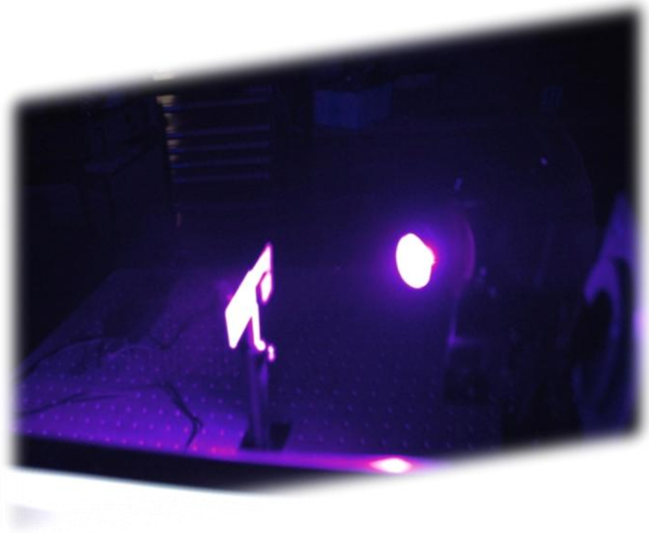
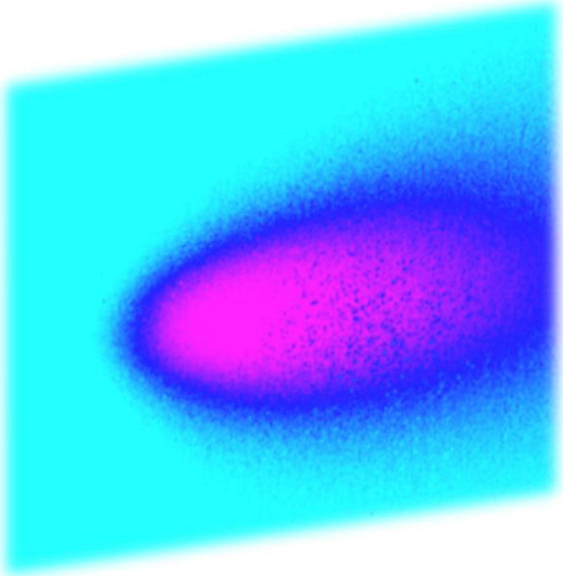
2009

Lab 2: PSP Data Acquisition and Processing





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Lab 2: PSP Data Acquisition and Processing

Introduction: Two programs are used to gather and analyze the PSP data. OMS Acquire Apogee is used to capture images and export them to a file for analysis, and OMS Lite is used to process the images and display pressure and temperature measurements. This experiment will introduce the experimental setup and cover the data acquisition and data reduction procedure.

Hardware: To acquire data, a CCD Alta U2000 camera from Apogee is used in sequence with a LM2X-DM 400 nm LED lamp. The LED lamp illuminates the painted test object exciting the luminescent probe in the paint. This probe is excited by the absorption of a photon. The emission from the probe is then captured by the CCD camera through a long-pass filter.

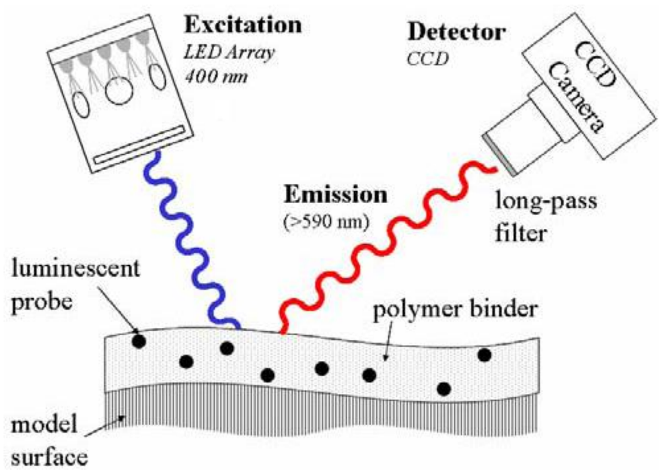


Figure 1: Experimental setup

The CCD camera connects to a computer with the OMS Acquire Apogee software to capture and record desired images. It is necessary to take images under three conditions to produce accurate, uncompromised pressure measurements. The three images that will be captured are a *background* image, a *wind-off* image, and a *wind-on* image. Factors that can compromise data are excess noise or illumination, such as ambient light in the test area from light sources other than the LED lamp. Before beginning setup, check to assure that all of the necessary equipment is present.

Figure 3: Alta U2000 CCD camera

Figure 2: LM2X-DM 400 nm LED lamp

Pictured are, the CCD camera (Figure 2) and LED lamp (Figure 3) each with their respective power supplies connected. Be sure that each power supply is present and that there is a 120V outlet to plug into. Next, be sure the laptop (Figure 4), its power supply, and a USB to USB 2.0 cable are present.

Figure 4: Laptop and USB to USB 2.0 cable

Figure 5: Mounting equipment and tools

A clean and open workspace will be needed to set up the experiment. Proper mounting brackets (Figure 5) and a sturdy workbench should be used to prevent the model and equipment from being moved or disturbed during data aqcuisition. Any movement in equipment or the model can result in innaccurate data.

<u>Experimental Setup:</u> Begin the setup by securing the mounting hardware to the test table. The camera, LED, and test object should be set up similar to Figure 6. Be sure all equipment is fastened tightly to the mounting brackets to avoid movement during data aqcuisition. The test object (left side of Figure 6) may need to be moved further or closer to the camera lens to focus depending on the size of the lens being used. Once all equipment is mounted securely, connect the power supplies and USB to USB 2.0 cable. The power supply that connects to the LED lamp needs to be attached so that the two holes and prongs line up. Once is it lined up, screw the retaining ring on clockwise. The power supply connection for the LED lamp is shown in Figure 8 and the power supply for the CCD camera is shown in Figure 7.

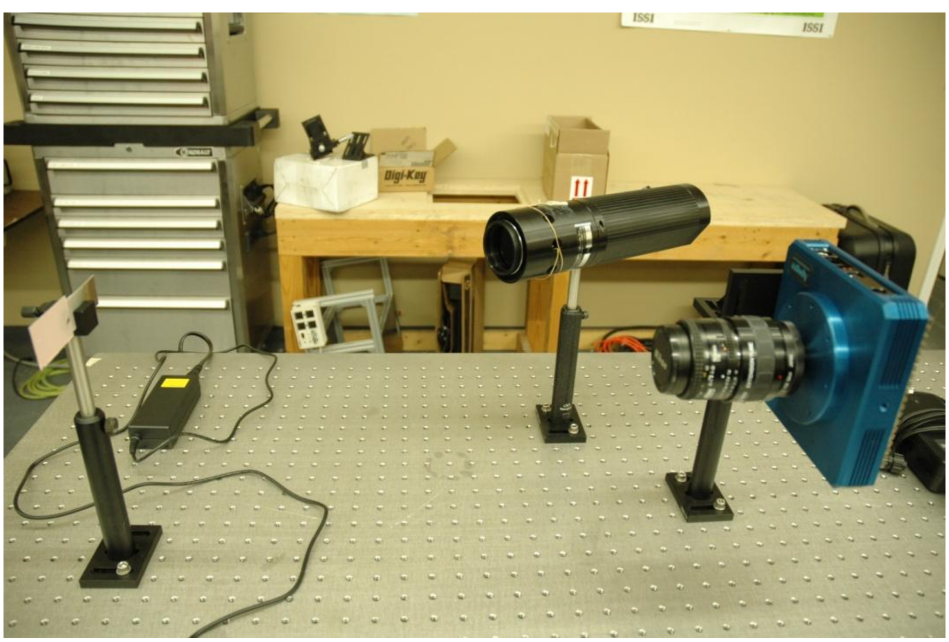


Figure 6: Equipment setup

Figure 7: CCD Camera Connections

Figure 8: LED Lamp power supply connection

Plug the power supplies into 120V outlets. The noise from the fans on the CCD camera and LED lamp will assure they are powered on. Open up the laptop and power it on. Once the desktop is displayed plug the other end (USB end) of the USB to USB 2.0 cable into one of the three available

USB outlets. The computer should recognize that the USB connection has been established with the camera.

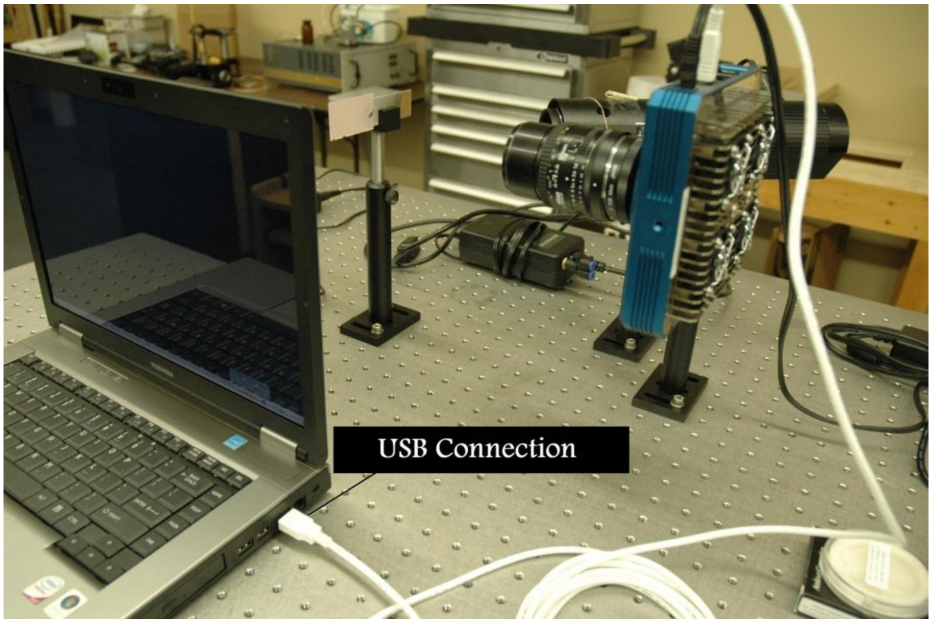


Figure 9: USB connection to laptop

Data Acquisition: Open up OMS Acquire Apogee by double-clicking on the  icon on the desktop. This will bring up the capture software in OMS Acquire and will look like the Figure 10.

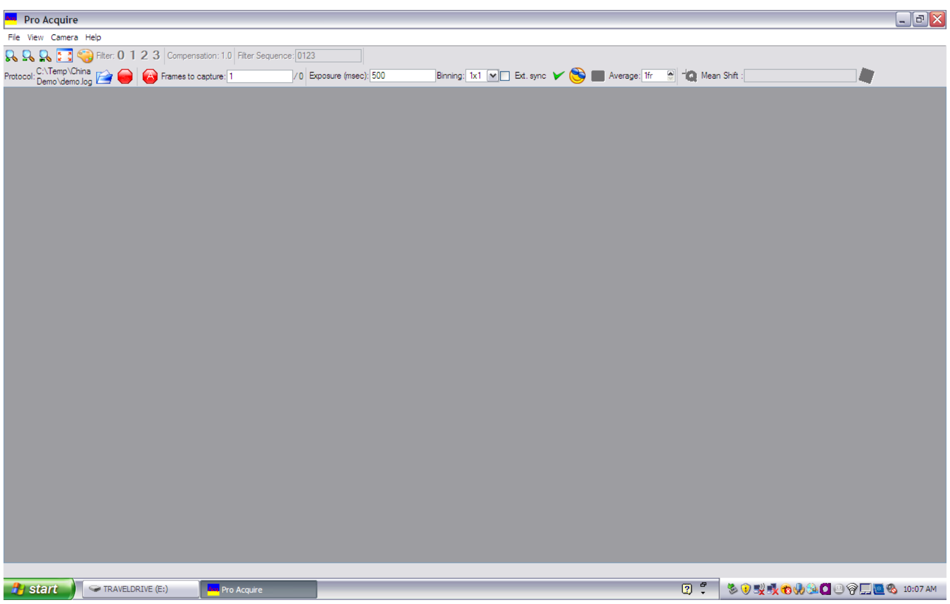


Figure 10: OMS Acquire main page

A new file folder will need to be created by the user for all data to be stored. Make sure to document the location of this file folder so that it can be easily found once all data is gathered. Once the new file folder is created, the file location path will need to be opened in OMS Acquire Apogee.

To open a new file path, click the  icon on the toolbar. This will bring up a window so that new folder can be selected. Locate the file folder that was created and select it in the drop-down menu at the top of the window. This folder is empty and will appear that way. Type in a file name in the empty box where is says 'File name:' and click save. The name typed in this box will be the name of the files located in this folder during each data acquisition. Each file will have a number extension attached to it and four images (reference and signal images) will be saved during each type of data capture (background, wind-on , wind-off). It is important to know which file is the background, and which are the wind-on, and wind-off, so name them accordingly during each capture to avoid confusion.

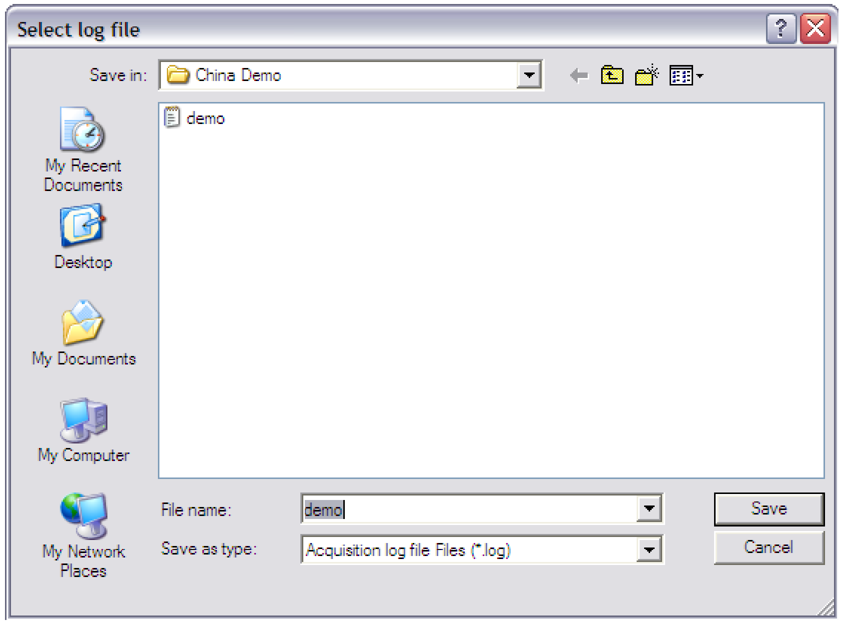
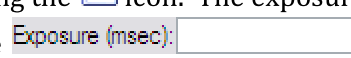
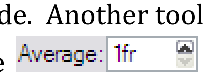


Figure 11: New log file window

The test object will need to be placed at the appropriate distance from the camera so that it is easily focused in the lens. To view a live preview of the image, click the  icon or press Ctrl+P. This will display a live view of what the camera is seeing and allow the user to focus the camera lens. The preview can be made full-screen by clicking the  icon. The exposure time can be adjusted by entering a value (in milliseconds) in the 

box. The exposure time is the time that the aperture is open and the image sensor is exposed to light. In a darker environment, a longer exposure time may be desired to allow more light in so that the camera receives more light. Adjust the exposure time accordingly in the live preview mode. Another tool to clarify the image is the frame averaging tool. This can be adjusted by use of the 

box. Averaging more frames per image gives more signal data and a better signal-to-noise ratio.

To capture a single image, click the  icon. To capture multiple images, click the  icon and specify the number of images next to the icon. An adjustment to the color palette can be applied to the image for better clarity. This tool, opened by clicking the  icon, will bring up the window in Figure 12. It allows the user to adjust the paint min and max for the image. The paint max is the signal level associated with the top of the color map and the paint min is the signal level associated with the bottom of the color map. These values, by default, are set to the minimum and maximum signal level of the image displayed. These values can be adjusted to enhance the features of a desired area of the image. The palette can also be adjusted to a color scale or grayscale that can enhance features of the image as well. This can also be done in OMS Lite during data processing.

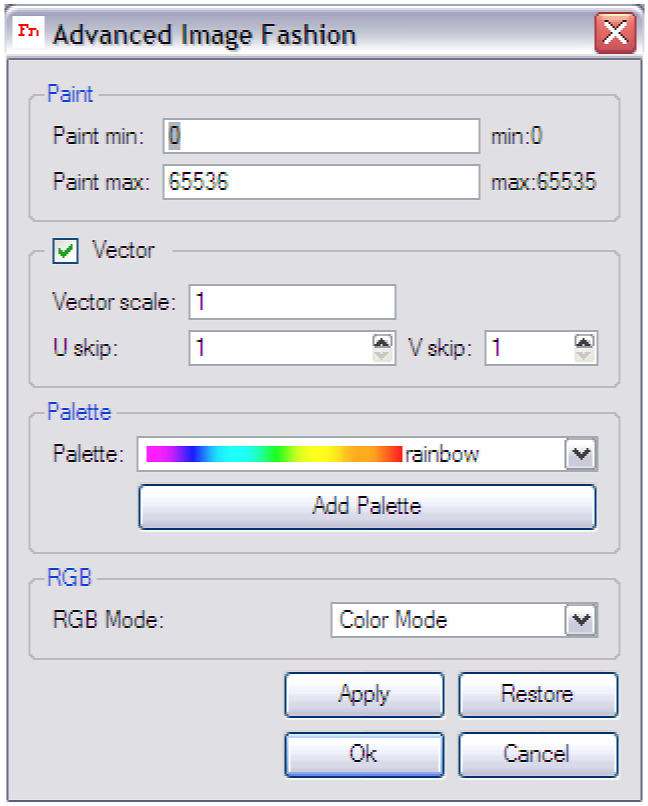


Figure 12: Advanced Image Fashion window

The first image that should be captured is the background image. This image is captured to compensate for any ambient light present. Take the background image with the LED lamp and any room lighting turned OFF.

Figure 13: Background Image

The background image is just that, the background or backdrop of the camera's view during data acquisition. The background image is subtracted from the wind-off and wind-on images to remove the effects of ambient light present in the room.

The next image to be taken is the wind-off condition image. For this condition, the painted test object should be imaged with the LED lamp turned on for several minutes to stabilize as seen below. It is important to let the LED lamp remain on for several minutes before the image is acquired so that it reaches equilibrium. To turn the LED lamp on, flip the switch by pulling up and pushing towards the side labeled 'Cont.'.

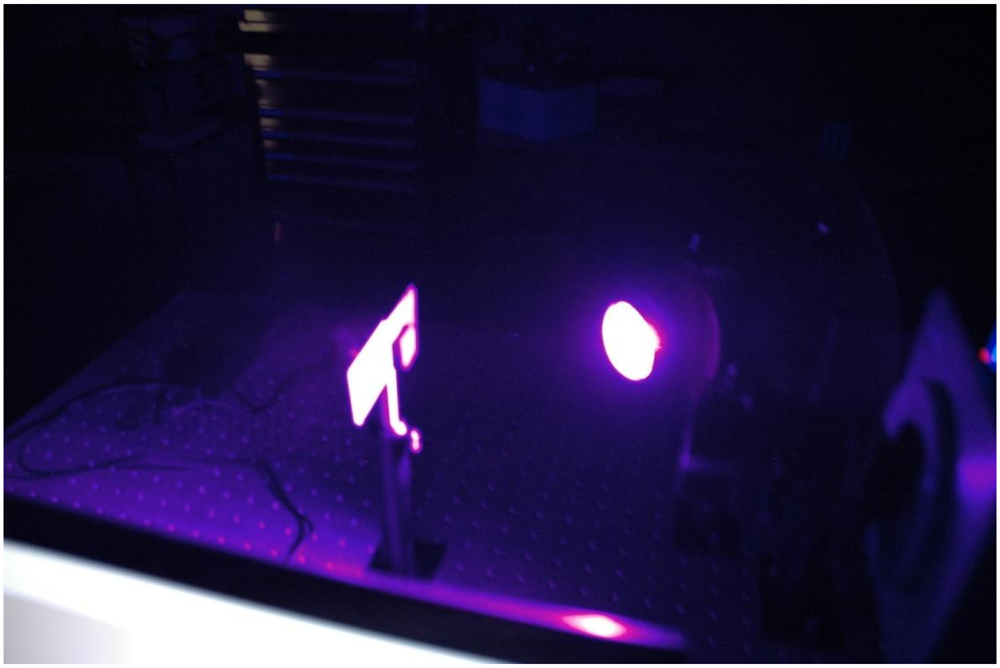


Figure 14: Acquiring the wind-off image

The wind-off image is taken without any load being applied to the test object and shows the illumination of the paint at static, ambient conditions. This image is used to remove the static conditions from the wind-on image by taking a ratio of the two images.

The final image to be acquired is at the wind-on condition. For this image, a jet (can of dust-off) is directed towards the surface of the test object at a known angle α. Be sure the jet is held close to the surface so that a clear pressure difference is detected on the surface of the test object.

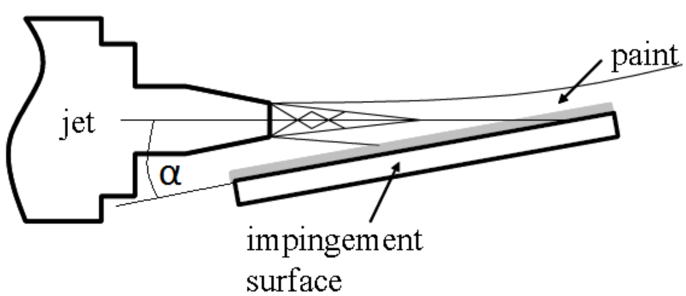


Figure 15: Wind-on condition setup

Be sure to leave the jet on until the image has been captured (it may take a few seconds). All images needed for data processing are now acquired and stored in the folder created by the user.

Data Reduction: Reducing the data into an image of pressure involves taking the ratio of the wind-off / wind-on images and then calibrating the image to relate the ratio to pressure.

Creating a new project: Begin by opening up the program OMS Lite by double-clicking the icon on the desktop. Create a new project by clicking the icon. A message will come up asking the user to choose the type of experiment they wish to run. Select the PSP Single Channel and click OK.

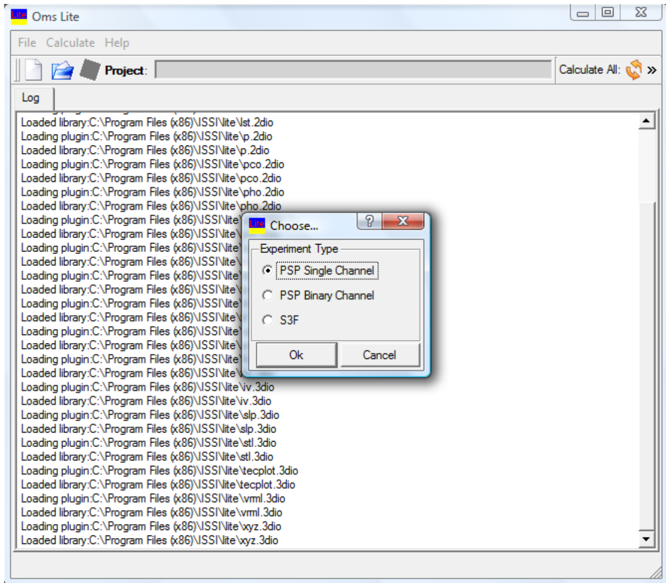


Figure 16: Select experiment type

The user will now be asked to create a file name for the new data reduction case. Type the desired name (*impinging_jet.ims)* into the box labeled ‘File name:’ and click save. Locate the new folder you created earlier where the images are saved and save the file there. This can be opened by clicking the icon in Figure 16 and selecting the file.

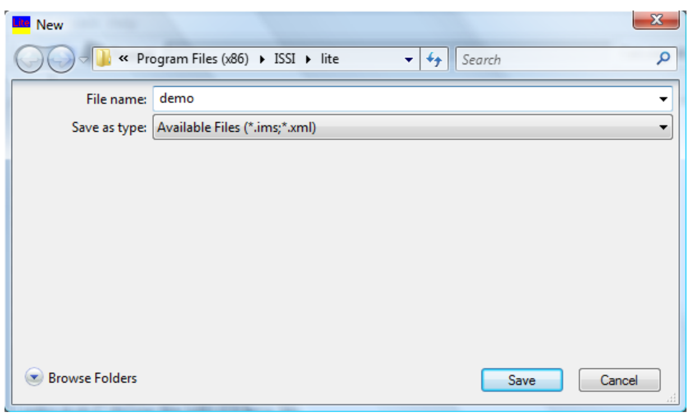
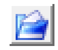


Figure 17: Save a new experiment

Once the new file has been saved, the OMS Lite project window (Figure 18) will appear. This window will allow the user to import the wind-on, wind-off, and background images into OMS Lite.

Select and load source images: Import the images by clicking the  icon next to the boxes labeled Wind Off, Wind On, and Background (the same background should be used for both conditions).

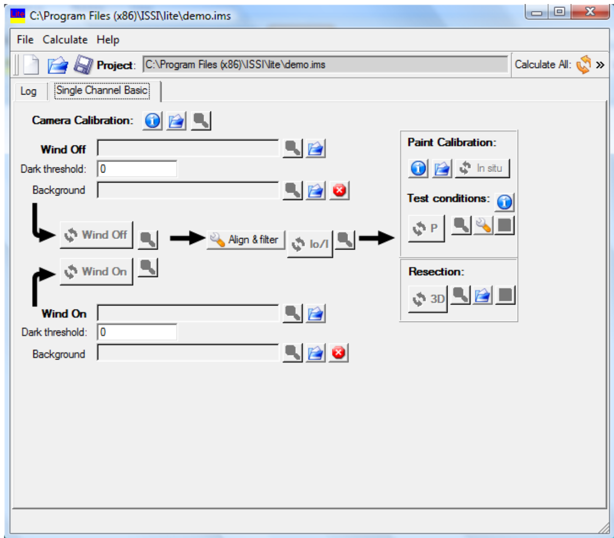


Figure 18: Single Channel tab of OMS Lite

Locate the file folder that was created during data acquisition where all of the images are stored. You will notice that there are four images from each image capture done in OMS Acquire. The four images for each capture represent the different pixel colors associated with the camera's filter (red, green, and blue).

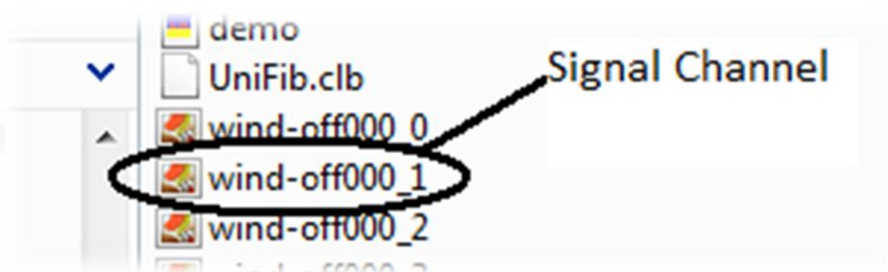


Figure 19: Selecting an image

The red image is the signal channel (pressure) and the others are reference channels. In the case of the camera used in this test, the signal channel was 1, but that may differ from camera to camera. The signals channel is the channel that should be used in data reduction. To determine what channel is the signal channel, load each image into OMS Lite and examine them by using the magnifying glass icon. The image with the highest intensity will be the signal channel. You will notice a distinct contrast in the signal channel image versus the reference channel images. The signal channel image will appear similar to Figure 20 and the reference channel will be the same image but lower in intensity.

View and interrogate and image using the viewer: Once the *wind-off*, *wind-on*, and *background* images have been loaded, they can be viewed by clicking the  icon next to each box. An image similar to the Figure 20 will then appear on the screen. Open up each saved image and view to assure the correct pressure image (red) is being used. Note that the toolbar at the top of the image window includes tools for saving (), zooming (), and probing () the image as well as a set of tools for working with markers (Add, Move, Delete, Toggle). Select the Probe button to inspect the signal level of the image at a selected location. Determine the signal level of the image at a given location by moving the mouse to that location and left clicking the mouse. The location and signal level will appear at the bottom of the window. It is also necessary to view these raw images to determine what the dark threshold should be set at. PSP measurements are based on the measurement of the luminescent signal intensity from the painted surface. It is not uncommon for some regions of the surface to produce substantially smaller signals than the bulk of the painted surface. This may be due to poor illumination, physical damage to the paint (chipping), or the presence of markers on the surface that are used for image alignment. If the signal level is too low in a given region, the signal to noise ratio is not sufficient to yield meaningful data. These regions should be excluded from the remainder of the data processing as they will yield inaccurate data. The  (Modify) button may be used to change the upper and lower limits of the display as well as select the color palette for the current display. Selecting the  (Modify) button causes the Advanced Image Fashion panel to appear as shown in Figure 21.

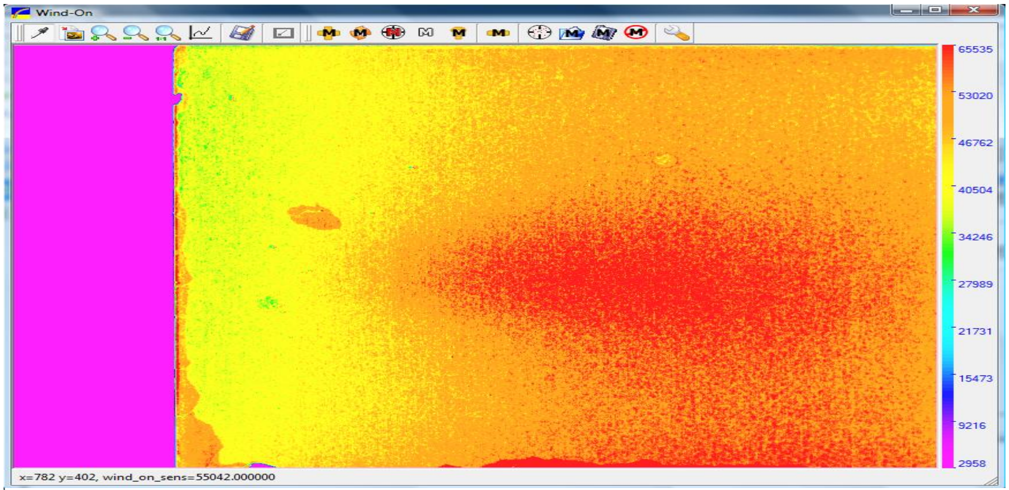


Figure 20: Raw wind-on image

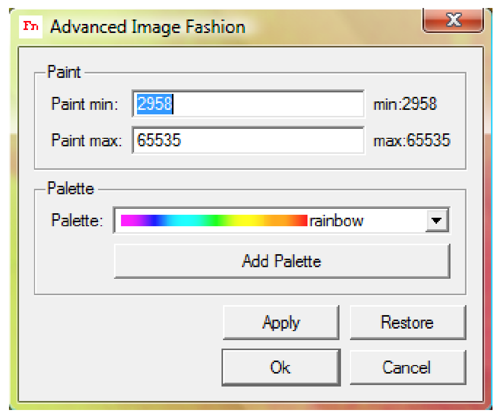
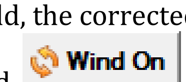


Figure 21: Advanced Image Fashion

Notice in the raw image (Figure 20), any value below about 9000 signal level appears to be background noise. This is not desirable data so it is eliminated by setting the dark threshold to 9000 for this case. Set the dark threshold where it says 'Dark threshold' in Figure 18. Upon setting the dark threshold, the corrected wind-off, and wind-on images can be computed by clicking the 

, and 

icons. This will give a view of the image with background noise eliminated and with the dark threshold noise filtered. Figure 22 shows this corrected image.

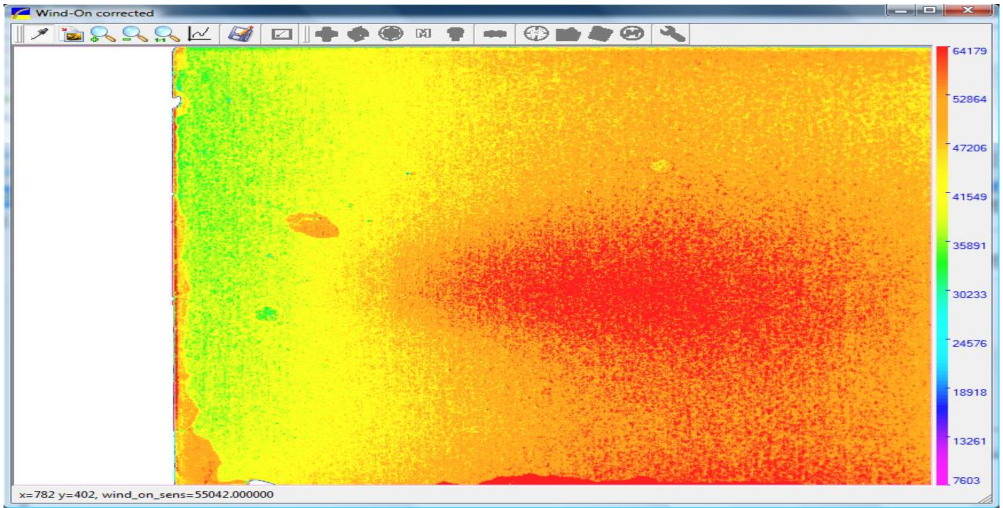


Figure 22: Corrected wind-on image

Notice the difference in the raw and corrected images. It can be observed that the background signal noise has been eliminated.

Align, ratio, and filter: The next step in the data reduction process is computing the ratio of the wind-off over the wind-on image. This ratio will then be converted to pressure using the calibration of the PSP. Click the 

icon to bring up a window (Figure 23) with alignment and filtering options. The noise level on the ratio image can be improved by applying a low-pass filter to the image after taking the ratio. In OMS Lite, this is accomplished by using the Filter option in the Alignment and Filtering panel (Figure 23). The low-pass filter options include Flat, Gauss, and Median filters. The size of the filter is set using the Dx: and Dy: boxes. For this example, we will apply a (Dx:) 3 pixel by (Dy:) 3 pixel Flat filter to the image. It is important to remember that the spatial resolution of the final image will be reduced by the application of a low-pass filter. The size of the filter should be selected to smooth the data without compromising the spatial resolution unnecessarily. Finally, minimum and maximum limits may be set that will exclude data that is out of the prescribed range by use of the Threshold option. This will exclude any intensity level out of that range. OMS Lite also includes two image alignment procedures: Markers and QPED. Both procedures attempt to determine the shift between the wind-off and wind-on image. The wind-on image is then shifted or mapped onto the wind-off image before the image ratio is computed. For this example the QPED algorithm is used. This procedure attempts to use a cross-correlation procedure to detect and correct for slight movement between the wind-off and wind-on images. The QPED alignment procedure is activated by checking the QPED box in the Alignment and Filtering window (Figure 23). For this experiment use the numbers shown in Figure 23 to align and filter the image ratio.

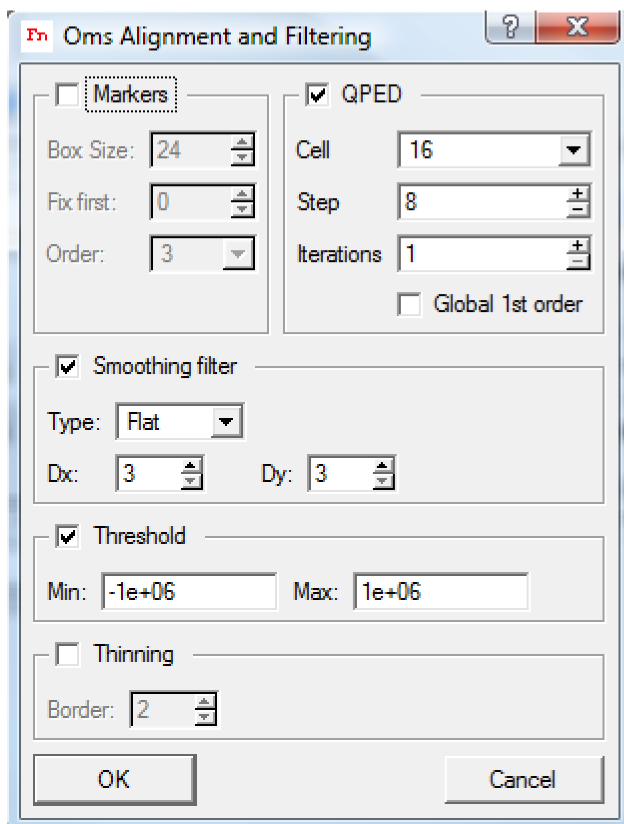


Figure 23: Alignment and Filtering

Now that the alignment and filtering options have been set, the ratio image can be computed by clicking the Io/I button. This image is viewed by clicking the icon next to the ratio button. Note that the ratio image (Figure 24) is more detailed and eliminates noise seen in the wind-on and wind-off images. Without the alignment and filter options being applied, the pressure difference would be difficult to see any detail in the ratio image.

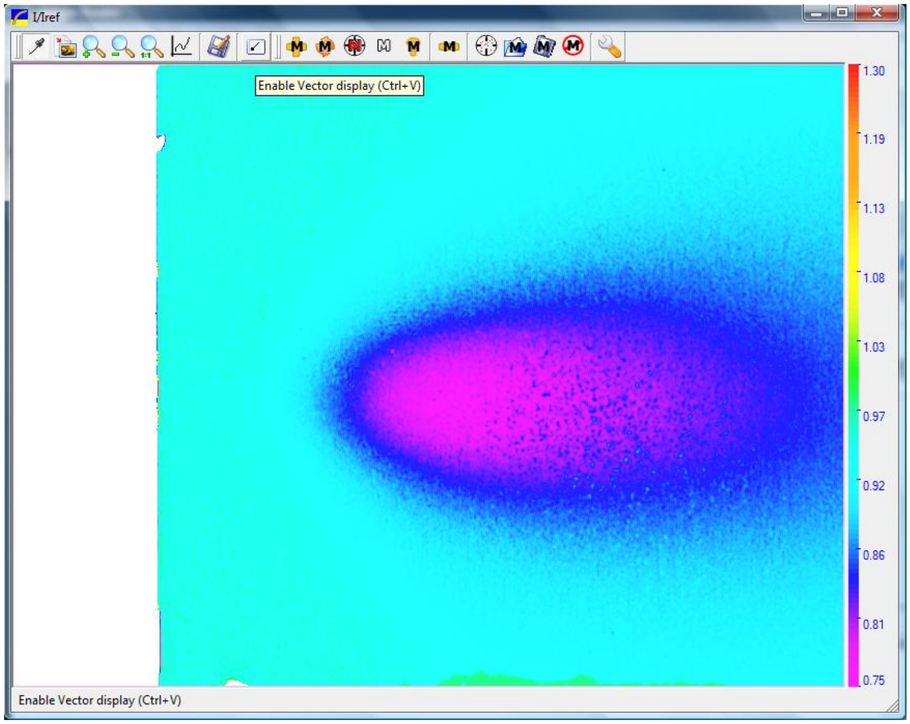


Figure 24: Ratio Image

Experiment with each filter option to observe its effect on the ratio image. This image will usually appear with a vector field displayed. To eliminate the vector field, click on the icon in the toolbar.

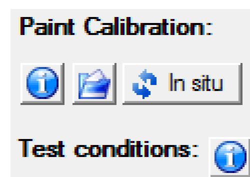


Figure 25: Paint Calibration

Convert to Pressure: The final step of the data reduction is to convert the ratio image to pressure. This may be done using either an in-situ (in place) or a-priori calibration. The a-priori process will be demonstrated here. The paint calibration can be loaded automatically by clicking the icon. The paint calibration parameters can also be entered manually by clicking the icon beneath where it says 'Paint Calibration'. The tools for doing either are in the 'Paint Calibration and Test Conditions' block (Figure 25). When automatically loading a paint calibration, a window will appear and the file UniFib.clb will appear in the selection box. Click on the file and open it. Now that the paint calibration file has been uploaded, the test conditions need to be entered. These conditions can be entered by clicking the icon next to where it says 'Test conditions' in

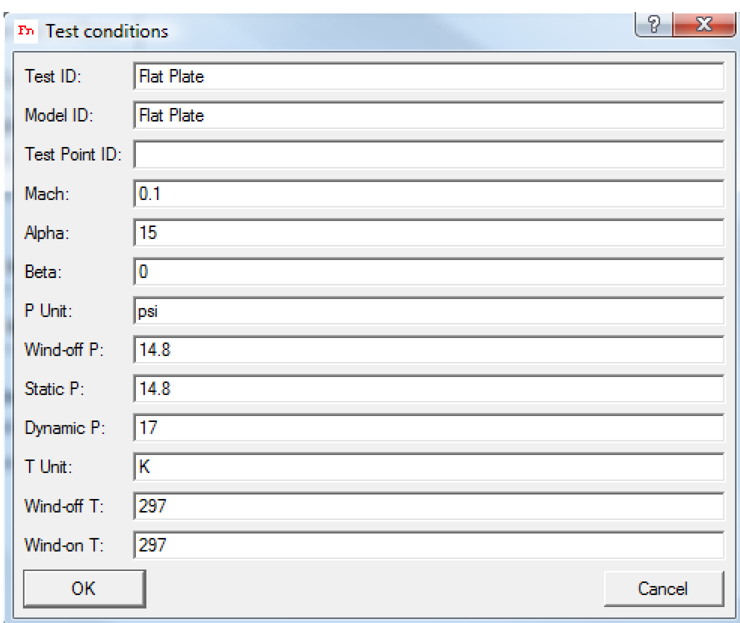


Figure 26: Test Conditions window

the Figure 25. This will open up a window which allows the user to enter the test conditions present at the test site (Figure 26). Be sure to enter the appropriate units for pressure (Pa, psi) in the 'P Unit' box and for temperature (K,C) in the 'T Unit' box. 'Static P' is the atmospheric pressure at the test site. The box labeled 'Alpha' is the angle at which the jet is incident on the impingement surface and 'Beta' is the angle at which the object is pitched left or right on an x-y plane (yaw). For this experiment, the test conditions shown in Figure 26 are appropriate.

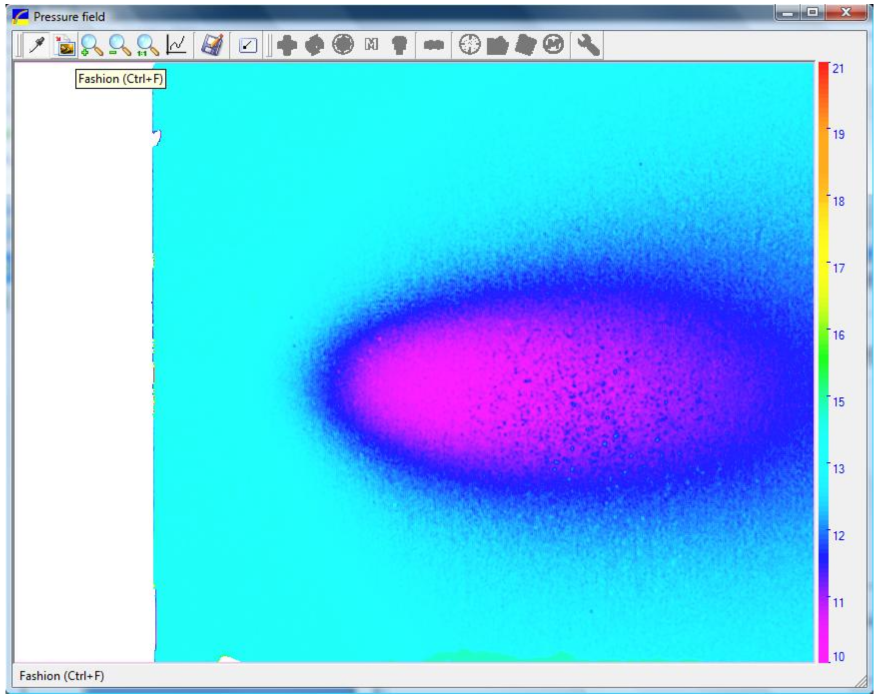


Figure 27: Pressure field

Now that the test conditions have been entered, the image can be converted to pressure. Process the pressure image by clicking the  icon. Once the image has been calculated, view it by clicking the  icon next to processing button. This image can then be interrogated, scaled, or mapped by use of the advanced image fashion tool () in the toolbar of the image. Figure 27 shows the final pressure field that is computed. This image can be saved () and graphical data can be taken off of it by use of the  tool. To use the graphing tool place the cursor over the image, left click and hold. Drag the line across the picture and then release left click. A graph (Figure 28) will now appear on the screen that shows the pressure distribution over the prescribed location. The Data Range function allows the user to set a new field minimum and maximum for the graph. This graph can be saved by clicking the  icon.

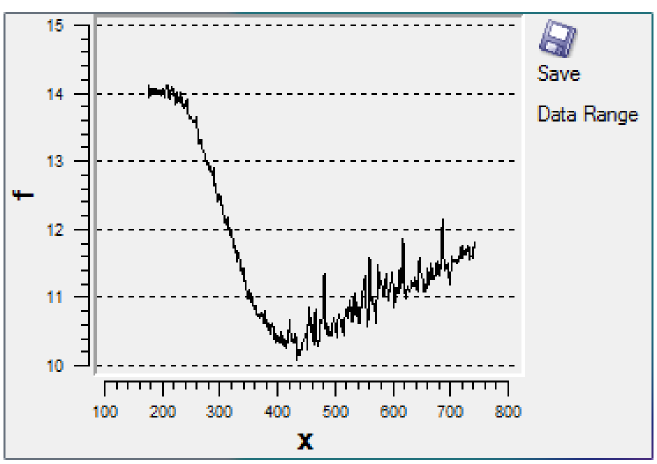


Figure 28: Pressure field distribution

The reason the area of high pressure appears as an area of low pressure is because the PSP is sensitive to the partial pressure of oxygen. Since the oxygen was pushed away during wind-on conditions by the dust-off (not oxygen), it appears as an area of low pressure.