UMECH NETWORKED PROBE STATION USERS MANUAL

30 November 2000

Contents

Important safety information

The Umech networked probe station uses 120V line power and lasers.

Do not open the server box as you can be exposed to 120V.

Do not open the optics module, it contains a class III laser. Under normal operation the optical power coming out of the optics head is class II.

Do not look directly into the objective on the optics box.

System contents

One server box

One optics module

Two damped rods

One 6 conductor cable

One 12 conductor cable

One 50 conductor cable

One flat screen display

One VGA cable

Two power cords

Two spare fuses

Hardware setup

Step 1: Make sure you have all the parts listed in the system contents list.

Step 2: Place optics module on damped rods and secure constructed unit to a vibration isolated base.

Step 3: Locate server box within 6 feet of optics module (to ensure that the cables will reach).

Step 4: Make sure the main power switch is off (the O should be depressed).

Step 5: Plug in the main power cord.

Step 6: Plug in the cables

Power connector for display
VGA cable from display to server box
Network cable from server box to wall network jack
50 conductor cable from server box to optics module
6 conductor cable from top of optics module to bottom of optics module
12 conductor cable from server box to optics module

Step 7: (OPTIONAL) if the server has not been configured for your network you will also need to plug in the mouse and keyboard. Please contact support@umech.com for assistance in configuring the server on your network.

Step 8: Turn on main power switch (the fan on the back of the server box should turn on)

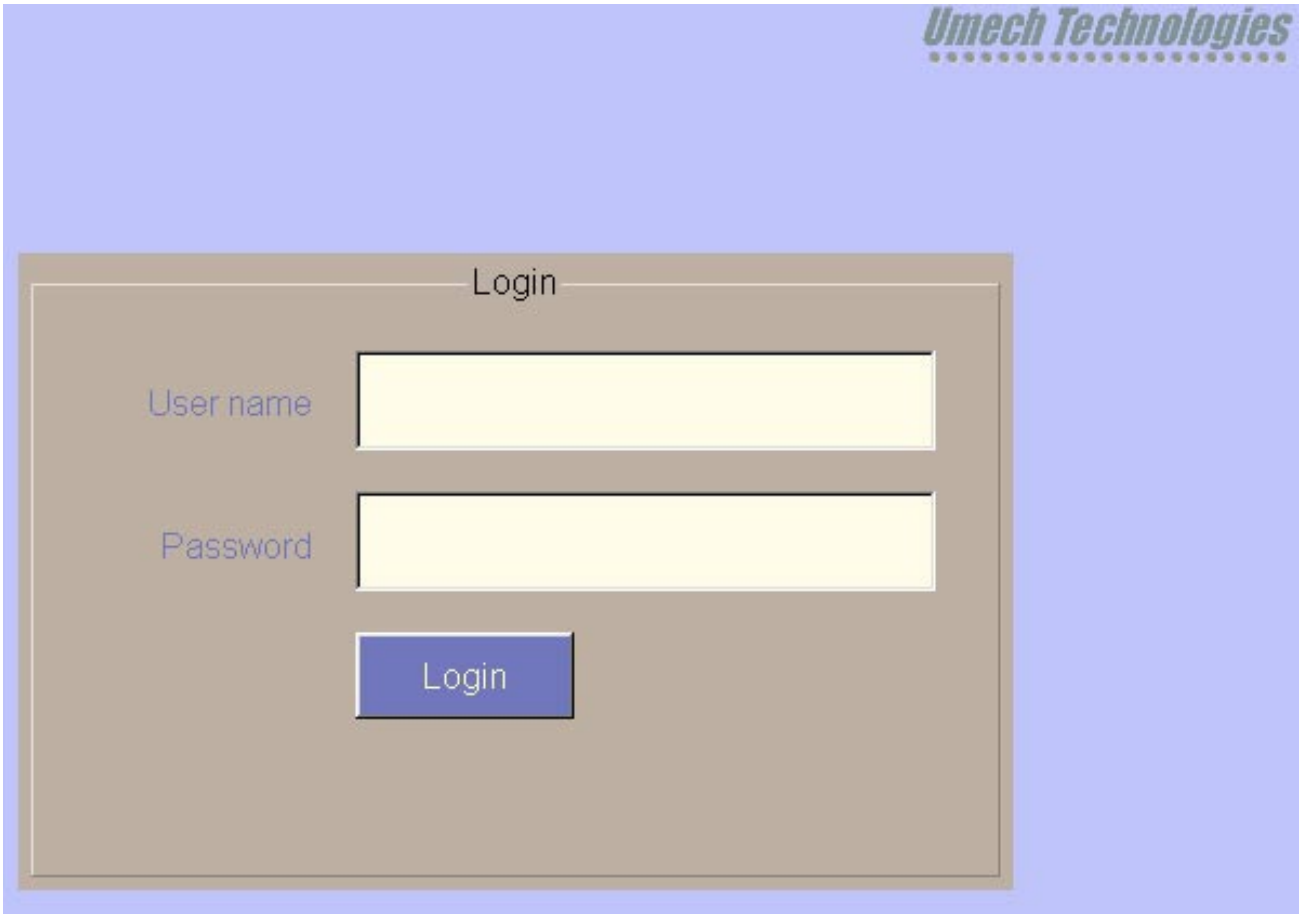
Step 9: Depress and release the momentary switch. The system should come up and you will be able to access it over your network.

Logging on

You will need to know the network address of your Networked MEMS Probe Station as well as a user name and password assigned by your server administrator. If you are the server administrator and need help please contact us at support@umech.com.

Start Netscape (version 4.7 or above) and open http://your server address/ (if you do not know the proper address please contact the person responsible for you Networked MEMS Probe Station).

The following screen will appear:



Type in your user name and password and select the login button. A message will appear below the login button saying *Welcome (your username)*. If the message reads *the server is not ready* there are three possibilities (1) someone else is using the system to collect or analyze data (2) the system is not on, and netscape is showing you a cached page or (3) the system has crashed. Please see the trouble shooting section for more information on trouble logging in.

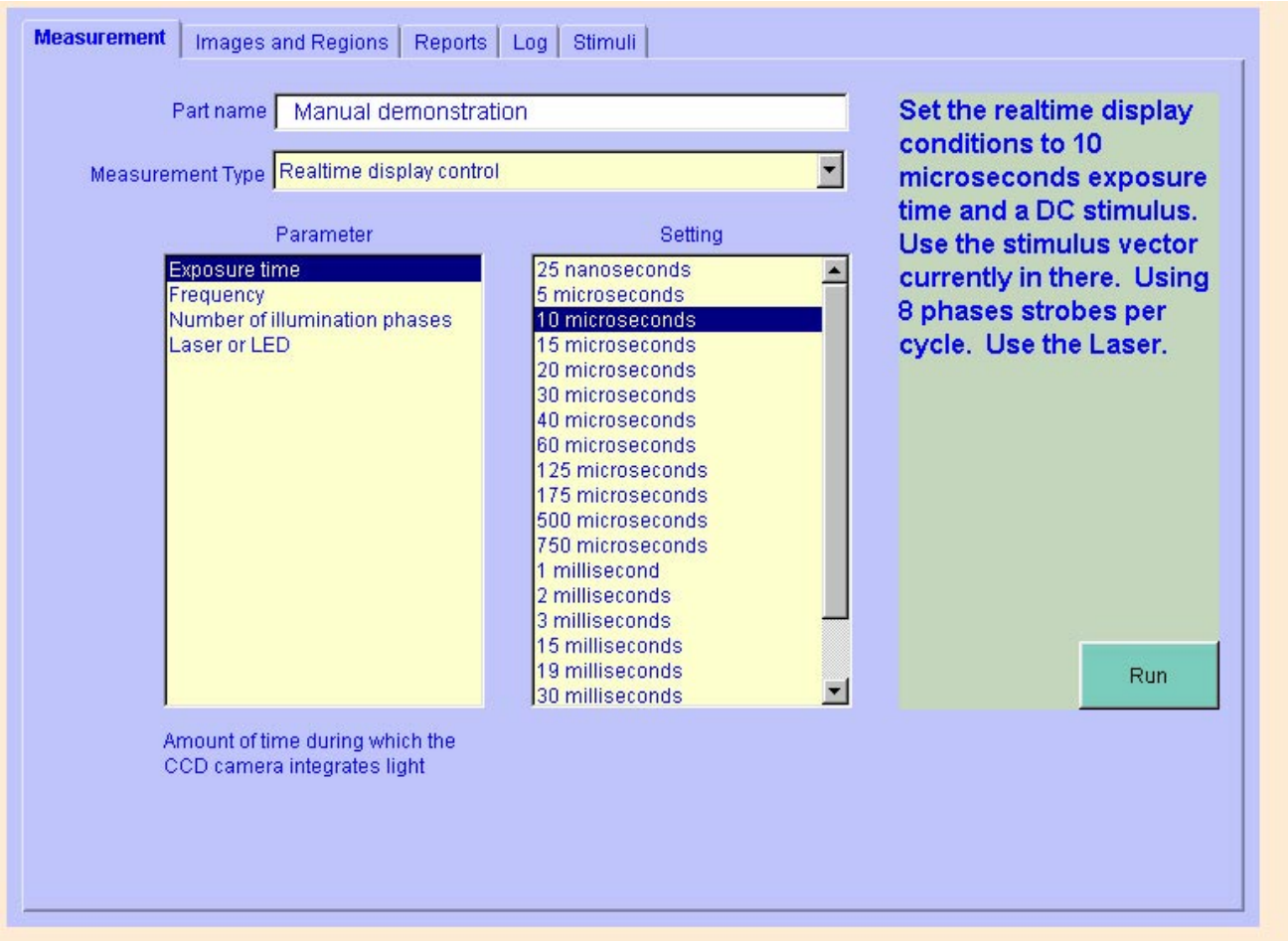
After successfully logging on you will be presented with the system user interface.

The user interface

The user interface is setup to facilitate the typical progression of steps in an experiment:

(1) Setting up the experiment
(2) Defining stimulus parameters
(3) Getting a qualitative understanding of the data you will collect
(4) Collect data
(5) Analyze data
(6) Share your results
(7) At the end you should have a good log of what you have done

With this in mind, we have grouped the functionality of the system into 5 "tab panels". Shown below is the user interface with the "Measurement" tab panel in the foreground:



In this case you could switch to the "Images and Regions", "Reports", "Log", or "Stimuli" tab panel by clicking on the appropriate tab with your mouse pointer.

Using the real time display control

A visualizatoin enabling feature of the Networked MEMS Probe Station is the ability to see your MEMS devices moving in real time. This section describes how to control the real time display.

Focus behavior

When the system is not collecting or analyzing data, the real time display will be updating continuously. The characteristics of the real time display are controlled in the measurement tab panel under the measurement type *Realtime display control* which can be selected from the associated pulldown menu. All of the *Measurement Types* have parameters that the user controls. The list of parameters appears in the left hand list box titled *Parameters*. Each parameter has some associated set of possible values which appear in the right hand box titled *Setting* when a parameter is selected. The real time display control has the following parameters the user can set:

(1) Exposure time
(2) Frequency
(3) Number of illumination phases
(4) Laser or LED

Exposure time

The exposure time is the amount of time that the target is illuminated before the image is transferred from the optics module to the server box. The longer the exposure time, the brighter the pictures are. If too little light is returned to a CCD pixel to contain useful information the pixel is displayed as green on the real time display. If too much light hits a CCD pixel and the pixel saturates (another state containing no useful information) the pixel is displayed as red on the real time display. Normally you want to set the exposure time so that no pixels are red or green.

Frequency

The frequency setting corresponds to the frequency you want the arbitrary waveform generator to output the selected periodic waveform(s). For an explanation of how to define arbitrary waveforms, see the stimulus control section. For the most part the frequency setting is self explanatory, you simply select the frequency you wish the waveforms be generated. The two special settings are DC and PHASE LOCK (if your system does not support phase locking, the setting will not appear). Selecting DC stops the arbitrary waveform generator, and the output amplifiers are held at a constant value. The camera is also left in free running mode and works like a normal (not strobed) video microscope. Selecting PHASE LOCK allows the system to be synchronized with an external trigger. Phase locking synchronizes both the arbitrary waveform generation and strobed image acquistion with the trigger. The phase lock is triggered of the rising edge of a 0 to 3.3V digital signal.

Number of illumination phases

The number of illumination phases lets you select how finely you want to sample the motion of your device. It also effects how fast your device will appear to move on the real time display. The display rate of the real time display is around 20 frames per second under normal conditions. Suppose you set the number of illumination phases parameter to be 20. This means that each image captured corresponds to one twentieth of the stimulus period. Since the display rate is 20 frames per second, your device would appear to complete one cycle of motion every second.

Impact of illumination phases on real time display

Now suppose that you change the number of illumination phases to 10. Now each image captured corresponds to one tenth of the stimulus period. Since the display rate is still 20 frames per second, your device would appear to complete two cycles every second. It is important to remember that the rate the device appears to move on the display is primarily a function of the number of illumination phases and frame rate (the frame rate actually depends on exposure time, frequency, and number of illumination phases (lower frequencies, longer exposures, and more illumination phases cause the frame rate to decrease).

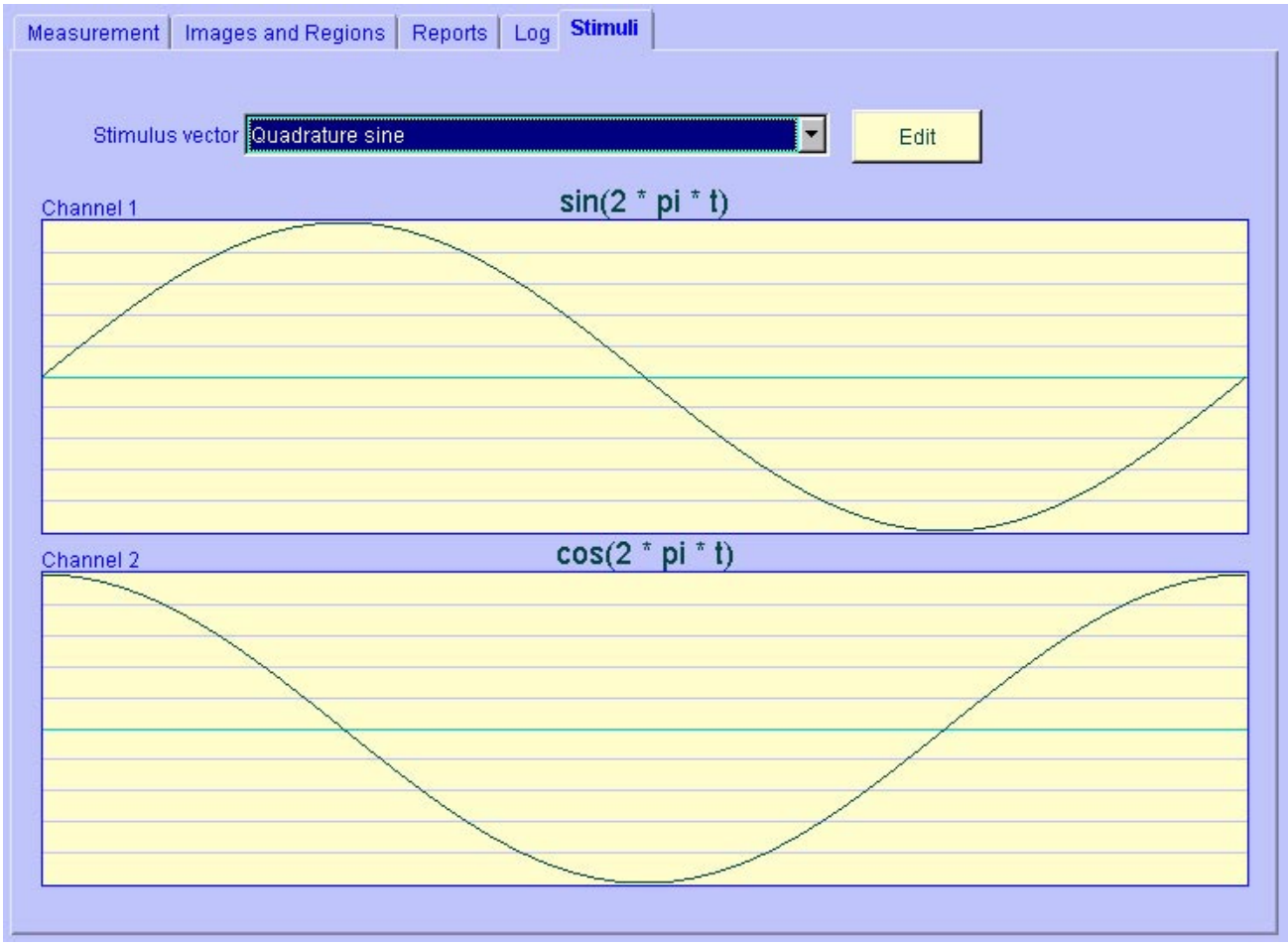
Laser or LED

The Laser or LED setting lets you select which light source you will use.

REMEMBER, YOU MUST CLICK THE **RUN** BUTTON FOR ANY CHANGES TO TAKE EFFECT

Stimulus Control

The stimulus tab panel allows you to control the arbitrary waveform generation (AWG) channels. Depending on the configuration of your system, you will have one or more AWG channels. When first selected, the panel looks similar to the one shown below:



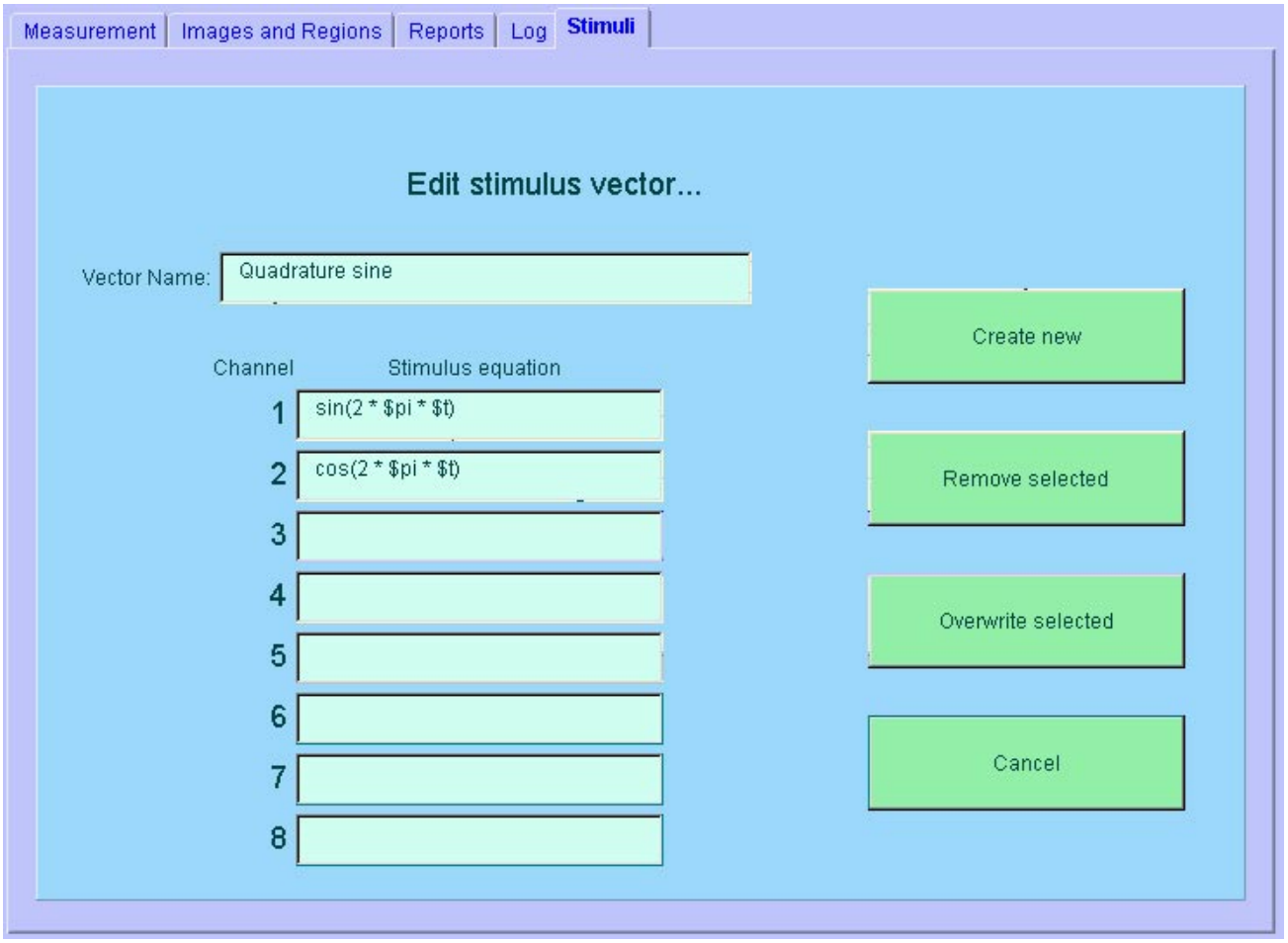
The name of the *stimulus vector* (set of waveforms) is shown in a pull down menu at the top of the panel. You can choose a different predefined stimulus vector by selecting it from the pull down menu. Beneath the pull down menu are plots of one cycle of the waveform for each channel.

Note: The frequency that the waveform is repeated at is set in the measurement tab panel. For instance, if you wanted to stimulate your device with a 20kHz sine wave and see it on the real time display; you would define one cycle of a sine wave in the stimulus editor, go to the *measurement tab* and select and run *load waveform*, then select *real time display* and set the frequency for 20kHz (and click run).

The wavefrom plot axes have time going from 0 to 1 on the horizontal axis, and output level from -1 to 1 on the vertical axis. The actual voltage of the stimulus will depend on the configuration of the amplifiers in your system; -1 in the waveform editor corresponds to the lowest voltage the channel can output, and 1 corresponds to the highest voltage the amplifier can output.

The horizontal axis represents one cycle of a waveform. The left side of the axis represents the beginning of a cycle, and the right side represents the end. If you want a waveform without a sudden jump, you need to make sure that the value on the left side is nearly equal to the value on the right side.

To edit or define a new stimulus vector, you can click on the edit button which is on the right side of the stimulus vector pull down menu. This will bring up a number of text fields you can edit, as shown below:



The top field is the name of the stimulus vector. The `create new' button will create a new entry in the stimulus vector pulldown menu in the main stimulus panel display. The `remove selected' button will remove the named entry from the pulldown menu in the main stimulus panel display. The `overwrite selected' button will erase the entry that was selected when the edit window was brought up and replace it with the information in the `edit stimulus vector' window. The `cancel' button will return you to the wave form display window.

Below the name entry field are the equations which correspond to the output of the individual channels.

Stimulus equations

Below are examples of common waveforms and constructs:

(remember, wave forms are defined as $t goes from zero to one, and the amplitude is limited from -1 to 1.)

Sine wave: sin(2*$pi*$t)
Cosine wave: cos(2*$pi*$t)
Sine wave at twice the frequency of the base stimulus: sin(4*$pi*$t)
Positive square wave : ($t > 0.5)*1
The equation interpretter parses <, >, ==, >=, <= as Booleans so they need to be multiplied by a constant to turn it into a real value.
Square wave : ($t>0.5)*2 - 1
Chirp signal : sin(2*$pi*($t**2))

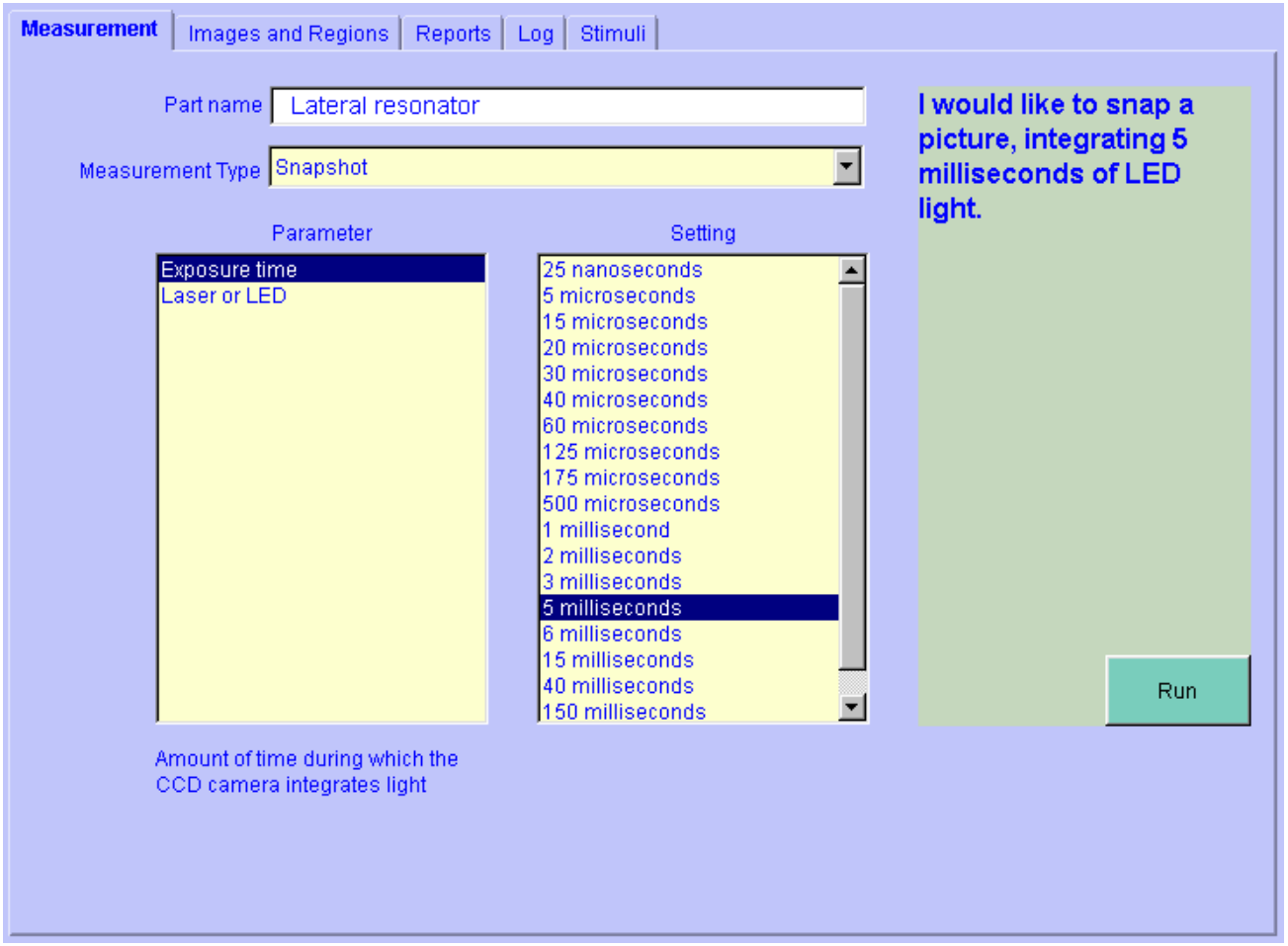
Acceptable functions include
sin($t)
cos($t)
sqrt($t)
log($t)
abs($t)
exp($t)

Constants
$pi

Taking a snapshot

Taking a snapshot at the beginning of an experiment is a good idea. It will give you a simple reference for what the field looked like at the beginning of your experiment, and you can use a snap shot to make some static measurements and configure the system (using functions in the images and regions tab panel as described in the next section).

Taking a snapshot is done with the measurement tab panel raised and snapshot selected from the measurement type pull down menu as shown below:



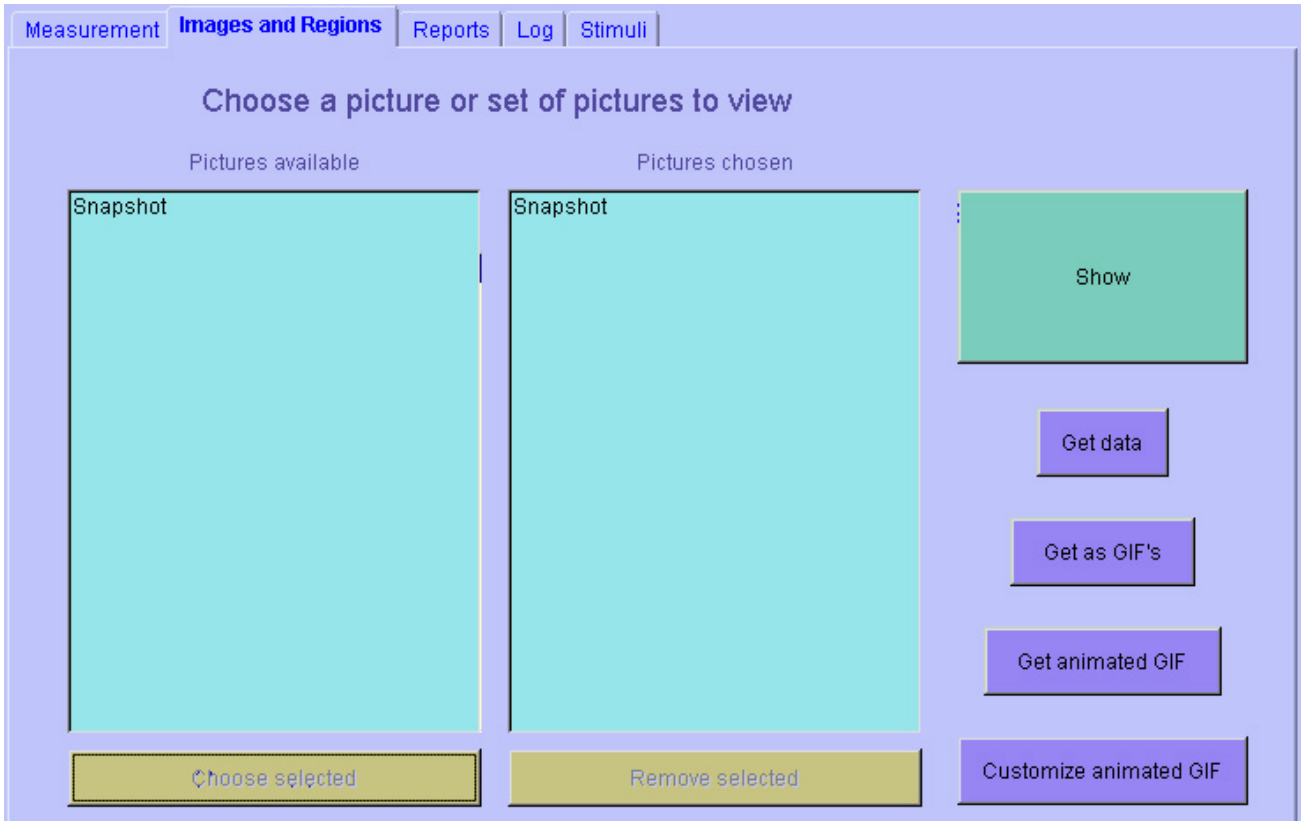
As shown in the Parameter box, there are two parameters you can set. The exposure is the amount of time you want the device illuminated before the picture is collected; if you have a good picture on the real time display, you can select the same exposure time setting for the snapshot. The Laser or LED parameter lets you select whether you want an interferogram (laser) or bright field image (LED).

Click run to take the picture. When the snap shot is complete, the reports tab panel will be on top and you can see the snapshot you took by viewing the most recent report.

You can also look at the snapshot using the Images and Regions tab panel as explained in the next section.

Images and Regions

The images and regions tab panel has two windows, a data selection window and a data animation window. The data selection window is shown below:

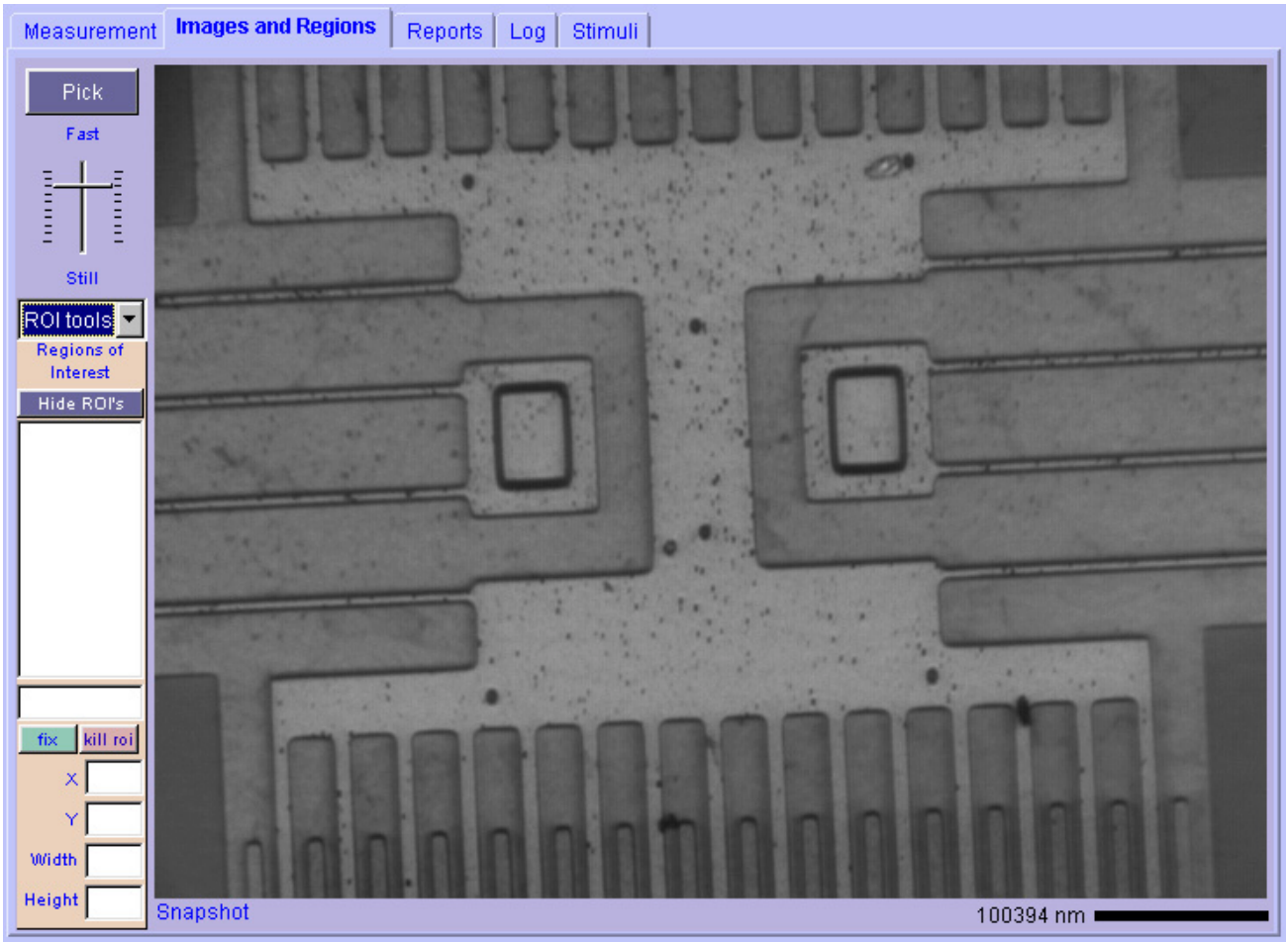


All the raw data that is currently on the system will be displayed in the left hand box, sorted alphabetically. Notice in this case, snapshot is the only available data since no two or three dimensional frequency responses have been taken. The data from a two dimensional frequency response will have names that start with 2DFR. The data from a three dimensional frequency response will have names that start with 3DFR.

Data is selected by clicking on the file name(s) in the pictures available list. When you have selected the data you want to look at, click the choose selected button. This action will add the file names you selected to the pictures chosen list. Names can be removed from the pictures chosen list by clicking on the name and clicking on the remove selected button.

Once you have chosen data to show, you can invoke the animation mode by clicking on the Show button. The animation window is shown on the next page.

The *Get Data* button will bring up a netscape dialog box which will allow you to save the raw data (in PPM format) to your local computer. The *Get as GIFs* button will allow you to get the raw data in GIF format. The *Get animated GIF* will compile all the pictures in the *Pictures Chosen* list into an animated GIF and allow you to download it.



In this case Snapshot was the only picture selected so the animator is displaying the same picture over and over again (hence it looks still).

Explanation of the animator window:

In the upper left is the Pick button, clicking on it will return you to the data selection window.

Below the Pick button is the animation speed slide bar. By moving the slide bar up or down you can increase or decrease the animation rate.

Below the animation rate slide bar is a pull down menu to select the type of operation you want to perform on the image. The types of operations will be explained in detail later on.

Below the pull down menu is an interface for the operation you have selected from the pull down menu.

Underneath the image on the left hand side is the name of the image being displayed. If multiple images are being animated, the name corresponds with the image being displayed at that moment.

Underneath the image on the right hand side is a scale bar.

Animator Operations

ROI tools: shown below is the *ROI tools* interface

You can draw a region of interest(ROI) on the animation by holding down the mouse button while you draw a rectangle. The ROI will be listed in the list of ROIs and its parameters (X position, Y position, width and height) will be displayed. You can edit the ROI name by editing the text in the box below the list and pressing return (if you do not press return, the change will not take affect). You can also edit the X, Y, width, and height parameters to adjust the ROI you drew with your mouse. You can make as many regions of interest as you like.

ROIs are selected by clicking on the name of the ROI in the ROI list. If you try to click on a ROI in the animator, you will create another ROI. The selected ROI will be highlighted in red on the animator, the unselected ROIs will be blue. You can toggle the ROIs to be displayed or not by selecting the Hide/ Show ROIs button.

To delete a ROI, select its name in the ROI list and click the *kill roi* button.

You can use the *fix* button to tell the analysis software that the area of the animation enclosed by the ROI will not move during your experiment (any motion in a fixed ROI should only be due to noise). The analysis software can use this information when it analyzes your data to measure the differential motion between a fixed area on your device and the part of your device that is actually supposed to move.

Please see the picking regions of interest sub-section for more information on how to select ROIs.

Dot tool: shown below is the *Dots tool* interface,

Selecting the dots interface will cause the system to calculate the estimated in-plane motion for each ROI and display a dot corresponding to that motion on the animation. You can exaggerate the motion of the dots using the slide bar in the interface.

Measure tool: shown below is the *Measure tool* interface,

The measure tool allows you to measure distances on the animation, and to calibrate the system.

Holding down the mouse button on the animation will allow you to draw a line. The coordinates of the end points of the line are displayed in the bottom of the Measure tool interface. In this case, they are (285,245) and (348, 242) which correspond to a line whose length is 63 pixels. Given the current settings in the system, the analysis tools think that 63 pixels corresponds to 63320 nm or 63.320 microns.

You can calibrate the system by taking a picture of a structure with known dimensions, and with the measure tool, draw a line that known distance. Type that distance into the editable text window. The system is now calibrated for in-plane motion measurements.

Pan tool: the *pan tool* lets you drag the animation around in the window. You can re-center the animation by clicking on the origin button.

GIF maker tool: The *GIF maker* interface is shown below

The GIF maker allows you to make an animated GIF of the animation. You can scale the GIF by typing in a scale factor in the scale box. You can control how many cycles the animation will play by typing in the loop count box (typing forever will cause the animated GIF to cycle forever). You can use a ROI to crop the image (only the region inside the selected ROI will be saved to the GIF). When you have selected the parameters you want, select make GIF. The server will create the GIF and allow your web browser to save the file.

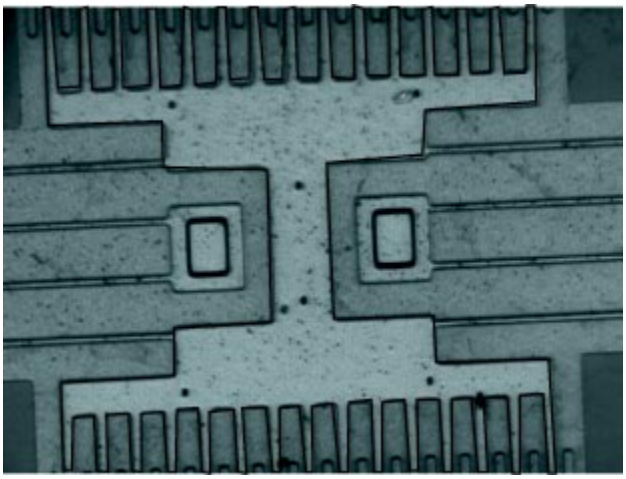
Picking regions of interest (ROIs)

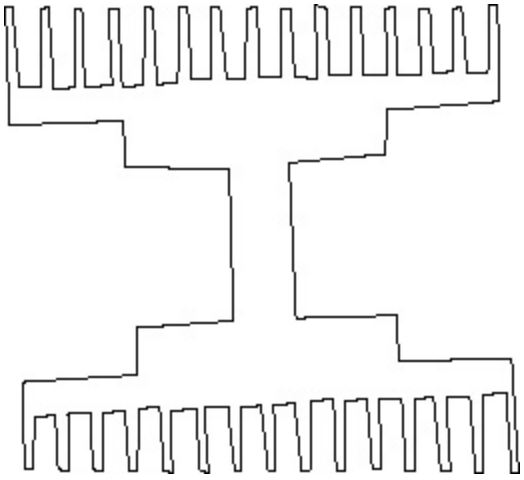
Key points:

(1) ROIs should contain areas of the device that are rigidly connected
(2) The amount of computation time is proportional to the size of the ROI (try not to exceed a 50x50 pixel area)
(3) The motion estimates are better for larger ROIs
(4) 2D frequency response ROIs should contain high contrast structures, while 3D frequency response ROIs should contain flat, uniform surfaces.

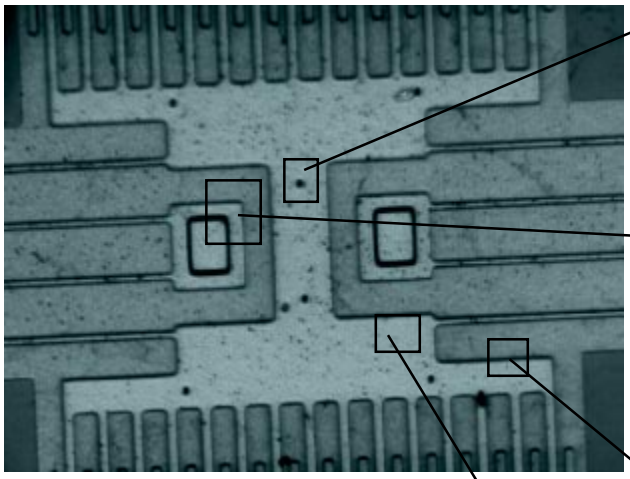
We generally recommend ROIs be 10 by 10 pixels for optimal noise/speed performance.

In the image below, we have outlined the proof mass (the moving part of the device) of a lateral resonator.





We are interested in seeing how this device moves, so we would pick the ROIs shown below:



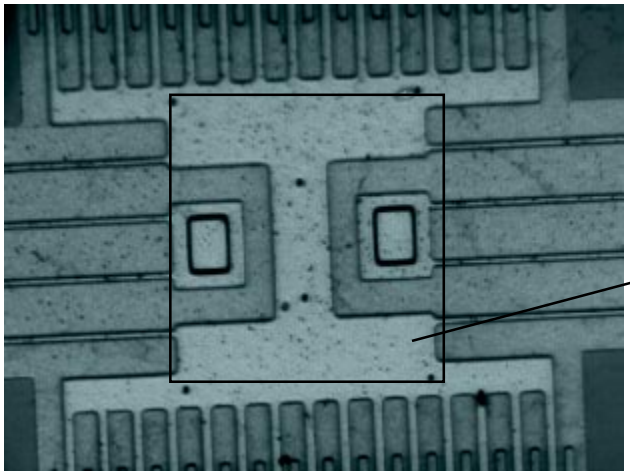
Good ROIs

This ROI contains a high contrast structure that is rigidly connected to the proof mass. The ROI is large enough to provide a good estimate of the motion and small enough for fast computation.

This ROI contains a high contrast structure that is anchored to the substrate. The ROI is again a reasonable size for speed/performance.

Bad ROIs

This ROI is a fine size, but it contains areas of the proof mass and the substrate. The motion estimate for this ROI will be somewhere in between the motion estimate for the substrate and the motion estimate for the proof mass (and consequently not very useful).

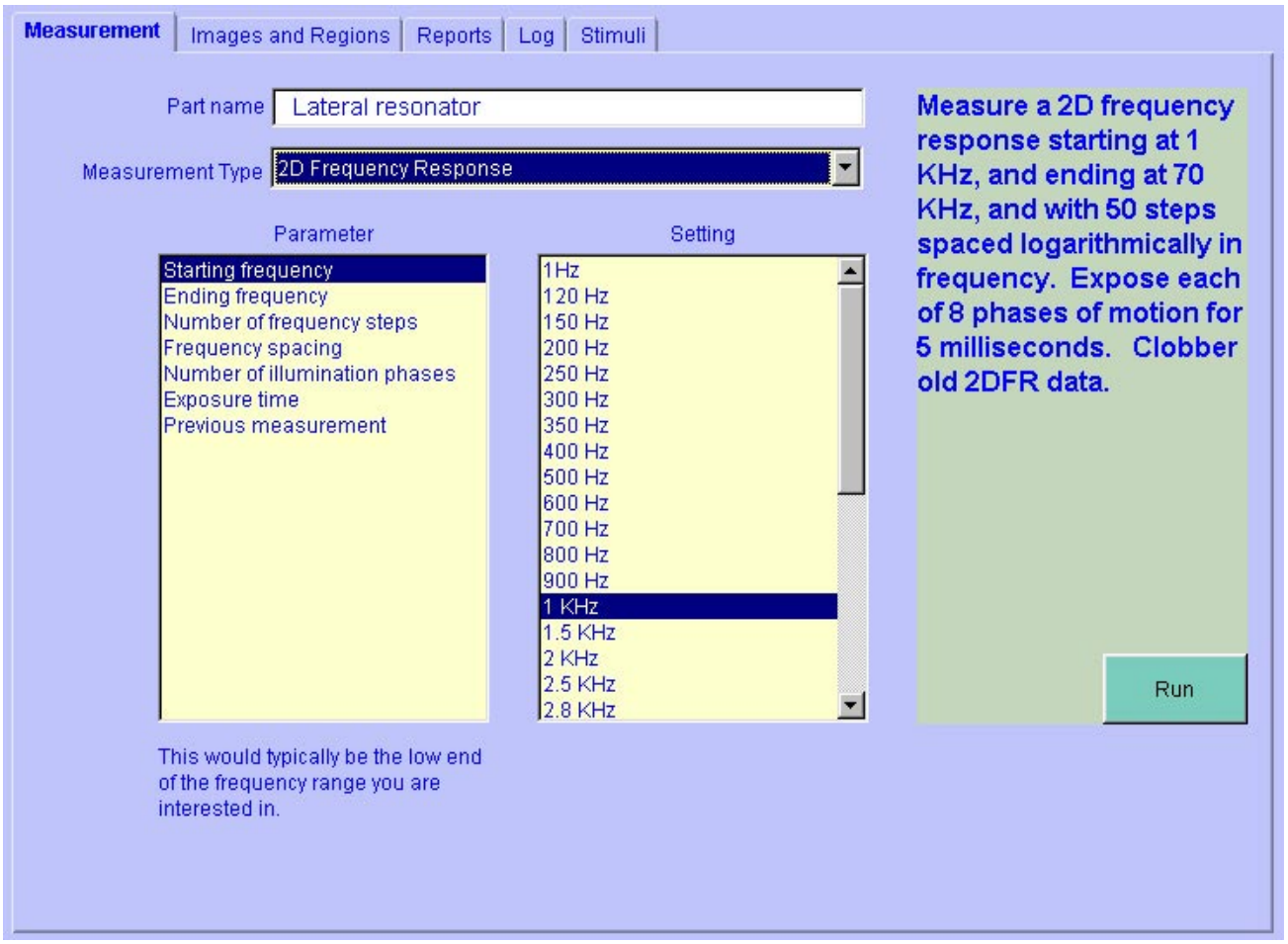


This roi has the same problem as the previous ROI. Though not obvious in this frame, as the shuttle moves it will move out of the ROI, so some frames will have areas of the substrate in the ROI.

Too big.

Taking a 2D frequency response

A 2 dimensional frequency response (2DFR) measurement allows you to collect and analyze data on the in plane motion of your device. The images collected are always illuminated with the LED. The 2D frequency response is run from the measurement tab panel as shown below:



Before you can run the 2DFR measurement you must select at least one region of interest. Consequently you should take a snapshot of your device, and then use the ROI tool in the animator window of the Images and Regions tab panel to select a ROI.

The measurement parameters and their settings are explain below:

Starting frequency: The lowest frequency (in Hz) at which you wish to collect data. If you only want to collect data for one frequency, set the starting frequency to be that frequency and set the number of frequency steps to be 1.

Ending frequency: The highest frequency (in Hz) at which you wish to collect data.

Number of frequency steps: The total number of frequencies (spaced evenly or

logarithmically as described below) that data is collected. If the number of frequencies is set to 1, data is collected at the starting frequency.

Frequency spacing: This parameter is not used if number of frequency steps is set to 1. The settings for this parameter are *spaced evenly in frequency* and *spaced logarithmically* in frequency. If you select even spacing in frequency, the frequencies are calculated as follows:

If you select logarithmic spacing in frequency, the frequencies are calculated as follows:

Number of illumination phases: This is the number of samples to take during one stimulus period.

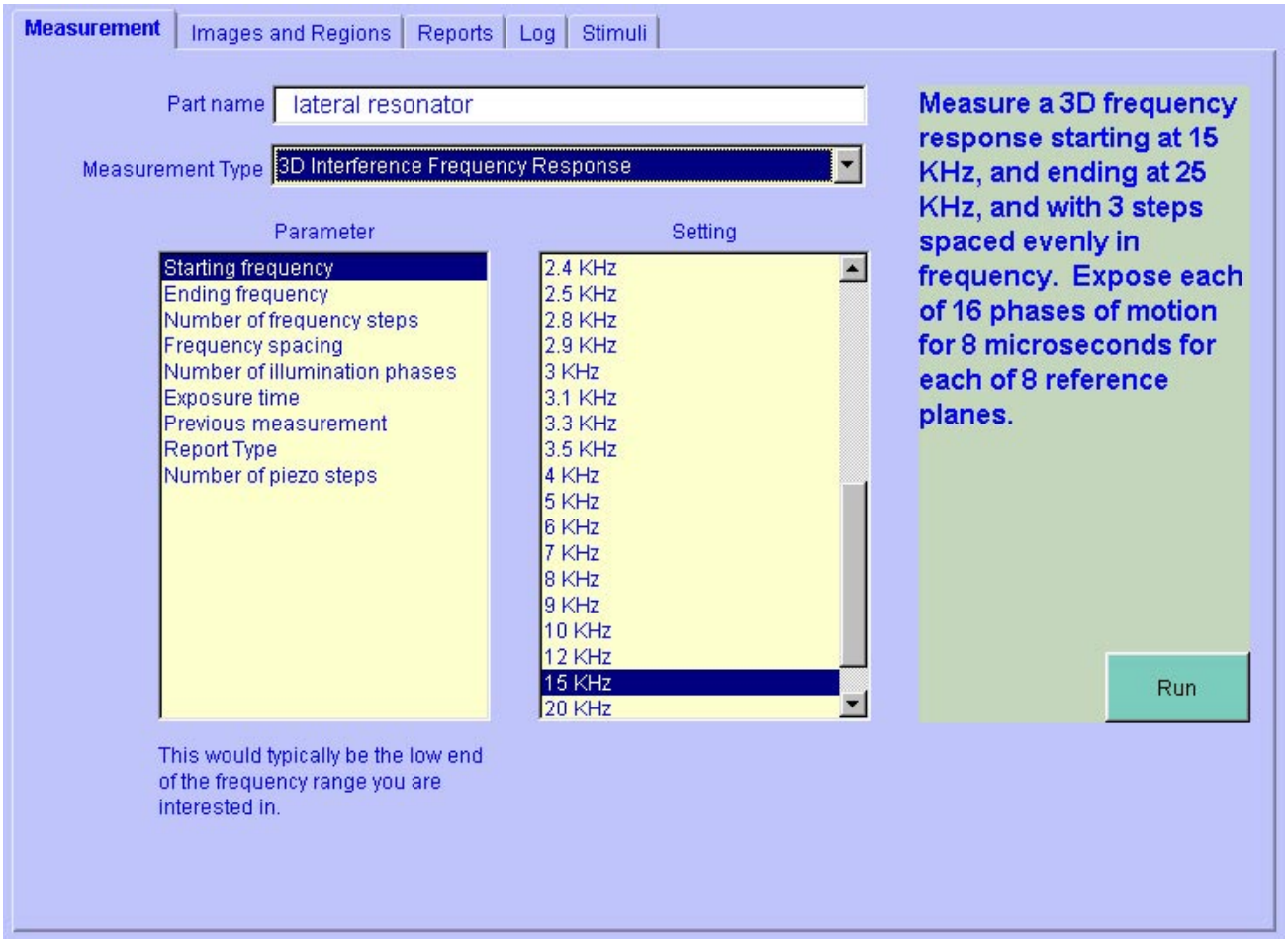
Exposure time: The exposure is the amount of time you want the device illuminated before the picture is collected

Previous measurement: if you would like to combine this data with the previous measurement (for instance if you are zooming in on a frequency region, you can select the *append data* setting. If you would like to delete the old data, select the *clobber* setting.

You will need to selected at least one ROI before collecting the data. When you have selected a ROI in the Images and Regions tab panel and have set the parameters to your liking, press the *RUN* button to start collecting data. The display will switch to the log tab panel and display the progress of the data collection. When the data collection is complete, the system will analyze the data for the ROI you selected.

Taking a 3D (interference) frequency response

An interference frequency response (3DFR) measurement allows you to collect and analyze data on the out of plane (axial) motion of your device. The images collected are always illuminated with the laser. The 3D interference frequency response is run from the measurement tab panel as shown below:



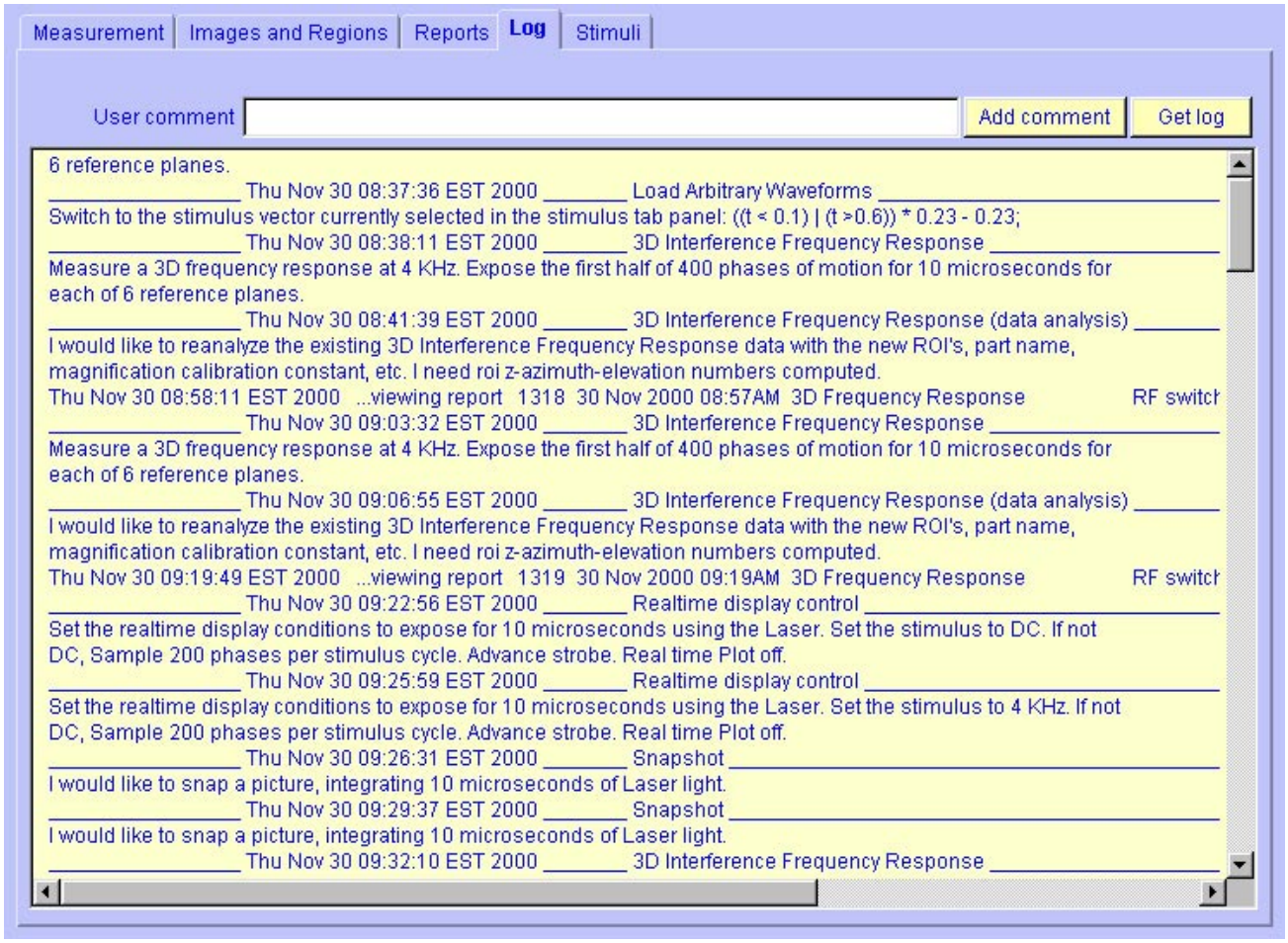
The parameters and settings are similar to those of the 2D frequency response measurement. The only added parameter is the number of piezo steps parameter. The number of piezo steps sets the number of reference mirror positions at which data will be taken. This should always be set to 8 unless ortherwise instructed by someone from Umech.

You will need to selected at least one ROI before collecting the data. When you have selected a ROI in the Images and Regions tab panel and have set the parameters to your liking, press the *RUN* button to start collecting data.

When the data is collected the systems does not automatically analyze the data, you need to select the *analyze 3D interference data* from measurement type menu of the Measurement tab panel.

The Log tab

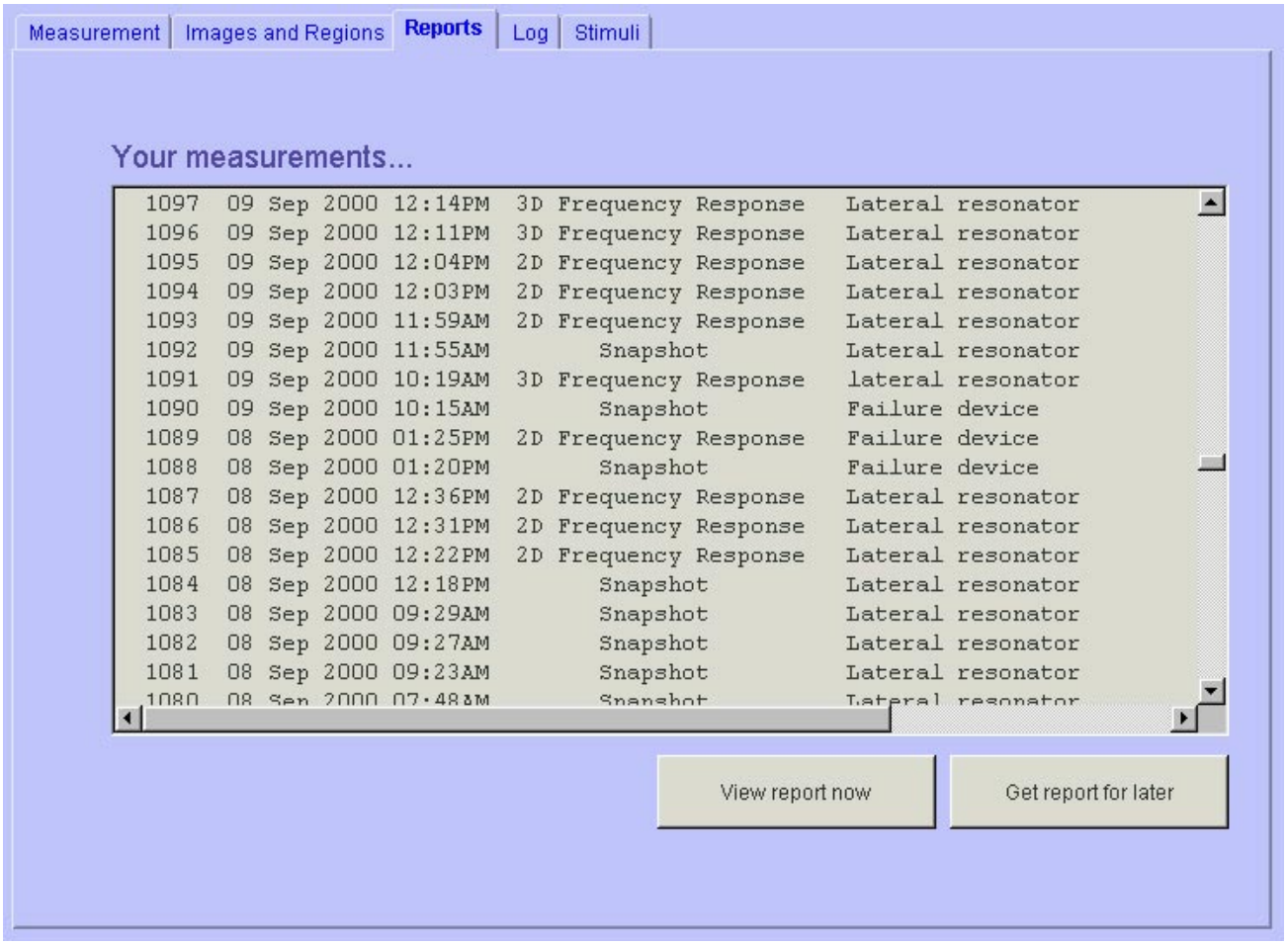
The server keeps a log file of every request the user makes: changing the real time display, collecting data, analyzing data. Shown below is the *Log tab panel*.



The window in the *Log tab panel* shows the most recent 200 lines of the entire log. You can retrieve the entire log by clicking the *get log* button. You can add comments to the log by typing your text in the comment box and pressing the *add comment* button.

The Reports Tab

The *Reports tab* shows a list of all the reports you have generated on the system. They are sorted by date. An example report list is shown below:



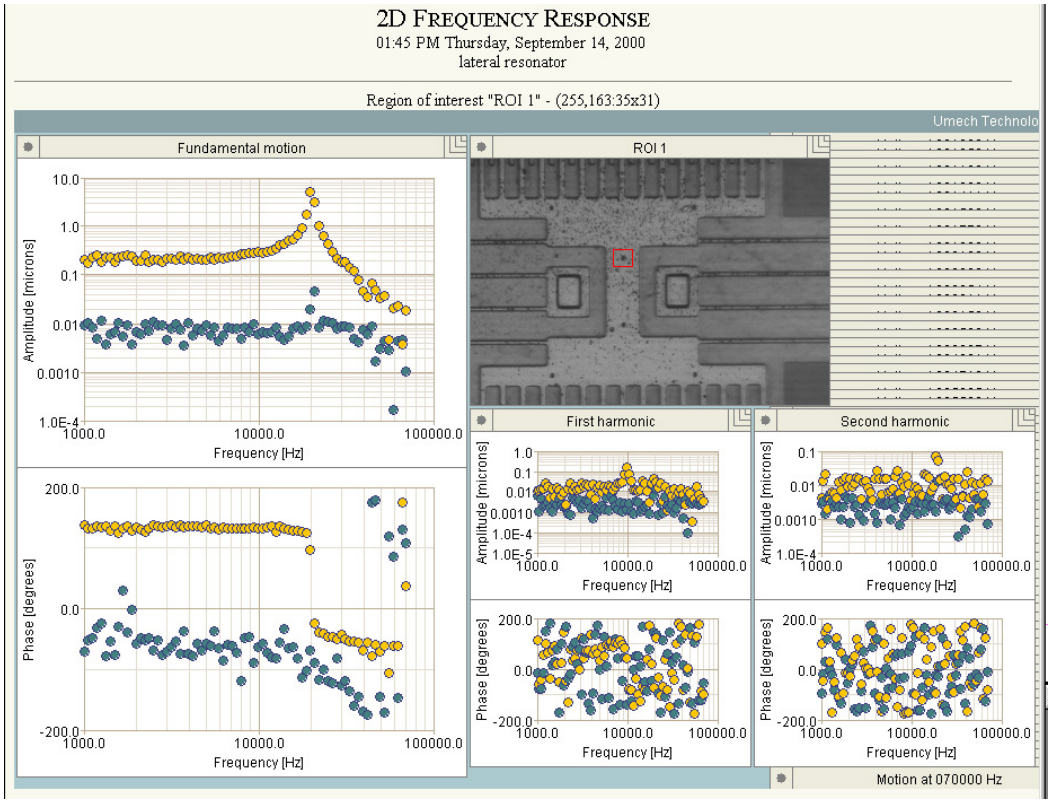
Each entry contains the report number, the date the report was generated, the report type, and the part name. You can edit the part name for an entry by double clicking on the entry in the report list.

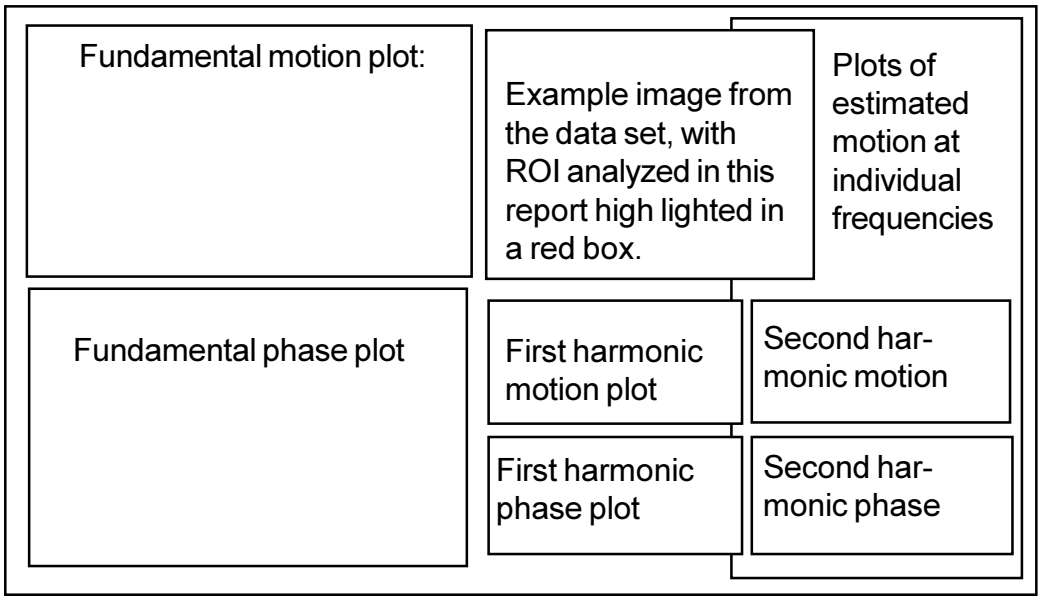
To view a report, select it by clicking on its entry row and click the *View report now* button. This will open a new netscape window and show you the report.

To save a report to your computer for later viewing or to send it to a friend, click the *Get report for later* button. This will generate a zip file that contains the report data and a report.html file. You can view the report by uncompressing the zip file in its own directory and opening the report.html file in netscape.

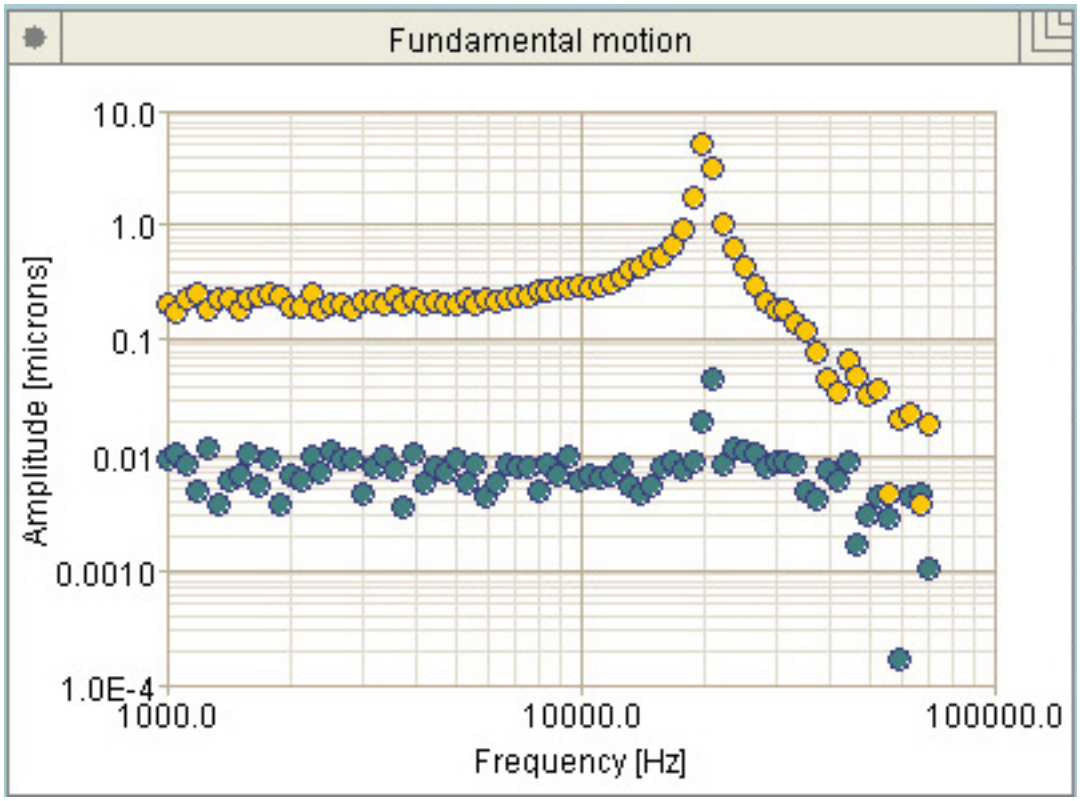
In plane measurement reports

Shown below is the standard in plane motion report. At the bottom of the page is a diagram that identifies the different sections of the report. In all plots, characteristics (motion or phase) of the vertical direction (Y) are shown in yellow, and all characteristics of the horizontal direction(X) are shown in blue.





A report 'window manager' is generated for each ROI that was selected before the analysis was run. On the previous page is shown one such window manager. Within the window manager are a number of windows. Shown below is an example of the Fundamental Motion plot window:



All windows can be moved by holding down the mouse button while the cursor is on the title bar. All windows can be minimized or maximized by clicking on the gray circle in the upper left hand corner of the window. All windows can be resized by holding down the mouse button while the cursor is in the upper right hand corner of the window.

Windows in the 2D frequency response report

There are eight basic types of windows in the 2D frequency report, as shown in the box diagram on the bottom of the previous page. They are

Plots of estimated motion at individual frequencies: these are plots of estimated motion versus illumination phase. The motion estimates for a particular illumination phase are made using the data for that phase, the phase before it, and the phase after it.

The fundamental motion plot: this is a plot of the magnitude of the motion at the stimulus frequency versus the stimulus frequency. The data points at each frequency are generated by taking the magnitude of the FFT of the estimated motion plots described above.

The fundamental phase plot: this is a plot of the phase of the motion at the stimulus frequency versus the stimulus frequency. The data points at each frequency are generated by taking the phase of the FFT of the estimated motion.

The first harmonic motion plot: this is a plot of the magnitude of the motion at twice the stimulus frequency versus the stimulus frequency. These plots are generated via the FFT of the estimated motion plots.

The first harmonic phase plot: this is a plot of the phase of the motion at twice the stimulus frequency versus the stimulus frequency. These plots are generated via the FFT of the estimated motion plots.

The second harmonic motion plot: this is a plot of the magnitude of the motion at three times the stimulus frequency versus the stimulus frequency. These plots are generated via the FFT of the estimated motion plots.

The second harmonic phase plot: this is a plot of the phase of the motion at three times the stimulus frequency versus the stimulus frequency. These plots are generated via the FFT of the estimated motion plots.

The image data window: This window contains an image from the actual data set with the region of interest high-lighted in red.

Each window has special functions which can be accessed by clicking the buttons that will appear at the top of the window manager when a window is selected.

Windows that contain plots have the following functions:

Get Data: clicking this button will bring up a text window that contains the raw numbers used to generate the plot.

Get PDF: this will generate a PDF file with a print quality version of the plot in the window.

Zoom in: this will enlarge the plot in the window.

Zoom out: this will shrink the plot in the window.

X axis: this toggles the horizontal axis between linear and log scales.

Y axis: this toggles the vertical axis between linear and log scales.

Windows that contain images have the following functions:

Get Data: clicking this button will bring up the image in its own netscape window.

Zoom in: this will enlarge the plot in the window.

Zoom out: this will shrink the plot in the window.

1:1 : this will scale the image so that one pixel in the image takes one pixel on the screen.

Out of plane motion reports

Out of plane motion reports are the same as in-plane motion reports except the plots contain dark blue dots only. The dark blue dots represent out of plane characteristics.

Trouble shooting

Loggin on

* these steps assume that you have successfully logged into the machine before

First check to see if the system is plugged in and on. The switch above the power plug should be in the on position. If the main switch was off, turn it on and press the momentary switch to bring the server up.

If the system is on and you still have trouble logging in, the system may be in a confused state. Shut it down by holding down the momentary switch for ten seconds (yes, really ten seconds). The system can then be re-started by momentarily depressing the same switch.