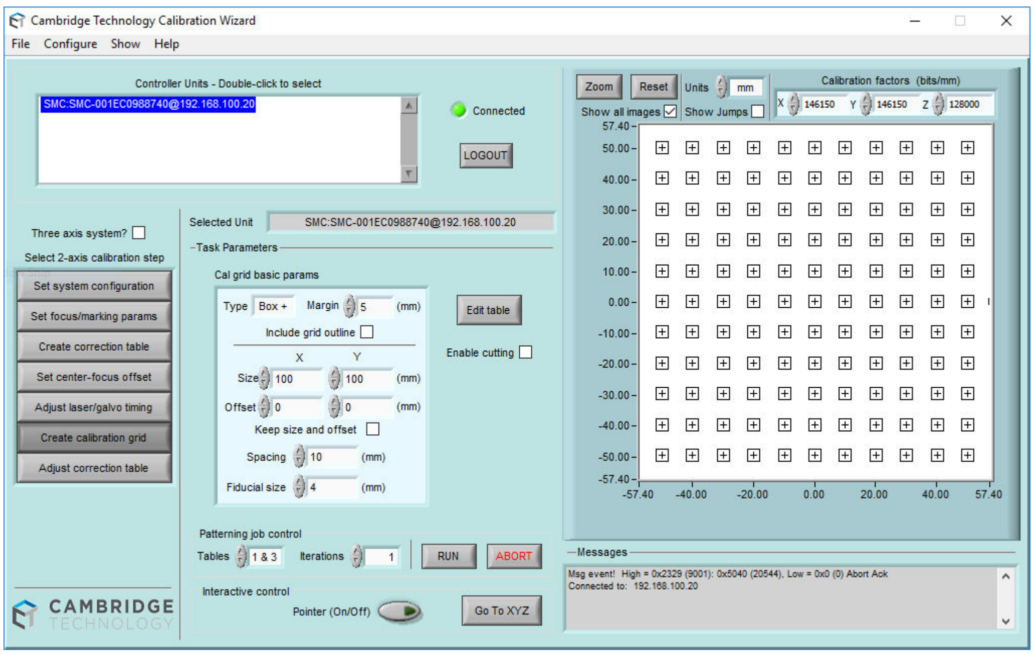
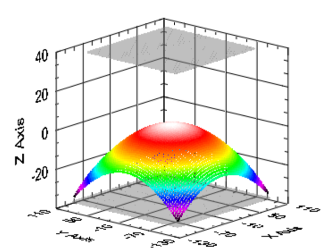
Calibration Wizard

User Manual

Advanced Calibration Solutions for 2x and 3x Scanning Heads



Read carefully before using.
Retain for future reference.



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1 IMPORTANT INFORMATION

For your protection, carefully read these instructions before installing and operating the scan head.

Retain these instructions for future reference.

Novanta reserves the right to update this user manual at any time without prior notification.

If product ownership changes, this manual should accompany the product.

1.1 SAFETY SYMBOLS

This manual uses the following symbols and signal words for information of importance.

DANGER

Indicates a hazardous situation which, if not avoided, will result in serious injury or death.

WARNING

Indicates a hazardous situation which, if not avoided, could result in serious injury or death.

CAUTION

Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.

IMPORTANT

Indicates information considered important but not directly hazard related (e.g. security, hygiene, or equipment or property damage).

1.2 SAFETY LABELS

DANGER

Laser radiation

can cause severe retinal and corneal burns, burns on the skin, and may pose a fire risk.

- To avoid injury and reduce risk of fire, please follow the control measures and safety guidelines provided by the laser's manufacturer, and those established by your Laser Safety Officer (LSO), Radiation Safety Officer (RSO), or safety department of your business or institution.

ESD WARNING

Electrostatic discharge and improper handling

can damage MOVIA scan head's electronics.

- Keep the equipment sealed until it is located at a proper static control station.

1.3 CUSTOMER SUPPORT

Before contacting Novanta for assistance, review appropriate sections in the manual that may answer your questions.

After consulting this manual, please contact one of our worldwide offices between 9 AM and 5 PM local time.

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2 INTRODUCTION

2.1 GENERAL NOTES

Novanta reserves the right to make changes to the products covered in this manual to improve performance, reliability or manufacturability.

Although every effort has been made to ensure accuracy of the information contained in this manual, Novanta assumes no responsibility for inadvertent errors. Contents of the manual are subject to change without notice.

2.2 USING THIS MANUAL

2.2.1 Purpose

This manual provides directions to help users safely and effectively install and operate the ScanMaster Controller (also known as SMC) for various laser processing applications using Galvanomter based laser scanning head and laser. The manual also includes material such as system specifications and optimization guidelines. It is assumed that the reader has a general knowledge of galvos and command controllers.

2.2.2 scope

This manual covers the 3-Axis scanning systems only. Refer to the controller vendor's documentation for information on how to integrate the 3-Axis systems to a controller.

2.2.3 Revision History

The following table shows the revision history for this document.

Table 1 - Revision History

REVISION	DATE	Changes from previous revision
A	February 12, 2012	First release of this manual.
B	October 16, 2012	Update for V1.2 Changes; Add more information on the calibration process.
C	September 26, 2013	Update for V1.3 Changes; Separated 2-Axis and 3-Axis procedures.
D	May 12, 2013	Update for V1.5 changes; New presentation. Added figure captions to all figures. Made extensive copy-edits and technical updates.
E	October 11, 2016	Clarified the background modulation setting Use the new CT logo Update flat-bed scanner information
F	March 21, 2017	Added MicroVUE measurement data support. DPI resolution increased to 1200DPI for smaller flatbed scanner. Added capability to create a grid that is spaced to land on correction table location. Updated views for when first starting CalWizard to eliminate adapter dialog box selection since it is now automatic. Updated pset data file format tables to show headers as table column headers and not in the data file. Other miscellaneous edits.
G	January 29, 2019	Extended the scan range of the A320 to 11.9″ x 17″ Permit setting image contrast and brightness for image analysis Adjusted the edge detection parameters to establish a better fit Removed 20-bit correction table choice. Only 16-bit and 24-bit are supported.

2.3 WARRANTY INFORMATION

The Customer shall examine each shipment within 10 days of receipt and inform Novanta of any shortage or damage. If no discrepancies are reported, the shipment will be considered as delivered complete and defect-free. Novanta warranties products against defects up to 1 year from manufacture date, barring unauthorized modifications or misuse. Repaired product is warrantied for 90 days after the repair is made, or one year after manufacture date - whichever is longer.

Contact Customer Service at +1-781-266-5700 to obtain a Return Materials Authorization (RMA) number before returning any product for repair.

All orders are subject to the Terms and Conditions and Limited Warranty. Contact your local sales office for the latest version of these documents and other useful information.

Customers assume all responsibility for maintaining a laser-safe working environment. OEM customers must assume all responsibility for CDRH (Center for Devices and Radiological Health) certification.

3 PRODUCT INTRODUCTION

3.1 DESCRIPTION

The Calibration Wizard™ User Manual describes how to create and adjust correction tables for CT laser scanning controllers. A correction table allows the scan controller to compensate for projection distortions caused by the physical geometry of the steering system, non-ideal opto-mechanical fabrication tolerances, electrical non-linearity of the galvanometer position control system, lens distortion, system misalignment and scaling errors. System accuracy is improved by a calibration process which involves creating and measuring scanning artifacts in an iterative fashion until a desired accuracy is reached.

With the Calibration Wizard you can set marking parameters, create and adjust a correction table, set scanner timing, create a calibration grid, and pattern that grid on a suitable substrate to create an artifact for measurement. The CalWizard offers several modes for measurement data collection. Measurement data is analyzed in the software and table adjustments made in an interactive data-visualization editor environment.

The Calibration Wizard supports the following methods to acquire measured coordinates:

- Automatic analysis of a scanned grid image from a flatbed scanner
- Analysis of a grid measurement file provided by the user

Manually guided grid adjustments.

The calibration process is iterative, as shown in the following diagram:

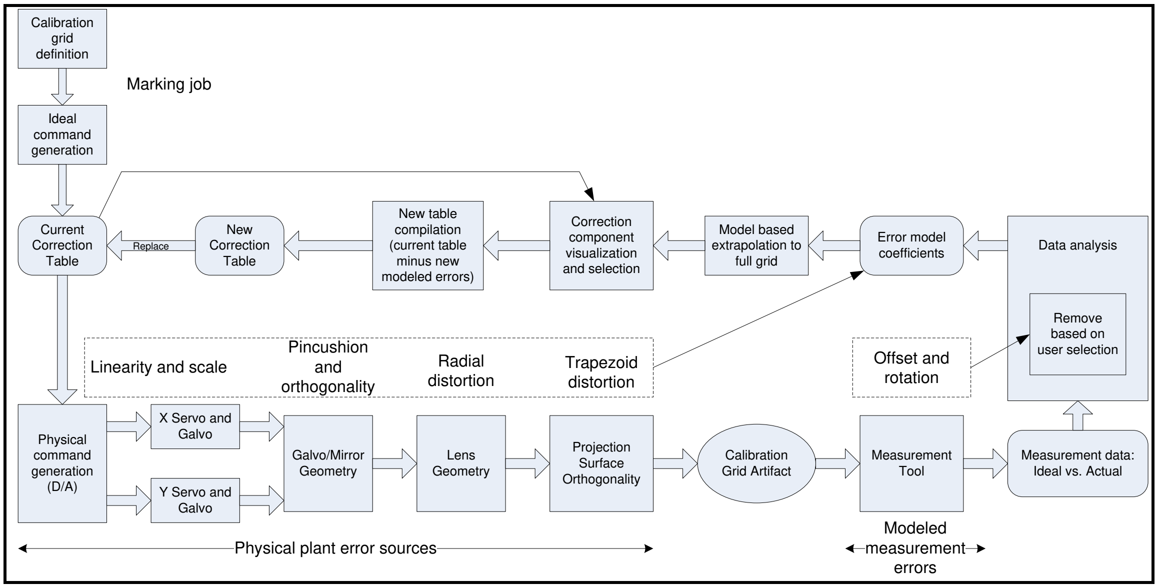


Figure 1 - Overall View of the Calibration Process

4 PRINCIPLES OF OPERATION

4.1 CORRECTION TABLE STRUCTURE

While it is possible to create a correction table without an initial correction, it is recommended that you start the process with a synthesized correction—a correction calculated based on the system's geometry. This correction is a rough approximation that serves as a starting point for an iterative process that will result in increasingly accurate imaging capability.

The correction table has 4225 entries for each of the three axes (X, Y and Z). Several bit-resolutions formats (16, 20, 24-bit) may be used to represent the correction data depending on the target controller platform. The bit resolution is defined in header information contained in the table. The table is arranged in a 65x65 matrix corresponding to X-Y command values ranging from (min-value, min-value) to (max-value, max-value) in an X-Y Cartesian coordinate system. The numbers min-value and max-value represent the range of numbers possible for a given bit resolution.

Table entries are offsets that are added to the command value to create a new "corrected" value that causes the beam to deflect in such a way as to compensate for distortions induced by the lens, mirror spacing, and system alignment errors. Job command values that fall between the defined coordinates of the table are compensated based on bilinear interpolation of the four immediately adjacent defined table coordinates.

The number of measured points is often very low compared to the size of the table, so mathematical error source models (based on two-dimensional polynomial models) are used to populate table entries where measurements are not directly available. This is possible since the errors encountered in such a steering system are generally smoothly varying functions.

Measurement results are folded back into the table to create better optimized values.

NOTE: The final accuracy of the steering system is a direct function of the number of points that are measured and the accuracy of the measurements. Inaccurate and/or non-repeatable measurements will yield inaccurate/non-repeatable results.

4.2 USING CORRECTION TABLES

The controller can use up to four different correction tables in pairs. (Two tables and only two are in use at any time.) For the SMC, tables 1 and 2 are used for the main XY2-100 and GSBus command channels 0, 1, and 2, while tables 2 and 4 are used for the Auxiliary XY2-100 port and GSBus command channels 3, 4, and 5. The figures on the following page illustrate these relationships.

Typically, tables 1 and 3 are used to correct for distortions when using the marking laser, while Tables 2 and 4 are used when a pointer laser is active. In cases where the controller is driving two scan heads, it is possible to specify data for tables 3 and 4 independently of the data in tables 1 and 2.

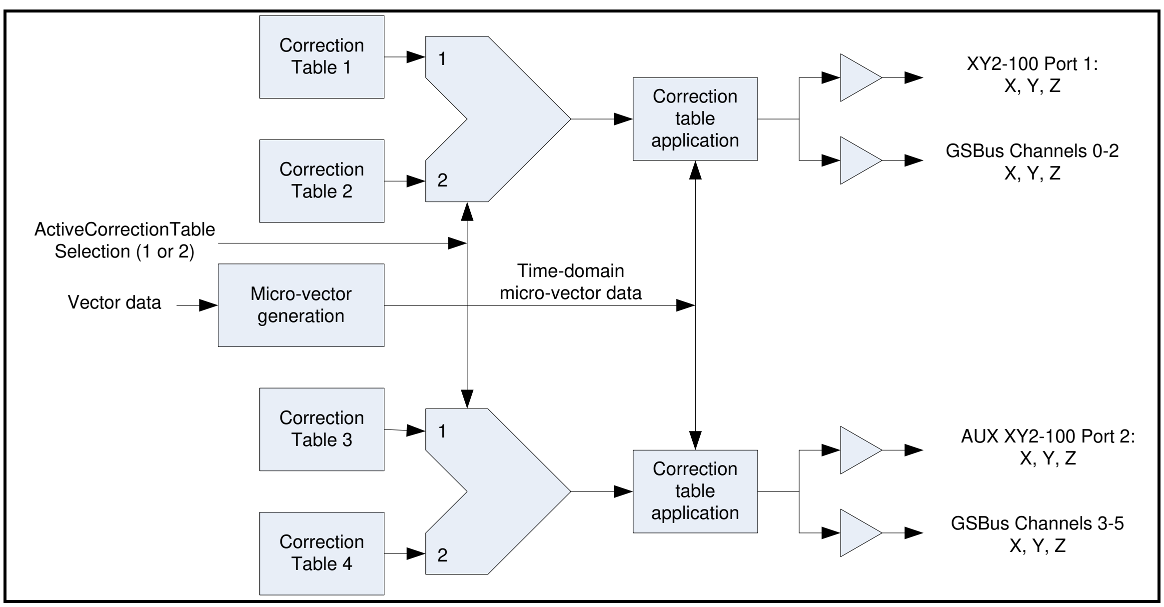


Figure 2 - SMC Correction Table Mapping

5 USING THE CALIBRATION WIZARD

This section provides you with general information about the Calibration Wizard

The Calibration Wizard is used for three different purposes:

- Creation of a new correction table.
- Full adjustment of an existing correction table using a grid.
- Global adjustment of an existing correction table using a simple Box and Cross pattern.

A brief overview of the creation of a new correction table follows. Separate overviews are provided for 2-Axis configurations and 3-Axis configurations, since a 3-Axis configuration requires several additional steps. This “high-level” overview is useful for understanding the full process, and it also serves as a “check list” for experienced users. Individual chapters describe each of the process steps in detail. If you use the manual on a computer, use the links to jump from the overview to the detailed section of each step, and then back to the overview. If you prefer a printed version, identify the relevant sections for your situation and rearrange the printed pages to create your own manual.

5.1 CALIBRATION WIZARD MAIN WINDOW

Interact with the Calibration Wizard through the Main Window and the Correction Table Editor.

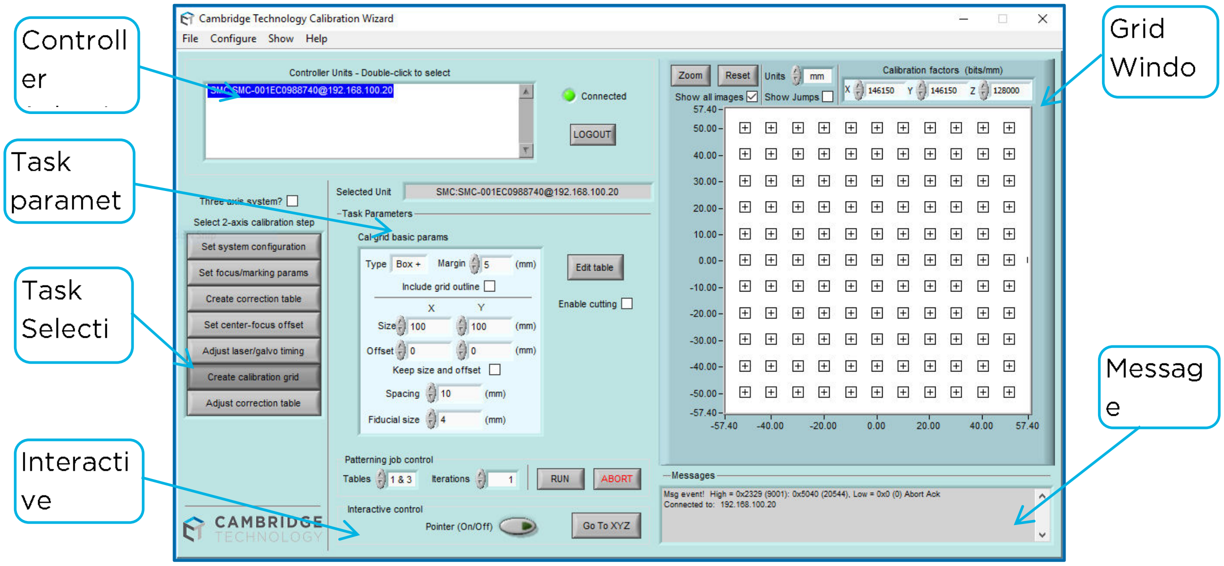


Figure 3 - Calibration Wizard Main Interface

The use of the Controller Selection, Task Selection, Tasks Parameters and Graphic Window is described later in the manual. The use of Patterning Job Control, Interactive Control, and the Message Window is as follows:

Patterning Job Control – use to select the following:

- Tables

1 and 3 – Correction tables for Main Laser 1 and Main Laser 2

2 and 4 – Correction tables for Guide Laser 1 and Guide Laser 2

- Iterations – The number of times the job is to be executed
- Run – Instructs the connected controller to execute the current job
- Abort – Instructs the connected controller to abort execution of the current job
- Interactive control window – use to do the following:
- Pointer (On/Off) – Activate / deactivate the guide laser
- Go To XYZ – Move the galvos to point at the required XYZ coordinate within the scanner's field.
- Messages Window – use to display event information, error messages and other information generated during the controller's operation.

5.2 CORRECTION TABLE EDITOR MAIN WINDOW

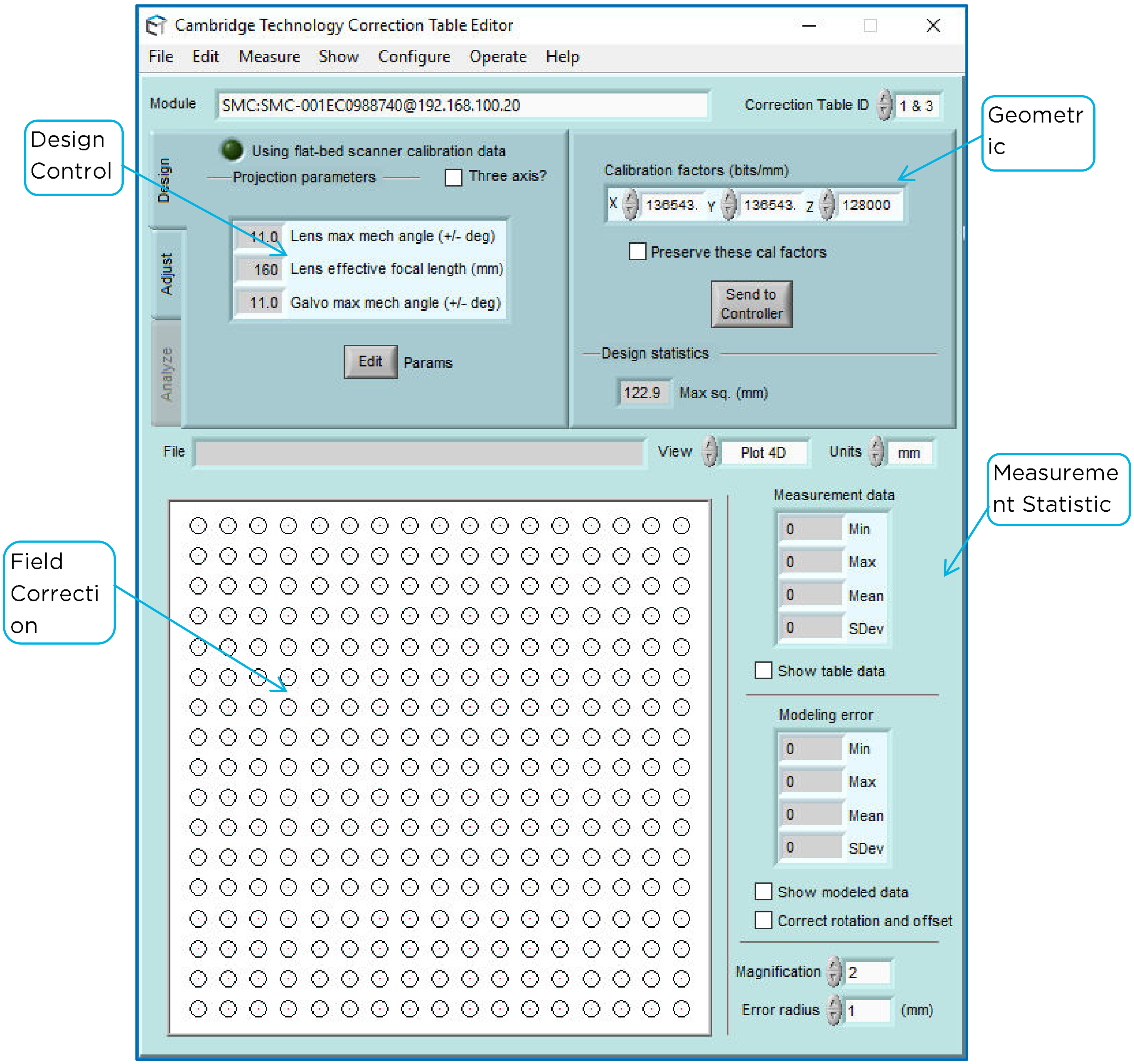


Figure 4 - Correction Table Editor

5.3 ADJUST A PREVIOUSLY SAVED CORRECTION TABLE

To perform a complete adjustment of the correction table, skip to the create correction table step of the relevant overview in the following pages. Click the "Edit table" button to invoke the CTI Correction Table Editor window.

1. To perform a simple adjustment of the correction table, skip to the "Adjust correction table" step of the relevant overview in the following pages. Click the "Edit corr table" button to invoke the CTI Correction Table Editor window.
2. To load the file you have saved before, use the File→Load→Correction table →From local file menu option.
3. A browser window opens to enable you to find and select the file you want to load:

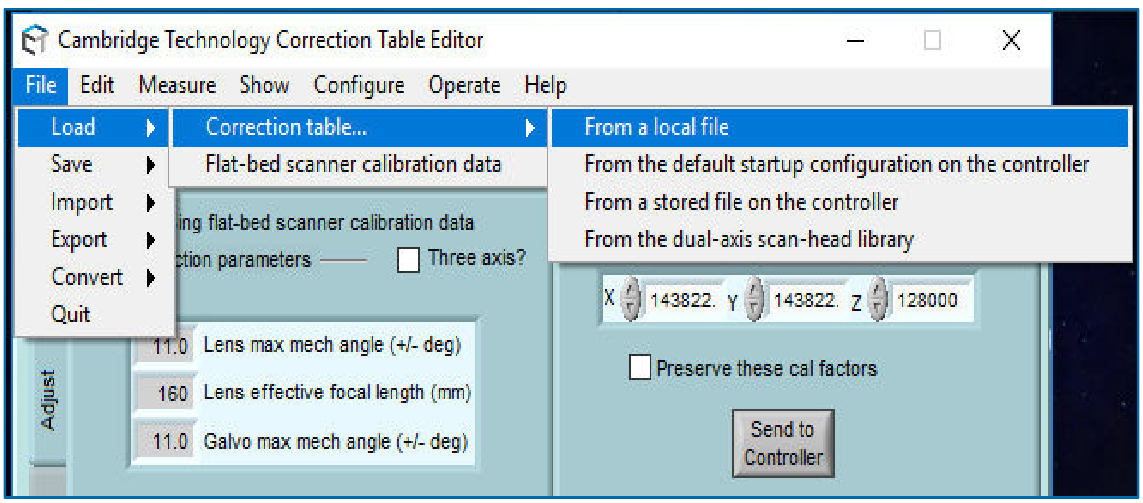


Figure 5 - Load Correction Table Menu Option

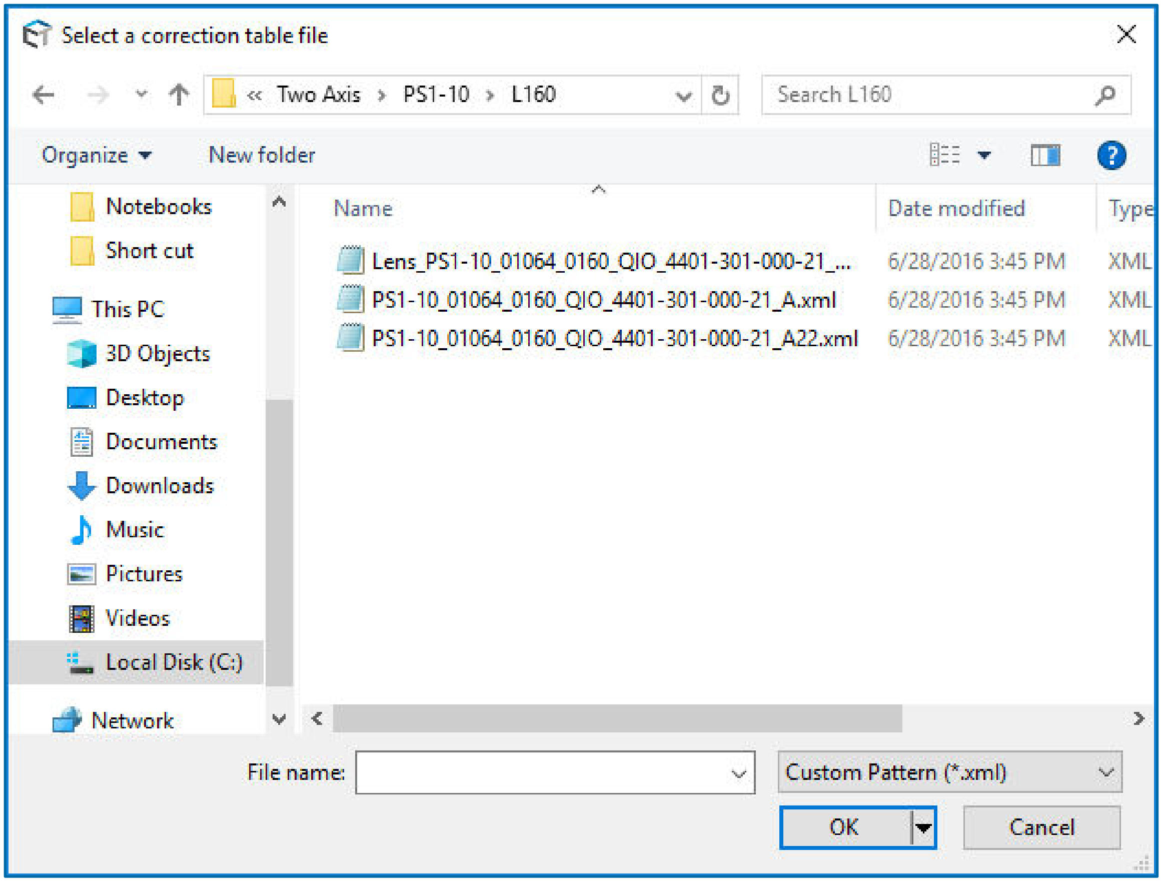


Figure 6 - Select Correction Table Window

6 TWO-AXIS CALIBRATION PROCESS

This section provides guidelines for two axis calibration with different calibration methods.

6.1 CONTROLLER CONNECTION

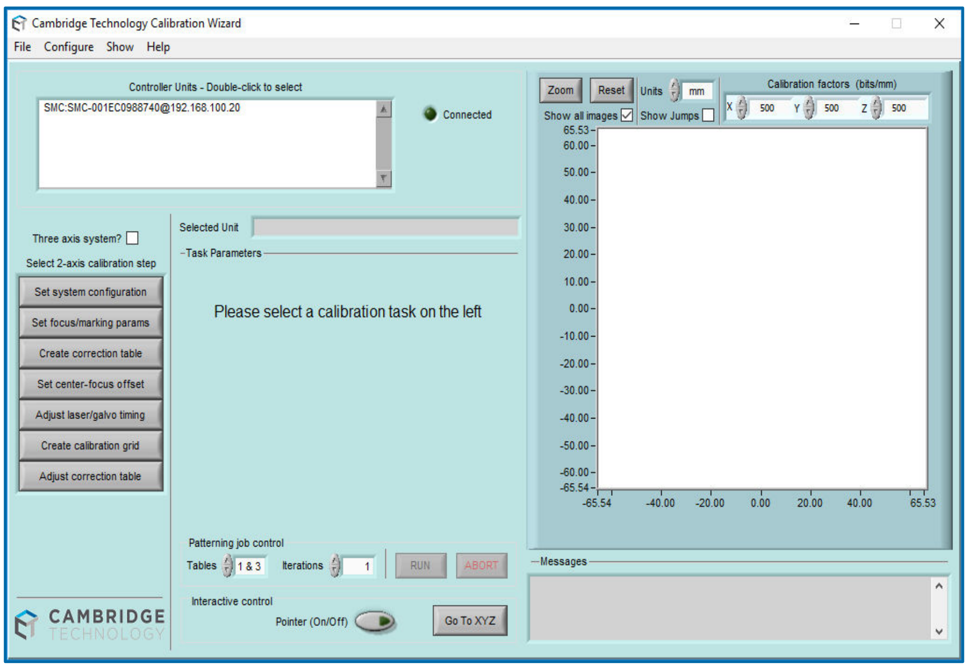


Figure 7 - Calibration Wizard Main Window

1. The Calibration Wizard application searches for existing controllers and displays them in the Controller Selection window.

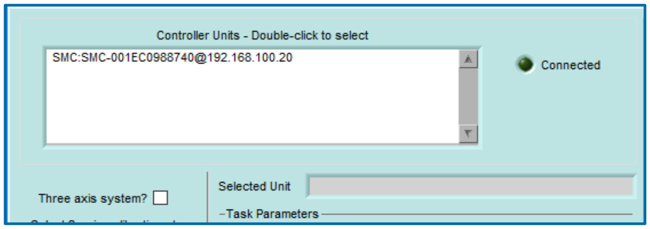


Figure 8 - Controller Selection Window

2. Double-click on the controller you wish to connect to. Status windows appear for a few seconds.

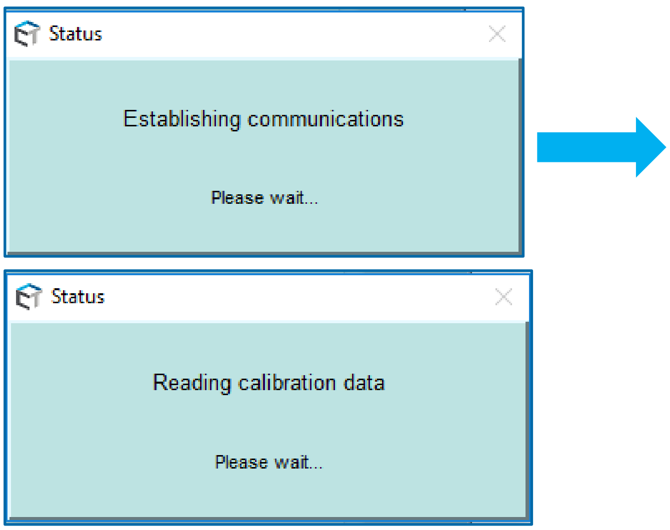


Figure 9 - Controller Connection Status Windows

3. Finally, the “Connected” indicator turns green.

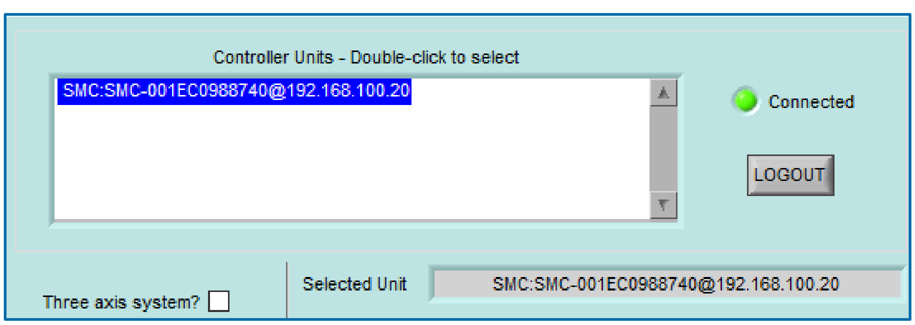


Figure 10 - Connected Indicator

Note: If the controller finds an existing correction table, it is loaded and the selection of 2-Axis vs. 3-Axis is done automatically to reflect the information in this table.

6.2 SET SYSTEM CONFIGURATION

If you have saved a calibration configuration in the past, you can load it using the File menu.

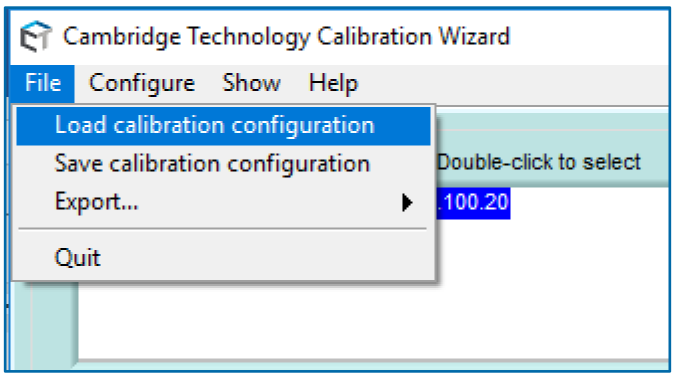


Figure 11 - File→Load calibration configuration

1. The software recognizes the configuration and automatically sets all the fields.
2. If you do not have a previously saved configuration, start by selecting the type of system you have (2-Axis) to display the relevant menu. The first button is the Set system configuration button:

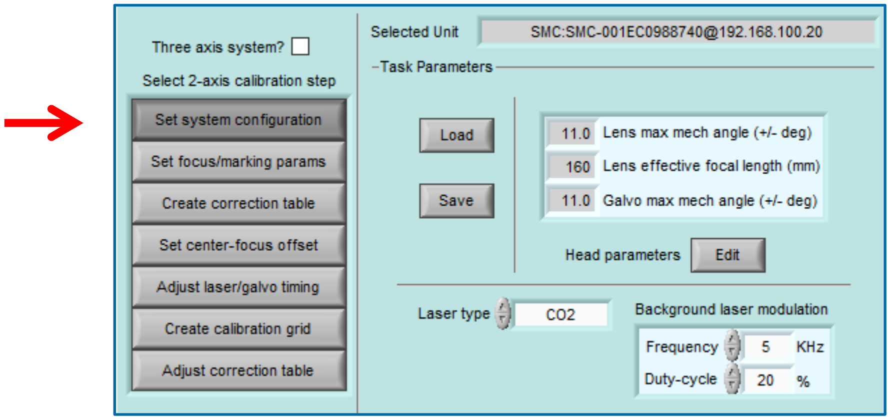


Figure 12 - System Type Selection

3. In the Task Parameters window, you can select or set the following head-related projection parameters for synthesizing a correction table:

   Lens max mech angle (± deg) and effective focal length (mm)

   Galvo max mech angle (± deg)

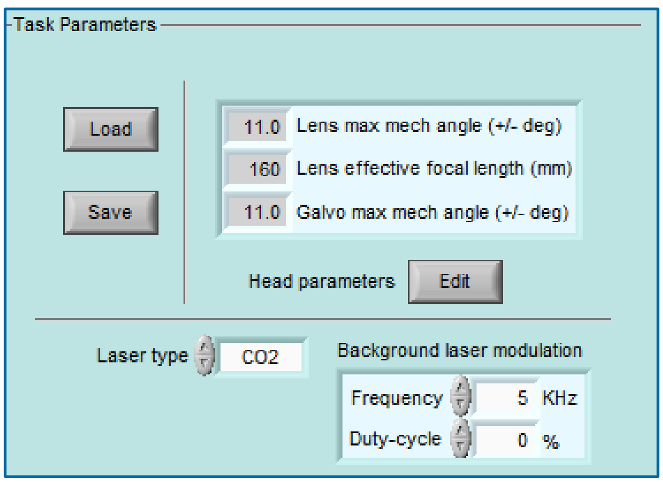


Figure 13 - Task Parameters

4. In addition, the following laser-related parameters can be set to inform the software what laser controls to display in subsequent screens, and how to manage the laser when it is NOT lasing.

NOTE: The frequency and duty-cycle values are initialized from the LaserConfig file on the controller during the "Connect" process. This may override values stored in the CalWizard configuration file. Likewise, if a CalWizard configuration file is loaded after connection, the default parameters from the board will be overridden.

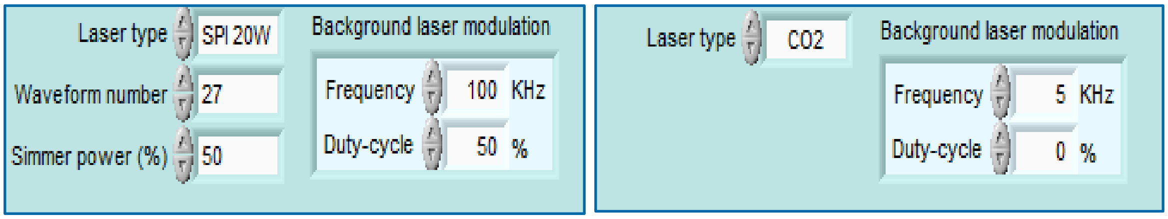


Figure 14 - Laser Settings

Laser type: CO_2, IPG YLP, IPG YLS, IPG YLR, SPI 12W, SPI 20W, Generic

Waveform number: For SPI laser types only

Simmer power (%): For SPI laser types only

Frequency (kHz): For Background modulation (when laser is "off")

Duty-cycle (%): For Background modulation (when laser is "off")

5. At this time, it is recommended that you verify/adjust your laser properties through the Configure→Laser Properties menu option:

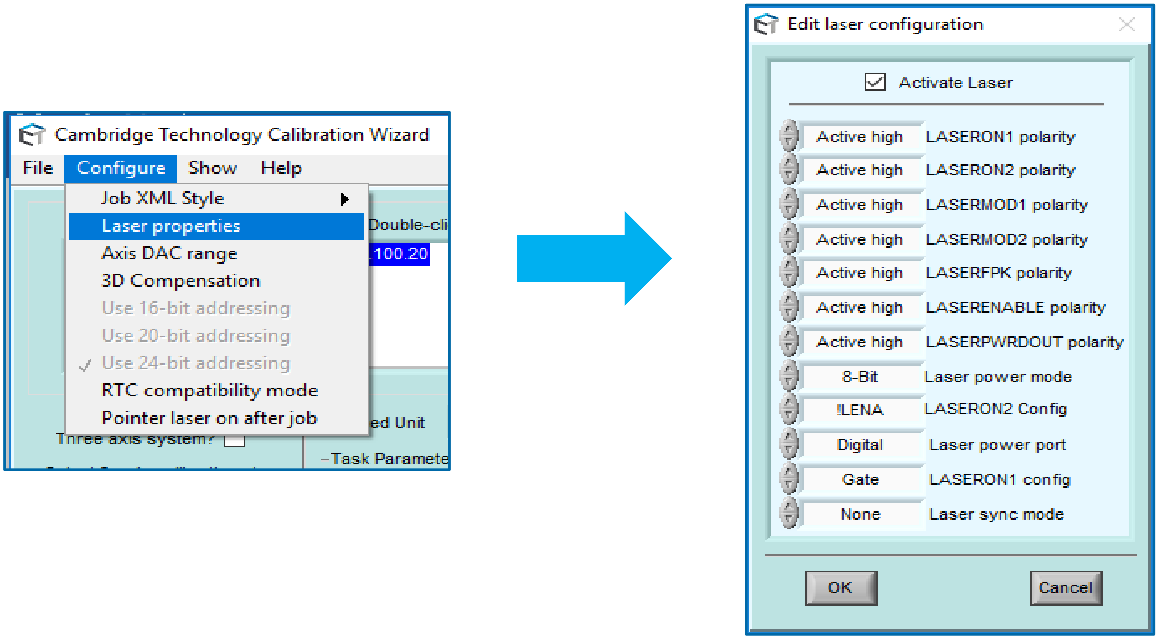


Figure 15 - Laser Properties

6. Finally, save the configuration for future reference through the File menu.

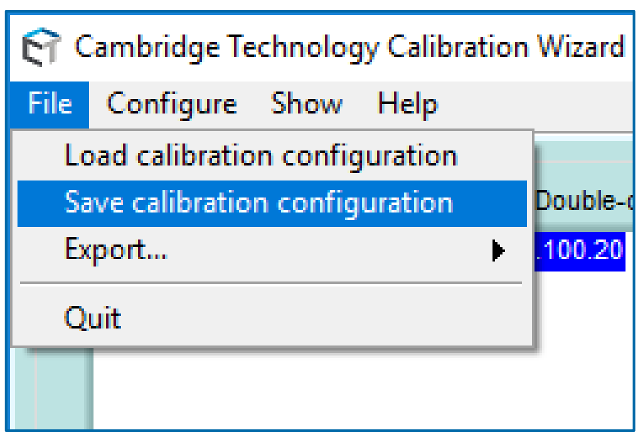


Figure 16 - File→Save calibration configuration

6.3 SET FOCUS/MARKINGS PARAMETERS

CalWizard supports the following laser settings for different modes of operation:

- Marking—Medium power level to leave a clear mark on the media
- Focusing—Low power level to enhance variations in the mark due to focus quality
- Cutting—High power level to cut the marked pattern to be measured

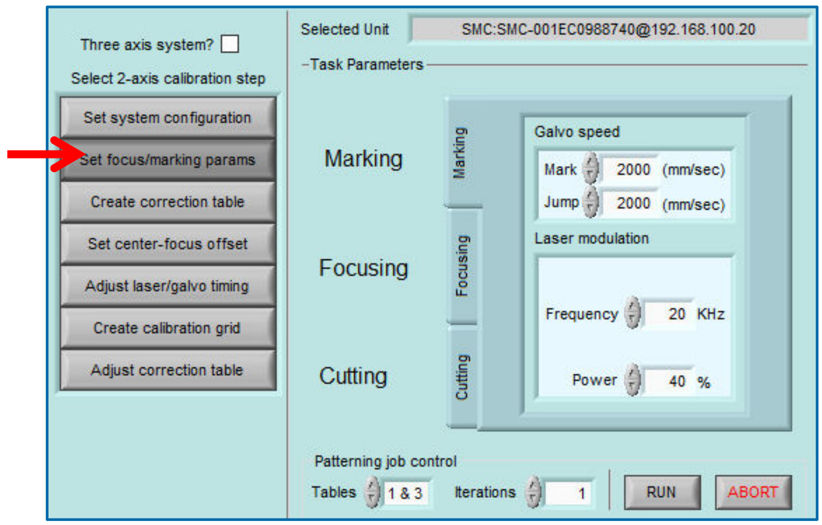


Figure 17 - Focus→Marking→Cutting Parameters View

Notes:

1. Mark and Jump speed selections depend on the scan head model being used, as well as the application's accuracy and throughput requirements.
2. The availability of specific Laser controls varies depending on the laser type selected (see previous sections for details).

When you are finished, save the configuration for future reference through the File menu.

6.4 CREATE CORRECTION TABLE

The calibration process is an incremental process: each calculation result is superimposed over the previous corrections.

To eliminate any potential for error, all existing correction information is cleared by default when you open the Correction Table Editor by clicking the "Create correction table" button.

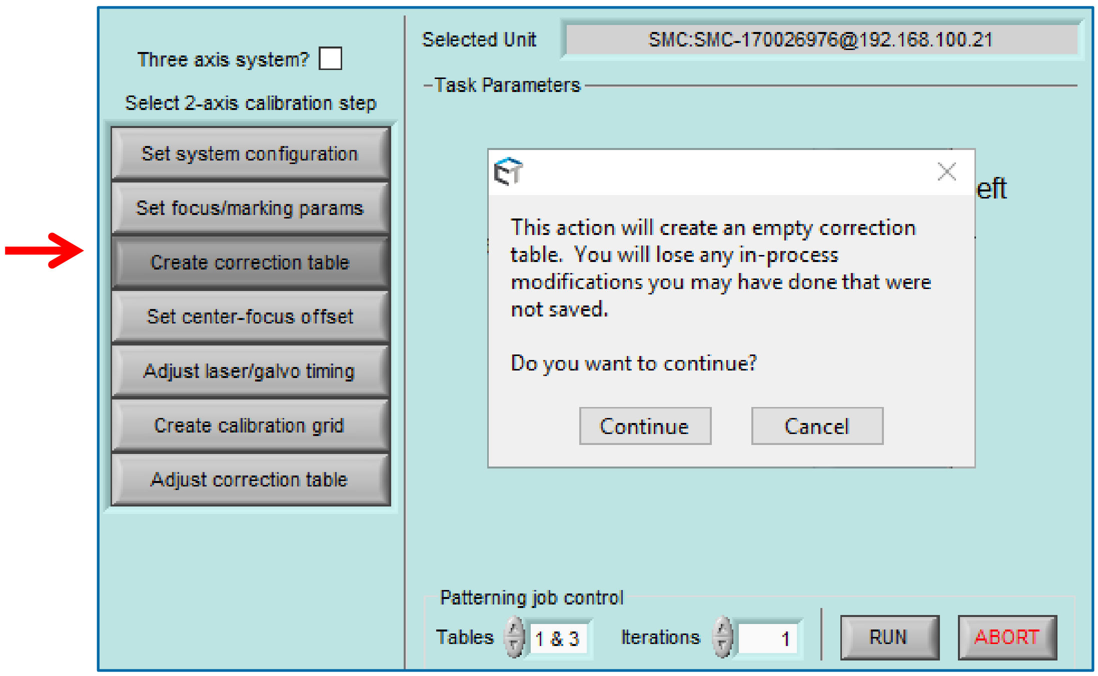


Figure 18 - Create correction table button

To prevent erroneous clearing of information, the following confirmation pop-up appears: Pop-up. After you press "Continue" in the Confirmation pop-up, the Correction Table Editor displays:

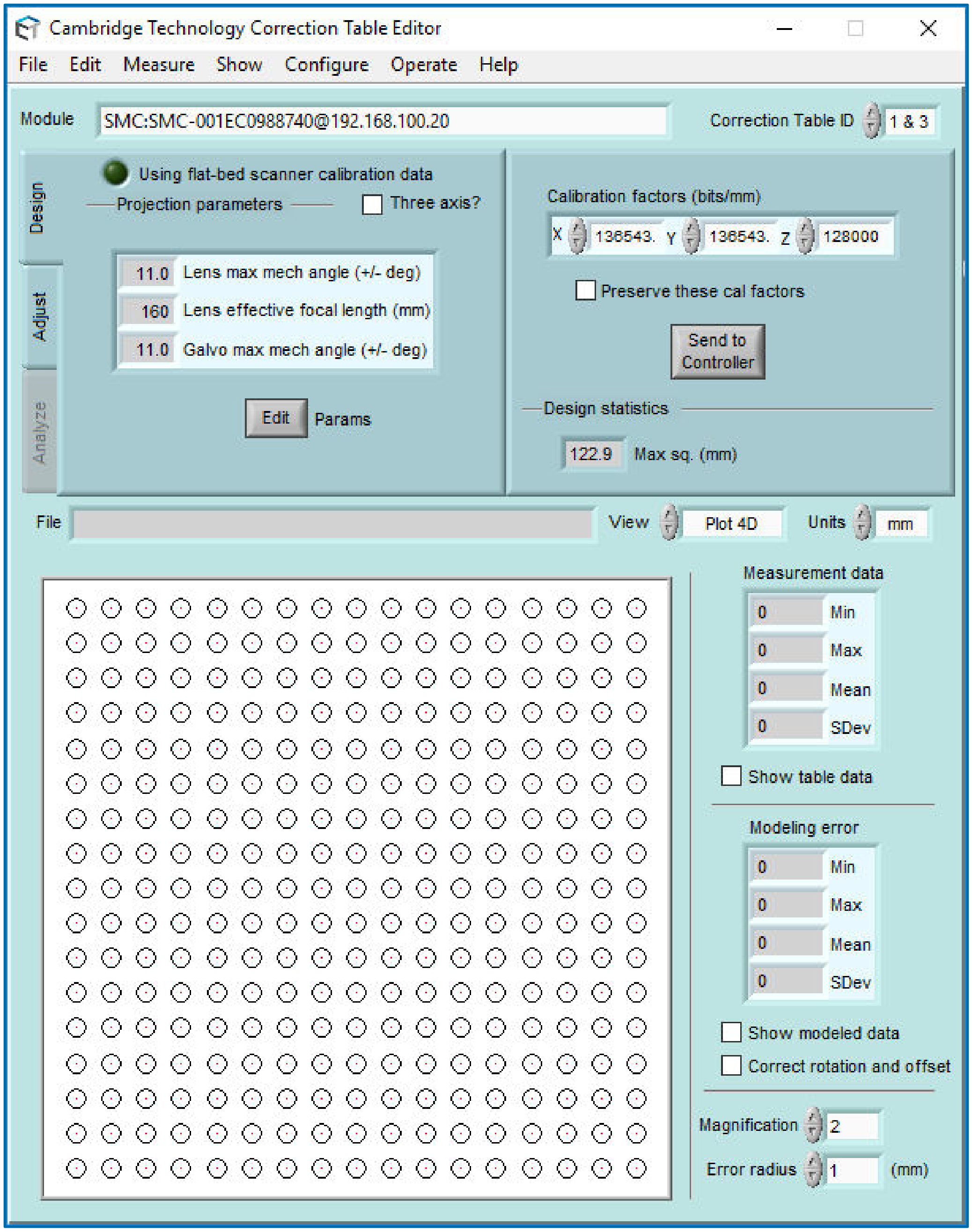


Figure 19 - Correction Table Editor View

Bit-resolution defines the scanner control system's ability to drive the galvos smallest angular move. As the SMC controller supports 24-bit resolution. So by default Bit-resolution is set to 24-bit as shown in below figure.

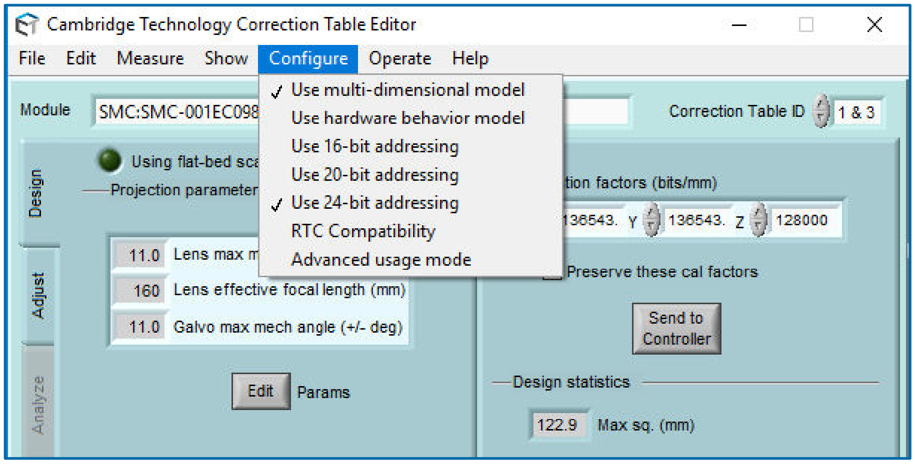


Figure 20 - Calibration Resolution Selection

The Projection parameters in the Design tab are set to values you have entered previously and are used to synthesize a correction table based on your optical path geometry. To synthesize a baseline table, select Edit→Synthesize baseline corrections.

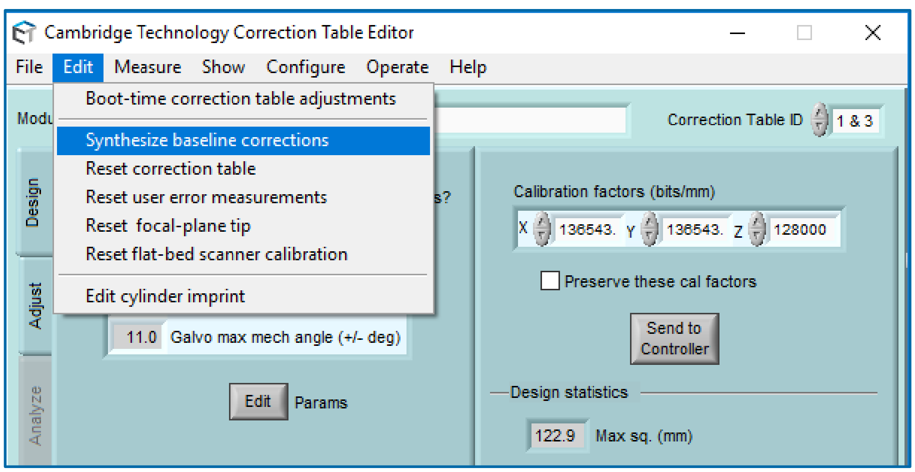


Figure 21 - Edit | Synthesize Baseline Corrections

The editor calculates a pin-cushion distortion compensation derived from mirror spacing, and lens distortion compensations. It automatically rescales the table contents and the calibration factors to optimize the use of the galvo command range.

After this process is complete, the new table is displayed. For an example, see the figure on the next page.

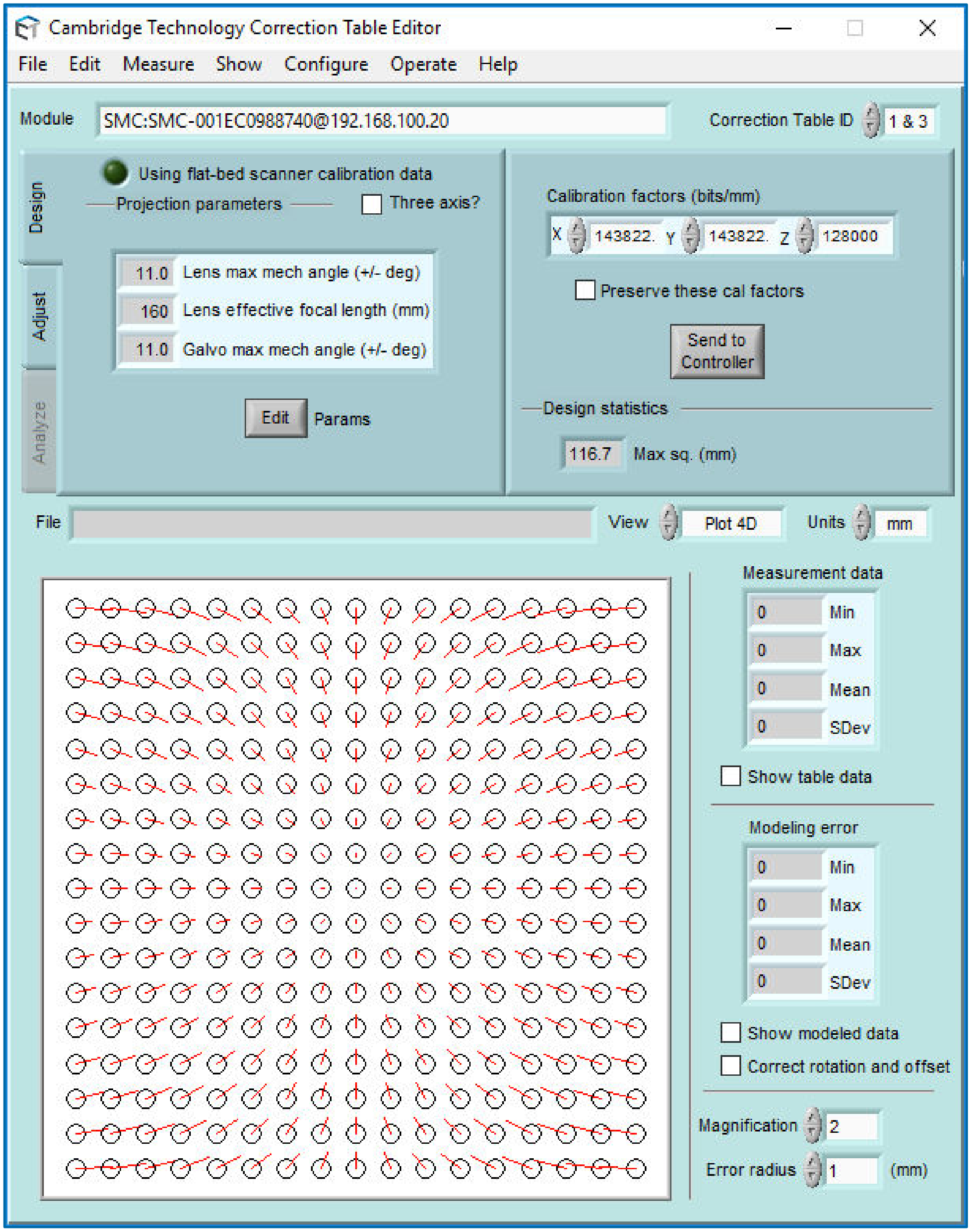


Figure 22 - New Correction Table

6.5 CALIBRATION METHOD

The Calibration Wizard supports several different methods for adjusting correction files.

The following table provides a quick-reference overview to four calibration methods. Choose one of these methods to adjust the correction table. Use the links in the table to navigate to different steps in each method in the text below. Each of these is described in greater detail in the pages that follow.

Collect Box/Cross Grid Data	
Quick Method for initial or approximate accuracy Yields a usable approximation when accuracy is not so important Good for both 2-axis and 3-axis	
Set Center Focus Offset	Adjust laser beam focus (head distance from grid)
Adjust Laser/Galvo Timing	Optimize Laser/Scanner delay
Adjust Correction Table	Approximate calibration
Mark Grid	Mark grid on black-coated surface
Measure Geometry	Enter measured values in table
Accuracy Check	Repeat until calibration satisfactory
Guided Grid Measurement	
Suitable for calibrating any scan field size, but is best suited to fields larger than 300mm x 300mm.	
Grid Setup	Set grid paper or characterization plate on marking field
Guided Grid Measurement	Create and edit correction table
Automatic Scan and Analyze	
The preferred method to acquire measured coordinates	
Overview and Requirements	Automatic analysis of measured coordinates
Load Flatbed Scanner Correction File	Load reference file used by scanner to create initial scan grid
Set Center Focus Offset	Adjust laser beam focus (head distance from grid)
Adjust Laser/Galvo Timing	Optimize Laser/Scanner delay
Create Calibration Grid	Compare known coordinates to actual marked coordinates

Mark Grid	Mark grid on black coate surface
Automatic Scan and Analyze	Place marked grid on scanner
Accuracy Check	Repeat until calibration has SDev < 0.05
Analysis of Grid Measurement File Supplied by User	
Correction tables created based on analysis of ideal vs. measured coordinate sets	
Set Center Focus Offset	Adjust laser beam focus (head distance from grid)
Adjust Laser/Galvo Timing	Optimize Laser/Scanner delay
Create Calibration Grid	Compare known coordinates to actual marked coordinates
Mark Grid	Mark grid on black coate surface
Grid Analysis by External System	Camera Vision or Metrology System

6.5.1 Collect box/cross grid data (quick method for "good-enough" accuracy)

For 2-Axis applications that require only basic accuracy ("it looks straight to me!"). Mark field size square and horizontal and vertical line and measure actual vs. ideal and feed into the Correction Table Editor. A simple correction can be achieved by doing the following:

You are still in Correction Table Editor window. Exit Correction Table Editor by File→ Quit, then press "OK" in following message and accept changes in table as shown below.

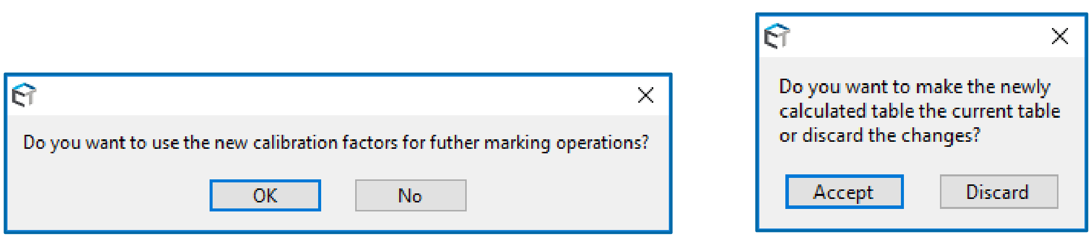


Figure 23 - Calibration Factor Accept

NOTE: This message appears only when a fresh table is started.

Save correction file on local drive. (Saving correction file on local drive is optional. User can cancel saving correction file on local drive.)

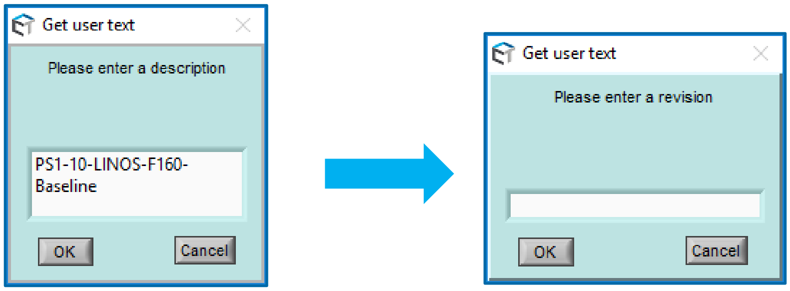


Figure 24 - Save correction file

Press “OK” to load table to controller as shown below.

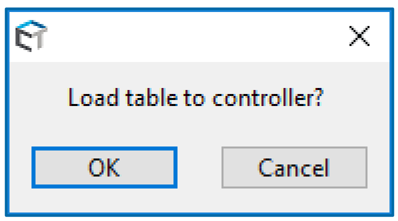


Figure 25 - Load table

1. Set Center-Focus offset

This step adjusts the system to achieve a focused beam at the center of the field. The optical path through the head’s mirrors and the lens is fixed, so the distance between the head and the target surface is adjusted to achieve a focused grid image.

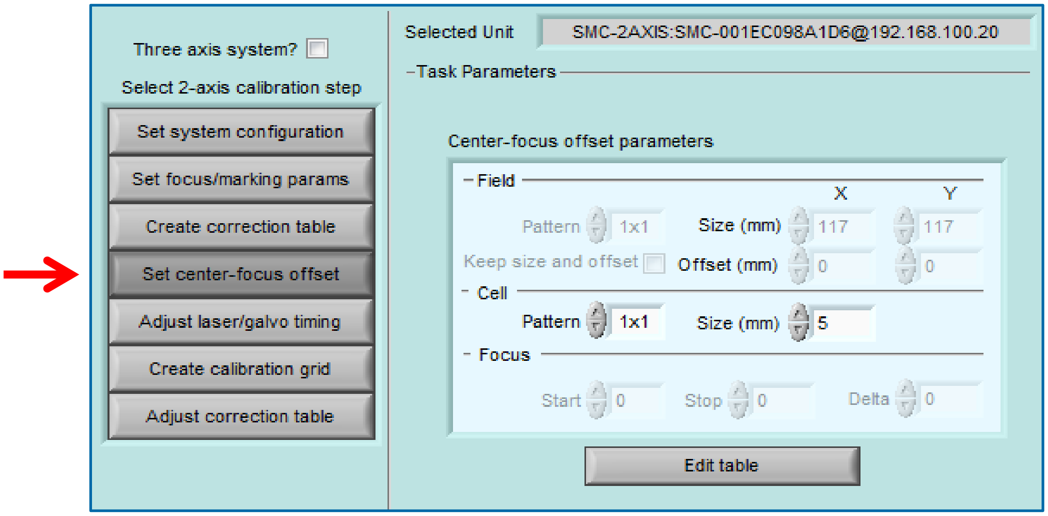
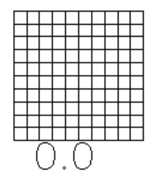


Figure 26 - Center Focus

CAUTION

Your next action will fire the laser! Use Caution to avoid damage or injury!



Define grid size.

Click the “Run” button to mark the grid.

Adjust the work distance and repeat until you get a well-focused mark.

2. **Adjust Laser/Galvo Timing**

Now that the laser is focused, optimize laser and scanner delays under Adjust laser/galvo timing. Do not skip this step, since low-quality marking of the grid might cause the upcoming measurement and analysis to fail.

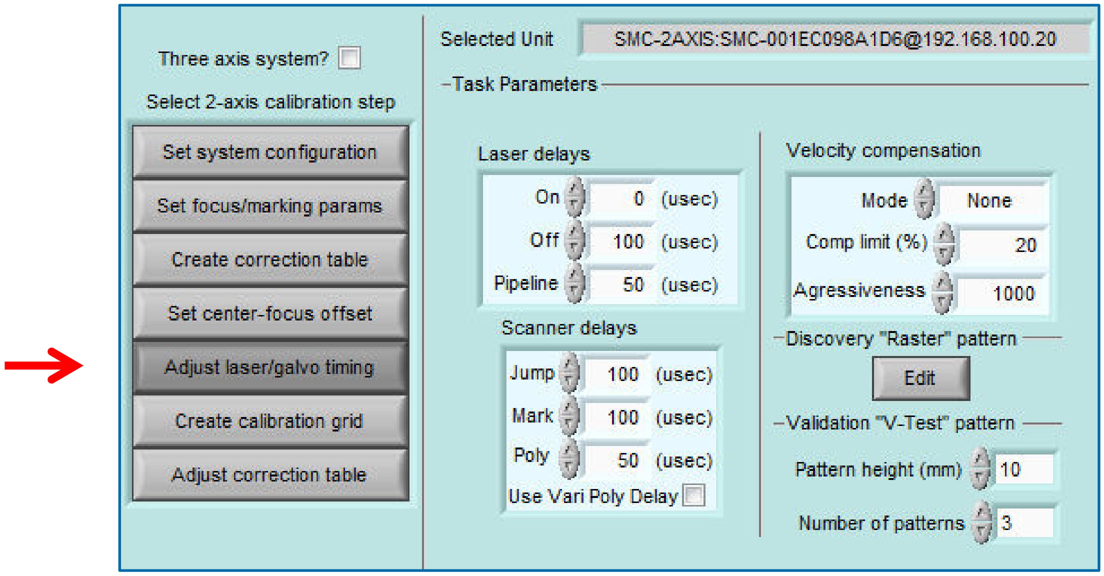


Figure 27 - Adjust Laser/Galvo Timing.

Set correct Laser ON Delay, Laser OFF Delay, Jump Delay, Mark Delay and Poly Delay and mark V-Test and change delay value based on V-test observation. For details on V-Test and about how to optimize delays, see **Appendix A - Optimizing Laser/Galvo Delays.**

Different lasers require different settings for the Pipeline delay, Laser On delay, and Laser Off delay, while application considerations may require different values for the Mark, Jump and Polygon delays (known as “Application Delays”).

Many of the delays are interdependent, so changing one may affect another, resulting in a long trial-and-error process until you find the values you need. Novanta has developed a process to guide you through correct, streamlined set-up of the various delays for your specific laser and application needs, as follows.

The process starts with a coarse adjustment to get the parameters close to the required values, followed by a much finer adjustment to optimize those values. For the coarse adjustments, use a mark size that can be seen easily and a speed 30%-50% higher than you intend to use for the application. For the finer adjustments, the pattern size should be similar to your job, while the speed is adjusted as needed.

The Laser On and laser Off delays are better set with a higher speed than you intend to use for the application, because the delays may no longer be valid when speed is increased. However, laser timing will improve as the speed is decreased, ensuring better accuracy in turning the laser on and off.

The same is not true for the Application delays. As you mark faster, you may need to increase the application delays to maintain the quality of the mark, while as you slow down you might create excessive delays that will either burn-in or waste time idling at some points. For that reason, Laser delays are set first at a higher speed, and then the Application delays are set at the intended operational speed.

3. **Adjust Correction Table**

An easy calibration method if system does not require the greatest accuracy. Both adjustment and coarse calibration can be achieved through the Adjust correction table menu.

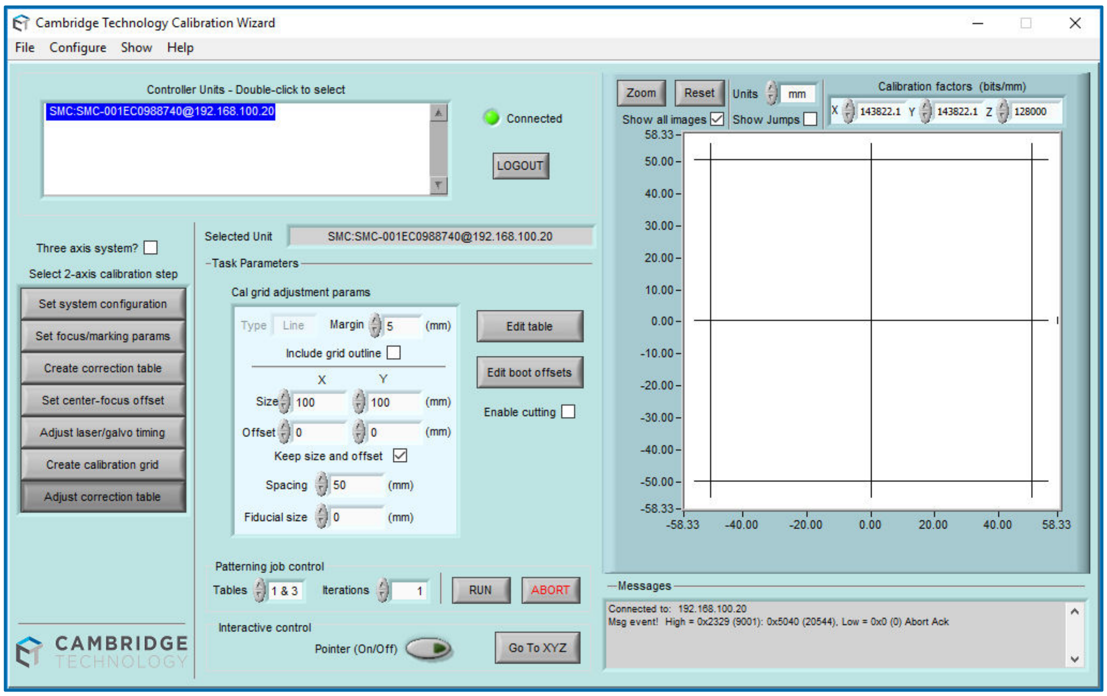


Figure 28 - Adjust Correction Table

Set marking size based on available marking field for e.g. 100x100, 180x180, etc.; the margin is the extra line outside from the square to see nice cross-section of two lines.

4. **Mark Grid**

Once all settings are done, press "Run" to mark grid. CTI recommends using high-contrast cardboard paper such as Bindakote paper or black anodized aluminum plate to get better marking contrast.

CAUTION

Your next action will fire the laser! Use Caution to avoid damage or injury!

5. **Measure Geometry**

Press "Edit Table" and go to "Correction Table Editor" as shown below and select "Collect Box/Cross Grid Data."

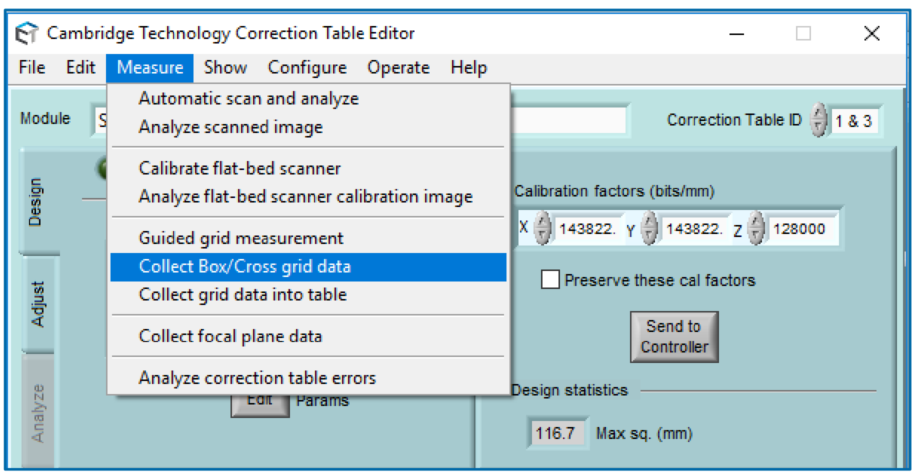


Figure 29 - Collect Box/Cross grid data

Measure all dimensions shown below in laser marked grid and enter all measured values in the table, then press "OK". **Do not change Ideal Size.**

After it asks to save measurement data; you can save if you wish or press "Cancel."

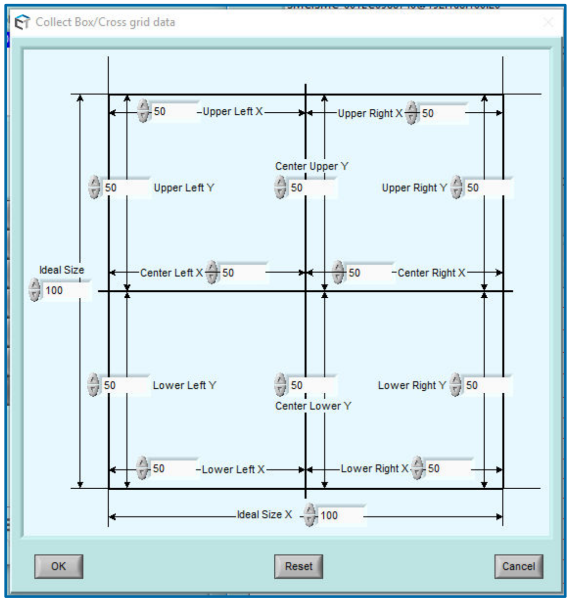


Figure 30 - Collect Box/Cross grid Data

Exit Correction Table Editor by repeating the same steps as before to exit the correction table.

6. **Accuracy check**

Measure the square dimension and check the accuracy.

7. **Repeat steps 4-6**

Repeat steps 4-6 until you achieve desired accuracy.

6.5.2 Guided grid measurement (useful for larger than 300x300mm)

This correction method is suitable for calibrating any scan field size, but is most useful for fields larger than 300mm x 300mm. The software uses the information in the current correction table to position a guide laser on the points of a user-defined grid. Using on-screen controls, you then adjust the laser beam onto an accurate position (referring to. a grid paper or Characterization plate (for field size<300mm). This method's accuracy is limited by the guide laser's spot size and the targets used. In addition, this calibration method can require more effort than the others.

This method is somewhat tedious because it is necessary to manually visit many grid points. The higher the number of points visited, the greater the accuracy and longer time to measure. Also, this method does not require actual laser to mark the grid because if actual laser is available to mark you should use previous method or another better method of calibration.

1. Grid Setup

Set Grid paper or Characterization plate (available for purchase at CT) on the marking field as shown below. Have a guide laser and try to align grid paper or plate as straight as possible.

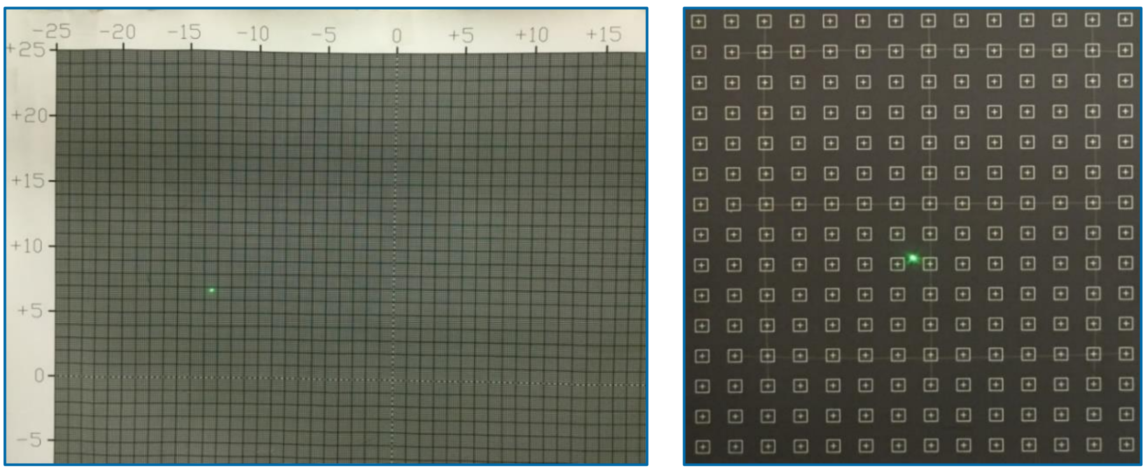


Figure 31 - Grid Paper or Characterization Plate

2. Guided Grid Measurement

You are still in Correction Table Editor window. Click the “Edit Table” button to open the Correction Table Editor. Then select the Measure→Guided grid measurement menu option as shown below.

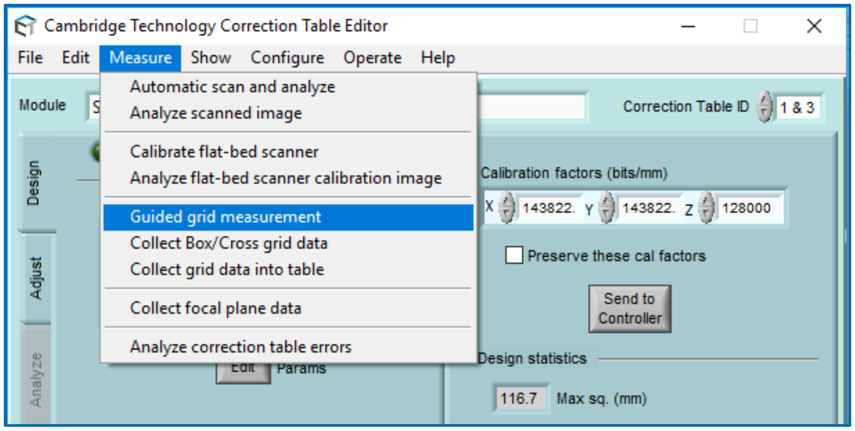


Figure 32 - Select Guided grid measurement

The Guided grid measurement screen displays.

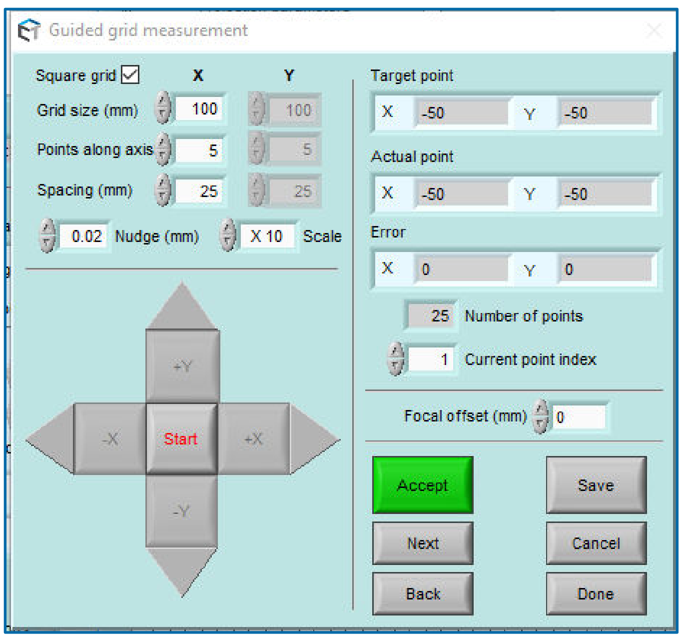


Figure 33 - Guided Grid Measurement

Use the Focal offset control to focus your guide laser on the target. This is required to compensate for the difference in wavelength from the main laser.

Define the grid you want to use through the Grid size, Points along axis, and Spacing controls (note that they are interrelated). Define the "nudge" size and scale, then click the "Start" button in the middle of the arrows.

The software moves the guide laser to the first point of the grid. Use the arrows to "nudge" it to the required position on the target. Change nudge size and scale as needed.

Once the guide laser is in position, click the "Accept" button to add this correction to the table in the computer's memory and move the laser to the next point in the grid.

Use the "Next" and "Back" buttons to move between points on the grid without affecting the correction value in memory.

Use the "Save" button to save the updated table to a "pset" (point set) file. Refer to the next section for information about the use of pset files in generating a correction table.

Use the "Done" button to close the tool window and load the corrections into the Correction Table editor tool.

Note: You can use a 3x3-point grid for the first iteration to eliminate most of the errors, so that the positional accuracy of the software for subsequent iterations will be much improved.

6.5.3 Automatic scan and analyze (limited field 300x300mm)

1. **Overview and requirement**

The preferred method to acquire measured coordinates is automatic analysis of a scanned image. This correction method is suitable for calibrating scan fields up to 300mm x 300mm. In this method, Novanta's patent-pending Scanner Based Metrology uses standard document scanning equipment coupled with advanced vision processing algorithms to create a good correction table with one or two passes of imaging, measurement, and analysis. This system electronically captures a large array of fiducial images (produced by a laser system on a substrate) into a TIFF pixel-based image file. The image file is then methodically analyzed in sub-regions, using vision processing software at each "ideal" fiducial location to produce an X-Y offset of the fiducial relative to the "ideal" position. These offsets are measured in pixel units but are easily converted into English or Metric units based on the scanning resolution of the equipment being used.

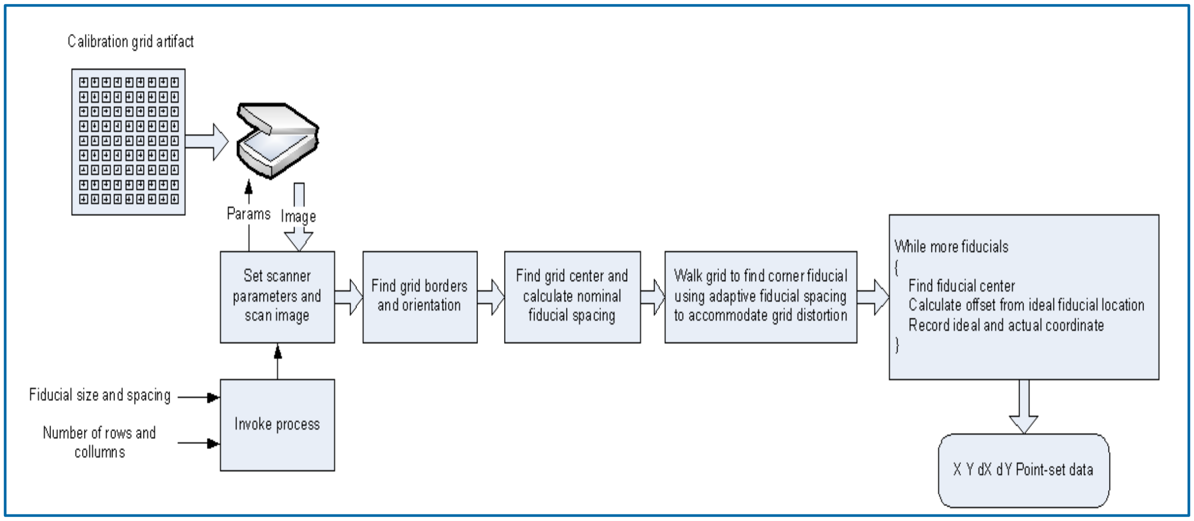


Figure 34 - Flatben scanner diagram

Note: The Calibration Wizard currently supports four types of flat-bed scanners:

Canon Canoscan 9000F

Plustek OpticPro A320

Flat-bed scanner support in the Calibration Wizard is based on National Instruments vision recognition libraries and the user will need to purchase a NI Vision Development Module Run-Time License for "**Deployment**" level Software Use from National Instruments.

You are still in "Correction Table Editor" window.

2. **Load flatbed scanner correction file**

Loading the Flatbed Scanner Calibration file is optional. It is a reference file that a flatbed scanner uses while correcting marking grid for better calibration accuracy. For information about how to create a flatbed characterization grid, **see Appendix B: Flatbed Scanner Characterization.**

Two-axis Calibration Process

Load the flatbed calibration file from File→ Load → Flatbed scanner calibration data and a green LED saying “Using flatbed scanner calibration data” goes ON as shown below.

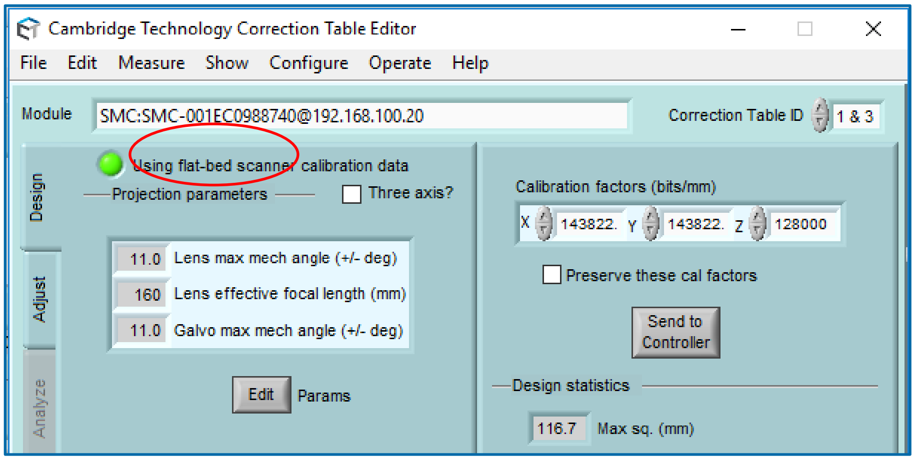


Figure 35 - Scanner correction file

Exit Correction Table Editor by pressing File→Quit, then pressing “OK” as shown in the following message windows to accept changes in table as shown below

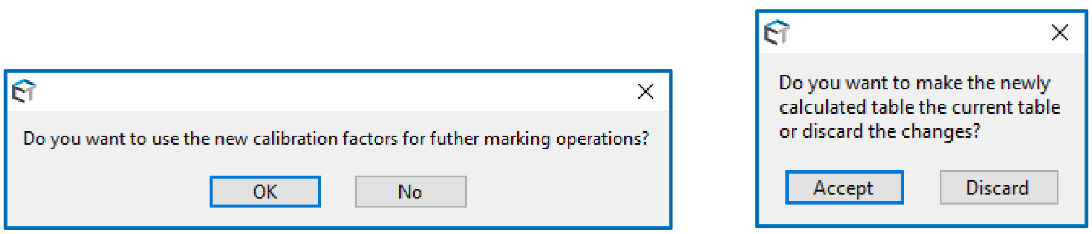


Figure 36 - Calibration factor accept

(This message will appear only when a fresh table is started)

Save correction file on local drive. Saving correction file on local drive is optional. User can cancel saving correction file on the local drive.

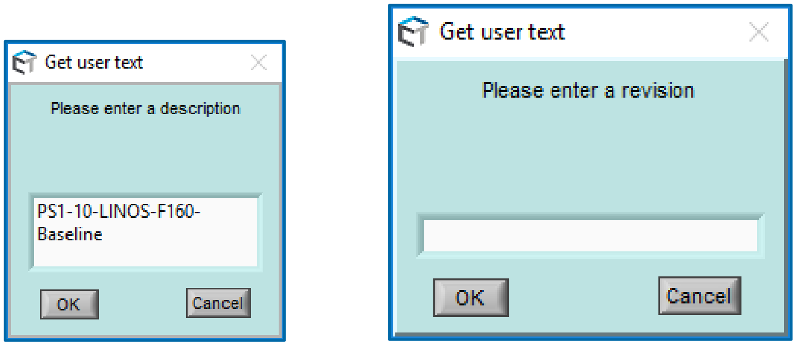


Figure 37 - Save correction file

Press “OK” to load table to controller as shown below:

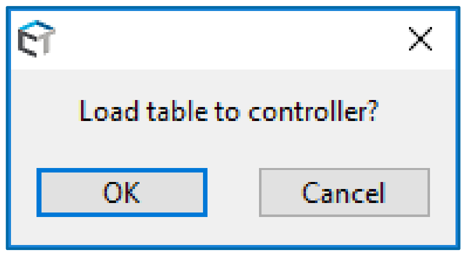


Figure 38 - Load table

3. Set Center-Focus offset

In this step, you adjust the system to achieve a focused beam at the center of the field. The optical path through the head’s mirrors and the lens is fixed, so the distance between the head and the target surface is adjusted to achieve a focused grid.

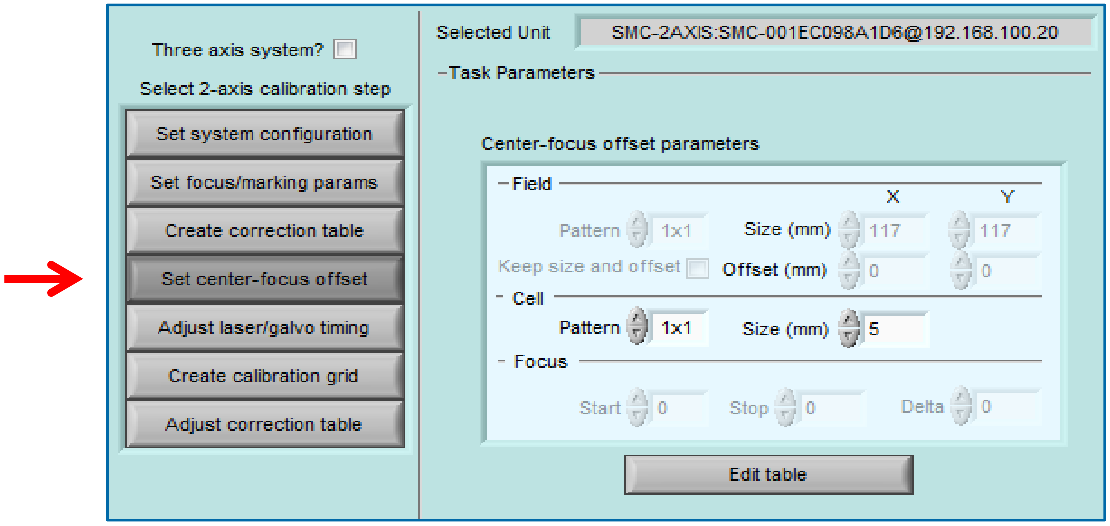


Figure 39 - Center Focus

⚠ CAUTION

Your next Action will fire the laser! Use Caution to avoid damage or injury!

Define Grid Size.

Click the “Run button to mark the grid.

Adjust the work distance and repeat until you get a well-focused mark.

4. **Adjust Laser/Galvo Timing**

   Now that the laser is focused, optimize laser and scanner delays under Adjust laser/galvo timing. Do not skip this step, since low-quality marking of the grid might cause the upcoming measurement and analysis to fail.

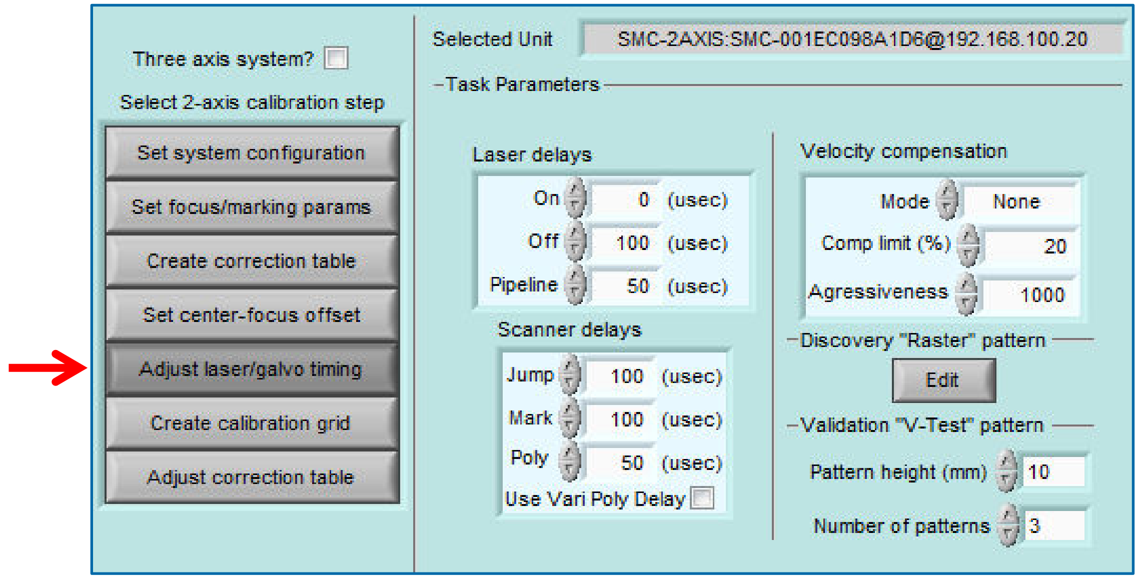


Figure 40 - Adjust Laser/Galvo Timing

Set correct Laser ON Delay, Laser OFF Delay, Jump Delay, Mark Delay and Poly Delay and mark V-Test and change delay values based on V-test observation. To learn more about how to optimize delays, see Error! Reference source not found.**Optimizing Laser/Galvo Delays.** Different lasers require different settings for the Pipeline delay, Laser On delay, and Laser Off delay, while application considerations may require different values for the Mark, Jump and Polygon delays (referred to as "Application Delays").

Many of the delays are interdependent, so changing one may affect another, resulting in a long trial-and-error process until you find the values you need. Novanta has developed a process to guide you through correct, streamlined set-up of the various delays for your specific laser and application needs.

5. The process starts with a coarse adjustment to get the parameters close to the required values, followed by a much finer adjustment to optimize those values. For the coarse adjustments, use a mark size that can be seen easily and a speed 30%-50% higher than you intend to use for the application. For the finer adjustments, the pattern size should be similar to your job, while the speed is adjusted as needed.
6. The Laser On and laser Off delays are better set with a higher speed than you intend to use for the application, since they may no longer be valid when the

speed is increased. However, laser timing will improve as the speed is decreased, ensuring better accuracy in turning the laser on and off. The same is not true for the Application delays. As you mark faster, you may need to increase the application delays to maintain the quality of the mark, while as you slow down you might create excessive delays that will either burn-in or waste time idling at some points. For that reason, Laser delays are set first at a higher speed, and then the Application delays are set at the intended operational speed.

7. Create Calibration Grid

   Adjusting the correction table requires comparison of a known pattern's coordinates with measurements of actual coordinates on a marked piece. The Create calibration grid menu provides parameters to define a grid pattern. Five grid types are available:

   1. Box and Cross
   2. Line
   3. Box
   4. Dot
   5. Circle and
   6. Cross

The preferred grid type is Line since it is less sensitive to improper laser/galvo timing settings, but for this example, we chose Box and Cross since it contains more edge information potentially yielding

more accurate measurement data. For more detail on various Grid types, see Appendix C: Calibration Grid Artifact.

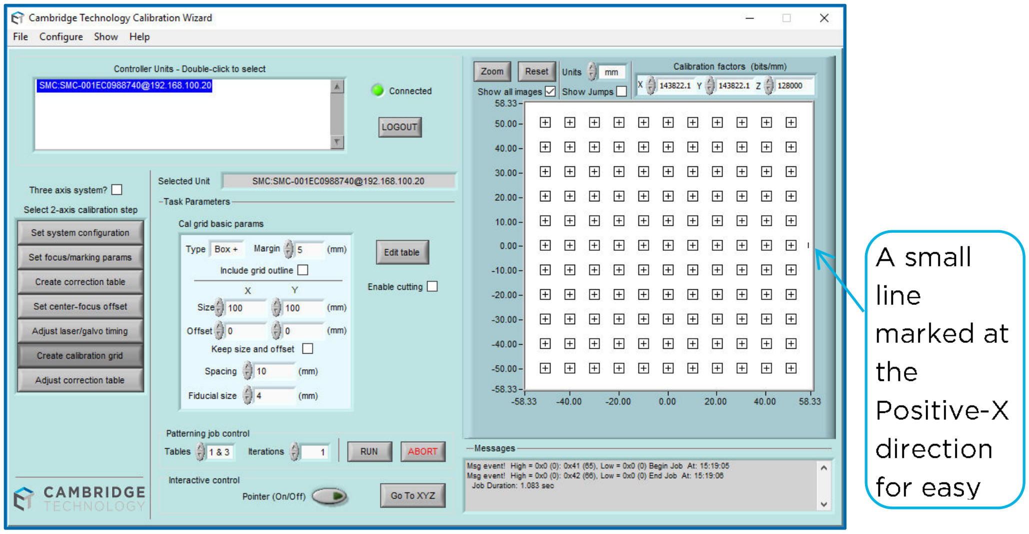


Figure 41 - Create Calibration Grid

The software attempts to use the full field size available, modifying the grid based on the Size, Offset, Spacing and Fiducial Size values. The software might display windows that inform you on required changes, since a Fiducial must always be positioned at the center of the field.

> ⚠ **CAUTION**
>
> **Your next Action will fire the laser! Use Caution to avoid damage or injury!**

8. Mark Grid

   Once all settings are done, press “Run” to mark grid. CTI recommends using high-contrast cardboard paper such as Bindakote paper or black anodized aluminum plate to get better marking contrast. The marked grid will look like the figure below. It clearly shows distortions in the marking pattern.

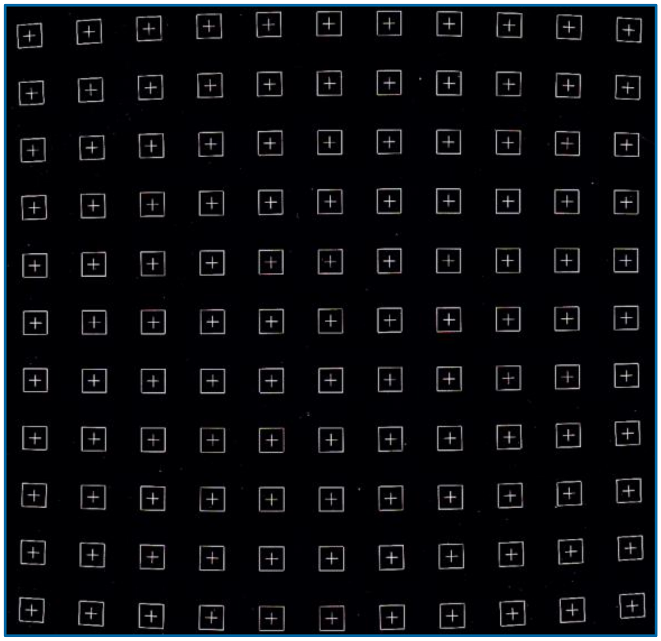


Figure 42 - Marked Grid

9. **Automatic Scan and Analyze**

   Place marked grid in flatbed scanner with correct orientation and press “Edit table” go to Correction Table Editor. Press “Automatic Scan and Analyze” to scan marked grid and analyze as shown below.

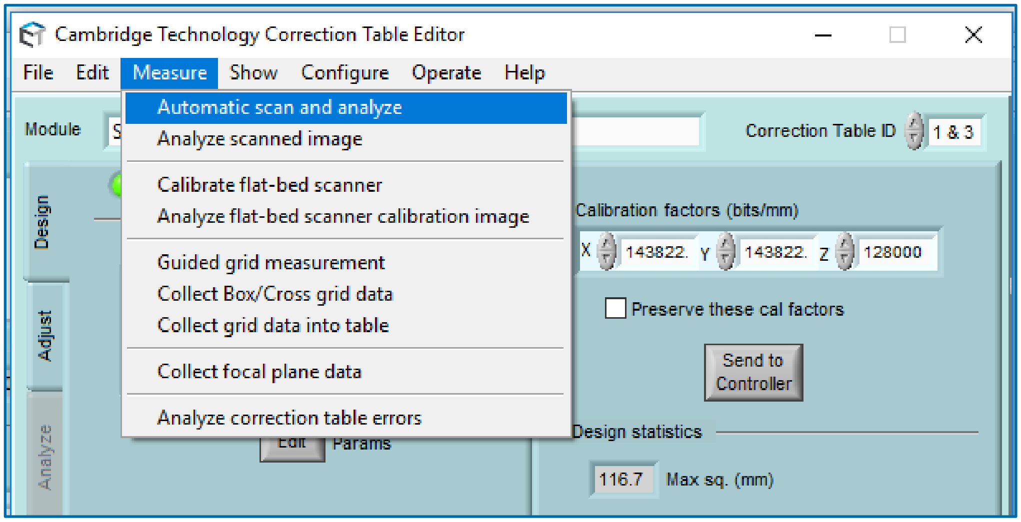


Figure 43 - Automatic Scan & Analyze Menu Option

Enter the name of the file (file name is usually an iteration of marking grid) as shown below. Save file on disk.

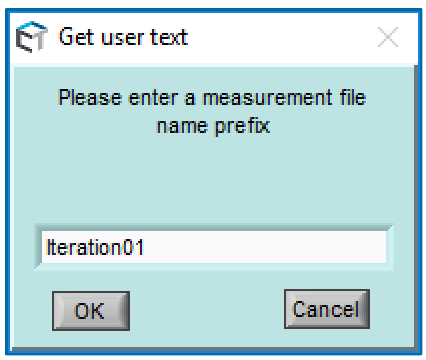


Figure 44 - Select Scanner type

Select scanner size and define the orientation of the scanned image on the flatbed document scanner.

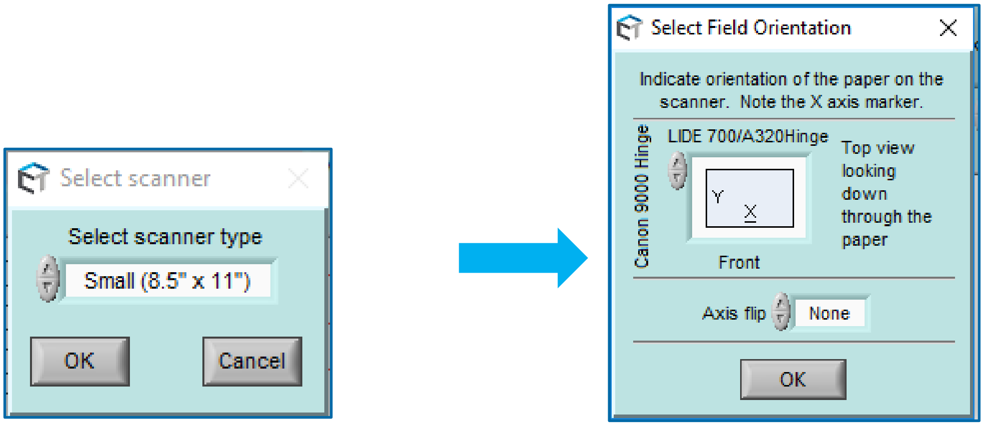


Figure 45 - Select Scanner size and field orientation

Select scanner type.

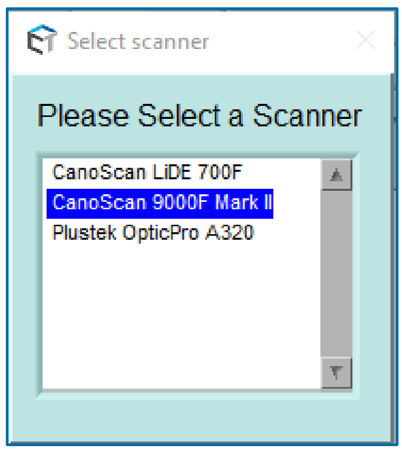


Figure 46 - Get user data

An activity bar shows that scanner is scanning the image and then it shows analyzing window as shown in the following figure.

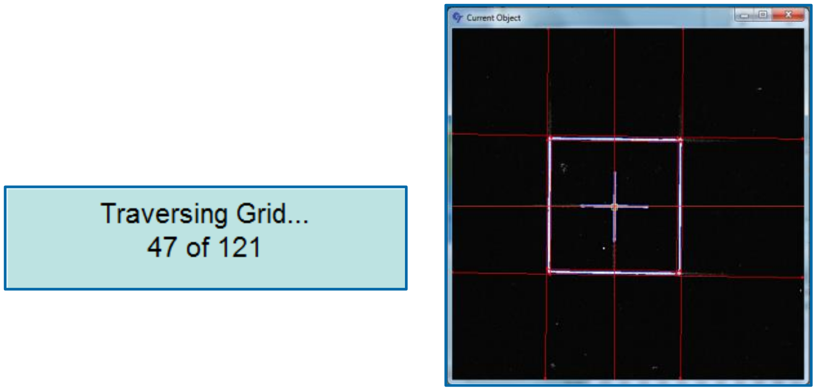


Figure 47 - Grid scanning

After analysis is complete, a .pset file is created from the scanned image and saved to a location that you choose through a dialogue box.

Once a set of measured coordinates exists for each of the design points, the differences between these values and ideal values are analyzed using least-squares regression techniques to develop coefficients for mathematical models of system errors.

In addition, calibration factors are calculated automatically based on the deviation of the measured overall dimension from the designed one.

10. Accuracy check

    It is recommended to have an SDev (Std Deviation) value less than 0.05 in measurement Data in the Correction table Editor. Please check SDev after each iteration.

11. Repeat Steps 6 to 8

    If the SDev value is larger than 0.05, exit the Correction Table Editor, accepting all changes in table. Repeat steps 6 through 8 until Sdev value is less than 0.05.

6.5.4 Analysis of a grid measurement file provided by user

Correction tables are created based on the analysis of ideal vs. measured coordinate sets. This analysis is done by the software but requires different actions depending on the method you choose.

You are still in Correction Table Editor window. Exit Correction Table Editor by File→Quit, then press "OK." In the following message windows, accept changes in table as shown below.

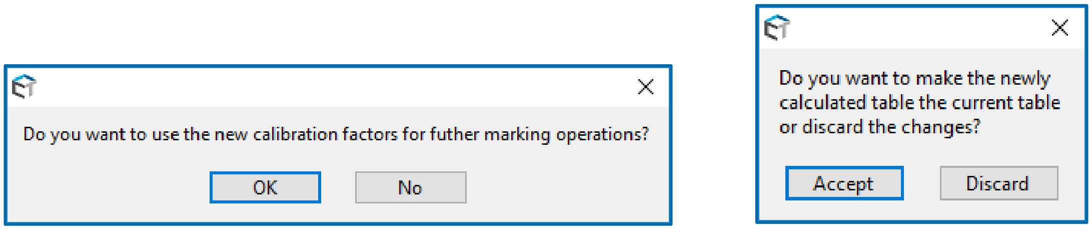


Figure 48 - Calibration factor accept

(This message appears only when a fresh table is started)

Save correction file on local drive. Saving correction file on local drive is optional. User can cancel saving correction file on local drive.

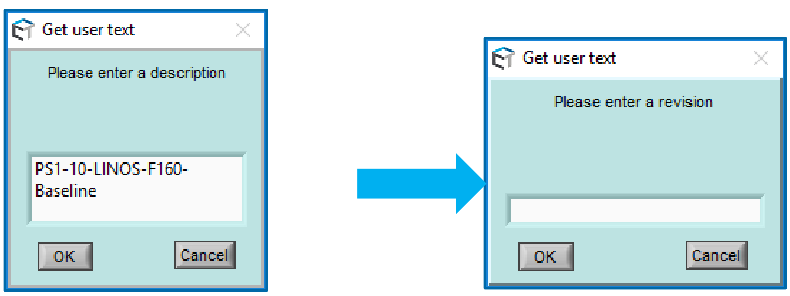


Figure 49 - Save correction file

Press "OK" to load table to controller as shown below

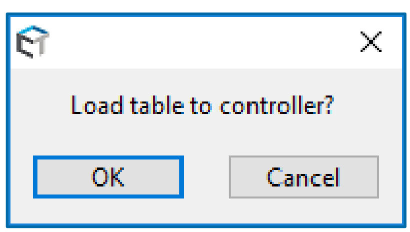


Figure 50 - Load table

1. Set Center-Focus offset

In this step, you adjust the system to achieve a focused beam at the center of the field. The optical path through the head's mirrors and the lens is fixed, so the distance between the head and the target surface is adjusted to achieve a focused grid.

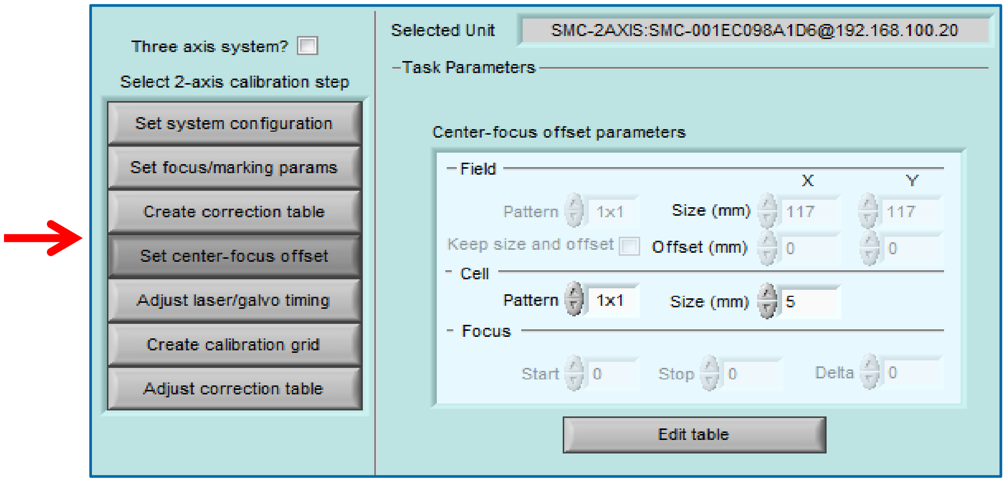


Figure 51 - Center Focus

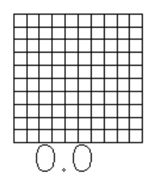
⚠ CAUTION

Your next Action will fire the laser! Use Caution to avoid damage or injury!

Define grid size.

Click the "Run" button to mark the grid.

Adjust the work distance and repeat until you get a well-focused mark.



2. Adjust Laser/Galvo Timing

   Now that the laser is focused, optimize laser and scanner delays under **Error! Reference source not found.**Optimizing Laser/Galvo Timing. Do not skip this step, since low-quality marking of the grid might cause the upcoming measurement and analysis to fail.

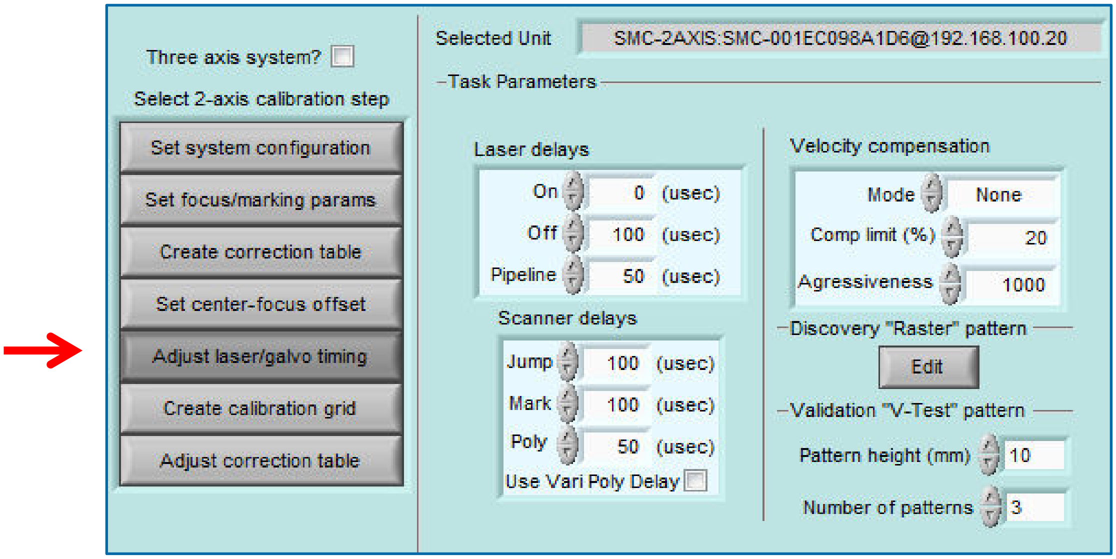


Figure 52 - Adjust Laser/Galvo Timing

Set correct Laser ON Delay, Laser OFF Delay, Jump Delay, Mark Delay and Poly Delay and mark V-Test and change delay values based on V-test observation. For more information about how to optimize delays, see **Appendix A: Optimizing Laser/Galvo Timing.**

Different lasers require different settings for the Pipeline delay, Laser On delay, and Laser Off delay, while application considerations may require different values for the Mark, Jump and Polygon delays (referred to as "Application Delays").

Many of the delays are interdependent, so changing one may affect another, resulting in a long trial-and-error process until you find the values you need. Novanta has developed a process to guide you through correct, streamlined set-up of the various delays for your specific laser and application needs.

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The Laser On and laser Off delays are better set with a higher speed than you intend to use for the application, since they may no longer be valid when the speed is increased. However, laser timing will improve as the speed is decreased, ensuring better accuracy in turning the laser on and off.

The same is not true for the Application delays. As you mark faster, you may need to increase the application delays to maintain the quality of the mark, while as you slow down you might create excessive delays that will either burn-in or waste time idling at some points. For that reason, Laser delays are set first at a higher speed, and then the Application delays are set at the intended operational speed.

3. Create Calibration Grid

   Adjusting the correction table requires comparison of a known pattern's coordinates with measurements of actual coordinates on a marked piece.

The Create calibration grid menu provides parameters to define a grid pattern. Five grid types are available:

1. Box and Cross
2. Line
3. Box
4. Dot
5. Circle
6. Cross.

The preferred grid type is Line since it is less sensitive to improper laser/galvo timing settings, but for this example, we chose Box and Cross since it contains more edge information potentially yielding more accurate measurement data.

For more detail on various Grid types, see Appendix C - Calibration Grid Artifact
The software attempts to use the full field size available, modifying the grid based on the Size, Offset, Spacing and Fiducial Size values. The software might display windows that inform you of required changes, since a Fiducial must always be positioned at the center of the field.

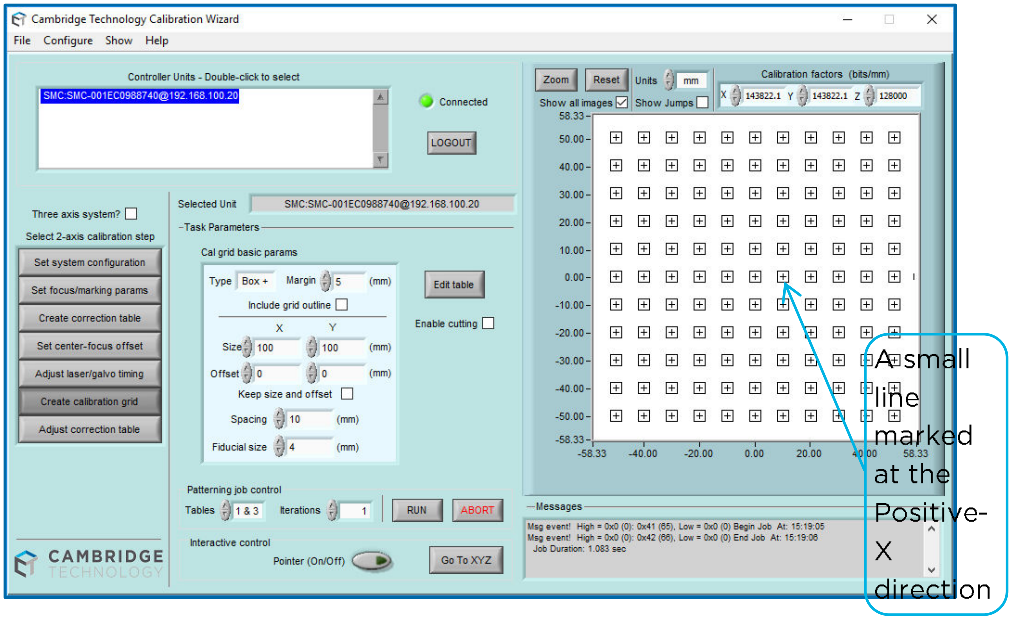


Figure 53 - Create Calibration Grid

4. Mark Grid

   Once all settings are done, press “Run” to mark grid. CTI recommends using high-contrast cardboard paper such as Bindakote paper or black anodized aluminum plate to get better marking contrast.

> ⚠ **CAUTION**
>
> **Your next Action will fire the laser! Use Caution to avoid damage or injury!**

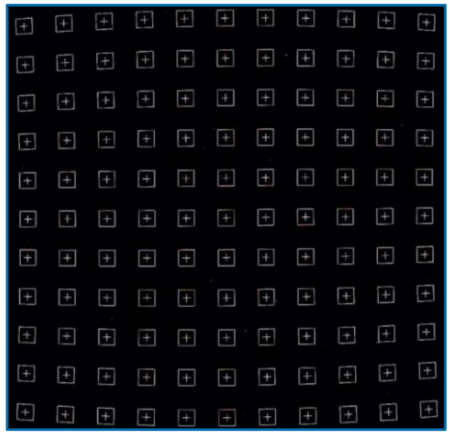


Figure 54 - Marked Grid

5. **Grid Analysis by External system**

   Use your own method such as XY system with Camera vision or Metrology system to measure the coordinates of the marked pattern points. Then, create an ASCII text file listing ideal and measured coordinates side by side. As an alternative, you can list the ideal coordinate together with the position error of the corresponding measured coordinates.

Both point-set (pset) formats use multiple lines of text in a file, each line representing a separately measured grid point expressed in standard units of measurement (mm or inches). In each line, values can be separated by spaces, tabs or semi-colons.

The sample format of data as shown below and saved as a .dat or .pset file.

Note: The column headers should <u>not</u> be in the file.

.dat Format (tab separator)					.pset Format (semicolon→ separator)			
X-Ideal	Y-Ideal	X-Actual	Y-Actual		X-Ideal	Y-Ideal	X-Delta*	Y-Delta*
-128.0→ -128.0→ -127.6778→ -128.011					-30.000000;-30.000000;0.298739;-0.583034			
-128.0→ -102.4→ -127.8725→ -102.5328					-25.000000;-30.000000;0.325006;-0.518194			

<table>
<tr><td rowspan="12">-128.0→ -76.8→ -127.9894→ -
76.9497
-128.0→ -51.2→ -128.0576→ -
51.3114
-128.0→ -25.6→ -128.0836→ -
25.6478
-128.0→ 0.0→ -128.0820→
00.0108
-128.0→ 25.6→ -128.0528→
25.6455
-128.0→ 51.2→ -127.9810→
51.2527
-128.0→ 76.8→ -127.8751→ 76.8149
-128.0→ 102.4→ -127.7240→
102.3285
-128.0→ 128.0→ -127.4911→
127.7597
-102.4→ -128.0→ -102.2990→ -
127.8040
-102.4→ -102.4→ -102.4243→ -
102.3363
-102.4→ -76.8→ -102.5034→ -
76.7753
-102.4→ -51.2→ -102.5497→ -
51.1900</td><td rowspan="12"></td><td>-20.000000;-30.000000;0.358461;-0.454425</td></tr>
<tr><td>-15.000000;-30.000000;0.383666;-0.390759</td></tr>
<tr><td>-10.000000;-30.000000;0.423006;-0.311030</td></tr>
<tr><td>-5.000000;-30.000000;0.423832;-0.222179</td></tr>
<tr><td>0.000000;-30.000000;0.457070;-0.151964</td></tr>
<tr><td>5.000000;-30.000000;0.492804;-0.087841</td></tr>
<tr><td>10.000000;-30.000000;0.529238;-0.016025</td></tr>
<tr><td>15.000000;-30.000000;0.535826;0.059729</td></tr>
<tr><td>20.000000;-30.000000;0.531174;0.149579</td></tr>
<tr><td>25.000000;-30.000000;0.563012;0.227755</td></tr>
<tr><td>30.000000;-30.000000;0.623177;0.302295</td></tr>
<tr><td>30.000000;-25.000000;0.521047;0.373780</td></tr>
</table>

*X-Delta = X-Axtual - X-Ideal; Y-Delta = Y-Actual – Y-Ideal

Figure 55 - User Measurement file sample

Click “Edit Table” to go back to the Correction Table Editor and select File→Import→Measurement data from...→CTI point-set format file as shown below.

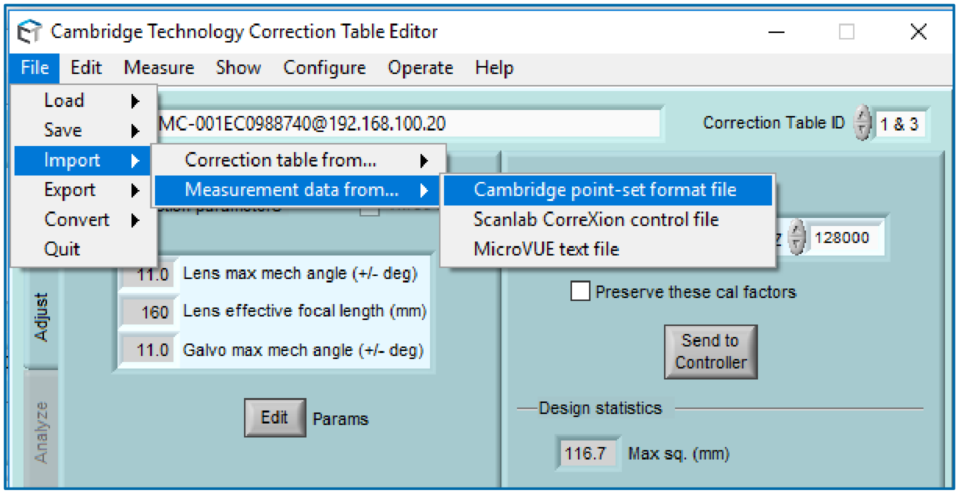


Figure 56 - Path to import file

Click "Import" for the format (.pset or .dat) of the table you have for import as shown in the following figure.

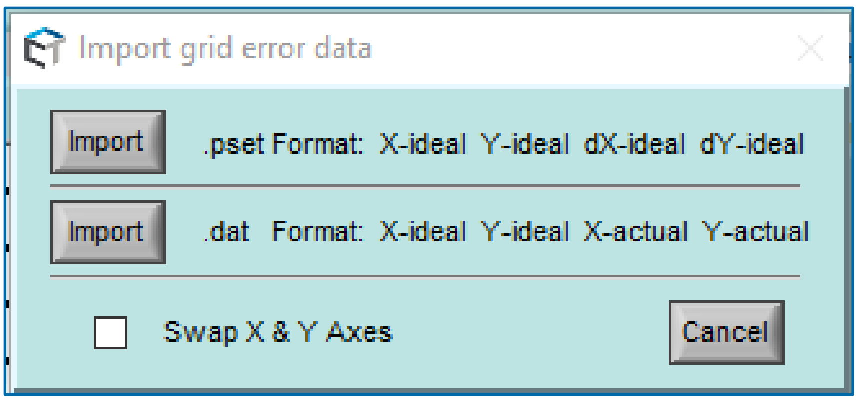


Figure 57 - Select file format

Regardless of the method you use to calculate the correction table, the editor DOES NOT include rotation and offset corrections in the table data. In addition, calibration factors are calculated automatically based on the deviation of the measured overall dimension from the designed one.

Measurement data statistics represent the errors in the actual raw data with offset and rotation removed. Model accuracy statistics represent how well the mathematical models are predicting the actual measurements (i.e., the difference between the actual measurements and the modeled measurements at each location). Min and Max represent the worst-case errors in the field; Mean is the average error, and SDev is the standard deviation

6. **Repeat Steps 3 through 5**

   If the SDev value is larger than 0.05 then exit the Correction Table Editor with "Accepting all changes" in table. Repeat step 5-8 until Sdev value is less than 0.05.

7 SAVE CALIBRATION FILE TO CONTROLER

Once measurement is completed and gives good accuracy, press "Edit Table" in "Adjust Correction Table" to go to "Correction Table Editor."

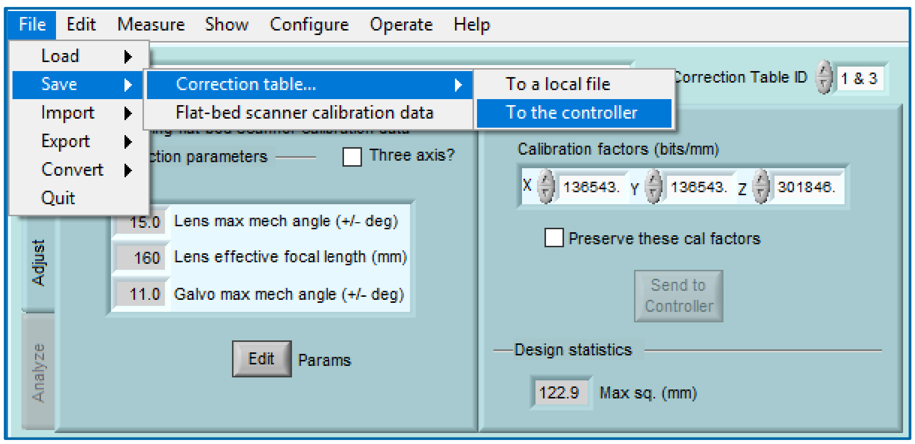


Figure 58 - Saving correction file

It will prompt you to save the calibration file to local drive. Press "Yes" to save on local drive. Enter a calibration file name in the box as shown below (the name is user defined and can include only alphanumeric characters, underscore (_) and dash line (-)).

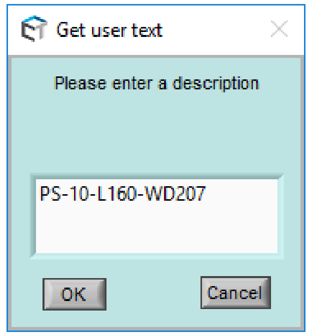


Figure 59 - File name

File revision is optional. Leave blank and press" OK."

CalWizard asks permission to make the most recent calibration file active as Table 1 and Table 3 as shown below. Press "OK" both times.

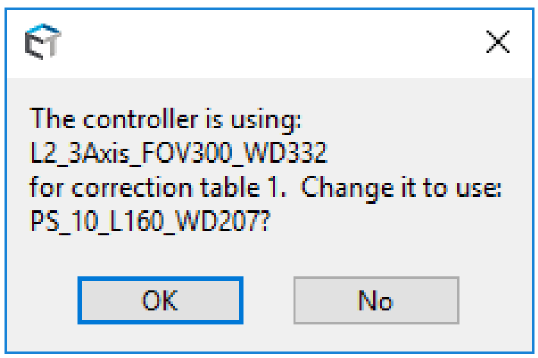


Figure 60 - Activate new correction file

7.1 READY TO USE

The SMC controller is ready to use with new correction file.

8 THREE-AXIS CALIBRATION PROCESS

8.1 CONTROLLER CONNECTION

For a 3D correction table, the X and Y corrections are created as already described, while the initial calculated Z correction is adjusted by “flattening the field,” which ensures consistent focus over the entire scan field.

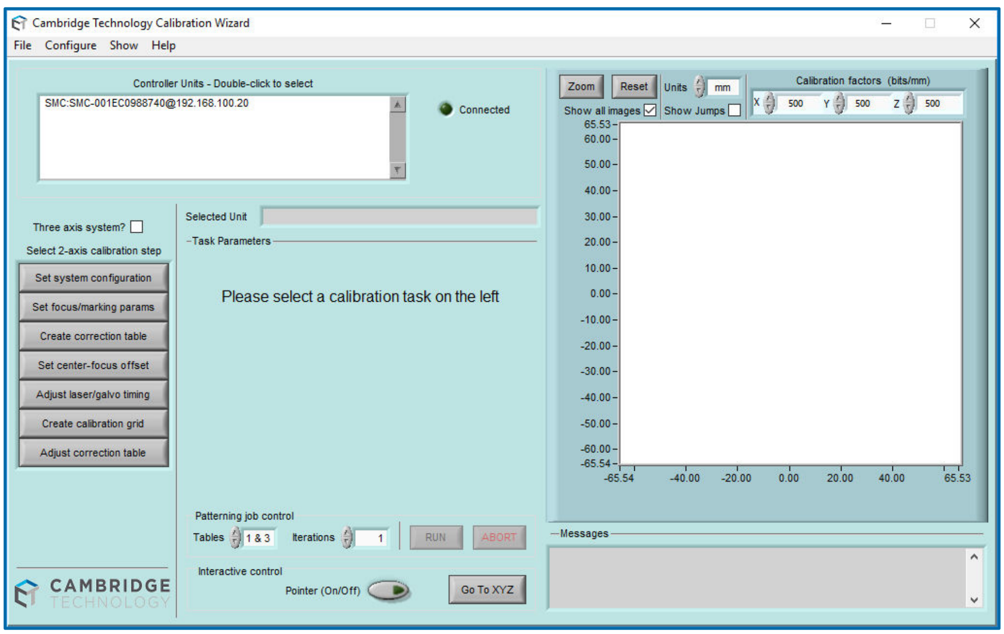


Figure 61 - Calibration Wizard Main Window

The Calibration Wizard searches for available controllers and displays them in the Controller Selection window.Double-click on the controller you wish to connect to. And finally, the “Connected” indicator turns green as shown in the following figure.

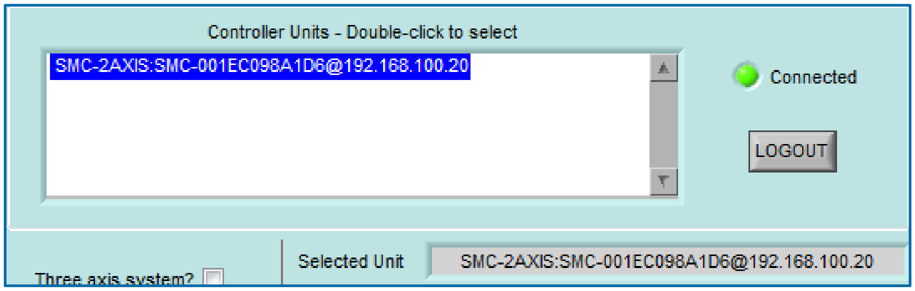


Figure 62 - Connected Indicator

Note: If the controller has a correction table present, it will be loaded and the selection of 2-Axis vs. 3-Axis will be done automatically to reflect the information in this table

Select 3-Axis check box as shown below.

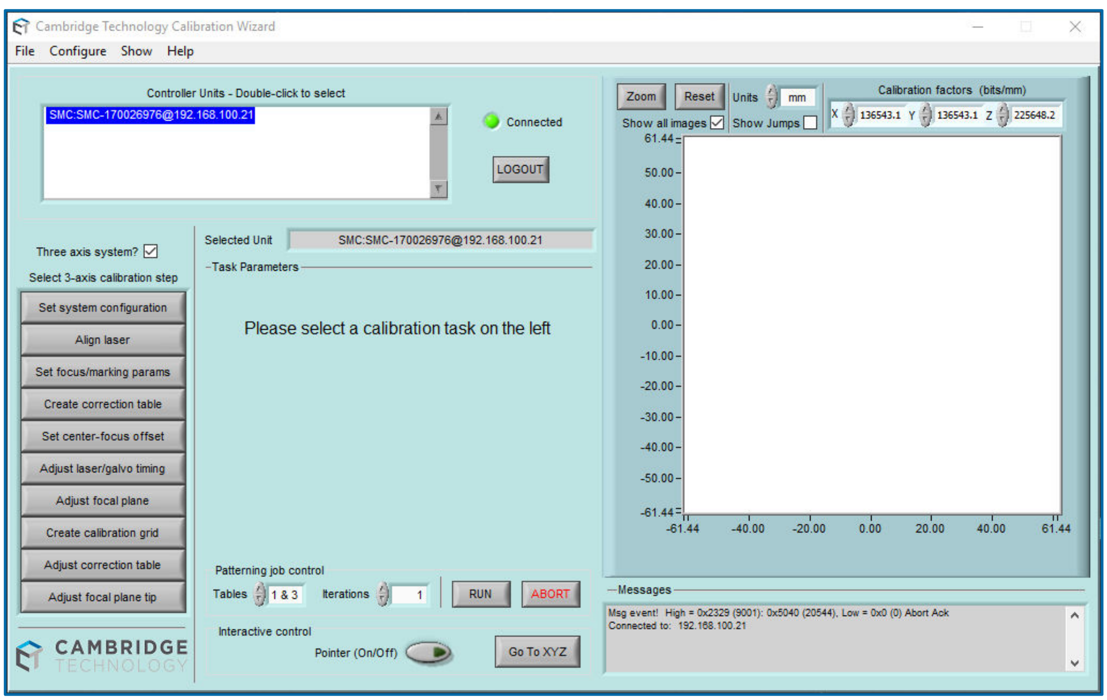


Figure 63 - 3-Axis Initial

8.2 SET SYSTEM CONFIGURATION

Select 3-axis scanning head from the Head type. Each head type has its own head configuration, so be sure to choose the right system.

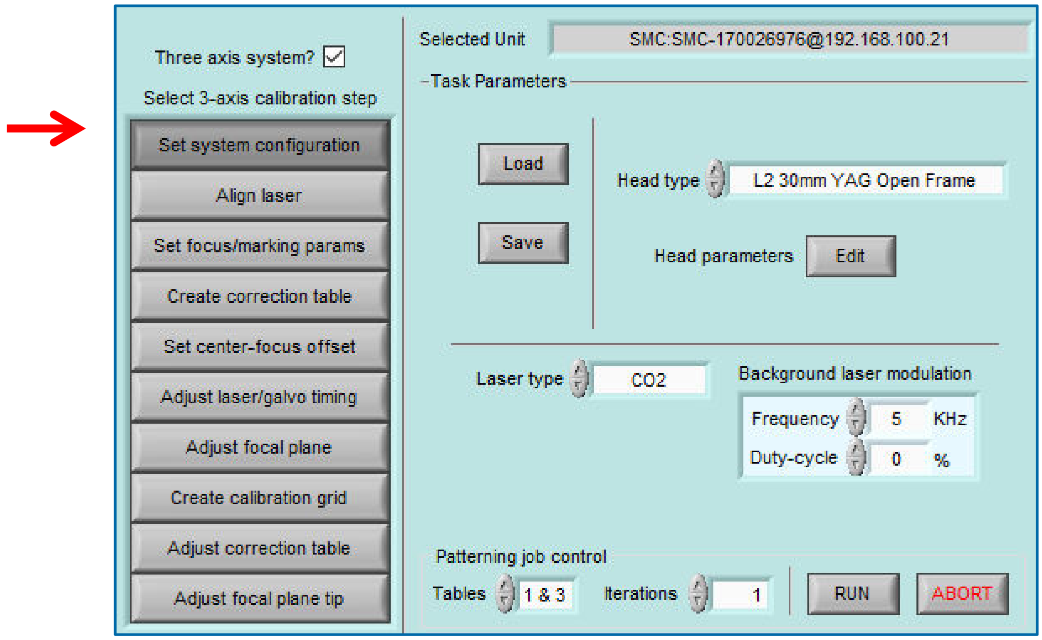


Figure 64 - System Configuration

There is an option to load CalWizard Configuration file (*.ccgf) if it has been saved previously for that particular Scan Head and F-Theta lens. It is always good to save the configuration file once all the steps have been passed through. Set Laser type. CalWizard is readily configured to integrate IPG and SPI Fiber lasers and Coherent and NOVANTA CO2 lasers. If a laser is different, then check Laser Properties in Configure menu as shown below:

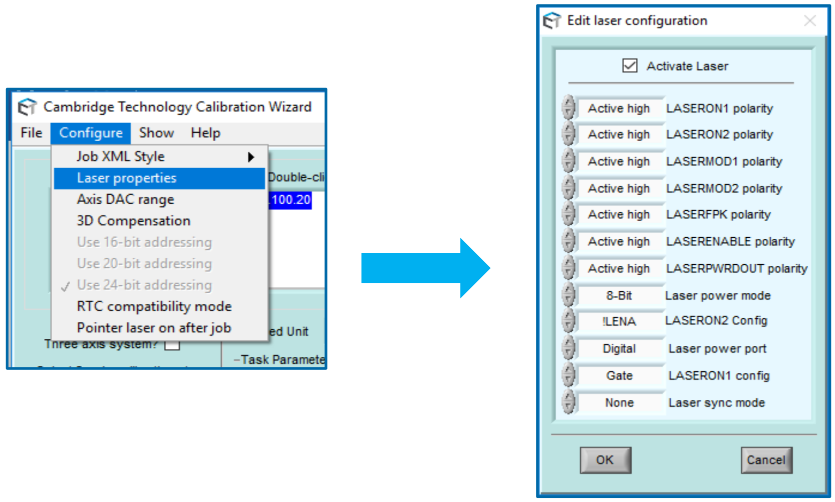


Figure 65 - Laser Properties

8.3 ALIGN LASER

3-axis requires alignment of the laser beam to the optical path of the head. To enable the alignment process for manual laser control, click “Align Laser” as shown below.

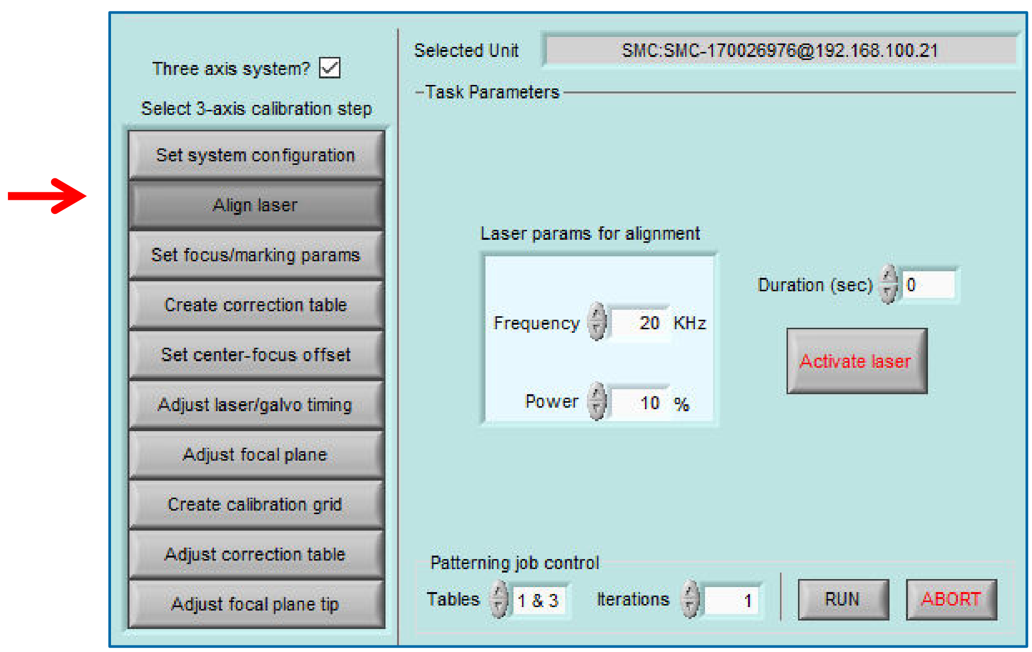


Figure 66 - Align Laser

Set Duration to the number of seconds' the laser is to be ON before turning OFF automatically. Entering "0" for duration turns laser ON for indefinite time. If laser needs to fire at particular XYZ coordinates, press "GO TO XYZ" and set coordinates of system where laser needs to fire.

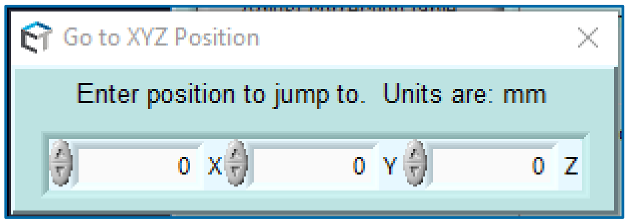


Figure 67 - Go to XYZ position

After parameters are set as needed, press "Activate laser" to fire the laser.

> ⚠ **CAUTION**
>
> **Your next Action will fire the laser! Use Caution to avoid damage or injury!**

A confirmation pop-up will appear. Press "OK" to fire the laser for the set duration or until you press a manual OFF button (whichever comes first)

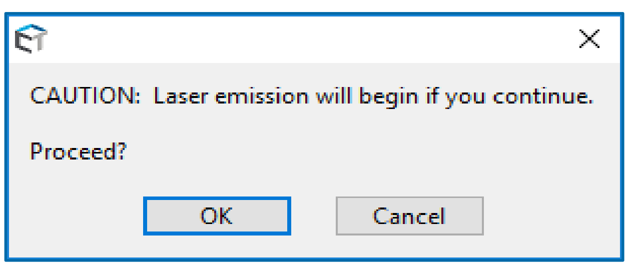


Figure 68 - Laser ON confirmation

To turn OFF the laser, click flashing yellow "OFF" button or hit any key on the keyboard.

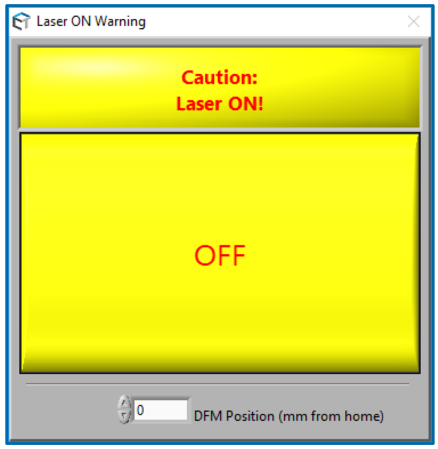


Figure 69 - Laser ON/OFF window

8.4 SET/FOCUS/MARKING PARAMETERS

CalWizard supports the following laser settings for different modes of operation:

- Marking – Medium power level to leave a clear mark on the media
- Focusing – Low power level to enhance variations in the mark due to focus quality
- Cutting – High power level to cut the marked pattern to be measured

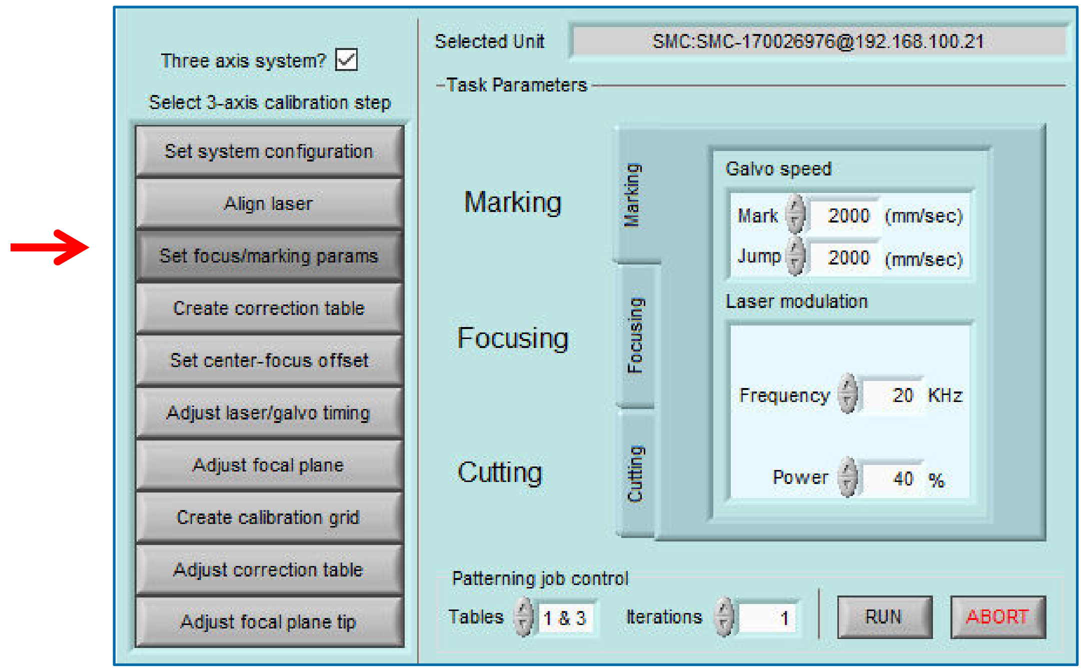


Figure 70 - Focus / Marking / Cutting Parameters

Note: Mark and Jump speed selections depend on the scan head model being used, as well as the application's accuracy and throughput requirements.

The availability of specific Laser controls will vary based on the laser type selected (see previous sections for details).

8.5 CREATE CORRECTION TABLE

The calibration process is incremental: each calculation result is added to over the current corrections. To eliminate any potential for error, all existing correction information is cleared when you open the Correction Table Editor by clicking the Create correction table button as shown in the following figure.

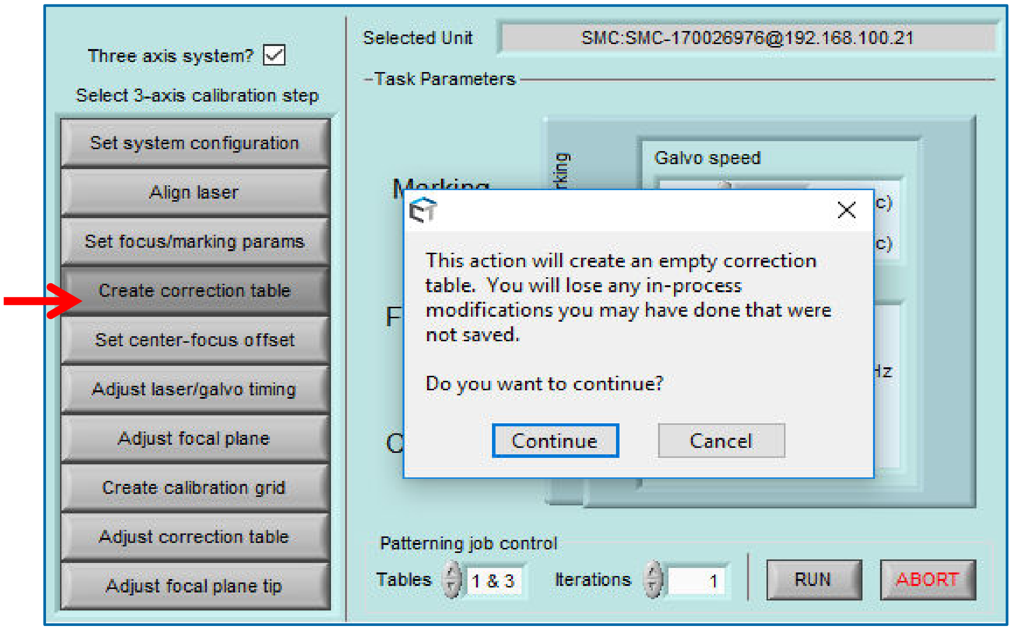


Figure 71 - Create Correction Table

After you press "Continue", the Correction Table Editor appears as shown below.

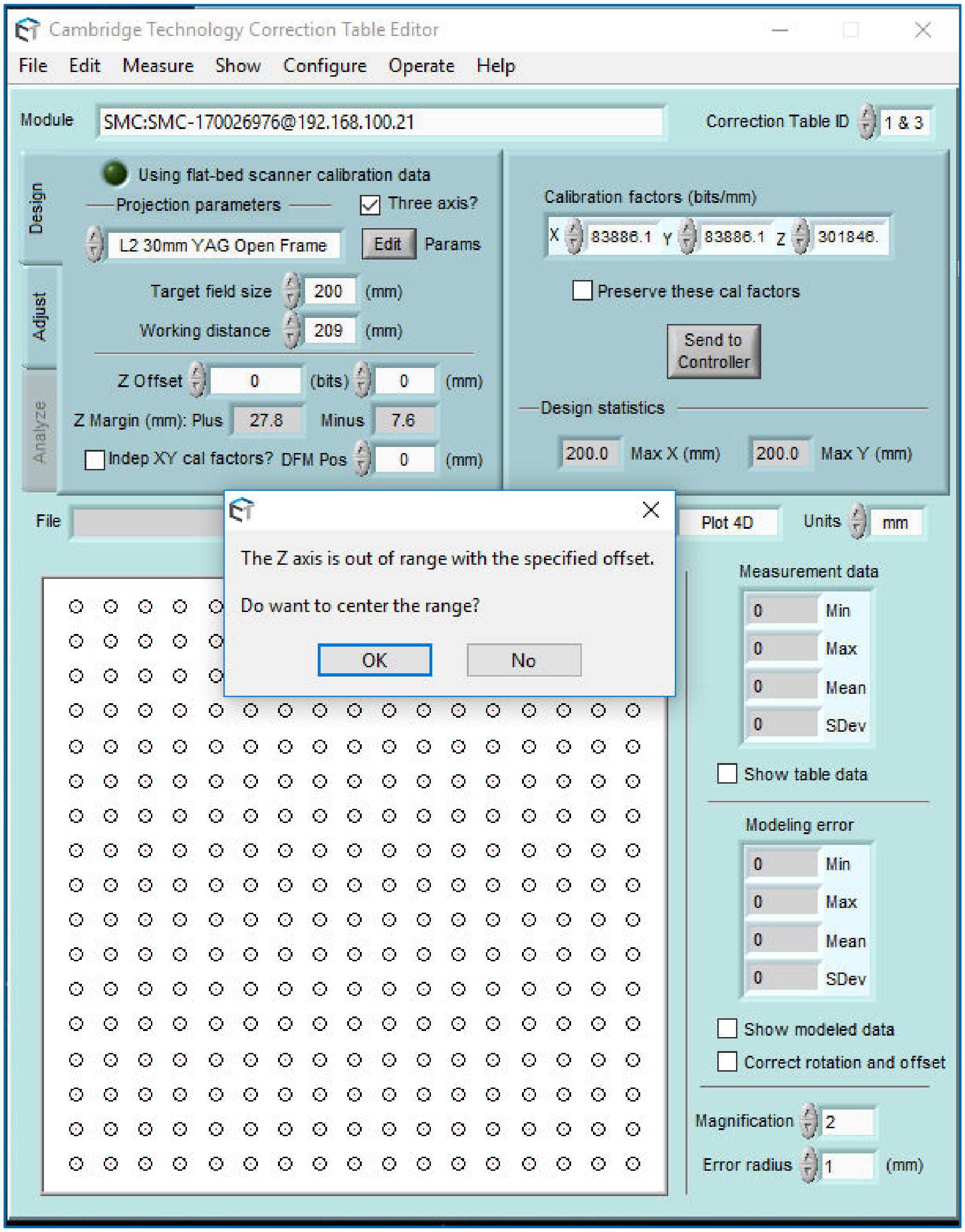


Figure 72 - Create correction table button

A popup window will appear because calculated Z axis data is out of range based on default field size and/or working distance. Select “OK” to center the Z-axis range.

Bit-resolution defines the scanner control system's ability to drive the galvos smallest angular move. As the SMC controller supports 24-bit resolution. So by default Bi-resolution is set to 24-bit as shown in below figure

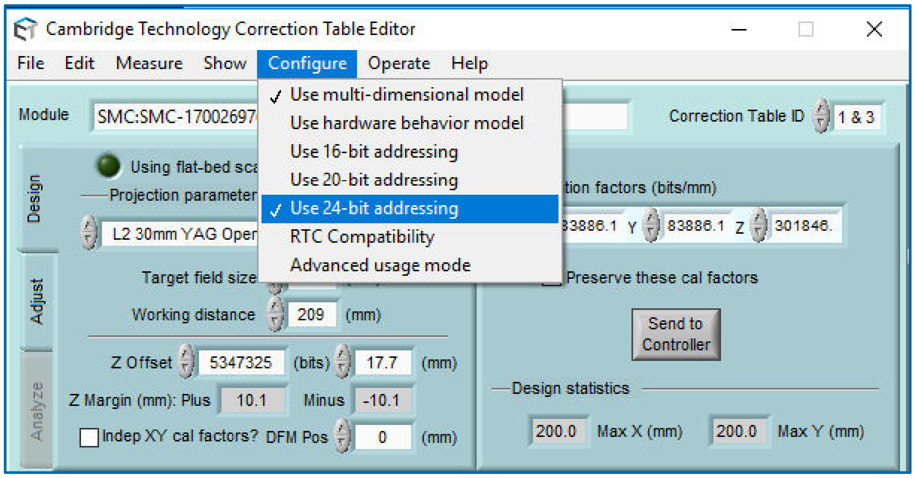


Figure 73 - Calibration Resolution selection

A correction table is calculated based on the pre-set or custom head type that was set in the Set System configuration.

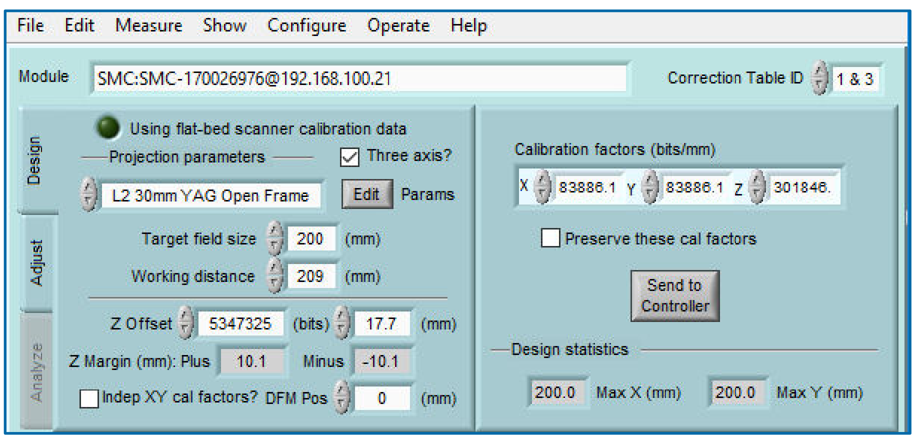


Figure 74 - System parameter

Field Size: Working distance and Target field size depend on each other. Choose either Target field Size or Working distance and the other sets automatically.

Suppose Target field Size requires 300x300mm; set Target Field Size at least 5% larger than the actual field size you intend to use. This ensures that features of the calibrating grid used later will fit within the usable field. And Working Distance 345mm is calculated automatically as shown below.

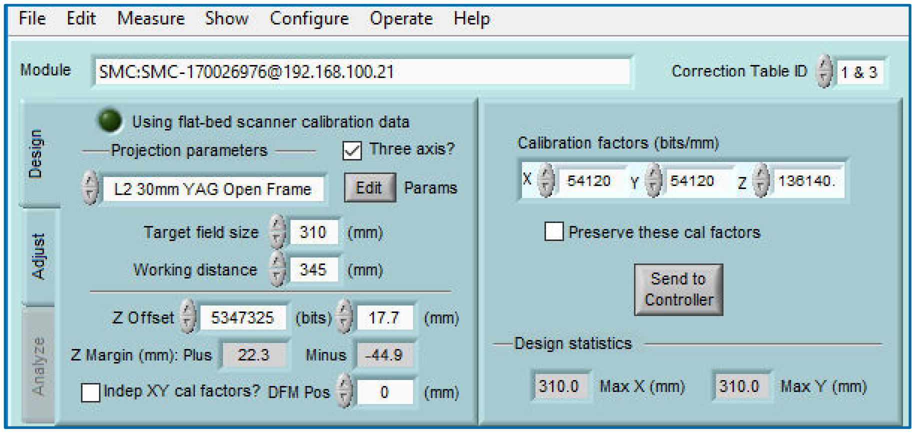


Figure 75 - Field size setup

Alternatively, if a Working distance is fixed, enter the number and the Target field size will be recalculated. For example, a Working Distance of 550mm for the scan-head configuration shown will yield a Target Field size of 476x476mm as shown in the following figure. Note that there is no calibration margin built into the field size when it is set this way.

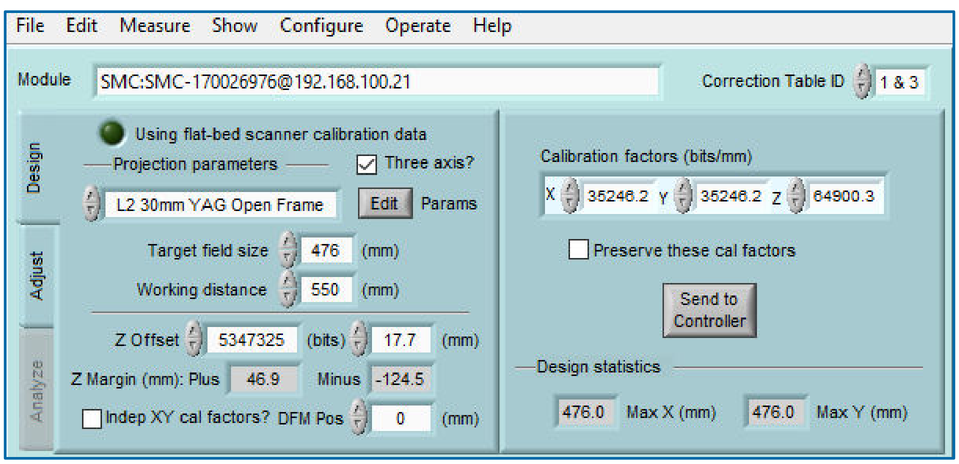


Figure 76 - Working Distance setup

Once the desired Working Distance or Field Size is established, the software calculates for Z-Margin (Plus & Minus) with Z-Offset. The default is for X and Y calibration factors to be set to the same value to produce a square imaging field, but they can be set independently to allow for rectangular fields (limited by the Y field dimension) and X-field size will be approximately 30mm larger than Y-field as shown below.

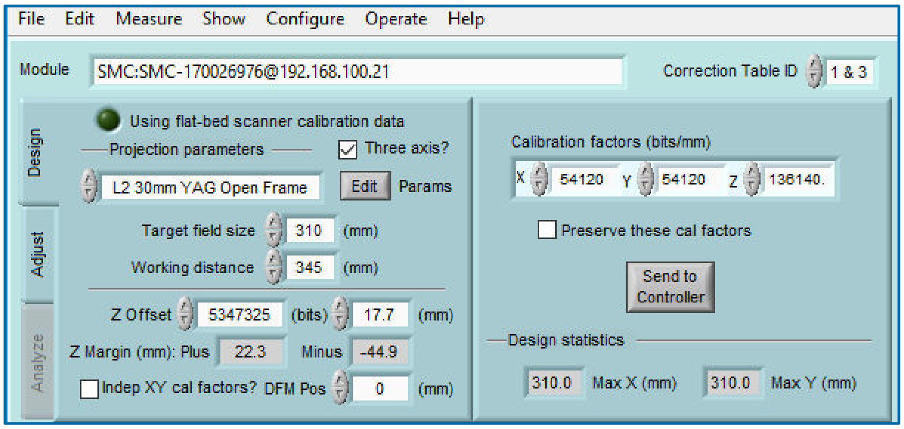
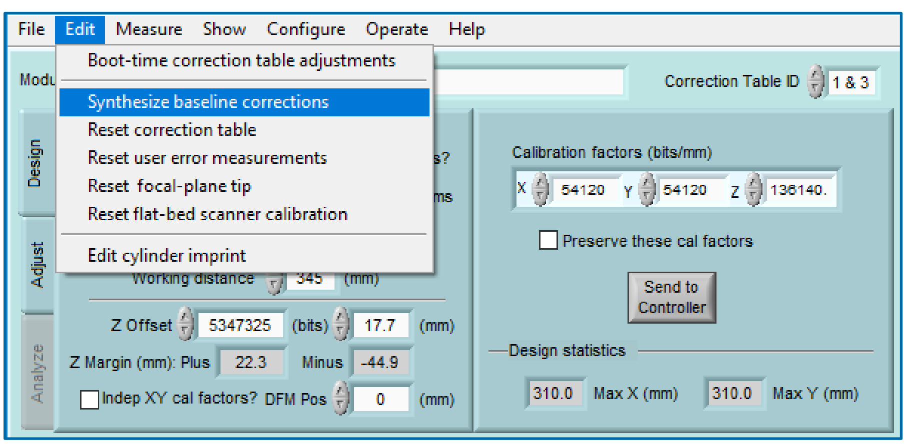


Figure 77 - Z-margin setup

Z-Margin shows the available travel distance beyond field flattening for 3D operation. Z-Plus is the distance above marking field and Z-Minus is the distance blow marking field which allows 3D marking.

Z-Offset is used for electrical fine tuning of the nominal position of the focusing mirror to achieve a good focus at the center of the field.

Projection parameters in the Design tab are set to the values you have entered previously and are used to synthesize a correction table based on your optical path geometry. To synthesize a baseline



table, select Edit →Synthesize baseline corrections.

Figure 78 - Synthesize baseline

The editor calculates pin-cushion distortion compensation derived from mirror spacing and lens distortion compensation. It automatically rescales the table contents and the calibration factors to optimize the use of the Galvo command range shown below.

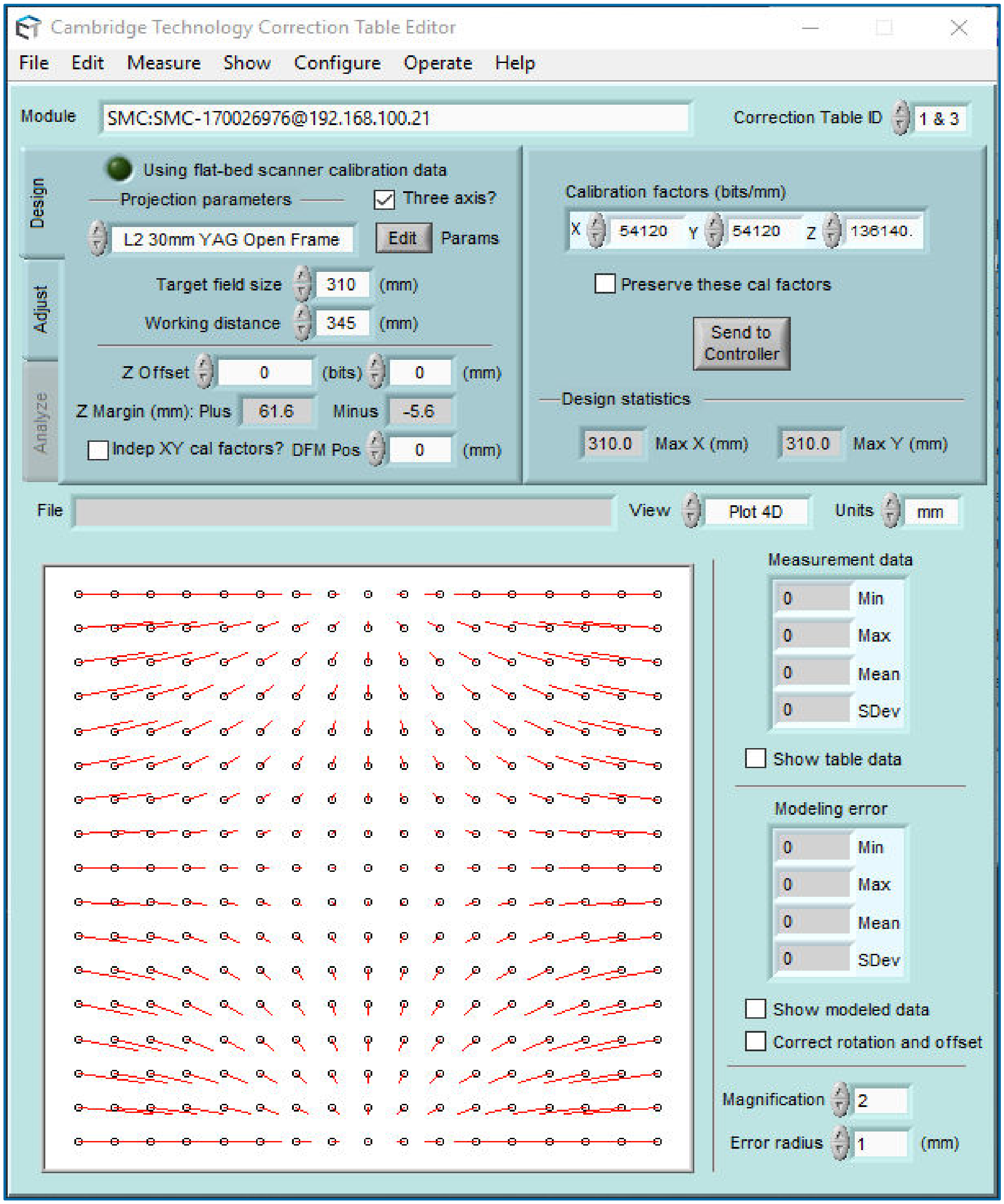


Figure 79 - Synthesized Correction table

For example, 300x300mm field size Z-offset is 0 and Z-margin (+) is 61.6mm and Z-margin (-) is -5.6 mm. That means DFM (Dynamic Focusing Module) is not positioned in center as shown below.

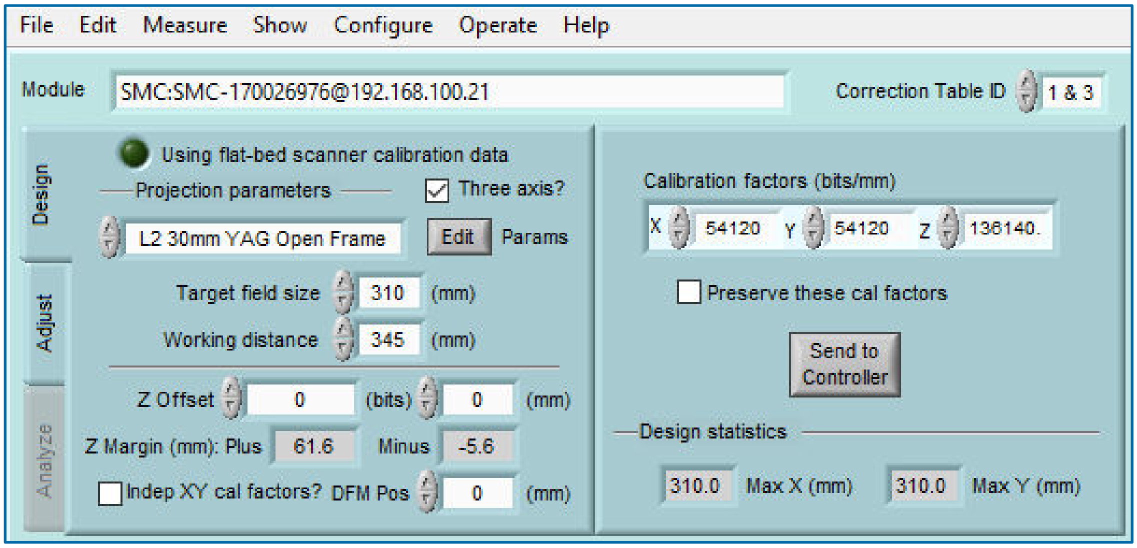


Figure 80 - Z-Offset and Z-Margin

Selecting "Center DFM Range" as shown below allows DFM to position in center and set values for Z-margin.

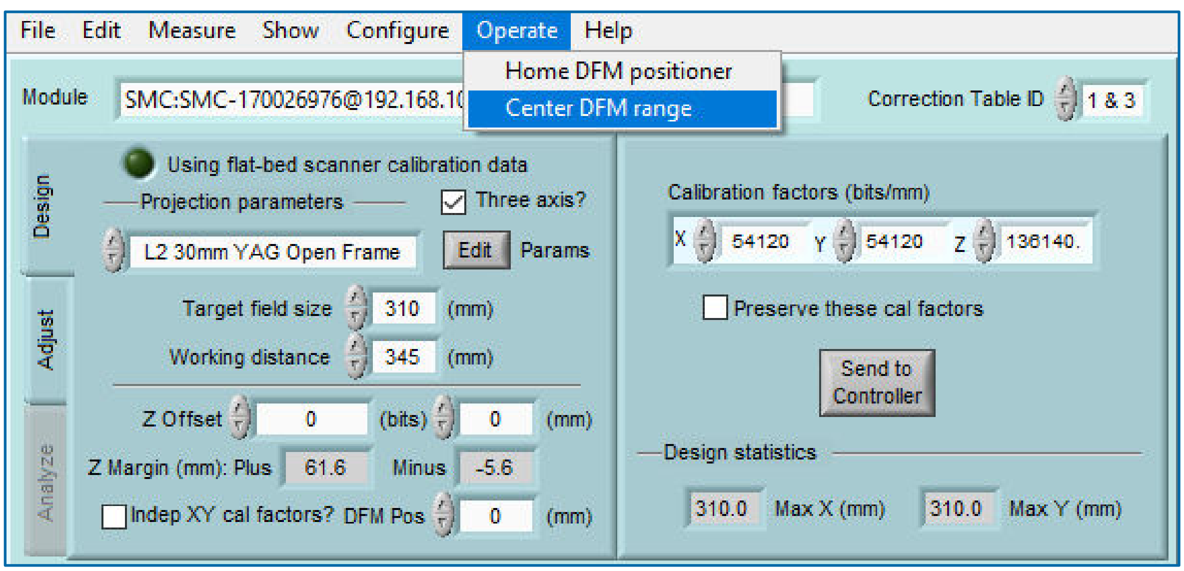


Figure 81 - Center DFM range

Press "OK" to send new table information to the controller.

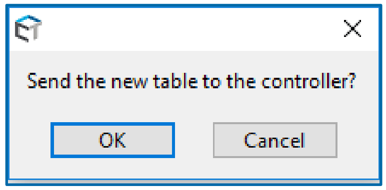


Figure 82 - Send new table

Z-Offset has been set and Z-Margin Plus and Minus also set as shown below.

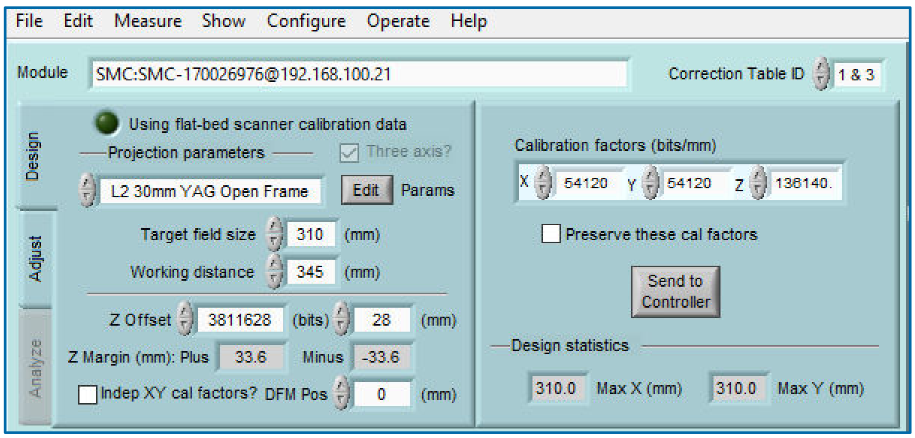


Figure 83 - Z-margin Plus and Minus set

Exit Correction Table Editor by File→Quit, then press "OK" in the following message window.

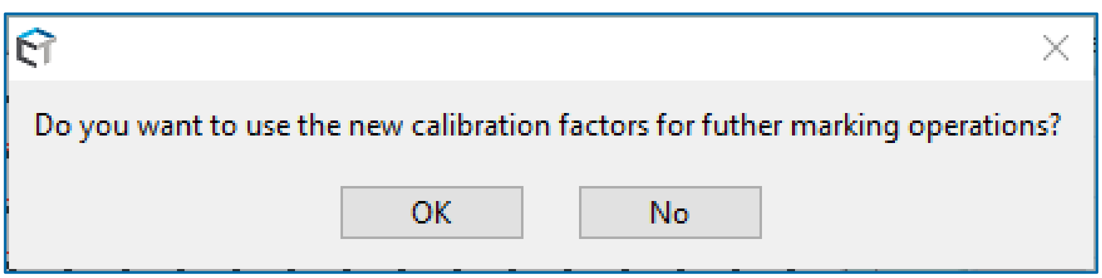


Figure 84 - Exit Correction table editor

(This message appears only once, when a fresh table is started)

Accept changes in table as shown below.

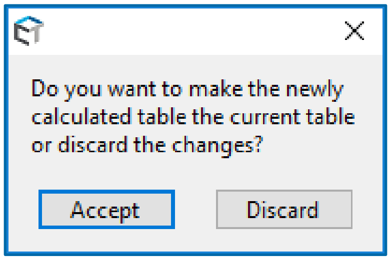


Figure 85 - Accept new changes in correction table

Save correction file in local drive. Press "OK" to load table to controller as shown below.

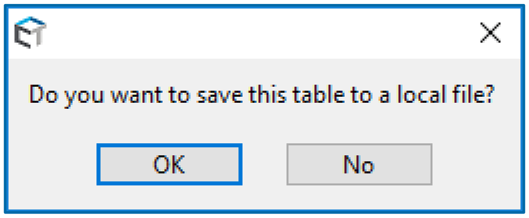


Figure 86 - Save correction file to local drive

Load correction table to controller temporary. Press "OK to send correction table data to controller as shown below

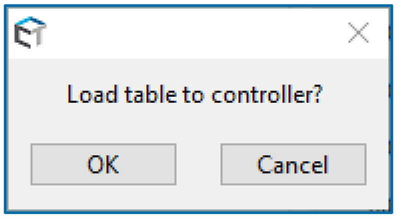


Figure 87 - Load table to controller

8.6 SET CENTER-FOCUS OFFSET

In this step, the system is adjusted to achieve a focused beam at the center of the field.

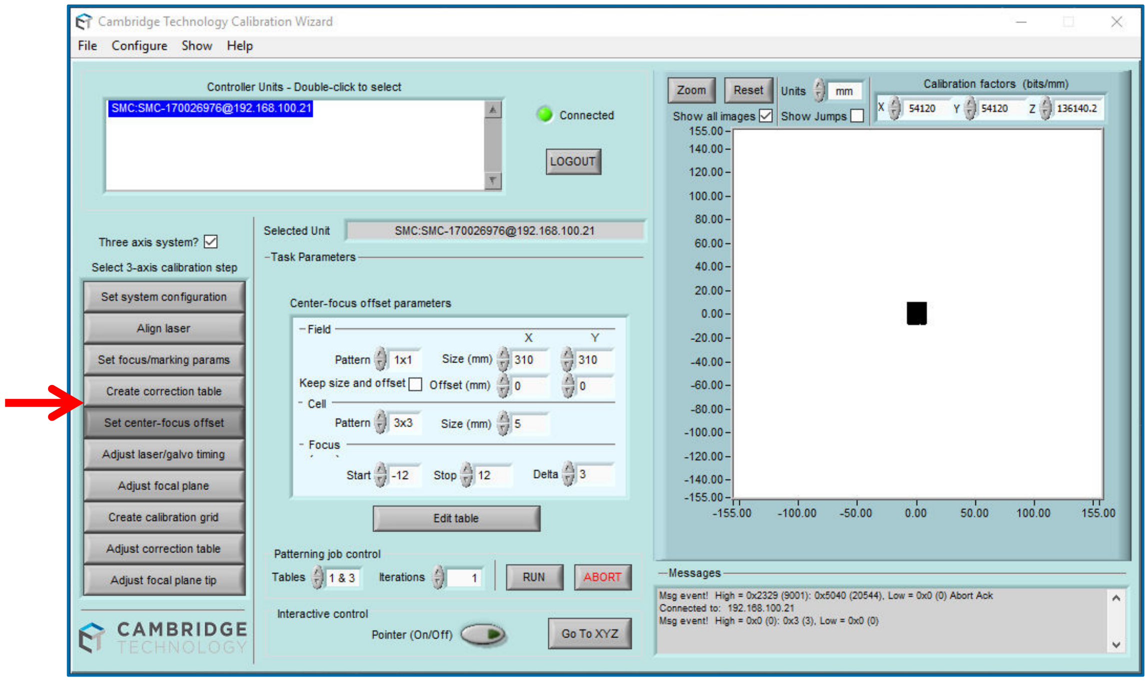


Figure 88 - Center Focus

Set field size (here it is 300). Preferred Cell pattern is 5x5 and cell size 5mm up to 400mm field size, 10mm up to 800mm field size and 15mm up to 1500mm field size (all values are generic; user can have his own choice of value).

Focus variation +12 to -12 is up to 500mm field size then +18 to -18 up to 800mm field size and +24 to -24 up to 1500mm field size (all values are generic; user can have his own choice of value).

In 3-axis system, there are two ways to adjust focus.

Coarse Adjustment of the nominal focal length is done by physically moving DFM module either towards Objective lens or away from objective lens.

⚠ CAUTION

Your next Action will fire the laser! Use Caution to avoid damage or injury!

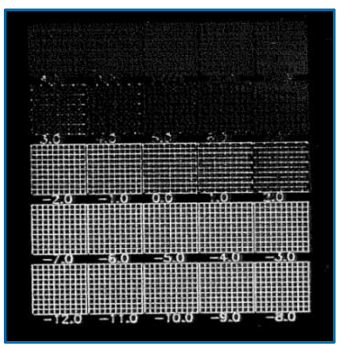
Set all values and click “Run” to mark pattern

Check the marking, if it is not visible or legible DFM toward Objective in scale of 1mm and mark again. Repeat marking until legible marking is visible. Direction of DFM movement depends on field size.

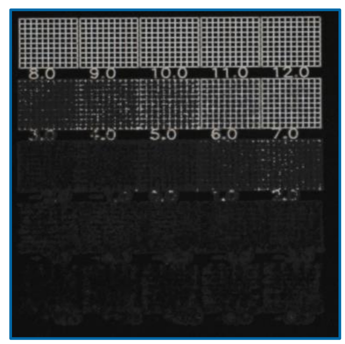
If field current field size is larger than previous one, then DFM moves toward Objective lens and if current field size is smaller than previous field size then DFM moves away.

Once legible marking is visible; it may look like one of the following

A marking pattern like Image (a) means focus is below working distance, so move DFM toward Objective lens and if the image looks like (b), focus is above working distance so move DFM away from Objective lens



(a)



(b)

Repeat marking until you achieve marking pattern like that in the following figure.

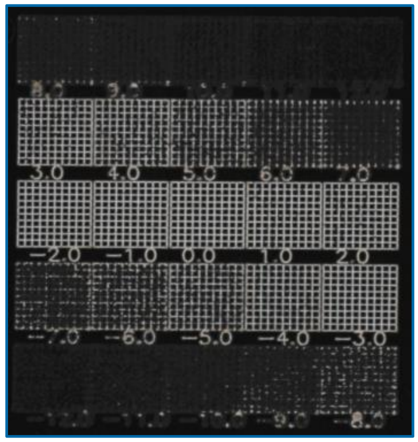


Figure 89 - Center Focus

In a well-focused system, the mark quality starts very poor, improves toward the center of the array, and then deteriorates again on the other side. Fix the DFM position and mark again and check whether center focus is unchanged.

Fine Adjustment of the nominal focal length is done by updating Z-Offset value in Correction Table Editor. Sometimes it is hard to move DFM assembly in sub mm distance while maintaining correct focus at the same time. Use Fine adjustment of DFM by updating Z-Offset value. In the following figure, focus is around 2mm above the center.

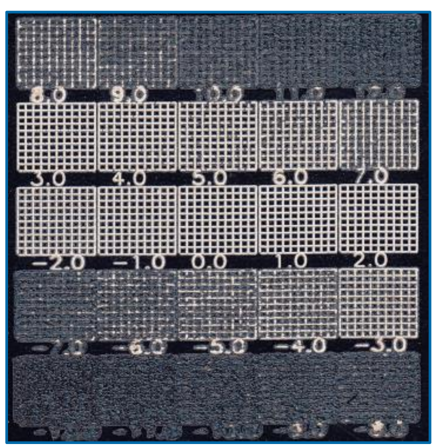


Figure 90 - Center off by 2mm

Click “Edit Table” to go to “Correction Table Editor” as shown below.

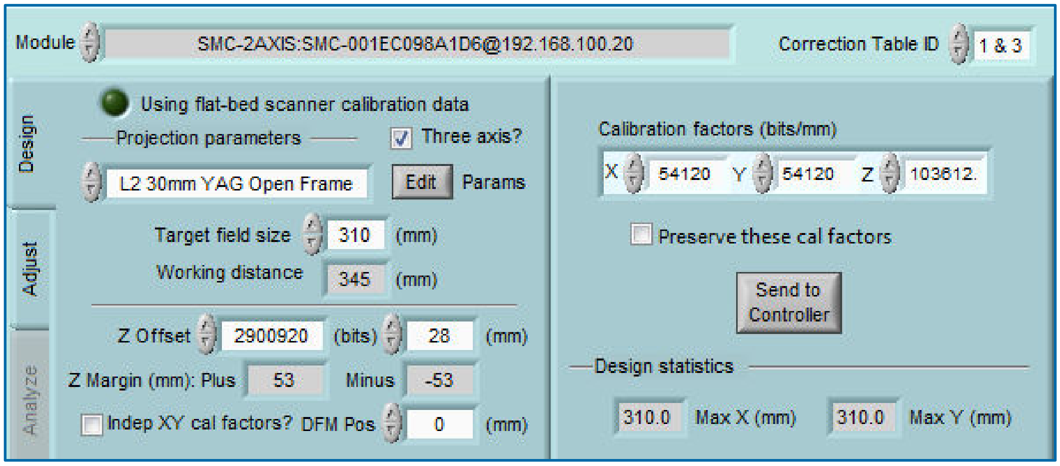


Figure 91 - Z-offset setup

Here Z-Offset value is in two different units Bits (2900920) and mm (28). As the offset is 2mm above the center, add 2mm in 28mm and exit Correction Table Editor by accepting all changes in table.

Similarly, if the focus is below center; subtract that value from the Z-offset.

Mark Focus Grid again and see check the result. Repeat above steps until achieving perfect center focus as shown in **Figure 89 - Center Focus.**

8.7 ADJUST LASER/GALVO TIMING

Now that the laser is focused, optimize laser and scanner delays under Adjust laser/galvo timing. Do not skip this step, since low-quality marking of the grid might cause ensuing measurement and analysis to fail. Please refer Error! Reference source not found.**Optimizing Laser/Galvo Timing**

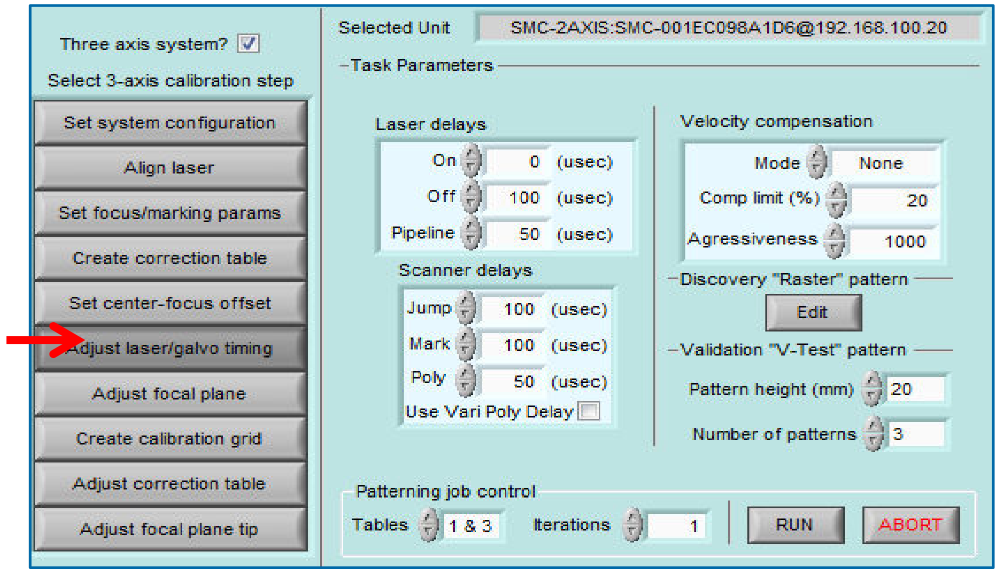


Figure 92 - Laser / Galvo timing

Set Laser ON Delay, Laser OFF Delay, Jump Delay, Mark Delay and Poly Delay and mark V-Test and change delay value based on V-test observation. For more information about how to optimize delays, see Error! Reference source not found. **Optimizing Laser/Galvo Timing.**

Different lasers require different settings for the Pipeline delay, Laser On delay, and Laser Off delay, while application considerations may require different values for the Mark, Jump and Polygon delays (referred to as "Application Delays").

Many of the delays are interdependent, so changing one may affect another, resulting in a long trial-and-error process until you find the values you need. Novanta has developed a process to guide you through correct, streamlined set-up of the various delays for your specific laser and application needs

The process starts with a coarse adjustment to get the parameters close to the required values, followed by a much finer adjustment to optimize those values. For the coarse adjustments, use a mark size that can be seen easily and a speed 30%-50% higher than you intend to use for the application. For the finer adjustments, the pattern size should be similar to your job, while the speed is adjusted as needed.

The Laser On and laser Off delays are better set with a higher speed than you intend to use for the application, or the values might no longer be valid when the speed is increased. However, laser timing will improve as the speed is decreased, ensuring better accuracy in turning the laser on and off.

The same is not true for the Application delays. As you mark faster, you may need to increase the application delays to maintain the quality of the mark, while as you slow down you might create excessive delays that will either burn-in or waste time idling at some points. For that reason, Laser delays are set first at a higher speed, and then the Application delays are set at the intended operational.

8.8 ADJUST FOCAL PLANE

Having arrived at good marking parameters, adjust the focal plane for 3-axis system to ensure a focused beam over the entire field.

It is just like doing center focus, but here everything is in software.

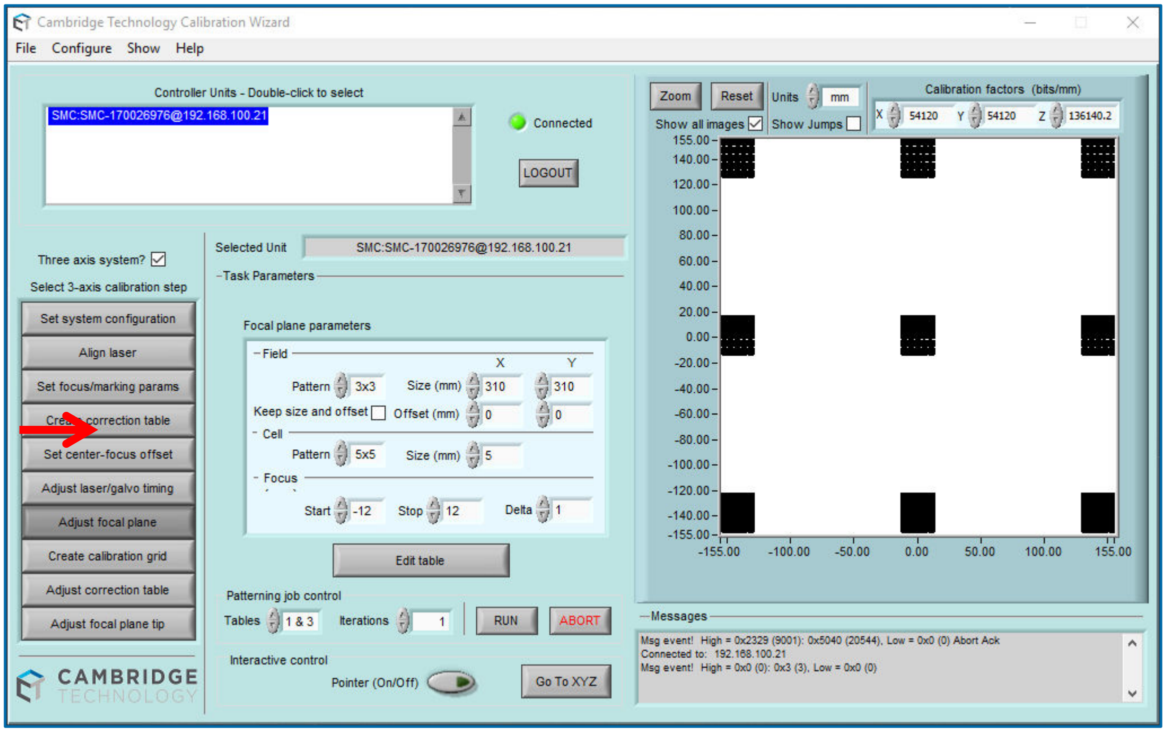


Figure 93 - Focal plane adjustment

The preferred cell pattern will be the same as center focus.

CAUTION

Your next Action will fire the laser! Use Caution to avoid damage or injury!

Mark the pattern and check result. For example, it should look as shown below.

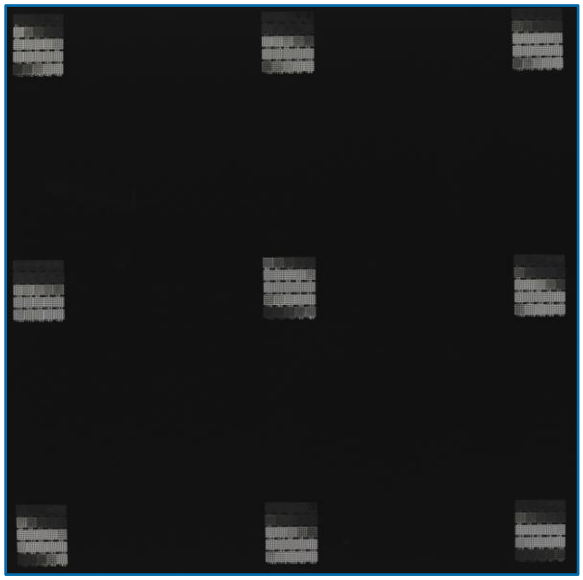


Figure 94 - Marked pattern

Make a note of how far the best focus point (highest contrast) is offset for each pattern. Each cell is annotated with the Z offset that was used when it was imaged. The best value can be either positive or negative.

Click "Edit table" and go to Measure →Collect Focal Plane Data. A Focus Array Data window pops up.

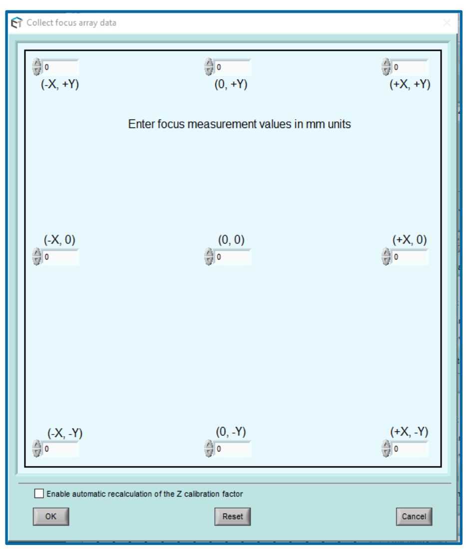


Figure 95 - Focus Array Data

For each Focus array location, find the offset value that results in a focused beam, enter it in the corresponding field in the window and press" OK".

Note: The information entered through this tool is accumulative, so while the presented values are reset to zero every time you open the tool, previously applied corrections remain in effect.

Exit Correction Table, accept all changes, and mark focal plane grid again and check. If it still seems out of focus at the center, repeat above step until you get perfect Focal Plane Grid as shown below.

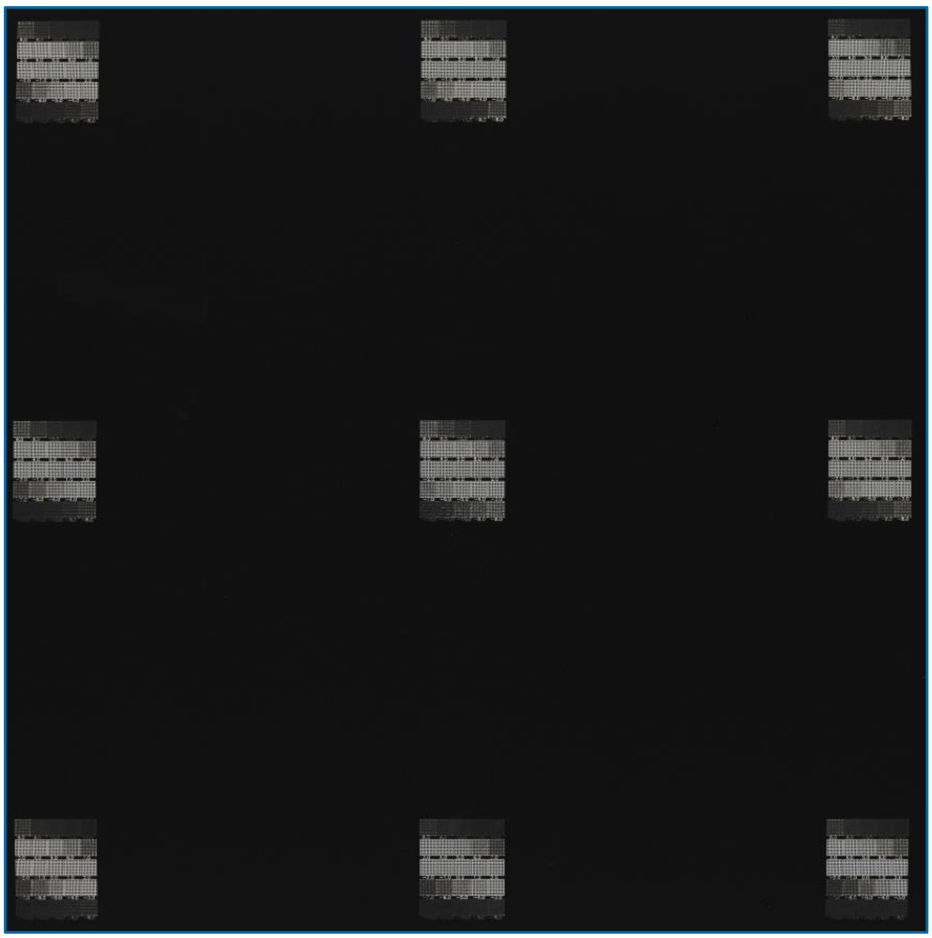


Figure 96 - File→Load calibration configuration

8.9 CALIBRATION METHOD:

The Calibration Wizard supports several different methods for calibrating a correction table. The following table provides a quick-reference overview to four calibration methods. Choose one of these methods to calibrate the correction table. Use the links in the table to navigate to different steps in each method in the text below. Each of these is described in greater detail in the pages that follow.

Collect Box/Cross Grid Data	
Quick Method for initial or approximate accuracy Yields a usable approximation when accuracy is not so important Good for both 2-axis and 3-axis	
Adjust Correction Table	Approximate calibration
Mark Grid	Mark grid on black-coated surface
Measure Data and Enter	
Accuracy Check	Repeat until calibration satisfactory
Guided Grid Measurement	
Suitable for calibrating any scan field size, but is best suited to fields larger than 300mm x 300mm.	
Grid Setup	Set grid paper or characterization plate on marking field
Guided Grid Measurement	Maneuver the guide laser
Automatic Scan and Analyze	
The preferred method to acquire measured coordinates	
Overview and Requirements	Automatic analysis of measured coordinates
Load Flatbed Scanner Calibration File	Load reference file used by scanner to create initial scan grid
Create Calibration Grid	Compare known coordinates to actual marked coordinates
Automatic Scan and Analyze	Place marked grid on scanner
Accuracy Check	Repeat until calibration has SDev < 0.05
Analysis of Grid Measurement File Supplied by User	
Correction tables created based on analysis of ideal vs. measured coordinate sets	
Create Calibration Grid	Compare known coordinates to actual marked coordinates
Mark Grid	Mark grid on black coated surface

Grid Analysis by External System	Camera Vision or Metrology System

8.9.1 Collect box/cross grid data (quick method for "good-enough" accuracy)

For 3-Axis applications that only require basic accuracy ('it looks straight to me!"). Mark field size square and horizontal and vertical line and measure actual v/s ideal and feed in Correction Table editor. A simple correction can be achieved by doing the following:

1. **Adjust Correction Table**

An easy calibration method if your system does not require the greatest accuracy. Both adjustment and coarse calibration can be achieved through the Adjust correction table menu:

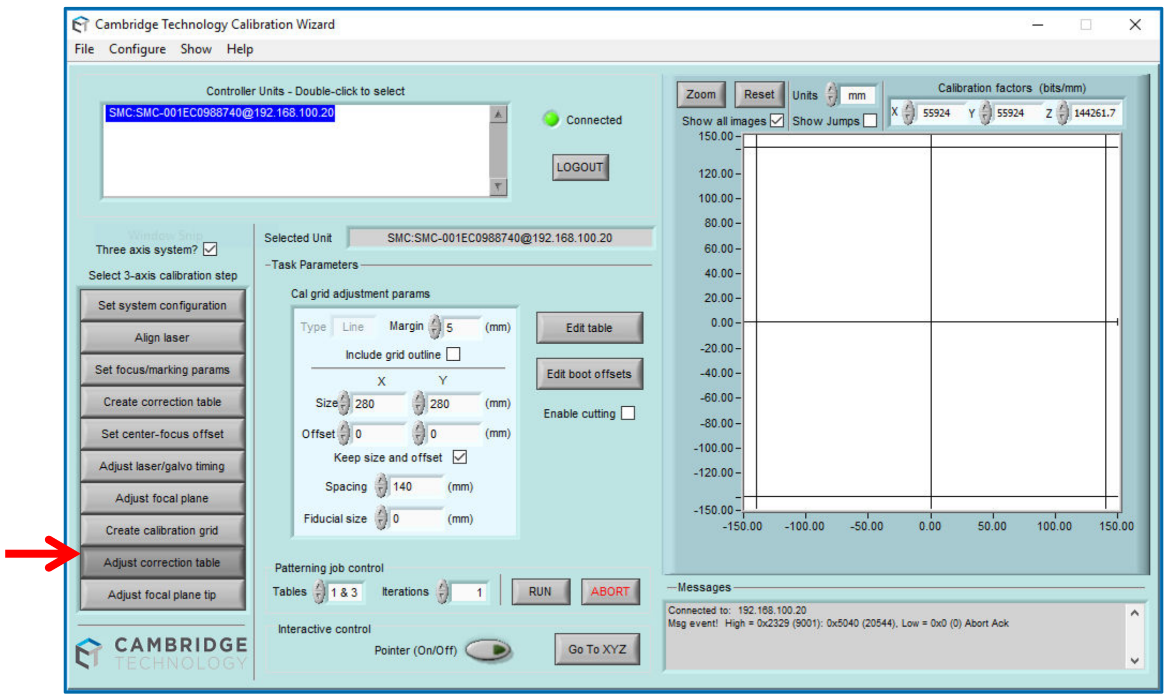


Figure 97 - Adjust Correction Table

Set marking size based on available marking field for e.g. 300x300, 500x500, etc. or set Spacing to be half of the field size. Margin is the extra line outside from the square to see nice cross-section of two lines.

⚠ CAUTION

Your next Action will fire the laser! Use Caution to avoid damage or injury!

2. Mark Grid

Once all settings are done, press “Run” to mark grid. CTI recommends using high-contrast cardboard paper such as Bindakote paper or black anodized aluminum plate to get better marking contrast.

3. Measure Data and Enter

Click “Edit Table” button to open the Correction Table Editor. Then select the Measure→Collect Box/Cross grid data menu option as shown below.

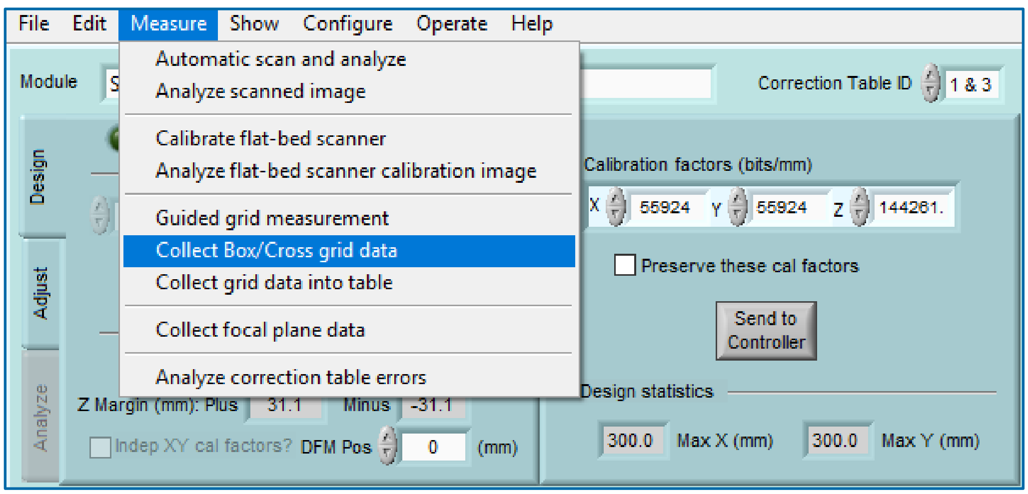


Figure 98 - Collect Box/Cross grid data

Now measure relevant dimensions on the marked pattern and enter them into the relevant locations in the diagram below.

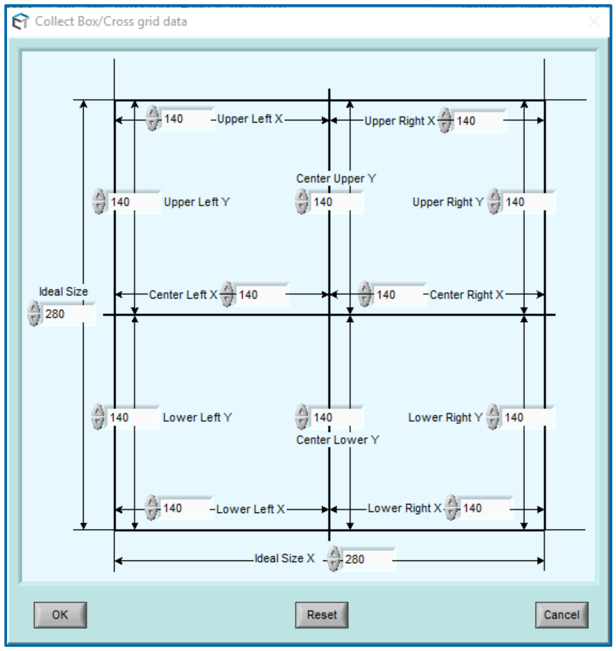


Figure 99 - Box/Cross data

Note: Do not change Ideal Size.

Press “OK” to save changes in correction table and it will prompt to save measurement data. Click “OK” in the message window shown in the following figure to save entered measurement data.

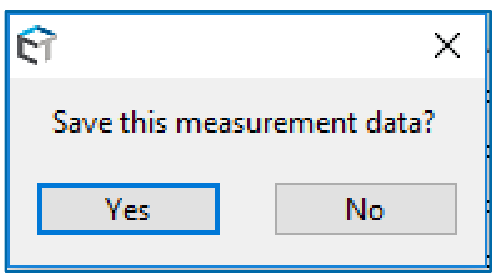


Figure 100 - Save Data

Exit Correction Table Editor and accept all changes in Correction Table.

4. **Accuracy check**

Measure the square dimension and check its accuracy

5. Repeat steps

Measure grid and check its accuracy. Repeat steps 2 – 4 until you reach the desired accuracy

8.9.2 Guided grid measurement (useful for larger than 300x300mm)

This correction method is suitable for calibrating any scan field size, but is most useful for fields larger than 300mm x 300mm. The software uses the information in the current correction table to position a guide laser on the points of a user-defined grid. Use on-screen controls to adjust the laser beam onto an accurate position (referring to a grid paper or characterization plate (for fields of size <300mm). This method's accuracy is limited by the guide laser's spot size and the targets used. In addition, it can involve more effort than the other calibration methods.

This method is somewhat tedious as it is necessary to manually visit many grid points. The higher the number of points visited, the greater the accuracy and longer time to measure. Also, this method does not require actual laser to mark the grid because if actual laser is available to mark you should use a previous method or another better method of calibration.

4. Grid setup

Set Grid paper or Characterization plate (available at CT to purchase) on the marking field as shown below. Enable the pointer laser and try to align grid paper or plate as straight as possible.

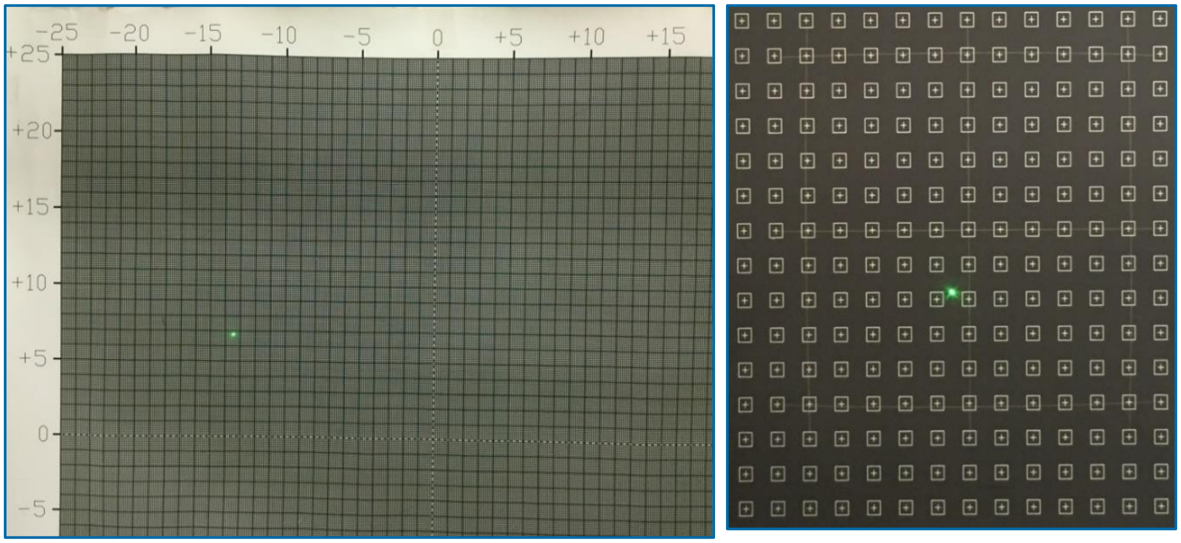


Figure 101 - Grid Paper or Characterization Plate

5. **Guided Grid Measurement**

Click "Edit Table" button to open the Correction Table Editor. Then select the Measure→Guided grid measurement menu option as shown below.

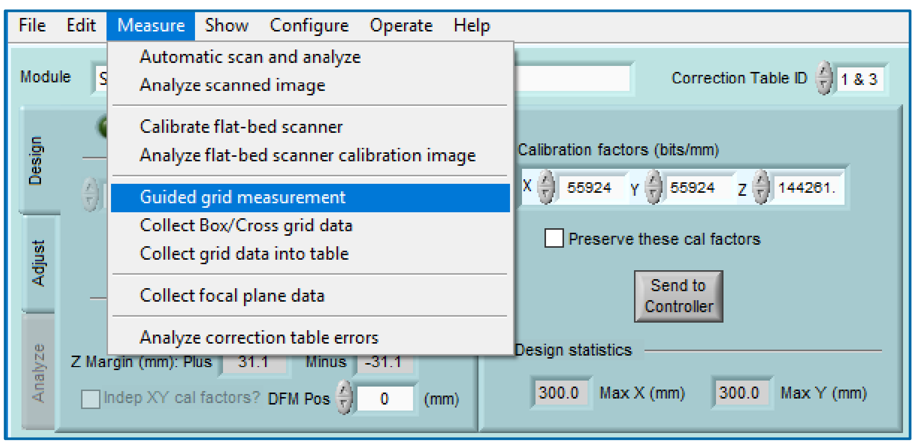


Figure 102 - Guided grid measurement

After you select the Guided grid measurement menu option, the Guided Grid measurement window pops up as shown below:

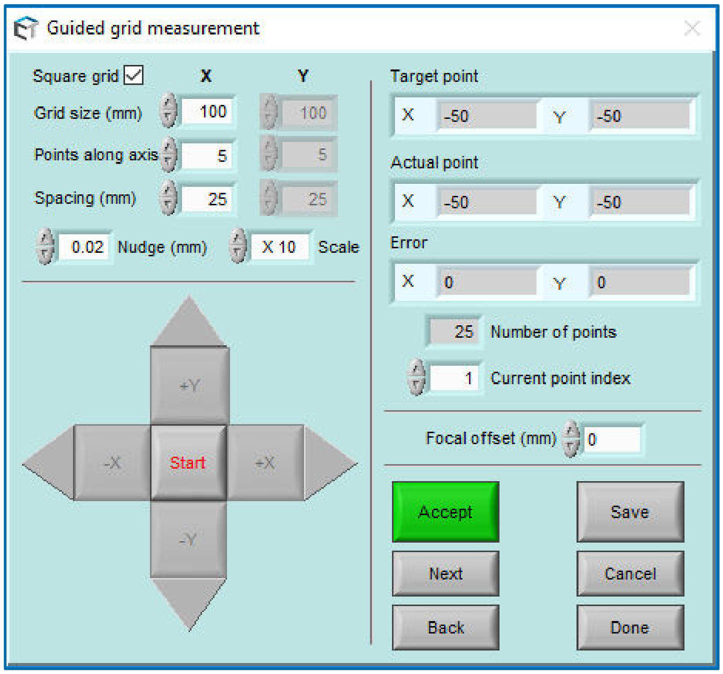


Figure 103 - Guided grid measurement window

Use the Focal offset control to focus your guide laser on the target. This is required to compensate for the difference in wavelength from the main laser. This adjustment will NOT affect the Z offset value already set. See Chapter 2, Principles of Operation.

Define the grid you want to use through the Grid size, Points along axis, and Spacing controls (note that they are interrelated). Define the "nudge" size and scale, and then click the "Start" button in the middle of the arrows.

The software moves the guide laser to the first point of the grid. Use the arrows to "nudge" it to the required position on the target. Change nudge size and scale as needed.

Once in position, click the "Accept" button to add this correction to the table in the computer's memory and move the laser to the next point in the grid.

Use the "Next" and "Back" buttons to move between points on the grid without affecting the correction value in memory.

Use the "Save" button to save a copy of the updated table from the computer's memory to a "pset" file. Refer to the next section for information about "pset" files and their use for generating a correction table.

Use the “Done” button to close the tool window and load the corrections into the Correction Table editor tool.

Note: Use a 3x3-point grid for the first iteration to eliminate most of the errors so that the positional accuracy of the software for the next iteration will be much improved.

8.9.3 Automatic scan and analyze (limited field 300x300mm)

1. **Overview and requirement**

The preferred method to acquire measured coordinates is the automatic analysis of a scanned image. This correction method is suitable for calibrating scan fields up to 300mm x 300mm. In this method, Novanta's Scanner Based Metrology uses standard document scanning equipment coupled with advanced vision processing algorithms to create a good correction table with one or two passes of imaging, measurement, and analysis.

This system electronically captures a large array of fiducial images (produced by a laser system on a substrate) into a TIFF pixel-based image file. The image file is then methodically analyzed in sub-regions, using vision processing software at each "ideal" fiducial location to produce an X-Y offset of the fiducial relative to the "ideal" position. These offsets are measured in pixel units but are easily converted into English or Metric units based on the scanning resolution of the equipment being used.

NOTE: The Calibration Wizard currently supports four types of flat-bed scanners:

Canon Canoscan 9000F

Plustek OpticPro A320

Flat-bed scanner support in the Calibration Wizard is based on National Instruments vision recognition libraries and the user will need to purchase a NI Vision Development Module Run-Time License for "Deployment" level Software Use from National Instruments.

2. **Load flatbed scanner correction file**

Loading the Flatbed Scanner Calibration file is optional; it is a reference file that a flatbed scanner uses while correcting grid marking for better calibration accuracy. For information about how to create a flatbed characterization grid, **see Appendix B: Flatbed Scanner Characterization.**

Click "Edit table" to go in Correction table Editor. And Load flatbed calibration file from File→ Load → Flatbed scanner calibration Data; a green LED indicating "Using flatbed scanner calibration data" comes ON as shown below":

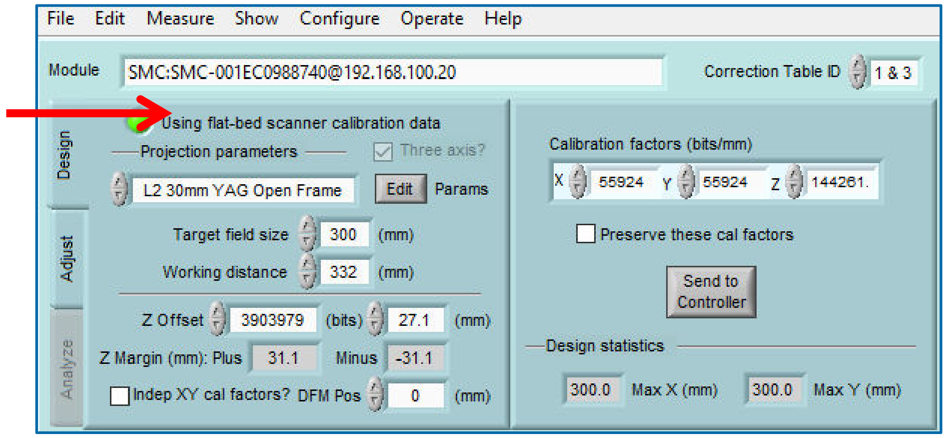


Figure 104 - Scanner correction file

Exit Correction Table Editor by File→Quit then press "OK." and accept all changes in Correction Table.

3. **Create Calibration Grid**

Adjusting the correction table requires comparison of a known pattern's coordinates with measurements of actual coordinates on a marked piece. The Create calibration grid menu provides parameters to define a grid pattern as shown in Figure 105 - Marking grid setup (on the next page).

The Create calibration grid menu provides parameters to define a grid pattern. Five grid types are available: 1.) Box and Cross, 2). Line, 3.) Box, 4.) Dot, 5.) Circle and 6.) Cross. The preferred grid type is Line since it is less sensitive to improper laser/galvo timing settings, but for this example, we chose Box and Cross since it contains more edge information potentially yielding more accurate measurement data.

For more detail on various Grid Types, See **Calibration Grid Artifact**.

The software attempts to use the full field size available, modifying the grid based on the Size, Offset, Spacing and Fiducial Size values. The software might display windows that inform you on required changes, as a Fiducial must always be positioned at the center of the field.

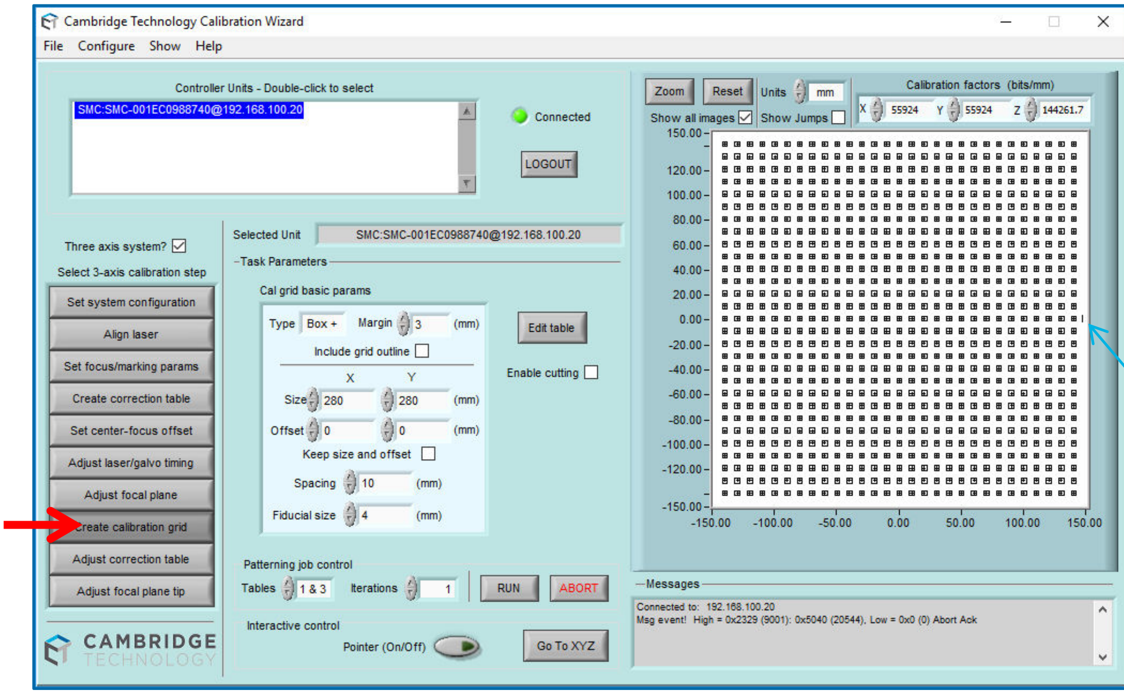


Figure 105 - Marking grid setup

4. **Mark Grid**

Once all settings are done, press "Run" to mark grid. CTI recommends using high-contrast cardboard paper such as Bindakote paper or black anodized aluminum plate to get better marking contrast.

> ⚠ **CAUTION**
>
> **Your next Action will fire the laser! Use Caution to avoid damage or injury!**

The marked grid will look like the figure below. It clearly shows distortions in the marking pattern

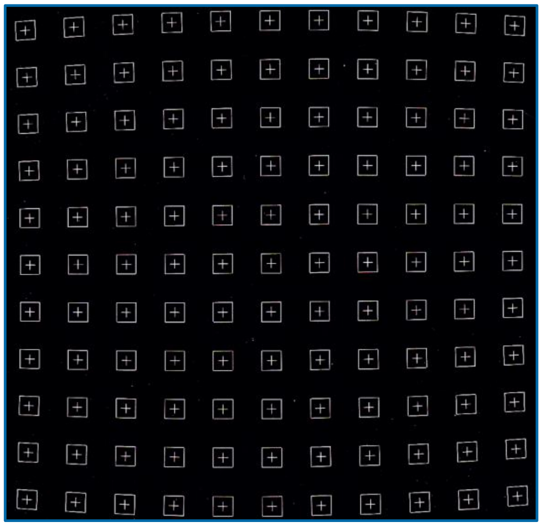


Figure 106 - Marked Grid on Black Paper

5. **Automatic Scan and Analyze**

Place marked grid in flatbed scanner with correct orientation and press “Edit table” go to “Correction Table Editor.”

Press “Automatic Scan and Analyze” to scan marked grid and analyze as shown below:

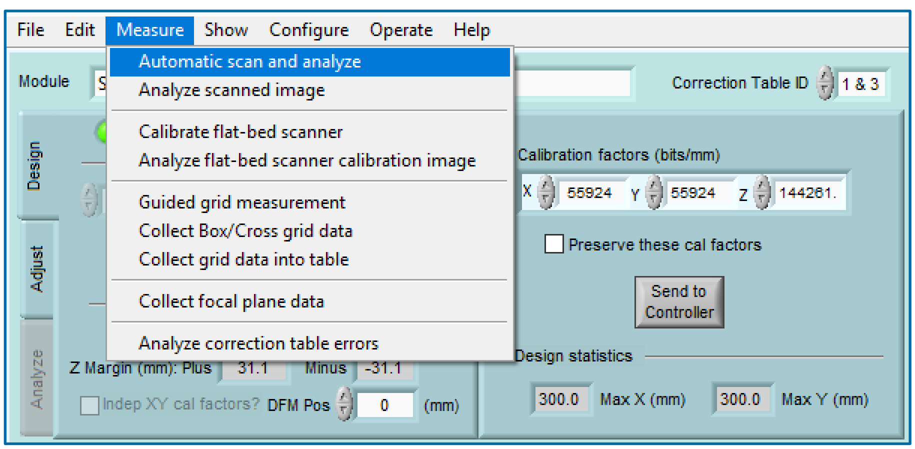


Figure 107 - Automatic scan and analyze

Enter name of file (File name usually is an iteration of marking grid) as shown below and save the file on the computer.

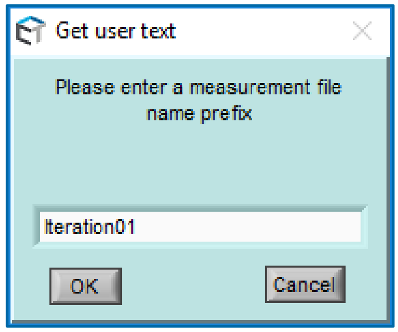


Figure 108 - Get user data

Select the Scanner size and define the orientation of the scanned image on the flatbed document scanner.

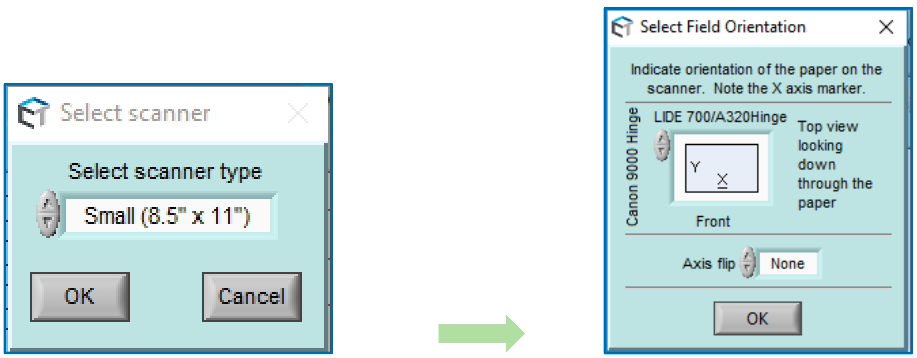


Figure 109 - Select Scanner size and field orientation

Select Scanner type.

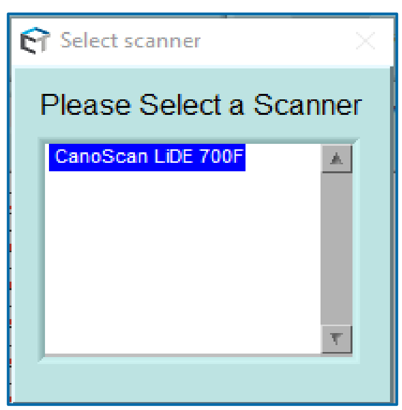


Figure 110 - Select scanner type

An activity bar shows that the scanner is scanning the image; next, it shows the analyzing window as shown in the following figure.

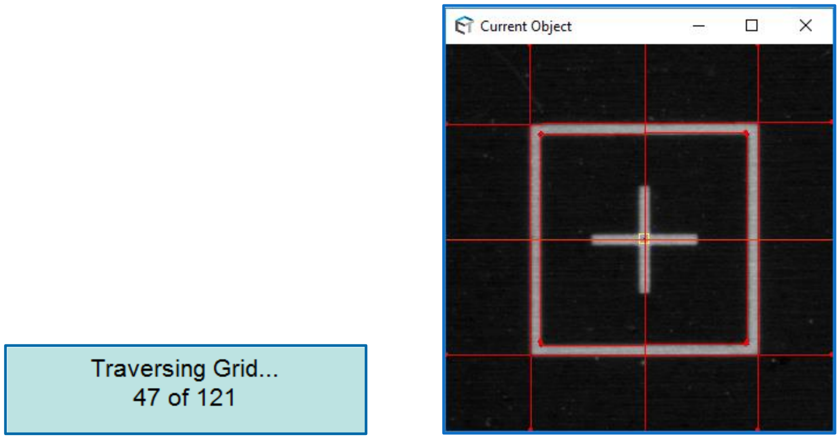


Figure 111 - Grid Scanning

After completing analysis, a “pset” file is created from the scanned image and saved to the location where it has been selected previously.

Once a set of measured coordinates is available for each of the design points, the differences are analyzed using least-squares regression techniques to develop coefficients for mathematical models of the system errors.

In addition, Calibration factors are calculated automatically based on the deviation of the measured overall dimension from the designed one.

6. **Accuracy check**

It is recommended to have a SDev (Std Deviation) value less than 0.05 in measurement Data in Correction table Editor. Please check SDev after each iteration until it is less than 0.05.

7. **Repeat Steps 5 to 7**

If the SDev value is larger than 0.05 then exit the Correction Table Editor, accepting all changes in table.Repeat steps 6 and 7 until Sdev value is less than 0.05.

8.9.4 Analysis of a grid measurement file provided by user

Correction tables are created based on the analysis of the ideal vs. measured coordinate sets. This analysis is done by the software but requires different actions depending on the method you chose.

1. Create Calibration Grid

Adjusting the correction table requires comparison of a known pattern's coordinates with measurements of actual coordinates on a marked piece.

The Create calibration grid menu provides parameters to define a grid pattern. Five grid types are available: 1.) Box and Cross, 2). Line, 3.) Box, 4.) Dot, 5.) Circle and 6.) Cross. The preferred grid type is Line since it is less sensitive to improper laser/galvo timing settings, but for this example, we chose Box and Cross since it contains more edge information potentially yielding more accurate measurement data.

For more detail on different Grid types, see Error! Reference source not found.Calibration Grid Artifact

The software attempts to use the full field size available, modifying the grid based on the Size, Offset, Spacing and Fiducial Size values. The software might display windows that inform you on required changes, as a Fiducial must always be positioned at the center of the field.

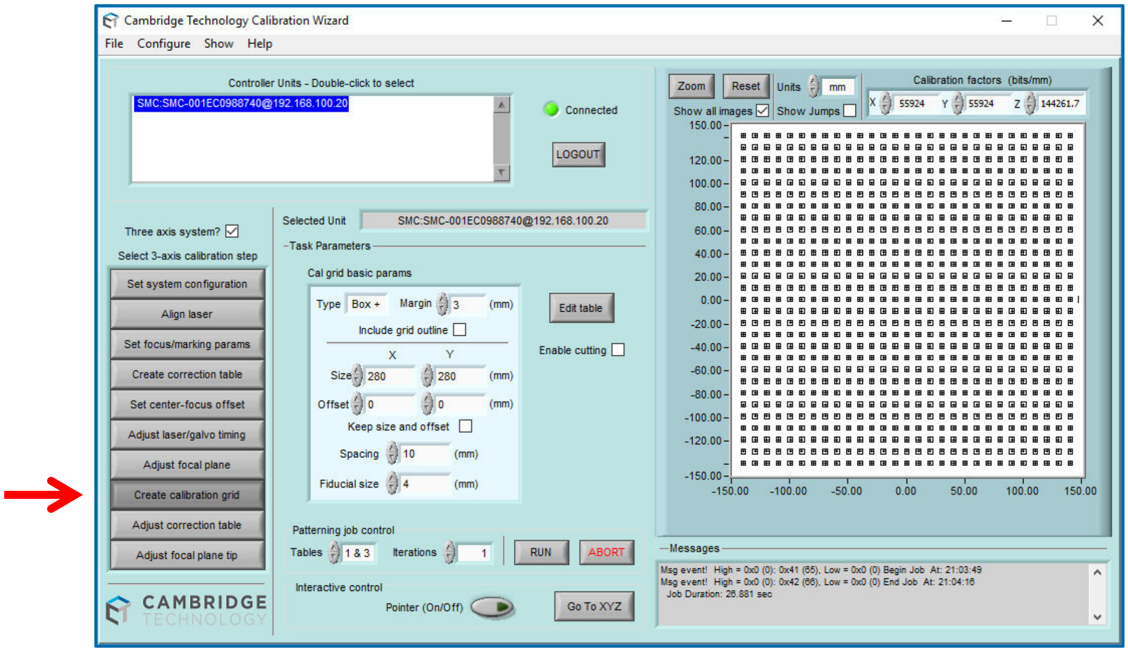


Figure 112 - Marking Grid Setup

2. **Mark Grid**

Once all settings are done, press "Run" to mark the grid. CTI recommends using high-contrast cardboard paper such as Binadkote paper or black anodized aluminum plate to get better marking contrast.

⚠ CAUTION

Your next Action will fire the laser! Use Caution to avoid damage or injury!

The marked grid will look like the figure below. It clearly shows distortions in the marking pattern

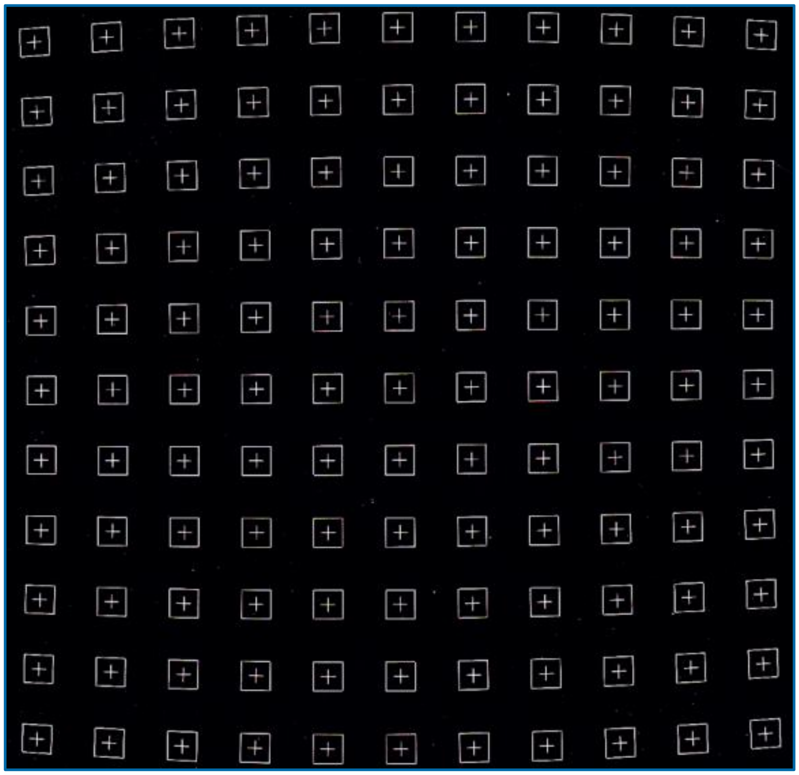


Figure 113 - Marked grid on a back paper

3. Grid Analysis by External system

Use your own method such as XY system with Camera vision or Metrology system to measure the coordinates of the marked pattern points. Then, create an ASCII text file listing ideal and measured coordinates side by side. Alternately, you can list the ideal coordinate together with the position error of the corresponding measured coordinates. Both point-set (pset) formats use multiple lines of text in a file, each line representing a separately measured grid point expressed in standard units of measurement (mm or inches). In each line, values can be separated by Spaces, Tabs, or Semi-colons.

The sample format of data as shown below. Save as a .dat or .pset file.

Note: The column headers should not be in the file.

.dat Format (tab separator)			
X-Ideal	Y-Ideal	X-Actual	Y-Actual
-128.0→	-128.0→	-127.6778→	-128.011
-128.0→	-102.4→	-127.8725→	-102.5328
-128.0→	-76.8→	-127.9894→	-76.9497
-128.0→	-51.2→	-128.0576→	-51.3114
-128.0→	-25.6→	-128.0836→	-25.6478
-128.0→	0.0→	-128.0820→	00.0108
-128.0→	25.6→	-128.0528→	25.6455
-128.0→	51.2→	-127.9810→	51.2527
-128.0→	76.8→	-127.8751→	76.8149
-128.0→	102.4→	-127.7240→	102.3285
-128.0→	128.0→	-127.4911→	127.7597
-102.4→	-128.0→	-102.2990→	-127.8040
-102.4→	-102.4→	-102.4243→	-102.3363
-102.4→	-76.8→	-102.5034→	-76.7753
-102.4→	-51.2→	-102.5497→	-51.1900

.pset Format (semicolon→ separator)			
X-Ideal	Y-Ideal	X-Delta*	Y-Delta*
-30.000000;-30.000000;0.298739;-0.583034			
-25.000000;-30.000000;0.325006;-0.518194			
-20.000000;-30.000000;0.358461;-0.454425			
-15.000000;-30.000000;0.383666;-0.390759			
-10.000000;-30.000000;0.423006;-0.311030			
-5.000000;-30.000000;0.423832;-0.222179			
0.000000;-30.000000;0.457070;-0.151964			
5.000000;-30.000000;0.492804;-0.087841			
10.000000;-30.000000;0.529238;-0.016025			
15.000000;-30.000000;0.535826;0.059729			
20.000000;-30.000000;0.531174;0.149579			
25.000000;-30.000000;0.563012;0.227755			
30.000000;-30.000000;0.623177;0.302295			
30.000000;-25.000000;0.521047;0.373780			

*X-Delta = X-Axtual - X-Ideal; Y-Delta = Y-Actual – Y-Ideal

Figure 114 - User Measurement file sample

4. **Import .pset or .dat file**

Click “Edit Table” to go back to the correction table editor and select File | Import | Measurement data from... | CTI point-set format file as shown below.

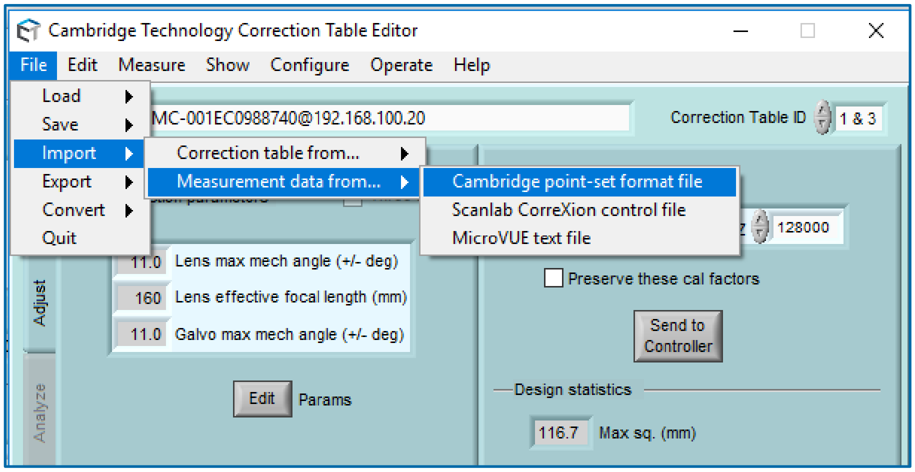


Figure 115 - Path to import file

Click Import for the format (.pset or .dat) of the table you have for import as shown below.

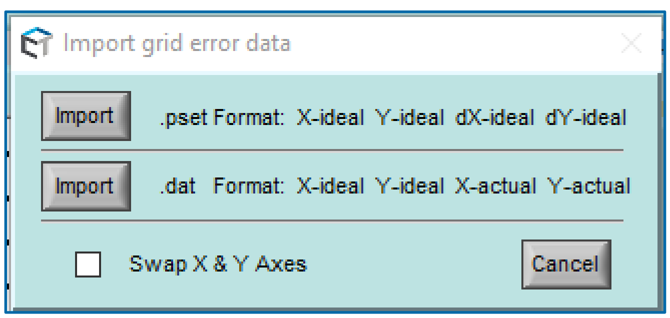


Figure 116 - Select file format

By default, for most situations the editor DOES NOT include rotation or offset corrections derived from the measurement data in the correction table. This is because these errors are often due to fixturing non-repeatability between the imaging system and the measurement system. This behavior can be overridden using a switch on the editor:

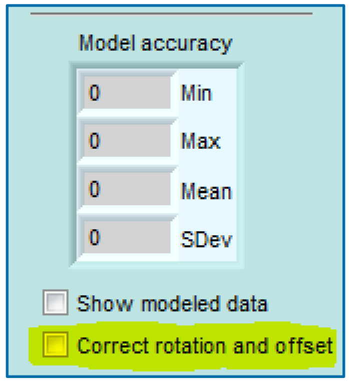


Figure 117 - Enabling Rotation and Offset Correction

Calibration factors are recalculated automatically based on the deviation of the measured overall dimension from the designed grid. If the correction table entries would result in galvo command values that exceed the maximum range possible, then a warning is presented and a choice given to accept new calibration factors and a corresponding adjustment of the table data. If the measurement data results in a correction table that does not fully utilize the dynamic range of the galvos (> 5% loss of potential range), then a warning is presented and a choice given to accept new calibration factors and a corresponding adjustment of the table data.

Measurement data statistics represent the errors in the actual raw data with offset and rotation removed. Model accuracy statistics represent how well the mathematical models are predicting the actual measurements (i.e., the difference between the actual measurements and the modeled measurements at each location). Min and Max represent the worst-case errors in the field; Mean is the average error, and SDev is the standard deviation

5. **Accuracy check**

It is recommended to have a SDev (Std Deviation) value less than 0.05 in measurement Data in Correction Table Editor. Please check SDev after each iteration.

6. **Repeat Steps 2 to 5**

If the SDev value is larger than 0.05, exit the Correction Table Editor, accepting all changes in table. Repeat steps 2 to 5 until Sdev value is less than 0.05

9 SAVE CALIBRATION FILE TO CONTROLLER

Once measurement is completed and gives good accuracy. Press "Edit Table" in "Adjust Correction Table" to go to "Correction Table Editor".

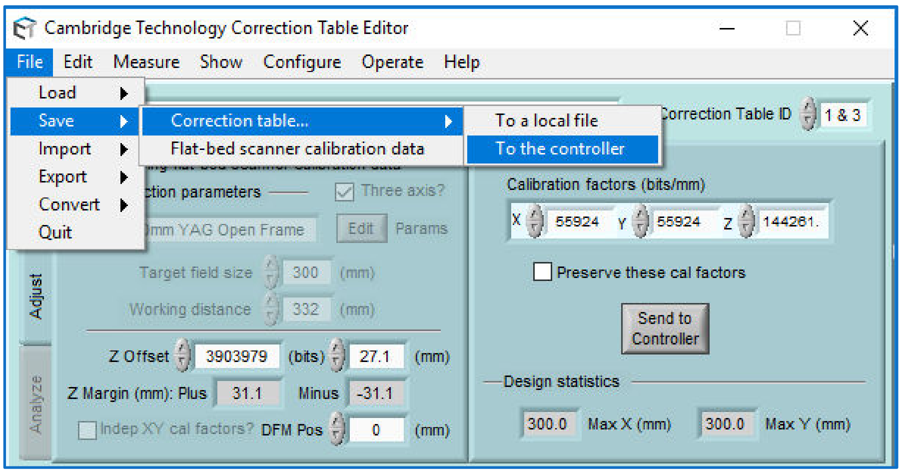


Figure 118 - Saving correction file

It will also prompt to save the calibration file to local drive; press “Yes” to save on local drive. Provide the calibration file name in the box as shown below (name is user-defined and can have only alphanumeric characters, underscore (_) and dash line (-)).

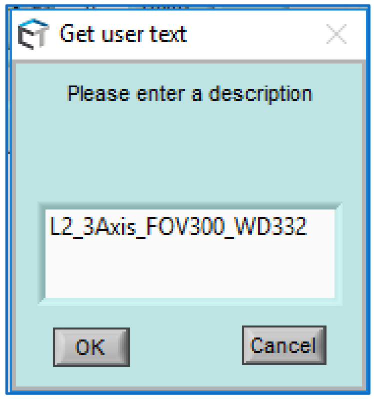


Figure 119 - File name

File revision is an optional. Leave blank and press “OK”.

CalWizard asks permission to make latest Calibration file active to Table 1 and Table 3 as shown below. Press "OK" both times.

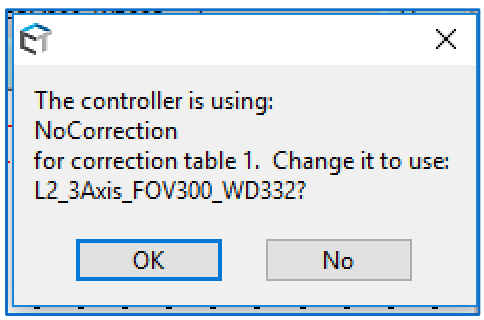


Figure 120 - Activate new correction file

9.1 READY TO USE

SMC Controller is ready to use with new correction file.

10 APPENDIX A- OPTIMIZING LASER/GALVO TIMING

10.1 ADJUST LASER/GALVO TIMING

Now that the laser is focused, optimize laser and scanner delays under Adjust laser/galvo timing. Do not skip this step, since low-quality marking of the grid might cause the ensuing measurement and analysis to fail.

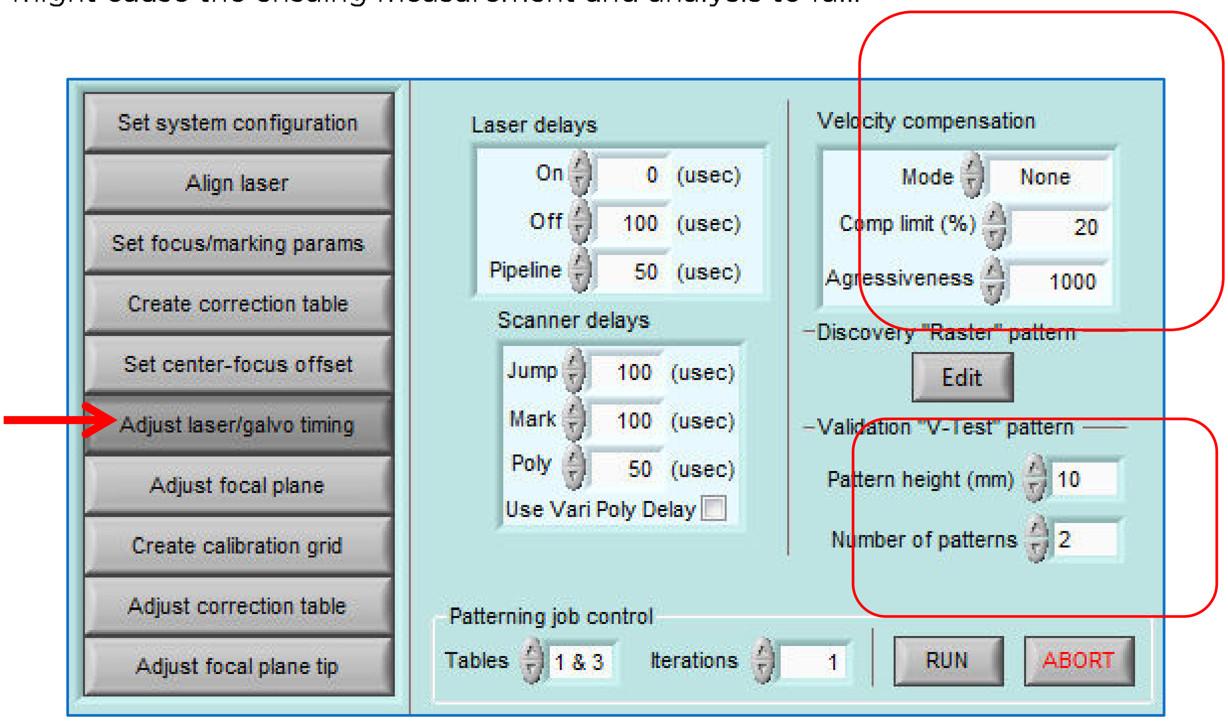


Figure 121 - Set Laser/Galvo Timing View

Different lasers require different settings for the Pipeline delay, Laser On delay, and Laser Off delay, while application considerations may require different values for the Mark, Jump and Polygon delays (referred to as "Application Delays").

Many of the delays are interdependent, so changing one may affect another, resulting in a long trial-and-error process until you find the values you need. Novanta has developed a process to guide you through correct, streamlined set-up of the various delays for your specific laser and application needs.

The process starts with a coarse adjustment to get the parameters close to the required values, followed by a much finer adjustment to optimize those values. For the coarse adjustments, use a mark size that can be seen easily and a speed 30%-50% higher than you intend to use for the application. For the finer adjustments, the pattern size should be similar to your job, while the speed is adjusted as needed.

The Laser On and laser Off delays are better set with a higher speed than you intend to use for the application, because they may no longer be valid when the speed is increased. However, laser timing will improve because the speed is decreased, ensuring better accuracy in turning the laser on and off.

The same is not true for the Application delays. As you mark faster, you may need to increase the application delays to maintain the quality of the mark, while as you slow down you might create excessive delays that will either burn-in or waste time idling at some points. For that reason, Laser delays are set first at a higher speed, and then the Application delays are set at the intended operational speed.

10.2 SETTING LASER DELAYS

To set the Laser delays, a Discovery “Raster” pattern is used. An array of patterns is defined with Pipeline delay kept fixed per column and increasing between columns, and with Laser Off Delay kept fixed per row and increasing between rows:

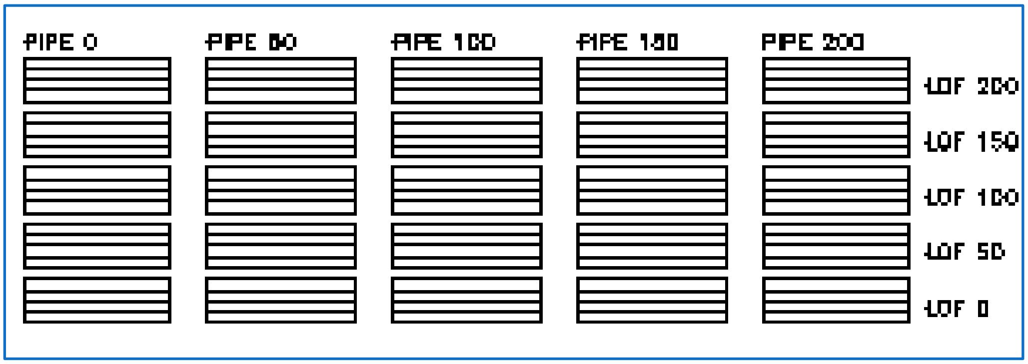


Figure 122 - Discovery “Raster” Pattern

10.2.1 Set Laser Delays

a. Set Laser On delay to 0.
b. Set Jump and Mark delays to a large value (≥1,000).
c. Set Velocity Compensation mode to “None” (even if you intend to use it!).
d. Click on the “Edit” button to set up a Discovery “Raster” pattern.

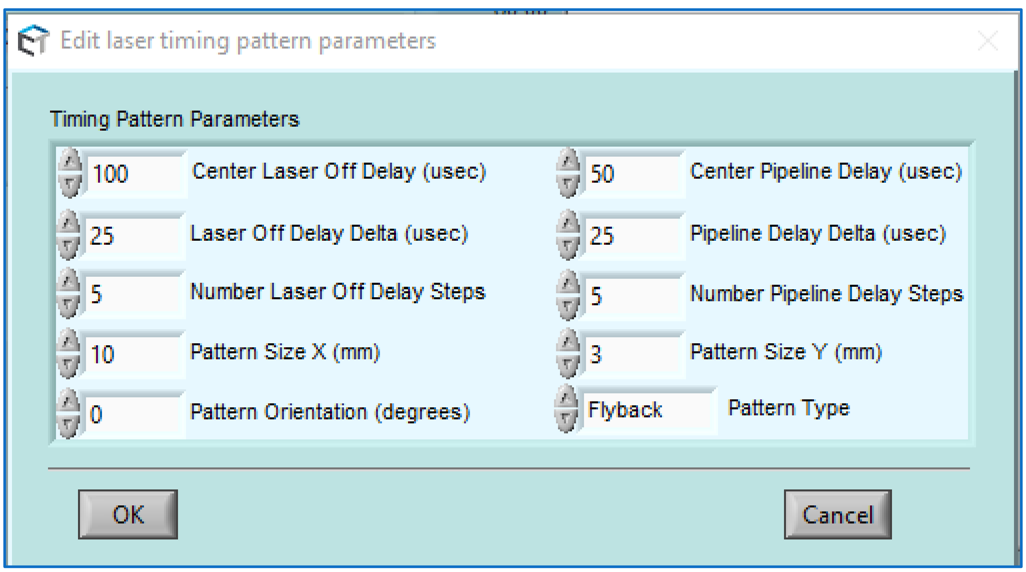


Figure 123 - Discovery “Raster” Pattern Setup

10.2.2 Define the array parameters

- Center value for each delay (use 700 for 3-Axis heads and 100 for 2-Axis heads)
- Delta value between columns / rows. (Start with 50 and adjust as needed.)
- Number of columns / rows
- Width and length of each pattern in the array
- Angular orientation of the array
- Set the pattern type to fly-back for this first mark

CAUTION

Your next Action will fire the laser! Use Caution to avoid damage or injury!

10.2.3 Run the pattern.

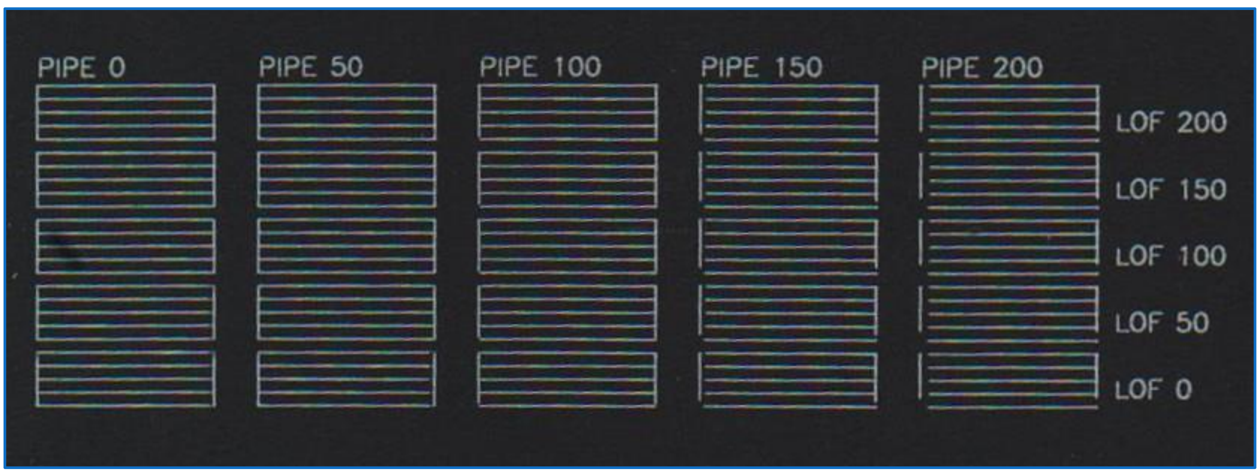


Figure 124 - Marked Pattern

1. Once the pattern is marked, compare the columns, left to right, looking at the left edge to find the best Pipeline Delay value (i.e., the one where the horizontal lines meet the left vertical line but are not over-burnt).

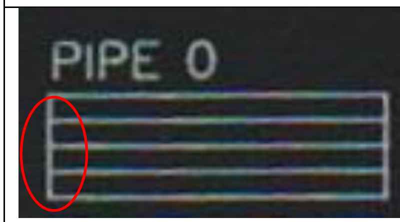
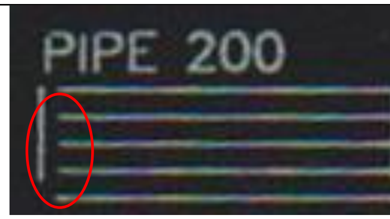
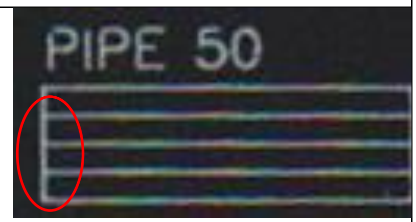
Over-burned – Too short	Not meeting – Too long	Just right
		

Figure 125 - Pipeline Delay

2. In the best Pipeline Delay column, examine from bottom to top the right edge looking where the corner is well connected and not over-burned. The best row identifies the best Laser Off Delay.

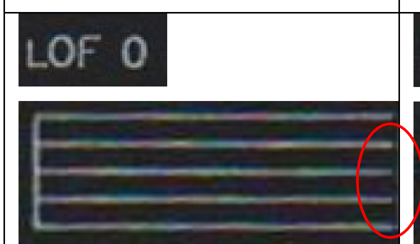
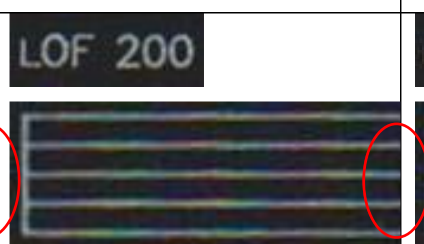
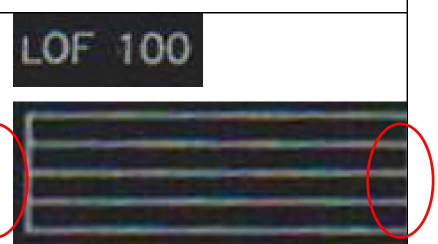
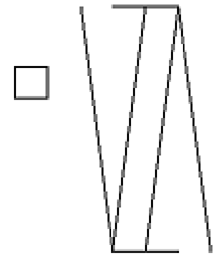
Not meeting – Too short	Over-burned – Too long	Just right
		

Figure 126 - Laser OFF delay

3. In the above example, the best values will be Pipeline Delay = 50µs and Laser Off Delay = 100µs. Set these values as your new center values, reduce the delta to get better resolution, and mark again. If you intend to use Velocity Compensation, change its mode to the desired one now and repeat the process several times to achieve ideal settings.

10.3 SETTING APPLICATION DELAYS

To set the Application delays, use the "V-Test" pattern on the right. The V-Test pattern is a series of marks and jumps that is set up to highlight the effect of the various delays. It contains a small square, two "V" shapes (one pointing down and the other pointing up), and two lines connecting the tip of one "V" with the middle of the other at both the top and bottom. To avoid confusion due to random irregularities, two or three V-Test patterns should be used (as seen in the image below).



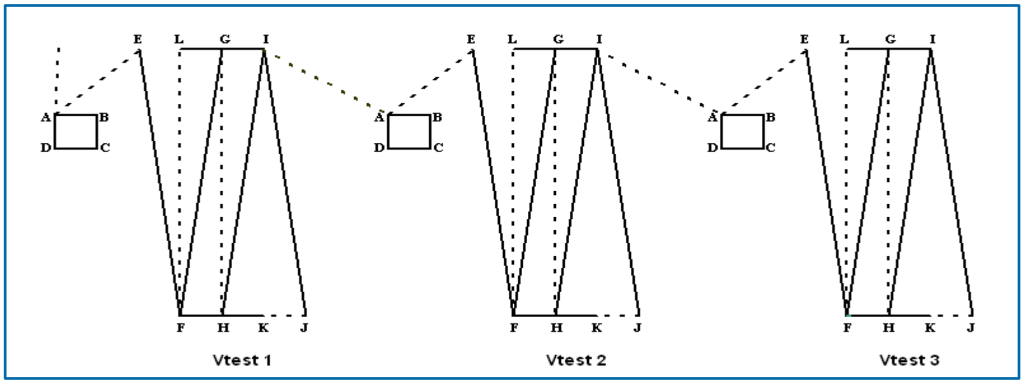


Figure 127 - V-Test 3-Pattern Array

To use the process effectively, you need to know the path the laser follows for each jump and mark. For that, we label each point where a delay might be observed with a letter, and number each of the V-Test patterns in the array. We depict a jump as a dashed line and a mark as a solid line.

In the discussion that follows, segment EF2 refers to the marked vector that is the left side of the first V in the middle (2nd) pattern. Following the same guidelines, square ABCDA1 refers to the start point, path, and end point of the leftmost square (drawn from point A to point B to Point C to point D and Back to Point A, in Vtest1). It may help to print V Test 3 Pattern Array on page 85 and Figure 130 reference in the following few pages.

1. Jump to A1

11. Jump to point A2

21. Jump to point A3

2. Mark square ABCDA1
3. Jump to point E1
4. Mark "V" EFG1
5. Jump to point H1
6. Mark "V" HIJ1
7. Jump to point K1
8. Mark segment KF1
9. Jump to L1,
10. Mark segment LI1
12. Mark square ABCDA2
13. Jump to point E1
14. Mark "V" EFG2
15. Jump to point H2
16. Mark "V" HIJ2
17. Jump to point K2
18. Mark segment KF2
19. Jump to L2,
20. Mark segment LI2
22. Mark square ABCDA3
23. Jump to point E3
24. Mark "V" EFG3
25. Jump to point H3
26. Mark "V" HIJ3
27. Jump to point K3
28. Mark segment KF3
29. Jump to L3,
30. Mark segment LI3

Figure 128 - V-Test Pattern Sequence

Adjust Pattern height and number for the V-Test. (If you want to use the default values, change one and then change it back to the original in order to make the pattern appear on the screen). With the Laser delays set to the results of our previous test, start to adjust the application delays.

CAUTION

Your next Action will fire the laser! Use Caution to avoid damage or injury!

1. Click the "Run" button to mark the pattern.
2. Make coarse adjustments of application delays:

a. Observing the squares ABCDA2 & ABCDA3, look for quality issues in the B, C & D corners.

Figure 129 - Polygon delay defects

b. If you initially set this delay to zero, it is likely to be too short as shown in the image on the left. If the delay is set too short, the three corners will be rounded because the mirrors do not have enough time to reach those points. If the delay is set too long, there will be burned-in spots at three corners because the mirrors dwell too long on these points . The fourth is affected by the Jump delay at the start and the Mark delay at the end and is adjusted next.

c. It is now time to adjust the Mark delay—the delay at the end of a mark sequence before the laser is turned off for a jump. The effects of this delay are easily observed at point J of the V-Test pattern.

Figure 130 - Mark Delay Defects

d. If you initially set this delay to zero, it is likely to be too short as shown in the image on the left. If the Mark delay is too short, the line at the end of the V will be bent in in the direction of the jump that follows; if the Mark delay is too long, the end of the V might be burned-in. With the Laser Off delay set correctly, no noticeable artifact is produced, although the mirrors dwell there for too long a time.

This is not a concern just yet, since it will be properly handled during the fine adjustment stage.

e. Adjust the Mark delay to produce a correctly marked V shape.

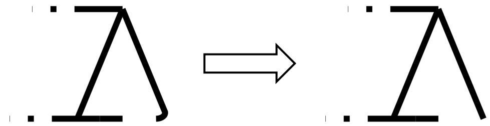


Figure 131 - Mark Delay Adjustment

f. Last, we adjust the Jump delay—the delay at the end of a jump. The effects of this delay are easily observed at point E of the V-Test pattern.

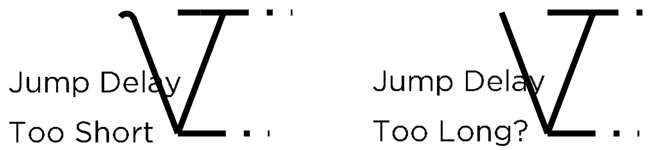


Figure 132 - Jump Delay Defects

g. If you initially set this delay to zero, it is likely to be too short, resulting in the image shown on the left. If the Jump delay is too short, the line at the start of the V will be bent in in the direction of the jump that preceeded it. If the delay is too long, the start of the V might be burned in. However, with the Laser On delay set correctly, no noticeable artifact is produced, although the mirrors dwell there for too long a time. This is not a concern just yet, since it will be correctly handled during the fine adjustment stage.

h. Adjust the Jump delay to produce a correctly marked V shape.

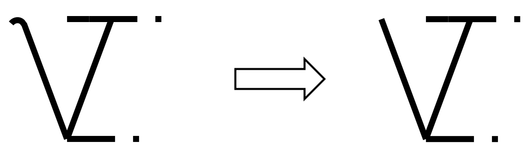


Figure 133 - Jump Delay Adjustment

3. Make fine adjustments of laser delays:
   a. Now that the delays are set to produce a reasonable mark, set them closer to our required parameters.

b. Start by setting the pattern size to a size similar to the job you want to run.
c. Set the speed to be 10%-20% higher than the speed you expect to use for the application, since higher speed will exaggerate deviations you may not have noticed before.
d. Observe points G and H of the pattern, since these are locations where separate marks should touch each other, and will often show small timing issues not noticed in other places.

Figure 134 - Laser Delays Fine Adjustment

e. To adjust, reduce the value of the relevant delay until a defect is visible, then increase it slightly to correct the defect. Do not increase the value too much, since no defect will be noticeable but the mirror will dwell for too long a time, increasing the job execution time for no good reason.
f. Ignore points F and I because they may be affected by the Polygon delay as well as the Mark Delay.

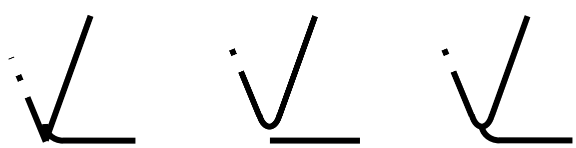


Figure 135 - Polygon Delay and Mark Delay Are Too Short

4. Make fine adjustments of application delays:
   a. Now that the Laser delays are set correctly, optimize the Application delays.

b. Set the speed to what you intend to use for the application. To maintain the mark's quality, Mark delay, Jump delay and Polygon delay may require adjustment when the speed changes. The Laser delays were set at a higher speed, so they will get more precise even as you slow down the speed.
c. Once again, start with the Polygon delay.
d. Set the Mark delay to a value 25% higher than its current value. This ensures that segments KF and LI end at points F and I respectively. since the mirrors have plenty of time to reach the end of those vectors before the next jump.
e. Observe points F and I for the position of the tip of each V, relative to the segment it should touch. Adjust the Polygon delay until the tips of the V's touch those segments and no burn in occurs.-

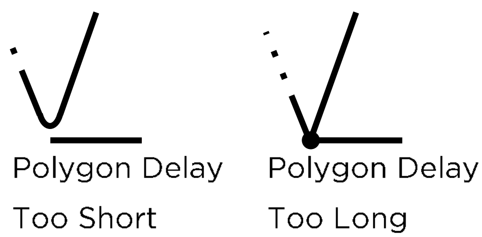


Figure 136 - Polygon Delay Fine Adjustment

f. Next, restore the Mark delay value to the coarse adjustment value (20% less than the current one) and then continue to reduce it until the segment's edge no longer touches the tip of the V. Now, increase it slightly to correct the defect. Do not increase the value too much; no defect is noticeable but the mirror dwells too long, increasing the job execution time for no good reason.

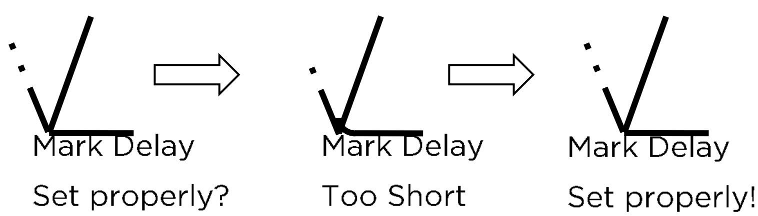


Figure 137 - Mark Delay Fine Adjustment

g. For Jump delay fine adjustments, repeat the above process while observing point H's connection to the middle of the segment. Reduce the Jump delay value until a defect can be seen, and then increase it slightly to correct the defect. Once again, avoid increasing the value too much to prevent the mirror from dwelling for too long, increasing the job execution time for no good reason.

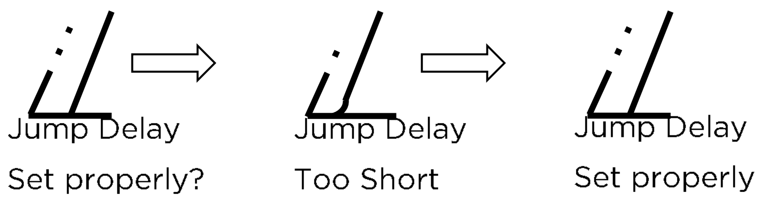


Figure 138 - Jump Delay Fine Adjustment

5. At this point, Laser delays should all be set correctly and Application delays will be right for a given type of job. For applications with very stringent quality requirements, final adjustments should be done with the actual job you want to mark. Keep in mind that some settings are interrelated, so changes to one delay can affect others. If things go wrong, repeat the fine adjustments step to correct them.

11 APPENDIX B- FLATBED SCANNER CHARACTERIZATION

Today's document scanning equipment uses high precision semiconductor process equipment and large area lithography methods that ensure good dimensional tolerances. For applications that require the greatest accuracy, the flatbed document scanner's inaccuracies can be characterized and eliminated from the measurements using the following process: Flatbed Scanner Calibration file is reference file that flatbed scanner will use while correcting marking grid.

NOTE: This process is required only once; if file already exists, then it may be skipped.

11.1 CONNECT TO A SCANNER

Connect Flatbed scanner to a computer. Acquire a Characterization grid from Novanta and place in scanner:

A. D09676-2 – 430mm x 290mm, suitable for 12" x 17" scanners
B. D09676-3 – 310mm x 210mm, suitable for 8.5" x 11" scanners

11.2 CALIBRATE THE SCANNER

Click the "Edit table" button to open the Correction Table Editor. From the editor's menu, select Measure→Calibrate flatbed scanner as shown below.

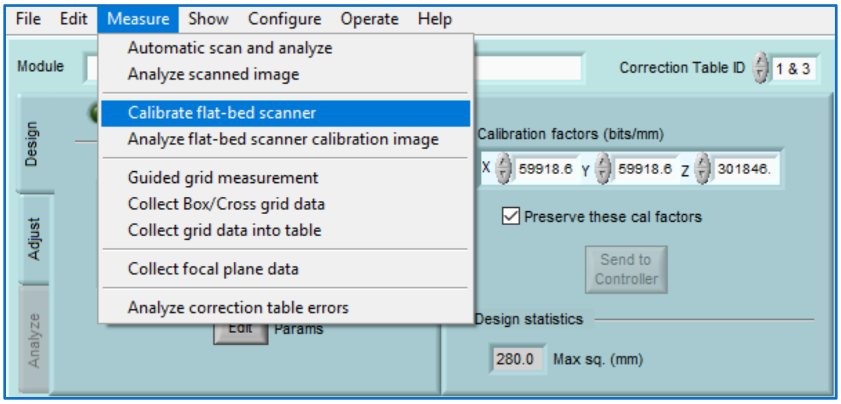


Figure 139 - Calibrate flatbed scanner

11.3 CHOOSE A SCANNER

Select scanner type 8.5”X11” (Canon LiDE 700F or 9000F Mark-II) or 12”X18” (Plustek OpticPro A320 or A320L)

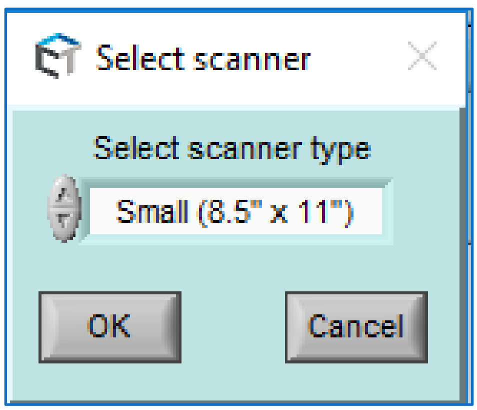


Figure 140 - Scanner size

11.4 SELECT THE FILE NAME

Enter the file name that will be the scanner calibration file for future use and press “OK” and select location in computer to save.

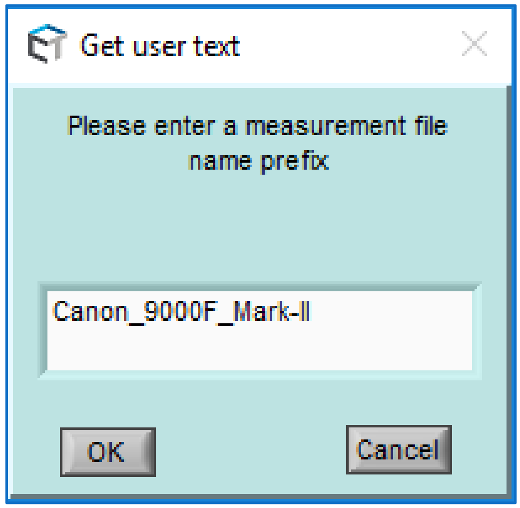


Figure 141 - Flatbed calibration File name

Choose appropriate flatbed scanner as shown below

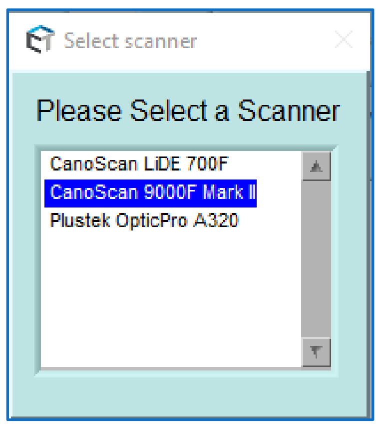


Figure 142 - Flatbed Scanner selection

Select the scanner type and then it will scan grid and show scanning process as below.

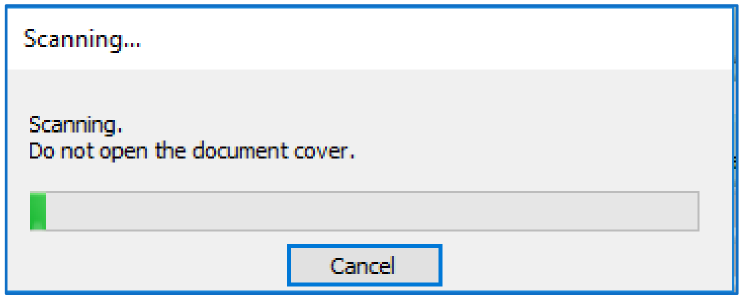


Figure 143 - Scanning

CalWizard will analyze the grid as shown below

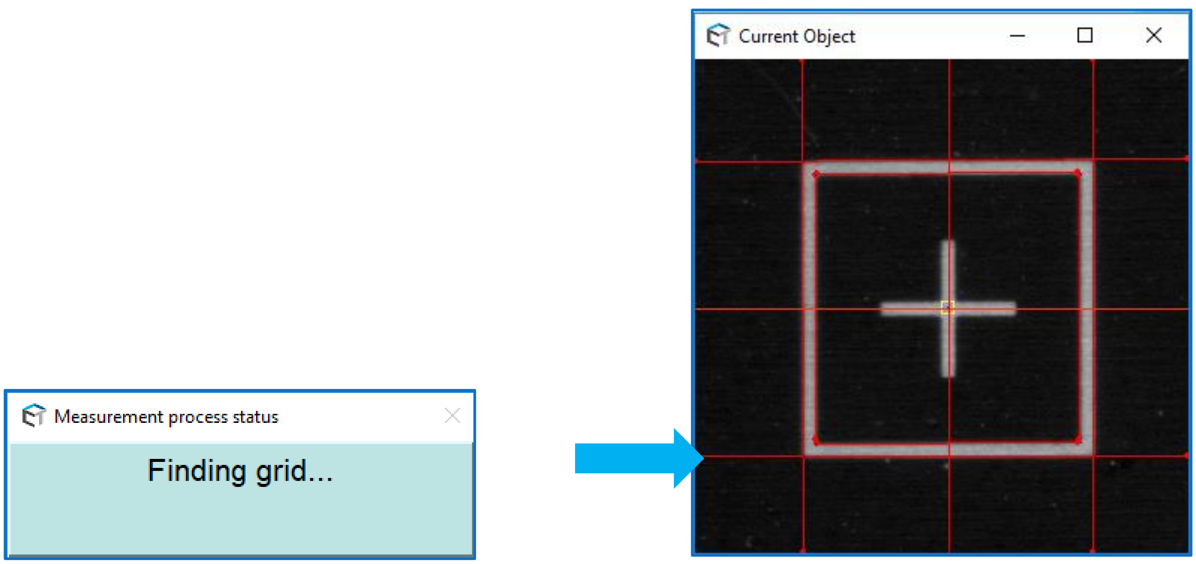


Figure 144 - Analyzing grid

11.5 GRID ANALYSIS

Once the analysis of the grid is done, the Correction table displays the result as shown below.

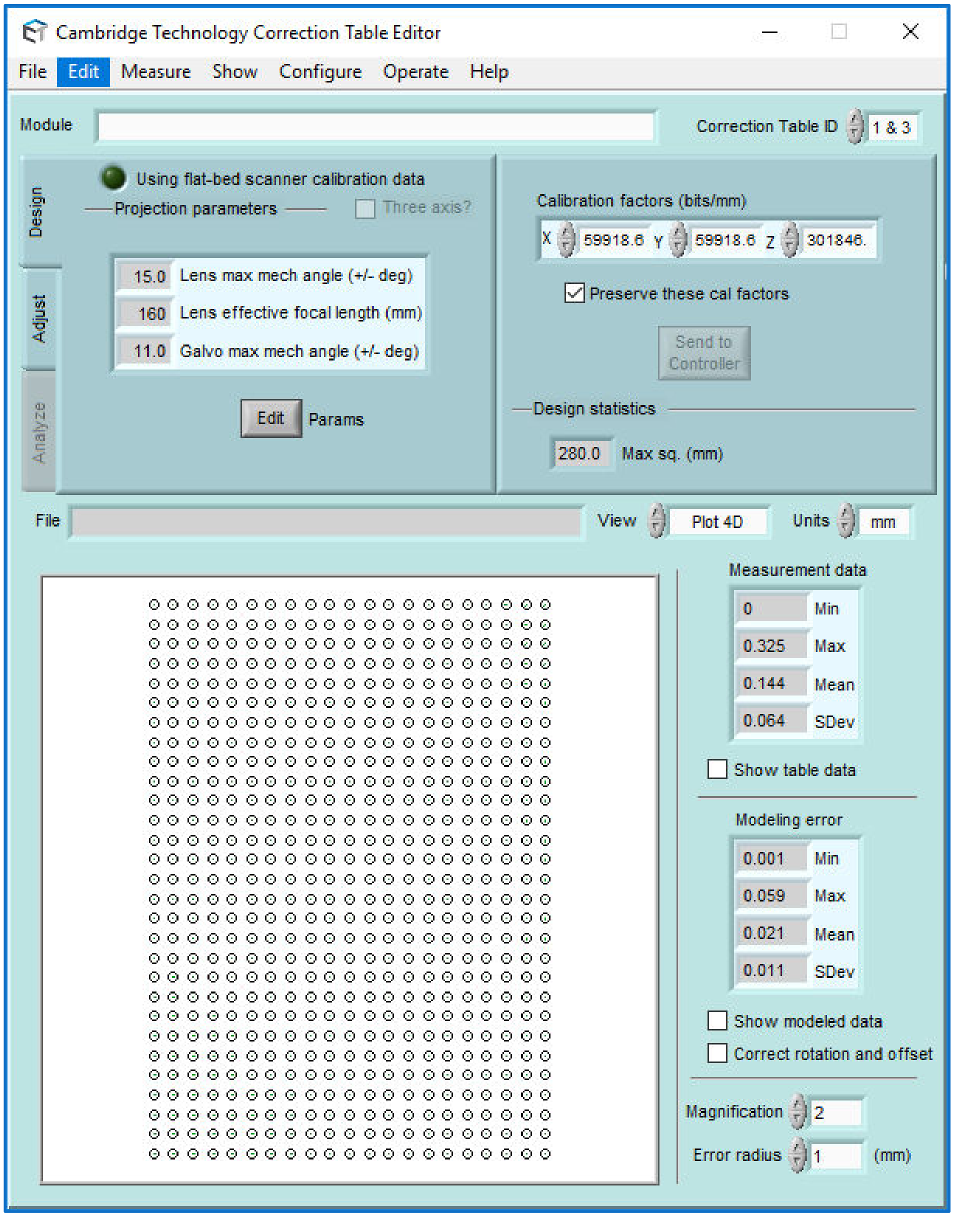


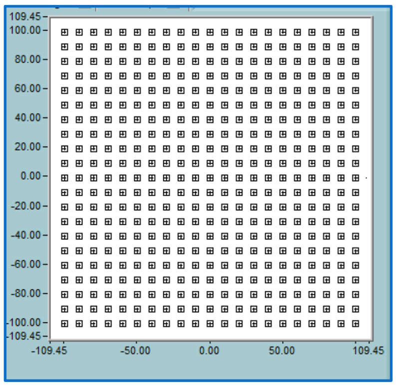
Figure 145 - Analyzed grid

Exit Correction Table Editor without accepting any changes in the field.

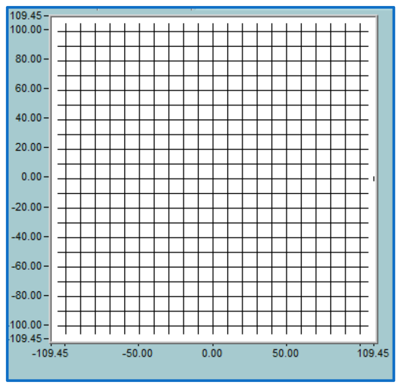
12 APPENDIX C- CALIBRATION GRID ARTIFACT

Adjusting the correction table requires comparison of a known pattern's coordinates with measurements of actual coordinates on a marked surface. The Create calibration grid menu provides parameters to define a grid pattern.

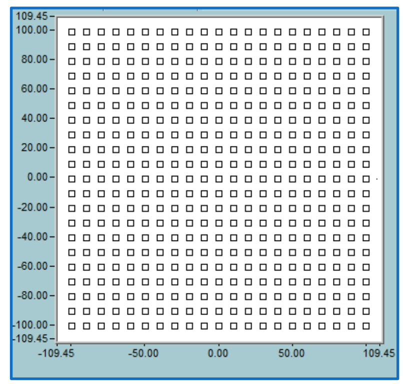
Five grid types are available:



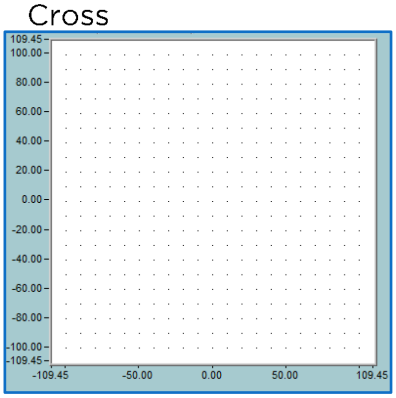
Grid with Box and Cross



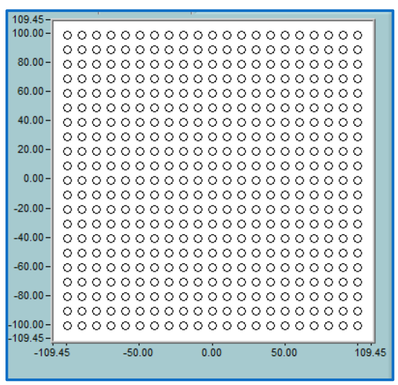
Grid with Lines



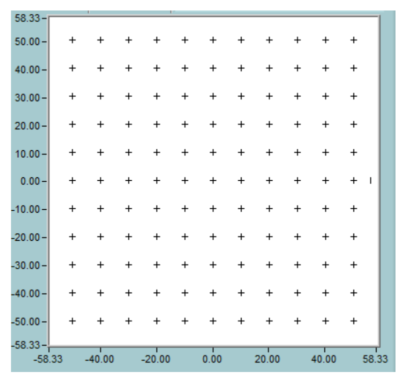
Grid with Box only



Grid with Dots



Grid with Circles



Grid with Cross

Figure 146 - Calibration Grid Types

1. The preferred type is the Line, because it results in clearly identifiable Fiducial (the junctions) and is generally insensitive to incorrect laser timing delays
2. The parameters in this view allow you to define the grid. For best accuracy, the grid size and position should be similar to the field area you intend to utilize. A grid is computed and presented in the editor's viewing area.

NOTE: Only Grid with Box and Cross and Grid with Lines are usable with Automatic Scan and Analyze measurement mode.

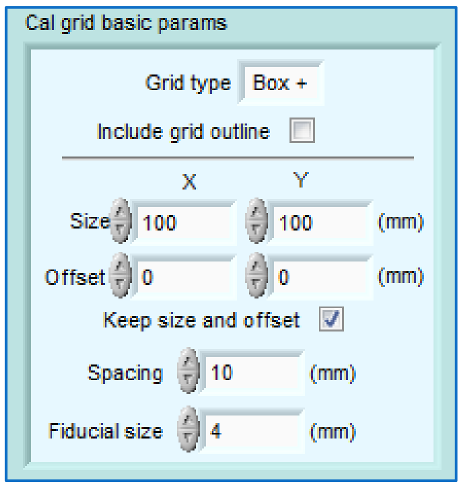


Figure 147 - Calibration Grid Parameters

3. The software attempts to use the full field size available, modifying the grid based on the Size, Offset, Spacing and Fiducial Size values. The software might display windows that inform you on required changes, since a Fiducial must always be positioned at the center of the field.
4. Check the "Include grid outline" box if you wish to mark the field's perimeter using the galvo's maximum command values. Additional registration marks are drawn in the corners of the outline and at the X and Y positive maximum extents. These marks are useful for correct orientation on measurement tools. Note that even without the outline, a dot is marked just outside the grid to identify the positive-X direction.

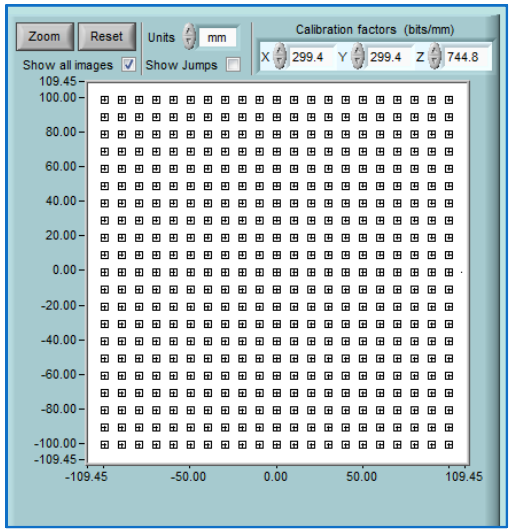


Figure 148 - Calibration Grid Display

5. If grid elements at the edges of the field are incomplete or missing due to the initial distortion, start with a smaller field size and adjust for the full field after achieving a square field.
6. In some situations, it is convenient to cut the media on which the pattern is marked for the measurement step. If your laser is powerful enough, you can do this using the Enable cutting feature of CalWizard.
7. Check the box and define the cut dimensions. Note that a notch is cut at the positive-X direction for easy orientation.

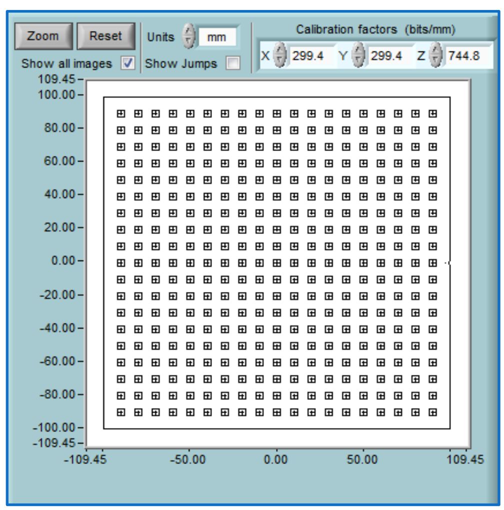


Figure 149 - Check the Box and Define the Cut Dimensions

8. When you are done setting the grid pattern, click the “Run” button to mark it on the target.

Note: Using Bindakote or Chromalux black paper results in good contrast for most laser types.

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