



**EXULUS-HD2,
EXULUS-HD2HP,
EXULUS-HD3,
EXULUS-HD3HP, &
EXULUS-HD4
Spatial Light Modulators**

User Guide



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Chapter 1 Warning Symbol Definitions

Below is a list of warning symbols you may encounter in this manual or on your device.

Symbol	Description
— — —	Direct Current
~	Alternating Current
~~	Both Direct and Alternating Current
⊕	Earth Ground Terminal
○ ⊕	Protective Conductor Terminal
	Frame or Chassis Terminal
▽	Equipotentiality
	On (Supply)
○	Off (Supply)
■ ■	In Position of a Bi-Stable Push Control
■ ■ ■	Out Position of a Bi-Stable Push Control
⚠ ⚡	Caution: Risk of Electric Shock
⚠ ⚡	Caution: Hot Surface
⚠ !	Caution: Risk of Danger
⚠ ⚡	Warning: Laser Radiation
⚠ ⚡	Caution: ESD Sensitive Components

Chapter 2 Safety

2.1. Precautions

Please read the instruction manual carefully before operating your Spatial Light Modulator. All statements regarding safety and technical specifications will only apply when the unit is operated correctly.

Refer to this User's Guide whenever the following symbols are encountered on the Spatial Light Modulators.



DO NOT OPEN HOUSING



Thorlabs' SLM has no user-serviceable parts. Service should only be performed by trained service personnel.



SHOCK WARNING



High voltage inside. To avoid electrical shock, before powering up, make sure that the ground pin of the power cord is correctly connected to the ground connector in the power socket. Improper grounding can cause electric shock resulting in severe injury or even death. Do not operate without the cover installed.



WARNING



This unit must not be operated in explosive environments. Do not operate in wet/damp conditions. Do not obstruct the air ventilation slots in the housing.



WARNING



Transportation and delivery may cause the SLM to be warm or cool upon receipt. Please wait for the whole device to reach room temperature before attempting to operate.

2.2. Product Care

Handle the complete system with care during transportation and unpacking. Banging or dropping the system can damage the unit or lower the system performance. If this occurs, the complete system will need to be sent back for recalibration. Please contact Thorlabs Technical Support for more information.

- Do not store or operate in a damp, closed environment.
- Do not store or operate on surfaces that are susceptible to vibrations.
- Do not expose to direct sunlight.
- Do not use the solvents on or near the equipment.
- Mobile telephones, cellular phones, or other radio transmitters should not be used with a range of 3 m of this unit since the electromagnetic field intensity may exceed the maximum allowable disturbance values, according to EN50082-1.
- Keep away from dust, dirt, and air-borne pollutants (including cigarette smoke). The system is not designed for outdoor use. Protect the equipment from rain, snow, and humidity.
- Do not expose to mechanical and thermal extremes. Protect the equipment from rapid variations in temperature.
- Handle all connectors with care. Do not use unnecessary force, as this may damage the connectors.
- Handle the SLM main unit with care. Mishandling may cause damage to the liquid crystal panel or optical head.
- Clean the protective window by using a soft, lint free cloth. Use of isopropyl alcohol is permitted; however, do not immerse in any liquid or solvent.
- Clean any accessible optical surfaces with an appropriate optics grade tissue or cloth.

2.3. Service



CAUTION



Except for the main fuse, which is accessible from the outside of the housing, the EXULUS® SLM has no user-serviceable parts. Service should only be performed by trained service personnel.

Only trained and approved Thorlabs' personnel should service the system. Please contact Thorlabs Technical Support at techsupport@thorlabs.com and a member of our team will be happy to assist you.

2.4. Accessories and Customization

Although the system is easily adapted for custom interfaces, to achieve the listed specifications, this system should only be used with accessories provided by Thorlabs. Any modification or servicing by unqualified personnel renders the warranty null and void, leaving Thorlabs free of liability.

A custom version with the panel and controller in separate units is available, please contact Tech Support for questions on customization.

Chapter 3 Introduction

This manual provides instruction on how to install and operate a Thorlabs EXULUS-HD2, EXULUS-HD2HP, EXULUS-HD3, EXULUS-HD3HP, or EXULUS-HD4 two-dimensional Spatial Light Modulator (SLM). To ensure correct usage, read this manual carefully before operating your EXULUS®.

3.1. Overview

Thorlabs' EXULUS® SLM is a reflective SLM based on Liquid Crystal on Silicon (LCoS) technology. It offers individually addressable pixels of phase shift or retardance and provides large phase stroke and excellent phase stability. Therefore, the EXULUS® SLM is ideal for many beam manipulation applications including optical trapping, beam steering and shaping, femtosecond pulse shaping, adaptive optics, imaging applications, holography, interferometry, laser processing, lithography, and others.

3.2. Principle – Liquid Crystal on Silicon (LCoS)

The Liquid Crystal on Silicon (LCoS) technology is a reflective retarder panel utilizing a liquid crystal layer sandwiched between a top transparent and conductive ITO layer, and the reflective electrode layer on the bottom. On the bottom layer, pixels are arranged as individual addressable aluminum electrodes. Together with the ITO layer on top, an electric field is built by applying a voltage between the two layers. The liquid crystal modules align according to the direction and strength of the electric field. Since liquid crystal is a birefringent material, the alignment of the liquid crystal modules in turn determines the retardance or phase shift of each pixel.

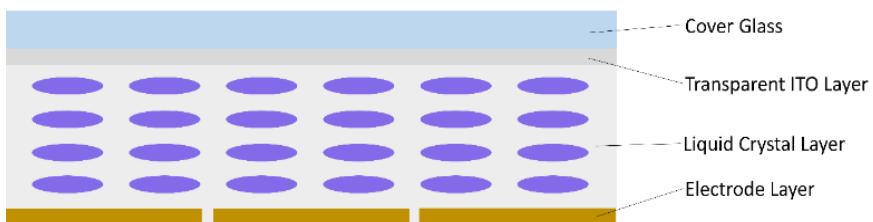


Figure 1 Schematic of Liquid Crystal on Silicon

3.3. Parts List – Accessories

The EXULUS® SLM is thoroughly tested and carefully packed at the factory. The complete package varies according to the EXULUS model. Standard SLMs (EXULUS-HD2, HD3, and HD4) consist of a main unit with a built-in SLM panel and relevant accessories. The High-Power SLMs (EXULUS-HD2HP and HD3HP) contains a main unit, an adapter board, an SLM head, and additional accessories. The adapter board and SLM head are pre-installed on the main unit.

Accessories of standard SLM:

- Power Supply (Item # DS12)
- USB Cable
- HDMI*-Compatible Cable
- HDMI-Compatible to DP*-Compatible Cable
- USB Drive with Software and Manual
- Hex Key Thumbscrew (Item # HKTS-5/64)

Accessories of High-Power SLMs:

- Power Supply (Item # DS12)
- USB Cable
- HDMI-Compatible Cable
- HDMI-Compatible to DP-Compatible Cable
- USB Drive with Software and Manual
- 1.3 mm Hex Key
- 2 mm Ball Driver
- Ø2" Dust-Proof Tape
- Tubing Clip
- 2.5 mm Stereo Cable for Thermistor Connection to Liquid Cooling System (Item # LK220)
- CPC® Valved Quick-Connection Fittings for 4.3 mm (0.17") Inner Diameter Hose
- CPC® Valved Quick-Connection Fittings for 6.0 mm (0.24") Inner Diameter Hose



Figure 2 Standard SLM, with Main Unit and Removable Dust Cover Installed



Figure 3 High-Power SLM, Main Unit with Adapter Board and SLM Head Pre-mounted



Figure 4 Power Supply
(Item # DS12)



Figure 5 USB Cable



Figure 6 HDMI-Compatible Cable



Figure 7 HDMI-Compatible to
DisplayPort-Compatible Cable



Figure 8 USB Drive with Software
and Manual



Figure 9 Hex Key Thumbscrew
(Item # HKTS-5/64)



Figure 10 CPC® Valved Quick-Connection Fittings for 6.0 mm (0.24") Inner Diameter Hose, 2 pcs



Figure 11 CPC® Valved Quick-Connection Fittings for 4.3 mm (0.17") Inner Diameter Hose, 2 pcs



Figure 12 2.5 mm Stereo Cable for Thermistor Connection with Liquid Cooling System (Item # LK220)



Figure 13 1.3 mm Hex Key



Figure 14 2 mm Balldriver (Item # BD-2M)



Figure 15 Tubing Clip, 4 pcs



Figure 16 Ø2" Protective Tape for SLM Head, 4 pcs

***Note:** HDMI is a trademark or registered trademark of HDMI Licensing Administrator, Inc. DisplayPort is a trademark owned by the Video Electronics Standards Association (VESA) in the United States and other countries. The use of such trademarks by Thorlabs does not constitute or imply any affiliation with or sponsorship, approval, certification, or endorsement by their respective trademark owners of Thorlabs or any Thorlabs products. All references by Thorlabs to such trademarks are for identification purposes only.

3.4. Operating Elements

3.4.1. Overview



Figure 17 Front View of Standard SLMs

Callout	Description
1	Horizontal & Vertical Fine Adjusters
2	Power Input
3	HDMI-Compatible Connector
4	Mini-B USB 2.0 Connector
5	Trigger Output Connector (SMA)
6	Power Switch
7	30 mm Cage System Mounting Holes (4-40 Tap, 4 Places)
8	SLM Panel

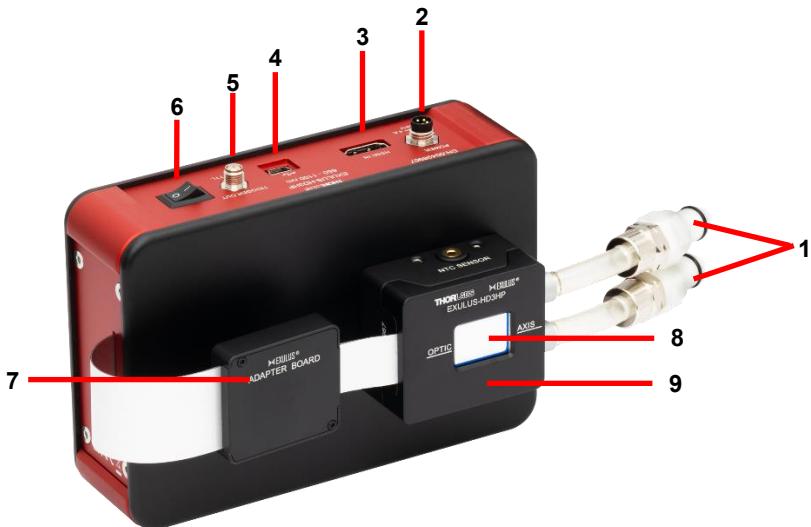


Figure 18 Front View of High-Power SLMs

Callout	Description
1	CPC® Valved Quick-Connection Fittings for 4.3 mm (0.17") Inner Diameter Hose
2	Power Input
3	HDMI-Compatible Connector
4	Mini-B USB 2.0 Connector
5	Trigger Output Connector (SMA)
6	Power Switch
7	Adapter Board
8	SLM Panel
9	SLM Head

3.4.2. Horizontal and Vertical Fine Adjusters (Standard SLMs)

Adjust the horizontal and vertical tilt of the Liquid Crystal panel. The designed adjustment range is $\pm 3.2^\circ$ for both horizontal and vertical.

3.4.3. SLM Head (High-Power SLMs)

The SLM head integrates a built-in liquid cooling module and an NTC thermistor. The NTC thermistor temperature can be read out by Thorlabs' LK220 liquid chiller or TSP01 temperature logger, as well as any third-party temperature logger compatible with the thermistor pin assignment once connected to a 2.5 mm stereo jack (see below).

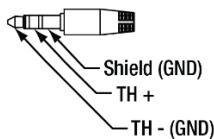


Figure 19 Pin Diagram for Connecting to the Thermistor

The SLM head is compatible with the Thorlabs 30 mm cage system, as well as our Polaris 1" mirror mount (Item # POLARIS-K1E) for additional panel tip/tilt adjustments. Two valved coupling inserts for 1/4" diameter hose are pre-installed for easy connection to Thorlabs' cooling system (Item # LK220), which is the recommended cooling system for EXULUS-HD3HP. For more information, please refer to Section 4.1.

3.4.4. Trigger Output Connector (SMA)

The trigger output connector (female SMA) on the SLM generates an output signal which can be used to synchronize external devices with the SLM.

The output signal is 5 V TTL with a pulse width of 54 μ s. The frequency follows the refresh rate of the SLM panel.

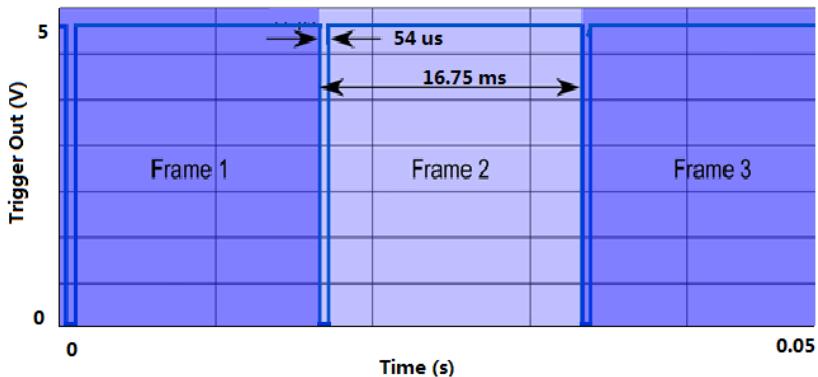


Figure 20 Trigger Timing Graph

3.4.5. Holes for the 30 mm Cage System (Standard SLMs)

These 4-40 mounting holes provide compatibility with the Thorlabs 30 mm cage system.

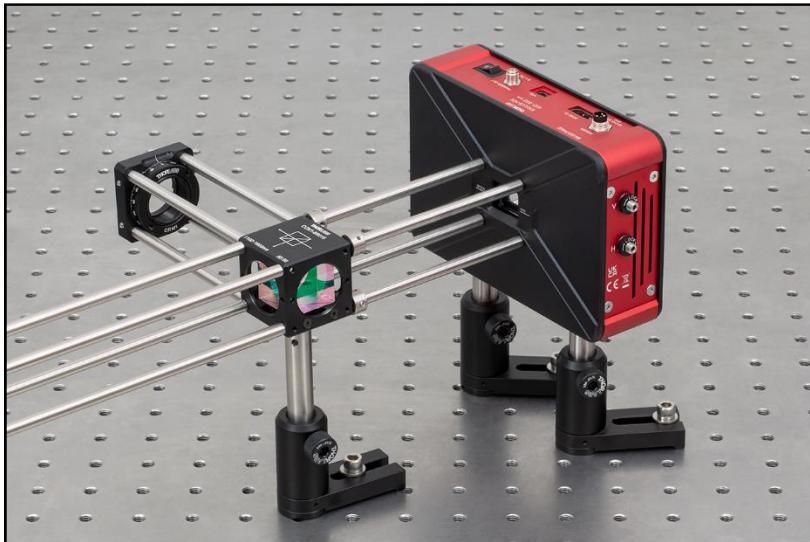


Figure 21 SLM with Attached 30 mm Cage System

3.4.6. Post Mounting Holes

The mounting holes shown below in Figure 22 and Figure 23 are designed for Thorlabs' optical posts. Note that these are universal tapped holes which accept both 8-32 and M4 threaded screws. Therefore, either imperial or metric posts are compatible (e.g.: Item # TR2 or TR50/M).



Figure 22 Two Mounting Holes on Bottom, Standard SLMs



Figure 23 Two Mounting Holes on Bottom, High-Power SLMs

3.4.7. Removable Dust Cover (Standard SLMs)

Prior to shipping, a magnetically coupled dust cover is installed on the front face of the Liquid Crystal panel. Remove it before using your SLM. While using the SLM, the dust cover can be mounted on the back panel of the SLM main unit, as illustrated in Figure 24.



Figure 24 Two Mounting Holes on the Side and Cover Plate Storage on the Back (Standard SLMs)

Chapter 4 Setup and Software Operation

4.1. Installing the SLM



SHOCK WARNING



High voltage inside. To avoid electrical shock, before powering up, make sure that the ground pin of the power cord is correctly connected to the ground connector in the power socket. Improper grounding can cause electric shock resulting in severe injury or even death. Do not operate without the cover installed.



WARNING



This unit must not be operated in explosive environments.



WARNING



Transportation and delivery may cause the SLM to be warm or cool upon receipt. Please wait for the whole device to reach room temperature before attempting to operate.



WARNING



Do not operate in wet/damp conditions. Do not obstruct the air ventilation slots in the housing!

To operate your SLM properly, place it on your lab table. For standard SLMs, two tapped holes are available for mounting on either the side or the bottom, as shown in Figure 25.



Figure 25 Post Mounting the standard SLM with Thorlabs' Ø1/2" Posts

For High-Power SLMs, the following two mounting methods are available:

- **All-in-One Mode**, two tapped holes are available for mounting on the bottom.

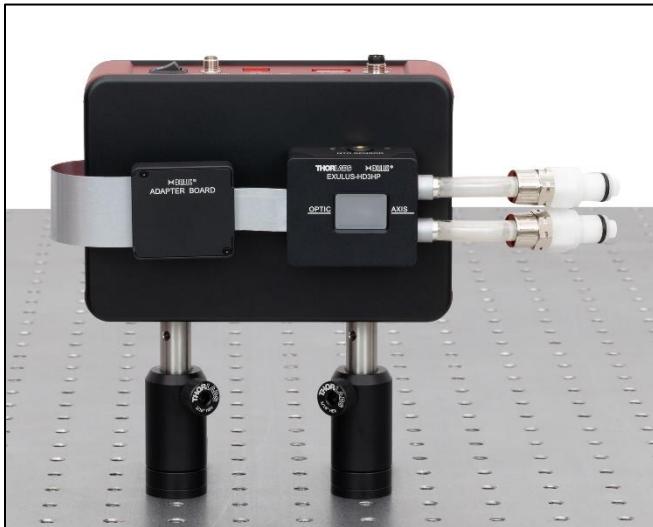


Figure 26 Post Mounting the High-Power SLM, All-in-One Mode

- **Separate-Panel Mode**, two additional tapped holes on the adapter board and SLM head are available for mounting on the bottom.



Figure 27 Post Mounting the High-Power SLM, Separate-Panel Mode

Here the SLM head is compatible with the POLARIS-K1E Ø1" Kinematic Mirror Mount for additional panel tip/tilt adjustments.

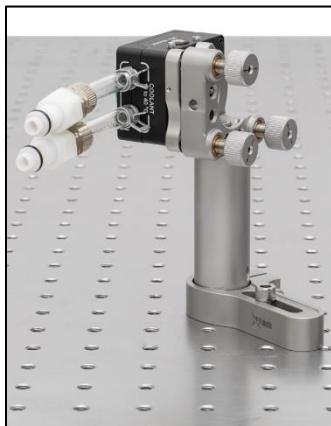


Figure 28 SLM Head Mounted with a Previous Generation Polaris-K1 Ø1" Kinematic Mirror Mount

Note:

Always use the recommended Ø1" Polaris Kinematic Mirror Mount (Item # POLARIS-K1E) or other kinematic mirror mounts with flat, front-face plates to mount the SLM head.

4.1.1. Mounting Method Conversion of High-Power SLMs

For the High-Power SLMs, the All-in-One mounting method supports height adjustment only. To enable extra panel tip/tilt adjustments and a more flexible

panel mounting configuration, convert the All-in-One mode to Separate-Panel mode.

To convert your SLM to Separate-Panel Mode, please always follow these steps:

- **Step 1: Wear anti-electrostatic band and talc-free gloves before any operations.** When the adapter board's cover is removed, **DO NOT touch any exposed electrical contacts.**
- **Step 2: Disconnect the FPC from the Adapter Board**

Using the included 1.3 mm hex key, remove the two locking screws from the adapter board's cover (marked with red in Figure 29).

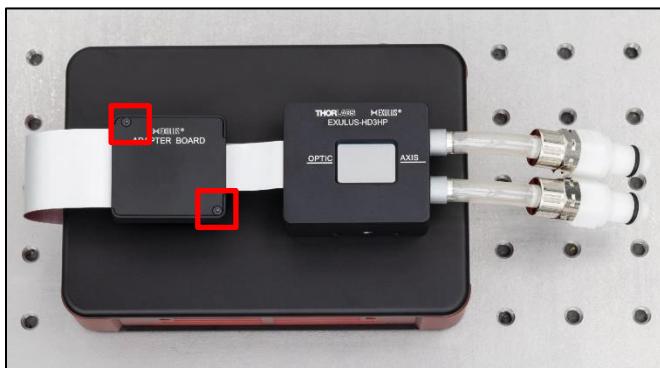


Figure 29 Front View of a High-Power SLM Unit

Remove this cover to expose the adapter board. Flip open the black latch that secures the FPC connector (marked with red in Figure 30) and carefully disconnect the panel side FPC.

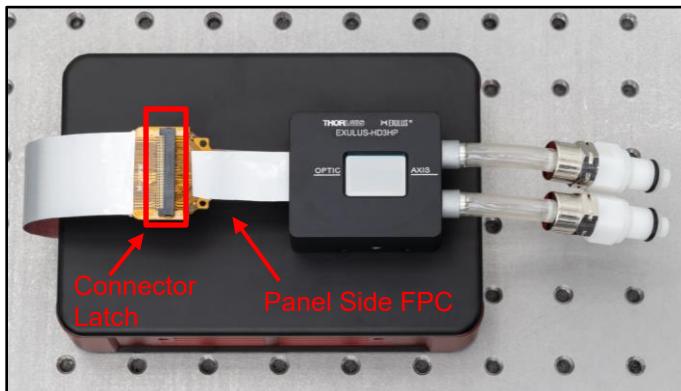


Figure 30 FPC Connection of Adapter Board

- **Step 3: Detach SLM Head from Main Body**

Using the included 2 mm balldriver, loosen the four screws on the sides of the SLM head (two on the top and two on the bottom, as shown in Figure 31). Once these screws are loosened, slide the SLM head free from the main body (see Figure 32).



Figure 31 Top View of a High-Power SLM Unit

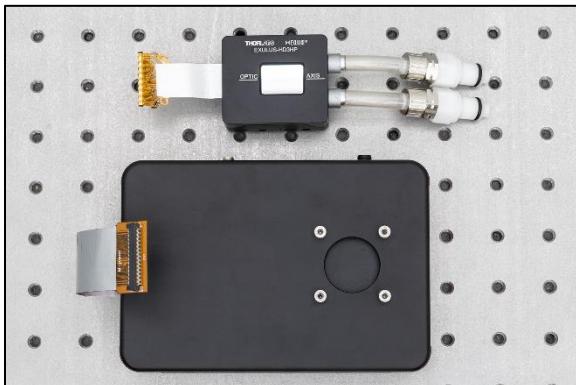


Figure 32 SLM Head Detached from Main Body

- **Step 4: Mount SLM Head and Main Body**

To reassemble all the parts, it is always recommended to mount the SLM head properly as the first step. Use a standard post (8-32 / M4 Taps) or a Polaris-K1E Ø1" Kinematic Mirror Mount for mounting, then adjust the height of the head to make sure that the incident beam illuminates the center of the panel's active area.

Once the SLM head is fixed, mount the main body nearby using standard posts (8-32 / M4 Taps) and adjust its height to match the SLM head so that the FPC can be reconnected in the next step (Figure 33).

- **Step 5: Reconnect SLM Head and Main Body**

Insert the panel side FPC back into the connector on the adapter board, taking care to seat it fully and with the proper alignment (see examples in Figure 34). Failure to do so can cause damage to the panel when powering on. Flip the black connector latch closed to secure the FPC.

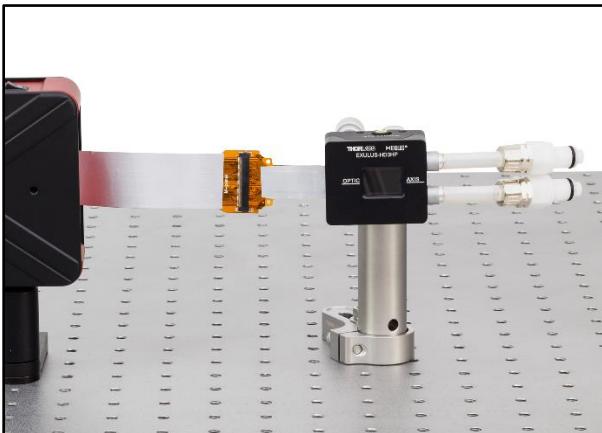


Figure 33 Re-connected FPC Between Main Body and SLM Head

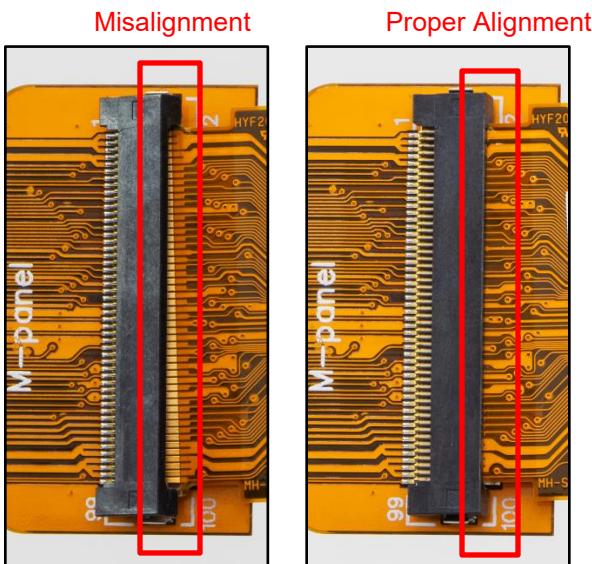


Figure 34 Examples of Improper and Proper Seating of FPC in Connector

Finally, reattach the adapter board's cover using the two locking screws from Step 2. This completes the mounting process, as shown in Figure 35:



Figure 35 Separate-Panel Mode

- **Step 5: Check Image on SLM Panel**

Complete the software installation, as described in Section 4.3. Then, upload an image to the SLM panel using File Mode (see Figure 46). Check that the image is being displayed on the active area of the SLM panel, which can be done by placing a linear polarizer with its T-axis 45° to the optic axis of the SLM panel.

Note:

If any dead pixels/lines are observed, or if parts of the image are missing, try reseating the FPC in the adapter board connector. If the problem persists, please **contact Tech Support**.

4.2. Hardware Requirements

To run the EXULUS® SLM software, you need to have a computer that meets the following hardware requirements:

- Operating System: Windows 7 64-bit, or Windows 10 64-bit
- One Available High-Speed USB 2.0 Port
- CPU: Intel Core i3 or Above
- RAM: 2 GB or More
- One available HDMI-Compatible Port or DisplayPort.

4.3. Installing the Software

The EXULUS® SLM software can be downloaded from the Thorlabs website or from the bundled USB drive. The installation contains 2 parts:

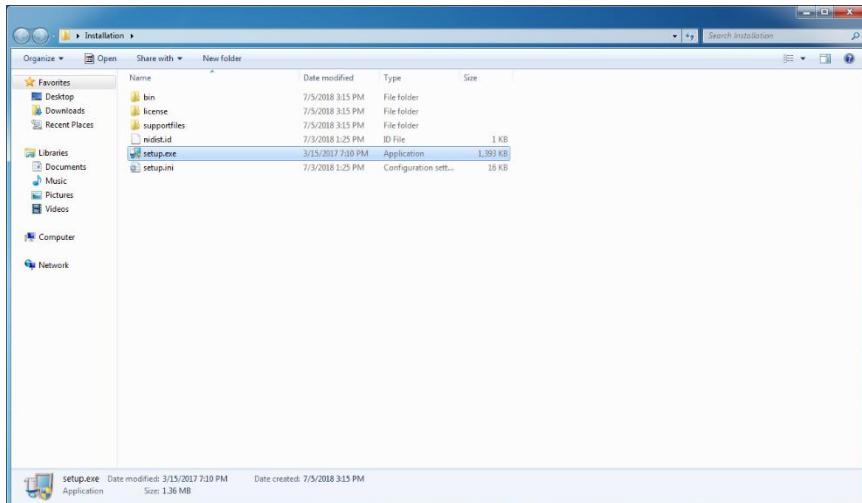
- Installation of Main UI
- Installation of USB Driver

Note:

Do not connect the SLM to your PC prior to software installation. Administrator privilege is required during installation.

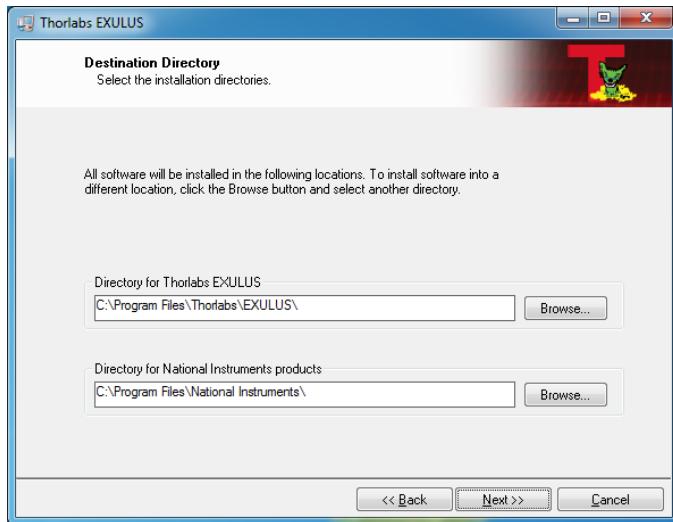
The following procedures describe the installation in Windows 7 64-bit.

- Start the Install Shield Wizard by double-clicking “**setup.exe**”.

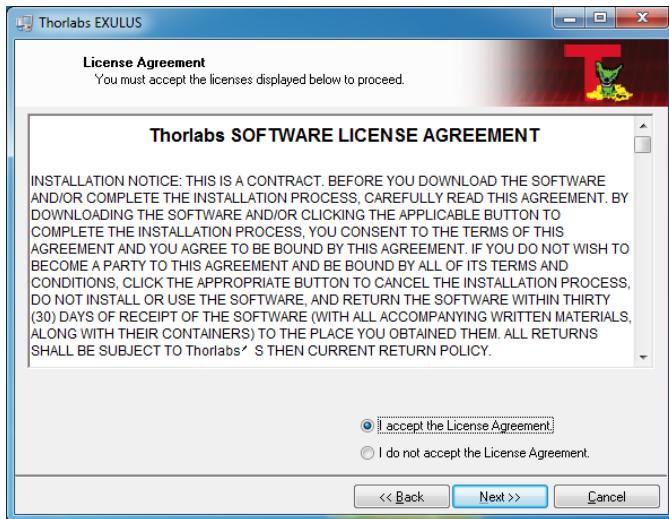


Installation of Main UI

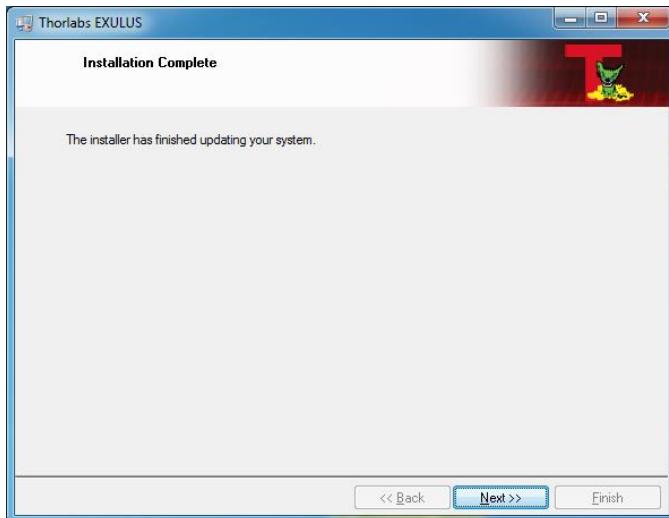
- The main UI is installed in your computer first. Click the “Next” to continue.



- Click “I accept the License Agreement” and “Next” to continue the installation.



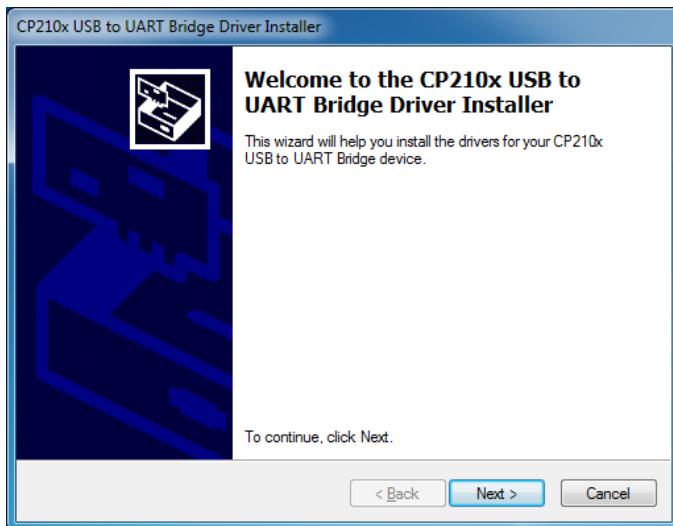
- Click “Next” to finish the installation of the main UI.



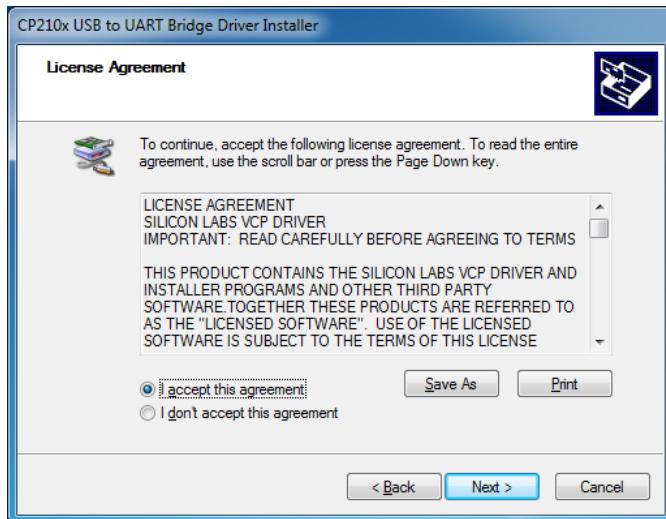
Installation of CP210x USB to UART Bridge Driver

The installer proceeds to install the CP210x USB to UART Bridge driver. Wait for the installation to be started.

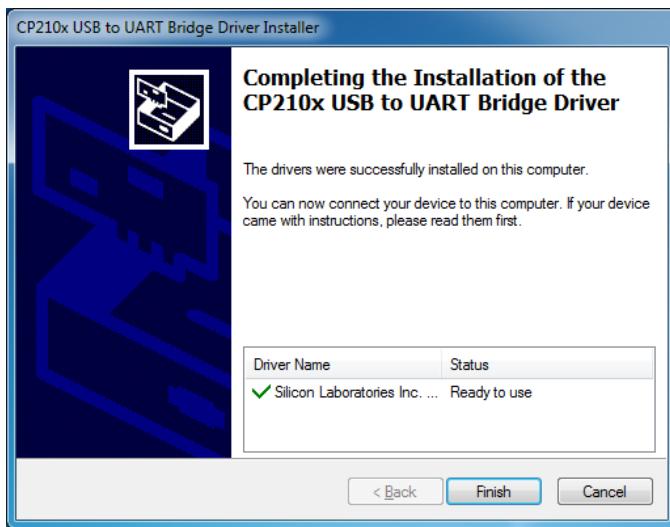
- Click the “Next” to continue.



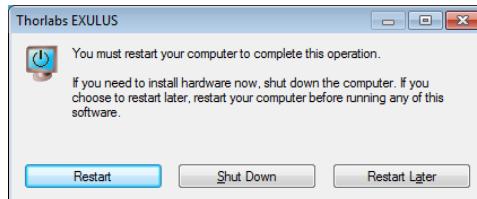
- Click “I accept the License Agreement” and “Next” to continue the installation.



- Click “Finish” to complete the installation.



Please reboot your computer when prompted. Click “Restart” to complete the EXULUS® SLM software installation.



4.4. Connect the SLM to the PC

To operate your SLM with your computer, follow the steps below:

- Connect the included power supply to the mains power and the DC input on the SLM.
- Connect the SLM to a High-Speed USB 2.0 port of your computer. Use only the cable that is bundled with the SLM or a cable qualified for High-Speed USB 2.0 standard.
- Connect the SLM to a HDMI- (or DP-) compatible port of your computer. Use the provided HDMI-compatible or DP- to HDMI-compatible cable.

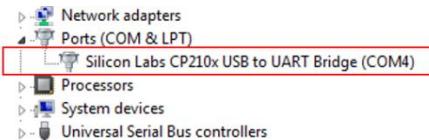
- Remove the dust cover (standard SLMs only) and switch the power switch to the “ON” position.

Note:

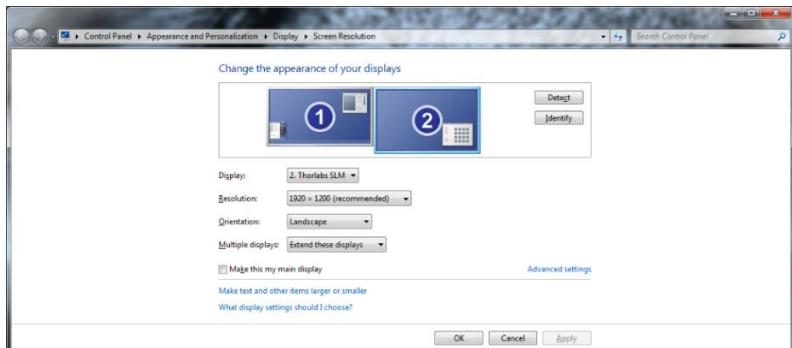
For standard SLMs, the Liquid Crystal panel is warmed up after the power is turned on. It may take up to about 30 minutes to stabilize. Since the phase of the SLM panel is slightly dependent on temperature, for applications which are sensitive to phase fluctuation, we recommend waiting for 30 minutes after power on before operating.

For the High-Power SLMs, we recommend using a liquid chiller (item # LK220) to stabilize the panel temperature after powering on.

- Wait for Windows to recognize the hardware. The SLM connects to the computer as a USB Serial Port. Connection can be verified in the Device Manager, under the Ports list.



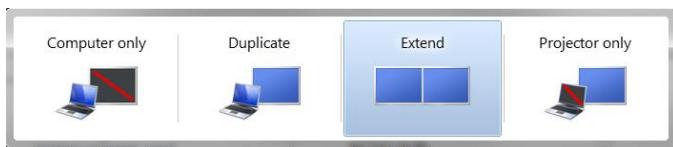
- Wait for Windows to detect the SLM display. Check the connection of the SLM panel by right-clicking on the desktop and choose Screen Resolution. Once the SLM display has been detected, your computer will show it as an additional display.



Note: If the SLM display is not shown as extended, try the **Win + P** key combination:



and configure the SLM display in Extended Mode.



Then, run the application software “Thorlabs EXULUS” from the desktop icon. It may take several seconds before the software is ready to connect.

4.5. Software GUI

The Software GUI provides complete control of SLM panel. If a High-Power SLM is used, the temperature reading from the liquid chiller (Item # LK220) is also available. It is divided into six functional areas:

- Main Menu
- Sequence Setting
- Preview Window
- Operation Mode
- Display Mode
- Status Bar

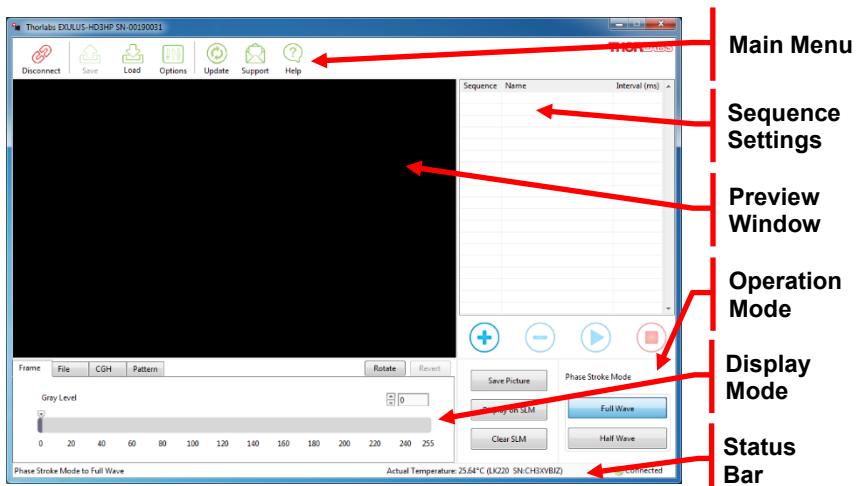


Figure 36 Main UI Window of EXULUS SLM Software

4.5.1. Main Menu

The main menu contains basic connection and software operations.



Figure 37 Main Menu Area of GUI Window

Connect/Disconnect

Connect or disconnect the EXULUS® SLM, and the liquid chiller (Item # LK220) for the High-Power SLMs, from your PC. A connection wizard appears to assist in connecting the devices after clicking the “Connect” button.

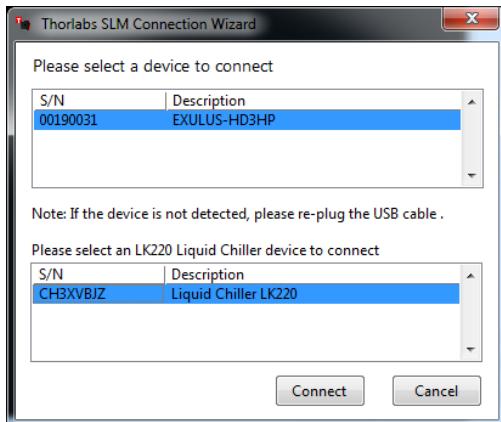


Figure 38 Thorlabs SLM Connection Wizard

As an example, here, “EXULUS-HD3HP” is the model of your SLM, “00190031” represents its serial number, and “CH3XVBJZ” is the serial number of Liquid Chiller LK220.

If there is no EXULUS or Liquid Chiller device listed, check that the power switch is switched to “ON” and the USB cable is properly connected to your computer. Otherwise please check Chapter 5 for a solution.

Select your SLM (and Liquid Chiller if available) and click Connect. All the features are then activated.

Note:

Liquid Chiller selection is only available when the High-Power SLM is selected. If the SLM device is not detected, please reconnect the USB cable to the SLM. The USB driver is pre-configured with a “Power Save / Suspend Mode” after a 10 sec connection, which may cause the device to become invisible to the software.

The SLM software only monitors the LK220 chiller temperature readings. If other functions require software control, do not connect the LK220 chiller from the SLM software UI and use its own software instead.

Save and Load

These two buttons provide the save/load of user-defined sequence settings in XML format.

Options

- **SLM Setting**

- **Screen ID:** Normally, the main computer screen is recognized as Screen ID 1 and the SLM panel as Screen ID 2. However, in some cases, especially for systems with multiple screens, the SLM's Screen ID might be different. Therefore, it needs to be properly set in the SLM Setting Window. Otherwise the SLM does not respond to all the operations by this application.

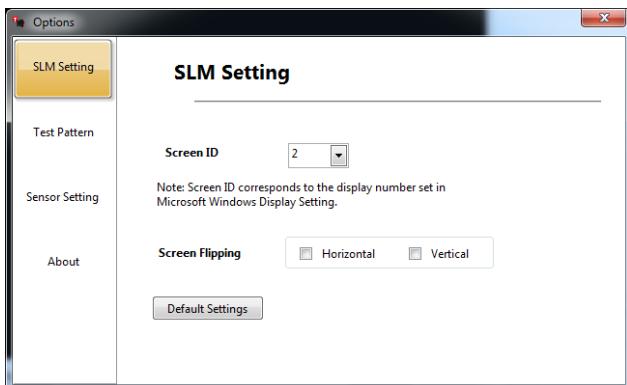


Figure 39 SLM Screen ID Setting

- **Screen Flip:** Flip the SLM panel in the Horizontal or Vertical orientation.
- **Default Settings:** Save the current settings of Screen Flipping and Phase Stroke Mode as default.

Note:

Default settings ensures that the Screen Flipping and Phase Stroke Mode are preserved while unit is switched off.

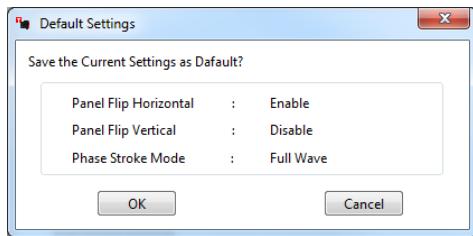


Figure 40 SLM Default Settings

- **Test Pattern:** The SLM contains an internal stair-case test pattern and can be applied directly to your SLM panel. This pattern is not transferred through PC/Laptop connection and is intended for troubleshooting. It returns to the normal Video In mode when the “Option” window is closed.

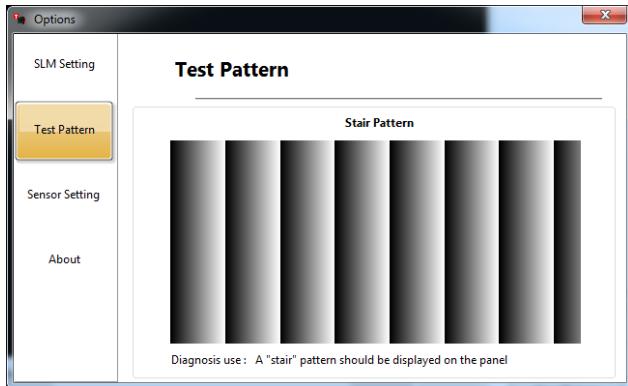


Figure 41 Internal Grayscale Test Pattern

- **Sensor Setting (only available when the LK220 chiller is connected)**
 - **Sensor Mode:**
 - Internal: provides the temperature reading from the output coolant temperature.
 - External: provides the temperature reading from the thermistor of High-Power SLM head read out by the LK220. If the external mode is selected while no sensor is connected to the liquid chiller, an error message as well as alarm will be set off. The liquid chiller will be disabled until the thermistor is connected or the sensor mode is switched to internal. Note that this will not readout the temperature from the Thorlabs' TSP01 or a third-party temperature logger.

- **Temperature Window:** The color of temperature value displayed in status bar changes depending on the reading from the LK220 chiller. Min and Max are the thresholds for changing from black font to red, respectively.

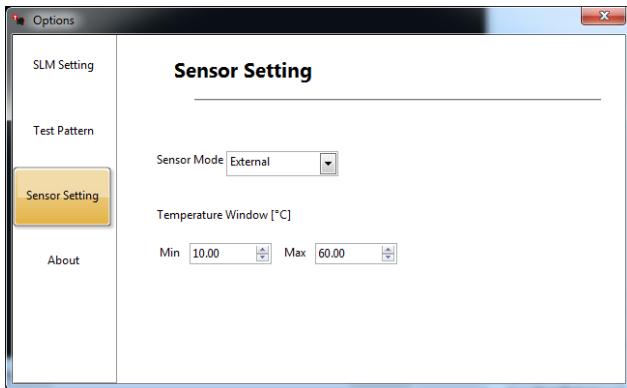


Figure 42 Sensor Setting of the Liquid Chiller

- **About:** Displays the version information about the SLM software. Please have these details available when contacting Thorlabs Technical Support.

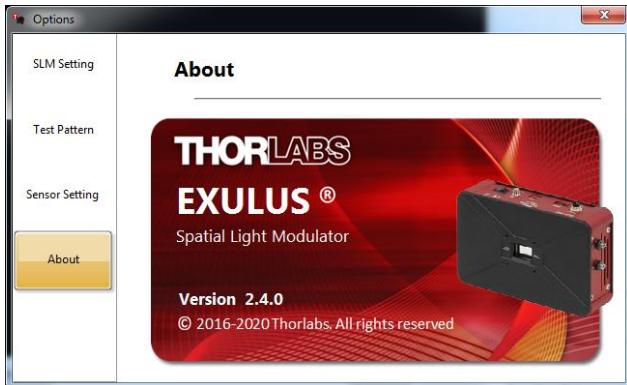


Figure 43 Software Version Information

Update

Updates the software to the latest version if any updates are available.

Support

For technical support, this button links to techsupport@thorlabs.com.

Help

Opens the SLM manual.

Thorlabs Logo

Opens the Thorlabs homepage.

4.5.2. Preview Window

The Preview Window provides a preview of the image to be displayed on the SLM.

4.5.3. Operation Mode

The operation mode provides Phase Stroke Mode selection of both Full Wave and Half Wave, as well as the control setting of the preview image.

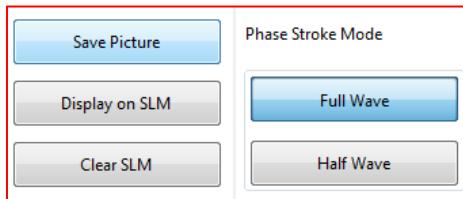


Figure 44 Operation Mode Area

Save Picture

Allows the user to save the current preview pattern as a PNG image format with resolution of 1920 x 1200.

Display on SLM

Uploads the current preview pattern to the SLM.

Clear SLM

Clear the displayed pattern on the SLM panel and reset the SLM with a black background.

Phase Stroke Mode

The Full Wave mode provides a total phase stroke of 2π , while the Half Wave mode offers a total phase stroke of π (at 633 nm for EXULUS-HD2 and EXULUS-HD2HP; at 1064 nm for EXULUS-HD3 and EXULUS-HD3HP; at 1550 nm for EXULUS-HD4).

4.5.4. Display Mode

The EXULUS® SLM software contains four different modes for the image displayed on the SLM panel and the Rotate Function for rotating the image preview.

- Frame Mode
- File Mode
- CGH Mode
- Pattern Mode
- Rotate Function

Frame Mode

By default, the software initially starts with Frame Mode. A uniform gray level from 0 to 255 can be set by the user and a related gray scale pattern is created and shown in the preview window.

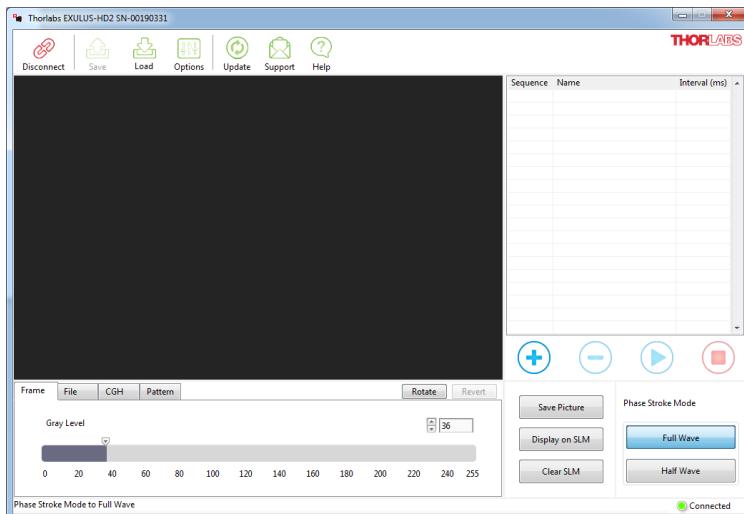
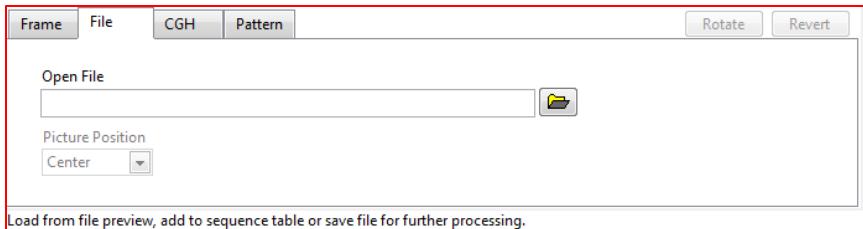


Figure 45 Frame Mode

File Mode

The file mode allows the user to upload a custom pattern in common image format (PNG, JPEG, and BMP).



The uploaded image is converted automatically to 8-bit gray scale. A scaling and/or cropping is applied for images with resolution that is different than the panel and is selected in the Picture Position list.

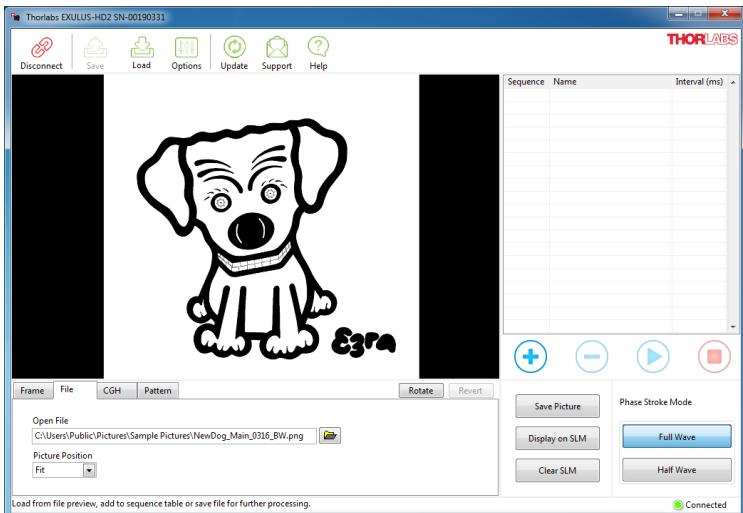


Figure 46 Uploaded PNG File in Fit Position

CGH Mode

Computer Generated Holography (CGH) is a widely used method of digitally generating holographic interference patterns. In this mode, a fast CGH algorithm is applied to generate such patterns.



Figure 47 CGH Mode Settings

A user defined image is converted to its holographic pattern. The Tilt in both X and Y orientation and the focal length (the distance from the SLM, where the hologram is imaged to) of the generated pattern can also be defined. A small preview window shows the input image which can be zoomed by clicking on it.

The uploaded image is converted to 8 bit. Also, the image position and the inversion of black and white can be user-defined before generation. The wavelength, which is set at 633 nm as the default for EXULUS-HD2 (EXULUS-HD2HP), 1064 nm for EXULUS-HD3 (EXULUS-HD3HP), and 1550 nm for EXULUS-HD4, should be set so that it matches the wavelength of the light source.

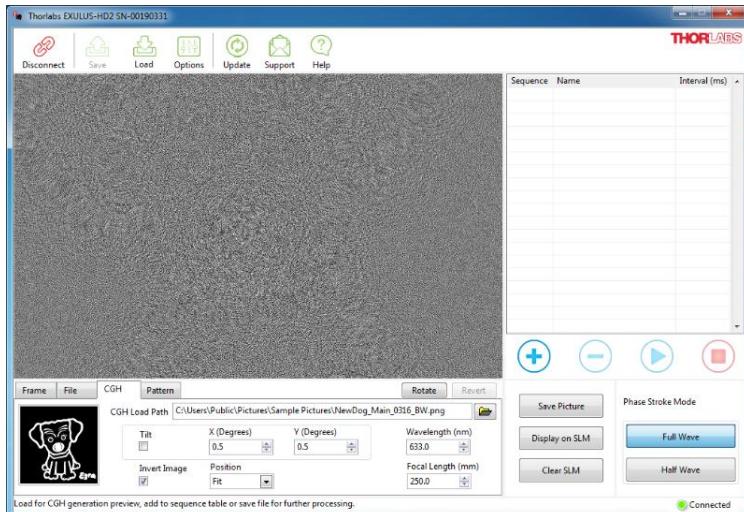


Figure 48 Generated CGH Pattern of Uploaded Image

Pattern Mode

The pattern mode consists of four commonly used patterns: Fresnel Lens, Diffraction, Vortex, and Cubic Phase.

In Fresnel Lens mode, the wavelength and focal length can be defined by the user. It is used to primarily focus an incoming collimated beam to a spot at approximately the defined focal length.

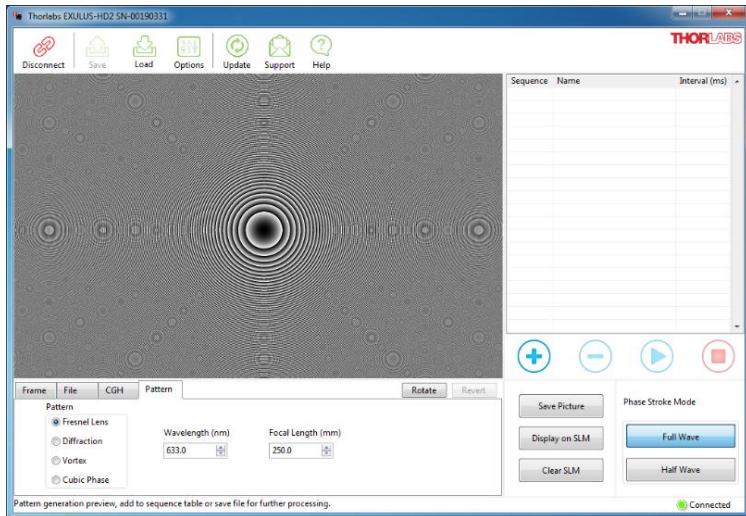


Figure 49 Generation of Fresnel Lens Pattern

The Diffraction mode contains three parameters: wavelength, diffraction angle, and rotation angle. It is used to tilt/steer the incoming beam to a specific angle.

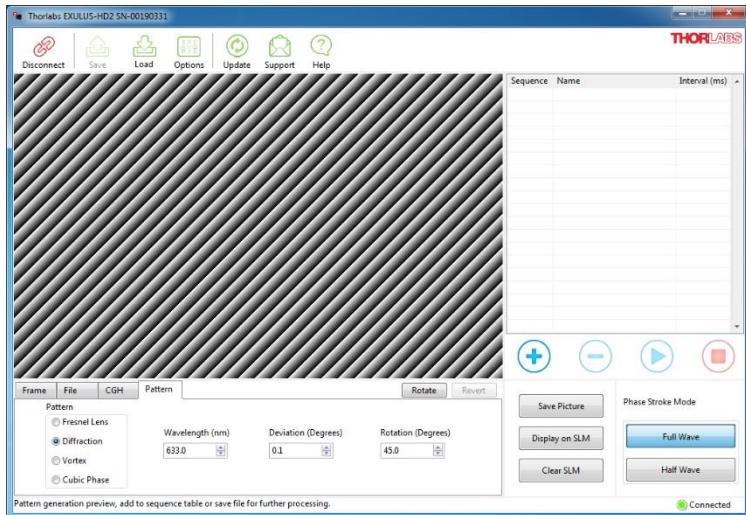
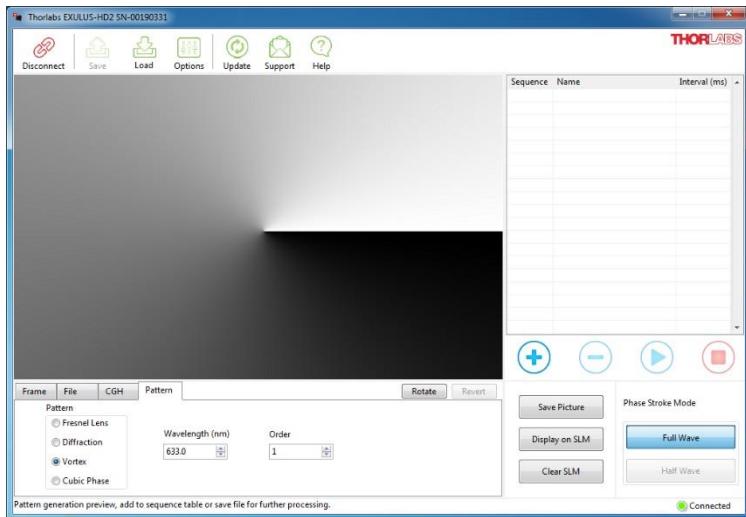
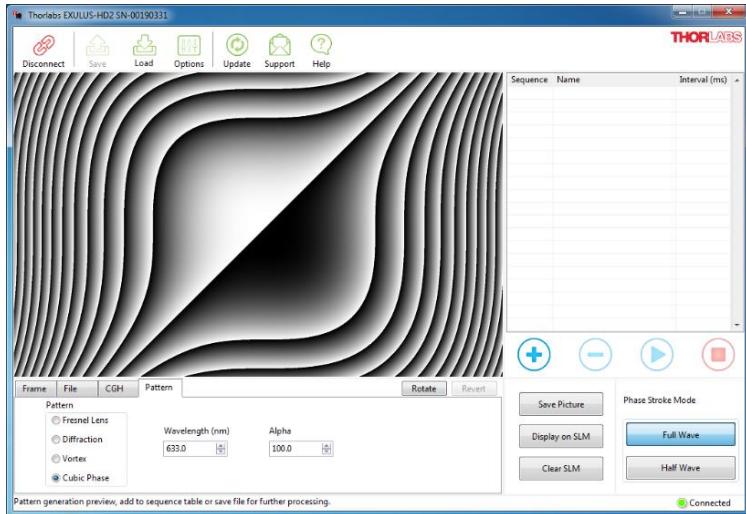


Figure 50 Generation of Diffraction Pattern

The Vortex mode contains two parameters: wavelength and pattern order m. This pattern creates a helical output beam and contains a characteristic donut beam profile.

**Figure 51 Generation of Vortex Pattern**

The Cubic Phase mode contains two parameters: wavelength and alpha. It is used to generate a non-diffracted beam with self-recovery characteristics, commonly called an Airy beam.

**Figure 52 Generation of Cubic Pattern**

Rotate Function

The Rotate button allows users to rotate the image in the Preview Window clockwise by 90°. The image can be restored to default by clicking the Revert button.

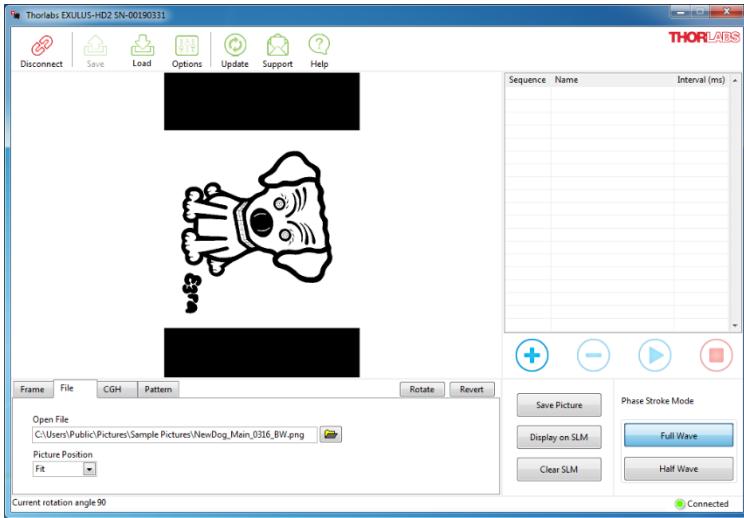


Figure 53 Image Rotation in Preview Window

4.5.5. Sequence Setting

The Sequence Setting table consists of a list of pre-defined patterns and four control buttons. Each pattern is regarded as a frame and is displayed sequentially.

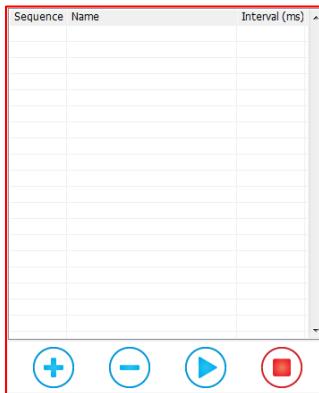


Figure 54 Sequence Setting Area

User defined patterns (up to 50 frames) are supported in the sequence table. The default interval is 300 ms.

The four control buttons from left to right are “Add to Sequence”, “Remove from Sequence”, “Play Sequence” and “Stop Sequence”.

Add to Sequence

Add the current preview pattern into the sequence table.

Remove from Sequence

Remove the selected pattern from the sequence table.

Play the Sequence

Run the sequence with defined interval. While playing the sequence, this button can be used to temporarily pause the sequence playing.

Stop the Sequence

Stop and quit the sequence mode.

4.5.6. Status Bar

The status bar displays information about the system status, actual temperature reading from the liquid chiller (if connected) and the SLM device status.



Chapter 5 Troubleshooting

Symptom	Possible Cause	Solution
SLM is not detected by Software	USB driver times out before connection	Reconnect the USB cable to the SLM then click Connect
System does not start	No power is supplied to the device	Connect the power supply
	Power switch is off	Switch on the power
	Power cord is broken	Change power cord
	Power supply is broken	Contact Thorlabs Technical Support
GUI does not start	USB port is not connected	Connect the USB cable
	USB cable is broken	Change USB cable
System does not output correct pattern	HDMI-compatible connector is not connected	Connect the HDMI-compatible cable
	HDMI-compatible cable is broken	Change HDMI-compatible cable
	SLM display is not shown as extended (Refer to Section 4.4)	Set the SLM display as extended (Refer to Section 4.4)
	Incorrect SLM ID setting	Change the SLM ID (Refer to Section 4.5.1)
	SLM panel failure	Contact Thorlabs Technical Support

If the problem cannot be identified, contact Thorlabs Technical Support at techsupport@thorlabs.com.

Chapter 6 Specifications

Item #	EXULUS-HD2	EXULUS-HD3	EXULUS-HD4
Type	Liquid Crystal on Silicon (LCoS), Reflective, Phase Only		
Operating Wavelength	400 - 850 nm	650 - 1100 nm	1550 nm
Panel Resolution	1920 x 1200 (WUXGA)		
Panel Active Area	15.42 mm x 9.66 mm		
Pixel Pitch	8 μ m		
Fill Factor	>92%		
Reflective Coating	Aluminum		Dielectric
Average Reflectance	80% (Typical)		82% (Typical)
Phase / Retardance Range	2 π at 633 nm (Full Wave)	2 π at 1064 nm (Full Wave)	2 π at 1550 nm (Full Wave)
	π at 633 nm (Half Wave)	π at 1064 nm (Half Wave)	π at 1550 nm (Half Wave)
Angle of Incidence ¹	0°		
Optic Axis	0°		
Reflected Wavefront Distortion	< $\lambda/2$ @ 633 nm	<0.4 λ @ 633 nm	
Frame Rate	60 Hz		
Fluctuation / Flickering (RMS) ²	<0.01%	<0.05%	<0.15%
Beam Deviation by Panel Tip / Tilt	$\pm 3.2^{\circ}$		
Trigger Output	SMA Female		
Trigger Output High Voltage Level	5 V (TTL)		
Trigger Output Pulse Width	54 μ s		
Dimension (L x W x H) ³	155.9 mm x 104.3 mm x 42.0 mm		
Weight	0.76 kg		
Storage Temperature	0 to 60 °C		
Operating Temperature ⁴	10 to 40 °C		
PC Connection	HDMI-Compatible and USB 2.0		
Bit Depth	8 Bit, 0 - 255 Gray Level		

1. Other angles of incidence will result in phase shifts that differ from the programmed pattern. Angles of up to 10° are possible without significantly affecting performance.
2. Fluctuation / Flickering is the phase fluctuation as the percentage of the entire phase range and is dependent on the current phase setting. The value stated is the maximum fluctuation and typically occurs at a quarter of the phase range.
3. The reported length dimension includes the maximum travel range of the adjuster knob. The specified height does not include the dust cover; when included, this dimension is nominally 46 mm.
4. Ambient temperature fluctuations may cause the characteristics of your SLM to change. Using it at an ambient temperature of 25 °C is recommended.

Item #	EXULUS-HD2HP	EXULUS-HD3HP
Type	Liquid Crystal on Silicon (LCoS), Reflective, Phase Only	
Operating Wavelength	400 - 850 nm	650 - 1100 nm
Panel Resolution	1920 x 1200 (WUXGA)	
Panel Active Area	15.42 mm x 9.66 mm	
Pixel Pitch	8 μ m	
Fill Factor	>92%	
Reflective Coating	Aluminum	
Average Reflectance	80% (Typical)	
Phase / Retardance Range ¹	2 π at 633 nm (Full Wave)	2 π at 1064 nm (Full Wave)
	π at 633 nm (Half Wave)	π at 1064 nm (Half Wave)
Angle of Incidence ²	0°	
Optic Axis	0°	
Reflected Wavefront Distortion	< $\lambda/2$ @ 633 nm	<0.4 λ @ 633 nm
Optical Power Handling ³	\leq 200 W/cm	
Frame Rate	60 Hz	
Fluctuation / Flickering (RMS) ⁴	<0.01%	<0.15%
Beam Deviation by Panel Tip / Tilt	N/A	
Trigger Output	SMA Female	
Trigger Output High Voltage Level	5 V (TTL)	
Trigger Output Pulse Width	54 μ s	
Dimension (L x W x H)	220.0 mm x 104.0 mm x 68.0 mm (All-in-One Mode) 420.0 mm x 104.0 mm x 42.0 mm (Separate-Panel Mode)	
Weight	0.7 kg	
Storage Temperature	0 to 60 °C	
Operating Temperature ⁵	10 to 40 °C	
PC Connection	HDMI-Compatible and USB 2.0	
Bit Depth	8 Bit, 0 - 255 Gray Level	
Connector Type (for Tubing)	CPC® Valved Thumb Latch Quick-Disconnect Fitting	
Tubing Dimensions	0.17" (4.3 mm) Inner Diameter (Pre-installed) 0.24" (6 mm) Inner Diameter (Optional)	
Type	SLM Head Thermistor VISHAY NTC LE413 ($R_0 = 10 \text{ k}\Omega$ @ $T_0 = 25^\circ\text{C}$, $B = 3435 \text{ K}$)	
Accuracy	$\pm 0.5^\circ\text{C}$ (@ 25 °C)	

1. Phase/retardance range values are for 30 °C when used with the LK220 liquid chiller.
2. Other angles of incidence will result in phase shifts that differ from the programmed pattern. Angles of up to 10° are possible without significantly affecting performance.
3. Specification with Liquid Chiller (Item # LK220)
4. Fluctuation / Flickering is the phase fluctuation as the percentage of the entire phase range and is dependent on the current phase setting. The value stated is the maximum fluctuation and typically occurs at a quarter of the phase range.
5. Ambient temperature fluctuations may cause the characteristics of your SLM to change. Using it at an ambient temperature of 25 °C is recommended.

Chapter 7 Mechanical Drawings

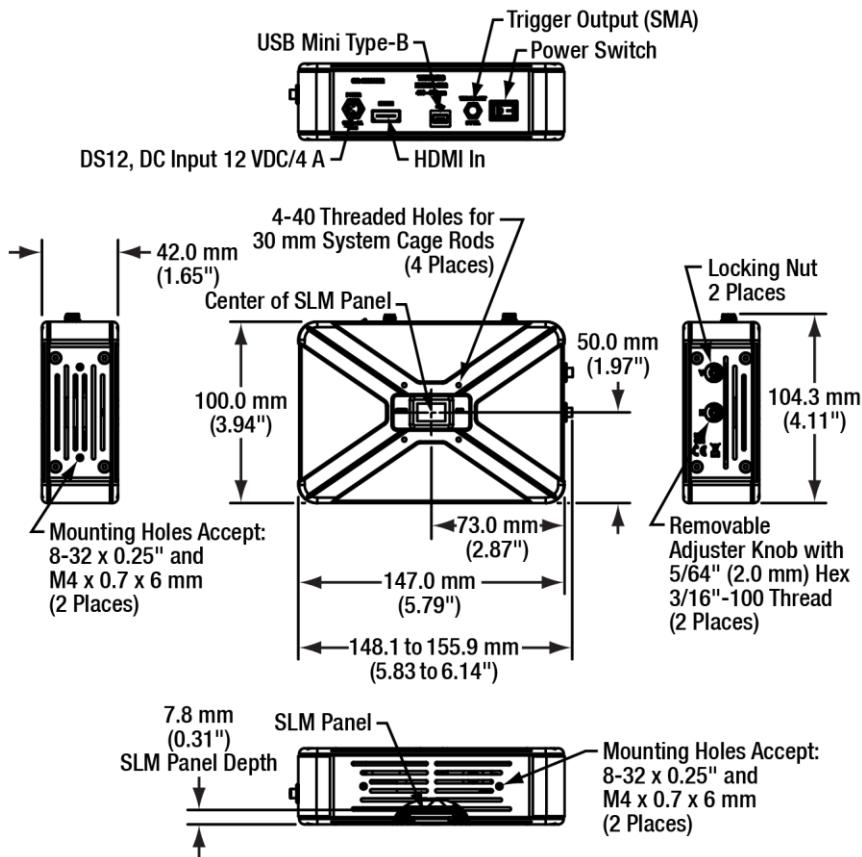


Figure 55 EXULUS-HD2, EXULUS-HD3, and EXULUS-HD4 Diagram

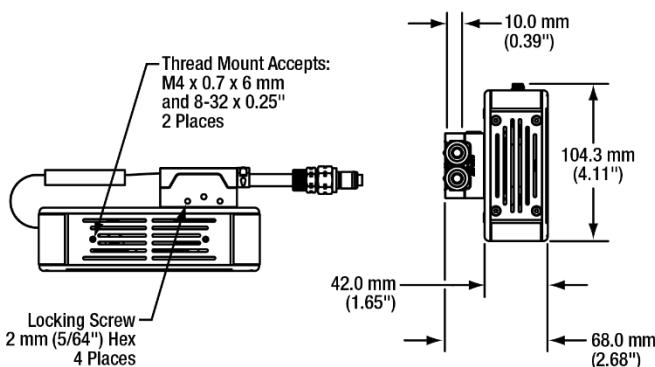
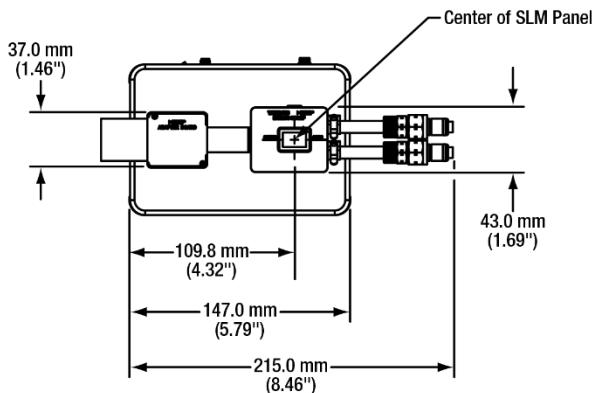
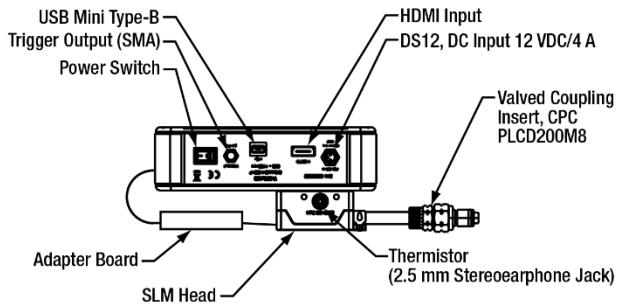


Figure 56 EXULUS-HD2HP and EXULUS-HD3HP All-in-One Configuration Diagram

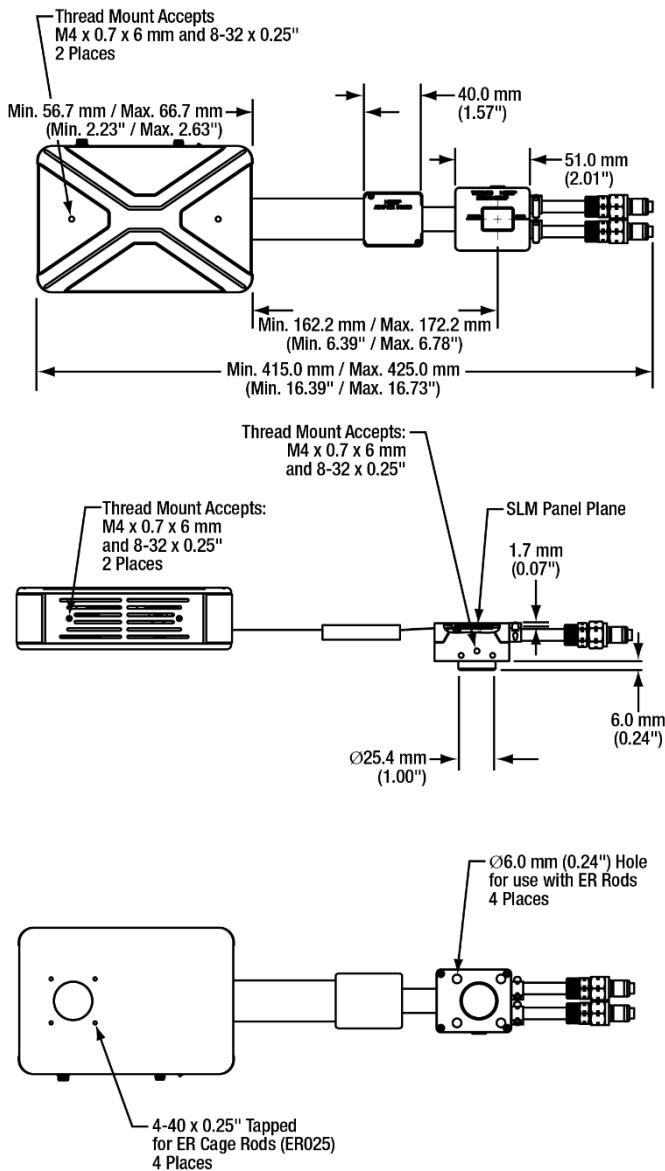


Figure 57 EXULUS-HD2HP and EXULUS-HD3HP Panel-Separate Configuration Diagram

Chapter 8 CE/FCC Certification

Declaration of Conformity

**Thorlabs Optical Electronic Technology(Shanghai) Co.,Ltd
Room A101, No.100, Lane 2891, South Qilianshan Rd., Shanghai**

declares under it's own responsibility, that the product:

2D Spatial Light Modulator

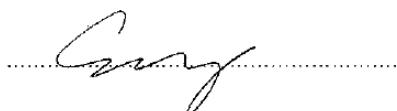
Model No.: **EXULUS-HD2, EXULUS-HD3, EXULUS-HD4**

fulfills the requirements of the standard

CISPR PUB. 22, FCC Part 15 Subpart B

and therefore corresponds to the regulations of the directive.

Shanghai, 15. October 2019



Place and date of issue

Name and signature of authorized person



Declaration of Conformity

We: Thorlabs Optical Electronic Technology (Shanghai) Co., Ltd
of: Room A101, No.100, Lane 2891, South Qilianshan Rd, Shanghai

In accordance with the following Directive(s):

2014/35/EU	Low Voltage Directive (LVD)
2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Use of Certain Hazardous Substances (RoHS)

hereby declare that:

Model: EXULUS-HD2, EXULUS-HD3, EXULUS-HD4
Equipment: 2D Spatial Light Modulator for Visible
2D Spatial Light Modulator for Near Infrared
2D Spatial Light Modulator for 1550 nm

Is in conformity with the applicable requirements of the following documents:

EN 61010-1:2010 (Third Edition)
EN 61326-1:2013
EN 61326-2-1:2013
EN 61326-2-2:2013
EN 55011:2009 + A1:2010 (Class B)
EN 61000-3-2:2014
EN 61000-3-3:2013
EN 61000-4-2:2008
EN 61000-4-3:2006 + A1:2007 + A2:2010
EN 61000-4-4:2012
EN 61000-4-5:2014 + A1:2017
EN 61000-4-6:2013
EN 61000-4-8:2009
EN 61000-4-11:2004 + A1:2017

and which, issued under the sole responsibility of Thorlabs, is in conformity with Directive 2011/65/EU of the European Parliament and of the Council of 8th June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, for the reason stated below:

does not contain substances in excess of the maximum concentration values tolerated by weight in homogenous materials as listed in Annex II of the Directive.

I hereby declare that the equipment named has been designed to comply with the relevant section of the above referenced specifications, and complies with all applicable Essential Requirements of the Directives.

Signed:

on: 15. October 2019

Name: Shanshan Song
Position: General Manager

Declaration of Conformity

**Thorlabs Optical Electronic Technology (Shanghai) Co., Ltd
Room A101, No.100, Lane 2891, South Qilianshan Rd., Shanghai**

declares under it's own responsibility, that the product:

2D Spatial Light Modulator, High Power

Model No.: **EXULUS-HD2HP, EXULUS-HD3HP**

fulfills the requirements of the standard

CISPR PUB. 22, FCC Part 15 Subpart B Class A

and therefore corresponds to the regulations of the directive.

Signed:

on: 16th Sept 2020

Name: Shanshan Song
Position: General Manager



Declaration of Conformity

We: Thorlabs Optical Electronic Technology (Shanghai) Co., Ltd
of: Room A101, No.100, Lane 2891, South Qilianshan Rd, Shanghai

In accordance with the following Directive(s):

2014/35/EU	Low Voltage Directive (LVD)
2014/30/EU	Electromagnetic Compatibility (EMC) Directive
2011/65/EU	Restriction of Use of Certain Hazardous Substances (RoHS)

hereby declare that:

Model: EXULUS-HD2HP, EXULUS-HD3HP
Equipment: 2D Spatial Light Modulator for Visible, High Power
2D Spatial Light Modulator for Near Infrared, High Power

Is in conformity with the applicable requirements of the following documents:

EN 61010-1: 2010 (Third Edition)
EN 61326-1: 2013
EN 61326-2-1: 2013
EN 61326-2-2: 2013
EN 55011: 2016 + A1: 2017 (Class A)
EN 61000-3-2: 2014
EN 61000-3-3: 2013
EN 61000-4-2: 2009
EN 61000-4-3: 2006 + A2: 2010
EN 61000-4-4: 2012
EN 61000-4-5: 2014 + A1: 2017
EN 61000-4-6: 2014
EN 61000-4-8: 2010
EN 61000-4-11: 2004 + A1: 2017

and which, issued under the sole responsibility of Thorlabs, is in conformity with Directive 2011/65/EU of the European Parliament and of the Council of 8th June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment, for the reason stated below:

does not contain substances in excess of the maximum concentration values tolerated by weight in homogenous materials as listed in Annex II of the Directive.

I hereby declare that the equipment named has been designed to comply with the relevant section of the above referenced specifications, and complies with all applicable Essential Requirements of the Directives.

Signed:

on: 16th Sept 2020

Name: Shanshan Song
Position: General Manager

Chapter 9 Warranty

Thorlabs warrants material and production of your EXULUS for a period of 24 months starting with the date of shipment.

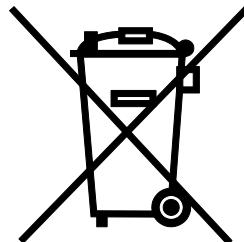
All specific warranty and repair information can be found in the general terms and conditions located at https://www.thorlabs.com/Images/PDF/LG-PO-001_Thorlabs_terms_and_%20agreements.pdf.

Chapter 10 Regulatory

As required by the WEEE (Waste Electrical and Electronic Equipment Directive) of the European Community and the corresponding national laws, Thorlabs offers all end users in the EC the possibility to return "end of life" units without incurring disposal charges.

- This offer is valid for Thorlabs electrical and electronic equipment:
- Sold after August 13, 2005
- Marked correspondingly with the crossed out "wheelie bin" logo (see right)
- Sold to a company or institute within the EC
- Currently owned by a company or institute within the EC
- Still complete, not disassembled and not contaminated

As the WEEE directive applies to self-contained operational electrical and electronic products, this end of life take back service does not refer to other Thorlabs products, such as:



Wheelie Bin Logo

- Pure OEM products, that means assemblies to be built into a unit by the user (e.g. OEM laser driver cards)
- Components
- Mechanics and optics
- Left over parts of units disassembled by the user (PCB's, housings etc.).

If you wish to return a Thorlabs unit for waste recovery, please contact Thorlabs or your nearest dealer for further information.

Waste Treatment is Your Own Responsibility

If you do not return an "end of life" unit to Thorlabs, you must hand it to a company specialized in waste recovery. Do not dispose of the unit in a litter bin or at a public waste disposal site.

Ecological Background

It is well known that WEEE pollutes the environment by releasing toxic products during decomposition. The aim of the European RoHS directive is to reduce the content of toxic substances in electronic products in the future.

The intent of the WEEE directive is to enforce the recycling of WEEE. A controlled recycling of end of life products will thereby avoid negative impacts on the environment.

Chapter 11 Thorlabs Worldwide Contacts

For technical support or sales inquiries, please visit us at
www.thorlabs.com/contact for our most up-to-date contact information.



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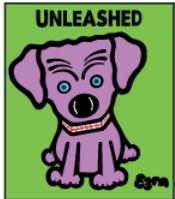
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