Calibration Wizard

User Manual

Advanced Calibration Solutions for 2x and 3x Scanning Heads

	r Units - Double-click to select			Zoom	Reset	Units		nm						bits/mn		
SMC:SMC-001EC0988740@	192.168.100.20	Connected	5	show all ima	iges 🗹	Shov	v Jump	os 🗌	×Ð	14615	0 Y	146	150	Z 🌔 1	.28000	
		LOGOUT		50.00 -	Ŧ	Ŧ	Ŧ	Ŧ	+	Ŧ	Ŧ	+	Ŧ	Ŧ	Ŧ	
ļ	7			40.00 -	+	+	+	Ŧ	+	+	Ŧ	+	+	+	+	
	Selected Unit SMC:SMC-001EC09887	40@192.168.100.20		30.00 -	+	Ŧ	Ŧ	Ŧ	+	+	+	+	+	+	+	
Three axis system?	-Task Parameters			20.00 -	Ŧ	+	÷	Ŧ	+	+	Ŧ	Ŧ	÷	+	+	
Set system configuration	Cal grid basic params			10.00 -	Ŧ	Ŧ	Ŧ	Ŧ	+	Ŧ	Ŧ	Ŧ	Ŧ	Ŧ	Ŧ	
Set focus/marking params	Type Box + Margin 5 (mm)	Edit table		0.00-	Ŧ	Ŧ	Ŧ	Ŧ	+	Ŧ	Ŧ	+	Ŧ	+	Ŧ	1
Create correction table	Include grid outline			-10.00 -	Ŧ	Ŧ	Ŧ	Ŧ	+	Ŧ	+	+	Ŧ	+	Ŧ	
Set center-focus offset	X Y Size 100 100 (mm)	Enable cutting		-20.00 -	+	+	Ŧ	+	+	+	+	+	+	+	+	
Adjust laser/galvo timing	Offset			-30.00 -	+	+	+	+	+	Ŧ	Ŧ	+	+	+	+	
Create calibration grid	Keep size and offset			-40.00 -	Ŧ	Ŧ	+	Ŧ	+	Ŧ	Ŧ	+	Ŧ	+	Ŧ	
Adjust correction table	Spacing 10 (mm)			-50.00 -	+	+	+	Ŧ	+	+	Ŧ	+	Ŧ	+	+	
	Fiducial size 4 (mm)			-57.40 - -57	.40	-40.00	-	20.00	0	0.00		20.00		40.00	57	ہـ 7.40
	Patterning job control															
	Tables 1 & 3 Iterations 1	RUN ABORT	-	essages -	= 0x232	9 /9001	- 0x504	10 (205	44) 1 00	w = 0x0	(0) Ab	ort Ack				
Msg event! High = 0x2329 (3001): 0x6040 (20544), Low = 0x0 (0) Abort Ack Connected to: 192.188.100.20																

Read carefully before using. Retain for future reference.



ENGINEERED BY CAMBRIDGE TECHNOLOGY



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Table 1 - Revision History

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.

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

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

1 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.

Americas, Asia Pacific

Novanta Headquarters, Bedford, USA Phone: +1-781-266-5700 Email: <u>photonics@novanta.com</u>

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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.

1040-0008 Revision

REVISION	DATE	Changes from previous revision
А	February 12, 2012	First release of this manual.
В	October 16, 2012	Update for V1.2 Changes; Add more information on the calibration process.
С	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.

Table 1 - Revision History

Introduction

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 \rightarrow Load \rightarrow Correction table \rightarrow 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

😭 Cambridge Technology Calib	aration Wizard	- <u>p</u>	×
File Configure Show Help			
Controller SMC:SMC-001EC0988740@1 Three axis system? Select 2-axis calibration step Set system configuration Set focus/marking params Create correction table Set center-focus offset Adjust laser/galvo timing Create calibration grid Adjust correction table	Units - Double-click to select 1922.188.100.20 Selected Unit -Task Parameters Please select a calibration task on the left	Zoom Reset Units Tmm Calibration factors (bits/mm) Show all images Show Jumps Y 300 Y 300 Z 500 50.00- 40.00- 30.00- 20.00- 10.00- 10.00- 10.00- - - - - - - - -	
CAMBRIDGE TECHNOLOGY	Patterning job control Tables () 1 & 3 terations () 1 RUN ABORT Interactive control Pointer (On/Off) () Go To XYZ	-65.54-1 -40.00 -20.00 0.00 20.00 40.00 65.5 -65.54 -40.00 -20.00 0.00 20.00 40.00 65.5 -Messages	3

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.

😭 Status		×	
	Establishing communications Please wait		
😭 Status		×]
	Reading calibration data Please wait		

Figure 9 - Controller Connection Status Windows

3. Finally, the "Connected" indicator turns green.

Controller	Units - Double-click to select	
SMC:SMC-001EC0988740@	Connected	
		LOGOUT
Three axis system?	Selected Unit SMC:	SMC-001EC0988740@192.168.100.20

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.

😭 Cambridge Technology Calibration Wizard					
File	Configure	Show	Help		
Lo	Load calibration configuration				
Sa	Save calibration configuration Double-click to select				
Ex	Export • .100.20				
Q	Quit				

Figure 11 - File \rightarrow 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:

	Three axis system?	Selected Unit SMC:SMC-001EC0988740@192.168.100.20 -Task Parameters
→	Set system configuration Set focus/marking params	Load 11.0 Lens max mech angle (+/- deg) 160 Lens effective focal length (mm)
	Create correction table Set center-focus offset Adjust laser/galvo timing	Save 11.0 Galvo max mech angle (+/- deg) Head parameters Edit
	Create calibration grid Adjust correction table	Laser type CO2 Background laser modulation Frequency 5 KHz Duty-cycle 20 %

Figure 12 - System Type Selection

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

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

Galvo max mech angle (± deg)

Task Parameters ——	
Load	11.0 Lens max mech angle (+/- deg)
	160 Lens effective focal length (mm)
Save	11.0 Galvo max mech angle (+/- deg)
	Head parameters Edit
Laser type	CO2 Background laser modulation
	Frequency 6 KHz
	Duty-cycle 0 %

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.

Laser type 🚽 SPI 20W	Background laser modulation	Laser type 쉬 CO2	Background laser modulation
Waveform number 27	Frequency 100 KHz	v	Frequency 5 KHz
Simmer power (%) 🚽 50	Duty-cycle 🚽 50 %		Duty-cycle 🌍 0 %
Ť			

Figure 14 - Laser Settings

Laser type: CO2, 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.

😭 Cambridge Technology Calibration Wizard					
File	Configure	Show	Help		
Lo	Load calibration configuration				
Sa	Save calibration configuration Double-				
Ex	Export • 100.20			.100.20	
Quit					

Figure 16 - File \rightarrow 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.

→	Three axis system?	Selected Unit SMC:SMC-170026976@192.168.100.21 -Task Parameters This action will create an empty correction table. You will lose any in-process modifications you may have done that were not saved. Do you want to continue?
	Create calibration grid Adjust correction table	Continue Cancel Patterning job control Tables

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 \rightarrow 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

Two-axis Calibration Process

1040-0008 Revision

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 approx	rimate accuracy			
Yields a usable approximation wh	-			
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 f than 300mm x 300mm.	ield size, but is best suited to fields larger			
<u>Grid Setup</u>	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	Load reference file used by scanner to			
Correction File	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	e Supplied by User
Correction tables created based of sets	on analysis of ideal vs. measured coordinate
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
<u>Grid Analysis by External</u> <u>System</u>	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 \rightarrow Quit, then press "OK" in following message and accept changes in table as shown below.

	ÊÎ	×
\mathfrak{K} $ imes$ $ imes$ Do you want to use the new calibration factors for futher marking operations?	calculated t	nt to make the newly able the current table he changes?
OK No	Accept	Discard

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.)

😭 Get user text 🛛 🖂	A -
Please enter a description	😭 Get user text 🛛 👋
PS1-10-LINOS-F160- Baseline	Please enter a revision
OK	OK

Figure 24 - Save correction file

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

ÊÎ		×
	Load table	to controller?
	ОК	Cancel

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.

	Three axis system?	Selected Unit SMC-2AXIS:SMC-001EC098A1D6@192.168.100.20 -Task Parameters Center-focus offset parameters
_	Set focus/marking params Create correction table Set center-focus offset	Field X Y Pattern 1x1 Size (mm) 117 Keep size and offset Offset (mm) 0
	Adjust laser/galvo timing Create calibration grid	- Cell Pattern 1x1 Size (mm) 5 - Focus Start 0 Stop 0 Delta 0
	Adjust correction table	Edit table

Figure 26 - Center Focus

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.

\vdash	-	-		_	_	_		-	
\vdash	-	-		_	_	_	-	-	
\vdash	-	-	H		_	-	-	-	Н
\vdash	-	-	H			-		-	Н
									H
	0.0								

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 setup 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.

€7 Cambridge Technology Cal File Configure Show Help			÷	×
Controlle	rr Units - Double-click to select 192.168.100.20 Selected Unit SMC:SMC-001EC0988740 -Task Parameters Cal grid adjustment params Type Une Margin 5 (mm) Include grid outline X Y Size 100 100 (mm) Cffset 0 0 0 (mm) Fiducial size 0 0 (mm) Patterning job control Tables 1.8.3 terations 1	Connected LOGOUT @192.168.100.20 Edit table Edit boot offsets Enable cutting	Zoom Reset Units mm Calibration factors (bits/mm) Show all mages Show Jumps X 143822.1 Y 143822.1 Z 128000 56.33 -	33
CAMBRIDGE TECHNOLOGY	Interactive control Pointer (On/Off)	Go To XYZ	Connected to: 192 168, 100. 20 Msg avent! High = 0x2329 (9001): 0x5040 (20544), Low = 0x0 (0) Abort Ack	^ ~

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 highcontrast cardboard paper such as Bindakote paper or black anodized aluminum plate to get better marking contrast.



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 \rightarrow 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: <u>Canon Canoscan 9000F</u>

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 <u>NI</u> <u>Vision Development Module Run-Time License</u> 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**.

Load the flatbed calibration file from File \rightarrow Load \rightarrow Flatbed scanner calibration data and a green LED saying "Using flatbed scanner calibration data" goes ON as shown below.

হি ০	ambrid	lge Techno	ology Co	rrection Tabl	e Editor			_		×
File	Edit	Measure	Show	Configure	Operate	Help				
Modu	Nodule SMC:SMC-001EC0988740@192.168.100.20 Correction Table D									
Design	Calibration factors (bits/mm)						ſ			
Adjust		160 Le	ns effect	iech angle (+/- ive focal lengt nech angle (+	h (mm)		Preserv	e these cal factors Send to Controller		
Analyze			E	dit Params		-	Design statistic	s sq. (mm)		-

Figure 35 - Scanner correction file

Exit Correction Table Editor by pressing File \rightarrow Quit, then pressing "OK" as shown in the following message windows to accept changes in table as shown below

	ÊÎ	×
€7 × Do you want to use the new calibration factors for futher marking operations?	calculated	ant to make the newly I table the current table the changes?
OK No	Accep	t Discard

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:

লি				Х
	Load table	to c	ontroller?	
	ОК		Cancel	

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.

	Three axis system?	Selected Unit SMC-2AXIS:SMC-001EC098A1D6@192.168.100.20 -Task Parameters Center-focus offset parameters
	Set focus/marking params Create correction table	-Field X Y Pattern 1x1 Size (mm) 117 117
\rightarrow	Set center-focus offset Adjust laser/galvo timing	Keep size and offset Offset (mm) 0 0 - Cell Pattern 1x1 Size (mm) 5
	Create calibration grid Adjust correction table	- Focus Start 0 Stop 0 Delta 0
		Edit table

Figure 39 - Center Focus

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 setup 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**.

Cambridge Technology Calit ile Configure Show Help	Nation Wizard														×		
Controller Units - Double-click to select SMC-5MC-601620638740@19216810020 Connected		Zoom Show all ime 58.33 -	Reset Iges 🗹	Units	1	nm Is 🔲	×		lbration					1			
		LOGOUT	50.00 -	+	+	Ŧ	Ŧ	Ŧ	Ŧ	Œ [Ð	+	Ŧ	Ŧ		L	
	M		40.00 -	+	Ŧ	Ŧ	Ŧ	Ŧ	Ŧ	Ξ	Ξ	+	+	Ŧ			
_	Selected Unit SMC:SMC-001EC0988740	@192.168.100.20	30.00 -	±	÷	Ŧ	Ŧ	±	Ŧ	Ð	Ð	+	÷	±			
Three axis system?	-Task Parameters		20.00 -	+	+	+	Ŧ	+	+	± [Ŧ	+	+	+			
Set system configuration	Cal grid basic params		10.00 -	Ŧ	+	Ŧ	Ŧ	Ŧ	Ŧ	Ð	Ð I	÷	Ŧ	Ŧ			
Set focus/marking params	Type Box + Margin 5 (mm)	Edit table	0.00 -	+	+	+	Ŧ	+	+	±	Ð	+	Ŧ	+ 1			A small
Create correction table	Include grid outline		-10.00 -	+	+	+	+	+	+	±	Ŧ (+	+	+	N		A SHIdii
Set center-focus offset	X Y	Enable cutting 📃	-20.00 -	Ŧ	Ŧ	Ŧ	Ŧ	Ŧ	±	Ξ	Ŧ	+	+	Ŧ		K	line
Adjust laser/galvo timing	Size 100 100 (mm)		-30.00 -	+	+	Ŧ	Ŧ	+	+	± [Ð	+	÷	+		Ľ	
	Keep size and offset		-40.00 -	+	+	+	Ŧ	+	+	±	Ð (+	+	Ŧ			marked at
Create calibration grid	Spacing 10 (mm)		-50.00- + + + + + + + + +		L	the											
Adjust correction table	Adjust correction table Fiducial size 4 (mm)		-58.33-	22	-40 00		20 00		0 00	20	00		00	58	2		
			-00	33	-40.00		20.00		0.00	20	.00	-	1.00	50.		L	Positive-X
Patterning job control		-Messages -														direction	
Tables () 1 & 3 kerations () 1 RUN ABORT Tables () 1 & 3 kerations () 1 RUN ABORT Interactive control Pointer (On/Off) Go To XYZ			Msg event! High	= 0x0 (0): 0x41	(85), Lo	w = 0x0	(0) Be	gin Job	At: 15:1	9.05	-	-		^		unection
			Mag event: High = 0x0 (0): 0x42 (06), Low = 0x0 (0) End Job. At: 15:19:06 Job Duration: 1.083 sec					for easy									

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.

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.

ମ୍ବି Ca	ambri	dge Technology Correction Table Editor	– 🗆 X
File	Edit	Measure Show Configure Operate Help	
Modul	e s	Automatic scan and analyze Analyze scanned image	Correction Table ID
Design	-	Calibrate flat-bed scanner Analyze flat-bed scanner calibration image Guided grid measurement	Calibration factors (bits/mm) X (143822. Y (143822. Z (128000
Adjust		Collect Box/Cross grid data Collect grid data into table	Preserve these cal factors
_ 		Collect focal plane data	Send to Controller
ze		Analyze correction table errors	Design statistics
Analyze			116.7 Max sq. (mm)

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.

😭 Get user text	×
	neasurement file prefix
Iteration01	
ОК	Cancel

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.





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 \rightarrow Quit, then press "OK." In the following message windows, accept changes in table as shown below.

	ÊÎ	\times
€î ×	Do you want to make the calculated table the currer	
Do you want to use the new calibration factors for futher marking operations?	or discard the changes?	
OK No	Accept Disc	ard:

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.

😭 Get user text 🛛 🕹	
Please enter a description	🕅 Get user text 🛛 👋
	Please enter a revision
PS1-10-LINOS-F160- Baseline	
OK	OK

Figure 49 - Save correction file

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

লি			×
	Load table	to controller?	
	ОК	Cancel	

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.

Three axis system?	Selected Unit SMC-2AXIS:SMC-001EC098A1D6@192.168.100.20 -Task Parameters
Set system configuration	Center-focus offset parameters
Set focus/marking params	-Field X Y
 Create correction table	Pattern 2 1x1 Size (mm) 2 117 2 117
Set center-focus offset	Keep size and offset Offset (mm)
Adjust laser/galvo timing	Pattern 👌 1x1 Size (mm) 分 5
Create calibration grid	- Focus
Adjust correction table	Start 0 Stop 0 Detta 0
	Edit table

Figure 51 - Center Focus

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 setup 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.

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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

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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.

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

+	+	+	+	+	+	+	+	+	+	[+]
(+)	+	+	+	+	+	+	+	+	+	Ŧ
+	+	+	+	+	+	+	+	+	+	+
\pm	+	+	+	+	+	+	+	+	+	+
÷	+	+	+	+	+	+	+	+	+	+
+	+	+	+	+	+	+	+	+	+	+
+	+	+	+	(\pm)	+	+	+	+	+	+
+	+	+	+	+	+	+.	+	+	+	+
(+)	+	+	+	+	+	+	+	+	[+]	+
+	+	+	+	+	+	+	+	+	+	+
+	+	+	+	+	+	+	+	+	+	+

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.

.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→ 102.5328	-102.4	1→ -127	.8725→ -		-25.000 0.51819	,	0.000000	;0.325006;-

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

- 128.0→	- 76.8→	-127.9894→ -	-20.00000;-30.00000;0.358461;-
76.9497			0.454425
- 128.0→	- 51.2→	-128.0576→ -	-15.000000;-30.000000;0.383666;-
51.3114			0.390759
- 128.0→	-25.6→	- 128.0836→ -	-10.000000;-30.000000;0.423006;-
25.6478			0.311030
- 128.0→	0.0→	-128.0820→	-5.000000;-30.000000;0.423832;-
00.0108			0.222179
-128.0→	25.6→	-128.0528→	0.000000;-30.000000;0.457070;-
25.6455	F1 0	107.0010	0.151964
-128.0→	51.2→	-127.9810→	5.00000;-30.00000;0.492804;-
51.2527 -128.0→	76.8→	-127.8751→ 76.8149	0.087841
-128.0→ -128.0→	102.4→	-127.7240→	10.000000;-30.000000;0.529238;-
120.0⇒ 102.3285	102.∓→	127.7240→	0.016025
-128.0→	128.0→	-127.4911→	15.000000;-
127.7597			30.000000;0.535826;0.059729
-102.4→	- 128.0→	- 102.2990→ -	20.000000;-
127.8040			30.000000;0.531174;0.149579
- 102.4→	- 102.4→	- 102.4243→ -	
102.3363			25.000000;- 70.000000;0 567012;0 227755
-102.4→	- 76.8→	-102.5034→ -	30.000000;0.563012;0.227755
76.7753			30.00000;-
- 102.4→	- 51.2→	- 102.5497→ -	30.00000;0.623177;0.302295
51.1900			30.00000;-
			25.000000;0.521047;0.373780

*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 \rightarrow Import \rightarrow Measurement data from... \rightarrow 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.

R Import	grid error data	×
Import	.pset Format: X-ideal Y-ideal	dX-ideal dY-ideal
Import	.dat Format: X-ideal Y-ideal	X-actual Y-actual
□ s	wap X & Y Axes	Cancel

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."

File Edit	Me	asure Show Configure Operate H	elp
Load	•]	
Save		Correction table 🕨	To a local file
Import	►	Flat-bed scanner calibration data	To the controller
Export Convert Quit) 	ction parameters Three axis?	Calibration factors (bits/mm) X 쉬 136543. y 쉬 136543. z 🖨 301846.
Adjust	1	 Lens max mech angle (+/- deg) Lens effective focal length (mm) Galvo max mech angle (+/- deg) 	Preserve these cal factors Send to Controller
Analyze		Edit Params	—Design statistics

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 (-)).

Save Calibration File to Controler

🕅 Get user text 🛛 🕹			
Please enter a description			
PS-10-L160-WD207			
OK			

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.

€î ×				
The controller is using: L2_3Axis_FOV300_WD332 for correction table 1. Change it to use: PS_10_L160_WD207?				
OK No				

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.

Cambridge Technology Calibra	ation Wizard	- 🗆 🗡
SMC:SMC-001EC0988740@192	nts - Double-click to select 2 168 100 20 Selected Unit - Task Parameters - Please select a calibration task on the left	Zoom Reset Units Imm Calibration factors (bits/mm) Show all mages Show Jumps X 500 Y 500 Z 500 60.00- 50.00- 40.00- 30.00- 20.00- 10.00- 10.00- -
Create calibration grid Adjust correction table	Patterning job control Tables 1 & 3 terations 1 RUN ABORT	-50.00- -60.00- -65.54 -65.54 -85.54 -40.00 -20.00 0.00 20.00 40.00 65.53 -Messages
CAMBRIDGE TECHNOLOGY	Pointer (On/Off) Go To XYZ	

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.

Controller Units - Double-click to select		
SMC-2AXIS:SMC-001EC098A1D6@192.168.100.20	Connected	
τ	LOGOUT	
Three axis system? Selected Unit SMC-2AXIS:SMC-001EC098	A1D6@192.168.100.20	

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

Cambridge Technology Calibration Wizard File Configure Show Help	X
Controller Units - Double-click to select Connected Connected Connected Connected Connected	Zoom Reset Units mm Calibration factors (bits/mm) Show all mages Show Jumps X 135543.1 Y 135543.1 225648.2 61.44 50.00 - 40.00 - -
Three axis system? Selected Unit SMC:SMC-170026976@192.168.100.21 -Task Parameters Set system configuration Align laser Set focus/marking params Create correction table Set center-focus offset Adjust loser/galvo timing Adjust focal plane Create calibration grid	30.00- 20.00- 10.00- -10.00- -20.00- -20.00- -30.00- -40.00- -50.00- -50.00- -51.44= -61.44
Adjust correction table Patterning job control Adjust focal plane tip Tables (1 & 3) terations (1 RUN ABORT) Tables (1 & 3) terations (1 RUN ABORT) Interactive control Pointer (On/Off) (1 Control)	Messages Msg event! High = 0x2229 (9001): 0x5040 (20544), Low = 0x0 (0) Abort Aok Connected to: 152.168.100.21

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.

Three axis system? 🗹 Select 3-axis calibration step	Selected Unit SMC:SMC-170026976@192.168.100.21 -Task Parameters
Set system configuration Align laser	Load Head type D L2 30mm YAG Open Frame
Set focus/marking params	Save Head parameters Edit
Create correction table	
Set center-focus offset	
Adjust laser/galvo timing	Laser type CO2 Background laser modulation Frequency 5 KHz
Adjust focal plane	Duty-cycle 0 %
Create calibration grid	
Adjust correction table	Patterning job control
Adjust focal plane tip	Tables 2 1 & 3 Iterations 2 1 RUN ABOF

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:

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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.

Three axis system? Select 3-axis calibration step Set system configuration	Selected Unit SMC:SMC-170026976@192.168.100.21 -Task Parameters
Align laser	
Set focus/marking params	Laser params for alignment
Create correction table	Frequency 20 KHz
Set center-focus offset	Activate laser
Adjust laser/galvo timing	Power () 10 %
Adjust focal plane	
Create calibration grid	
Adjust correction table	Patterning job control
Adjust focal plane tip	Tables (1 & 3 Iterations () 1 RUN ABO

Figure 66 - Align Laser

Set Duration to the number of seconds' the laser is to be ON before turning OFF automatically. Entering "O" 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.



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

Three-axis Calibration Process



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.

Three-axis Calibration Process

Three axis system?	-Task Parameters	3		
Set system configuration		-	Galvo speed	
Align laser	Marking	,iz	-	× ^{c)}
Set focus/marking params		a will encede		c)
Create correction table	table. Yo	u will lose an	an empty correction y in-process y have done that y	
Set center-focus offset	not saved	l.		
Adjust laser/galvo timing	Do you w	ant to contin	ue?	łz
Adjust focal plane	c [Continue	Cancel	
Create calibration grid			9	
Adjust correction table	Patterning job c	ontrol	7	
Adjust focal plane tip	Tables	tterations		RUN

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

CT Ca	mbridge Technology Co	on examination of the second	- 🗆 X
File	Edit Measure Show	Configure Operate Help	
Module	SMC:SMC-17002697	✓ Use multi-dimensional mode Use hardware behavior mode	Constitute Table ID / 100
Design	Using flat-bed sca — Projection parameter	Use 16-bit addressing Use 20-bit addressing	tion factors (bits/mm)
Des	L2 30mm YAG Oper	✓ Use 24-bit addressing	33886.1 Y 2 83886.1 Z 2 301848.
_	Target field size	RTC Compatibility Advanced usage mode	Preserve these cal factors
Adjust	Working distance	209 (mm)	Send to
	Z Offset 🜖 534732	where the second s	Controller
Analyze	Z Margin (mm): Plus 10.	1 Minus -10.1	Design statistics 200.0 Max X (mm) 200.0 Max Y (mm)

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.

	dit Measure Show Configure Operate He	F 2
Module	SMC:SMC-170026976@192.168.100.21	Correction Table ID 1 & 3
Design	Using flat-bed scanner calibration data Projection parameters Three axis? UL 2 30mm YAG Open Frame Edit Params	Calibration factors (bits/mm) X () 83886.1 Y () 83886.1 Z () 301846.
Adjust	Target field size 200 (mm) Working distance 209 (mm)	Preserve these cal factors Send to Controller
Analyze	Z Offset 5347325 (bits) 17.7 (mm) Z Margin (mm): Plus 10.1 Minus -10.1 Indep XY cal factors? DFM Pos 0 (mm)	Design statistics

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.

File	Edit Measure Show Configure Operate Help	p
Modu	le SMC:SMC-170026976@192.168.100.21	Correction Table ID 剑 1 & 3
Design	 Using flat-bed scanner calibration data Projection parameters Three axis? L2 30mm YAG Open Frame Edit Params 	Calibration factors (bits/mm) X 💮 54120 Y 💮 54120 Z 💮 138140.
Adjust	Target field size 310 (mm) Working distance 345 (mm)	Preserve these cal factors Send to Controller
Analyze	Z Offset 5347325 (bits) 17.7 (mm) Z Margin (mm): Plus 22.3 Minus 44.9 Indep XY cal factors? DFM Pos 0 (mm)	Design statistics

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 scanhead 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.

File	Edit Measure Show Configure Operate Hel	p
Module	SMC:SMC-170026976@192.168.100.21	Correction Table ID 👌 1 & 3
Design	 Using flat-bed scanner calibration data Projection parameters // Three axis? L2 30mm YAG Open Frame Edit Params 	Calibration factors (bits/mm) X 👌 35246.2 Y 👌 35246.2 Z 👌 64900.3
Adjust	Target field size 5 476 (mm) Working distance 550 (mm)	Preserve these cal factors Send to Controller
Analyze	Z Offset S347325 (bits) 17.7 (mm) Z Margin (mm): Plus 46.9 Minus -124.5 Indep XY cal factors? DFM Pos 0 (mm)	Design statistics

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.

File		Correction Table ID
Design	Using flat-bed scanner calibration data Projection parameters L2 30mm YAG Open Frame Edit Params	Calibration factors (bits/mm) X () 54120 Y () 54120 Z () 138140.
Adjust	Target field size 310 (mm) Working distance 345 (mm)	Preserve these cal factors Send to Controller
Analyze	Z Offset 5347325 (bits) 17.7 (mm) Z Margin (mm): Plus 22.3 Minus 44.9 Indep XY cal factors? DFM Pos 0 (mm)	Design statistics

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



Three-axis Calibration Process

table, select Edit \rightarrow 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.

File	Edit Measure Show Configure Operate He	lp
Modu	le SMC:SMC-170026976@192.168.100.21	Correction Table ID 剑 1 & 3
Design	Using flat-bed scanner calibration data — Projection parameters — Three axis? L2 30mm YAG Open Frame Edit Params	Calibration factors (bits/mm) X 2 54120 Y 2 54120 Z 136140.
Adjust	Target field size 310 (mm) Working distance 345 (mm)	Preserve these cal factors Send to Controller
Analyze	Z Offset 0 (bits) 0 (mm) Z Margin (mm): Plus 61.6 Minus -5.6 Indep XY cal factors? DFM Pos 0 (mm)	-Design statistics 310.0 Max X (mm) 310.0 Max Y (mm)

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.

File Ed	lit Measure Show Conf	igure Operate	Help	_
Module	SMC:SMC-170026976@192	100 10	DFM positioner DFM range	Correction Table ID 쉬 1 & 3
Analyze Adjust Design	Working distance 3 Z Offset 3 0 (b	- ✓ Three axis Edit Parar 10 (mm) 45 (mm) its) ↔ 0 (m Minus -5.6	ms X J 5412 Pres m) — Design stati	factors (bits/mm) 20 Y 2 54120 Z 136140. serve these cal factors Send to Controller istics Max X (mm) 310.0 Max Y (mm)

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Figure 81 - Center DFM range

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

ধি	×
Send the new t	able to the controller?
ОК	Cancel

Figure 82 - Send new table

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

Correction Table ID 👌 1 & 3
factors (bits/mm) 20 Y 54120 Z 136140. serve these cal factors Send to Controller istics
ati

Figure 83 - Z-margin Plus and Minus set

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

ÊÎ			×
Do you want to use the	e new calibratior	n factors for futh	er marking operations?
	ОК	No	

Figure 84 - Exit Correction table editor

(This message appears only once, when a fresh table is started) Accept changes in table as shown below.

ধি	×
Do you want to m calculated table th or discard the cha	e current table
Accept	Discard

Figure 85 - Accept new changes in correction table

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

ধি		×
Do you want to save thi	s table to a loca	al file?
ОК	No	

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

Ê	×
Load table t	o controller?
ОК	Cancel

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.

Cambridge Technology Cali File Configure Show Help		- 0
Controller	Units - Double-click to select 168 100 21 LOGOUT T	Zoom Reset Units mm Calibration factors (bits/mm) Show all mages Show Jumps X 54120 Y 54120 Z 136140.2 140.00 - 100.00 - 100.00 - 540.00 2 54120 X 54120 X
Three axis system? 🗹 Select 3-axis calibration step	Selected Unit SMC:SMC-170026976@192.168.100.21 -Task Parameters	60.00 - 40.00 -
Set system configuration	Center-focus offset parameters	20.00-
Align laser	-Field X Y	0.00
Set focus/marking params	Pattern 1 1x1 Size (mm) 1310 1310	-40.00 -
Create correction table	Keep size and offset Offset (mm)	-60.00 -
Set center-focus offset	Pattern 3x3 Size (mm) 5	-80.00 - -100.00 -
Adjust laser/galvo timing	- Focus	-120.00 -
Adjust focal plane	Start -12 Stop -12 Delta -3	-140.00 - -155.00 -
Create calibration grid	Edit table	-155.00 -100.00 -50.00 0.00 50.00 100.00 155.
Adjust correction table	Patterning job control	
Adjust focal plane tip	Tables	Messages Msg event! High = 0x2329 (9001): 0x5040 (20544), Low = 0x0 (0) Abort Ack
	Interactive control Pointer (On/Off) Go To XYZ	Mag event! High = 0x23 (9001), 0x344 (2044), Low = 0x0 (0) Addit Adx Connected to 192 108 1002 1 Mag event! High = 0x0 (0): 0x3 (3), Low = 0x0 (0)

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.

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**

Three axis system? 🔽	-Task Parameters		C-001EC098A1D6@192.168.100.2
Set system configuration	Laser delays		Velocity compensation
Align laser	On 쉬	0 (usec)	Mode 🕘 None
Set focus/marking params	Off	100 (usec)	Comp limit (%) 20
Create correction table	Pipeline 🔗	50 (usec)	Agressiveness 1000
Set center-focus offset	Jump ()	100 (usec)	-Discovery "Raster" pattern -
Adjust laser/galvo timing	Mark 쉬	100 (usec)	-Validation "V-Test" pattern
Adjust focal plane	Poly	50 (usec) Poly Delay	Pattern height (mm) 分 20
Create calibration grid	Jose van	ory bondy	Number of patterns 分 3
Adjust correction table	Patterning job co	ontrol	
Adjust focal plane tip	Tables 쉬 1 & 3	Iterations 🧳	1 RUN ABOR

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 setup 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.

Cambridge Technology Cali File Configure Show Help		
	Units - Double-click to select	Zoom Reset Units mm Calibration factors (bits/mm) Show all images ✓ Show Jumps X \$4120 Y \$4120 Z 136140.2 155.00 - 140.00 - 1
Three axis system? 🔽 Select 3-axis calibration step	Selected Unit SMC:SMC-170026976@192.168.100.21 -Task Parameters	60.00 - 40.00 -
Set system configuration	Focal plane parameters	20.00 -
Align laser Set focus/marking params	-Field X Y Pattern 3 3x3 Size (mm) 310 310	0.00 - -20.00 - -40.00 -
Creat correction table	Keep size and offset Offset (mm)	-60.00 -
Set center-focus offset	Pattern 5x5 Size (mm) 5	-80.00 - -100.00 -
Adjust laser/galvo timing Adjust focal plane	- Focus Start -12 Stop 12 Delta 1	-120.00
Create calibration grid	Edit table	-155.00 -100.00 -50.00 0.00 50.00 100.00 155.00
Adjust correction table	Patterning job control	
Adjust focal plane tip	Tables 1 & 3 Iterations 1 RUN ABORT	Messages
CAMBRIDGE TECHNOLOGY	Interactive control Pointer (On/Off) Go To XYZ	Misg event High = 0xc2x3 (90/1): 0xc2v4 (200+4). Low = 0x0 (0) Abort Abx Connected to 122: 108:100: 102: 108:100 Aby 100: 100: 100: 100: 100: 100: 100: 100

Figure 93 - Focal plane adjustment

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



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 \rightarrow 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 \rightarrow 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		
<u>Mark Grid</u>	Mark grid on black-coated surface		
Measure Data and Enter			
Accuracy Check	Repeat until calibration satisfactory		
Guided Grid Measurement			
	d size, but is best suited to fields larger than		
300mm x 300mm.			
<u>Grid Setup</u>	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	Load reference file used by scanner to		
<u>File</u>	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 < 0.0			
Analysis of Grid Measurement File Su	upplied by User		
Correction tables created based on analysis of ideal vs. measured coordinate			
sets			
Create Calibration Grid	Compare known coordinates to actual		
	marked coordinates		
<u>Mark Grid</u>	Mark grid on black coated surface		

Grid Analysis by External System Camera Vision or Metrology System

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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:

Controlle	er Units - Double-click to select	Connected	Zoom Reset Units mm Calibration factors (bits/mm) Show all images Show Jumps X 55924 Y 55924 Z 14426 150.00 -
Three axis system? Select 3-axis calibration step Set system configuration Align laser Set focus/marking params Create correction table Set center-focus offset Adjust laser/galvo timing Adjust focal plane Create calibration grid Adjust correction table	Selected Unit SMC:SMC-001EC0988740 -Task Parameters Cal grid adjustment params Type Line Margin 5 (mm) Include grid outline (mm) Size 280 280 (mm) Offset 0 0 0 (mm) Keep size and offset Spacing 140 (mm) Fiducial size 0 (mm)	@192.168.100.20	10000 10000 60.00 10000 40.00 10000 20.00 10000 -20.00 10000 -40.00 10000 -60.00 10000 -100.00 -100.00 -150.00 -100.00
Adjust focal plane tip	Tables (1 & 3 terations (1) Interactive control Pointer (On/Off)	RUN ABORT	Messages Connected to: 192.188.100.20 Msg event! High = 0x2329 (9001): 0x5040 (20544), Low = 0x0 (0) Abort Ack

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.

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 highcontrast 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.

ধি	×	
Save this measurement data?		
Yes	No	
10		

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 userdefined 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 \rightarrow 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:

😭 Guided grid me	asurement	t		×
Square grid 🗹	x	Y	Target point	
Grid size (mm)	100	100	X -50	Y -50
Points along axis	5	5	Actual point	
Spacing (mm) 🖞	25	25	X -50	Y -50
0.02 Nudge ((mm)	X 10 Scale	Error	
	<u>.</u>		X 0	Y 0
			25 Number of points	
	+Y		👌 1 Cur	rent point index
-x :	Start	+x	Focal offset	(mm) 🗿 0
	-Y		Accept	Save
			Next	Cancel
	\checkmark		Back	Done

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: <u>Canon Canoscan 9000F</u>

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 <u>NI</u> <u>Vision Development Module Run-Time License</u> 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 \rightarrow Load \rightarrow Flatbed scanner calibration Data; a green LED indicating "Using flatbed scanner calibration data" comes ON as shown below":

Module	SMC:SMC-001EC0988740@192.168.100.20	Correction Table ID 👌 1 &
Design	Using flat-bed scanner calibration data — Projection parameters — V Three axis?	Calibration factors (bits/mm) X (2) 55924 Y (2) 65924 Z (2) 144261.
_	L2 30mm YAG Open Frame Edit Params	
Adjust	Target field size Working distance 332 (mm)	Preserve these cal factors Send to
-	Z Offset 3903979 (bits) 27.1 (mm)	Controller
Analyze	Margin (mm): Plus 31.1 Minus -31.1	Design statistics

Figure 104 - Scanner correction file

Exit Correction Table Editor by File \rightarrow 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.


4. Mark Grid

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

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:

File	Edit	Measure Sho	w Configure	Operate	Help		
-		Automatic s	can and analyz	e	<u>م</u>		
Modi	ule S	Analyze sca	nned image			Correction Table ID 🚽 1 & 3	
	(Calibrate fla	t-bed scanner				
Design	_	Analyze flat	bed scanner ca	libration in	nage	Calibration factors (bits/mm)	
ă		Guided grid	measurement			X 🔂 55924 Y 🔂 55924 Z 🔂 144261.	
	1	Collect Box/	Cross grid data			Preserve these cal factors	
Adjust		Collect grid	data into table				
Ā	_	Collect foca	plane data			Send to Controller	
e		Analyze cor	ection table err	ors		Design statistics	
Analyze	Z Ma	rgin (mm): Plus	31.1 Minus	-31.1			
An		ndep XY cal facto	rs? DFM Pos 分	0 (m	m)	300.0 Max X (mm) 300.0 Max Y (mm)	

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.

Three-axis Calibration Process

😭 Get user text	×
	measurement file : prefix
Iteration01	
ОК	Cancel

Figure 108 - Get user data

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

	🕅 Select Field Orientation 🛛 🗙
🕅 Select scanner 🛛 🖂	Indicate orientation of the paper on the scanner. Note the X axis marker.
Select scanner type	KLDE 700/A320Hinge Top view looking down through the paper Front
OK Cancel	 Axis flip None

Figure 109 - Select Scanner size and field orientation

Select Scanner type.

😭 Select scanner	×
Please Select a Scan	ner
CanoScan LiDE 700F	
J	<u> </u>

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.



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 <u>not</u> be in the file.

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.dat Forn	nat (tab se	eparator)		.pset Format (semicolon \rightarrow separator)			
X-Ideal	Y-Ideal	X-Actual	Y-Actual	X- Ideal	Y- Ideal	X-Delta*	Y-Delta*
- 128.0→	-128.0)→ - 127	.6778→ -	-30.00	0000;-30	0.000000	;0.298739;-
128.011				0.5830	34		
- 128.0→	-102.4	1→ - 127	.8725→ -	-25.000	0000;-30	0.000000	0.325006;-
102.5328				0.51819	4		
-128.0→	-76.8	8→ - 127.98	394→ -	-20.000	0000-30	000000	;0.358461;-
76.9497				0.4544	-		,01000 101,
- 128.0→	- 51.2–	→ - 128.05	76→ -			000000	0.797666
51.3114				0.3907	-	.000000;	0.383666;-
-128.0→	-25.6-	→ -	128.0836→				
-:	25.6478).000000;	0.423006;-
-128.0→	0.0→	-128.08	20→	0.31103	0		
00.0108				-5.000	000;-30.	000000;0).423832;-
-128.0→	25.6–	→ - 128.05	28→	0.22217	'9		
25.6455				0.0000	000;-30.0	0,00000	.457070;-
-128.0→	51.2→	-127.981	IO→	0.15196	4		
51.2527				5 0000	0030 (00000;0.	492804'-
-128.0→	76.8–	→ - 127.875	51→	0.0878			102001,
76.8149						000000;0	520270
-128.0→	102.4	→ -	127.7240→	0.01602		000000,0).529230, -
)2.3285						
- 128.0→	128.0-	→ -	127.4911→	15.0000	-		
	27.7597			30.000	000;0.5	35826;0.0	59729
-102.4→)→ - 102	2990→ -	20.000	000;-		
127.8040				30.000	000;0.5	31174;0.149	9579
-102.4→		1→ -102	.4243→ -	25.000	000;-		
102.3363				30.000	000;0.5	63012;0.22	27755
	-76.8-	→ -	102.5034→	30.000	000		
	-76.7753		30.000000;0.623177;0.302295				
-102.4→	-51.2-	→ - 102.54	9/→ -	30.000			
51.1900							7700
				25.000	000;0.52	21047;0.37	3760

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*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.

	'analaria	las 1	Tashnalasu C	orrection Tabl	o Editor						×
		-							_		^
File	Edit	Mei	asure Show	Configure	Operate	He	lp				
Lo	bad	•	40.0015.000	00740 0 402 44							
Sa	ive	≯.	MC-00TEC09	88740@192.16	58.100.20			Correc	ction lab	le ID 🍎 1	& 3
In	nport	•	Correctio	n table from	· • • 🔟						
Ex	port	►	Measurer	nent data fror	n 🕨	Car	mbridge point-set fo	ormat file			
C	onvert	⇒	paramote			Sca	nlab CorreXion con	trol file	A		1
Q	uit					Mie	croVUE text file		1	128000	
		11	.0 Lens max	mech angle (+/-	- deg)		Property	these cal f	iactora		
Adjust		- 10	60 Lens effec	tive focal lengt	h (mm)		Fieselve	these carr	actors		
PA		11	0 Galvo max	mech angle (+	(- deg)			Send to	1		
- 1								Controller			
e e							-Design statistics				
Analyze				Edit Params							
Ψ							116.7 Max	sq. (mm)			

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:

Model accuracy					
	0	Min			
	0	Max			
	0	Mean			
	0	SDev			
Show modeled data					
Correct rotation and offset					

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 (-)).

Save Calibration File to Controller

😭 Get user text	\times
Please enter a description	
L2_3Axis_FOV300_WD332	
OK	

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.

ধি	×
The controller is usir NoCorrection for correction table L2_3Axis_FOV300_W	- 1. Change it to use:
ОК	No

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 setup 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:

FIPE O	<u> </u>	<u>FIPE 180</u>	PPE 200
			LDF 260
			LOF 150
			LOF 160
			10F 5D

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 (\geq 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.

Ê	C Edit laser timing pattern parameters						
	Timing Patterr	n Parameters					
	100	Center Laser Off Delay (usec)	50	Center Pipeline Delay (usec)			
	25	Laser Off Delay Delta (usec)	25	Pipeline Delay Delta (usec)			
	5	Number Laser Off Delay Steps	5	Number Pipeline Delay Steps			
	10	Pattern Size X (mm)	3	Pattern Size Y (mm)			
	0	Pattern Orientation (degrees)	Flyback	Pattern Type			
	ОК			Cancel			

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

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).



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.



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 A111. Jump to point A221. Jump to point A3
```

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Appendix A- Optimizing Laser/Galvo Timing

2. Mark square ABCDA1	12. Mark square ABCDA2	22. Mark square ABCDA3			
3. Jump to point E1	13. Jump to point E1	23. Jump to point E3			
4. Mark "V" EFG1	14. Mark "V" EFG2	24. Mark "V" EFG3			
5. Jump to point H1	15. Jump to point H2	25. Jump to point H3			
6. Mark "V" HIJ1	16. Mark "V" HIJ2	26. Mark "V" HIJ3			
7. Jump to point K1	17. Jump to point K2	27. Jump to point K3			
8. Mark segment KF1	18. Mark segment KF2	28. Mark segment KF3			
9. Jump to L1,	19. Jump to L2,	29. Jump to L3,			
10. Mark segment LI1	20. Mark segment LI2	30. Mark segment LI3			
Figure 128 - V-Test Pattern Seguence					

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.

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.



Laser Off Delayaser Off Delay Too Short Too Long

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.-





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 \rightarrow 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)

$\widehat{\mathbf{e}}$ Select scanner $ imes$
Select scanner type
Small (8.5" x 11")
OK Cancel

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.

Appendix B- Flatbed Scanner Characterization

Scanning
Scanning. Do not open the document cover.
Cancel

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.

Cambridge Technology Correction Table Editor File Edit Measure Show Configure Operate Hel	X
Module	Correction Table ID
Using flat-bed scanner calibration data Projection parameters Three axis? 15.0 Lens max mech angle (+/- deg) 160 Lens effective focal length (mm) 11.0 Galvo max mech angle (+/- deg) Edit Params	Calibration factors (bits/mm) X 59918.6 Y 59918.6 Z 301846. Preserve these cal factors Send to Controller —Design statistics 280.0 Max sq. (mm)
File 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	0 0

Figure 145 - Analyzed grid

Appendix B- Flatbed Scanner Characterization

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

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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.



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.

Cal grid basic params					
Grid type Box +					
Include grid outline 📃					
	Х	Y			
	Size 100	100	(mm)		
Of	fset 쉬 0	0	(mm)		
Keep size and offset 🔽					
	Spacing 싉 1	10 (mm)			
Fi	ducial size 쉬	l (mm)			

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.

Appendix C- Calibration Grid Artifact



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.
- Check the box and define the cut dimensions. Note that a notch is cut at the positive-X orientation.
 Calibration factors (bits/mm) (Dimensional factors (bits/mm)) (



Figure 149 - Check the Box and Define the Cut Dimensions

Appendix C- Calibration Grid Artifact

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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