TImage V8.4

Imaging Software Suite

User Manual

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Introduction

The TImage V8.4 Imaging Software Suite is a set of Labview programs designed to operate the Microtech Instruments Imaging Hardware Kit which includes the DAU-3 data acquisition Unit, large aperture optical chopper, one caliper actuated linear stage, and two Zaber T-LS28-SI motorized linear stages.

The software includes:

Powermeter.vi – a metering program for system optimization preparatory to operation.

Positioner.vi – a simple program allowing the initialization and initial positioning of the motorized linear stages.

Knifeedger.vi – a program to collect the beam profile information allowing you to determine the location of the focal plane of the beam.

ImagerV8-4.vi – the program to collect images.

Example VI's for the motorized stages for those interested in program modification.

Additional VI's for understanding matrix to picture creation and the making of pictures from raw datasets.

This software suite was written in Labview 8.2. Operation in earlier versions of Labview is NOT guaranteed. Please use Labview 8.2 or newer.

When setting up the imaging hardware it is useful to have a program to monitor the detected signal/power levels. ThePowermeter program facilitates aligning and optimizing the optical system for maximum signal. Additionally, one can optimize the lock-in amplifier phase, accumulation period, and sensitivity settings. This information is then used in the knifeedger.vi and imagerV8-4.vi programs.

The positioner.vi is a simple program allowing the user to move the motorized linear stage positions around quickly to find the optimum starting positions for measurements. This program would typically be used with Powermeter to either find the beam edge for knife edge measurements or to find the starting point for an imaging scan.

Knifeedger.vi allows either vertical or horizontal measurement of the beam profile and saves the data to a file while giving a quick display of the data. The file is a text file of the excel .csv type. This allows the user to find the beam waist at various distances along the beam by using the included manual linear stage for axial displacement.

With the ImagerV8-4.vi one inputs the DAU-3 parameters, sets the motor parameters for the scan (start positions, number of steps and step size), chooses an image format and starts the program. When the scan completes the program displays the raw data and opens the first of two dialog boxes. In the first box you save the raw data to a .csv file. The second dialog box allows you to save the contrast enhanced image to the file and location of your choice. The image (in either bitmap or jpeg format) is linearly contrast enhanced so that the minimum signal produces true black (0) and the maximum signal produces a true white (255) in the 8 bit grayscale image.

The example VI's in the Zaber example folder are instructional for those interested in building a modified imaging system. The folder contains documentation on these simple programs making their operation easy to follow.

The additional VI's for picture manipulation allow the user to make new pictures from the raw data. There may be times that different contrast ratios are desired and with these simple programs one can find the optimal contrast for those cases where less contrast is desired and make new pictures from the raw data.

With this set of tools one can use the Imaging Hardware Kit to make images with any optical source and detector combination providing signal within the electrical operating range of the DAU-3. The limitations of the hardware in this kit make this kit capable of imaging down to as small a step size as 100 nm. The limitation for most experimental applications will be the users optical system. An example of this is below where an old slide was imaged with a helium-neon laser and a silicon detector for emitter detector. A compound lens system was used to provide a beam waist of 40 μm. The image was taken with 6,250 by 6,250 40 μm steps to image a 25 by 25 mm square area. Even the previous damage along the right edge from aging is clearly visible in this scan of a 40 year old family slide.

Since THz wavelengths are between 30 μm and 3 mm once one considers the diffraction limiting due to optics it is clearly evident that this system is capable of imaging to meet the needs of even the most serious applications.

We, at Microtech Instruments, are sure the user will find the simple interface, streamlined hardware with capacity in excess of the potential needs to be quite handy.

Chapter 1: Powermeter

The Powermeter software has 4 tabs, permanent side and bottom bars. The general layout is shown in Figure 1 (opened to the signal tab).

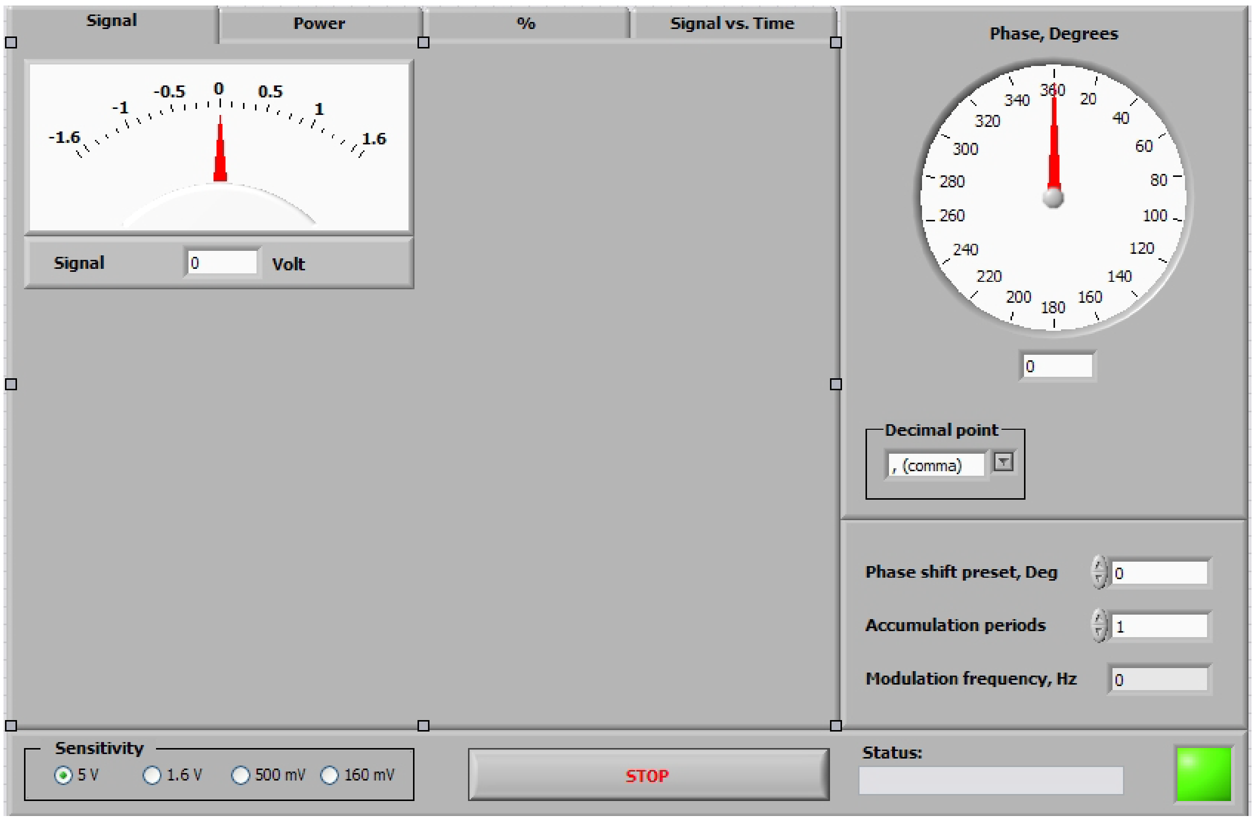

Figure 1: Powermeter open to the Signal tab. The right side bar and bottom bar are visible regardless of tab open.

Bottom Bar

It is advisable to always start with the sensitivity (shown in the bottom bar) set to 5 V to protect the system. If the status indicators (also in the bottom bar show overload (comment and color patch switches to red) once the program is running then you need to either turn up sensitivity to a higher setting or if at 5 V already shut the program down and adjust the hardware. Options for the hardware are to attenuate the beam, or change detectors to a detector that will produce output in the allowed range. Exceeding the electrical limits can damage the DAU-3. The bottom bar is shown below in Figure 2.

Figure 2: Bottom bar of Powermeter is shown. Sensitivity of the Lock-in amplifier is set through the radio buttons on the left. Middle stop button is used to stop program operation. The right has two status indicators.

If the signal is small enough you can adjust the sensitivity to lower settings. If the green square turns red and a comment appears in the status box switch back to a higher sensitivity. This can happen even if the measured signal is significantly smaller than the sensitivity setting chosen. This is because the measurement is of the AC portion that is noise is large enough to set the overload level while the AC component at the chopper frequency may be much smaller.

In the center of the bottom bar is the stop button. This is the correct way stop the program when it is operating. Attempting to shut the program down through the Labview project bar is disabled by program design. Shutting the program down any way other than the stop button will require closing and restarting Labview so that the DAU-3 driver is closed and reopened with an available channel correctly. Otherwise, an error message indicating the DAU-3 unit could not be found will be displayed.

Side Bar

To the right side of the program is the side bar that is visible in all windows. The side bar is shown in Figure 3.

The side bar has an indicator to show the relative phase at the top with a numerical indicator below that gives the phase value in degrees in real time per accumulation period. When operating the software there are two ways to adjust this value to optimum (0 degrees), One is to adjust the rotation angle of the chopper aperture. The other is to enter an angle of phase shift into the phase shift preset in the lower side bar box and hit enter. The appropriate angle is 360-the numerical value being displayed. This will rotate the angle back to 0.

In the center of the bar is a drop down list that allows you to choose the format option of decimal point as either a period or a comma to match the numerical formatting used in the text files for detector and filter calibrations. Typical applications will use period decimal points per US standard. Some could use commas mattering on file origin.

In the bottom portion of the side bar is the accumulation periods control. This is typical set at the default minimum of 1 which is fastest and best for most applications. Higher numerical values can be used if the signal is very small to separate it from the background.

At the very bottom the modulation frequency is indicated.

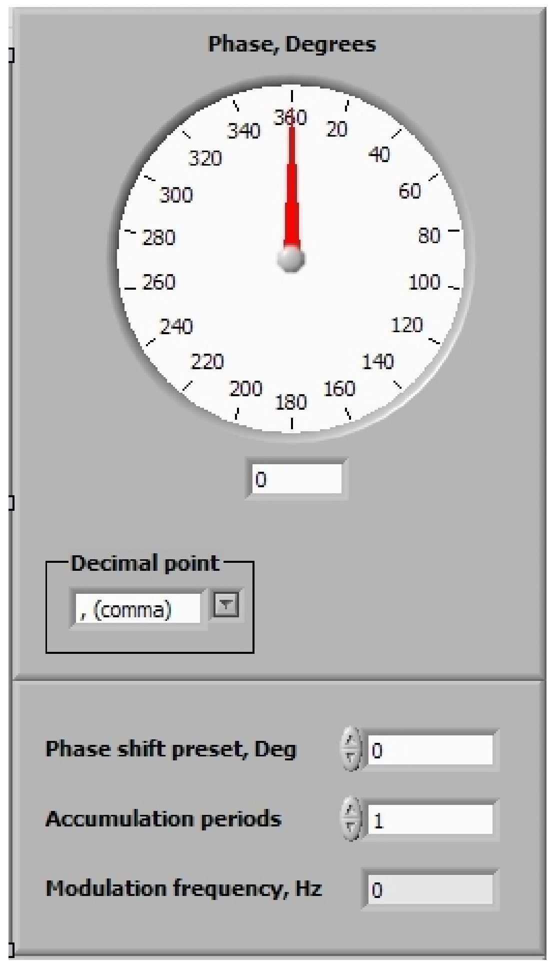

Figure 3: side bar sets the phase, numerical file format, accumulation period, also displays phase and modulation frequency.

Signal Tab

The signal tab shows the signal value in volts for the most current accumulation period. The scale automatically changes with the sensitivity. This tab is shown below in Figure 4.

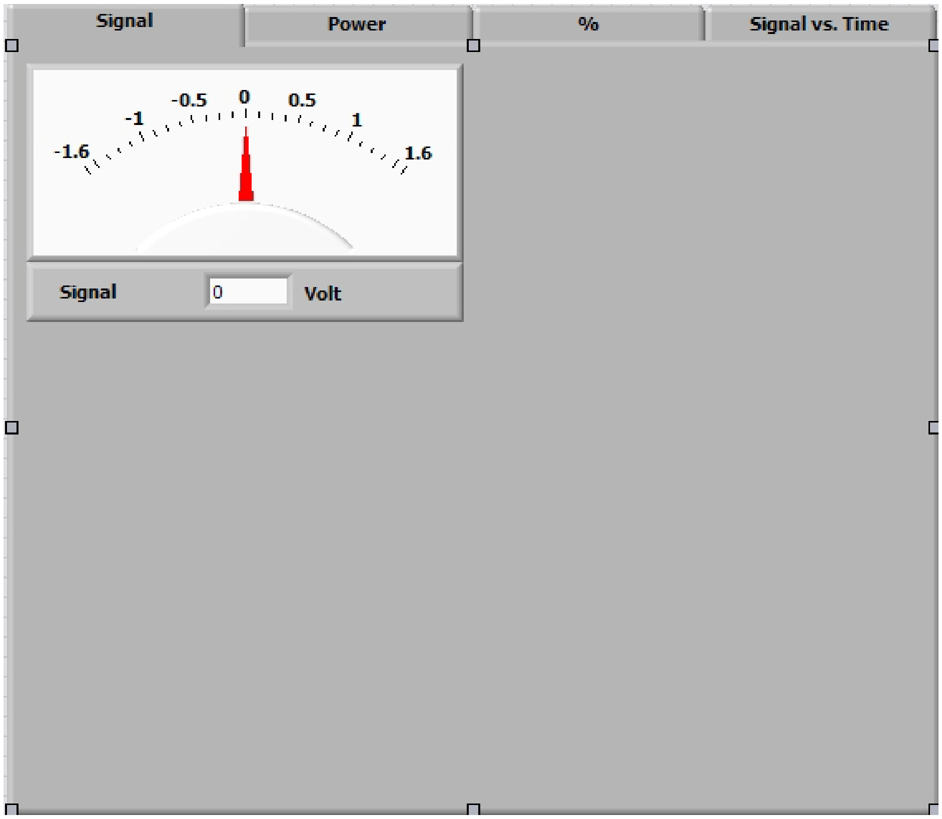

Figure 4: Signal tab. No controls are available on this page.

Power Tab

The power tab is the most useful tab as it can display correct absolute power measurements when configured correctly. This tab is shown in Figure 5.

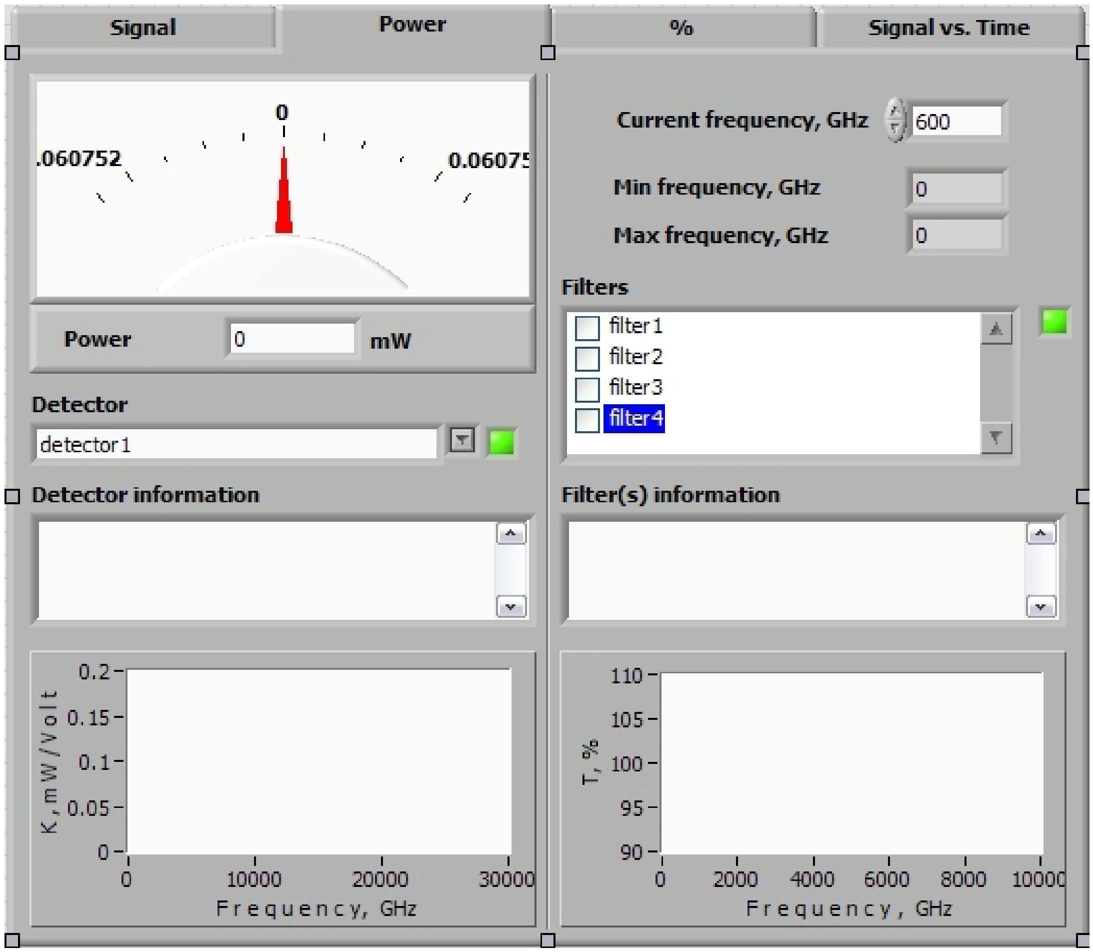

Figure 5: Power is displayed in the upper left indicators. The rest of the window is input for matching your hardware configuration.

One important thing to note with this window is to be sure that the correct decimal format is chosen in the side bar or the bottom two display windows will be blank as in Figure 5. One chooses the detector configuration file, the appropriate filters that are in use and sets the current frequency to the correct value. Then during operation the software displays the spectral response and transmission curves used to calculate power in the bottom windows. The power is calculated from the signal using this information and displayed in the upper left. This indicator also scales with the sensitivity radio buttons automatically. Below the current frequency control the spectral limits of the detector are displayed in indicators. Figure 6 shows the power tab as it looks during operation.

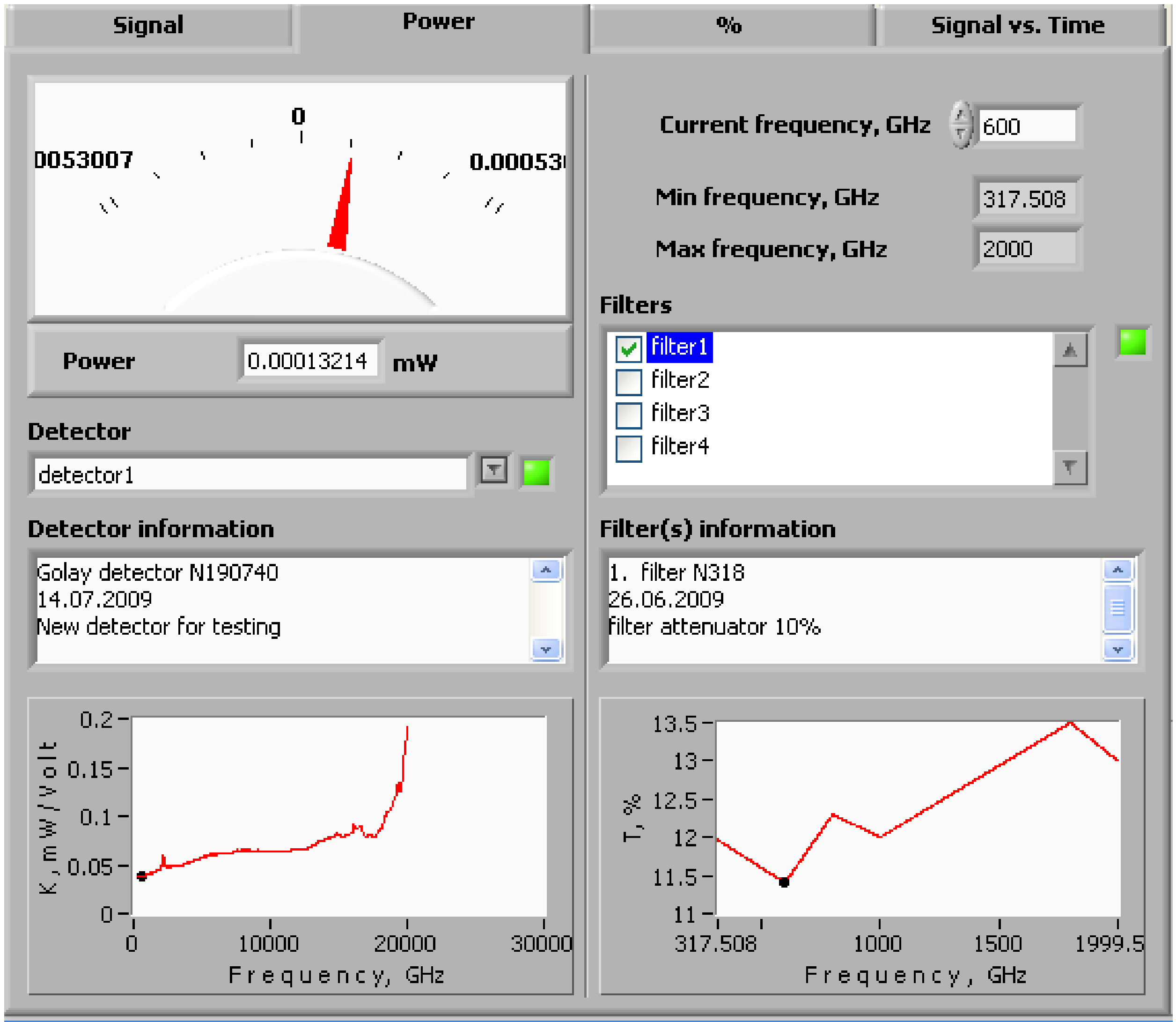

Figure 6: the power tab when the software is operating. Note the bottom windows now display in red. The power meter shows 132 μW power measured.

One can readily see the power per volt (inverse responsivity) for the Golay cell displayed in the lower left. The detector model and test date information is displayed above that. The transmission spectrum and filter information are displayed similarly. With this combination the input signal corresponds to 132 μW power currently incident at the detector.

When one chooses more than one filter the software automatically calculates the transmission of using the selected filters in series and displays this information as well as uses it to calculate the power.

% Measurement Tab

The % measurement tab is useful for being able to get quick rough estimates of the transmission properties of materials quickly. If one has a material known to have low absorption and a known thickness then Fresnel reflection could be used here also to quickly calculate the refractive index.

This tab offers a set of different parameters to choose for the percent displayed allowing you to choose between storing the signal value with or without the sample to do your calculations mattering on which method gives the most accurate and precise measurements for your sample. Before you store a value the tab information appears as shown in Figure 7.

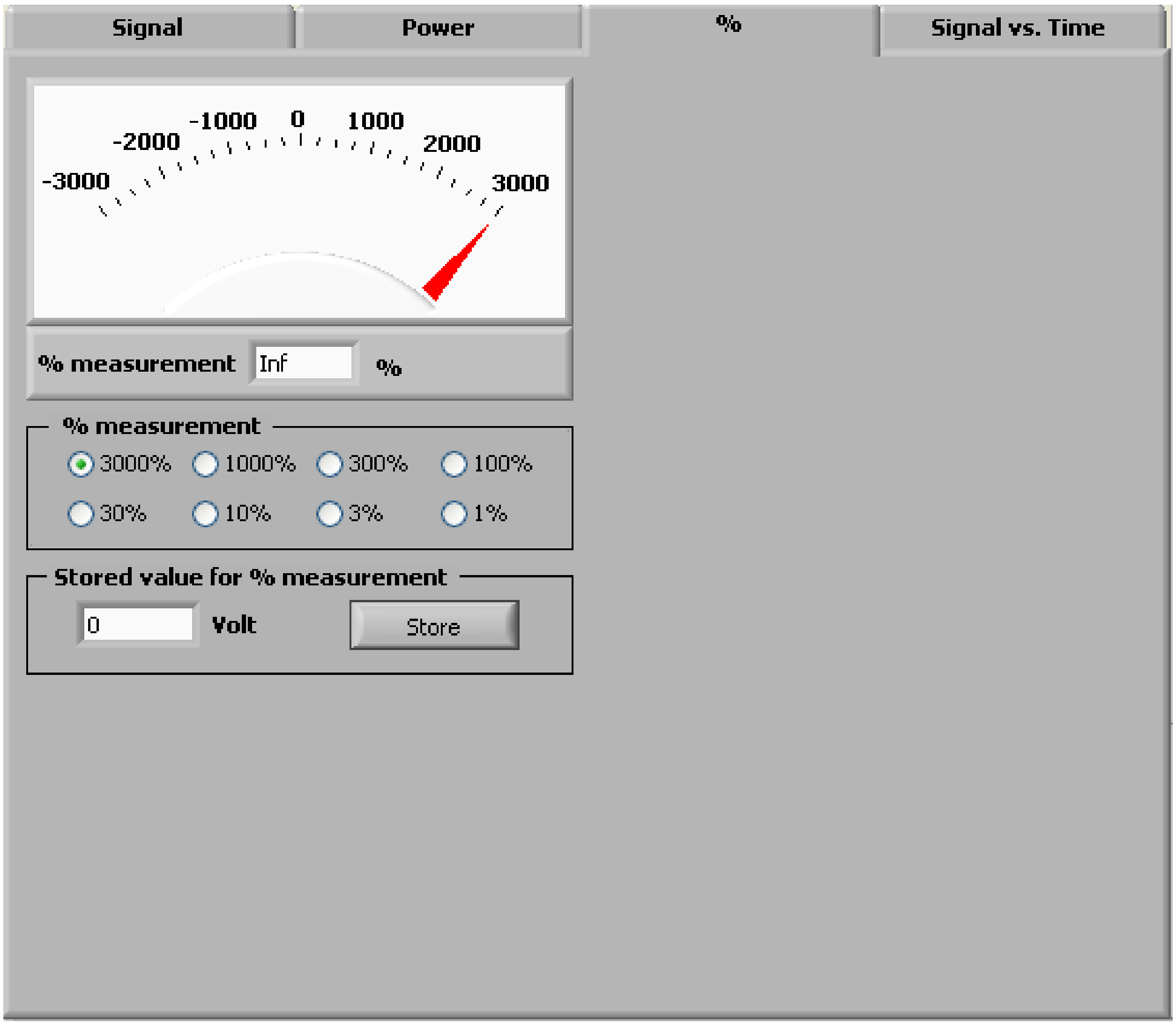

Figure 7: before you store the value all the parameters of this tab are as displayed.

Press the store button and the software automatically stores the current signal value for comparison. This number will then be displayed to the left of the button. Then the software will begin comparing subsequent signal values to the stored value and display the relative percentage in the meter display above. You can rescale at any time choosing a different % measurement radio button in the center to change the maximum range of the meter.

When the software has a stored value then the tab displays and looks similar to Figure 8.

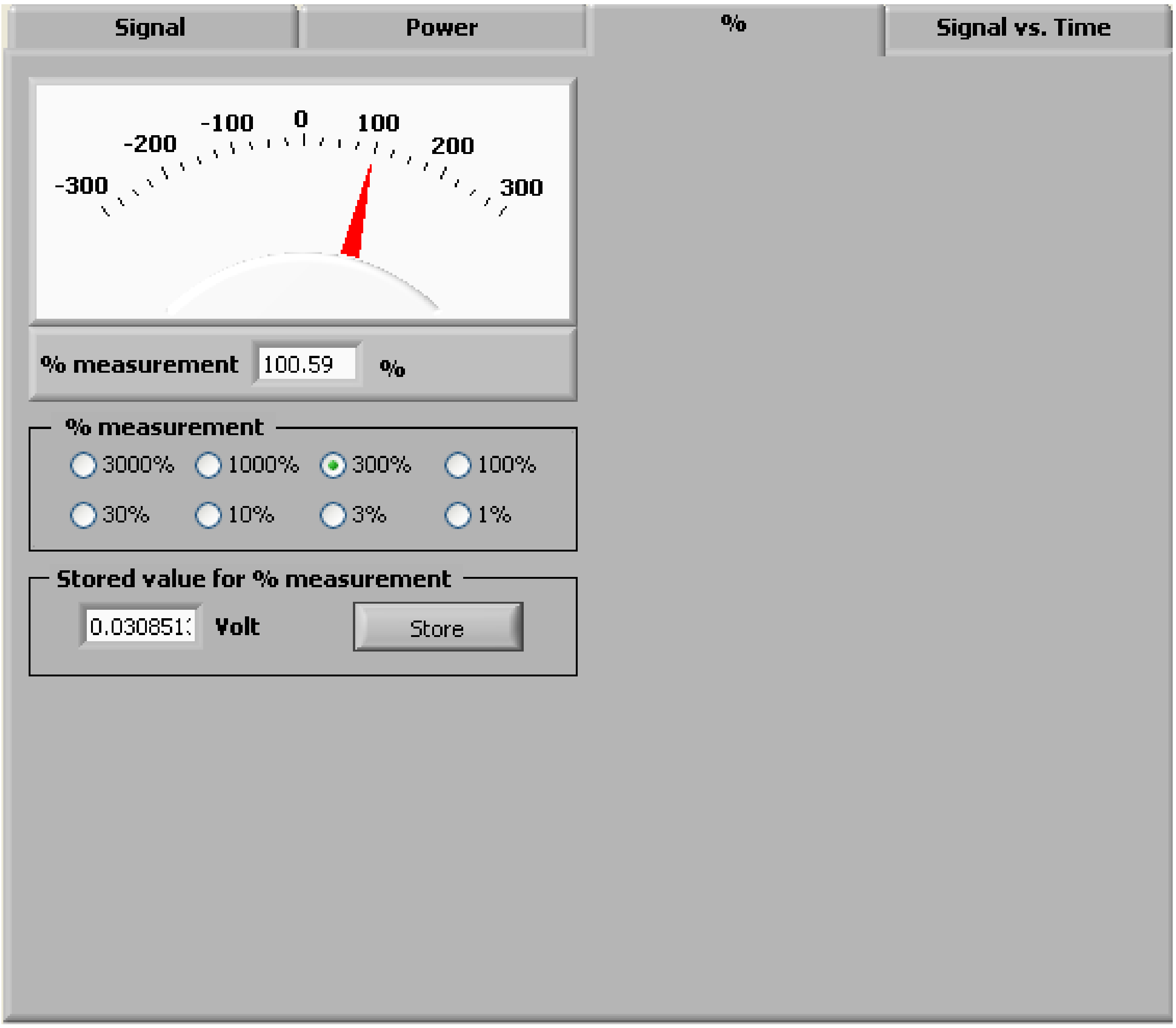

Figure 8: % tab with a stored value. The current measurement is 100.59% of the stored value.

One can see that at the time the store button was pressed the signal was .030851 Volts. The current signal is 100.59% of that value. The range of the meter has been changed from 3000% to 300% making it possible to look at measurements slightly above 100%.

Signal vs. Time Tab

Signal versus time tab gives you a real time display of the signal allowing you to watch the stability behavior of the system. Real time feedback is displayed as seen in Figure 9.

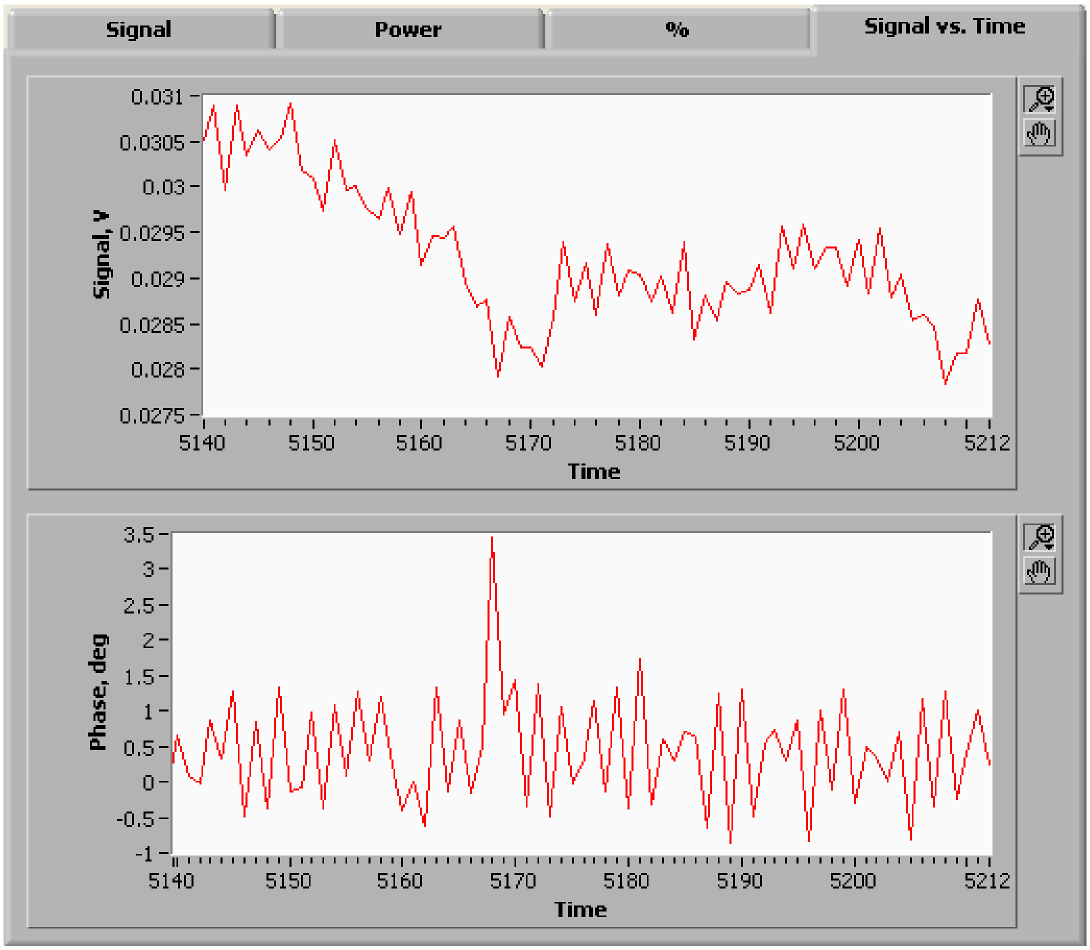

Figure 9: Signal vs. Time tab shows auto-scaling graphs of the signal and the phase as they change in real time.

The time scale is in samples. With the accumulation periods set to 1 as in this arrangement the time per point is about 46.4 ms.

Program operation

Once the hardware in place, hooked up to the computer and turned on, one simply hits the run button to start the program. The program immediately begins displaying the values associated with the current accumulation period. Once you have some signal you then adjust the phase offset to bring the phase to 0 as discussed earlier. Adjust the sensitivity if necessary to optimize the range. Then choose the appropriate decimal point format. Make power and filter choices if you want the power displayed.

Use the program to measure and optimize your imaging system as needed. When you are done with the program hit the stop button on the bottom bar.

Chapter 2: Knifeedger.vi

The knifeedger.vi program allows one to quickly obtain knife edge measurements (either vertical or horizontal) while familiarizing you with a simplified version of the Imaging program ImagerV8-4.vi. The layout and tools are similar. However, this stripped down program does NOT allow for changes in sensitivity, accumulation period, or phase while in operation. These are choices you must make before operation in this case.

The program has three tabs, a side bar, and a bottom bar. As in the powermeter.vi program, the side and bottom bars are visible in all tabs. The tabs are motion, phase, and signal vs. time.

One would typically use the Powermeter program first to set up the optical system and place the knife edge just outside the beam. If necessary one might use the positioned.vi to find the closest position to the beam and get the absolute position to input into knifeedger.vi.

First, let's review the program.

Side Bar

The side bar in this program is similar to the side bar in Powermeter.vi with a few differences. Instead of the phase displayed on the upper portion of the bar in a meter the signal is displayed. This allows the user to see the progress of the edging scan so that if you aren't coming to zero or are getting there too fast it becomes obvious before you even see the data. If some other issue with the power shows up you can see it in real time. As there is now power measurement or need for filter adjustments in the process of calculating the power there is no decimal point format drop down box. There are phase shift preset and accumulation period controls. Before starting the program one sets the values on these to the values found optimal in the Powermeter.vi program earlier. As shown in Figure 10, there is also a display box that shows the modulation rate during operation.

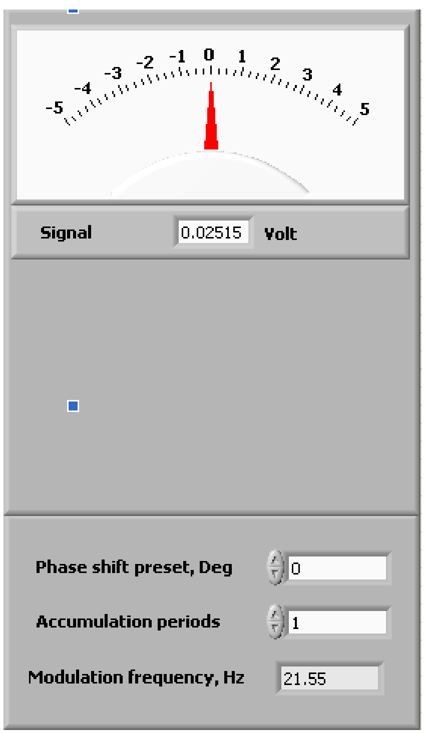

Figure 10: Side bar.

Bottom Bar

The bottom bar shows the sensitivity radio button selection and has the status indicators the same as in Powermeter.vi. Before starting the program one sets the sensitivity for the run. It does NOT update once the program starts so the setting must be correct before starting the program. The bottom bar is shown below in Figure 11.

Figure 11: bottom bar. This is very similar to Powermeter.vi without the stop button.

Motion Tab

This tab is the most important one in the program. Operation of this program does not require use of the other tabs. They are provided for feedback information in case you are having issues. Familiarity with this tab prepares one for the main imaging program. This tab is shown in Figure 12.

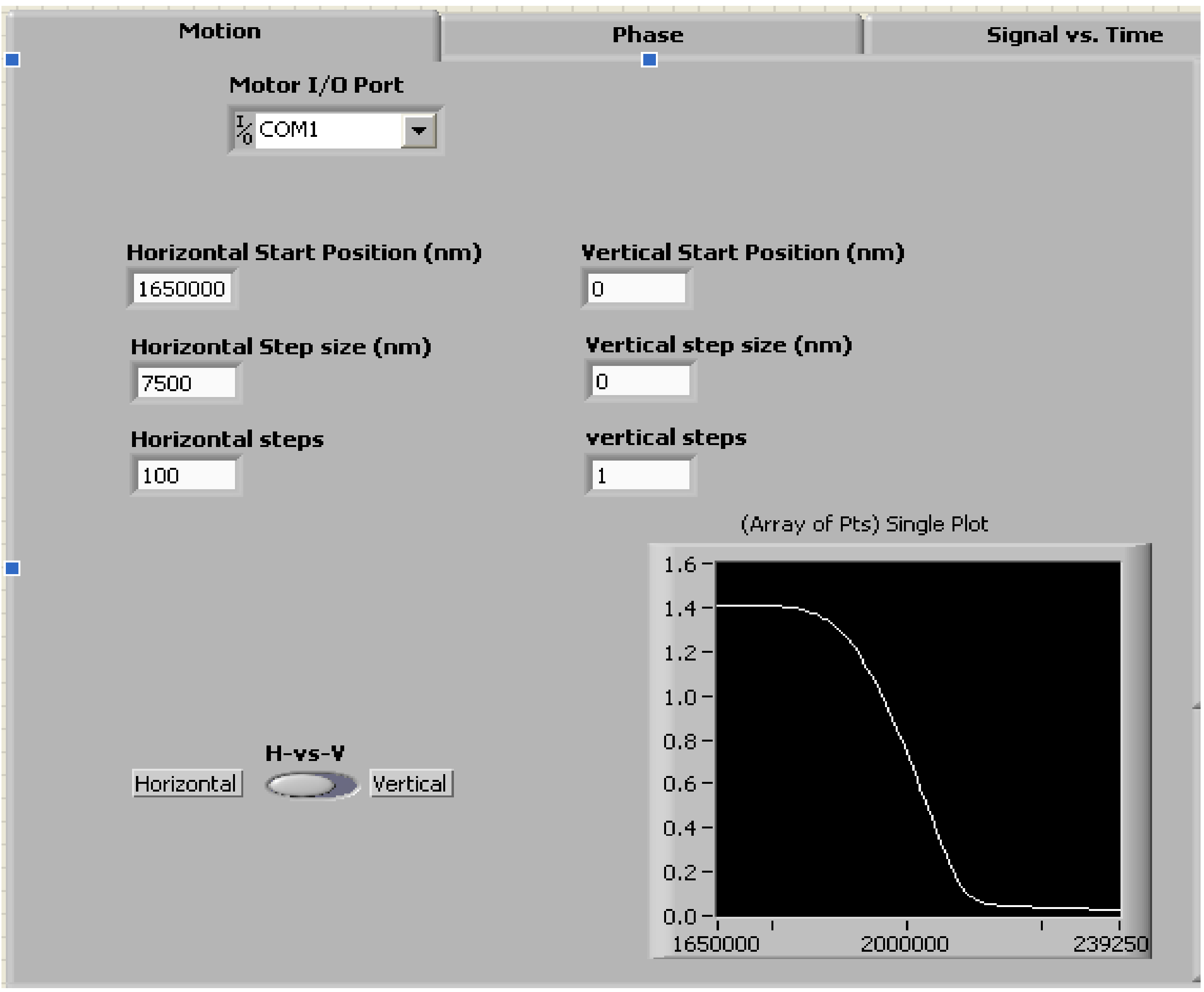

Figure 12: Motion tab. This tab is for input of all the relevant motion control parameters.

At the top is the drop down control where you choose the com port the motorized stages are attached to. At the bottom left is the horizontal versus vertical switch where you choose which axis the knife edge measurement will be on. Whichever one you choose then set the control box information for the other direction to step size of 0 with 1 step. In Figure 12 Horizontal is chosen and the vertical parameters are set properly for scanning. The start position is chosen to be optimal for the knife edge. In the example the knife edge was centered vertically with the z-axis stage homed. Set the initial position of the stage for knife edge measurement along the axis desired. Choose a number of data points you would like (between 25 and 100 is typical…I use 100). Set the distance to travel with each step in the appropriate step size control in increments of 100 nm (minimum motor step is 100 nm).

When scanning completes, the data is displayed for immediate viewing in the lower right graph.

Phase Tab

In the event of erratic data with high negative value signal one can switch to this tab and observe the phase of the accumulated signal. If the phase is changing rapidly through a large number of values this indicates some sort of data collection issue. Whether one has a large transient noise in their input path or has damaged software (whether from a virus or personal modification) this tab can give some clue as to whether there is a measurement issue. The only thing available in this tab is the meter displaying the phase of the current accumulation period.

Signal vs Time Tab

This tab is exactly the same as in Powermeter.vi. It provides a diagnostic tool for large signal fluctuations. If one has standing wave issues the phase will be relatively stable while this data will go through rapid changes that have some periodic behavior to them.

Operation of the Program

Set all the relevant parameters before operating as described earlier. Often times one needs to use a negative step size for the vertical scans. An example of this can be seen in Figure 13 where a vertical configuration is shown ready for scan. It is important to make sure the sensitivity is set correctly before beginning the scan to avoid overload conditions. If the Motor I/O port isn’t set to the correct com port then the program will return an error and close Labview. If the phase is set wrong the values of the data could become large magnitude negative numbers when most of the signal is still reaching the detector and may switch between positive and negative from one point to the next resulting in unusable data for fitting purposes.

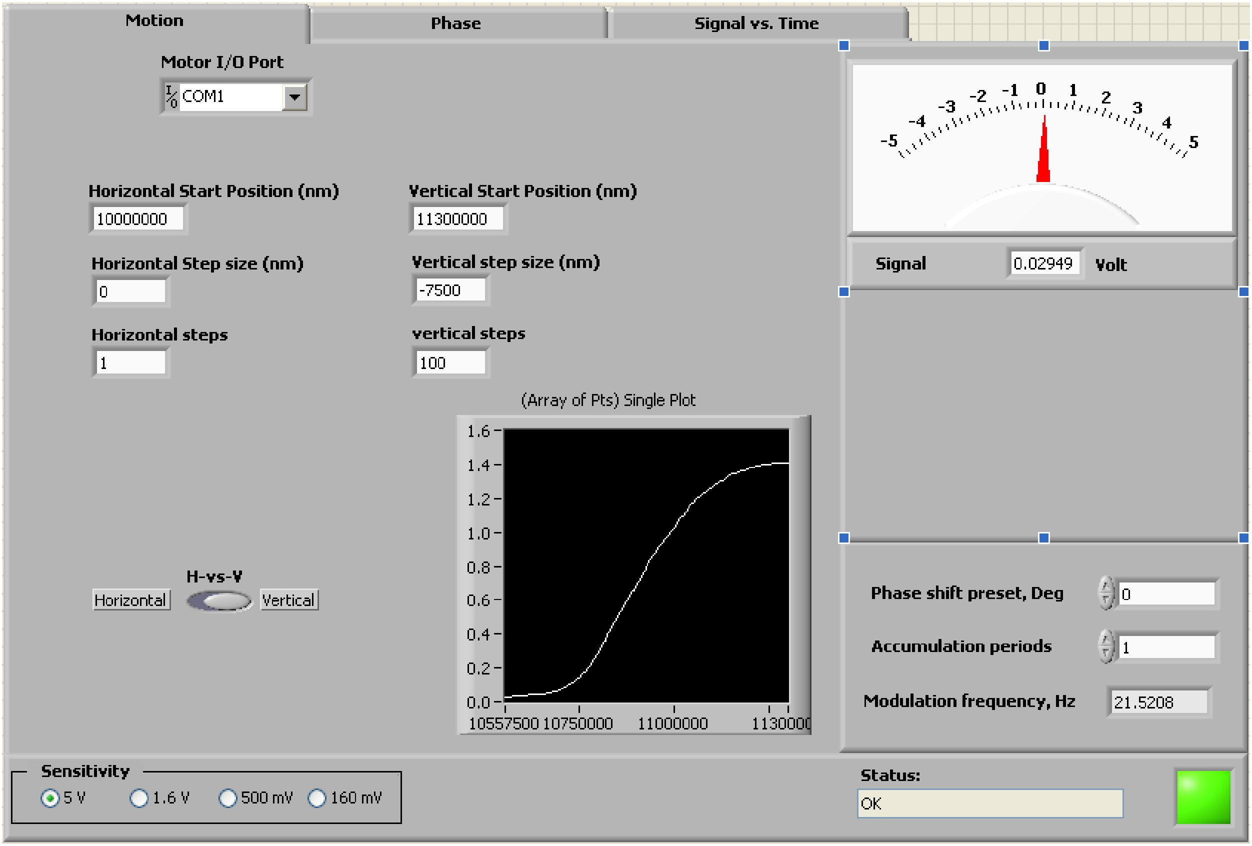

Figure 13: an example of a properly configured vertical knife edge measurement ready for operation.

Once the parameters are set press the run button to begin the scan. When the program has finished the knife edge measurement a dialog box (See Figure 14) automatically opens allowing you the option to save the file. The file will be in .csv format but it won't assign the .csv suffix automatically. You have to give the complete name of the file. You can navigate to the desired folder.

If the data is bad for some reason, such as you chose to large or small of a step size, then save the data to a junk file name. **DO NOT SAVE TO A FILE NAME TWICE AS THE PROGRAM WILL APPEND THE NEW DATA ONTO THE OLD FILE.**

Once you click the ok button in the dialog box the file is created with two columns. The left column is the absolute position of the appropriate stage measured in nm. The right column is the signal value measured at the position.

The program will complete at this point. The data is immediately viewable in the graph on the lower right of the motion tab.

One typically uses the caliper actuated linear stage mounted to change the knife edge along the beam path and takes a series of measurements at different distances. Typically I name the files so that this distance is included in the file name. When taking measurements one wants positions on either side of the focal plane so that an accurate fit can be done to find the focal plane.

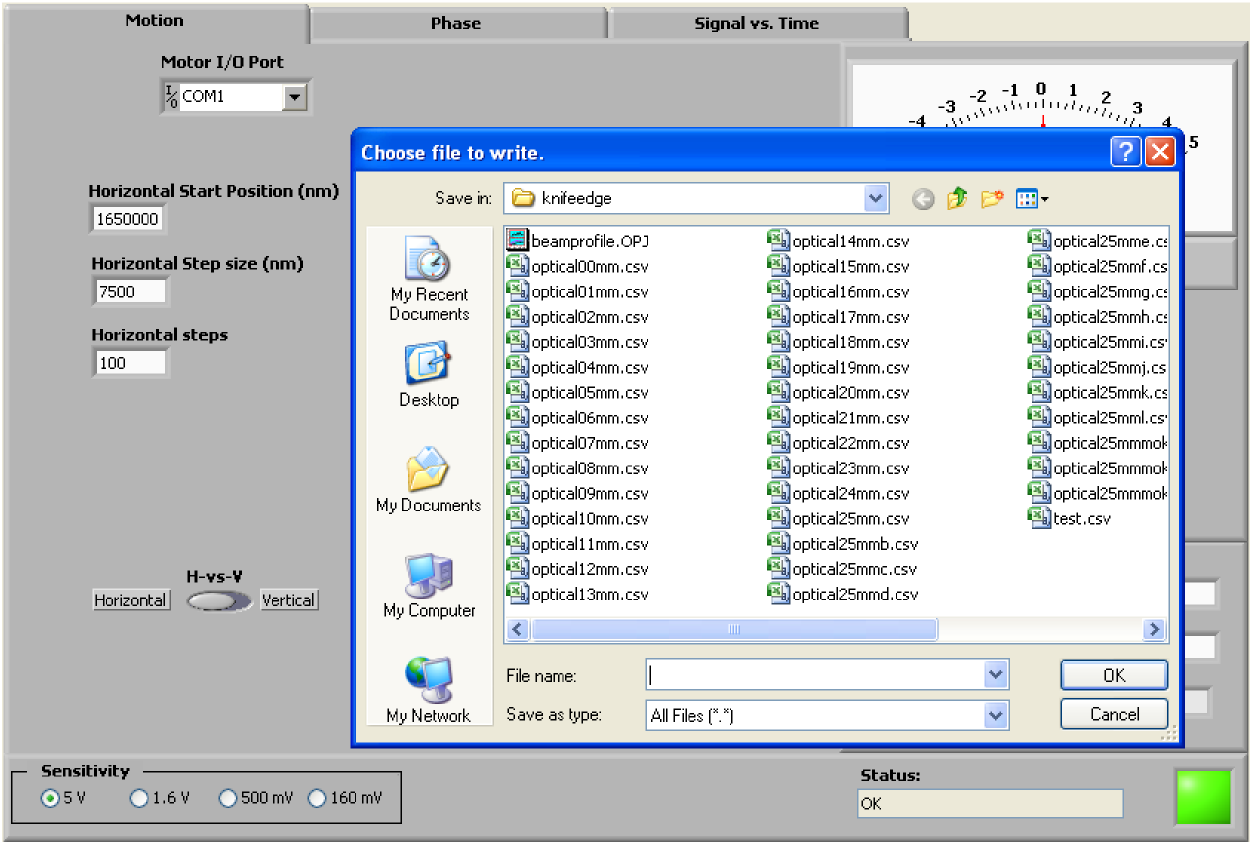

Figure 14: dialog box open to save the data to a file.

Using the data

To find the beam waist at any given position one needs to fit the data. I typically use the software program Origin to do fits. One can define a fitting function and quickly fit data with this program. The equation I use to generate my fitting function is:

$$V = \left(\frac{V_{Max} - V_{Min}}{2}\right)\left(1 - \int_{0}^{x} e^{-2\frac{(x'-x_0)^2}{w^2}} dx'\right)$$

Where V is the measured signal voltage, V_{Max} is the maximum signal voltage, V_{Min} is the minimum signal voltage, x is the position along the direction of the knife edge measurement, x_0 is the axis offset from the center of the beam, and w is the beam waist. The integral is commonly known as the error function.

In origin the function would be written (with units correction)

Y=(max-min)*(1-erf(sqrt(2)*(x-x0)/1000/w))/2

With max, mind w defined as the fit parameters in your custom fitting function. Alternatively one could divide the position column by 1000 to make a new x column and use the fitting function y=(max-min)*(1-erf(sqrt(2)*(x-x0)/w))/2

instead. An example of one fit is shown in Figure 15.

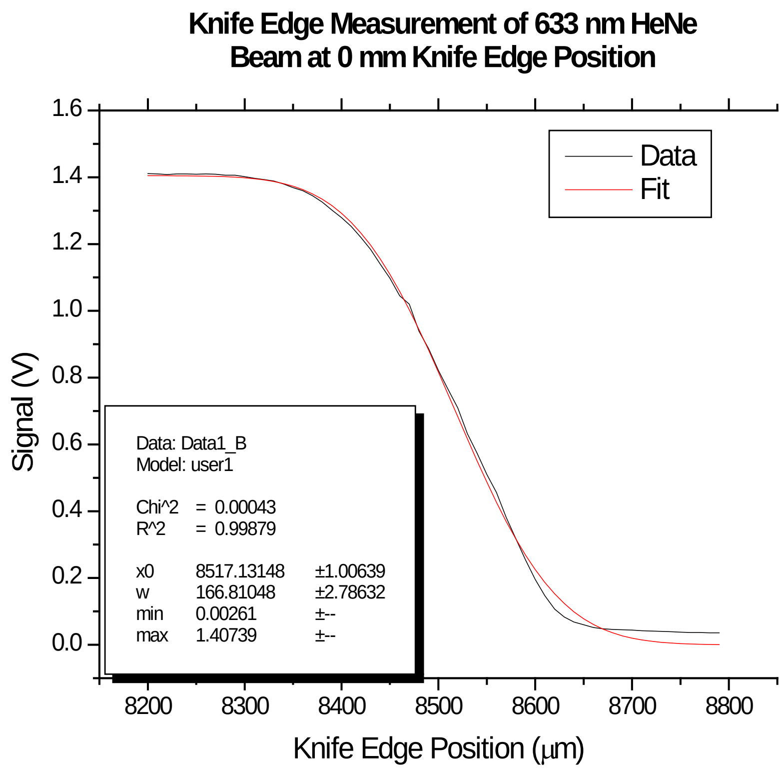

Figure 15: Origin data fit of a Helium Neon beam showing the beam waist of 166 µm at the 0 mechanical caliper actuated linear stage position.

Once a set of positions at various distances along the beam path have been fit the w values can be used to calculate the focal plane and minimum beam waist. The fitting function for that is

$$w = w_0 \sqrt{1 + \left(\frac{(z - z_0)\lambda}{\pi\, w_0^2}\right)^2}$$

Where w is the beam waist from the fits, z_0 is the offset from the focal plane along the beam to the position along the beam where the knife edge is at when the caliper actuated linear stage is at the 0 position, λ is the wavelength, w_0 is the minimum beam waist at the focal plane.

In origin it would be written

Y=w0*sqrt(1+((x-x0)*lambda/(pi*w0^2))^2)

An example of a fit in Origin is shown in Figure 16 for a 640 GHz focused beam.

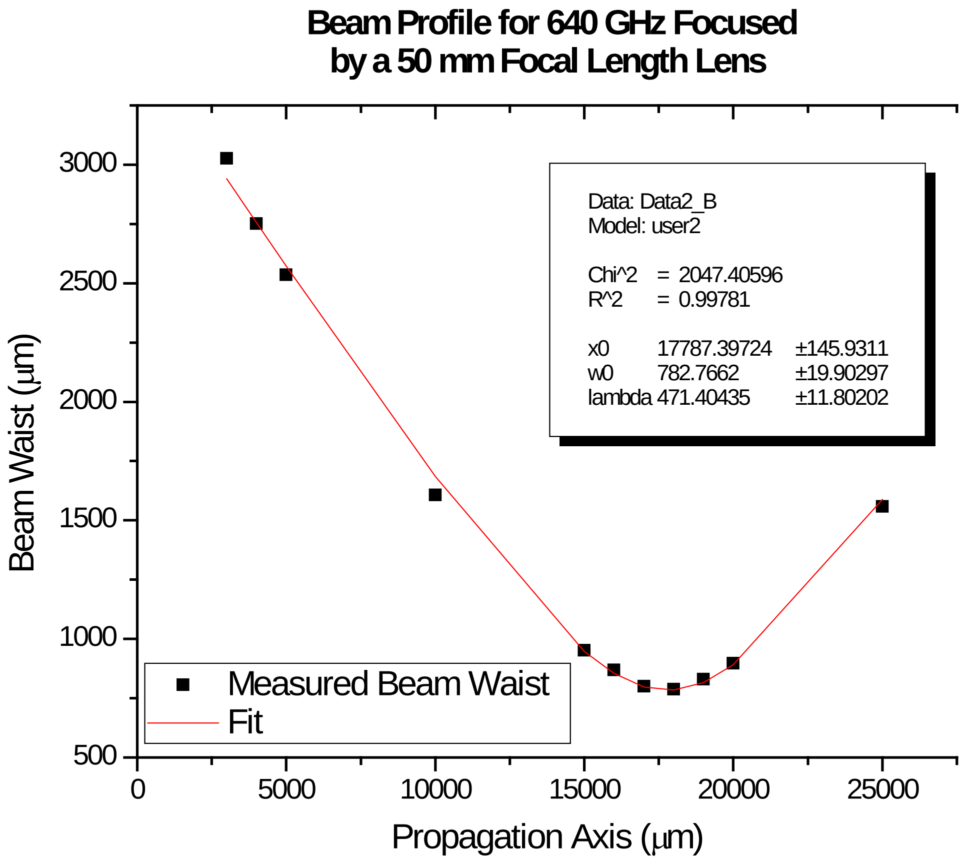

Figure 16: beam profile of a 640 GHz beam in the horizontal plane. Note: this is not an M^2 fit.

More advanced fitting functions involving the M^2 parameter can be used. Often for THz waves it is difficult to obtain a clean TEM_{00} mode Gaussian. However, in this case all the beam quality factor contributes is a correction to the wavelength. The minimum beam waist remains unchanged.

Chapter 3: Imager8-4.vi

Once the Optical system is constructed, the focal plane where the sample is to be placed has been located. One can place the sample to be imaged at the focal plane. Then you are ready to do imaging. While the imaging program bears a resemblance to the knife edge measuring program it does allow for changes in sensitivity, phase, and the accumulation period during operation.

This software has 4 tabs a side bar and a bottom bar. The principle tab to use is the motion tab. The image tab allows one to immediately view the image upon completion of the scan. The phase and signal vs. time tab are provided for diagnostic purposes for the same reasons as in the knifeedger.vi. The side and bottom bars are available with all tabs as in the Powermeter.vi program. This program is displayed in operation in Figure 17.

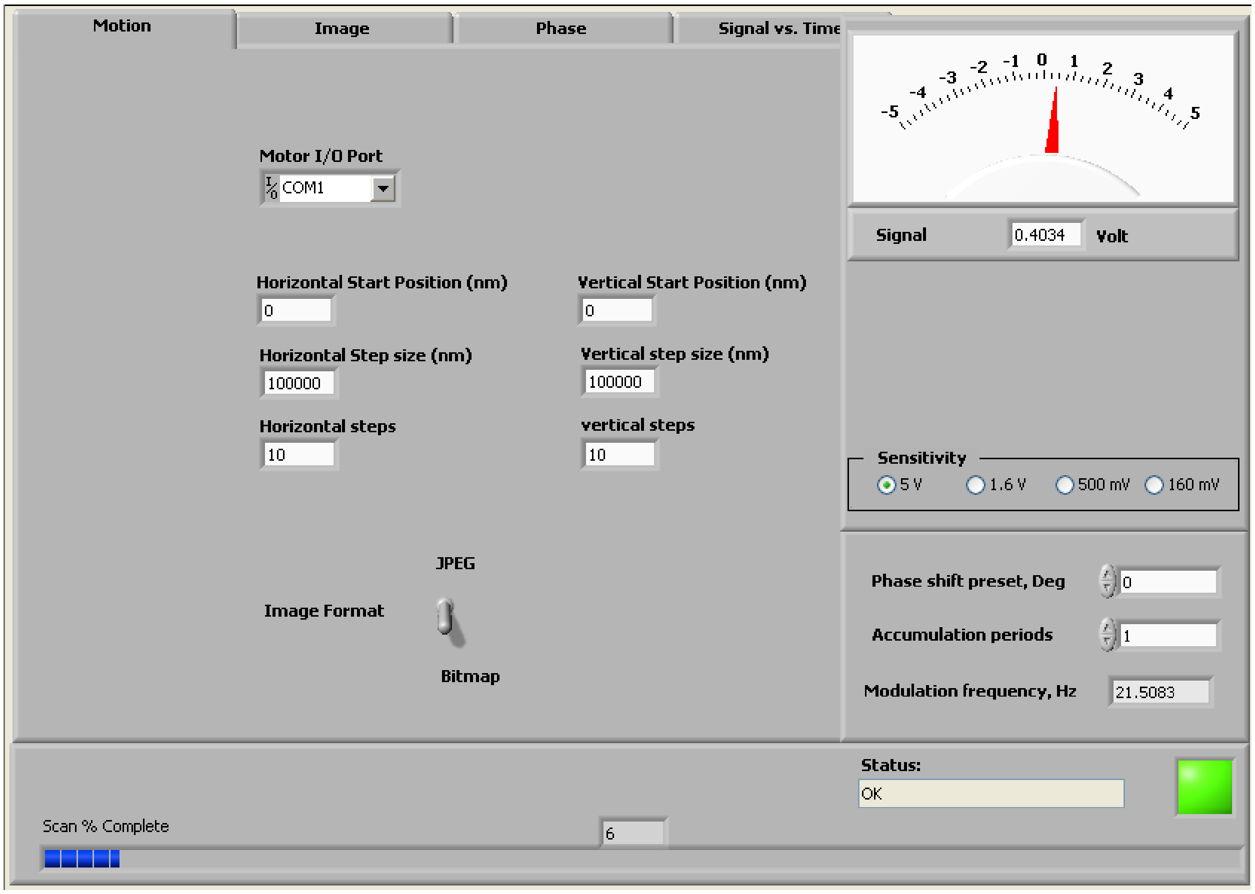

Figure 17: Imager8-4.vi in operation. The scan is 10 by 10 data points with 6 % completed.

This program opens 2 different dialog boxes consecutively upon completion of the scan. The first allows you to save the raw data as a .csv type excel file the same as the knife edge program. The second dialog box allows you to save a contrast enhanced 8 bit grey scale image of the data. You can choose from JPEG or bitmap formats.

The saved image has a full range of contrast. The minimum signal value is converted to true black {0}. The maximum signal value is converted to true white {255}.

There are some utility programs provided that can be used to open and make images from the raw data saved in the .csv file giving you the option of creating images of differing contrast levels as needed.

While the program is similar to the previous programs there are some differences. Going through it section by section one can see these.

Side and Bottom Bars

The side bar is very similar to the knifeedger.vi side bar with the addition of the sensitivity radio buttons which have been relocated here from the bottom bar making room for the scan % completed bar in the bottom bar. Using the numbers obtained from the power meter program one sets the sensitivity, phase offset, and the accumulation periods in this bar. These can be changed during operation so if the sample is sufficiently opaque one needs to change the sensitivity this can be done during the scan.

The bottom bar no longer has the sensitivity control. Instead it has a scan % completed display bar graph and indicator. During the scan this indicates the percentage of the scan completed.

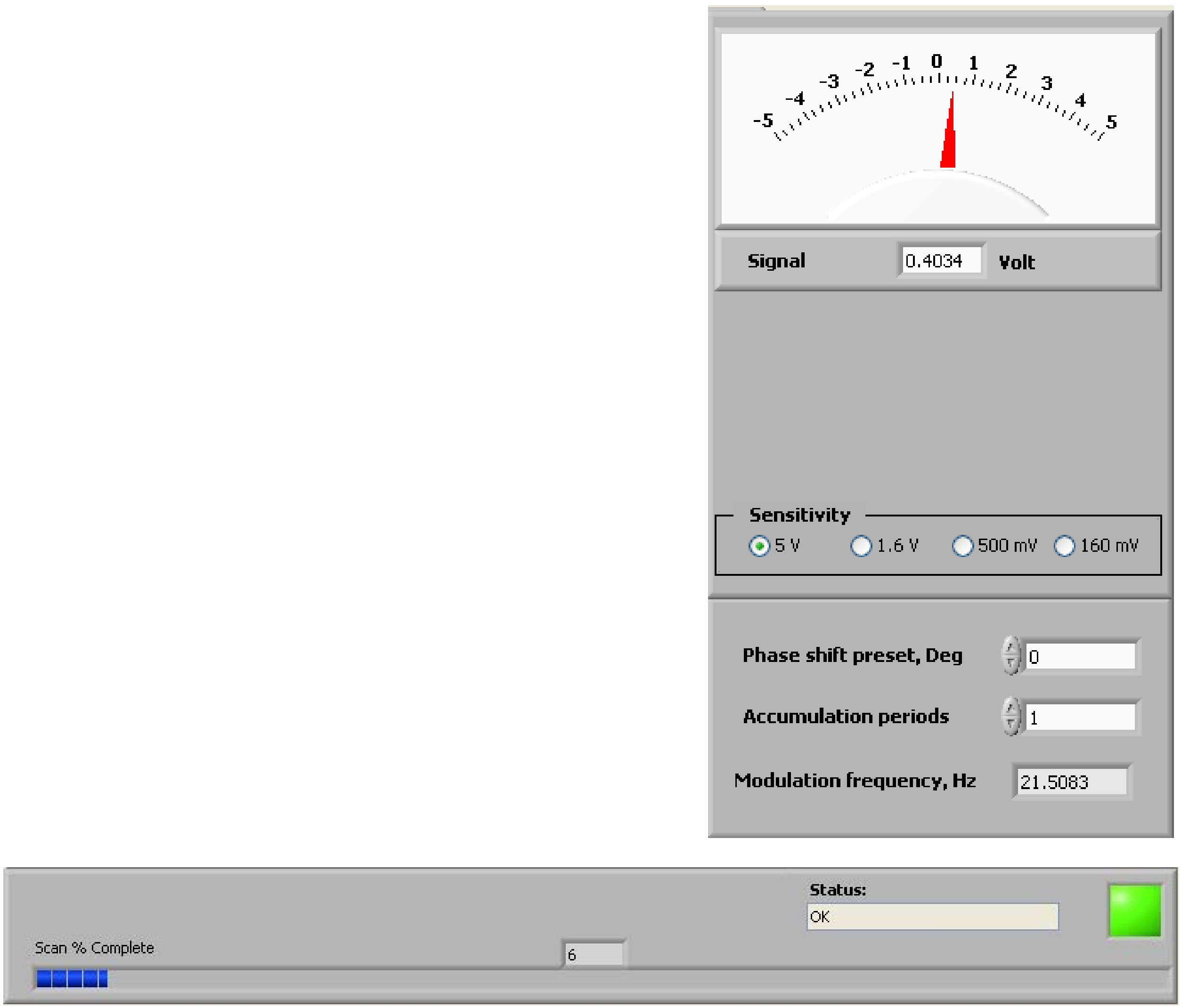

Figure 18: Upper right: Side Bar. Bottom: Bottom Bar.

Motion Tab

The motion tab is very similar between this program and Knifeedger.vi. One chooses the Motor I/O port (com port) before starting the program as before. The horizontal and vertical start positions are handled the same as well. You no longer need to set one axis to 1 step and the step size to zero. Now you choose the step size and number of steps appropriate for the desired image. The step size needs to be an integer in increments of 100. The minimum step size for these motors is 100 nm. This is far smaller than the shortest wavelength in the THz range so if one had a near field optical setup then this hardware would enable them to do near field imaging to the 100 nm scale level.

Instead of a horizontal/vertical switch for data saving as in the Knifeedger.vi program there is a switch to choose between JPEG and bitmap formats for saving the image. This is in addition to saving the raw data.

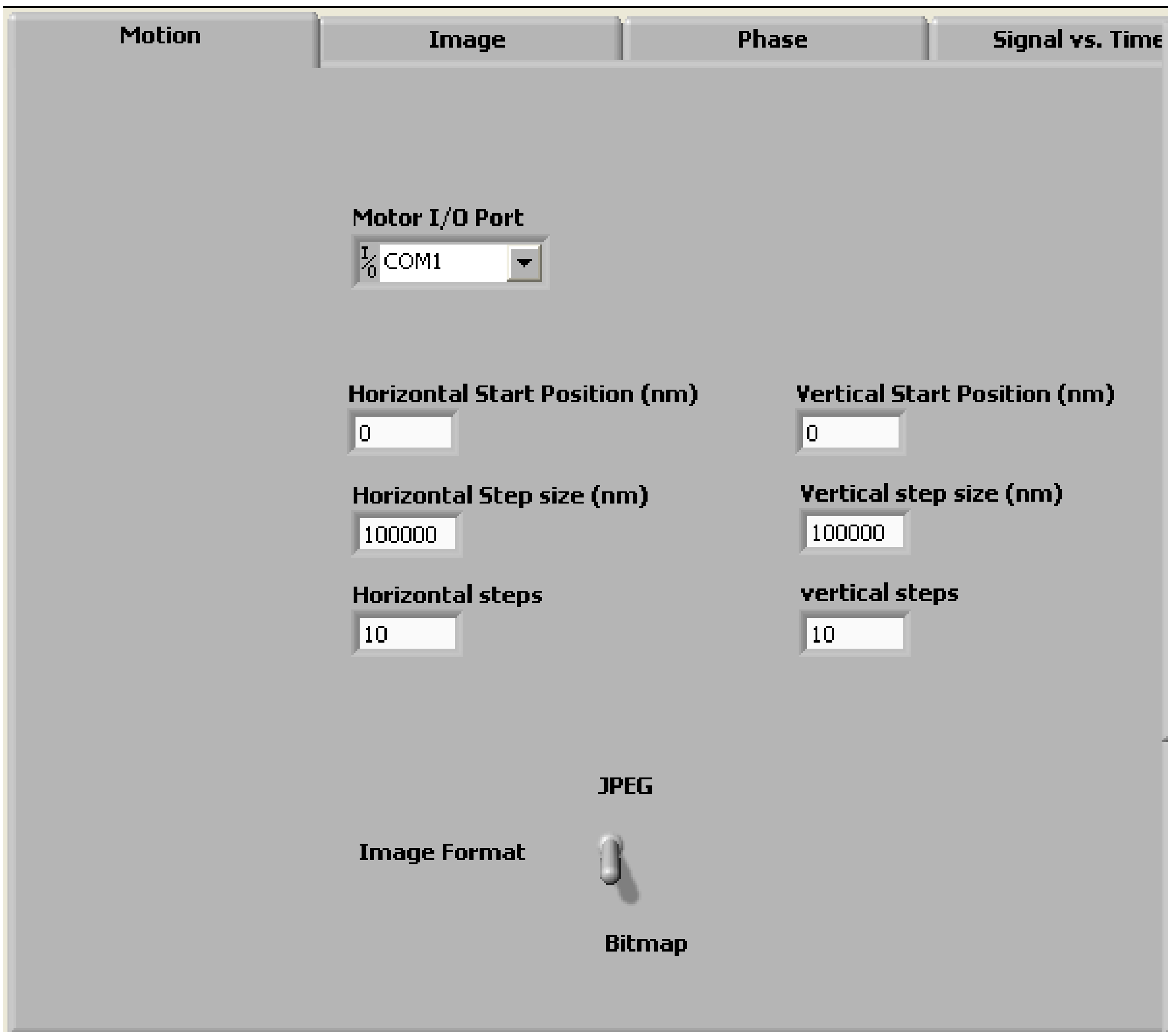

Figure 19: Motion tab. Both axes are set to 100 μm step size with 10 steps. The total scan area is 1 mm^2

Image Tab

The image tab has a grey scale intensity plot that directly plots the data. It is an auto-scaling plot that will give the user a quick view of the image just taken. The axes show the step position (Figure 20)

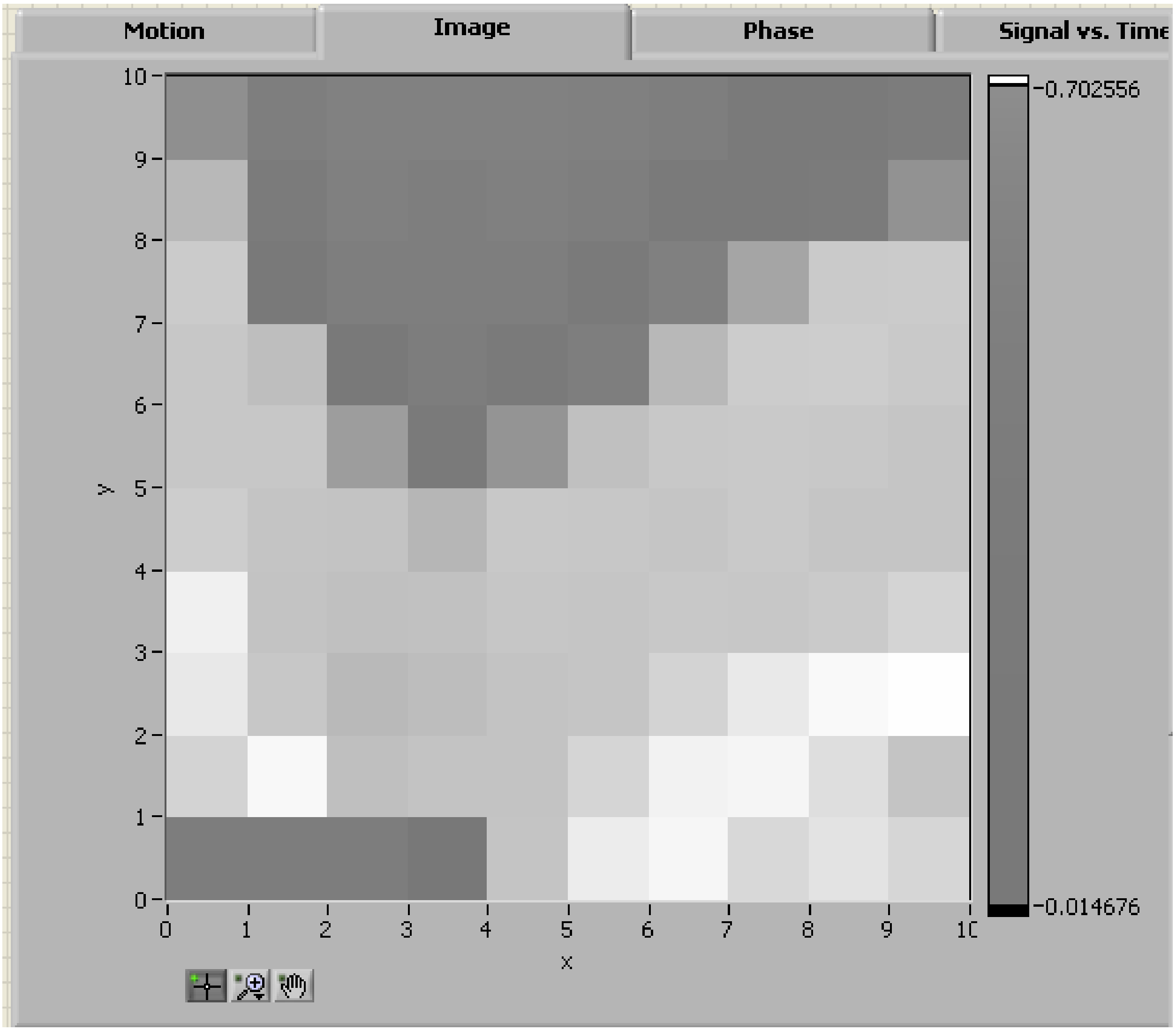

Figure 20: a 10 by 10 scan is displayed in the intensity plot on the image tab.

Phase Tab

In the event of erratic data with high negative value signal one can switch to this tab and observe the phase of the accumulated signal. If the phase is changing rapidly through a large number of values this indicates some sort of data collection issue. Whether one has a large transient noise in their input path or has damaged software (whether from a virus or personal modification) this tab can give some clue as to whether there is a measurement issue. The only thing available in this tab is the meter displaying the phase of the current accumulation period. The phase tab is shown in Figure 21.

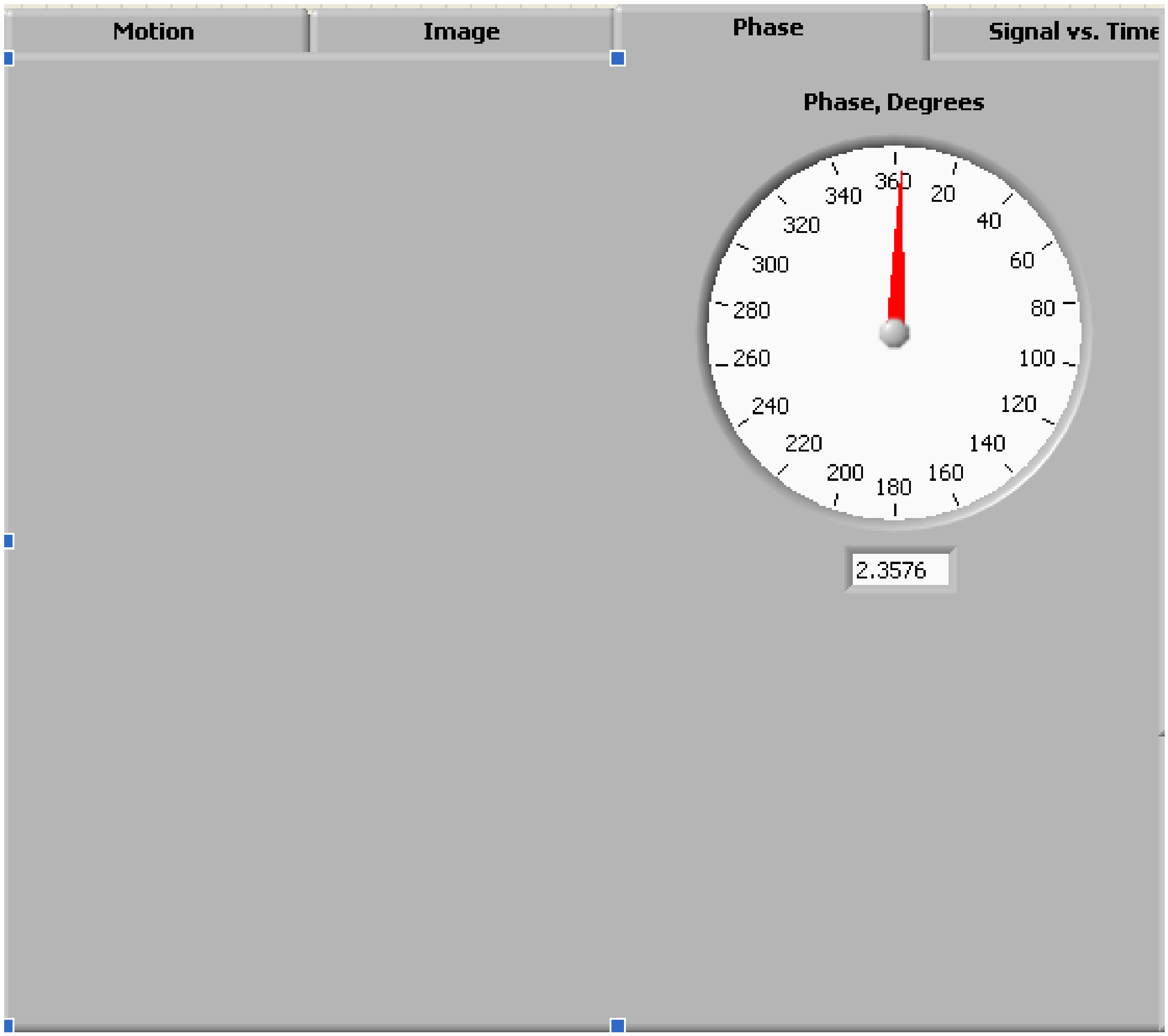

Figure 21: Phase tab.

Signal vs. Time Tab

This tab is exactly the same as in Powermeter.vi. It provides a diagnostic tool for large signal fluctuations. If one has standing wave issues the phase will be relatively stable while this data will go through rapid changes that have some periodic behavior to them.

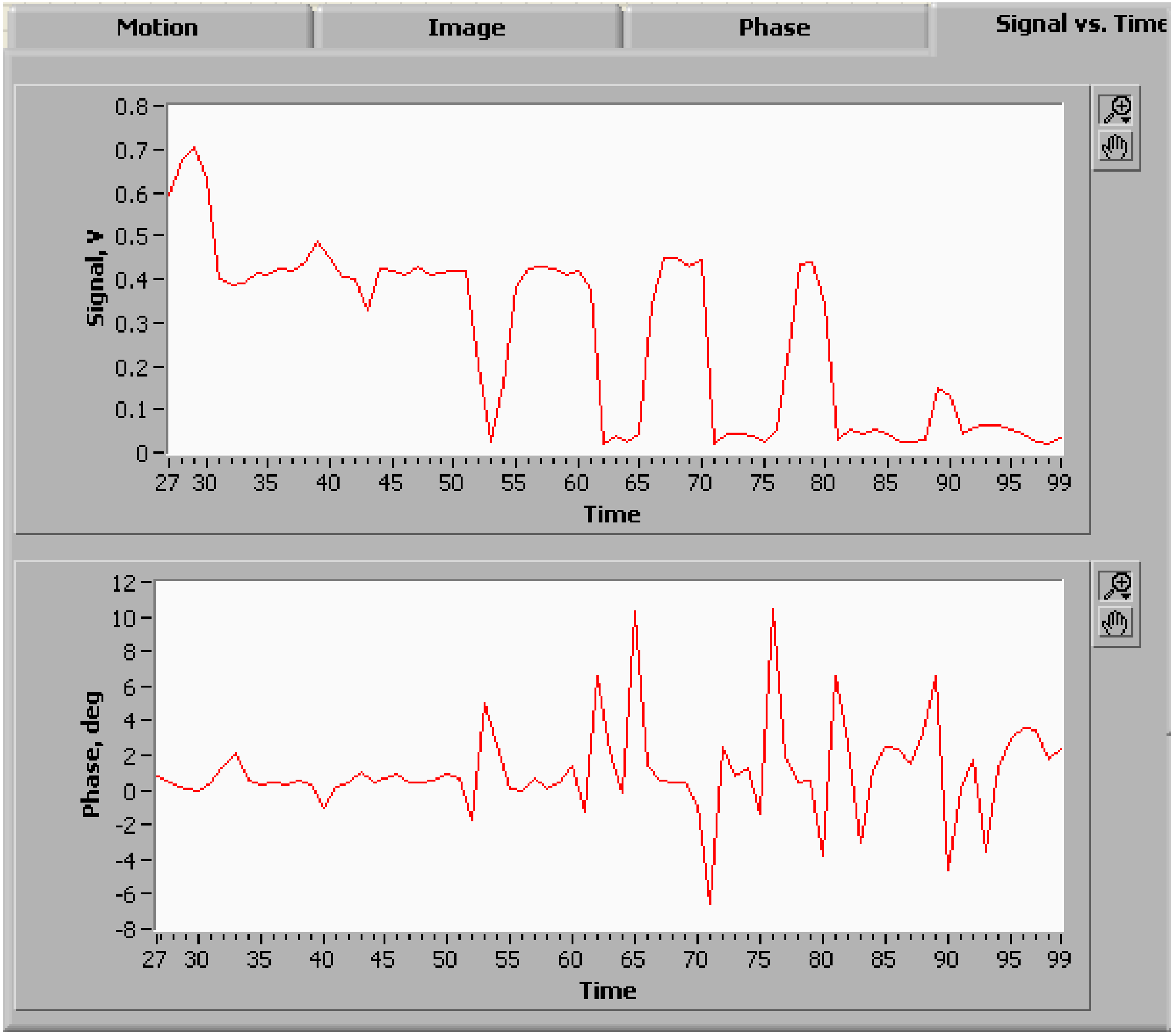

Figure 22: Signal vs. Time tab.

Operating Imager8-4.vi

Set all the relevant parameters before operating as described earlier.

It is important to make sure the sensitivity is set correctly before beginning the scan to avoid overload conditions. Since this is changeable during operation if you need to adjust it to a higher sensitivity due to the transmission and absorption properties of the material that is ok.

If the Motor I/O port isn't set to the correct com port then the program will return an error and close Labview.

If the phase is set wrong the values of the data could become large magnitude negative numbers when most of the signal is still reaching the detector and may switch between positive and negative from one point to the next resulting in an unusable image.

Once the parameters are set press the run button to begin the scan. The scan will immediately start and the scan % complete bar and indicator at the bottom will display the percentage of completion. Changing to the image tab at this point is ok. The image won't appear until the scan completes but you can get immediate feedback once the scan is complete on this tab.

When the scan is complete the data is displayed in the intensity graph and the first of two dialog boxes open up.

The first dialog box allows you to save the raw data into a .csv excel file. The data will be in the format of horizontal rows and vertical columns of the same number as you input in steps. Example: The 10 by 10 scan displayed earlier would produce a 10 row file with 10 columns. The dialog box does require that you add the .csv suffix to the file manually. Figure 22 shows the dialog box.

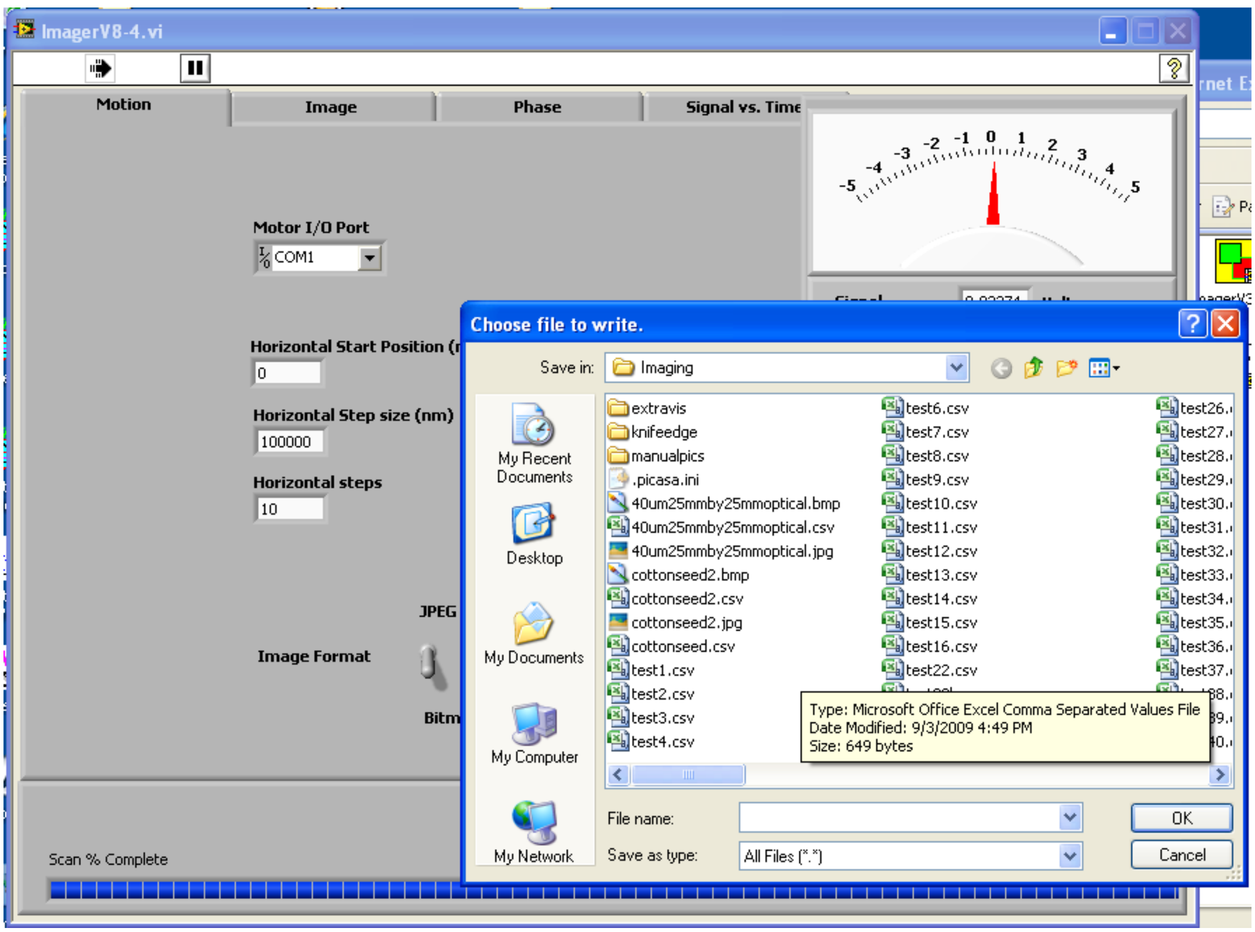

Figure 22: first of 2 dialog boxes is open. This box is for saving the raw data to a .csv file. The extension must be added manually to the file name.

DO NOT SAVE TO A FILE NAME TWICE AS THE PROGRAM WILL APPEND THE NEW DATA ONTO THE OLD FILE. Be sure to use a new name for each file. One trick I use is to decide to use a garbage file name and let it append onto that file if the scan (or knife edge file) is bad. Then later I only have one file to delete.

Once the first dialog box closes after clicking ok the second dialog box opens to save the image in contrast enhanced format. This dialog box does not require the file extension added manually. The files are not appended if you use a previous name. **CHOOSING THE SAME FILE NAME HERE WILL OVERWRITE THE FILE.**

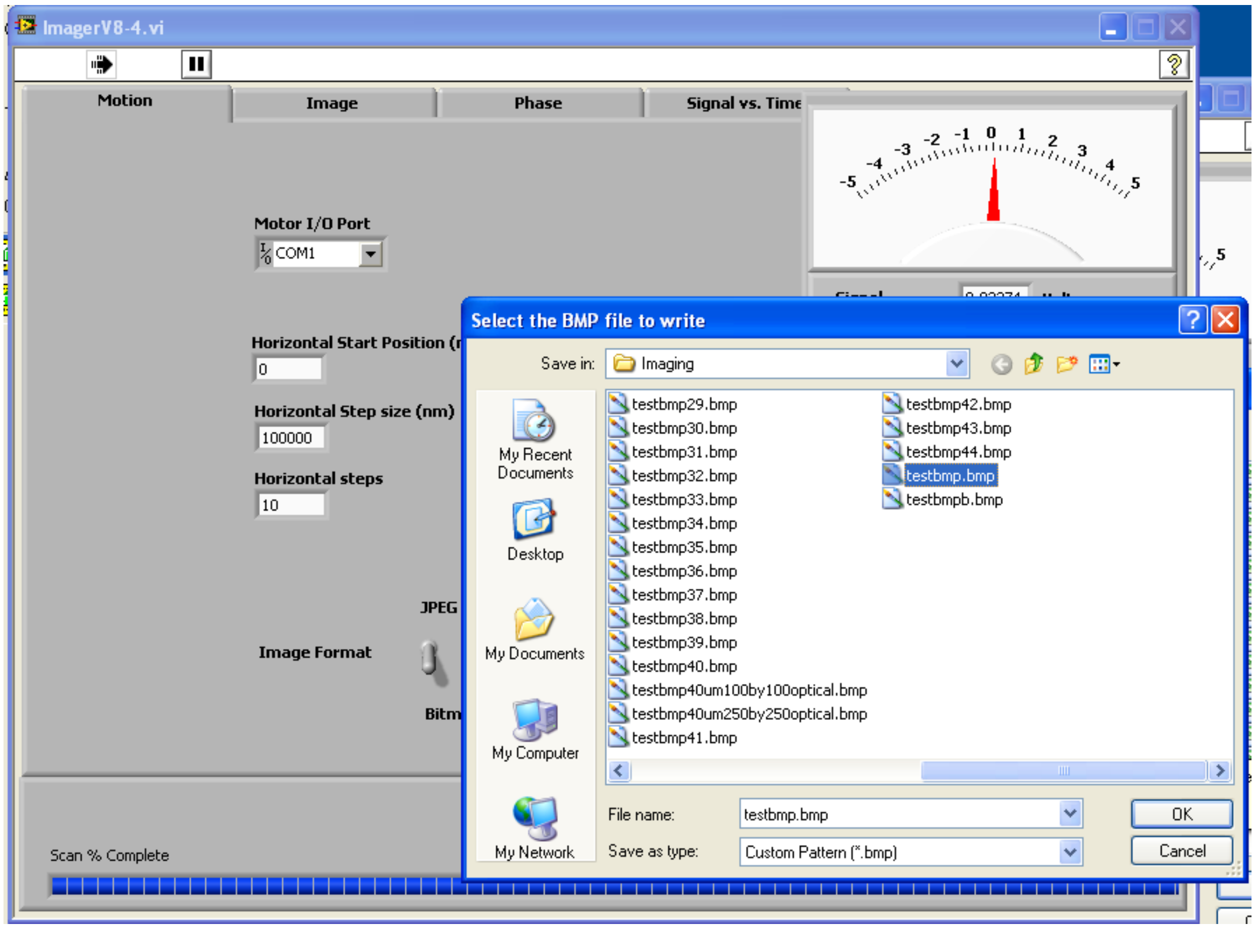

Figure 23: Second dialog box for saving the image file.

Once the image is saved the program completes running.

Chapter 4: Other Programs as Utilities

There are a set of additional programs as examples for the motorized linear stages in the zaber/zaberTseries/examples folder. These programs can be used to understand and build motor control programs for other purposes by the user.

There are two programs in the extraVIs folder that are useful in understanding image processing in Labview and for developing tools. One is ArraytoJpeg.vi which allows you to build your own array and use it to generate a new JPEG image file.

The other is Load_data.vi which allows you to load one of the raw data files and see it in different intensity graph formats (linear and logarithmic). It displays the data but doesn't save it.

Between these two you can learn how to do image processing and how to save the processed data. If you need some other contrast level or want to build a color format image of some type these tools are a good start.