# Understanding '1st Camera Max Centers 2.vi'

Main Idea: The code identifies the five centerlines of the laser and by measurement the pixels that are 'seeing' the lines it is able to calculate the height of an object. The code makes the conversion to micrometers and writes data into an Excel file.

Requirements and Installation: In order to make the program to run the camera needs to be connected to the pc and to LABView, and the 'NI Vision Acquisition' package must be installed. Connecting the camera through a 3.0 USB port should do the first one. For the second requirement, open 'NI MAX'; this should be on your Desktop or in your LABView folder. On the left side of the window, click the 'Devices and Interfaces' arrow and the list of all devices connected should appear. Select 'Basler acA2500-14 um "camX"'. If you do not see this list, you might have clicked on the words of 'Devices and Interfaces' instead of the arrow, tried again. If you have selected, you should have a window similar to the one shown below.
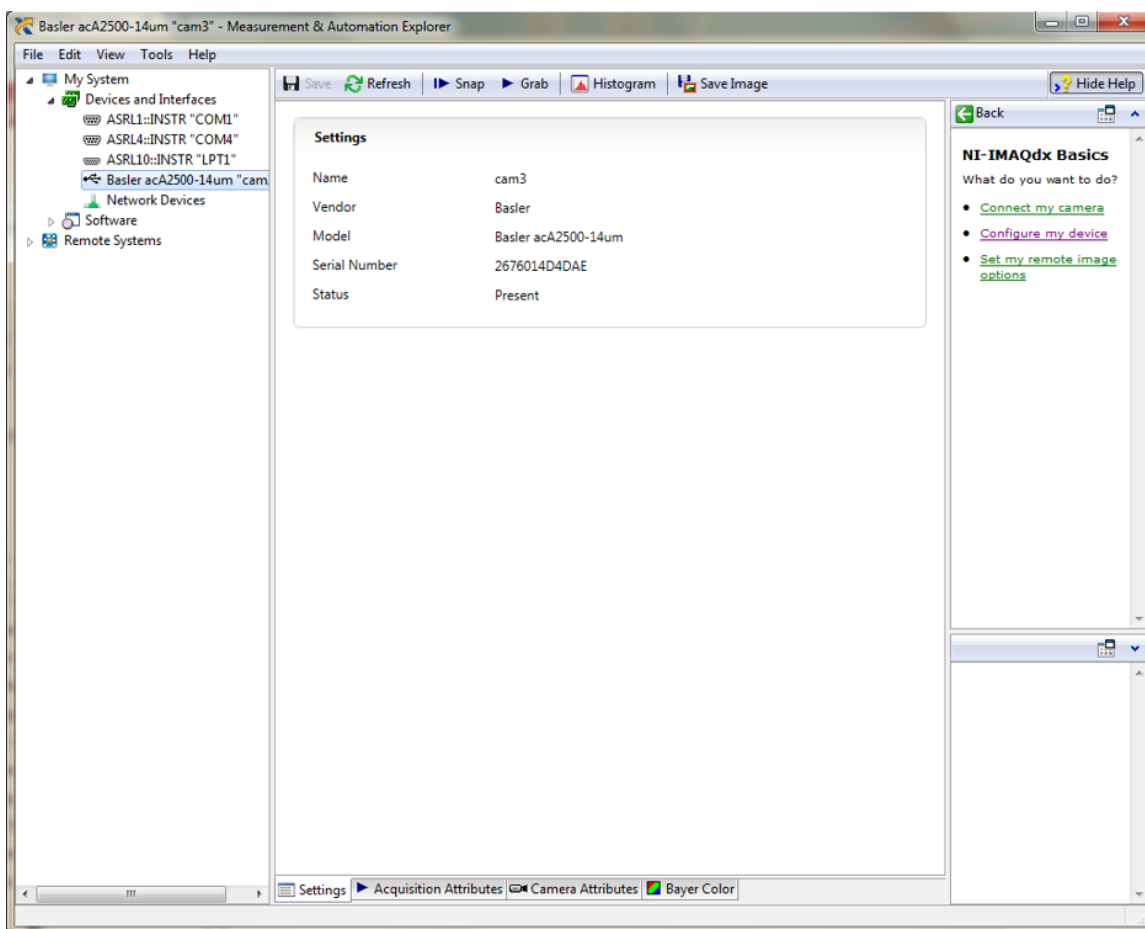
There are three things you need to check to connect the camera correctly to LABView.

1. On the list under 'Devices and Interfaces', right click on the camera and select 'Driver'. On the left side of the window click the 'Devices and Interfaces' arrow and the devices connected should appear. Two options should be available. First, 'Basler ace USB3 Vision Camera' should be selected if we want to use the camera in its own program. The second one, 'NI-IMAQdx USB3 Vision Device' should be selected in order to connected to all the National Instruments (NI) programs including LABView. A good test to make sure the camera is connected properly is clicking 'Snap' on top of the window and a quick photo from the camera should appear at the center of the window. Make sure you right click the image, select 'Viewer Tools' and click 'Zoom to Fit' to be able to see the entire FOV of the camera. It is important to keep in mind that the camera would not connect to our code until 'NI MAX' is closed, but if you can see this photo in 'NI MAX' all should be connected correctly once you close it.
2. Right click again on the camera as in [1] but this time clicks on 'Rename…' and select the camera's name. The default name should be 'cam0', but it is recommended to change the number (i.e. 'cam3') because the code can be confused if there is more than one camera or if new devices are connected. This name should be the one used on the code.
3. On the button of the window, select 'Acquisition Attributes' (or just click 'Snap' as in [1]). Go to 'Pixel Format' and change it to 'Mono 12' and then, go to 'Output Image Type' just below it, and choose 'Grayscale (U16)'.

One last thing must be done before running the program. An Excel file needs to be open with the same file and sheet name as the inputs in the code under 'Workbook Name' and 'Sheet Name'. If the file is not open, the code will not run.

For the observable object, it is necessary to have a plate of known height to be used as reference point. All the objects that are going to be measured need to be place on top of the plate. In our case, the stave is the plate and any flaw or defect will be measured.

This tutorial assumed that the laser, camera and filter (660 um) are the same used at Iowa State. The version of 64bit of LABView is not compatible with this code; please use the 32bit version.

Setting the interface and Running the program: Once all the previous conditions are met, the program is ready to run. However, there are some parameters that need to be entered manually and that are crucial to the measurements. For the stave case, they should be entered just once and keep the system isolated, otherwise a new calibration needs to be done. For this part of the explanation, we assumed the experiment is calibrated and aligned, as it will be explained in some future section.
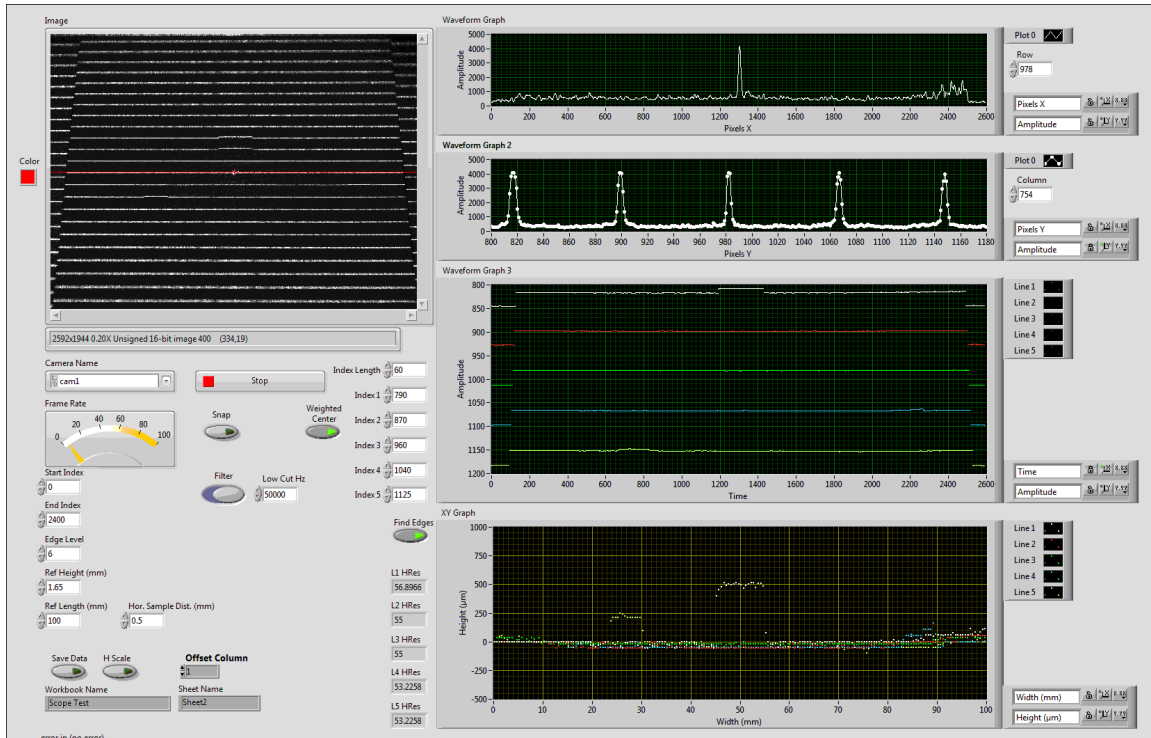
Before running the code, all the options should be turned off except the filter. Make sure the input of 'Camera Name' coincides with the one in 'NI MAX'. Also, and as we mentioned before, the name of the Excel file needs to be exactly the same as the inputs in 'Workbook Name' and 'Sheet Name' even if not data is being taken. To start the program, just click the black arrow at the left-top corner of the window as any LABView program. To stop it, click the 'stop' sign next to it or press the 'Stop' button that is on the left of the camera name. For zooming into the screen, just click in the desired area. To return to the entire Field of View (FOV) of the camera, right click on the screen and select the option 'Zoom to Fit'.

Three reference lines are used in this code; two blues and one red. They are always shown on the screen except is the 'Clear Overlay' button is pressed. The red line shows the center horizontal line of the camera's FOV. If you look closely, there is a cross in the middle of that line, which represents the center vertical line. The laser has a bright dot at the center of its center-line indicating the center of the laser. If these two are in the same position on the screen, the camera is centered with respect to the laser.

The two blue lines have different purposes. The horizontal one would be used latter for calibrating the preset of the 'Find Edges' subroutine, so for now we are not going to talk about the main purpose of it. However, it shows the line of pixels in the x-direction (choosing the x-axis to be the horizontal axis as usual) and plots their intensity amplitude in the first graph on the right side of the screen called 'Row'. The position of this line can be easily change by changing the number in 'Row' at the right of this plot.

The vertical blue line has a similar idea; it shows the intensity of the selected pixels and plots them on the graph called 'Column'. The position can be change at the 'Column' box on the right. In our experiment, we are only using five of the laser lines; then this blue line should be covering only those fives. To change the length of this line, right click on the 'Column' graph when the code is not running, and select the option 'Properties'. Under the tab 'Scales', select 'Pixels Y (X-Axis)' and unselect 'Autoscale'. You must enter the values for 'Minimum' and 'Maximum' and then click 'OK'. To find the values that apply to your own experiment and setup, you will need to check the image from the camera and check with the cursor the position of the lines. The camera should 'only' see the lines due to its filter, then the lines should be very sharp as shown in the below graph. Intensity will change depending on the surface's material. Darker material as the one used in this plot reduces the amplitude since it does not reflect too much of the line while lighter lines can reflect a larger percentage.
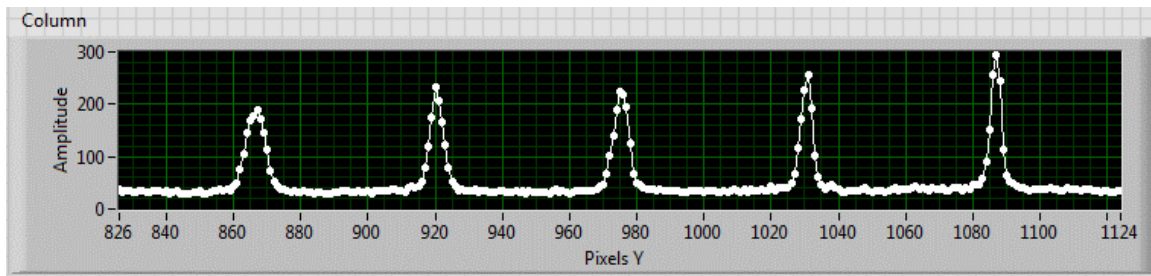

It is important to noticed that there is a maximum saturation for the pixels, and it was modified in the step 3 of the 'Requirements and Installation' section. The limit is 4,096; if the step 3 is omitted then the limit is only 256.

The next step is to fill these five boxes. In our experiment, it is required to have a plate or reference base as seen in the figure below. The camera's FOV should include the plate entirely in the x-direction including a small part of the base at both sides to

use as reference points. There is no condition with respect to the y-direction since that is the dimension for the stave's length, and we expect to be over a meter and a half. When the stave is moving with the linear stage, it moves in the y-direction of the camera, but the edges and the position of the stave in x remains the same. In our experiment, we will have a stave instead of a plate, and flaws instead of objects.
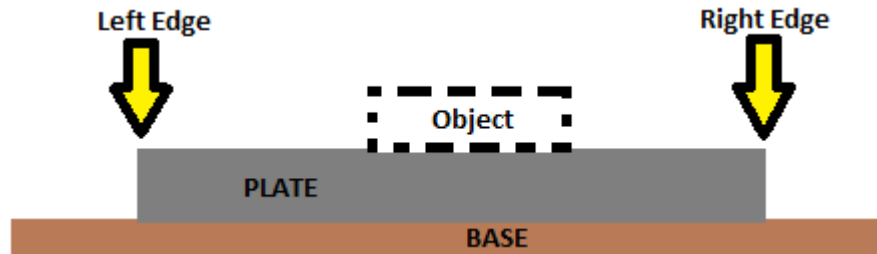
There is a subroutine called 'Find Edges' that will find both edges of the plate and calculate de height of the objects. This subroutine looks for edges from left to right. The user should give indication to the code where these edges are. The first button 'Start Index' should be at the left of the left edge, and 'End Index' at the left of the right edge. Around a hundred pixels apart from the actual edges of the plate would be enough. You can find those numbers by looking at the camera, or by looking at the 'Line Centers' graph where the pixels used in x and y are shown. Be careful because the lines are not the same due to the angle of the camera; then, it is better to select these numbers with respect to the closer line to the camera, i.e., the yellow line in the 'Line Centers' graph.

The button 'Edge Level' will tell to the 'Find Edges' subroutine the difference in number of pixels need to consider it an edge. 'Ref Height (mm)' refers to the height of the plate with respect to the base, and 'Ref Width (mm)' its measured width across the x-direction of the camera's FOV. There is another button at the left of 'Ref Width (mm)' called 'Hor. Sample Distribution (mm)' that we will explain it latter, but we recommend keep it at 0.5 mm. There is a button called 'Filter' that works as a low pass filter if it is on with a cutoff frequency indicated by the box named 'Low Cut Hz' usually at 40,000.

Before explaining the next buttons and parameters at the front panel, we will discuss how the camera measures the height of an object. The camera has a filter with the same wavelength that the laser has, making the camera 'blind' to other light present in the room. The laser line will have different height depending on the object where it lies. If we only have the base and the plate as Figure (a), the camera will see part of the line with a different line of pixels for the base than for the plate. In the case where there is an object on top of the plate as in Figure (b), then three different lines of pixels will be reading the laser line.

Figure (a)   Figure (b)
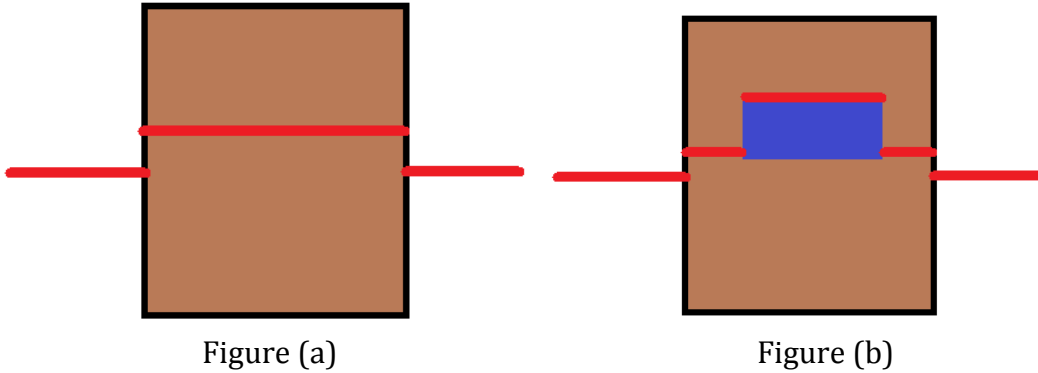
The key is finding the pixels that are reading each section of the laser line. For this, an area of search is defined per each line as shown in Figure (c) in dash line. Each vertical line inside this observable area will find the pixels with maximum amplitude and assume that is the pixels where the laser line is. One the entire scanner is over, the program should have the shape of the laser line in terms of the pixels in the camera and can be seen in the 'Line Centers' graph.
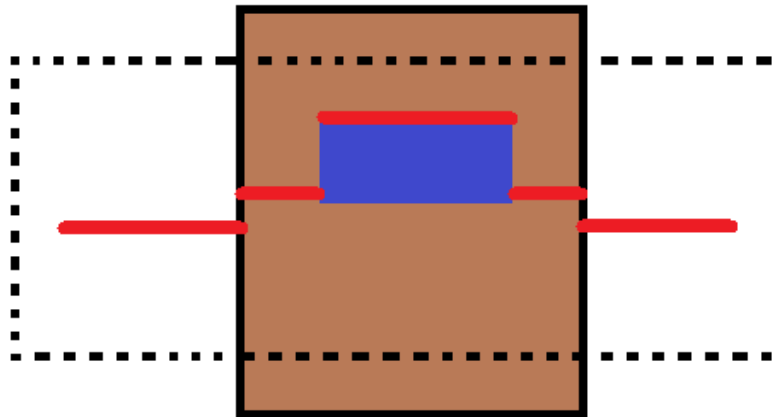

Figure (c)

The camera finds the maximum using two similar methods assuming that the amplitude created by the laser line has a Gaussian shape. The first method, finds the pixel with the maximum amplitude. In case of many pixels having the same value (for example, in case of saturated pixels), the code chooses the first pixel to have the maximum value. Then, the code counts the number of pixels with at least half of the maximum amplitude at each side of the maximum pixel. The difference between the number of pixels to the right and to the left is calculated, divided by two, and added to the position of the pixel with the maximum amplitude. This value is assumed to be the center of the laser line, and the pixel numbers is recorded.

There is a second method called 'weighted center', which takes into account the amplitude of each pixel. The position of all the pixels that have at least half of the maximum amplitude are multiple with their amplitude, and then divided by the sum of all of their amplitudes. This numbers is added to the position of the original pixel with the maximum amplitude. This method is more accurate especially when there are saturated pixels; however, observations have shown that both methods give similar results. There is button called 'Weighted Center' that selects either the first or the second method. It is recommended to have it always on.
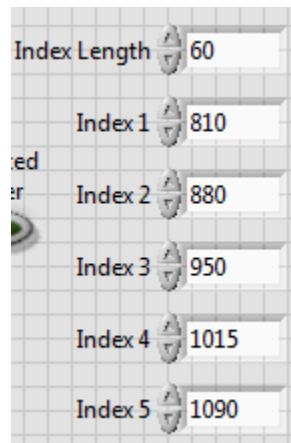

Now, we are focusing in how to select the observable area for the lines. There are two parameters needed for this: the initial line in the x-direction and the number of pixels in the y-direction. The number of pixels in the y-direction would be the same for all the lines and it can be changed in the box 'Index Length'. The starting line in the x-direction is different for each line and needs to be input at the corresponding box called 'Index N'. It is important to mention that the y-axis increases from top to bottom so this first line in always the top line of the observable area.

The observable area needs to be well defined with these two parameters in order to the program to function correctly. Many problems and mistakes can appeared if these parameters are wrong; we will mentioned some of them.

1. The observable area needs to include three parts: the base, the plate and the object. The program will always find a maximum even if it is not a laser line, so it is important to make sure the laser line is actually inside the observable area.
2. Remember that the five lines have different conditions due to the angle with respect to the camera. Make sure that (1) is satisfied for all five lines, especially for the furthest one (white line).
3. It can happened that due to the angle of the camera, two laser lines appear in the same observable area confusing the program. Make sure only the same laser line is inside the corresponding observable area.

4. If the plate's height is too big, it is possible that the line seen as base in the observable area is in fact part of another laser line. This will affect the calculation, as we will see later.
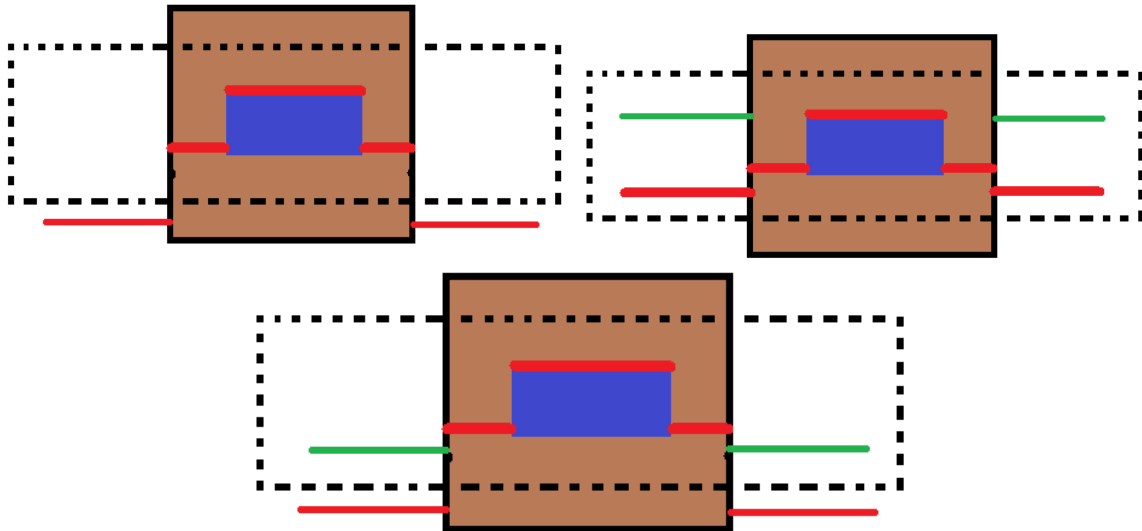

Once all these parameters have been correctly entered, a plot in the 'Line Centers' should look as the graph below. The color's label of each line is at the right of the plot.
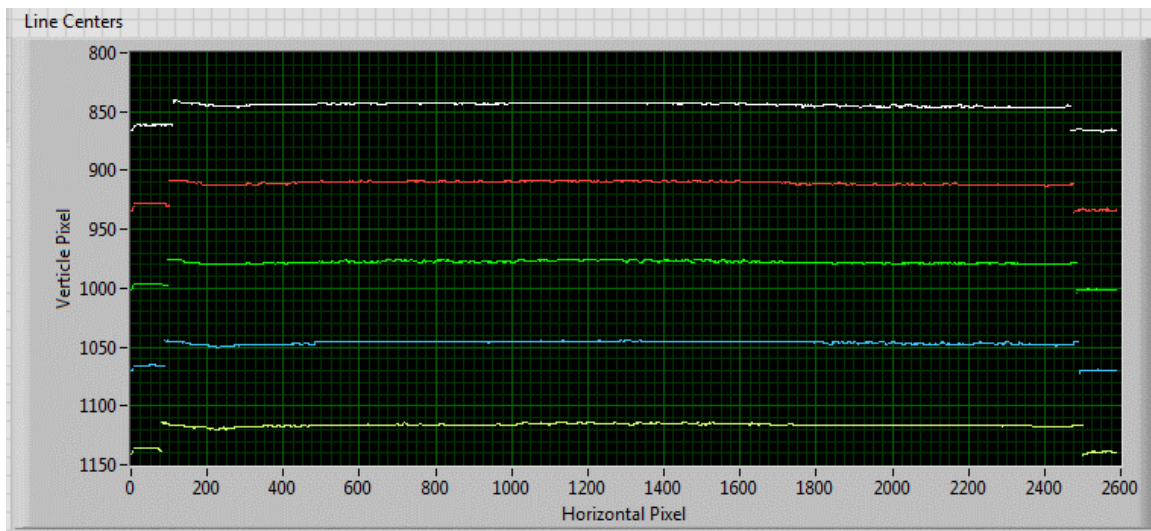
At this point, we can turn on the 'Find Edges' subroutine. This code will find the edges (left and right) as indicated by the 'Edge Level'. Since this height is know in 'Ref Height (mm)', the subroutine finds the number of pixels in this gap and finds the height resolution for each line. It also counts the number of pixels between both edges and finds the resolution in the x-direction by using the length of the plate entered at 'Ref Length (mm)'. Each line will have different resolutions due to the

angle of the camera, and they will be applied for any object or flaw on the plate's surface. With these resolutions, the subroutine will calculate the object's height in um instead of number of pixels choosing zero as the base of each line. All fives lines should be plotted in the 'Surface Plot' excluding the part on the base. The points on the x-axis are plotted as indicated by the box 'Hor. Sample Dist. (mm)' usually set at 0.5 mm. If there is an object at the plate's surface, this graph should look as the graph below. There is the option of using a present by selecting the option 'Set Present'. For this, you must need to enter the values of the base, horizontal and vertical resolution and the left edge manually. The program will stop finding the edges and do any calculation. These numbers will be assumed as correctly and 'Surface Plot' will be plotted based on those.
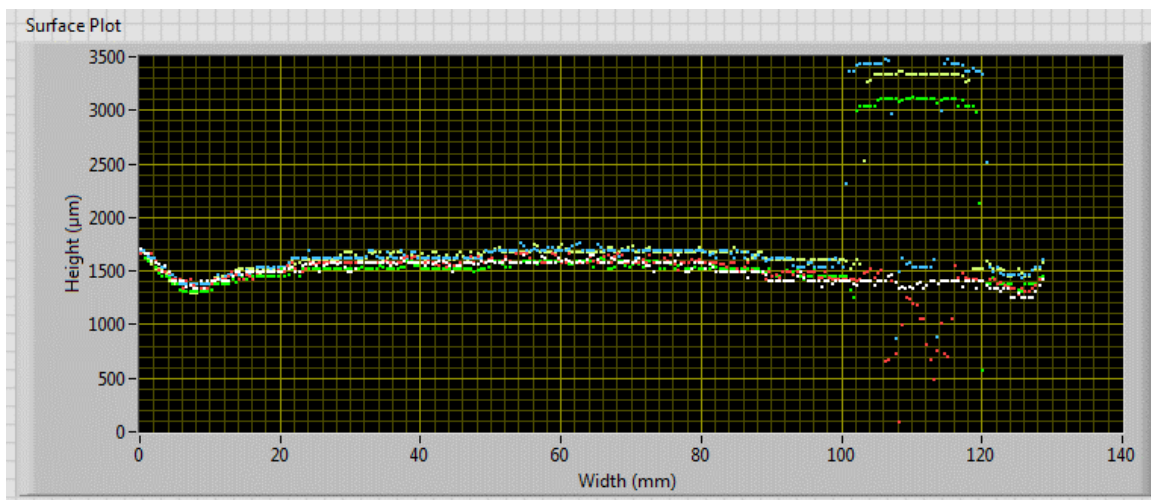
The data entered in the Excel file is the one used to fill the 'Surface Plot' if the option of 'Save Data' is selected. It is recommended to select the 'H Scale', which will write an extra column with the horizontal scale numbers. The output Excel file will contain five lines with the height values of each laser line, and the optional horizontal scale. There is an extra bottom called 'Snap' that will take a quick photo and stops after running the code once.