Optical Methods for Solid and Fluid Mechanics
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Lecture - 23
Lab Demo III: PIV and Schlieren

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 recording for particle image velocimetry, how these components are arranged and then later I will also show you how to take the PIV recording and then analyze it using one add-on software available in MATLAB and the name of the software is PIV lab. So let us look at the experimental setup for PIV.

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This is our specimen. It is a transparent fluid tank and I have kept water in it. It is kept on a magnetic stirrer and there is a magnetic bead inside the water and when I turn on this stirrer it rotates and it creates a flow field inside, the water that is kept inside this tank. Now I have also kept tracer particles in this water and I have used glass spheres with size 9 -13 micron in diameter as the tracer particles and this 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 then cylindrical lens, which I have earlier

demonstrated in the previous video. This cylindrical lens transform a cylindrical beam of light into diverging sheet of light. That sheet of light illuminates particles in a particular plane.

So let us 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 have kept the camera perpendicular to this plane. And this camera is recording the motion of the particles in that particular plane.

So let us 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 how it appears on the screen. And then I will also show how to segregate frames from this particular recording and then put it into MATLAB and using the PIV lab application how you can analyze the video and get the flow field in this particular plane. Okay.

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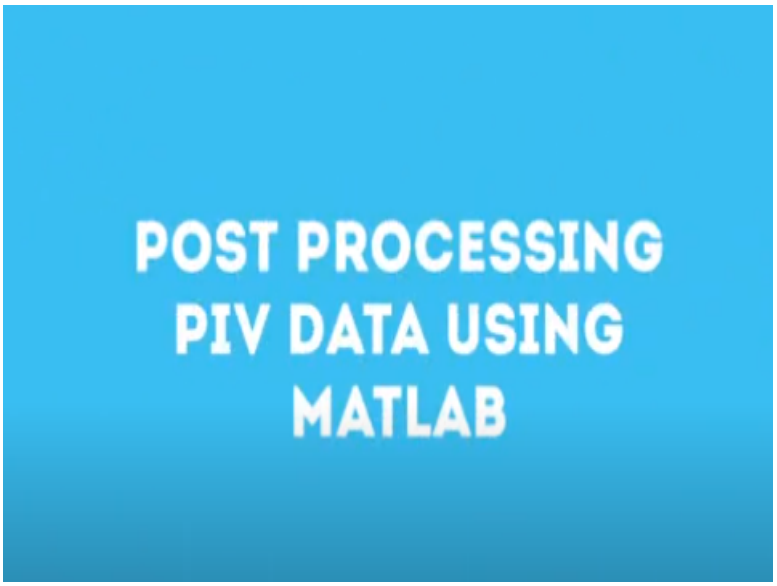

This is the video we have recorded for PIV analysis. **(Video Starts: 03:24) (Video Ends: 03:33)**. You can see the magnetic bead rotating at the bottom of the tank. And you can also get a qualitative estimate of the flow field on the plane of illumination just by visual inspection. I will play this video again and you can see the tracer particles moving on the plane of illumination.

Now we will see how to get quantitative flow field using PIV lab application which is available in MATLAB. But to do that, you have to first extract frames from this video, which I have already done and kept in this folder.

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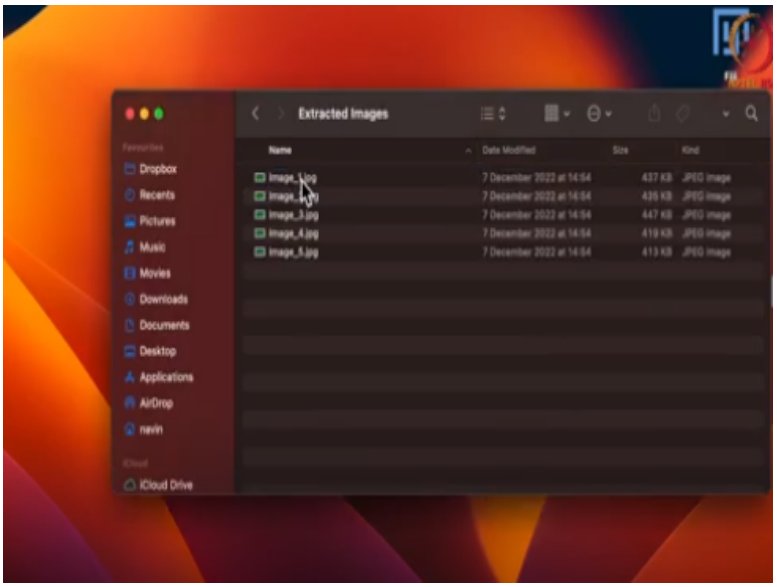

I have extracted first five frames of the video, but you can take more or even less. In principle, you require at least two frame to do the PIV analysis. Now let us open the MATLAB.

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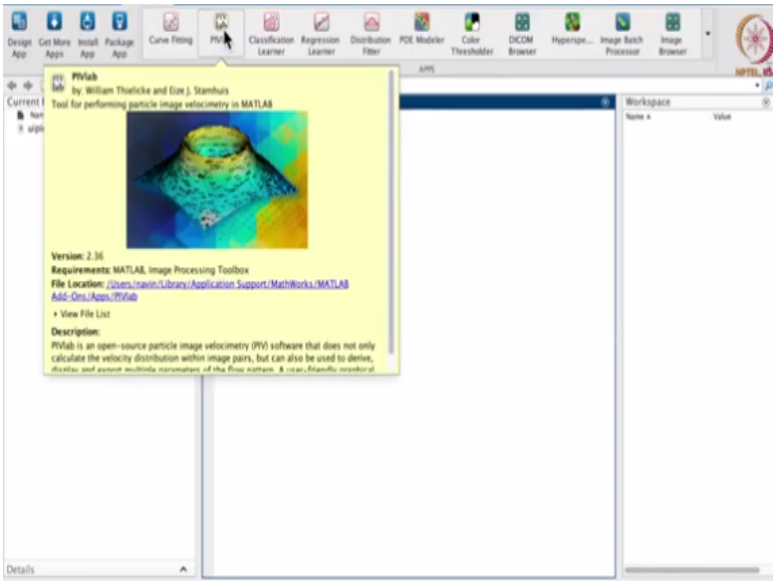

So this is the MATLAB window. And here on the top left, you will see the apps option. Here you will see the PIV lab application. If you do not have it already, then you can go to Get More Apps option and then install the PIV lab application. Now let us open this application. It will take some time to load.

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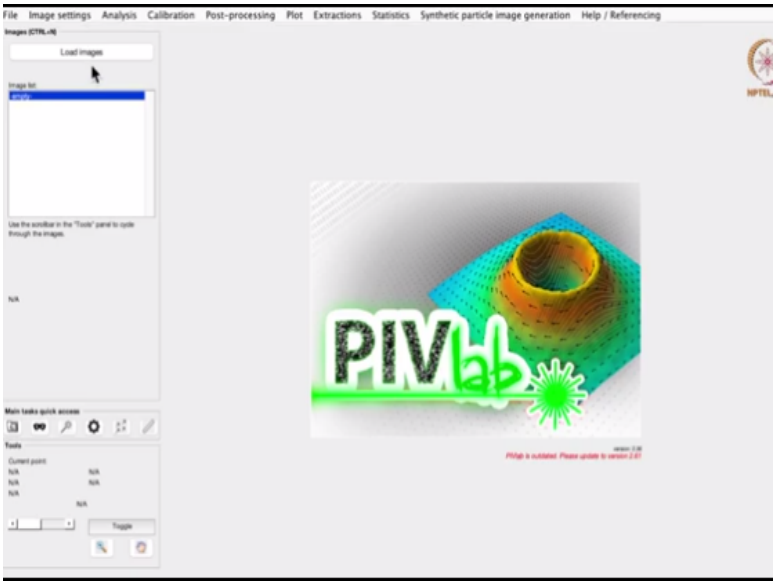

Okay, this is the window for PIV lab application. It is a very interactive software and there are lots of options available, but I am going to walk you through the key steps required to do the PIV analysis. So it majorly consists of three steps. First is pre-processing, then processing and then post-processing. In the pre-processing part, we do the preliminary image processing on the PIV recording, where we get rid of noises 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 do a filtering out of the spurious or the erroneous vectors. Okay.

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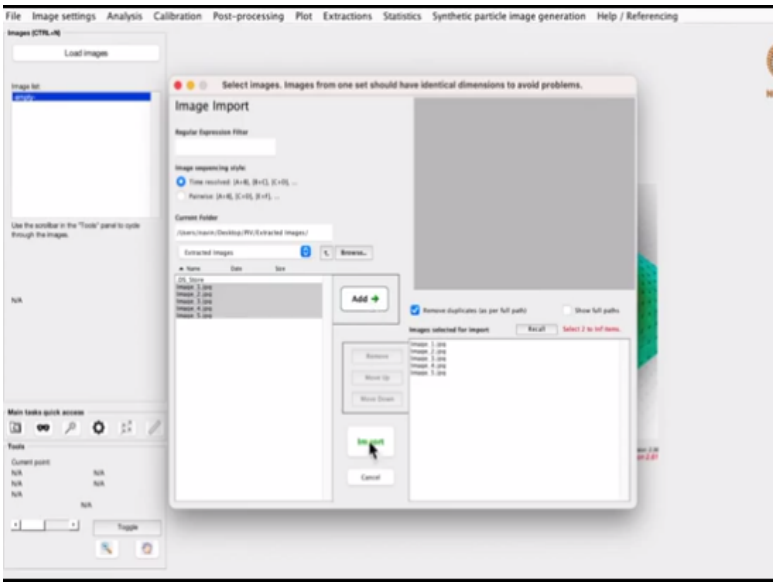

So the first step is to load the images that we have extracted from the PIV recording. So when you click on the load images, you will have the option to browse the folder where you have kept the images. Then select the images, add it to the PIV lab application and then import it.

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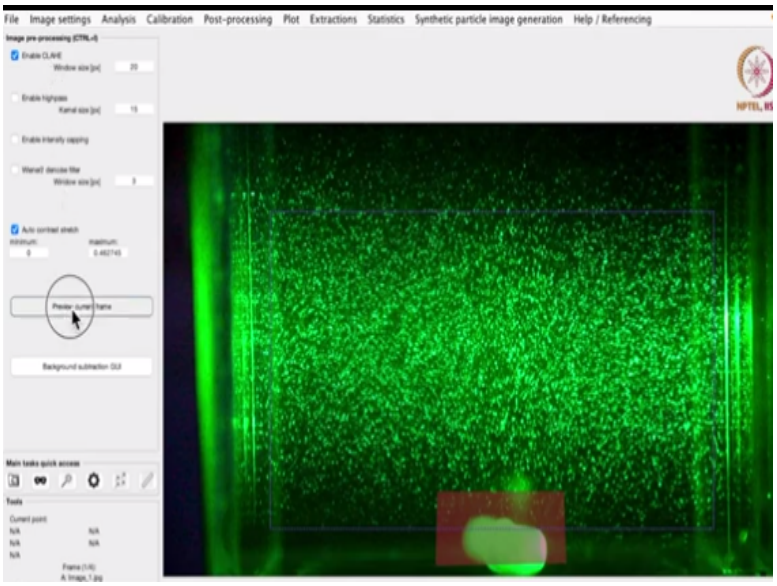

Now we have selected five frames, which will give you four pairs for PIV correlation, and that you can see here. So the first thing is pre-processing part where you can go to the image settings and there you will get the option of exclusions, selecting the region of interest and masking. When you click here, you will get the option to select the region of interest where you want to do the analysis.

For this tutorial, I am selecting this as my region of interest. Okay, now on 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 this draw mask for current frame. And then you just start putting markers, which captures the region where you do not want to do 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 from the analysis. Now you have drawn this mask only for one frame, you need to apply it to all the frames. That option you get from here, apply current mask to frames from first to last. Now you can see this mask is applicable for all the frames.

Going to the next step. Here we have image pre-processing. 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.

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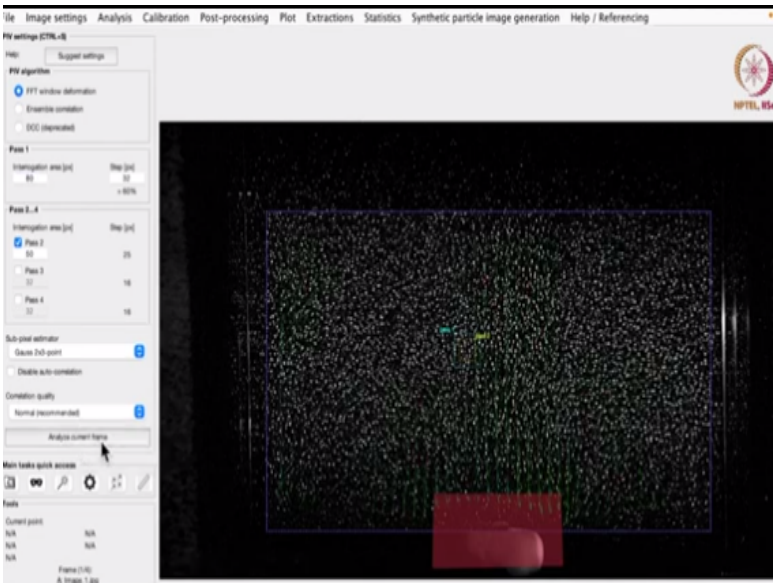

And once you click here, you see this is the final image where the analysis is going to be performed. It is still a little bit noisy. So let us try this enable high pass filter and then preview the current frame. Now it is better and we can proceed to the next step. Next part is doing the analysis. For 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 in two different levels, two different grids. First is pass one with bigger grid and then pass two with finer grid. Right now the pass two has a very small window size that is 32 by 32 pixels. So we will increase it a little bit more. Let us make it 50 by 50 pixels. Now pass one and pass two has become almost equal.

So I will increase the pass one around 80 pixels. Okay, now it looks perfect. After doing this, when we press this analyze current frame, it will run the correlation algorithm and give you a velocity vector field like this as the output.

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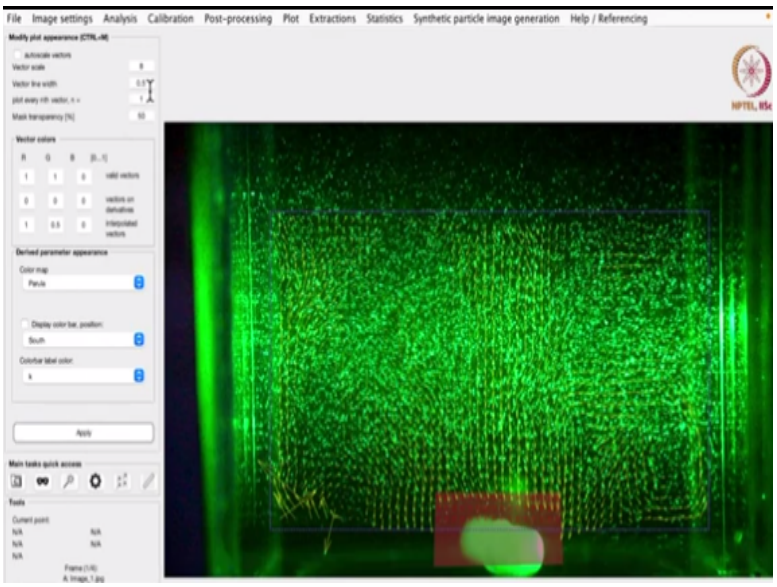

So right now the vector field is plotted in green and the background is also green. That is why they are not properly visible. So what we can do is, we can go to this plot menu, modify plot appearance. So the vectors are plotted in green, let us try to plot it in yellow, then apply. We can also increase the line width of these vectors. Let us make it around 1.

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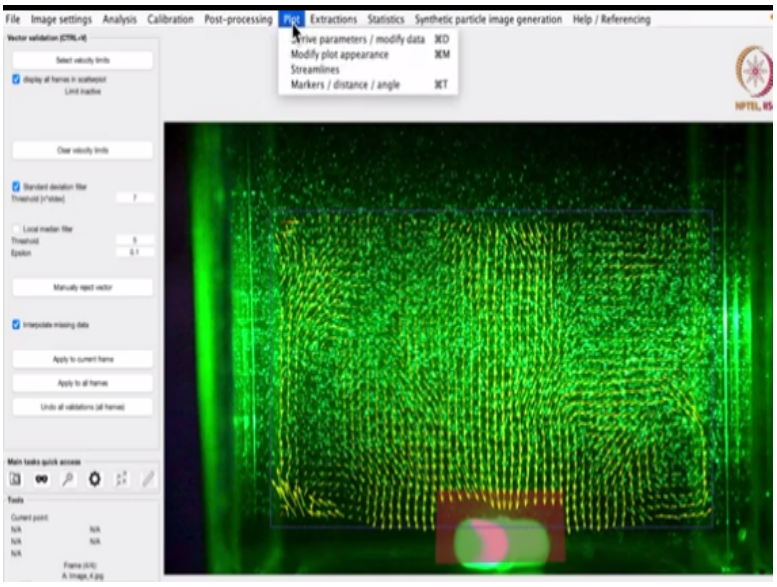

Okay, now it looks better. So you can see the velocity vector field on the plane of illumination. Again, there are some vectors which you can see on the bottom left corner, which are completely different from the nearby vectors and that is how we spot the spurious or the erroneous vector. Now we need to get rid of these vectors and that is our post processing part. So under this post processing menu, we go to the vector validation.

Again, there are lots of options available here, which you can explore on your own. For example, there is this standard deviation filter, local median filter. With this you apply some condition and how this, you will set the condition how these erroneous vectors are spotted, and then there is this option, interpolate missing data.

When you check this box, what this software will do is it will take out the spurious vector and replace it with another valid vector and that will be calculated by interpolating from the nearby vectors. Let us apply it to the current frame. And you see there were three spurious vector that has been removed and replaced with suitable vectors. There is one more vector that is not filtered out.

So either you can manually reject or you can put even more stringent criteria on your filter that how you 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 do the processing. And then again, you can go to the post-processing vector validation, and then apply to all the frames.

So it will remove spurious vector from all the frames. So these were the basic steps that you need to know for performing PIV analysis using this PIV lab application. Apart from this, you have lots of 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 then you go to draw streamlines across here will appear on the screen. So wherever you click, it will draw streamlines passing through that point. So 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 us change the color to red and increase the line width a little bit and then apply.

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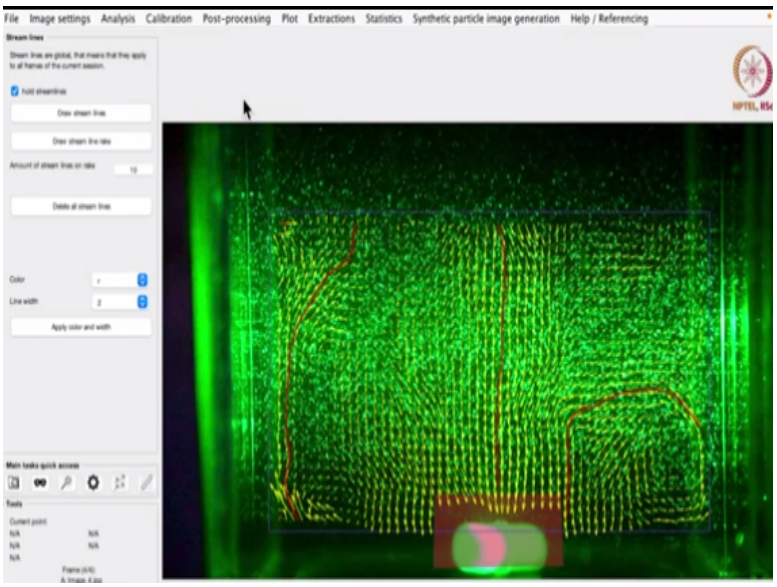

Okay, so now you can see the streamlines passing through the points that I selected earlier. There are similar other interesting option under this derived parameters and post processing and then calibration. Using calibration you can put an image to convert the pixels into some metric unit or any unit of your requirement. So I encourage you to go and try these options on your own.

Once your analysis is complete, you can also go to the File menu and export the output in different format and you can do further analysis on this data. With this, we will close this tutorial on PIV lab application and thank you.

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Hello everyone. Welcome to this lab demonstration session.

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In this session, I will show you what are the different components required to do Schlieren imaging setup and how these components are arranged. So there are various versions in which people do setup for Schlieren imaging. Either it can be using one mirror or two mirror and then they are arranged in different fashion.

The one that we have here, it is a setup with two parabolic mirror, and a light source and camera. And all these components are arranged in a fashion that looks like the letter Z when viewed from the top. So it is 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, and then it bounces off to the second parabolic mirror. And from here, it converges to this knife edge, and then 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 is part of the test section.

You can replace it with your specimen, whatever you want to capture in the Schlieren imaging. For example, so the Schlieren imaging works on the principle that it captures the gradient in refractive index. Now I have a lighter here. If I press it, there is a flame coming out of the lighter that creates a gradient of the refractive index and that gets captured into the Schlieren.

So I will keep this flame in the test section and let us see how it appears when captured through the setup.

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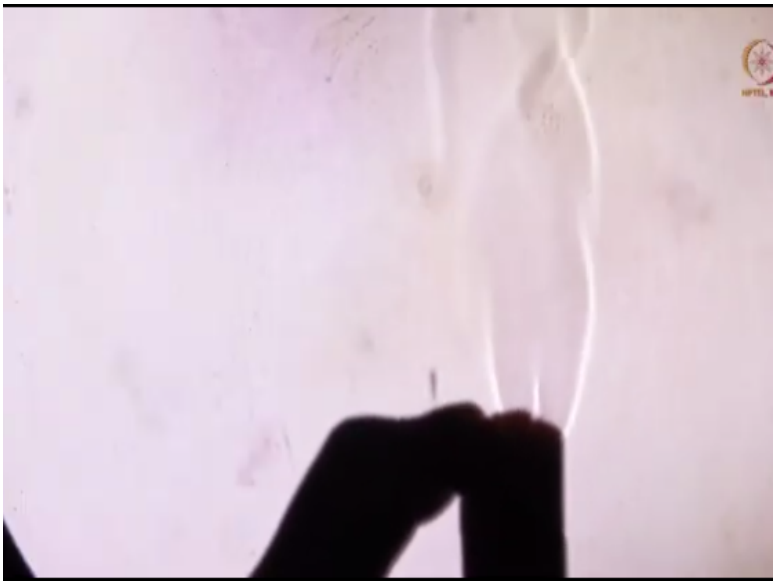

Now, if I partially raise this lighter, then there are combustible gases that are coming out of the lighter that have a different refractive index than the surrounding air. These gases are not visible by naked eye, but this can be easily captured through this Schlieren imaging setup. So let us see how it looks.

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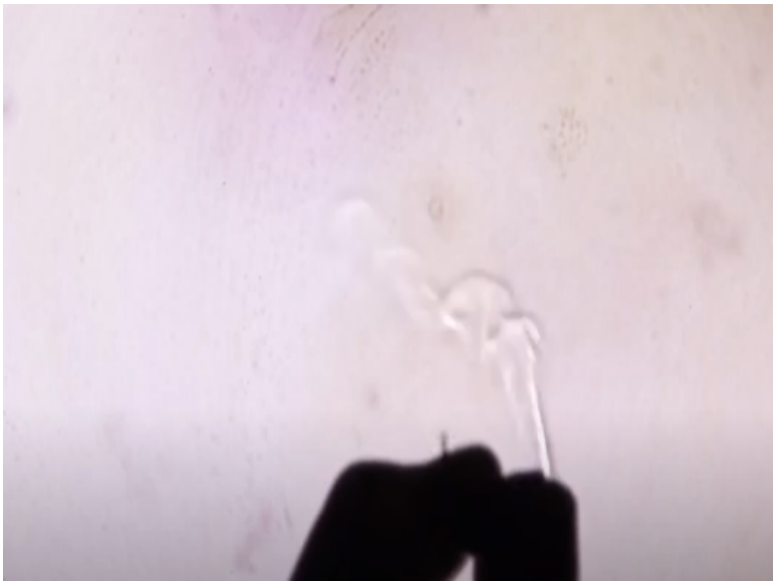

So I am partially pressing this lighter and keeping it in the test section and then let us see how it appears in this when captured through the setup. With this, we come to an end for this Schlieren imaging setup demonstration. And thank you.