and there you will get the option of exclusions, selecting the region of interest, and masking. When you click here, you'll have the option to select the region of interest where you want to do the analysis.

For this tutorial, I'm selecting this as my region of interest. Okay, now at the bottom, there is a magnetic bead, and since there are no particles, the PIV correlation algorithm will not run properly here, so we want to mask out this region. For that, you need to go to "Draw Mask for Current Frame," and then you just start putting markers, which Captures the region where you don't want to perform the PIV analysis. Then double-click on the first point to make it a closed geometry. And this is the region that you have masked out of the analysis.

Now you have drawn this mask for only one frame. You need to apply it to all the frames. That option you get from here applies the current mask to frames. from first to last. Now you can see that this mask is applicable for all the frames.

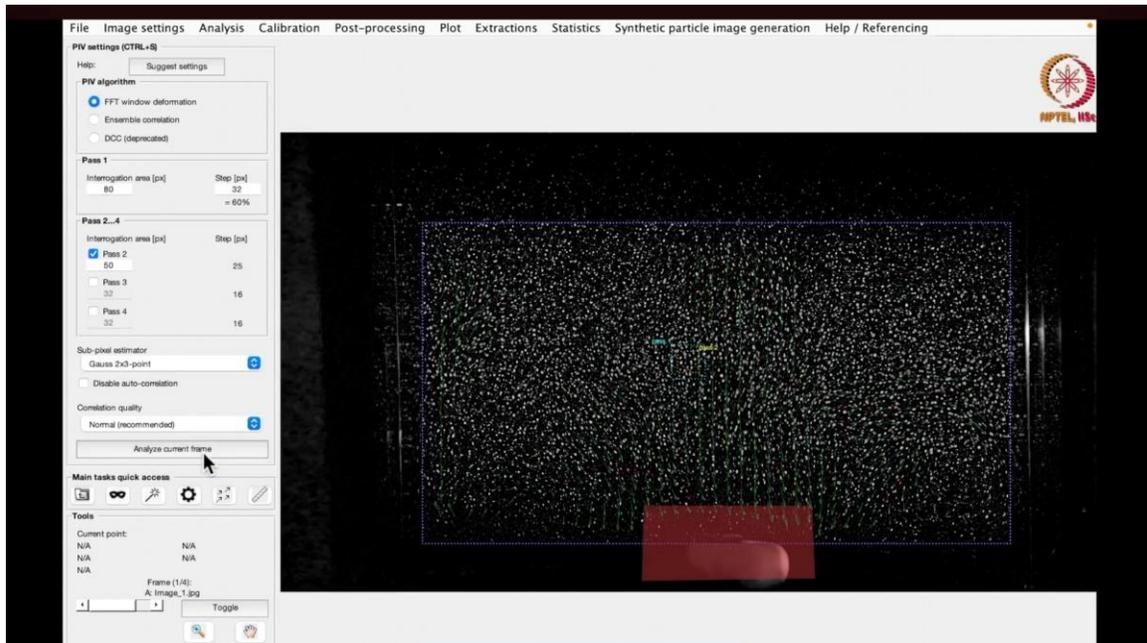


Going to the next step. Here we have image preprocessing. Here the CLAHE filter is enabled by default. And after enabling this filter, if you want to see what it does to your image, you can go to the preview current frame, and once you click here, you see this is the final image where the analysis is going to be performed. It is still a little bit noisy, so let's try enabling the high pass filter and then preview the current frame.

Now it is better, and we can. Proceed to the next step. The next part is doing the analysis; for that, we need to do the PIV settings, which you can find under the analysis menu. Once you go to the PIV settings, you will see that the PIV analysis the software performs is in two different levels: two different grids. The first is Pass One with a bigger grid. and then pass 2 with a finer grid. Right now, the pass 2 has a very small window size of 32 by 32 pixels.

So we will increase it a little more. Let's make it 50 by 50 pixels. Now pass 1 and pass 2 have become almost equal. So I will increase the pass by 1 around 80 pixels. OK, now it looks perfect. After doing this, when we press "Analyze Current Frame," it will run the correlation algorithm and give you a velocity vector field like this as the output.

So right now, the vector field is plotted in green, and the background is also green. That's why they aren't properly visible. So what we can do is go to this plot menu to modify the plot appearance. So, the vectors are plotted in green.



Let's try to plot it in yellow, then apply. We can also increase the line widths of these vectors. Let's make it around one o'clock. OK, now it looks better. So you can see the velocity vector field in the plane of illumination. Again, there are some vectors that you can see in the bottom left corner.

Which is completely different from the nearby vectors. And that's how we spot the spurious or erroneous vector. Now we need to get rid of these vectors. And that is our post-processing part.

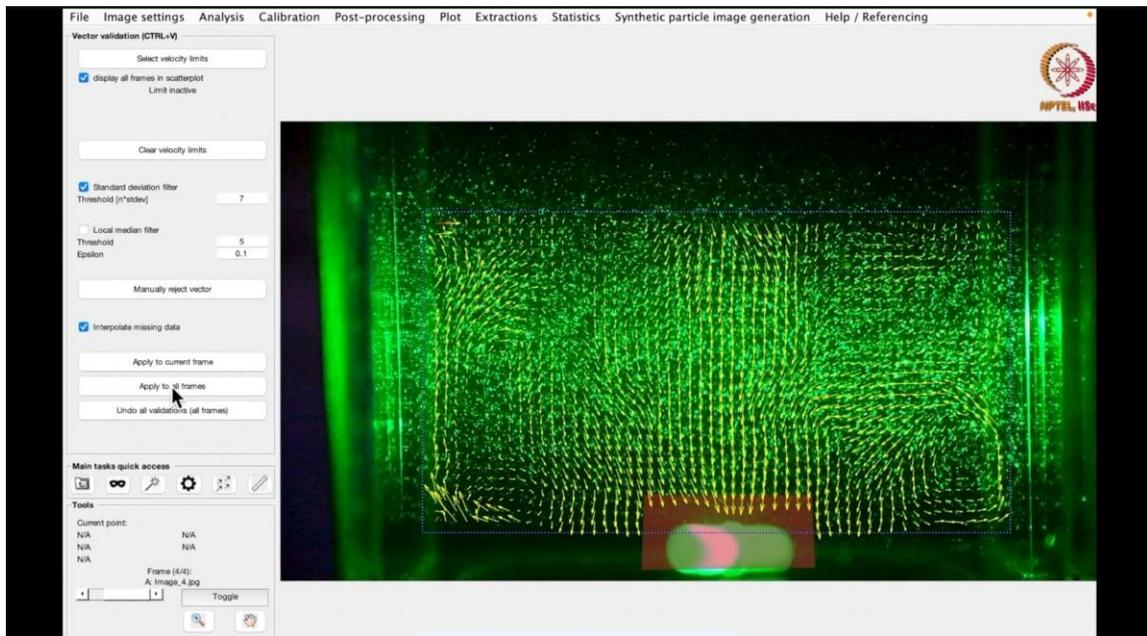
So, under this post-processing menu. We go to vector validation. Again, there are lots of options available here. You can explore it on your own. For example, there is this standard deviation filter, a local median filter, with which you apply some conditions on how these erroneous vectors are spotted, and then there is this option to interpolate missing data. When you check this box, what this software will do is take out the spurious vector and replace it with another valid vector, which will be calculated by interpolating from the nearby vectors. Let's apply it to the current frame, and you will see there were three spurious vectors that have been removed and replaced with suitable vectors.

There is one more vector that is not filtered out, so either you can manually reject it, or you can put even more stringent criteria on your filter for how to spot this erroneous vector. Okay, so right now we have done this analysis only for one frame. We can go to

the analysis menu, then analyze, and then analyze it for all the frames. So it will take some time to process. And then again, you can go to the post-processing vector validation and then apply it to all the frames.

So it will remove spurious vectors from all the frames. So these are the basic steps that you need to know. For performing PIV analysis using this PIV Lab application. Apart from this, you have many other interesting options under this plot menu. For example, I will show you one. For example, if you want to draw streamlines, then you select the streamlines option and go to draw streamlines.

Across here will appear on the screen, so wherever you click, it will draw streamlines passing through that point. Once you have completed the point selection, you just right-click anywhere on the screen, and you will see the streamlines. They are not properly visible; again, they are plotted in yellow. Let's change the color to.



Red and increase the line width a little bit, and then apply. Okay, so now you can see the streamlines passing through the points that I selected earlier. There are similar other interesting options under this "derive parameters" and "post processing," and then calibration. Using calibration, you can put an image. To convert the pixels into a metric unit or any unit of your requirement.

So I encourage you to go and try these options by yourself. Once your analysis is complete, you can also go to the file menu and export the output in different formats, and

you can do further analysis on this data. With this, we will close this tutorial on the PIV lab application and thank you. Hello everyone, welcome to this lab demonstration session. In this session, I will show you what the different components required to do a Schlieren imaging setup are and how these components are arranged.

So there are various versions in which people do setup for Schlieren imaging. Either it can use one mirror or two mirrors, and then they are arranged in a different fashion. The one that we have here is a setup with two parabolic mirrors, a light source, and a camera, and all these components are arranged in a fashion that looks like the letter Z when viewed from the top. So it's a two parabolic mirror Z type setup.



So, coming to the setup. This is the light source. And then there is a pinhole in front of the light source. From here, a diverging light goes to the first parabolic mirror, and this light source is kept at the focal point of the mirror. So from here, the light becomes parallel, then it bounces off to the second parabolic mirror, and from here, it converges to this knife edge. And then the camera is kept after the knife edge. Now the space between the first parabolic mirror and the second parabolic mirror is our test section and everything you see here.

It's part of the test section. You can replace it with your specimen whenever you want to capture in the Schlieren imaging. For example. So the Schlieren imaging works on the principle that it captures the gradients in refractive index.

Now I have a lighter. If I press it, a flame comes out of the lighter that creates a gradient of the refractive index and that gets captured in the Schlieren. So I will keep this flame in the testing section. And let's see how it appears when captured through this setup. If I partially press this lighter, then there are combustible gases coming out of the lighter that have a different refractive index than the surrounding air. These gases are not visible to the naked eye, but they can be easily captured through this slurring imaging setup.

So let's see how it looks. So I am partially pressing this lighter and keeping it in the test section. And then let's see how it appears in this when captured through the setup. With this, we come to the end of this Selenium imaging setup demonstration. And thank you.