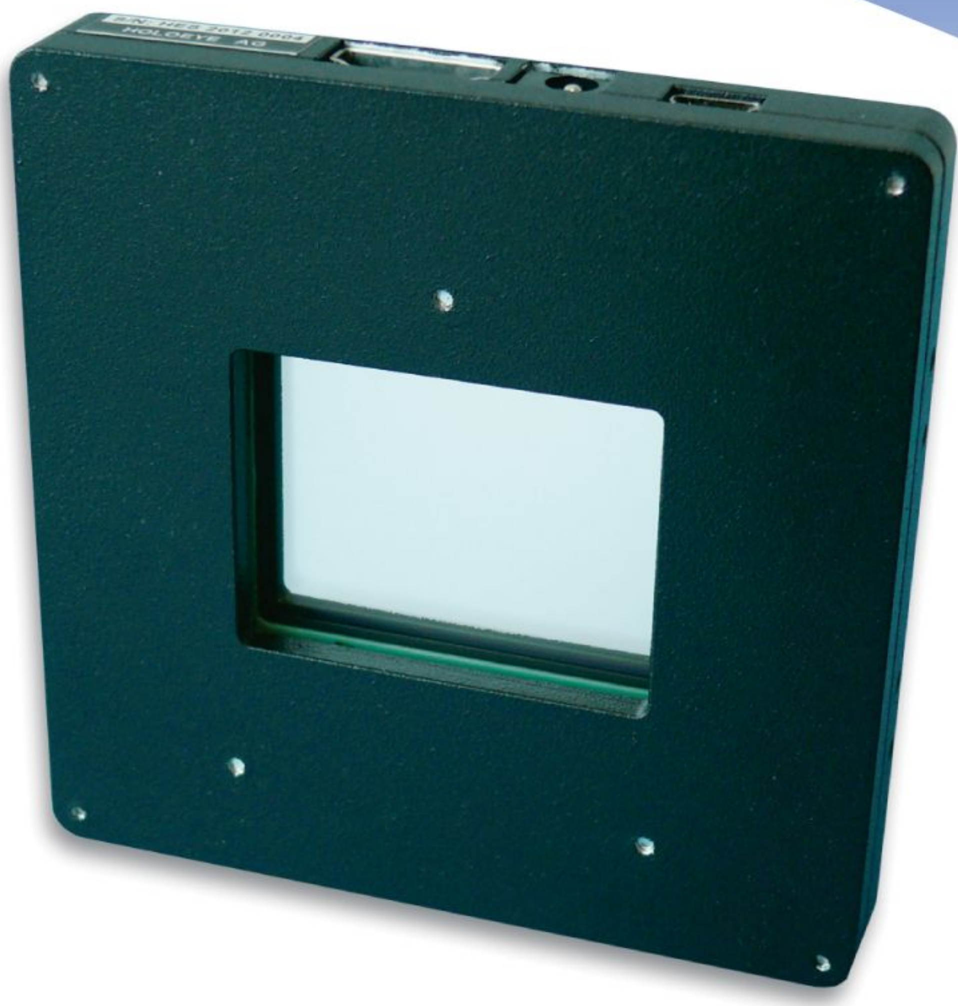
LC 2012

Spatial Light Modulator

Device Operating Instructions
SLM Software Instructions



HOLOEYE **Pioneers in Photonic Technology**

Note

This Instruction explains the correct usage of the device and serves prevention of danger. All persons who apply or use, care of, maintain and control the device have to read and follow it. It is part of the device and should always be at the user's disposal.

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Copyright notice

Technical specifications given in this document are subject to change without notification.

1 LC 2012 DEVICE MANUAL

1.1 Introduction

Figure 1: LC 2012 SLM

The LC 2012 is an easy-to-use Spatial Light Modulator system based on a transmissive liquid crystal microdisplay with a resolution of 1024 x 768 pixel (XGA).

The device can be used for phase or amplitude modulation (dependent on polarizer / analyzer settings). The drive electronics are housed in a compact box. The LC 2012 is addressed by standard HDMI interface and features an USB connection for advanced settings.

The LC 2012 SLM is a basic model mainly intended for proof-of-concepts or teaching.

The SLM device is delivered with a GUI based Configuration Manager software (for basic brightness / contrast and geometry settings) and with a HOLOEYE Pattern Generator software for simple generation of diverse dynamic optical functions like gratings, lenses, axicons and apertures as well as the calculation of diffractive optical elements (DOE) from user defined images.

1.2 Deliverables

- Driver unit with integrated transmissive LC display
- Device mount
- 12 V power supply + cable
- USB/Mini-USB cable
- HDMI cable
- Safety instructions & quick-start guide (test polarizer inside)
- Flash drive with software package and detailed manual

Figure 2: LC 2012 deliverables

1.3 General Usage Guidelines & Safety Instructions

Important safety instructions! Read this section carefully before initial operation!

This instruction provides information for a safe operation of your HOLOEYE Spatial Light Modulator. Please follow and retain all information included.

Please note: Power cables, power supplies and other components could bear safety risks, which especially at improper use could lead to personal injury or property damage. To lower the risks, please follow all safety instructions and note all warnings on the product itself and within the user manuals.

For a long lifetime of the SLM device please follow these general handling instructions:

- Do not use the kit outside buildings and in humid or dusty places and keep the kit away from extreme heat and coldness.
- Avoid touching the LCD display because this might cause damages or reduce its optical quality.
- If you plan to illuminate the kit with powerful light sources, we strongly recommend consulting HOLOEYE services.

The LC display is a electrostatic-sensitive part. To prevent electrostatic discharge (ESD) to cause malfunction of the SLM avoid touching this part with a finger or other conductor.

Set up and handle the display in a static controlled location and be properly grounded, e.g. wearing an ESD wrist strap.

The SLM (driver unit and microdisplay) and the power supply induce heat while operation. Please be careful touching these components and avoid keeping them in your hand for a longer period.

Do not cover the components or block the heat transfer to surrounding air in any other ways.

If you detect any signs of overheating or if you have any other safety concerns regarding the device, please interrupt the power supply connection and stop using the device until you are able to get in contact with HOLOEYE support.

Avoid shocks and shaking of the device (especially the microdisplay) and protect the device from strong mechanical force and scratches.

Only use power supplies and power cables recommended by HOLOEYE. Never use power supplies and power cables which show signs of damage!

Before you connect or disconnect the microdisplay to/from the driver unit make sure to interrupt the power connection.

Remark regarding LC microdisplays: The microdisplay contains a cover glass which could break by mishandling. If the display glass or other parts are broken and the included liquid crystal material gets in contact with skin or eyes, flush out the affected areas for at least 15 minutes with clear water and consult a doctor.

Please check the SLM and the included parts for damages, traces of wear or other signs of safety risks on a regular base. Do not use the device if you have any concerns about the proper condition of any part. In such cases please get in contact with HOLOEYE support!

1.4 LC Display Specifications

1.4.1 Display Parameter

Part No.:	HED 0017
Type:	Transmissive LCD
Mode:	TN (Twisted Nematic)
Phase Levels:	256 (8-bit) phase levels
Active Area:	36.9 x 27.6 mm
Display Diagonal:	1.8”
Resolution:	1024 x 768 Pixel
Pixel Pitch:	36 µm
Fill Factor:	58%
Input Frame Rate:	60 Hz
Transmittance:	~ 28%
Illumination (max.)	~ 0.5 W / cm² (CW laser). For high power and pulsed laser applications please contact HOLOEYE.
Operating Temp.:	+10°C to +70°C
Waveband:	420-850 nm (2π phase mostly modulation up to ~450 nm; Limited phase shift below 2π at 450 - 850 nm).

Figure 3: LC 2012 Spatial Light Modulator

⚠ **UV irradiation below 405 nm shall be blocked via an absorption filter**

1.5 LC 2012 Driver Unit

Figure 4: LC 2012 driver unit

The drive electronics are packaged into a compact housing. The device requires a 12V power supply (please only use the supplied power supply). The signal input is standard HDMI and the 8 Bit data from the green color channel will be used to address the SLM display.

The LC 2012 kit does not feature any control elements. Some adjustments (brightness, contrast and image flipping) can be done using the USB connection and the supplied calibration software. Advanced calibrations (like gamma corrections) can only be done using the functionality of the computers graphics card.

1.5.1 Mounting the SLM Device

For convenient integration into optical setups with standard posts, a mounting is supplied with the device.

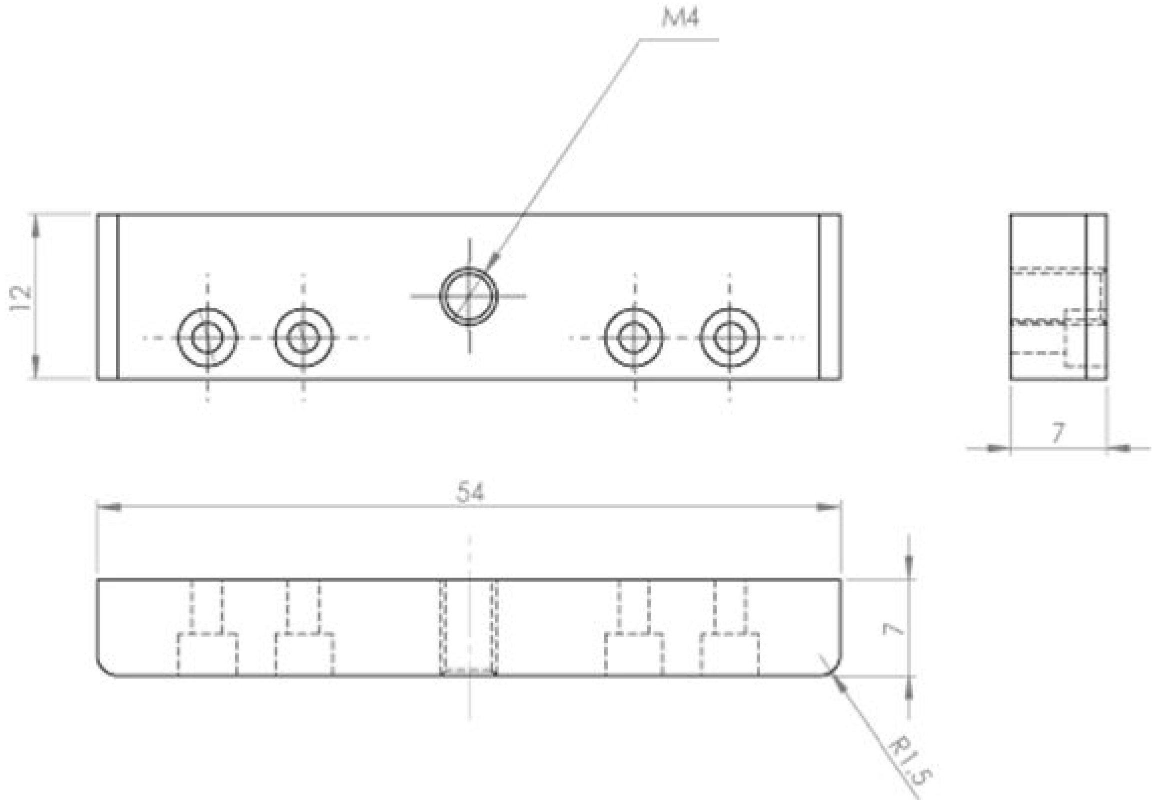


Figure 5: Standard mount for LC 2012 device

Please only use the delivered screws to attach the mounting adapter to the LC 2012 device.

The mounting works on posts/holders with M4 thread.

1.5.2 Dimensions of the LC 2012 Device

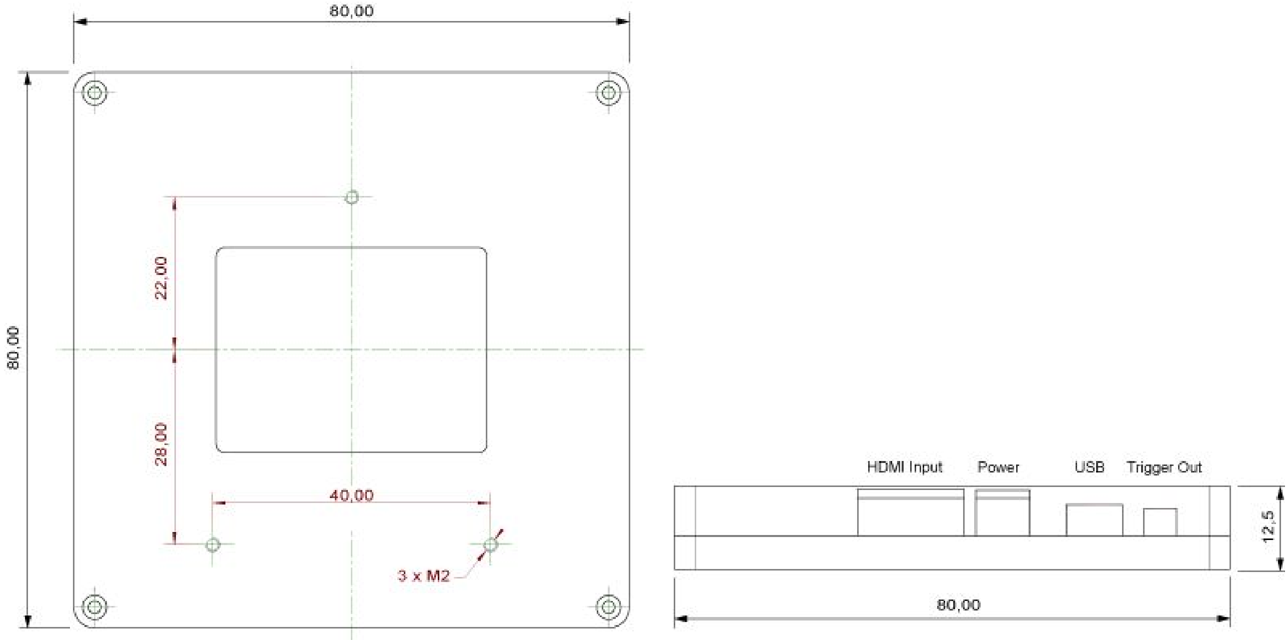


Figure 6: Driver interfaces and dimensions (values in mm)

1.5.3 Connectors of the Driver Unit

Back Side	
HDMI	Connection to computer via HDMI
Power	Connection of power supply (12 V -2.5 A)
USB	Connection of power supply and connection to virtual COM port of the computer used for SLM calibration using the Configuration Manager software
Trigger Out	Connection of v-sync trigger cable

Table 1: Connectors of the driver unit.

1.5.4 Power Supply

Switching Power Supply

Input: 100-240 V AC

50-60 Hz ~1.0 A

Output: 12 V --- 2.5 A

Power applies directly by plugging the power supply cable into the driver unit.

1.5.5 Video Sync Signal

The LC2012 device is equipped with an output for frame synchronization pulse (vertical synchronization pulse). This output can be used with 2-pole MOLEX 51021-0200 crimp connectors.

Figure 7: V-Sync output

The standard output stage delivers low-active synchronization pulses that are referred to ground potential.

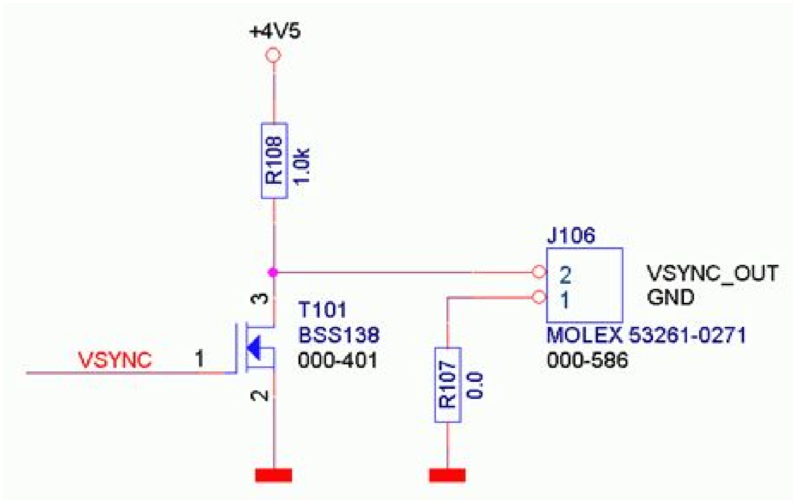


Figure 8: V-Sync TTL level output stage

Pulse amplitude is approximately 4.5 volt. Oscilloscope waveforms of the pulse are captured on frame time base and for the pulse in detail.

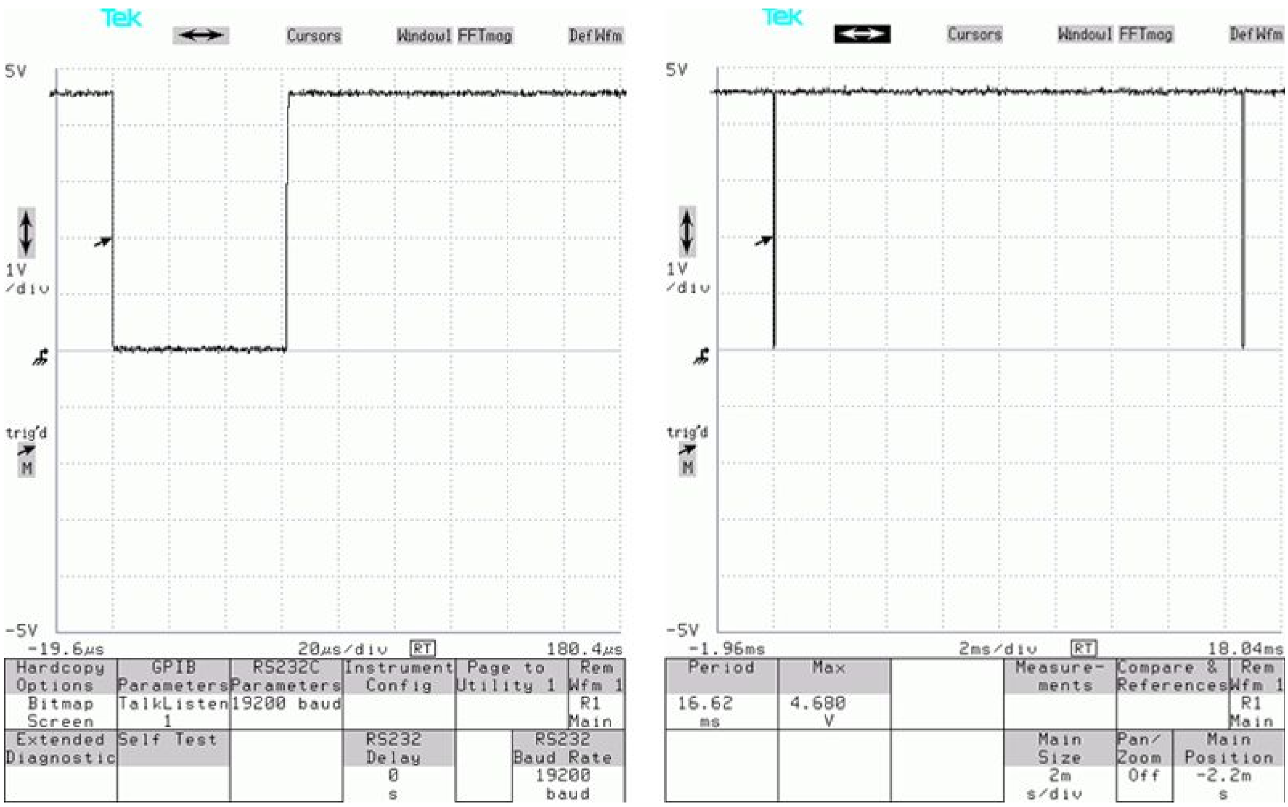


Figure 9: Output waveform

If DC separation between the LC 2012 and the sync pulse sink is required, the output stage can be modified on hardware level for driving the LED of an optocoupler. This feature is available on request only.

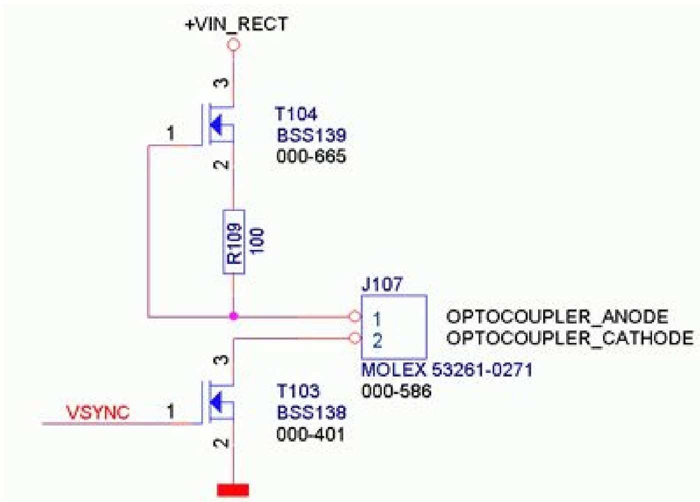
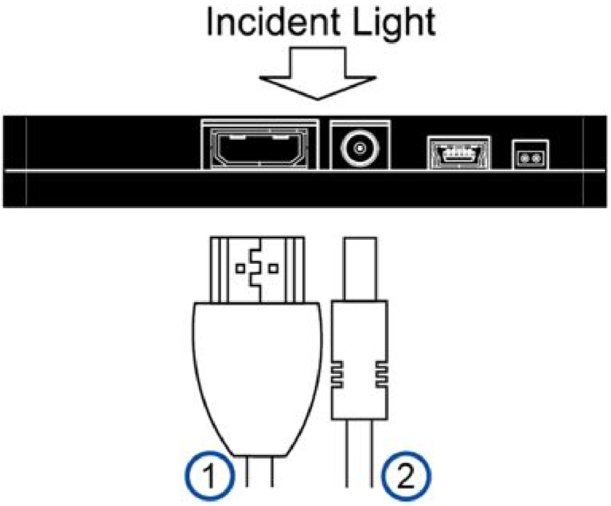


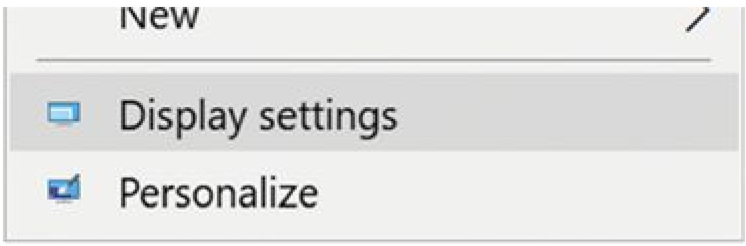
Figure 10: V-Sync optocoupler output stage

1.6 Quick-Start Guide

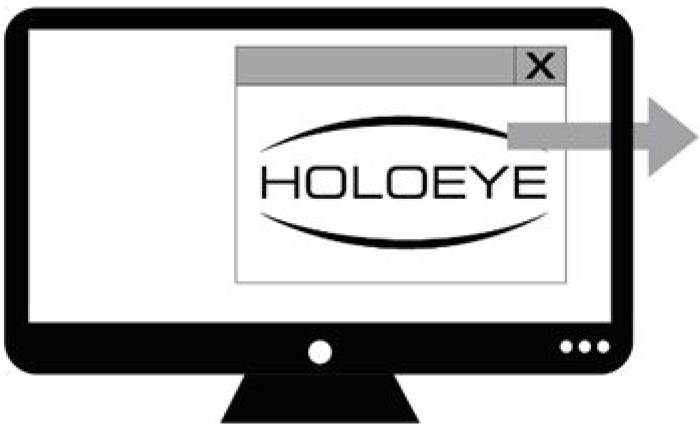
1. After booting your computer establish the HDMI connection to the SLM. Now connect the power supply. The incident light should face the connector side of the housing.



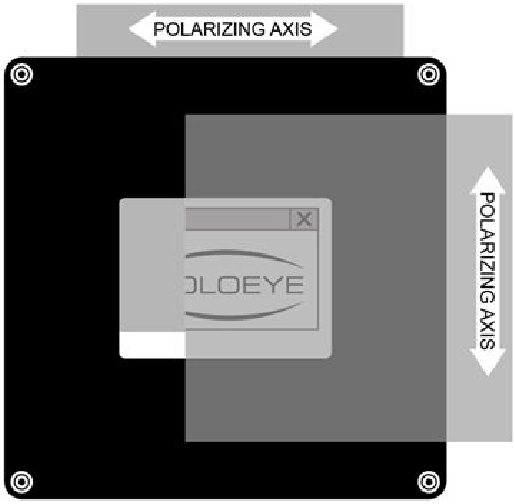
2. Right click on the desktop and select “Display Settings“. Set the device in extended desktop mode by selecting “extend these displays“ at the “Multiple Displays“ selectbox. Make sure the night light mode is <u>not</u> activated.



3. Open an image file in any image viewer software (e.g. Windows image viewer or IrfanView) and drag the image window to the second monitor (which is the SLM).



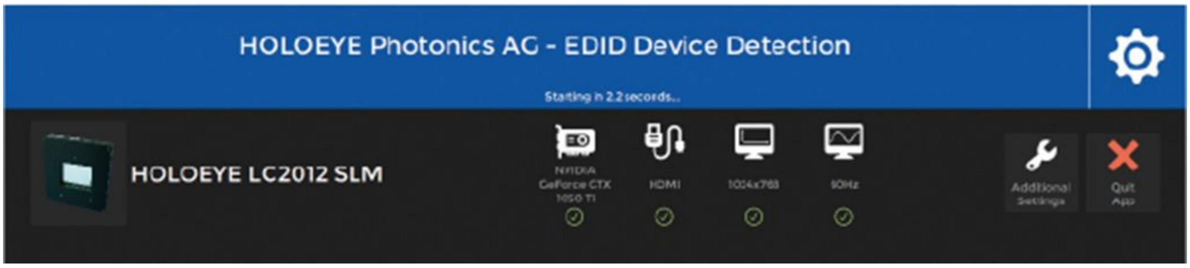
4 To finally check if all settings are correct and if the SLM works properly, place a polarizer (test polarizer included in printed quick start instruction) behind the SLM and a 90° crossed polarizer in front of the device to see the image.



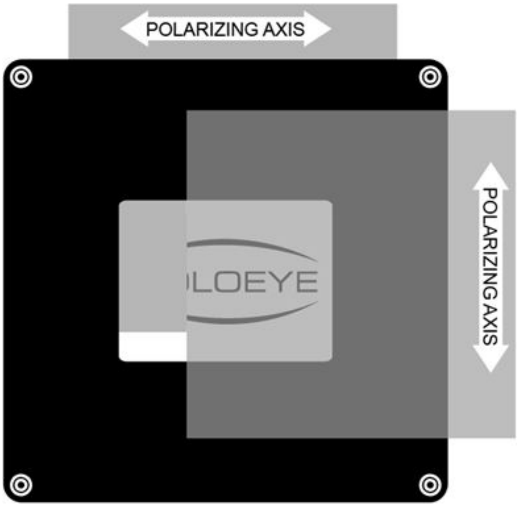
Alternatively you can use to HOLOEYE SLM Pattern Generator software or the Slideshow Player software to check your settings and to guide you through a proper configuration.

2a Install the HOLOEYE Slideshow Player software or the Pattern Generator software, which are included on the delivered USB drive and start the software.

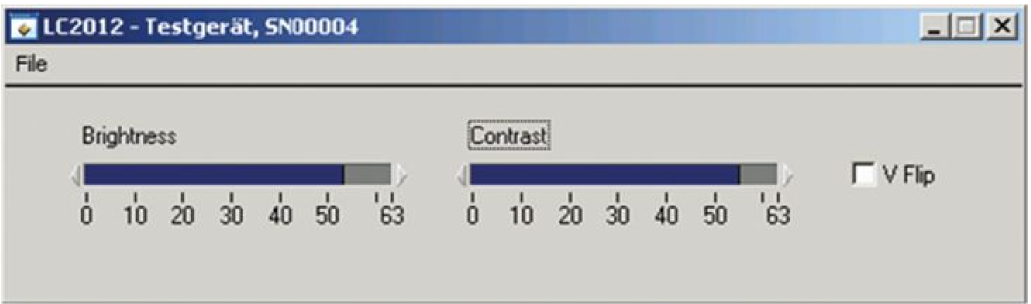
3a The HOLOEYE SLM software features a SLM device detection. The device detection checks graphics card settings, the HDMI connection and SLM configurations. If anything is not configured correctly a dialog will lead you through a proper configuration.



4a To finally check if all settings are correct, you can address any image on the SLM using the HOLOEYE SLM software (please refer to the detailed manuals which are included on the USB drive or are available by the “Help“ function of the software). Place a polarizer behind the SLM and a 90° crossed polarizer in front of the device to see the image.



5 The device is now ready for use. You can use the LC 2012 Configuration Manager software for some basic adjustments. Brightness and contrast can be adjusted in 64 steps and the image can be flipped in vertical direction.



Dependent on the incident polarization and the polarizer and analyzer settings you can use the SLM for amplitude modulation or phase modulation.

1.7 Phase & Amplitude Modulation Properties

1.7.1 Measurement Setup

Figure 11 shows the experimental setup for phase modulation measurements. The properties are determined for 450nm, 543nm and 633 nm. The Display is separated into two parts in which one will be addressed with a stable signal (gray level 0) and the other one will be modulated with gray levels from 0 to 255. The mask creates two beams (one for the stable and one for the modulated display half) which will be combined by the 2nd lens in order to interfere. The arising interference pattern will be guided to a CCD or webcam and is evaluated by software. Figure 12 shows the measurement setup for intensity modulation.

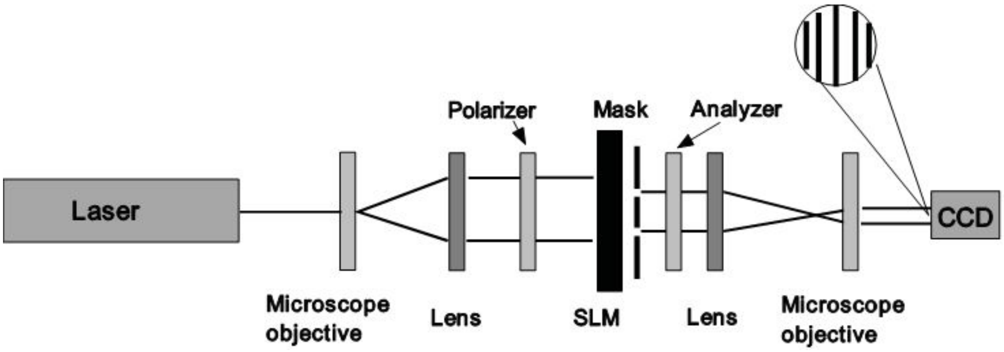


Figure 11: Experimental setup for phase modulation

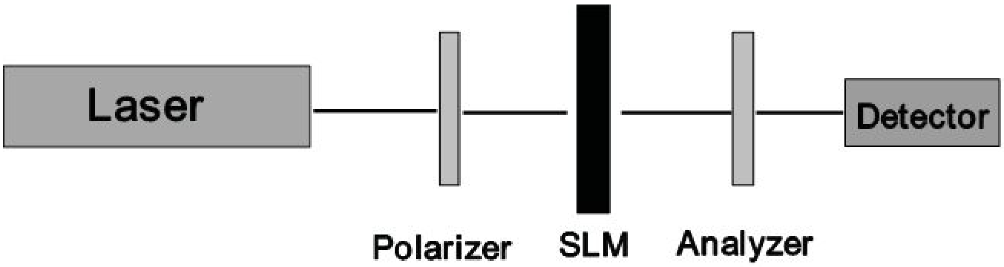


Figure 12: Experimental setup for intensity modulation

> ⚠ **NOTE**
>
> The mesurents displayed in the following chapters are performed with certain Polarizer and Analyser settings which are stated at the captions below the graphs. The captions also state the brightness (B) and contrast (C) settings used for the measurement.

1.7.2 SLM Alignment

The LC 2012 should be aligned as shown in Figure 13.

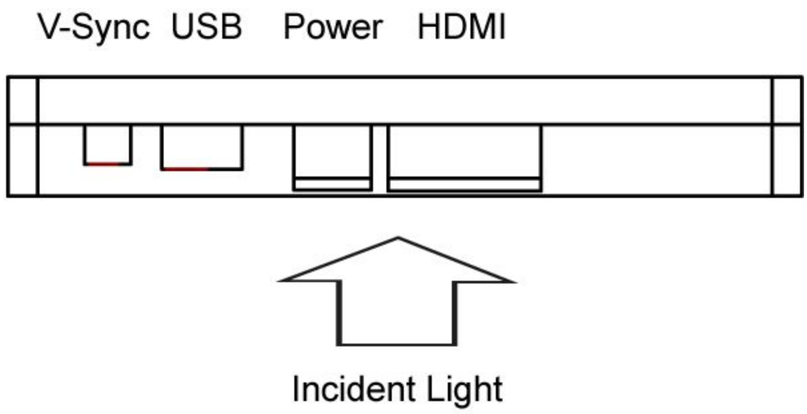


Figure 13: Incident light direction

1.7.3 Polarizer Settings

The polarizer used for the HeNe-Lasers and the analyzer are calibrated in such manner that the 0° position blocks horizontally polarized light and transmits vertically polarized light. The direction of polarizer rotation is mathematically positive.

1.7.4 Amplitude Modulation

The intensity modulation has been measured with the set up in Figure 12. The used polarisers are from Newport with a attenuation ratio of more than 1:1000. The results show that the behavior depends strongly on the used polariser. The usage of better polariser will enhance the contrast.

1.7.5 Brightness and Contrast Settings

Brightness and Contrast settings (see chapter "LC 2012 Configuration Manager") can be used to adapt the SLM to different working wavelengths. Brightness changes the offset and contrasts the dynamic range of the optical modulation. This is especially important for amplitude modulation at shorter working wavelengths in order to assure a steady rise of light transmission over the entire grey level range. Factory default settings are optimized for phase applications.

1.7.6 Amplitude Modulation @ 450 nm

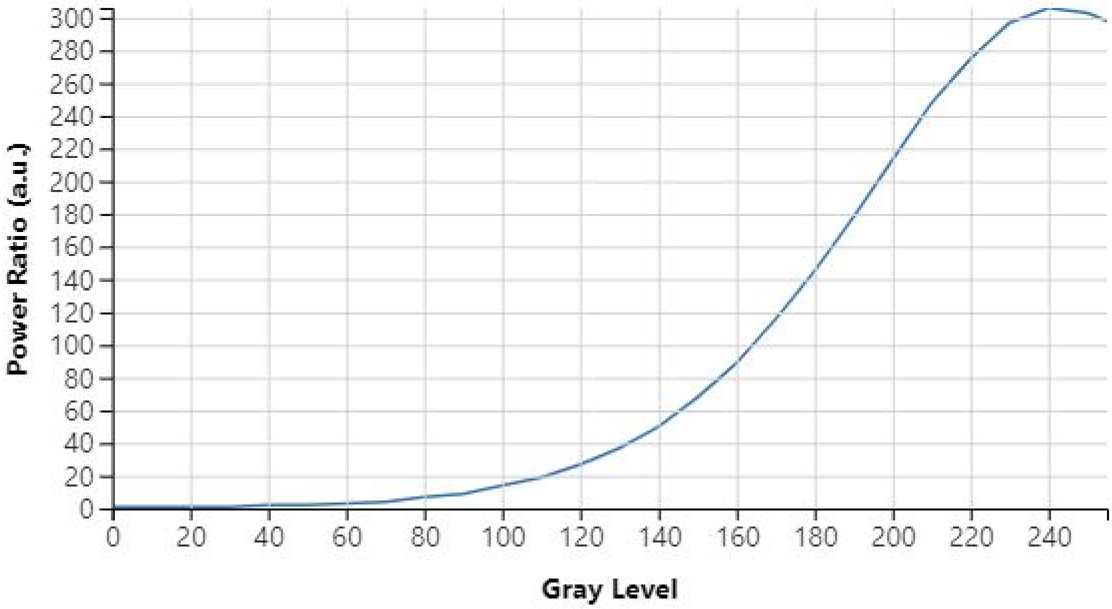


Figure 14: Intensity Modulation @ 450 nm : Pol. 0° - Ana. 90°; B:30 C:33

1.7.7 Phase & Coupled Intensity Modulation @ 450 nm

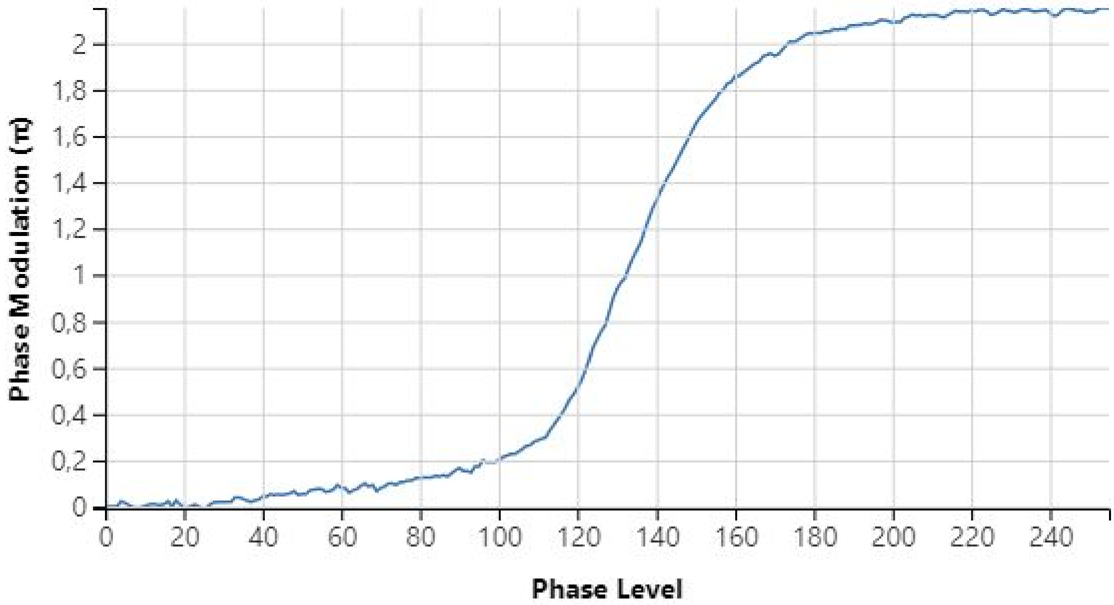


Figure 15: Phase Modulation @ 450 nm : Pol. 310° - Ana. 5°; B:45 C:63

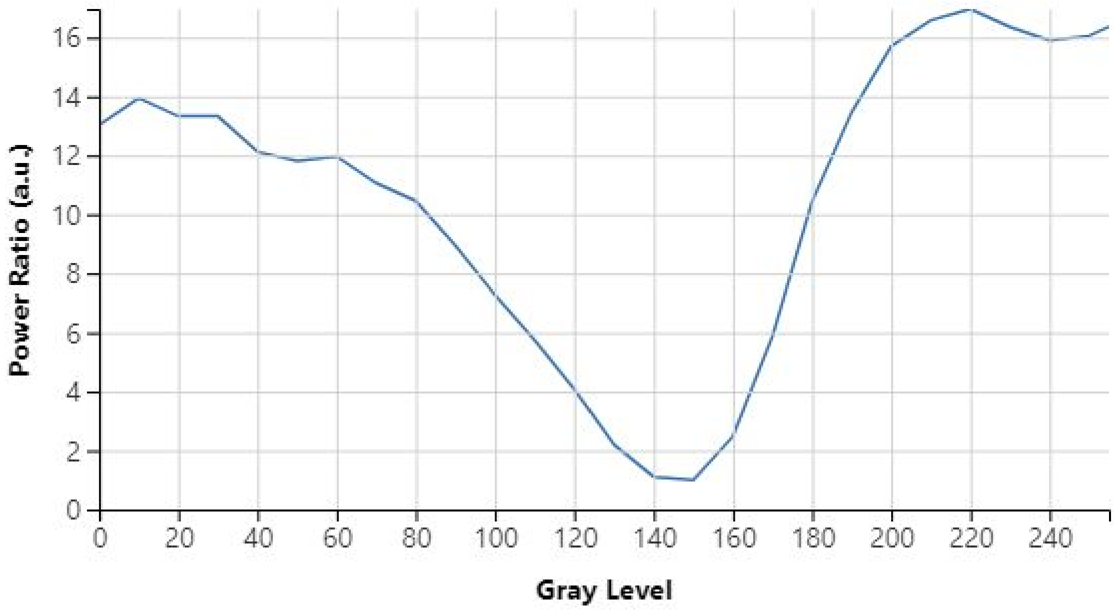


Figure 16: Coupled Intensity Mod. @ 450nm : Pol. 310° - Ana. 5°; B:45 C:63

1.7.8 Amplitude Modulation @ 543 nm

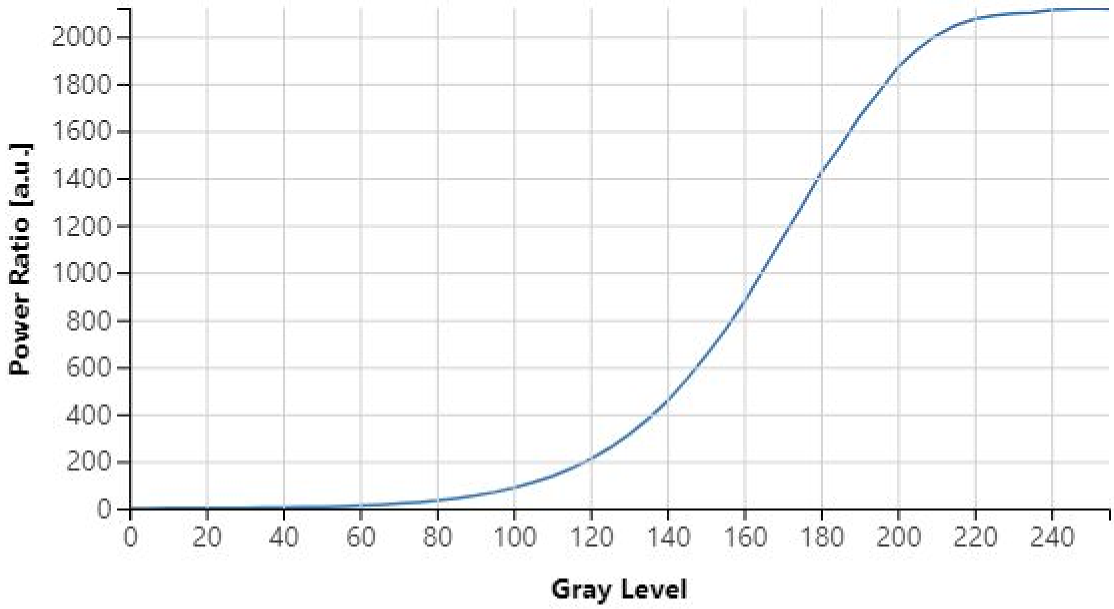


Figure 17: Intensity Modulation @ 543nm : Pol. 0° - Ana. 90°; B:45 C:63

1.7.9 Phase & Coupled Intensity Modulation @ 543 nm

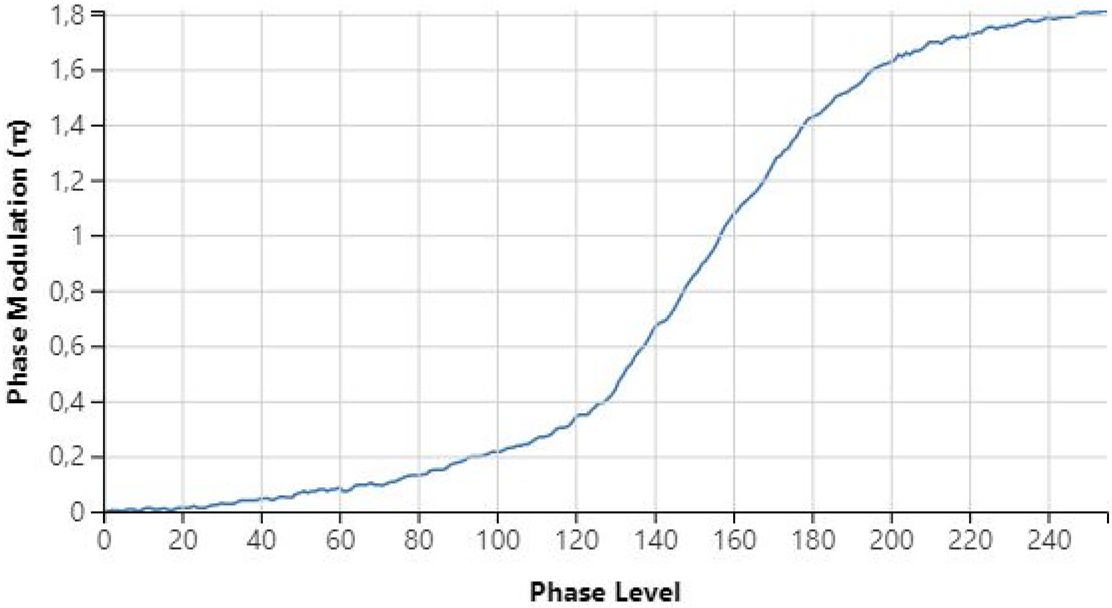


Figure 18: Phase Modulation @ 543nm : Pol. 315° - Ana. 15°; B:45 C:63

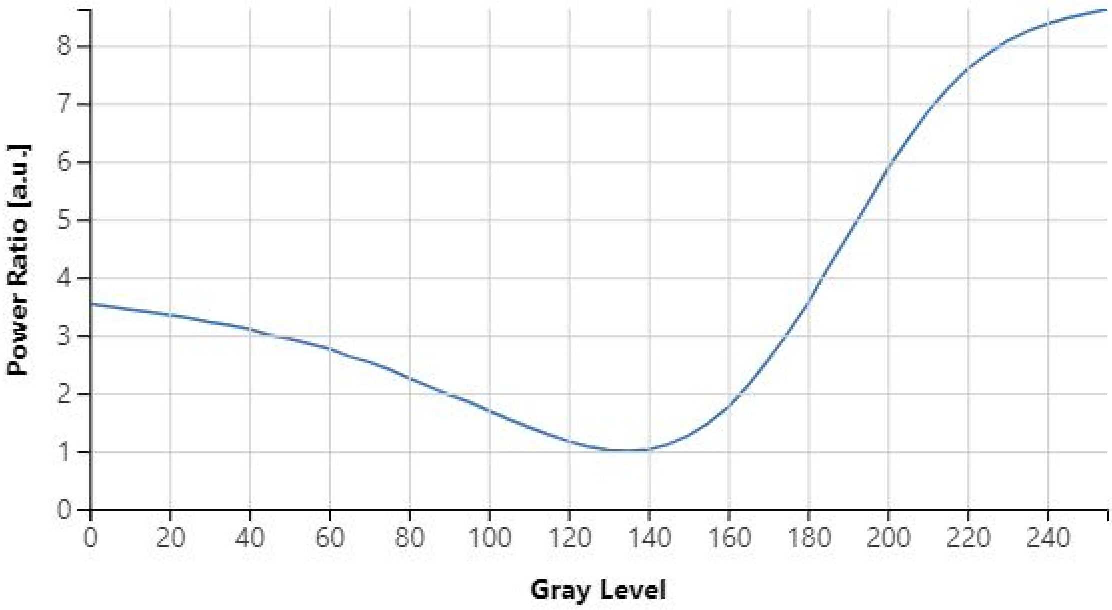


Figure 19: Coupled Intensity Mod. @ 543nm : Pol. 315° - Ana. 15°; B:45 C:63

1.7.10 Amplitude Modulation @ 633 nm

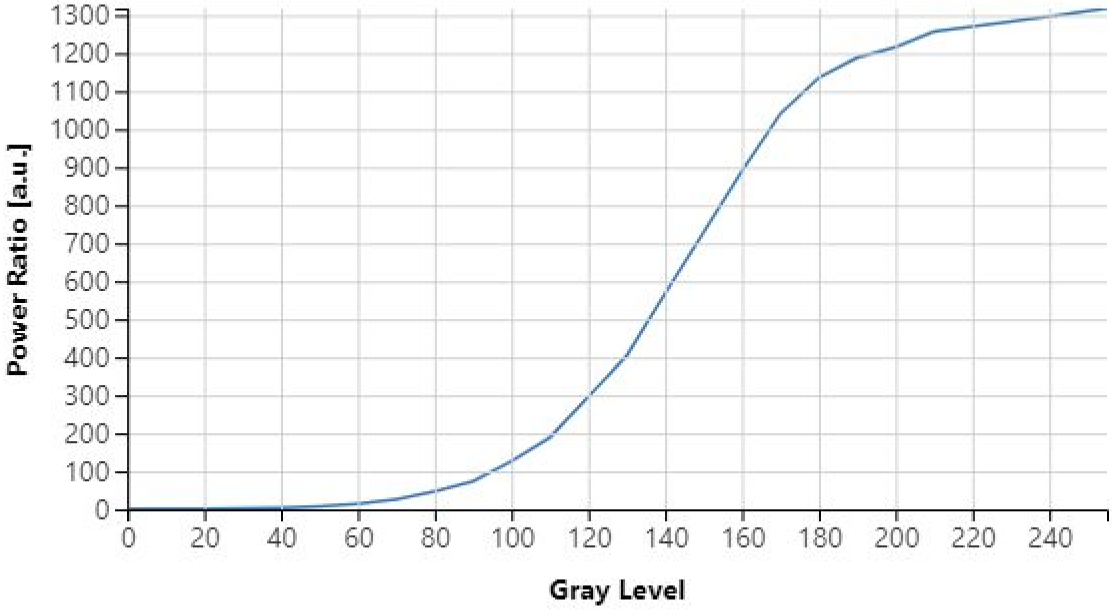


Figure 20: Intensity Modulation @ 633 nm : Pol. 0° - Ana. 90°; B:57 C:53

1.7.11 Phase & Coupled Intensity Modulation @ 633 nm

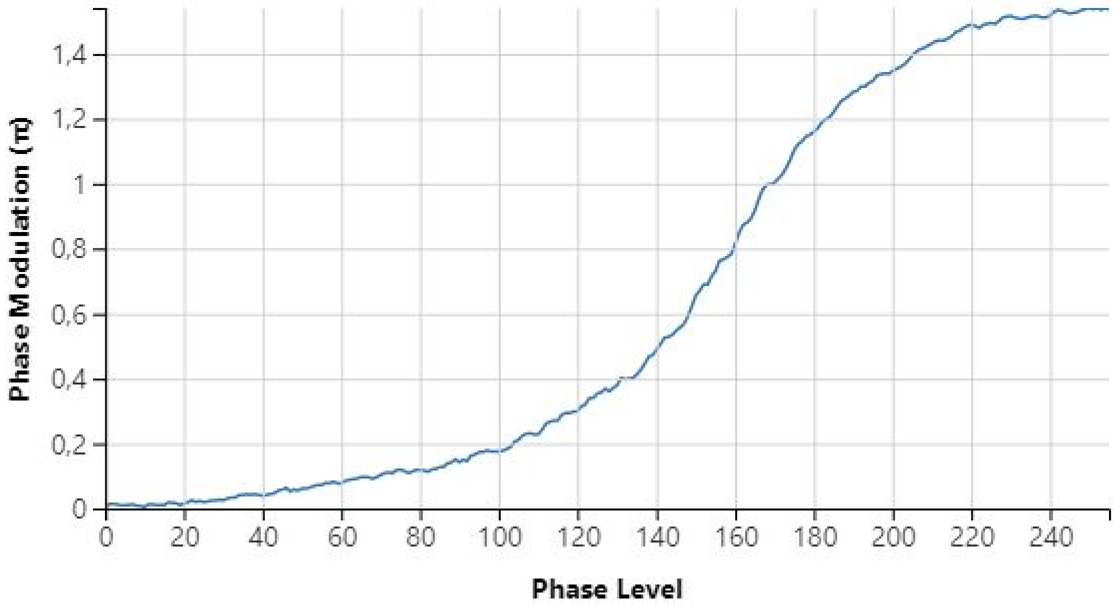


Figure 21: Phase Modulation @ 633 nm : Pol. 310° - Ana. 5°; B:45 C:63

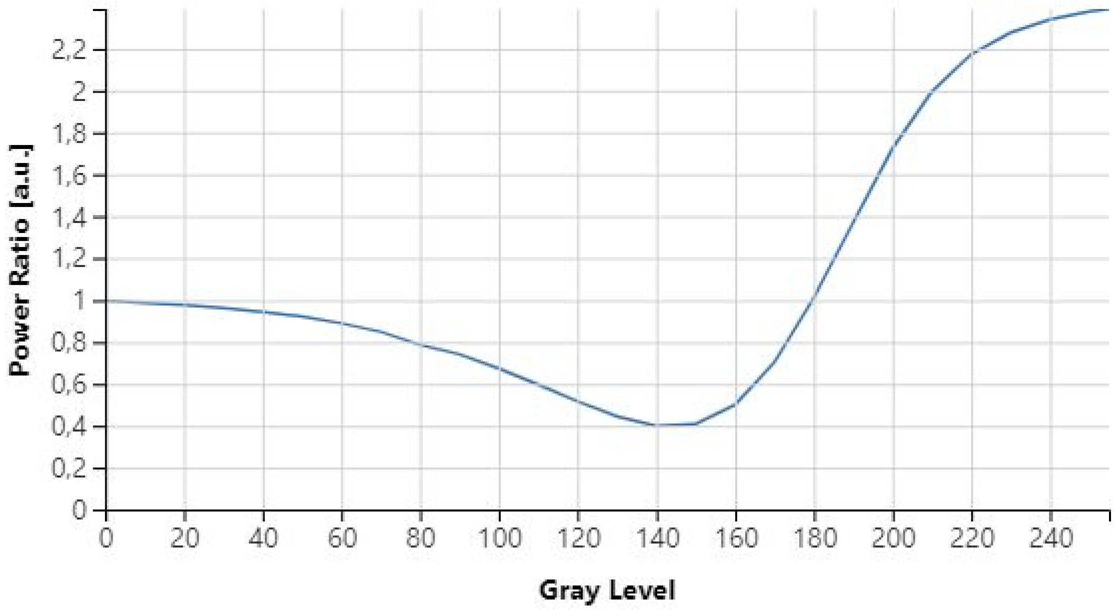


Figure 22: Coupled Intensity Mod. @ 633 nm : Pol. 310° - Ana. 5°; B:45 C:63

2 LC 2012 CONFIGURATION MANAGER

The LC 2012 SLM Configuration Manager allows basic control of the device. The software can be used to change the brightness and contrast of the LC 2012 display and for vertical flipping of the image. This requires an USB connection to the LC 2012 driver.

2.1 Install LC 2012 Configuration Manager

The installation data set includes the actual LC 2012 software files and an USB driver for the FTDI-circuit. The USB driver is installed in a seperate installation routine which starts automatically after installing the LC 2012 software.

You need to have administrator privileges to install the software and the USB driver.

Figure 23: Index of supplied software files

2.1.1 Establish USB Connection

For the installation of the USB driver the LC 2012 device has to be connected to an USB port and the power supply also has to be connected.

After establishing the USB connection typically Windows starts the automatic hardware detection. The Windows hardware detection has to be aborted.

2.1.2 Starting the Installation Routine

To start the insallation execute ***setup.exe*** and follow the instructions of the setup program.

You need to have administrator privileges to install the software.

1

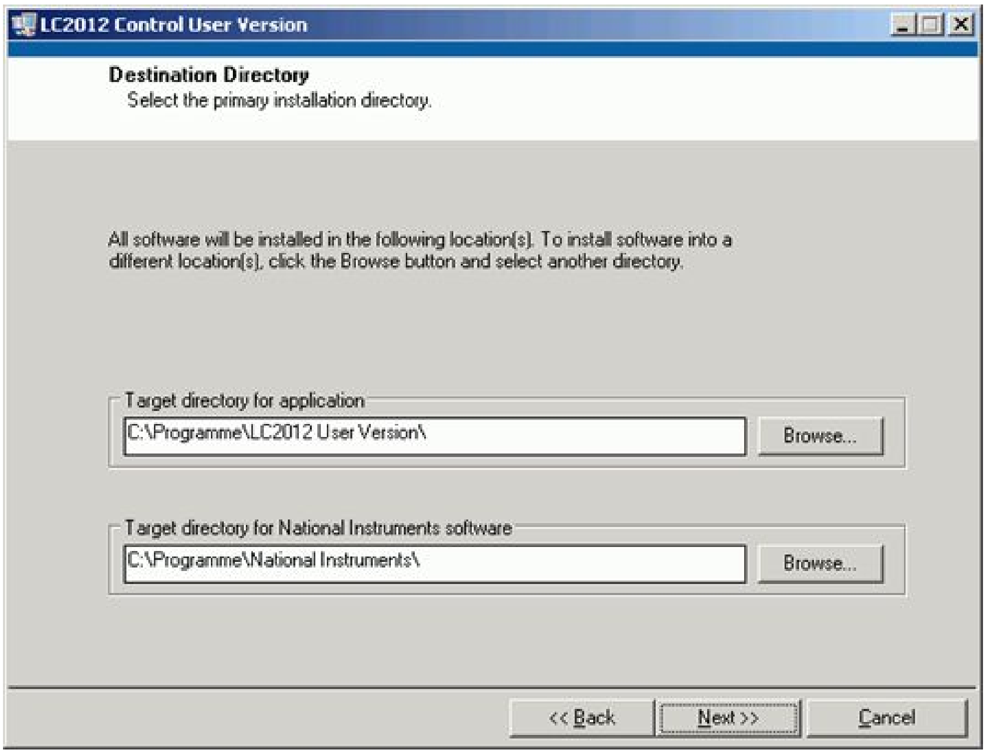


Figure 24: Select directory for the installation

2

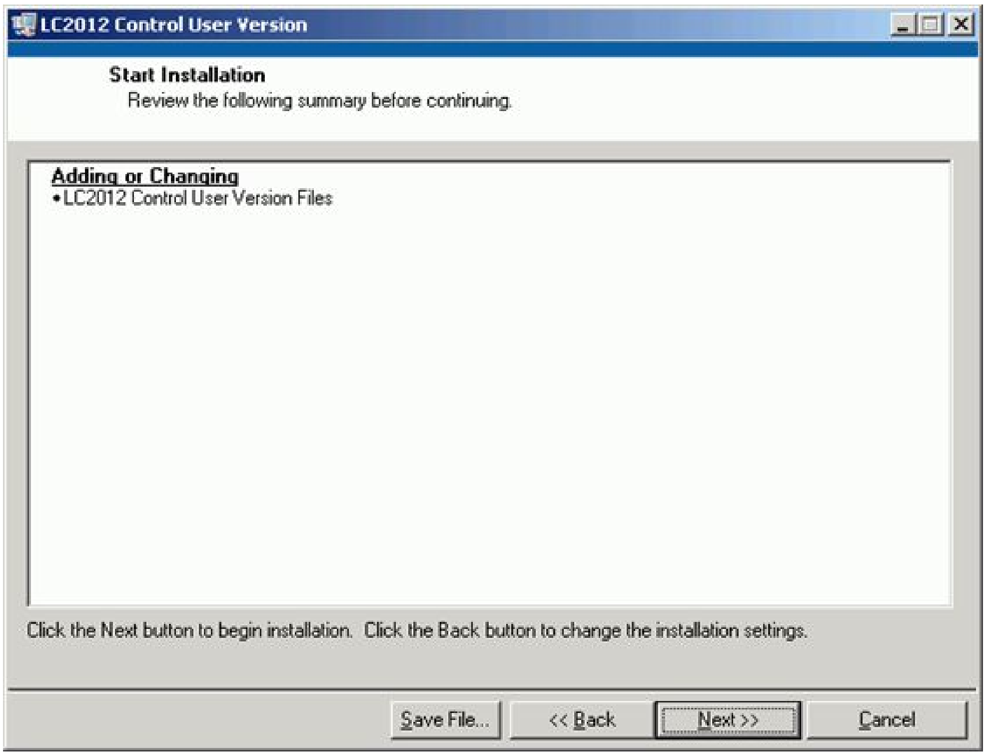


Figure 25: Click "Next" to start the installation.

3

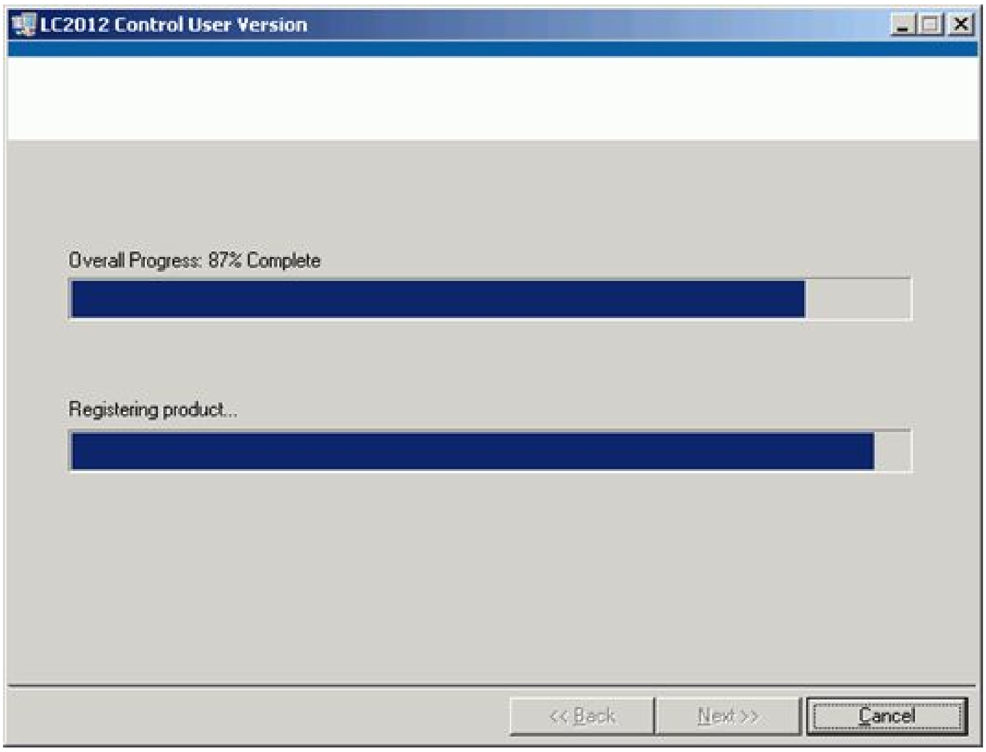


Figure 26: The LC 2012 Configuration Manager is now installed.

4

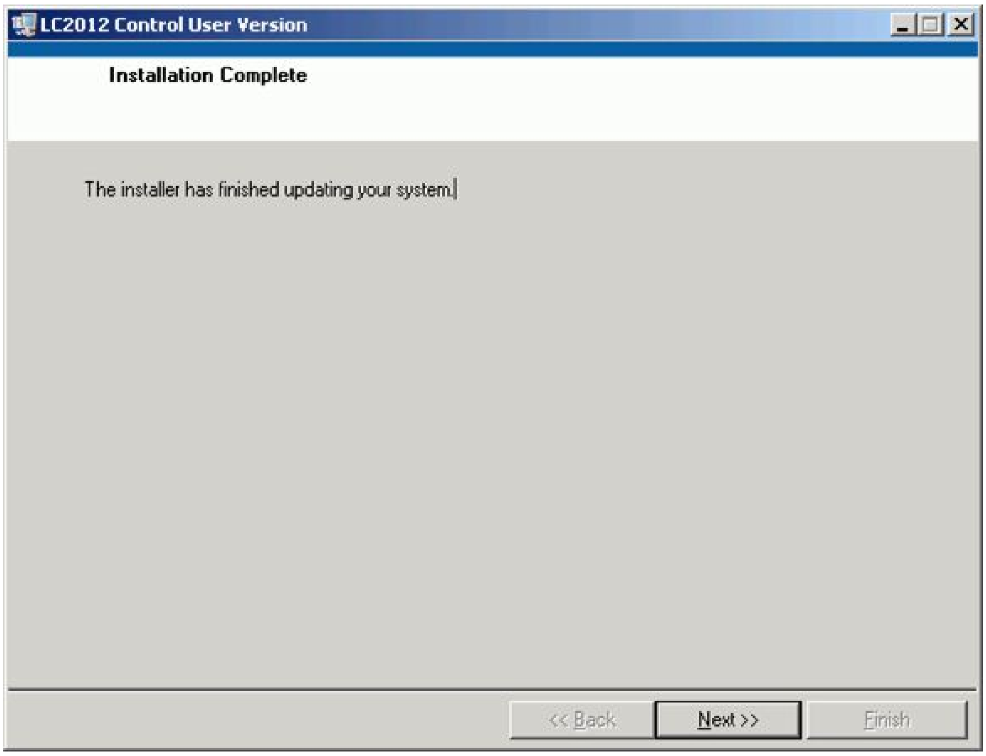


Figure 27: Click "Next" after the intallation is completed to start the USB driver installation.

2.1.3 Installing the USB Driver

After complete installation of the LC 2012 software you can start the installation of the USB driver by clicking next at the last screed of the software installation dialog.

While installation the USB driver identifies the connected LC 2012 device and validates it for usage. At this process you will possibly be asked for the administrator password again.

1

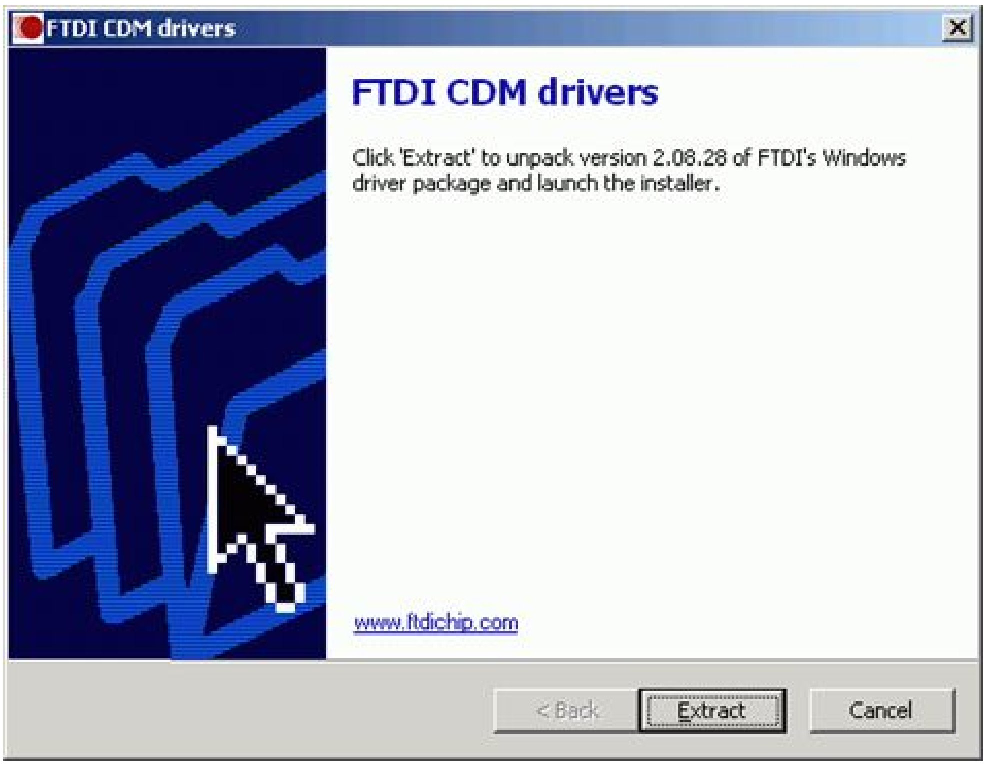


Figure 28: Click "Extract" to start the installation process.

2

Figure 29: Also click "Next" at the welcome sreen of the installation wizard.

3

Figure 30: The USB drivers are now installed.

4

Figure 31: Click "Finish" after installation of the USB drivers.

After succesfull installation of the USB driver you have to restart your computer.

2.2 Starting the Software

To start the LC 2012 calibration software select the file LC2012.exe from your installation directory.

At the current version, the software surface only features 3 settings.

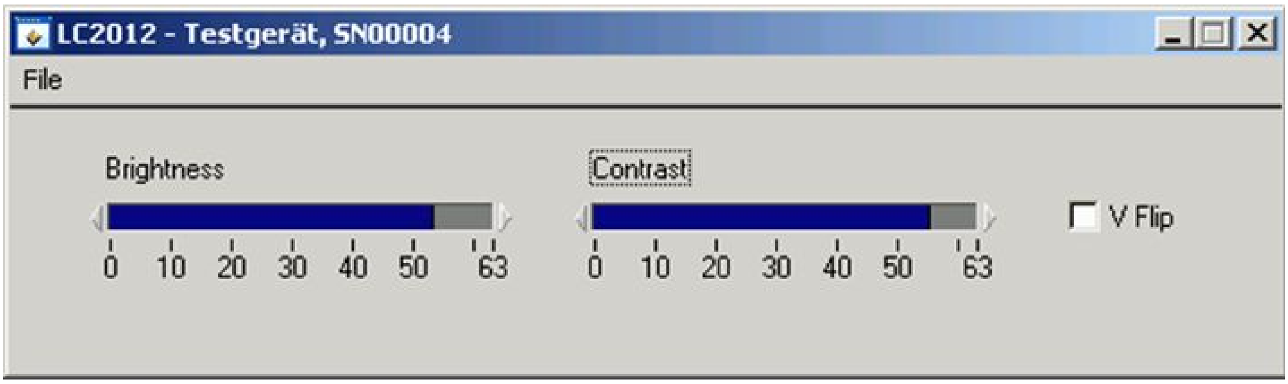


Figure 32: Screenshot of configuration options

Brightness and contrast can be adjusted in 64 steps and the image can be flipped in vertical direction.

As the LC 2012 device works like an external monitor, additional advanced settings (like gamma control) can be done using the settings of the graphics card.

3 EDID DEVICE DETECTION

The HOLOEYE SLM Pattern Generator software, the Slideshow Player software and the SLM Display SDKs feature an EDID device detection. On start-up a device detection dialog pops up which checks if a proper HOLOEYE SLM device is connected and if all system settings are correct.

3.1 Autostart Dialog

The autostart dialog allows you to quickly operate a single HOLOEYE SLM device, if it is already configured correctly. This is the default behavior, if not disabled in the settings.

3.1.1 Available Actions

The following actions are available at any point:

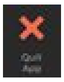
Action	Description
	Leaves the autostart mode and opens the settings dialog.
	Leaves the autostart mode and shows the system information dialog.
	Leaves the autostart mode and opens the full device detection.
	Quits the device detection and the current application.

Table 2: The available actions

3.1.2 No Device Detected

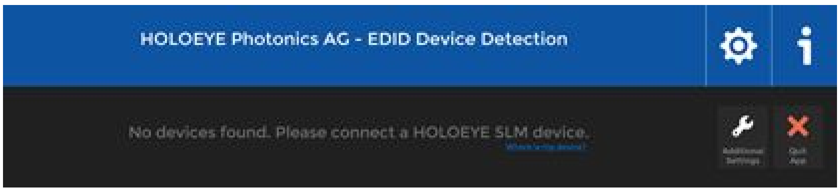


Figure 33: The autostart dialog if no device was detected.

If no device was found (Figure 33), a text is shown to indicate it. If your device is already connected, you can click on “Where is my device?” to get instructions on how to fix the issue.

3.1.3 Correctly Configured Device Detected

Figure 34: A correctly configured device was detected and the autostart timer is running.

If a correctly configured device is detected, it is displayed and an autostart timer starts running. The duration of the timer can be changed in the settings. If another configuration is desired, the “Additional Settings” button can be clicked to leave the autostart mode and enter the normal device dialog (see "Device Selection Dialog"). Once the timer finishes, the autostart dialog will disappear and the actual application comes up. See "Device Settings" for more information on the current device settings.

3.1.4 Quit Autostart Mode

The autostart mode will not be shown if any of the following applies:

- The user clicks the „Additional Settings” button.
- A misconfigured device was detected.
- Multiple devices were detected.
- The autostart was disabled in the settings.

3.2 Device Selection Dialog

The device selection dialog allows you to select one device from all detected devices to run the application with. It also allows you to configure devices as desired.

3.2.1 Available Actions

The following actions are available at any point:

Action	Description
	Leaves the autostart mode and opens the settings dialog.
	Leaves the autostart mode and shows the system information dialog.
 Quit	Quits the device detection and the current application.

Table 3: The available actions.

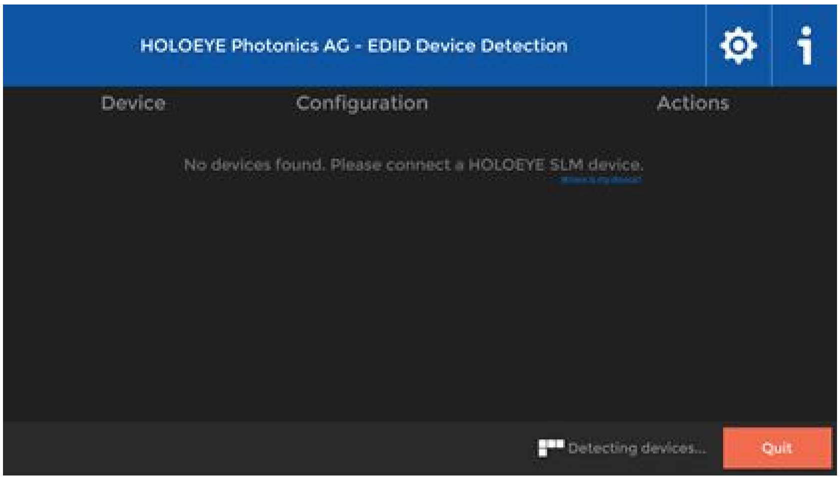


Figure 35: No device was detected.

When no device was found (Figure 35), a text is shown to indicate this. If your device is already connected, you can click on "Where is my device?" to get instructions on how to fix this.

3.2.2 Detected Devices

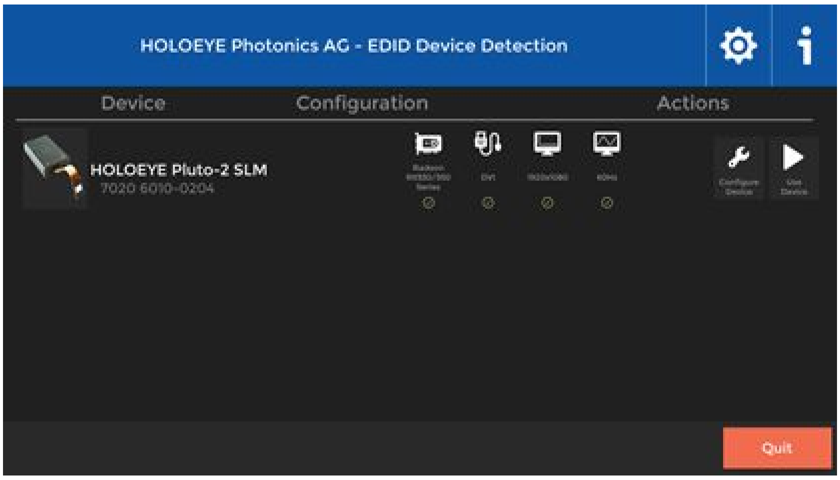


Figure 36: A single correctly configured device was detected and autostart is turned off.

If devices are detected, they are listed along with their basic properties.

3.2.3 Device Details

Figure 37: The details of the device.

The device details show the name of the device, an image representing the device as well as its serial number. For some older devices there may be no serial number displayed.

3.2.4 Device Settings

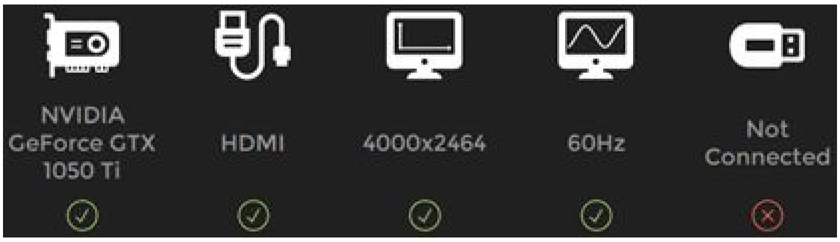


Figure 38: The current settings of the device.

The current device settings are shown for the following categories:

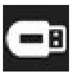
Action	Description
	The graphics card the device is connected to.
	The cable and adapter used to connect the device.
	The current resolution the device is set to.
	The current refresh rate the device is set to.
	Some devices and features require a USB license dongle to be connected. In these cases, this shows the status of the USB license dongle and the required license.

Table 4: The available actions.

3.2.5 Device Actions

The following actions can be performed for each device:

Action	Description
	Change the configuration of the device.
	Close the device detection and run the application using this device.

Table 5: The available actions.

3.2.6 Multiple Devices

If multiple devices are detected, one single device can be selected to run the application.

3.3 Configure Device Dialog

This dialog allows you to change the configuration of a device.

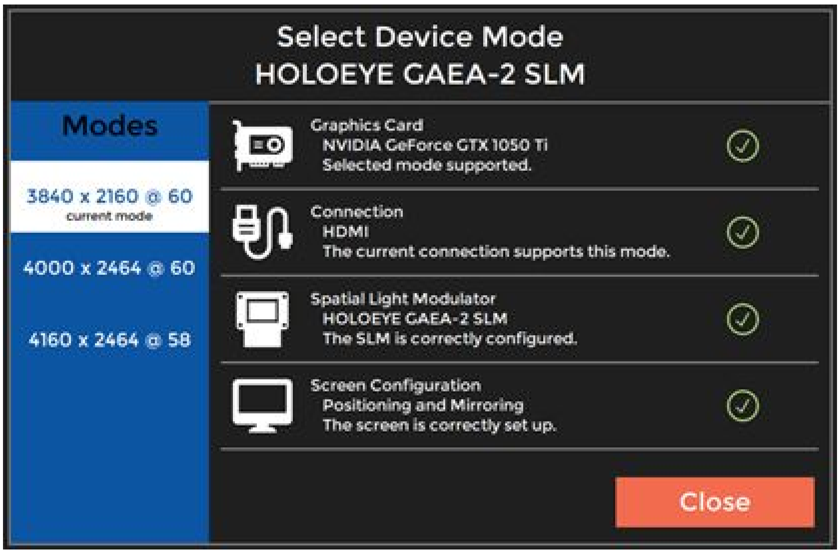


Figure 39: The current mode of the device.

The modes supported by the device are listed on the left, where you can select the mode you want to change to. On the right you can see if the selected mode is supported by your hardware setup.

The following hardware is checked:

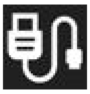
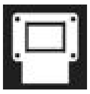
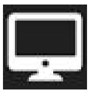
Action	Description
	Checks if the graphics card the device is connected to supports the selected mode.
	Checks if the used graphics card connector, cable and adapter support the selected mode.
	Checks if the SLM device is correctly configured for the selected mode.
	Checks if the screen setup is correct.

Table 6: The hardware setup checks.

3.3.1 Switch Mode

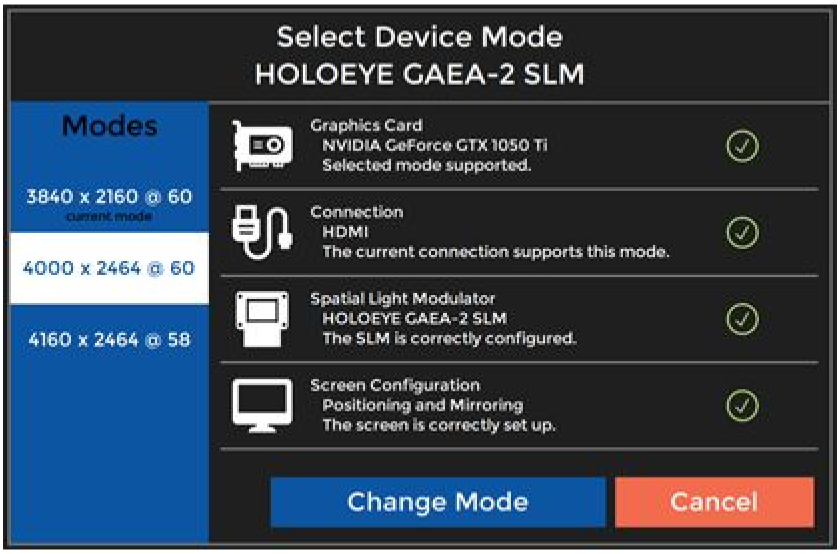


Figure 40: Dialog to change the current mode.

When selecting a different mode on the left, the information on the right updates to show if your hardware setup supports the selected mode. The “Change Mode” button becomes available, when there are no general problems with your setup. When clicking the button, the operating systems screen setup will adjust, so that the device is operated in the desired mode.

Not all modes can be checked immediately by the software. Some modes are only checked when you try to use them.

3.3.2 Unsupported Modes

If a mode is not supported, an info button will appear. Clicking this button will give you more details and instructions on how to solve the problem.

3.4 Settings Dialog

The settings can be opened via the icon in the top right corner of the device detection dialog.

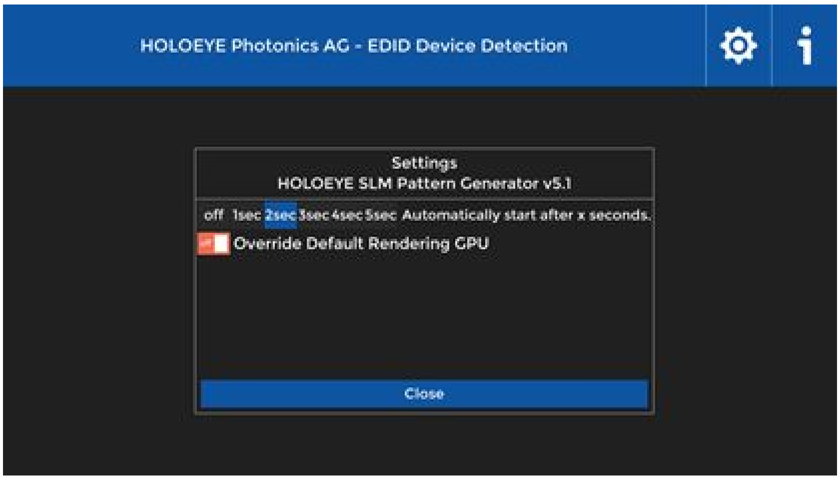


Figure 41: The device detection settings.

The settings dialog allows you to change some general settings of the device selection. The settings can be different for every application.

3.4.1 Autostart Timer

The duration of the autostart timer (see "Correctly Configured Device Detected") can be set here. You can also completely disable the autostart feature, if desired.

3.4.2 Override Default Rendering GPU

Using Windows, you can select which graphics card is used to calculate and render all the data. Usually, the device selection should automatically select the best GPU for this. After enabling this option and closing the settings, the GPU can then be selected from the device selection screen.

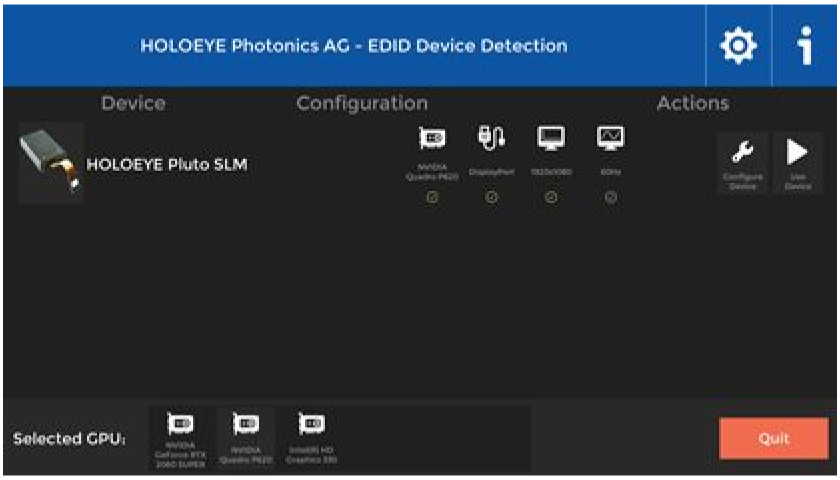


Figure 42: The GPU can be selected at the bottom left.

The application will use the GPU selected in the bottom left corner to handle the computation and rendering of data.

3.5 System Information

The system information dialogue shows you some general information about your system and your screen setup.

3.5.1 Operating-System Power Saving Features

As soon as there is data shown on the SLM, the software prevents the operating system from starting any power saving features, including screen locking. This means, all automatic functions, which would interrupt the SLM content display, are disabled.

Please note that if e.g. automatic screen locking is switched on for a good reason on the user's PC, it will be disabled as long as there is an open window on the SLM.

If you want to have a screen lock while displaying content on the SLM, please lock the screen manually. Of course, other energy saving features can be used manually too while there is content displayed on the SLM. However, when manually enabling such operating system power saving features, the actual addressed image output to the SLM hardware is interrupted.

3.6 Mirrored Displays (Monitor/SLM)

The SLM screen can be mirrored with a desktop monitor, using the same resolution. Mirrored displays are only accepted by the EDID device detection as long as the device detection window is not shown on the mirrored SLM screen.

4 SLM PATTERN GENERATOR SOFTWARE

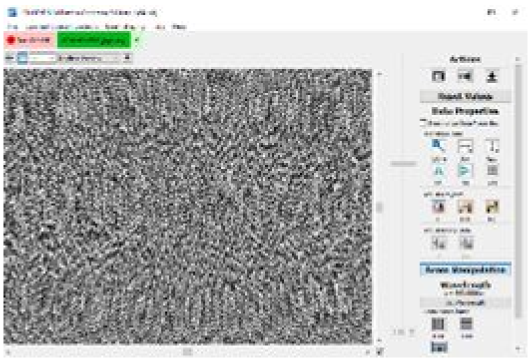


Figure 43: Screenshot of SLM Pattern Generator Software

The HOLOEYE SLM Pattern Generator software allows the computation of computer-generated holograms (CGH's) from user defined image files as well as the generation of elementary optical functions such as different kind of gratings etc., as well as the superposition of different CGH's. The generated CGH's can be addressed to the SLM within the software and can be modified by a superposition of holographic functions on the fly. In addition, there is an option to load wavefront compensation data for the used SLM.

The current version of the software is available for Microsoft Windows 8 operating system or later. For Windows 7 or Linux Ubuntu 18.04 LTS 64 bit we may have older versions.

4.1 Installation

4.1.1 Microsoft® Windows®

In order to make a successful installation, you should make sure that you have sufficient privileges in the computer's operating system (Microsoft Windows™ 10). You should be permitted to create a directory in the directory that contains programs and to copy files into that directory and to write into the 'all users' section of the start menu of your operating system. Of course, administrator privileges will be sufficient for all these operations.

Start the executable file 'HOLOEYE SLM Pattern Generator 5.1 (64|32 bit).exe' for 32- or 64-bit OS and follow the instructions of the installation menu.

Please accept the license agreement before selecting the program components to install. In order to install the complete version, mark all checkboxes. Choose the destination folder as well as the start menu folder. Select 'Install' to start the installation procedure and finally 'Close' to finish the installation.

4.2 Starting the Software

Before starting the software, it is recommended to connect the display interface (HDMI) as well as the power cable to the SLM and the computer. The correct display interface settings for the SLM can be done from within the EDID device detection, see next section.

Start the program using the icon  of the software, which was created during the installation process. The EDID device detection will show up. If the SLM is connected properly, the software will automatically continue. If not, please connect the HOLOEYE SLM and select it. After the SLM was properly detected, the software will start and is ready to use.

4.2.1 SLM Device Detection

When you start the software a device detection dialog pops up which checks if a proper HOLOEYE SLM is connected and if the system is configured correctly. You can find detailed information on the device detection in the chapter "EDID Device Detection" of this manual.

4.3 User Interface Concept and Preview

The main window of this application integrates a tab system to work with multiple images in parallel. Only one tab can be active on the SLM screen at the same time. Always the currently active tab is active on the SLM. The active tab is marked in dark green, and the inactive tabs have light green buttons. The first tab button is always red. It is dark red when there is no content shown on the SLM screen, i.e. other applications, e.g. the Windows desktop background image, will be visible on the SLM. If it is light red, another tab is active and shown on the SLM screen.

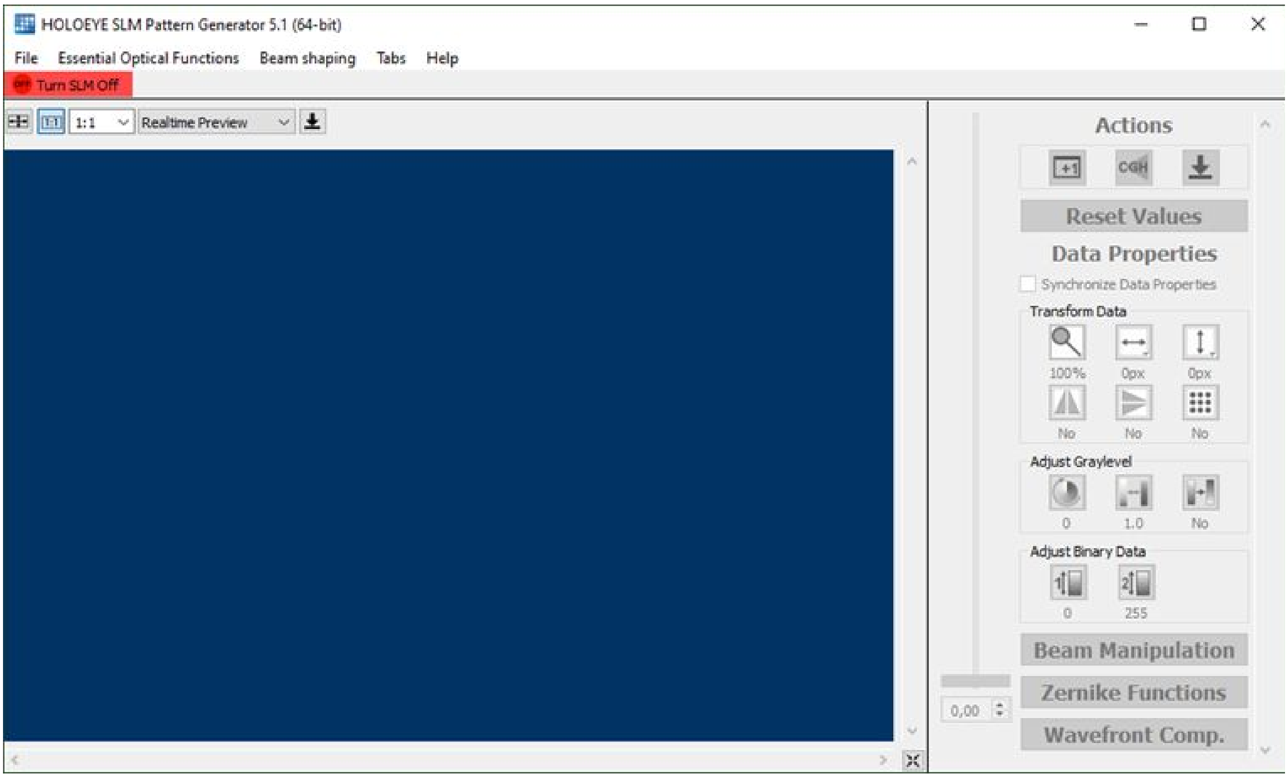


Figure 44: Main application window after start. There are no active tabs, and SLM screen is off (i.e. other applications can use SLM screen).

The image visible inside each tab is only a preview image of what is actually displayed on the SLM screen. The preview can be configured with the controls above the shown preview image. You have the option to scale the image in the preview for inspecting the content shown on the SLM. The default mode is “1:1” scaling, which means each pixel on the SLM is represented by a single pixel of your monitor. This is helpful to inspect most phase modulation pattern, like gratings etc.

The “Fit” option shows the full SLM screen and fits it into the preview area. This is helpful to get an overview of what is shown on the SLM screen. Anyway, you can put in any ratio, or select from predefined ratio numbers from the drop-down menu. In addition, the “Realtime Preview” mode can be changed to a “Capture SLM Screen” mode.

The “Realtime Preview” is faster but may not be 100% correct. The “Capture SLM Screen” mode is slower, but provides a better image quality and enables visualization of other applications visible on the SLM screen, like stay-on-top windows like Windows Task Manager or other applications using the SLM screen. The rightmost button of the preview controls saves the full SLM screen into an image file on disk. This image file can also be used to inspect the content on the SLM screen precisely.

Figure 45: Preview options of the current SLM screen content.

Beneath the preview is a sidebar, which allows manipulating the image data. Please refer to the chapter "Image Manipulation Sidebar" for more information on image and phase manipulation features.

4.4 Open Image Files

4.4.1 Open Amplitude or Pre-calculated Phase Data Image Files

Choose from the *File* menu the point ’Open amplitude/phase data from image file …’, and a file selection dialog will show up. Supported image formats are BMP, PNG, JPEG, GIF, XBM, XPM, MNG and the different PNM formats: PBM (P1 or P4), PGM (P2 or P5), and PPM (P3 or P6). Choose a supported image file and accept the file selection dialog. The image file(s) are loaded and are transformed to a picture with 256 gray-scale values. If the selected images contain an alpha channel, it will be ignored.

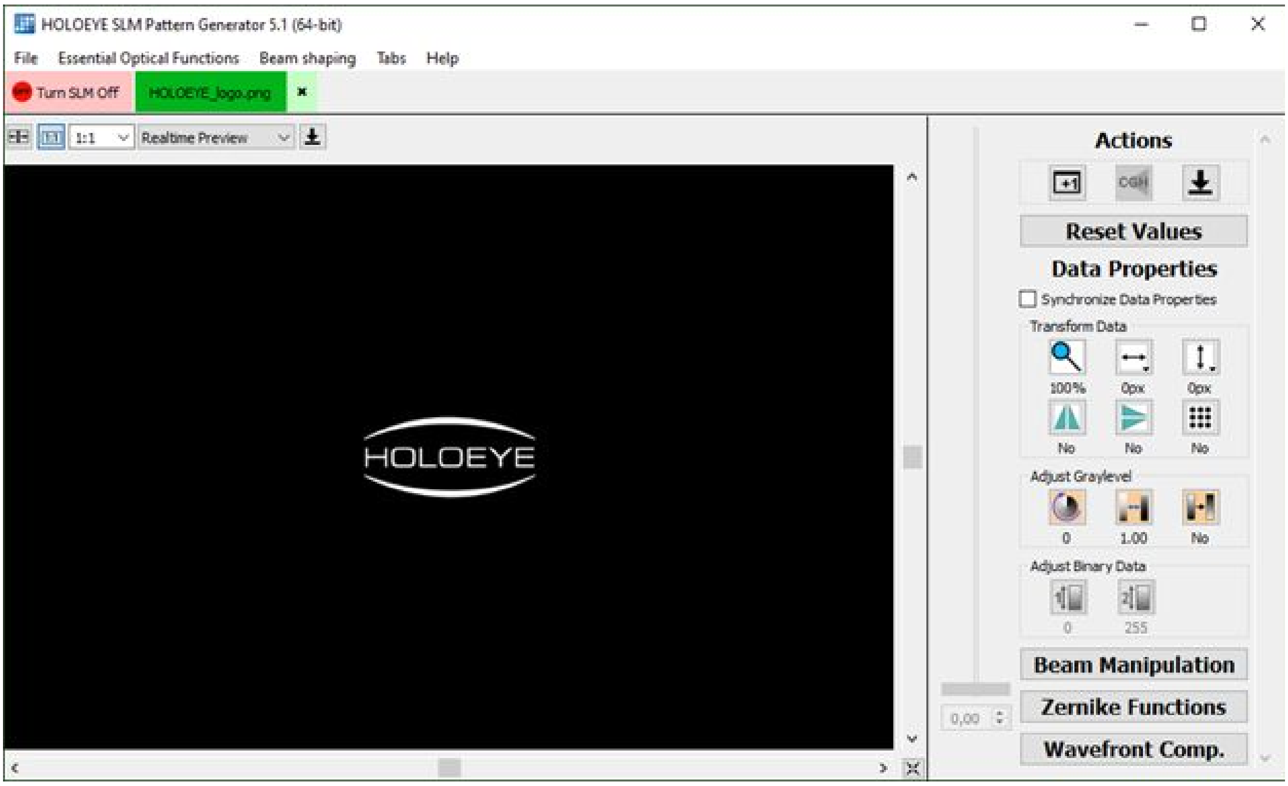


Figure 46: Image tab after opening the installed HOLOEYE logo from the signals folder.

The image file will appear in a new tab, and will be visible on the SLM screen directly. When selecting multiple files, all selected files will open in separate tabs, and the last of them will be active.

The image files are shown as is. In case of active manipulations synchronized from other tabs, these synchronized manipulations will be applied directly. When the check box 'Synchronize Data Properties' is off, images will open without any manipulations. The image file(s) cannot be computed into computer generated hologram (CGH) phase values if opened through this menu entry. This is indicated by the tab caption, which is the plain file name without any additions, and by the deactivated and grayed out action button "CGH".

Therefore, please use this menu entry only if you want to open either pre-calculated phase images or amplitude images. For creating phase images out of amplitude images using this software, please use one of the CGH computation options from the *File* menu. See below.

4.4.2 CGH Computation from Image Files

Please use the menu entry 'CGH computation from image files' from the *File* menu to select a single image file or a few image files for creating computer-generated holograms (CGH). The CGH computation needs information about the resulting holographic image in far field. A dialog will open once to select the resulting image size compared to the unit cell size, and to select the maximum unit cell size used in computation. When multiple files were selected, the dialog will open only once and will apply the same settings from the first image file to all. The CGH settings dialog is shown in Figure 54 and is explained in the chapter "Calculating a Computer Generated

Hologram (CGH)".

When you want to compute a lot of CGH files, e.g. for later slide show playback, please consider using the more advanced CGH batch computation dialog.

4.4.3 Open by Drag and Drop or via Clipboard

Images can be pasted directly into HOLOEYE SLM Pattern Generator from clipboard. To do so, please copy image data from image editing software to the clipboard and use the key combination CTRL-V to put the image into a new tab. The same can be done with image files. You can copy the file and paste it into the main window of HOLOEYE SLM Pattern Generator.

In addition, image files can be dragged from Windows Explorer and dropped into the main window of HOLOEYE SLM Pattern Generator. The files will be opened in the same way as if they would have been copied and pasted.

On each such paste or drop action, the software will ask in which mode the images shall be used, either as plain images with pre-calculated phase data or amplitude data, or as input image files for CGH computation. A dialog will open to select the mode, see Figure 47. If multiple images are given at the same time, the dialog will apply the same mode for all images.

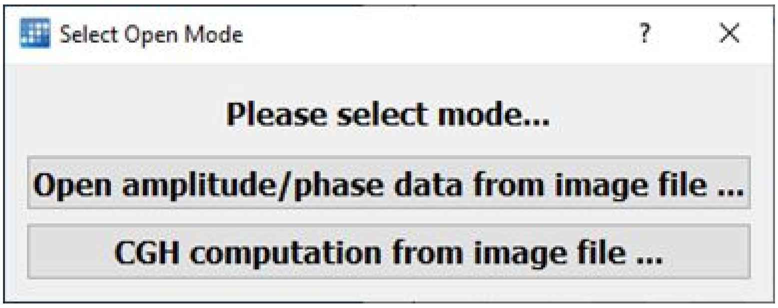


Figure 47: Selection dialog after dropping or pasting image files or data into the main window. Images files can either be shown directly or used as input for CGH computation.

Anyway, when multiple images are pasted or dropped, the software will open each image in a separate tab, using the selected mode.

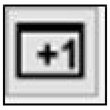
4.4.4 Copy Image Data

Please use the keyboard shortcut CTRL+C to copy the image data in full SLM size into clipboard. This data can then be pasted into other image editing software like Microsoft Paint in Microsoft Windows OS, Irfan View, GIMP, and many other similar applications.

4.5 Action Buttons in Sidebar

The top of the sidebar on the right side of the main window provides a few action buttons.

4.5.1 Clone Tab Action Button

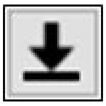


The first action button is to make a copy of the current tab with the loaded data and all current sidebar settings.

4.5.2 Compute CGH Action Button

This button is only enabled if the tab caption starts with 'CGH: '. This is the case when opening images in CGH computation mode, see "CGH Computation from Image Files" and "Open by Drag and Drop or via Clipboard". Pushing this button will re-open the CGH settings dialog (see Figure 54). Please apply new CGH settings and accept the dialog to re-compute the hologram and update the content in the current tab. The CGH settings dialog has two settings: the slider for the resulting image size inside the diffraction unit cell of the far field and the maximum unit cell size. It is recommended to stay with the default maximum unit cell size. Please see chapter "Calculating a Computer Generated Hologram (CGH)" for more information on CGH computation.

4.5.3 Save Data Action Button



This button does the same like the same button in the preview settings. It stores the current SLM screen content into an image file. You can use this image file for detailed inspection of the SLMs content. The saved image file can also be used later in other software, like HOLOEYE SLM Slideshow Player.

4.6 Image Manipulation Sidebar

On the right side of the main window, beneath the preview, a sidebar is visible. It contains multiple image and optical phase manipulation features like zoom, shift, flip, tiling, gray level adjustments, beam manipulations (beam steering and (de-)focus), Zernike parameter overlay, and wavefront compensation. In addition, there are a few actions (Clone data into a new tab, re-compute CGH, save current SLM image). All these options have a hint text, which pops up when the mouse cursor stays over the button for a short period. The hint texts explain the function of the button and show additional helpful information.

To edit one of the available manipulation values, please use the left mouse button and click on the icon. The large vertical slider will take the selected function and enables changing the value, if applicable. Some functions like 'Tiling Data' will disable the slider, because there is no value except for Yes/No. The current value of each manipulation is written below the manipulation button icon.

4.6.1 Sidebar Synchronization over all Tabs

On the top of the sidebar there is a check box 'Synchronize Data Properties'. When it is checked, all tabs will be synced to the same sidebar settings, except a few manipulation options, which are related to the data type, like tiling option for CGHs, and binary values for binary functions. The synchronization is useful in case the adjustments are made due to the optical setup. Synchronization may help in case you have a lot of similar images opened. Using no synchronization is recommended when the adjustments are made for the used image data.

Zernike overlay and the wavefront compensation are always synchronized in all tabs, independent of the check box, because these settings are meant to be used to correct for optical setup and device imperfections, e.g. optimizing a beam focus or correcting for wave front imperfections due to optical elements, including the SLM. Therefore, Zernike and wavefront compensation will be applied to new tabs too, even when you open amplitude images, because they will be used like pre-computed phase functions by the software.

The wavefront compensation overlay may not be visible on the preview, depending on the settings, see Figure 45. However, it has its own little preview in the sidebar, which may be hidden as well.

4.6.2 Reset Adjustments

There is one big ‘Reset Values’ button at the top of the sidebar. It resets all adjustments, which do not directly belong to the image data, except for a loaded wavefront compensation.

Additionally, each box can be reset separately by clicking the right mouse button onto the captions of the boxes. The same applies to each icon of the manipulations. You can right-click to reset its value to the default value.

4.6.3 Basic Image Manipulations

The first box is ‘Transform Data’ (see Figure 48) with the following features:

- **Zoom/Resize**: Performs a zoom of the bitmap data, i.e. there will be interpolation effects at least for non-integer zoom factors.
- **Shift X / Y**: Move the image in x and y direction over the SLM screen. Please click and hold on the buttons to open a sub-menu to change the slider range, if needed. By default, the slider range is set to the size of the opened image file, or adapted to the essential optical function. For some optical functions, one or both buttons may be inactive.
- **Flip X (Left/Right)**: Mirrors the image along the vertical center line.
- **Flip Y (Top/Bottom)**: Mirrors the image along the horizontal center line.
- **Tile Data**: Makes smaller images appear periodically continued, i.e. tessellated, initialized with the base image ‘tile’ shown in the screen center. This feature is enabled by default for CGH computation results and a few essential optical functions.

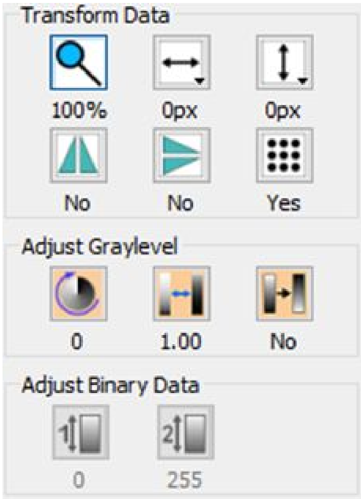


Figure 48: Basic image manipulations in sidebar.

The next box is 'Adjust Graylevel'. It allows overall adjustment of the gray levels of the currently used bitmap data. There are three adjustments:

- **Cyclic Shift**: Adds the selected gray value to the image, and if it exceeds the value 255, it jumps back to 0.
- **Gamma**: Applies an image gamma correction to the gray values. The actual formula is $v(x, y, \gamma) = v_{orig}(x, y)^{1/\gamma}$ with $v_{orig}(x, y)$ is the value at pixel position (x, y) of the original data without gamma applied, and $v(x, y, \gamma)$ is the gamma corrected value for the same pixel at (x, y) position. Values are in range [0, 1] instead of 8 bit gray values from 0 to 255. γ is the gamma slider value. Gamma correction is applied to the whole image including all other manipulations.
- **Invert Values**: If enabled (Yes), this feature inverts the gray values in the image so that black gets white and vice versa.

The last group of basic image manipulations are the two sliders for the first and second gray level in the image. This feature is only available if the image contains binary data. This applies to all binary elementary optical functions created within HOLOEYE SLM Pattern Generator, like binary axicon, divided screens, etc., and all amplitude/phase data user images loaded from file or via drag-drop or copy-paste, which contain only two different gray values in the whole image.

4.6.4 Beam Manipulation Phase Overlay

The software allows superposition of a beam manipulation phase overlay to the image data of each tab. Three functions are available: Beam steering in both directions x and y (blazed gratings), and a Fresnel zone lens overlay. The values set through the sliders are unified to a range between -1.0 and +1.0. Outside this range, the pixel size of the SLM makes the functions inaccurate. For the lens we allow a larger range (-5.0 to +5.0), because inaccuracies are starting at the edges, and the lens is still fine in the center for larger absolute values. Anyway, values outside the [-1.0, 1.0] range will have artefacts in the edges.

The unified values are the same values, which can be applied into the data handle of our advanced Application Programming Interface of HOLOEYE SLM Display SDK.

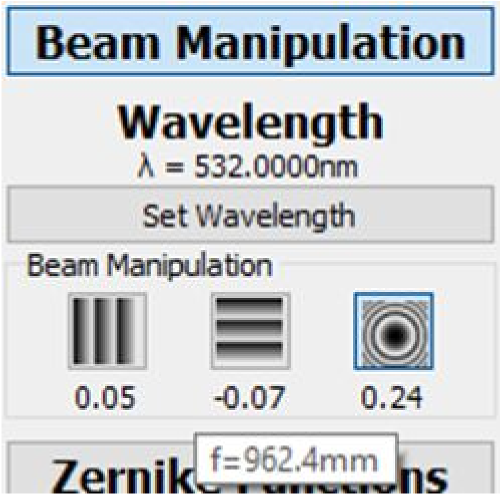


Figure 49: Beam manipulation feature.

To enable beam manipulation overlay, please click the large button ‘Beam Manipulation’ in the sidebar. If no incident laser light wavelength is set earlier, the software will ask for the wavelength when you apply any beam manipulation value. The incident laser light wavelength is needed to calculate the physical meaning of the unified values.

The labels below the icons show the unified value of the slider. The physical unit is shown in the hint texts of the labels.

The physical values are calculated as follows:

$$\alpha = \sin^{-1}\left[\frac{\lambda * \mathrm{beamSteerSliderValue}}{2 * \mathrm{Pixelsize}}\right]$$

and

$$\mathrm{f} = \left[\frac{\mathrm{SLMWidthPixel} * \mathrm{Pixelsize}^2}{\lambda * \mathrm{beamLensSliderValue}}\right]$$

- α is the corresponding beam deviation angle between the 0th and the first diffraction order.
- f is the focal length of the superimposed Fresnel zone lens.
- λ is the incident laser light wavelength.
- "Pixelsize" is the physical size of the SLMs pixel, e.g. 8µm for HOLOEYE PLUTO SLMs.
- "SLMWidthPixel" is the number of pixels in the large direction of the display.
- "beamSteerSliderValue" and "beamLensSliderValue" are the unified slider values.

4.6.5 Zernike Parameter Phase Overlay

To enable the Zernike overlay, please click the large button ‘Zernike Functions’ in the sidebar. Additional slider values will pop up. Please use the sliders to set Zernike parameters. There is an enable check box, which allows toggling between the selected slider values (i.e. Zernike parameters) and no Zernike overlay. When the button ‘Zernike Functions’ is pressed again, the Zernike sliders are hidden, but the values are still enabled until the enable check box is unchecked or the sliders are reset to 0. Figure 51 shows the Zernike sliders with the enable check box.

Zernike parameters will create a smooth optical wave front added to the displayed phase data. The phase values are generated out of the Zernike polynomials with their corresponding Zernike parameters (slider values). The Zernike polynomials are only defined inside the Zernike radius. Therefore, it makes sense to use the half SLM diagonal as the Zernike radius, but this software allows using your own Zernike radius, if needed. Anyway, the half diagonal is the default Zernike radius. To make the Zernike radius visible in the preview, the preview options are extended with a button. By pressing the button, the region outside the Zernike radius will be dyed red in the preview only to indicate the area where the Zernike polynomials are undefined.

Figure 50: Preview options when Zernike values are enabled. Please use the red button to visualize the undefined area outside the Zernike radius in the preview.

Please make sure to set the Zernike radius before applying the Zernike parameters. Using a smaller Zernike radius may be interesting for example when not using the whole SLM area.

Zernike polynomials and parameters are available up to the 4^{th} order. Zernike parameters will be applied to all tabs synchronously. The feature was added to correct for optical setup imperfections, like correcting the flatness of an optical element or optimizing the beam profile.

The general formula for calculating the phase shift over the area of the SLM is

$$\Phi(\rho,\theta) = 2\pi \mathrm{rad} \sum_{(n=0)}^{4} \sum_{(m=0)}^{n} A_{nm} U_{nm}(\rho,\theta)$$

with

$$\rho = \frac{r}{r_z} = \frac{\sqrt{(x^2+y^2)}}{r_z},$$

$$0 \leq r \leq r_{z},$$

$$0 \leq \rho \leq 1,$$

$$\theta = \mathrm{atan2}(\mathrm{y}, \mathrm{x}),$$

$$-\pi < \theta \leq \pi.$$

Figure 51: Zernike coefficients and Zernike radius sliders.

Below you find a list of the used Zernike polynomials:

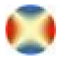
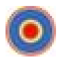
Name	Polynomial	n	m	Icon
Piston	1	0	0	
Tilt x	$\rho \sin(\theta)$	1	0	
Tilt y	$\rho \cos(\theta)$	1	1	
(De)focus	ρ^2	2	0	
Astigmatism 45°	$\rho^2 \sin(2\theta)$	2	1	
Astigmatism 0°	$\rho^2 \cos(2\theta)$	2	2	
Trifoil X	$\rho^3 \sin(3\theta)$	3	0	
Trifoil Y	$\rho^3 \cos(3\theta)$	3	1	
Coma (3rd order) X	$(3\rho^2\text{-}2p) \sin(\theta)$	3	2	
Coma (3rd order) Y	$(3\rho^2\text{-}2p) \cos(\theta)$	3	3	
Spherical abberation	$6\rho^4\text{-}6\rho^2\text{+}1$	4	0	
Astigmatism 2nd 45°	$4\rho^4\text{-}3\rho^2 \sin(2\theta)$	4	1	
Astigmatism 2nd 0°	$4\rho^4\text{-}3\rho^2 \cos(2\theta)$	4	2	
Quadrafoil X	$\rho^4 \sin(4\theta)$	4	3	
Quadrafoil Y	$\rho^4 \cos(4\theta)$	4	4	

Table 7: Zernike polynomials

Each Zernike parameter (i.e. slider value) can be changed in the range from -5.0 to +5.0. Parameters with a value of ±1.0 create a phase function, which modulates in the range [inside the Zernike radius.

The piston is not available as a Zernike parameter slider. If you need the piston, please use the 'Cyclic Shift' feature of the 'Adjust Graylevel' sliders instead.

The Zernike parameter values applied here can be applied with the function `heds_slm_zernike()` of our HOLOEYE SLM Display SDK, too. Both software will produce the same phase function for the same set of values.

4.6.5.1 Save and Load Zernike Parameters

The complete set of Zernike parameters available through the sliders can be saved into a text file format for later usage. The ‘File’ menu provides the options ‘Load Zernike parameter file …’ and ‘Save Zernike parameter file …’.

Both menu entries open a file selection dialog, where you need to either select an existing file when loading values, or select a new file for saving Zernike parameter values. The menu entries are only available when there is at least one tab open with any optical function.

The save menu entry stores the currently applied set of Zernike parameter values into the selected text file. The text file is saved with a file name ending ‘.zernike.txt’ by default, so that the ending indicates the type but is also easily editable with any text editor. The text format of the file content contains one parameter per line. Each parameter is indicated by its name, followed by the value, separated by a tab. In addition to the parameters, the Zernike radius is saved, too.

Loading such a zernike.txt file can for example be used to restore Zernike parameter values from a previous session. When loading the file, it is allowed that some Zernike parameters are not available in the file. Missing parameters will be assumed to be zero. The Zernike radius must be part of the file content, because the Zernike parameter values produce different phase functions for different Zernike radius values. After successful loading of such a file, the currently applied values in the sliders are overwritten instantly with the new values loaded from file.

4.6.6 Wavefront Compensation Phase Overlay

With version 5.1, there is an additional overlay button in the sidebar called “Wavefront Comp.”. If no wavefront compensation is loaded, pressing the button will open the “Wavefront Compensation Setup” dialog, see "Wavefront Compensation Overlay". Otherwise, the button will hide or show the sidebar box of the loaded wavefront compensation field, see Figure 52.

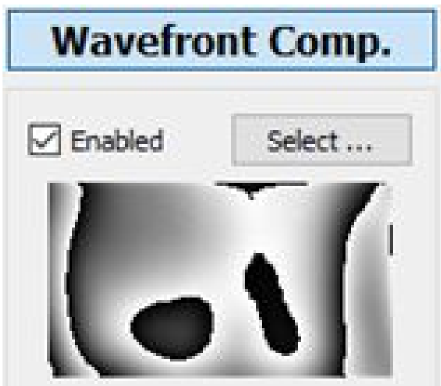


Figure 52: Wavefront compensation option in sidebar.

The “enable” check box will toggle the wavefront overlay on the SLM screen. The “Select …” button allows re-opening of the “Wavefront Compensation Setup” dialog.

Figure 53: Preview options when a wavefront comensation is loaded and the wavefront compensation is visible in the preview (i.e. button with hint text “Show Wavefront Compensation” is pressed).

As soon as a wavefront compensation overlay is loaded, the visibility in the preview windows “Realime Preview” mode can be activated, see Figure 53.

4.7 Calculating a Computer Generated Hologram (CGH)

To compute a CGH from an image, please open an image in the CGH computation mode, see chapter "CGH Computation from Image Files" and "Open by Drag and Drop or via Clipboard". Alternatively, there is a CGH batch computation dialog, which simplifies computation of multiple similar images.

After opening images for CGH calculation, the CGH settings dialog will appear, see Figure 54. The same dialog is integrated into the CGH batch computation dialog shown in Figure 56.

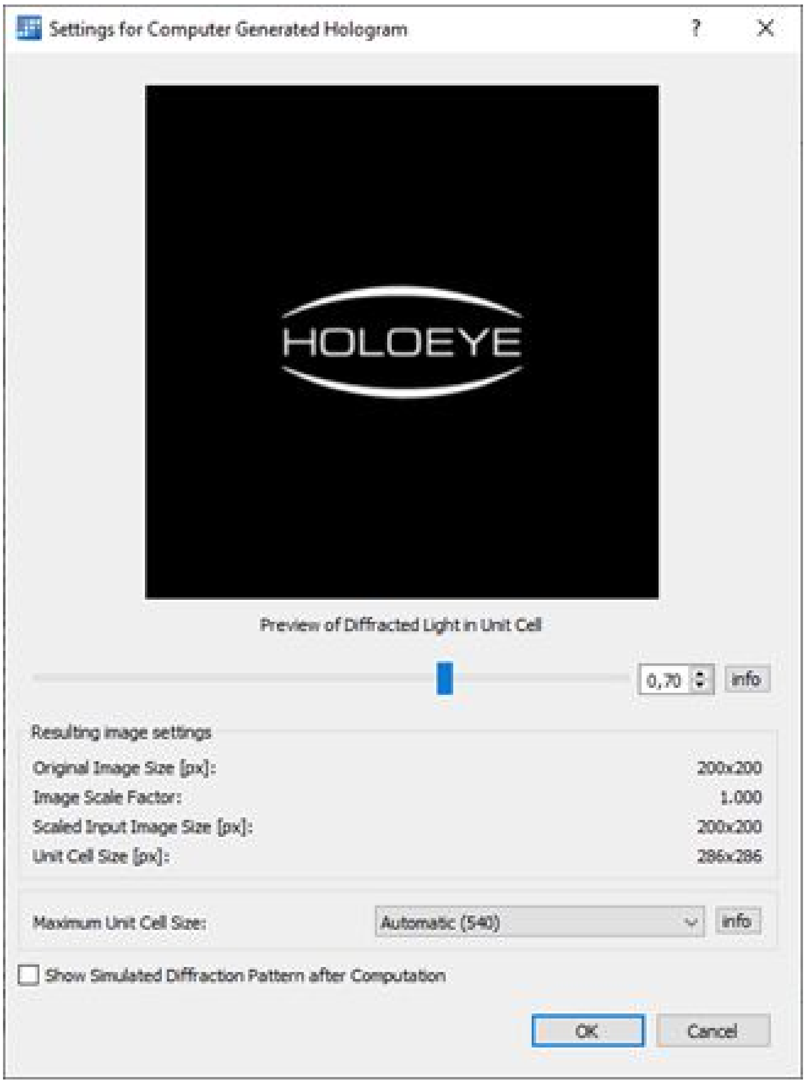


Figure 54: CGH settings dialog

After accepting the CGH settings dialog, the CGH computation will start.

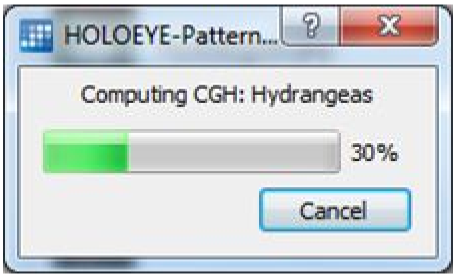


Figure 55: Progress of the CGH computation.

The computation of the hologram phase function will take a while, depending on the used unit cell size and the computer performance. The computation progress is indicated with a progress dialog like shown in Figure 55.

The result of the CGH computation is opened in a new tab, if new image files was opened. If a CGH is re-computed using the action button, the updated hologram will override the image data in the current tab.

If the check box “Show Simulated Diffraction Pattern after Computation” is checked in the CGH computation dialog, a numerical simulation of the resulting optical image in the far field will open in a separate, modal window. That means you must close the dialog first before using the main window again. The check box is not available if multiple image files are opened. The check box is unchecked by default because the information gain from the simulation is typically very small compared to the faster calculated preview inside the CGH settings dialog. However, in case of uncertainty, you can check the theoretical holographic projection result of the CGH computation for your input data.

For all tabs opened by the CGH computation, the tab caption starts with ‘CGH: ‘ and the re-compute action button is available.

4.7.1 CGH Settings Explained

For the computation of a hologram, we need to define the size of the unit cell. We measure the size in pixels of the SLM. There are two issues to be considered while selecting the unit cell size. The first issue is the resolution of the optical far field result. The larger the unit cell size, the better the quality of the optical result. However, if the unit cell on the SLM is not illuminated completely, then the quality will decrease. This means the second issue is to take into account the used beam diameter on the SLM.

The unit cell size is calculated automatically. It uses the input image size and the selected image size in the unit cell to use an optimal unit cell size. To account for the complete illumination of the unit cell, the algorithm uses a setting for the maximum unit cell size. This setting is automatically selected to be the SLM height divided by two. By selecting a smaller value, the algorithm is forced to reduce the quality and increase computation speed. By selecting a larger value, the algorithm gets more freedom to select a proper unit cell size. The maximum unit cell size can be increased up to the SLM height. However, selecting a higher maximum unit cell size should only be done if the beam diameter on the SLM is as large as the selected value or larger.

Please adjust the settings by using the dialog shown in Figure 54 or the settings embedded into the CGH batch computation dialog, shown in Figure 56.

The computation uses the Iterative Fourier Transformation Algorithm (IFTA). Note that the process of computing may take a short while, depending strongly on the unit cell size. Both progress dialogs (Figure 55 and Figure 57) permits interruption of the ongoing computation.

The result of the IFTA algorithm is a phase function, which can be addressed on the SLM directly. The algorithm converts the phase into gray levels from 0 to 255 assuming the SLM is properly calibrated to 2.0 π rad phase shift. The phase data result is a grayscale image. Either it will open in a new tab after accepting the CGH settings dialog, or when using the batch dialog, the resulting images are directly saved to disk.

4.8 CGH Batch Computation

With version 4.0 and later of the HOLOEYE SLM Pattern Generator Software, we introduce a new feature called CGH batch computation. The CGH batch computation should be used when many image files shall be used to generate hologram phase functions (see "CGH Computation from Image Files" and "Calculating a Computer Generated Hologram (CGH)". It is especially designed to compute image sequences for later slide show playback, e.g. using HOLOEYE SLM Slideshow Player software. Therefore, it can save the resulting phase fields directly into image files. Additionally, it provides easy testing by directly addressing the result onto the SLM screen.

Please use the menu 'File' à 'Open CGH Batch Computation …' to open the batch window. It will show as the first tab.

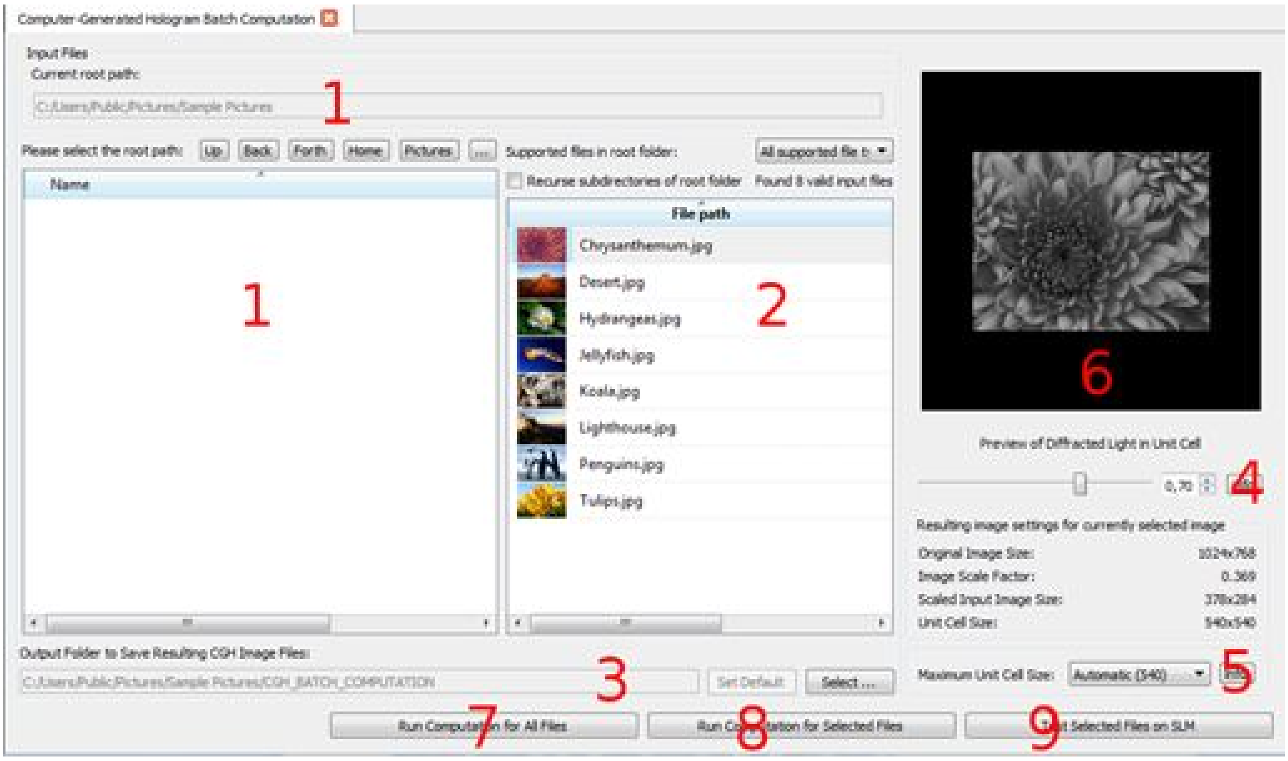


Figure 56: CGH Batch Window

The dialog consists of a folder selection box for the root path (1), a list of found files in the selected root folder (2), the CGH settings including a preview (4, 5, and 6), and the output folder selection (3). The buttons 7, 8, and 9 are used to start the computation process.

First, please navigate with the browser (1) to the base folder where all your input image files are stored. The currently selected root path is shown on the top. Please use the buttons 'Up', 'Back', and 'Forth' for navigation through the folders. The buttons 'Home' and 'Pictures' can be used as a shortcut to your current user directory and to the pictures folder of your current user directory. With the button '…' a system folder selection dialog will open which can also be used to navigate to the desired root folder.

As soon as the root folder changes, the files inside the root folder are being searched and listed in the file selector (2). The files are searched recursively if the check box 'Recurse subdirectories of root folder' is checked. Only valid input files are listed. The files can be filtered by the file extension. By default, all supported file extensions are shown. Other file extensions can be filtered with the drop-down-selector. During the file search, the text below the drop down selector will show 'Searching valid input files: N'. When all files are searched through, the text changes to 'Found N valid input files'. During the file search, the button (7) is disabled.

The image files in the file selection box (2) can be multi-selected. The latest selected file will be loaded into the preview (6). The buttons 8 and 9 are disabled until at least one file is selected.

Please use the slider or the related edit field (4) to set up the image size in the unit cell. See explanation in section CGH Settings Explained. If needed, the maximum unit cell size can also be changed (5).

Please note that both settings (4 and 5) apply to all images which are computed in one batch run. However, this means that the unit cell size is still selected for each image individually.

The preview (6) is a grayscale animation of the theoretically resulting optical far field of the unit cell, respecting the made settings.

The text fields in the box 'Resulting image settings for currently selected image' show the resulting scale and unit cell size settings.

The output folder path (3) is selected automatically to be the subfolder 'CGH_BATCH_COMPUTATION' of the currently selected root path. The output path can also be selected manually. If a custom output path is selected, the output path is not adjusted anymore after the root folder was changed manually. If the output folder does not exist, it will be created automatically during the batch computation process.

With the two buttons 7 and 8 the output holograms will be saved as png files into the selected output folder. With the button 9 the files will be opened in SLM data tabs directly and no files will be saved. Each file, which finishes calculation, will be directly addressed to the SLM when button 9 was used.

During the file based computation (7 and 8), a progress dialog will open which shows both, the progress of each image file and also the overall progress of the batch computation (see Figure 57). The progress dialog also shows the preview and the used settings of the currently processed image file. It allows cancelling the whole batch computation process.

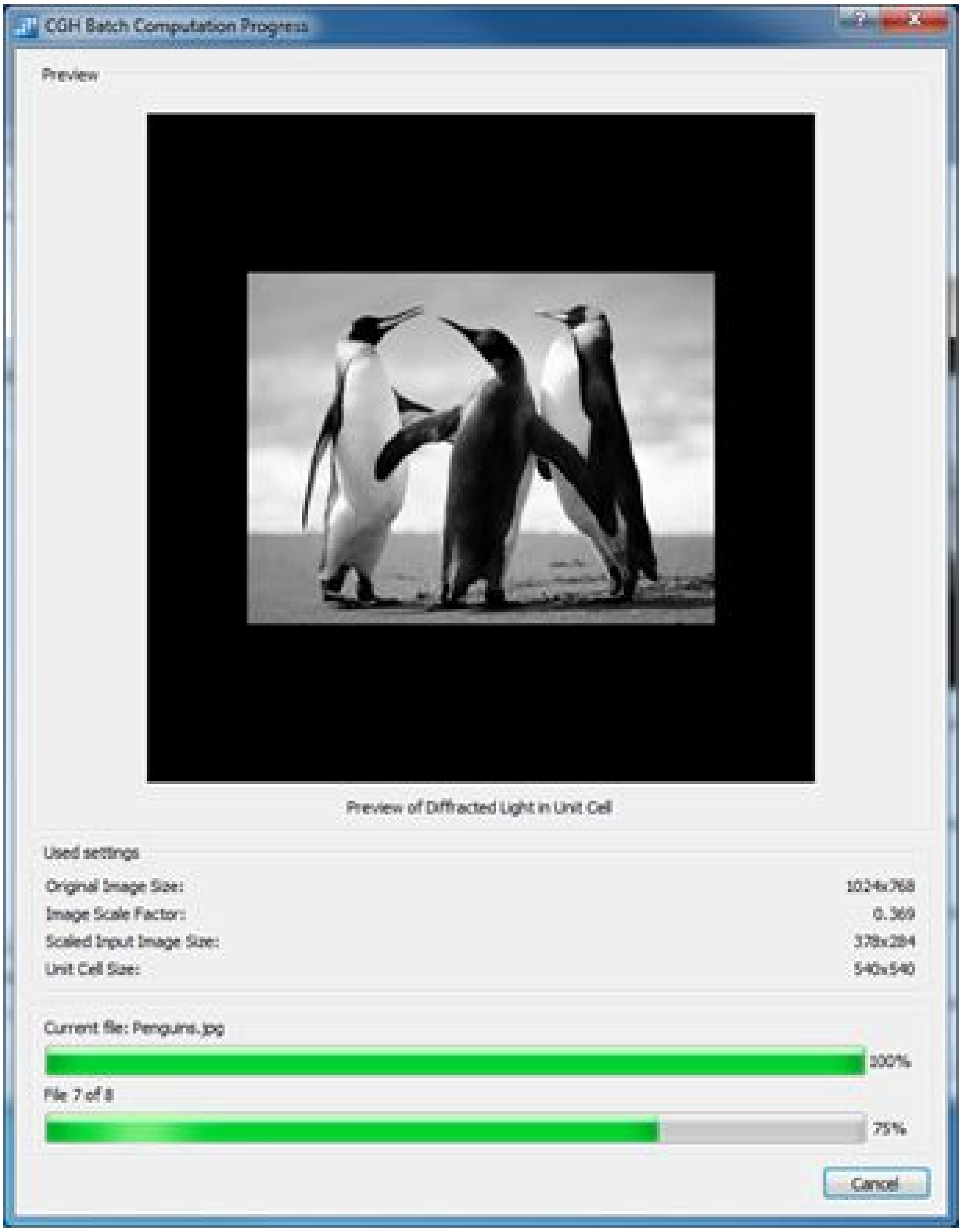


Figure 57: CGH Batch Progress Dialog

4.9 Wavefront Compensation

Since version 5.1, the software allows to load a full screen phase overlay field, which electro optically compensates for physical deformation of the displays backplane. The deformation of the backplane typically leads to a deformation of the wavefront of the reflected light. This can be compensated by addressing the inverse deformation as a phase pattern on the SLM. It requires a measurement of the wavefront deformation introduced by the display.

Wavefront compensation files are avaiable for LCoS SLM devices shipped after March 2021, containing an optical path difference field of the deformation. For LC 2012 devices wavefront compensation files are **not** available.

4.10 Creating Essential Optical Functions

All optical functions from the menu point "*Essential Optical Functions"* appear in a new tab after the required parameters are given. Depending on the optical function, binary or multilevel, some sidebar sliders may be disabled.

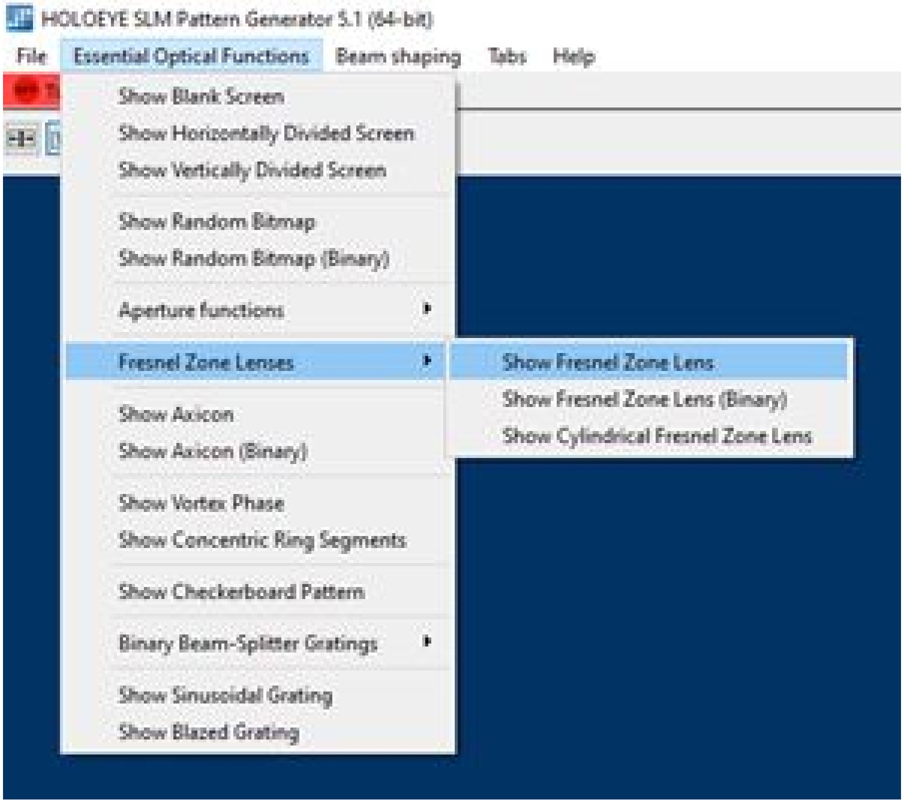


Figure 58: Menu entries for optical functions

4.10.1 Blank Screen

With this function, you can create a homogeneous graylevel screen. You will be asked to enter the desired graylevel. The given graylevel will set the 'Cyclic Shift' slider.

4.10.2 Horizontally Divided Screen

With this function you will create a horizontally divided screen, consisting of two homogeneous graylevel partial screens. Please use the gray level adjustment sliders to change the two values.

4.10.3 Vertically Divided Screen

With this function you will create a vertically divided screen, consisting of two homogeneous graylevel partial screens. Please use the gray level adjustment sliders to change the two values.

4.10.4 Random Bitmap

With this function you will create a random pixel distribution using 256 graylevels. This function can be used to realize the optical function of a random phase plate.

4.10.5 Random Binary Bitmap

With this function you will create a random pixel distribution using only two grayscale values. This function can be used to realize the optical function of a random binary phase plate.

4.10.6 Aperture Functions

4.10.6.1 Rectangular Aperture

Use this function to create a rectangular aperture. The size of the aperture can be defined by specifying the aperture width and aperture height. With the sliders on the taskbar one can change the gray levels of the background and of the aperture.

4.10.6.2 Circular Aperture

Use this function to create a circular aperture. The radius of the aperture can be defined by specifying a numbers of pixels. With the sliders on the taskbar one can change the graylevels of the background and of the aperture.

4.10.6.3 Single Slit and Double Slit

To create a single slit choose the point 'Show Single Slit' from the menu point *Aperture Functions.* The slit width can be defined by the number of pixels in the dialog window.

To create a double slit choose the point 'Show Double Slit' from the menu point *Aperture Functions.* Moreover the slit distance can also be defined. This refers to the distance between both slits.

4.10.7 Fresnel Zone Lenses

4.10.7.1 Fresnel Zone Lens

Use this function to create a 256-level Fresnel Zone Lens grayscale image representation. In the dialog field the lens function can be characterized by the radius of the smallest ring, which is defined by a number of pixels. The focal length of the lens is given by

$$\mathrm{f} = \frac{(\mathrm{n}_{\mathrm{r,min}}\mathrm{p})^2}{2\lambda}$$

where λ is the wavelength of the laser which was entered when starting the software. It can be specified whether the image representing the lens should be positive or negative.

4.10.7.2 Fresnel Zone Lens (Binary)

Use this function to create a Binary Fresnel Zone Lens graylevel image representation. In the dialog field the lens function can be characterized by the radius of the smallest ring, which is defined by a number of pixels $N_{r,min}$. The focal length of the lens is given by

$$\mathrm{f} = \frac{(\mathrm{n}_{\mathrm{r,min}}\mathrm{p})^2}{\lambda}$$

where λ is the wavelength of the laser which was entered when starting the software.

4.10.7.3 Cylindrical Fresnel Zone Lens

Use this function to create a 256-graylevel image representation of a Cylindrical Fresnel Zone Lens. In the dialog field the lens function can be characterized by the width of the central zone, which is defined by a number of pixels $N_{w,min}$. The focal length of the cylindrical lens is given by

$$\mathrm{f} = \frac{(\mathrm{n}_{\mathrm{w,min}}\mathrm{p})^2}{8\lambda}$$

where λ is the wavelength of the laser which was entered when starting the software. The angular orientation of the cylindrical lens can be entered in degrees (integer values only).

4.10.8 Axicon (Binary)

Use this function to create a Binary Axicon graylevel image representation. In the dialog field the lens function can be characterized by the radius of the smallest ring, which is defined by a number of pixels.

4.10.9 Axicon

Use this function to create a 256-level Axicon grayscale image representation. In the dialog field the axicon function can be characterized by the radius of the smallest ring, which is defined by a number of pixels. It can be specified whether the image representing the lens should be positive or negative.

4.10.10 Vortex Phase

Use this function to create a 256-graylevel image representation of a vortex phase (often also referred to as ‘helical phase’ or ‘spiral phase’). In the dialog field the radius a central zone with constant phase can be specified as a number of pixels. The order of the vertex can be entered also as an integer value, for production of higher-order Laguerre-Gaussian beams.

Note that the angular orientation of the line where the phase changes from 0 to 2 π can be modified by superposition of the displayed phase with a constant phase value (see chapter "Basic Image Manipulations": ‘Cyclic Shift’ of ‘Adjust graylevel’ box).

4.10.11 Concentric Ring Segments

Use this function to create binary images consisting of concentric ring segments. In the dialog field the image function can be characterized by the radius of the smallest ring, which is defined by a number of pixels, and the desired number of segments, which can be varied from two to 20 (even numbers only).

4.10.12 Airy Beam 1D

Use this function to create a 256-level grayscale image representation of a one-dimensional cubic phase function for the generation of a one-dimensional Gaussian-Airy beam. In the dialog field the Airy beam function needs to be characterized by the smallest inner zone, which is defined by the number of pixels at which the generated phase function reaches a phase shift of 2 π for the first time starting at the center of the phase field. In addition, a rotation angle of the Airy beam can be set in degree, which rotates the phase function in the (x,y)-plane.

Note that in the center of the generated phase function, the phase value changes from positive to negative values by default, which produces a wrap from black to white in the center. This wrap line cannot be avoided in general, but it can be moved outside the center by applying a cyclic shift on the gray levels, please see chapter "Basic Image Manipulations": ‘Cyclic Shift’ of ‘Adjust graylevel’ box.

4.10.13 Airy Beam 2D

Use this function to create a 256-level grayscale image representation of a two-dimensional cubic phase function for the generation of a two-dimensional Gaussian-Airy beam. In the dialog field the Airy beam function needs to be characterized by the smallest inner zone, which is defined by the number of pixels at which the generated phase function reaches a phase shift of 2 π for the first time starting at the center of the phase field. In addition, a rotation angle of the Airy beam can be set in degree, which rotates the phase function in the (x,y)-plane.

Note that in the center of the generated phase function, the phase value changes from positive to negative values by default, which produces a wrap from black to white in the center. This wrap line cannot be avoided in general, but it can be moved outside the center by applying a cyclic shift on the gray levels, please see chapter "Basic Image Manipulations": ‘Cyclic Shift’ of ‘Adjust graylevel’ box.

4.10.14 Binary Beam-Splitter Gratings

4.10.14.1 Linear Gratings and Crossed Linear Gratings

Choose from the menu *Binary beam-splitter gratings* the item '*Show Binary Linear Grating*' to create a grating. The grating period can be defined by the number of pixel. By selecting the boxes the grating direction can be chosen to horizontal or vertical. Check both boxes to overlap a horizontal with a vertical grating and obtain a crossed grating.

4.10.14.2 Built-in Binary Beam-Splitter Designs

Choose from the menu *Built-in binary beam-splitter designs* one of the menu items

- *Show Binary Linear 1-to-5 Linear Beamsplitter Grating* (Grating period 26 pixel)
- *Show Binary 1-to-(2x2) Separable Array Beamsplitter Grating* (Grating period 18x18 pixel)
- *Show Binary Array 1-to-(5x5) Separable Array Beamsplitter Grating* (Grating period 26x26 pixel)
- *Show Binary Array 1-to-(5x5) Non-separable Array Beamsplitter Grating* (Grating period 26x26 pixel)

to obtain a tab with one of the mentioned diffractive elements.

The basic tiles of these gratings are fixed and usable as examples for separable and non-separable binary diffractive optical elements (DOEs).

4.10.15 Sinusoidal Grating

Choose from the menu point *Essential Optical Functions* '*Show Sinusoidal Grating*' to create a sinusoidal grating. The size of the grating period can be specified by the number of pixels.

4.10.16 Blazed Grating

Choose from the menu point *Essential Optical Functions* '*Show Blazed Grating*' in order to create a blazed grating. The size of the grating period can be specified by the number of pixels.

4.11 Calculating a Beam-Shaping Phase Function for Gaussian Input Beams

For incident laser beams with Gaussian beam profile, the SLM can modify that beam shape into other intensity profiles by utilization of an appropriate phase function. The HOLOEYE SLM Pattern Generator software provides phase functions for two special cases of such transformation: conversion of a Gaussian beam into spherical and rectangular flat-top profiles.

The computation of the beam shaping phase field needs the incident laser light wavelength. If it is not set before creating such a phase function, a dialog will pop up to select the wavelength (see Figure 59).

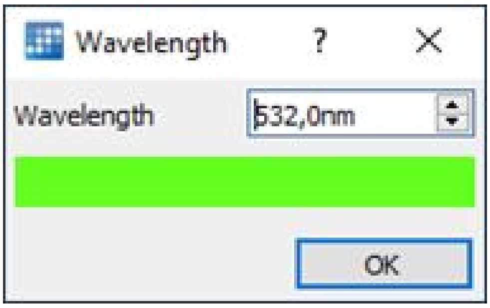


Figure 59: Please provide the wavelength of the incident laser light.

4.11.1 Transformation of a Gaussian Beam to a Circular 'Flat-Top' Beam

Select '*Transformation of Gaussian to circular Top-Hat beam*' from the '*Beam Shaping*' menu. The required parameters are the beam diameters ($1/e^2$) in the plane of the SLM, and the parameters of the desired output beam. The parameter 'Order of Super-Gaussian' will influence the slope steepness of the obtained profile. Higher Super-Gaussian Modes have a higher slope steepness.

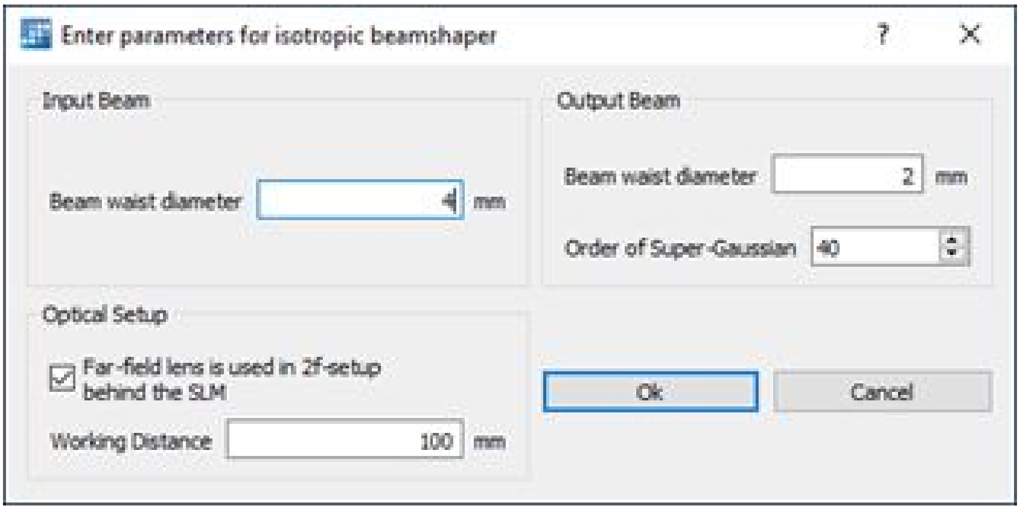


Figure 60: Parameters for computation of a beam-shaping phase

A laser beam can only be focused to a certain diameter depending on beam diameter, lens focal length and wavelength, and beam shaping phases cannot enable focusing below such limit. Therefore, if the target beam diameter is too small, the software will issue a message and suggest a more realistic target value. (The software currently does not check if the desired target beam size may be too large.)

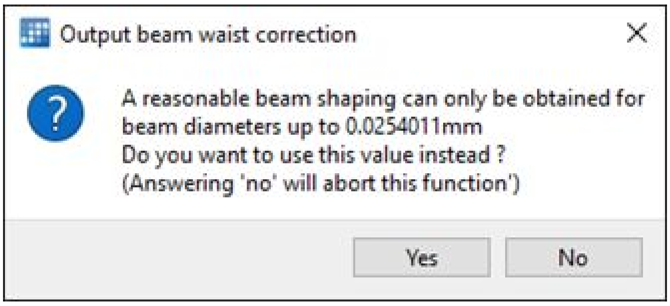


Figure 61: Warning message shown if target beam diameter is too small

The beam-shaping setup may incorporate a Fourier-lens and in this case the working distance is equal to its focal length, as the target plane is identical to the back focal plane. If no lens is used (and the corresponding checkbox is unchecked in the dialog shown above), the lens phase will just be superimposed to the beam-shaping phase.

4.11.2 Transformation of a Gaussian Beam to a Rectangular 'Flat-Top' Beam

Select '*Transformation of Gaussian to rectangular Top-Hat beam*' from the '*Beam Shaping*' menu. The required parameters are the beam diameters ($1/e^2$) in x and y direction in the plane of the SLM, and the size in x and y direction of the desired output beam. The parameter 'Order of Super-Gaussian' will influence the slope steepness of the obtained profile. Higher Super-Gaussian Modes have a higher slope steepness.

If the target beam dimension is too small to be feasible in either direction, the software will suggest a suitable beam size, maintaining the aspect ratio of the originally desired target beam.

4.12 The 'Tabs' Menu

The 'Tabs' menu item lists all currently open tabs and allows switching between them, even if a lot of tabs are open. The item 'Close all tabs' closes all currently opened tabs with a single click.

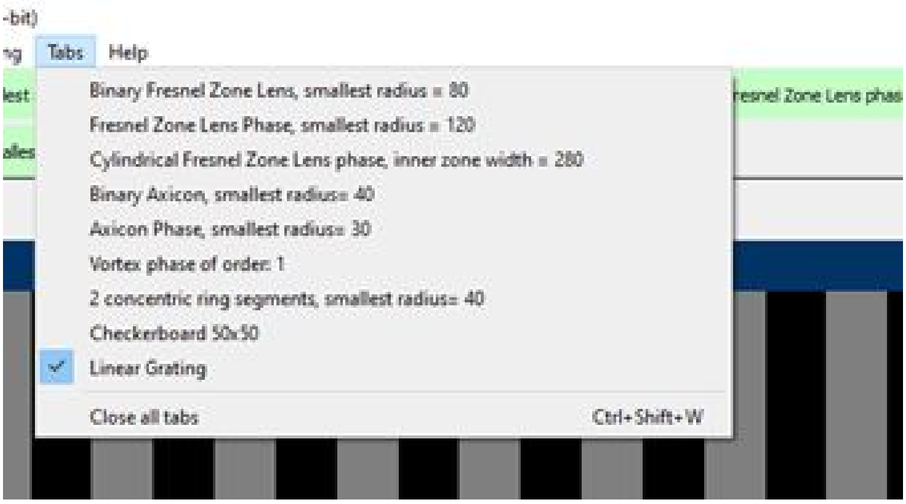


Figure 62: The menu 'Tabs' lists all tabs and allows switching and closing all.

4.13 The ‘Help’ Menu

This menu item provides information about this software, including the connected SLM. You can access this manual, and check if there is a newer software version available online.

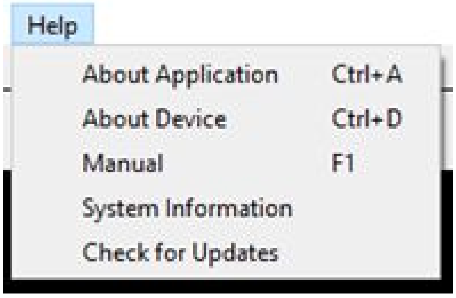


Figure 63: The menu ‘Help’ provides information about this software.

4.13.1 About Application

The about dialog of our software shows version information and provides web links to our web page, contact form, and trademark information.

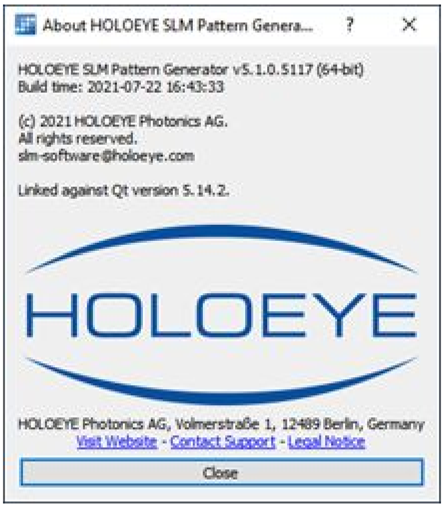


Figure 64: The about dialog shows basic version information and provides web-links to our web page. For detailed version informantion, please refer to system information.

Feel free to use the ‘Contact Support‘ link if you have questions related to this software. If you do so, please provide the system information text, which is available in the help menu ‘System Information’ and in the device detection’s info button. The latter is useful in case your SLM is not recognized correctly and this help menu is not accessible.

4.13.2 About Device

This menu entry opens a dialog, which shows information on the used SLM.

Figure 65: Device Information dialog.

4.13.3 Open Manual

This menu entry opens this manual in the configured PDF file viewer of your operating system.

4.13.4 System Information

This menu entry opens a dialog, which shows information on your system including connected monitors, graphic card driver version etc.

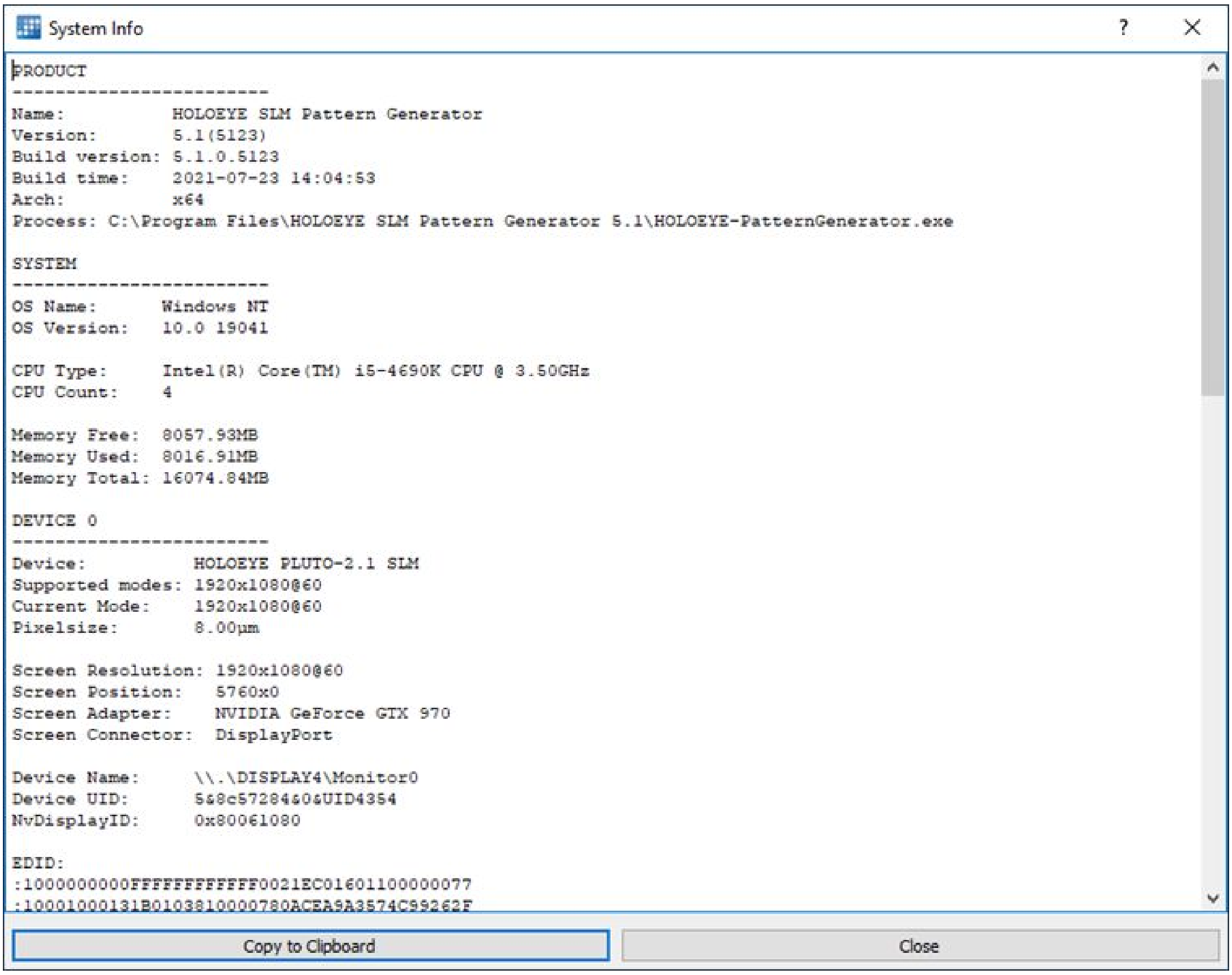


Figure 66: System Information dialog.

Please use the button 'Copy to Clipboard' to copy the full text into the clipboard of your operating system. Please provide this text to us when you contact our support team.

4.13.5 Check for Updates

This menu entry opens a dialog, which provides an easy way to check if there is a new software version available online. The software will not send out any information to us until you press the button 'Check for newer version' (see Figure 67).

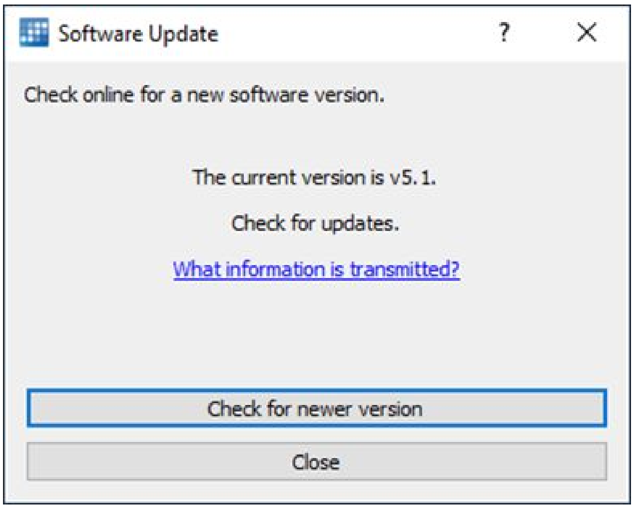


Figure 67: Software update dialog before the update check.

Please click on the blue text 'What information is transmitted?' to open a message dialog showing all information sent to our server at the update check if you have concerns about your privacy (see Figure 68).

Figure 68: What information is transmitted?' opens a dialog, which shows data sent when checking for new version.

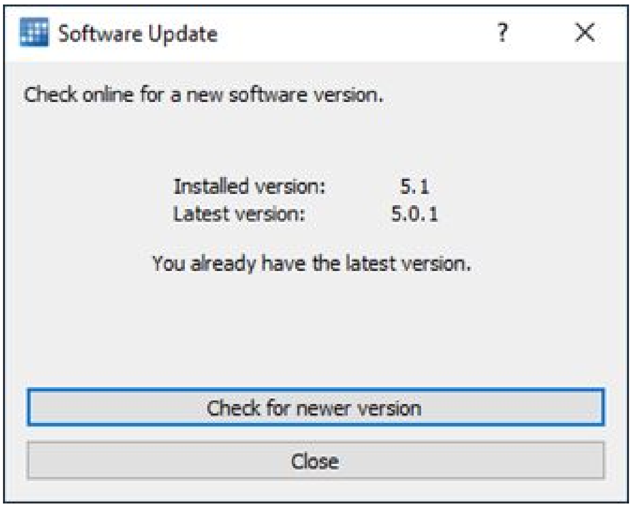


Figure 69: Software update dialog after the update check.

5 HOLOEYE SLM SLIDESHOW PLAYER

The “SLM Slideshow Player” software is intended to ease the display of images and image sequences on HOLOEYE Spatial Light Modulator (SLM) devices. These image files may represent phase maps (if the SLM is set up as a phase modulating device) or amplitude distributions (if the SLM is set up as an amplitude modulating device utilizing a polarizer). For details of these modes of operation, please refer to “Device Operation Instructions” in the manual of the connected SLM device.

During start-up, the software will detect the connected SLM device to make sure that images will be displayed on the SLM device properly. In order to do so, it will check if the SLM is set up properly as a screen in your operating system and use this screen for displaying images.

The software permits a selection of image files within a so-called root folder and its subfolders to be displayed on the SLM. This root folder can be changed during operation of the software. The concept of such root folders is used in order to speed up the search of previously generated configurations. Admittedly it is also assumed that images for display on the SLM are typically found in certain folders the user creates for this purpose.

The software is intended to display selected images as a sequence on the SLM with a user selected frame rate. This sequence of images is treated inside the software as a so-called 'playlist'. Playlists can be saved and loaded using this software. When saving a playlist, the play modes, speed and other settings are also saved as part of the playlist. The purpose is that for doing repeated experiments or demonstrations with an SLM device, it should be convenient to recover all related settings fast and to be able to start directly with displaying the prepared image sequence contained in such a playlist.

5.1 Requirements

5.1.1 Operating System Requirements

The following operating systems are supported by HOLOEYE SLM Slideshow Player:

- Microsoft Windows™ 7 or higher
- Apple Mac OS-X 10.7 or higher
- Ubuntu 14.04 LTS or higher with an OpenGL capable graphics card and an appropriate driver.

5.1.2 SLM Hardware Requirements

Before starting the SLM Slideshow Player please connect one of the following HOLOEYE SLMs to the device on which the software is running:

- PLUTO / PLUTO-2 / PLUTO-2.1
- LETO / LETO-3
- LUNA
- LC-R 1080
- LC-R 720
- LC 2012

- GAEA-2

Please make sure that the SLM is detected by the operating system as a separate screen and is configured with the correct resolution.

5.2 Installation

For all three operating systems, please make sure that you have sufficient rights to install the software. Please note that you may need administrator privileges to install the software.

5.2.1 Microsoft Windows™

Start the executable installer file “HOLOEYE SLM Slideshow Player 1.1 (64 bit)” if you are on a 64 bit System. Otherwise, install the 32 bit version. If the 64 bit version cannot be installed, please try the 32 bit installer.

After starting the installer, you are asked to accept the license agreement. Please read it carefully. If you do not accept this agreement, you are not allowed to install or use this software.

Follow the instructions of the installer. It is recommended to select all components to be installed. Otherwise, parts of the software may not work as intended.

After pressing the button “Install”, the installation will start. When installation is finished, select “Close” to exit the installer.

The installer will create a directory in the start menu folder for all users. To start the software, please use the start menu entry (e. g. “HOLOEYE SLM Slideshow Player 1.1 (64 bit)”).

If the same version is already installed, the installer will ask to uninstall the previous version before installing the new one. Please do so if you do not need this previous version any more. The settings are saved in a user specific directory and will not be changed by the uninstaller.

5.2.2 Apple Mac OS X

Open the installer file “HOLOEYE SLM Slideshow Player 1.1.dmg” by double clicking. A window will open to copy the application into the Applications directory. Do so by dragging the Slideshow Player icon on the right onto the Applications icon on the left side.

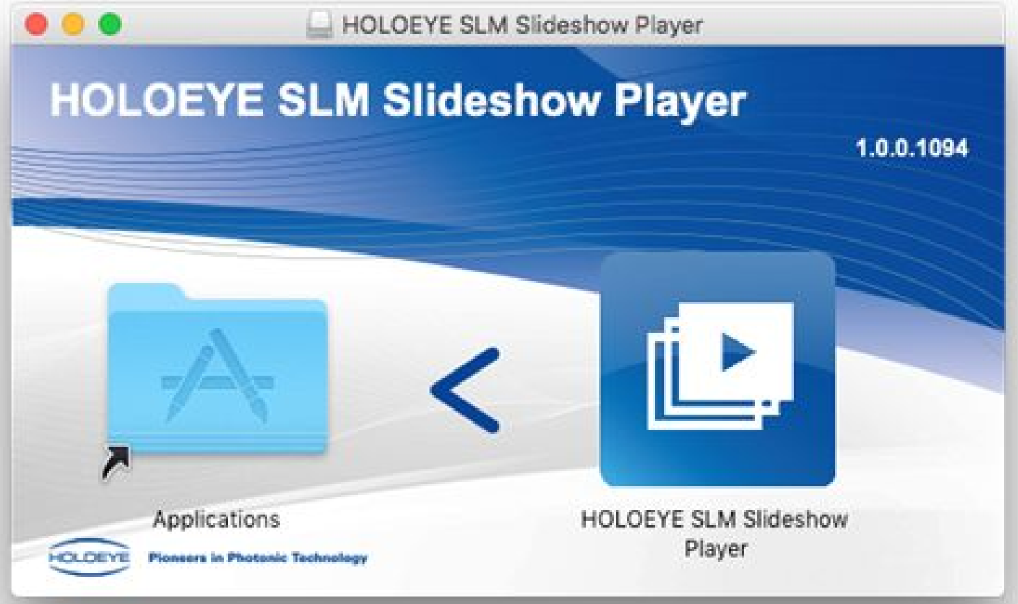


Figure 70: Applications directory window on Apple Mac OS X

To prevent the display of the OS X menu bar on the SLM the option “Displays have separate Spaces” needs to be disabled in the System Preferences -> Mission Control Settings. (See Figure 71).

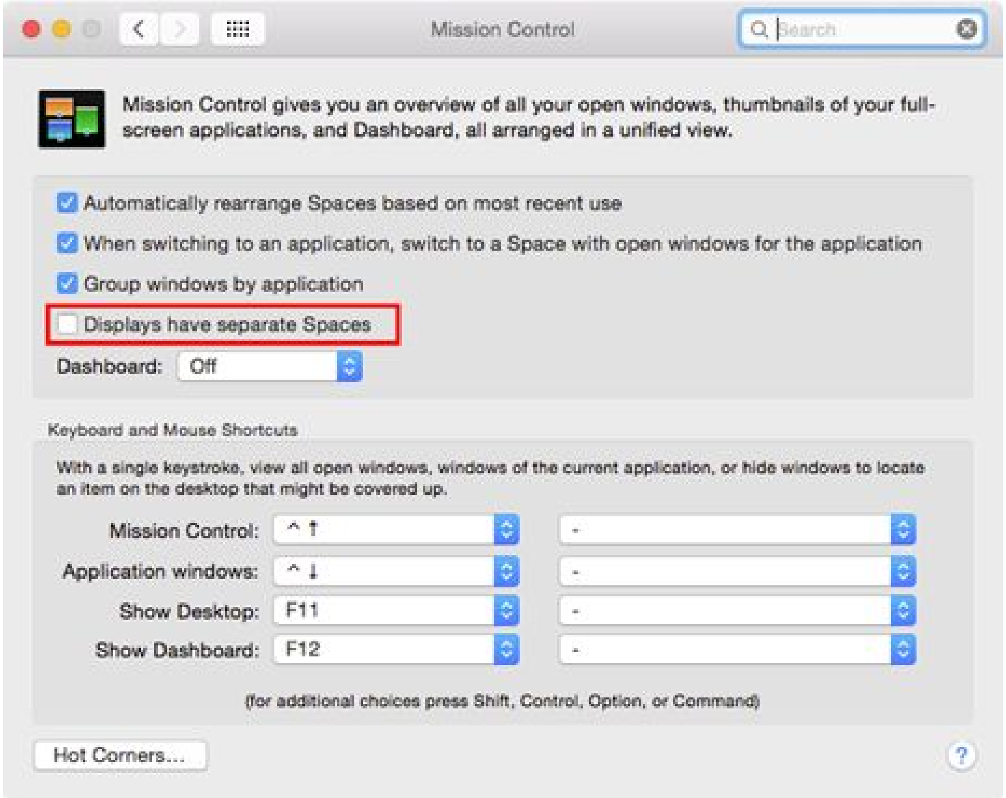


Figure 71: Misson control settings in Mac OS X. To prevent displaying the OS X menu bar on the SLM, please switch off the red marked setting "Displays have separate Spaces"

5.2.3 Ubuntu

Under Ubuntu, please install the package "HOLOEYE SLM Slideshow Player 1.0.deb" either by double click or by using "dpkg" in Terminal.

By double clicking the deb installer file, it should open in "Ubuntu Software Center". Installing the software by pressing "Install" should work. If not, please install the software by running the following commands in "Terminal":

```
cd path_to_installer_file/
sudo dpkg –i "HOLOEYE SLM Slideshow Player 1.1.deb"
sudo apt-get install -f
```

First of all please change to the directory where the installer file is located by using "cd". Then, install the package using "dpkg". Afterwards, please make sure all dependencies are fulfilled by using "apt-get". However, the required Qt 5.7 libraries are already installed automatically, so resolving any dependencies should not be necessary.

Depending on your distribution, it could be necessary to disable some desktop-panels on the screen of the device.

This software requires an OpenGL capable graphics card with appropriate drivers. It may be necessary to install the drivers provided by the manufacturer of your graphics card. For some graphic cards, you can install the driver by opening “Additional Drivers” in Ubuntu “System Settings -> Software & Updates” and selecting the proprietary driver.

5.2.4 Restore Defaults

To get back to the default application state of a fresh install, please delete the folder “HOLOEYE SLM Slideshow Player” in the “HOLOEYE”-folder located directly in the current user directory. Reinstalling the software will not delete this folder. This means, reinstalling the software will not delete any settings. Going back to the default settings could be helpful in case of any malfunction, e. g. corrupted sample images or settings. In such a case, reinstalling and deleting the settings should be done.

5.3 Operation of the Software

Before opening the software it is recommended to connect the SLM device and set it up correctly. The SLM needs to be set up as a separate screen via the graphics card settings of the OS. Under Windows, this mode is called “Extended Desktop”. This software is not intended to be used in cloning mode of the SLM with the primary screen. However, if two or more displays and the SLM are connected to the same computer, the secondary display can be cloned with the SLM.

To open the application “HOLOEYE SLM Slideshow Player” please use the menu entry  installed to your operating system.

After starting the software for the first time, you are requested to accept the license agreement. Please read it carefully. If you do not accept this agreement, you are not allowed to install or use this software.

5.3.1 SLM Device Detection

When you start the software a device detection dialog pops up which checks if a proper HOLOEYE SLM device is connected and if the system is configured correctly. You can find detailed information on the device detection in the chapter **"**EDID Device Detection**"** of this manual.

5.3.2 First Start

Afterward the device detection dialog, you will be presented with a screen like in Figure 72. The software consists of three main tabs. The “Files” tab is to select the files to be included into a playlist. The “Playback” tab is to manage the playlists and to play them onto the SLM. The “Settings” tab is to make some general application settings, mainly to optimize the performance.

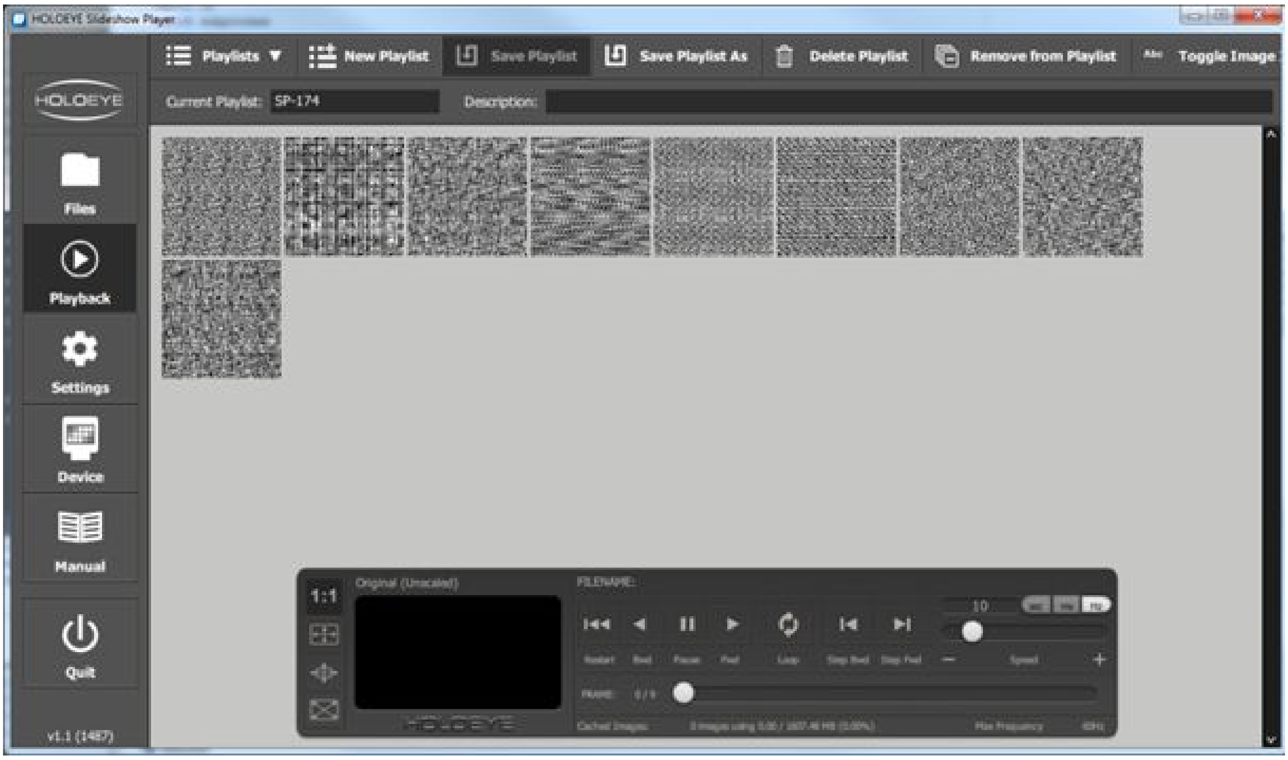


Figure 72: The "HOLOEYE SLM Slideshow Player" main window after starting the software for the first time.

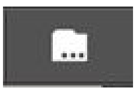
5.3.3 Operating-System Power Saving Features

As soon as there is content on the SLM, the software tells the operating system not to start any power saving features, including locking of the screen. This means, all automatic functions which would interrupt the SLM content display are disabled.

Please note that if automatic screen locking e. g. is switched on for a good reason on the user's PC, it will be disabled as long as the software is running. If you want to have a screen lock while using the software, please lock the screen manually. Also, energy saving features can be used manually while the software is running.

5.3.4 Select Root Folder

On first start-up the software starts into a dialog to select the root folder containing all images to be used. The initial root folder of the preinstalled sample images is already selected. You can navigate to any folder of your desktop computer. By pressing onto the "Samples" Button under "Places" you can always get back to the default sample images folder. If the desired folder is selected, please press "Confirm" to end the root folder selection. After pressing "Confirm" a page to select image files will appear.

You can always get back to the root folder selection by pressing the root folder selection button at the top right edge of the main window. 

After the root folder is selected, navigation into subfolders can be done on the “Files” tab. Please navigate to some images you like to display on the SLM. The path displayed in the top middle of the “Files” page will always show the relative path from the selected root path to the current directory.

If there is already a playlist saved, the software will start directly into the “Playback” tab. The last used playlist will be loaded (like shown in Figure 81). In this case, please refer to chapter Playlist Handling.

5.3.5 Adding Images

If there are any images in the current folder on the “Files” tab, you can add/remove them all to/ from the playlist with these two buttons:

add/remove them all to/from the playlist with these two buttons:

	Add all images
	Remove all images.

To add or remove individual images click the image thumbnail. The [+] or [-] symbol at the bottom left corner of the thumbnail shows if the image will be added or removed when clicking the next time (see Figure 73).

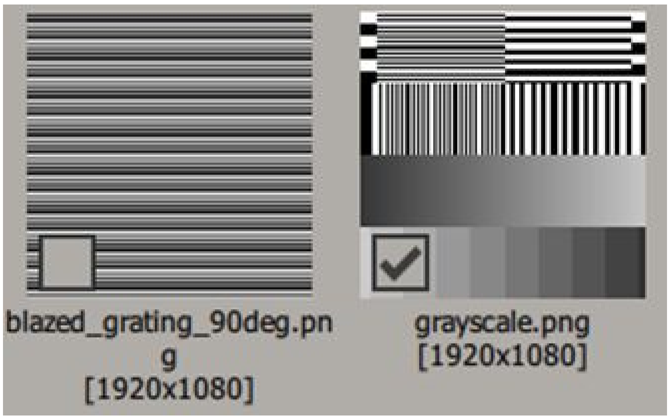


Figure 73: Image thumbnails (left: removed from playlist, right: added to current playlist)

You can navigate through all subfolders of the root folder and add as many images you like across all subfolders. All these added images will be shown in the playlist afterwards.

5.3.6 Slideshow Playback

Please click onto the “Playback” button to switch to the playback and playlist control page.

At the bottom of the window a control panel appears. This panel is explained in Figure 74.

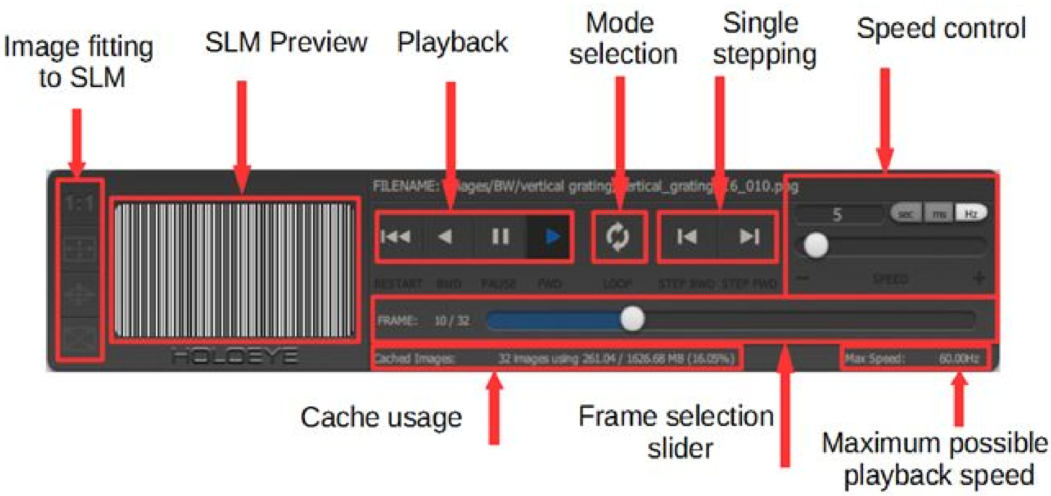


Figure 74: Slideshow Control Panel.

The playback control panel has the following options:

- Playback:
    - Forward
    - Backward
    - Pause
    - Reset
- Playback mode:
    - Single
    - Loop
    - Ping-Pong
- Single stepping:
    - Forward
    - Backward
- Speed control:
    - Seconds
    - Milliseconds
    - Hertz
- Image fitting to SLM:
    - Original 1:1
    - Best fit to SLM without cropping the Image
    - Best fit to SLM with cropping the Image
    - Stretch to full screen without maintaining the aspect ratio

The playback can be started forward and backward. To stop playback, press the pause button. With the reset button, the playback starts at the beginning of the playlist.

With the playback mode selection, it is possible to play images only once (single), in a continuous loop or with an alternating direction (Ping-Pong).

The images can be changed also by single stepping one image forward or backward. The images can also manually be changed by moving the frame selection slider or by clicking onto the previews of the images if direct navigation to a specific image is desired. If playback is running and one of the manual selections is done, playback will be paused automatically.

5.3.6.1 Speed Control

With the speed controls, the time between images can be selected either as a time between to frames or as a frequency of frames. The time between images can be selected either in seconds or milliseconds. This way, very long and also very short intervals can be selected easily by changing the speed slider. The current value is displayed above the speed slider and has the unit of the selection. By selecting Hertz (Hz) as the unit, the frequency can be given, which is the inverse of the time between two images.

5.3.6.2 Keyboard Shortcuts

Playback can also be controlled by keyboard shortcuts:

By pressing the Space key, playback can be started, paused and resumed.

The single stepping can be accessed with left/right arrow, and the speed control slider can be increased by pressing “+” or decreased by “-”.

5.3.6.3 Image Fitting

The image fitting selection allows using images with a different resolution when the SLM. All sample images have the right resolution and do not need this setting. In such a case when only images with the correct resolution are in the playlist, these options will be disabled. However, some user selected images may have a different resolution. In this case, these options get enabled. There are one option for displaying without scaling and three options to scale the not fitting image into the SLM. The options apply to all images in the playlist. Images will always be centred.

1. Original (unscaled): The default option is to display the image with its original size. This means, images which are too large will be cropped and images which are too small will be filled with black bars.
2. Scaled (Best fit to SLM): The first scale option will scale the images to the borders of the SLM. The aspect ratio will be maintained in this case, but some areas of the SLM will be filled with black bars.
3. Scaled (Cropped to fit): The second scale option will scale the images so that the full SLM is filled. Nevertheless the aspect ratio will be maintained. This means that parts of the images will be cropped if the aspect ratio does not fit.

Fullscreen (Stretched): The third scale option will stretch the images to the SLM. In this case, the aspect ratio will not be maintained and the width and height will be separately scaled. In this mode, no black bars are being inserted and no cropping will be done.

5.3.6.4 Preview

The preview inside the playback control panel always shows a small copy of what is displayed on the SLM.

5.3.6.5 Status Bar

The status bar of the playback control panel shows information about the possibility to reach the desired performance. It is displayed the number of images which are saved in memory (cache). Also, the size of these cached images is displayed in megabytes and as a percentage of the configured maximum cache size (see also chapter Settings).

In the right bottom corner, the maximum reachable speed is displayed. If this speed is lower than the configured frame rate (or higher than the selected time between frames), the playback is lagging. In such a case please refer to Settings.

5.3.7 Playlist Handling

Let us assume that we selected one RGB image and some diffraction patterns (CGHs) on the "Files" tab like shown in Figure 75. When we change to the Playback tab, we see something like in Figure 76.

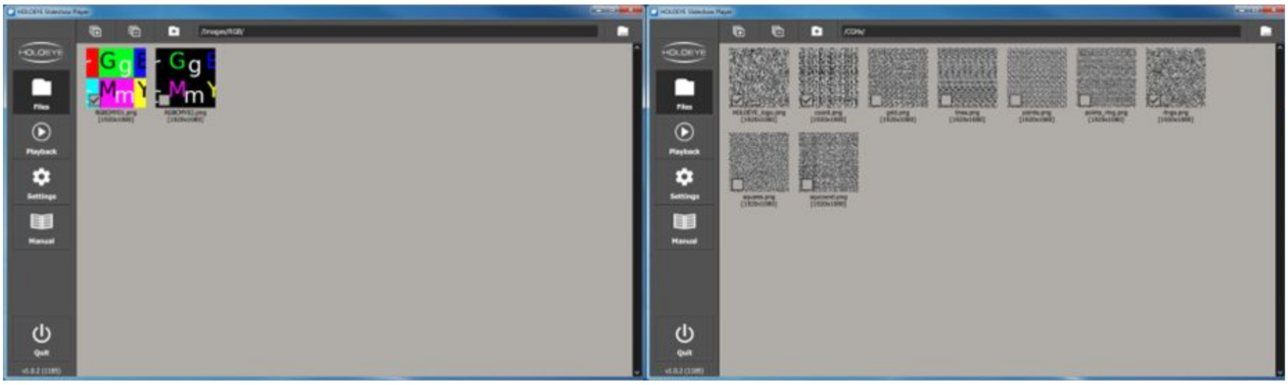


Figure 75: One selected image of the /Samples/RGB folder (left) and three selected CGHs (right) from two different folders will be combined to one playlist.

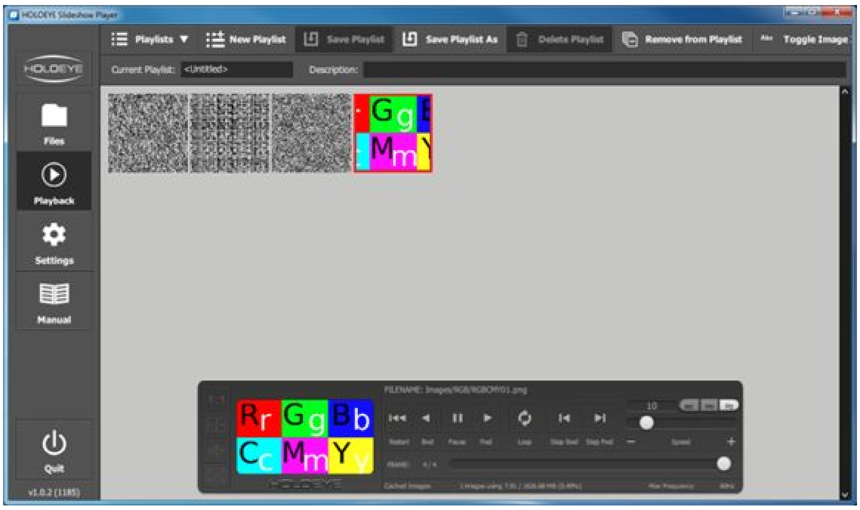


Figure 76: All selected images are combined to a new unsaved playlist automatically called "<Untitled>".

By clicking onto the play button (“FWD”, forward), the images will start to be played in the order of the playlist and with the settings from the playback control panel (see chapter Slideshow Playback).

If the button “Toggle Image Info” at the right of the tool bar is pressed (see Figure 76), it toggles the overlay with the resolution info and the file name on all images in the playlist.

5.3.7.1 Reorder Images

To reorder the images inside the current playlist, simply drag them to the desired position. To drag to the last position, please drag the desired last image to the last but one position and afterwards drag the last image to the last but one position.

5.3.7.2 Save Playlist

This playlist is now created only in volatile memory and needs to be recovered if the program crashes. If you now click the “Quit” button on the bottom of the left side panel, you will be asked to save the playlist. You have then the option to give it a name or to discard it.

If you do not exit the program and want to have access to the newly created playlist later, you must give the playlist a name by pressing the button “Save Playlist As”. A window will open (see Figure 77) where you should enter a concise name for the playlist. It will be saved to a playlist file (*.slideshow) in the deepest shared subfolder of the root directory. The name in the dialog will turn to a red text colour if this name already exists or not supported characters are used.

After saving the playlist, it shows up in the lists of playlists like to be seen in Figure 78.

Figure 77: Save the newly created playlist to the hard disk drive by pressing “Save Playlist As” so that it can be loaded easily after restarting the application. Playback settings will be saved with this playlist.

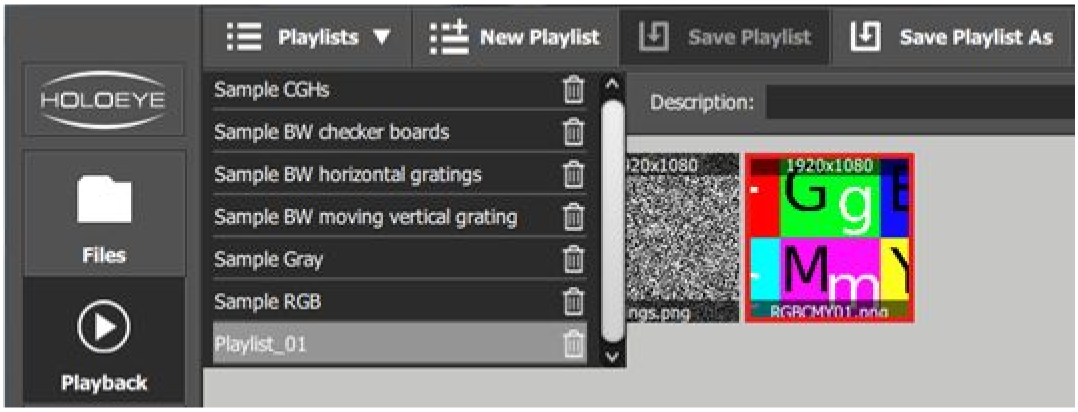


Figure 78: The newly saved playlist will show up under the "Playlists" button.

5.3.7.3 New Playlist

To create a new playlist, please click on the "New Playlist" button. A question dialog will appear to ask if the new playlist should be created as a copy of the current playlist (see Figure 79). If you click "Keep Images", the new playlist will be created as a copy of the current playlist. By pressing "Discard Images" you will get an empty new playlist. Regardless of what you select, you should save this new playlist under a new name.

It is possible to give each playlist a detailed description. The description can have more characters included and should be used to give the playlist a detailed explanation. To edit the description, simply click onto the description field and put in the new description into the upcoming dialog (see Figure 80).

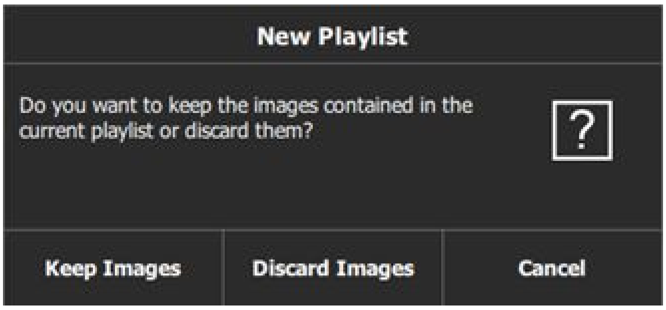


Figure 79: Creating a new playlist. Please answer the upcoming question if you want to use the images from the current playlist also for the new created one ("Keep Images") or not ("Discard Images").

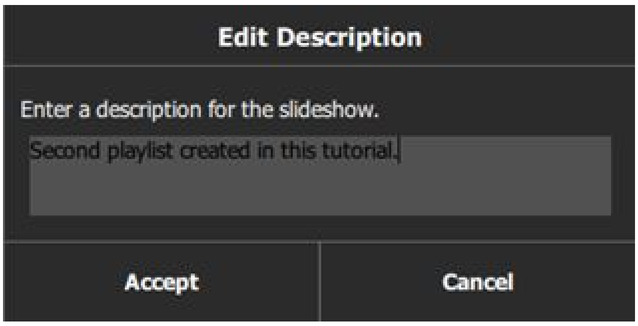


Figure 80: Give the playlist a description. This is dialog opens when clicking on the description.

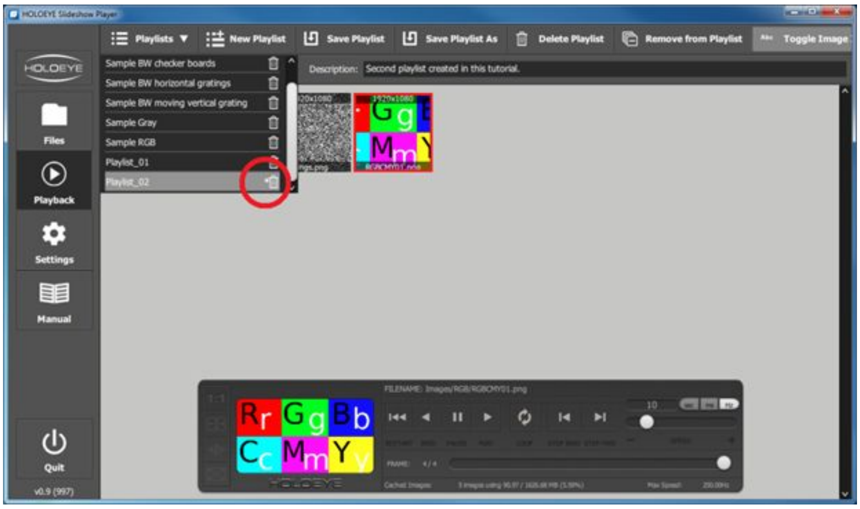


Figure 81: After changing settings (description, playback settings), the playlist will be marked with a star (*). Press "Save Playlist" to save the changes.

After changing any settings of the playlist, the playlist gets marked unsaved. This is indicated by a star (*) in the list of playlists. If this star is shown, you can save the playlist by pressing onto "Save Playlist" and it will be saved without entering the name again (see Figure 81). If you close the software with an unsaved playlist, it will ask you to save the changes before exiting. You can exit the program by pressing the "Quit" button on the bottom of the left sidebar or by closing the main window.

After restarting the HOLOEYE SLM Slideshow Player, it will load the last used playlist automatically.

The software performs auto saves in the background. If there are unsaved changes from a previous run, it will ask if these changes should be recovered. When discarding this recovery, the last manually saved state of the last used playlist will load.

If the root folder is set to the sample images folder, there will be some default playlists which can be used to access all the sample images for demonstration purposes.

5.3.8 Settings

This tab is only needed to optimize the playback performance. The following settings can be changed:

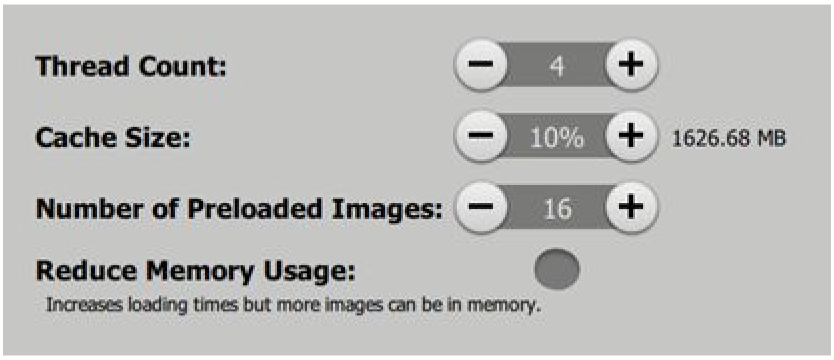


Figure 82: Default performance settings..

It is recommended to use the default settings. However, if the desired performance cannot be reached, you can play with these values. But please have in mind that if the computer hardware which is used is not fast enough or does not provide enough memory, changes to these values may not solve performance issues. Besides increasing the cache size, changing the default settings will most probably result in an even worse performance.

First of all, please make sure that no avoidable system load is generated by other tasks.

5.3.8.1 Thread Count

The number of CPU threads used in parallel to load images from the hard disk drive. Increasing this value can help for high resolution images. Decrease this value on a slow computer.

5.3.8.2 Cache Size

This value sets the maximum percentage of the computer's main memory to be used during playback.

Increase this value for high playback speed and many images in one playlist. For high playback speed, the occupied cache size while playback should be smaller than 90 %. Also see Figure 74.

5.3.8.3 Number of Preloaded Images

The software prepares images for displaying with a look-ahead algorithm. This number determines how many images into the future the algorithm should look.

Preloading 16 images is already a high number even on fast computers. Reducing this number can help slower computers to perform better.

The number should only be increased if a very fast computer is used and background tasks with unpredictable system load are running simultaneously.

5.3.8.4 Reduce Memory Usage

Selecting this option can help a little bit on computers with a small main memory (RAM), but will increase the computational load.

6 HOLOEYE SLM DISPLAY SDK

The HOLOEYE SLM Display Software Development Kit (SDK) is an interface to show images and data/phase arrays directly on the SLM from within many programming languages. It also supports some data manipulation functions like phase overlay calculated from Zernike coefficients, optical beam manipulations, data transformations, and a wavefront compensation field provided by HOLOEYE together with devices shipped since August 2021.

In order to make any use of this SDK, you need to have a supported development environment installed. Currently supported development environments are

- C or C++ compiler (e. g. Microsoft Visual C++ Compiler)
- National Instruments LabVIEW 11.0 and later
- MathWorks MATLAB R2009b and later
- Octave 5.2 and 6.4
- Python 2.7 and 3.x

In general, any development environment, which can import shared library files (.dll or .so) with C header files, can be used, but we will not provide any bindings and/or support for other languages than listed above.

The current version is only available for Microsoft Windows 10 operating system. The Windows version includes binaries for 64-bit and 32-bit development environments. For Windows 7 and Linux Ubuntu 18.04 LTS 64 bit we may have an older version.

> The SDK installs examples demonstrating almost all functionality of the SDK. See below for detailed information. Please first try to use the examples before developing your own applications. The examples should run out-of-the-box without issues. Please derive your own applications from our example files. On each new version, please check if the new examples have changes compared to your own code, which was hopefully derived from the old examples. There is also a migration guide in the HTML documentation, which describes how to adapt your old code to a new version.

6.1 Installation

6.1.1 Microsoft® Windows®

Before starting any installer of this SDK, it is highly recommended to install the desired development platform, e.g. LabVIEW, MATLAB, Octave, or Python. The SDK may not be fully installed otherwise. (see Figure 83)

The SDK can only be installed with administrative privileges. Please make sure you have administrative rights on the target Windows operating system.

The SDK comes in different installation packages (installers). Each installer is meant to be used with the specified development environment only. Every installer will install the files needed to use the 32-bit and the 64-bit version.

Please start the appropriate installer file and click through the installation steps. Please accept the license agreement to continue with the installation.

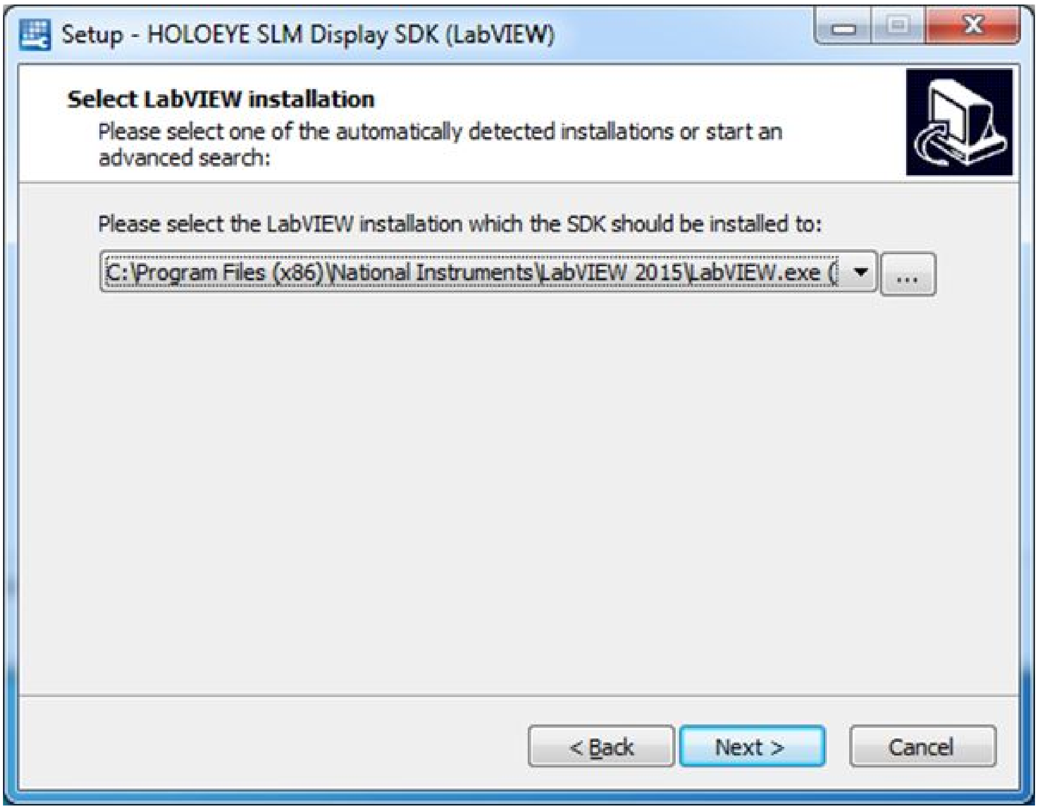


Figure 83: Select LabVIEW installation. The button "…" allows you to do a custom search on your system for valid LabVIEW installations. For an Octave SDK installation, also please make sure to select the proper octave.exe file on this page.

For the LabVIEW and the Octave installers, a selection dialog will appear (see Figure 83). The installer will search automatically for the required development environment. This typically works, and you just need to click next in the installer after something was found. If it fails for some reason, i.e. nothing was found, or if you have multiple environments installed (e.g. LabVIEW 2018 and LabVIEW 2019), please select the one you want to use with the SDK manually. If nothing was found automatically although the environment is installed properly, please press the "…" button and search for the files manually (see Figure 83). It needs to find the "LabVIEW.exe" or "octave_cli.exe" or similar file to run Octave. If this step is not done properly, the installation is incomplete. For LabVIEW, the installer copies the wrapper VI files into the user.lib folder inside your LabVIEW installation, and for Octave the installer needs to compile the mex files properly. The Octave version would not be able to access the API functions out-of-the-box, and you would need to do the (complicated) compilation manually afterwards.

For the LabVIEW SDK installation, please note that the VI files needed to access the SDKs .dll (.so) file are just copied into the LabVIEW user.vi library folder for the selected LabVIEW version. If you have multiple LabVIEW versions installed, and you want the VIs available in multiple versions, then please copy the appropriate HOLOEYE SLM Display SDK subfolder inside the "user.vi" folder manually into the other versions after finishing the installer, but before saving them for the first time in LabVIEW. (LabVIEW would store them in the newer format on saving).

For more details, please see chapter LabVIEW and Octave.

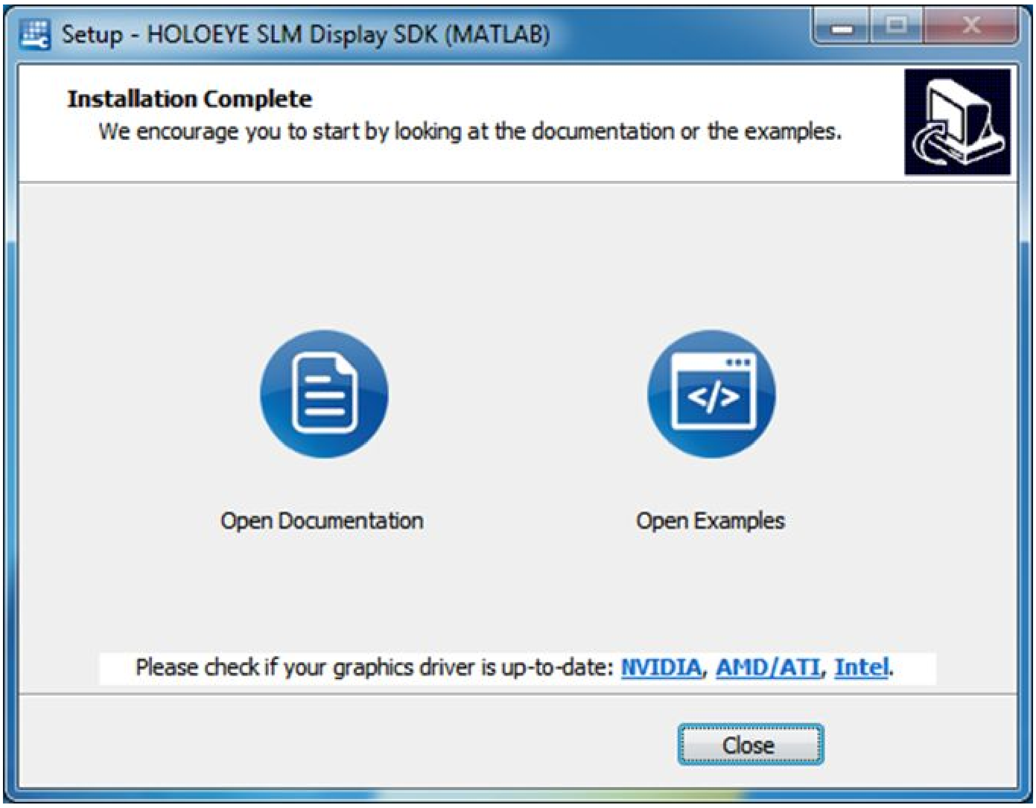


Figure 84: Installation finished. You can access examples and documentation from here, or from the start menu folders later.

Select 'Install' to start the installation procedure. After the installation is complete, a page opens which gives shortcuts to the examples and the documentation. You can use the examples also to validate the installation. See Figure 84.

The SDK is installed into the folder

```
%PROGRAMFILES%\HOLOEYE Photonics\SLM Display SDK …
```

and the examples are copied into the folder

```
%HOMEDRIVE%\Users\Public\Documents\HOLOEYE Photonics\SLM Display SDK …
```

The HTML documentation is installed inside the program files installation folder into

```
doc/__index__.html
```

inside the main installation folder.

Additionally, this manual and the license file as well as the uninstaller are installed inside the main installation folder.

We recommend not using any outdated graphics card drivers. This SDK makes use of DirectX11 / OpenGL functionality to speed up painting on the SLM screen. The graphics card plays an essential part when using this SDK. You can use the links on the last page of the installer to get to the main graphics card manufactures and to download their current drivers.

After you looked into the documentation and/or example files, you can press 'Close' to finish the installation. The example files might not work until you re-login your user account after the SDK installation is complete.

> When installing for Windows, you can install multiple versions in parallel. However, if the API version does not differ (see API function **heds_requires_version()**), the last installed SDK version with the same API version is started by the development environment. That means when you install multiple SDKs with different API versions, you can use them in parallel without any issues. The same is true for the different development environment versions, i.e. you can install and use the SDK in the same version for C++, Python, MATLAB, Octave, and LabVIEW in parallel without any issues.

6.1.2 Ubuntu Linux

Please consider the Linux version of the HOLOEYE SLM Display SDK as experimental, maybe even with missing features.

The Ubuntu Linux version comes as a .deb installer package. Please install the package using the command

```
dpkg -i <installer_filename>.deb.
```

The Debian package will install the binary files into "/usr/bin" and "/usr/lib", and the SDK files will be copied to "/usr/share/holoeye-slmdisplaysdk" folder.

The files in the folder "/usr/share/holoeye-slmdisplaysdk" should be very similar to the Windows version and are not explained in detail here.

6.2 Getting Started with Software Development

All installations should be usable out-of-the-box after installation, as long as you have installed the required development environment (LabVIEW, MATLAB, etc.). Therefore, you can start right away by running the example files provided for each HOLOEYE SLM Display SDK version. The example files show most of the functionality of the Display SDK, and it is highly recommended to use the examples as a start for your own projects. The example files are checked for working properly on each release.

For a full list of supported API functions of each SDK version, the documentation is installed as an HTML webpage into the main installation folder in the subfolder “doc”. There are links to this folder installed into Windows Start Menu and on the last page of the installation procedure.

For each SDK version the installer installs the binary files which are responsible for the main functionality of the SDK. These binary files are platform specific files and are installed into the subfolders “win32” and “win64” when using a Microsoft Windows operating system. Both folders are installed on a 32-bit and 64-bit Windows, in case the SDK needs to be used on a different architecture later. The architecture is automatically detected normally.

The binary files consists of a shared object file (.dll, .so), which provides the interface to our SDK in a general way and a background process, which is executed by the shared object file automatically.

The binary files on Microsoft Windows operating system depend on the Microsoft Visual C++ redistributables. The proper redistributable installers for both 32-bit and 64-bit binaries are installed automatically during the installation process and are also added into the subfolder “redist” for manual installation purposes, e.g. when there was an issue during Display SDK installation procedure.

For each development environment, there are additional files installed to make the use of the shared object file more convenient. These files are explained in the following sub-chapters.

6.2.1 MATLAB

Before using any function of this SDK, you need to add the path of the mex files to the MATLAB search path by running the command

```
add_heds_path;
```

The script file “add_heds_path.m” is installed into the folder where all example scripts are installed to. All examples call this script at the beginning to make sure the path to the SDK installation folder is known by MATLAB. Please copy this file into your projects, and call it at the beginning of all your scripts like the examples do. Alternatively you can run the script once and save your MATLAB path permanently (command savepath). We recommend calling add_heds_path in all your scripts and optionally save the path into MATLAB.

In the subfolders "win32" and “win64” there are also m-files installed which provides the API documentation accessible inside MATLAB by calling

```
help heds_{function_name}
```

which puts the documentation for this function into the MATLAB command line window.

To get a list of supported function names, you can enter “heds_” and press the “tab“-key in the command-line window. A list of functions from this SDK appears.

It is necessary to initialize the SLM display by running

```
heds_slm_init;
```

at the start of each of your scripts after running the “add_heds_path.m” script. You can unload the SDK at any time by calling the SDK function

```
heds_slm_close;
```

For further usage and functionality, please have a look into the example scripts and into the HTML documentation.

6.2.2 Compiling MEX Files Manually

Typically this procedure is not necessary for MATLAB users.

The installer of the MATLAB (and Octave) version of this SDK creates a subfolder “sdk” inside the installation folder. This “sdk” subfolder consist of a list of C++ files. Each cpp file is meant to be compiled into a mex file for MATLAB and to access a single API function of our SDK. There are also some header files installed which are needed by the cpp files to access the shared object file.

The generated binary mex files are created inside the “win32” or “win64” folder. In the “win64” folder the installer installs pre-compiled mexw64 files, which should be compatible with most MATLAB versions. However, if you are running e.g. an old 32 bit version of MATLAB, you will need to recompile these mex files manually.

To recompile the mex files, you must have installed a proper MATLAB compatible C++ compiler. There is a MATLAB script installed into this SDK which automates the compilation procedure for all API functions. Please run the script from a MATLAB command line and make sure the path to the SDK was added correctly:

```
add_heds_path
heds_build_sdk_mex_files
```

The compiled binary mex files will then be created inside the “win32” or “win64” folder dependent on the added path and the architecture.

After the mex files are compiled successfully, all the functions can be used inside MATLAB like normal m-file-based functions as long as this SDK is added to the MATLAB path.

6.2.3 LabVIEW

The installer of the HOLOEYE SLM Display SDK for LabVIEW will install the complete C SDK and the “Virtual Instrument” (“VI”) files needed to call the C API functions from within LabVIEW (API wrapper VIs). Like all other installers, it will also install each example of the C SDK implemented in a LabVIEW VI.

The API wrapper VI files are installed to a subfolder called “LabVIEW API VIs” in the main installation path of SLM Display SDK for LabVIEW. The same files are also installed to the "user.lib" folder inside your LabVIEW installation path, e.g. "C:\Program Files\National Instruments\LabVIEW\2019\user.lib\HOLOEYE SLM Display SDK 3.1". Please note that these files can only be installed when running the SLM Display SDK installer after installing LabVIEW, and only for the LabVIEW version selected during installation.

Figure 85 shows how the VIs installed into the users.lib folder will be accessible inside LabVIEW after the SDK is installed for all users and a LabVIEW installation was found and selected during installation.

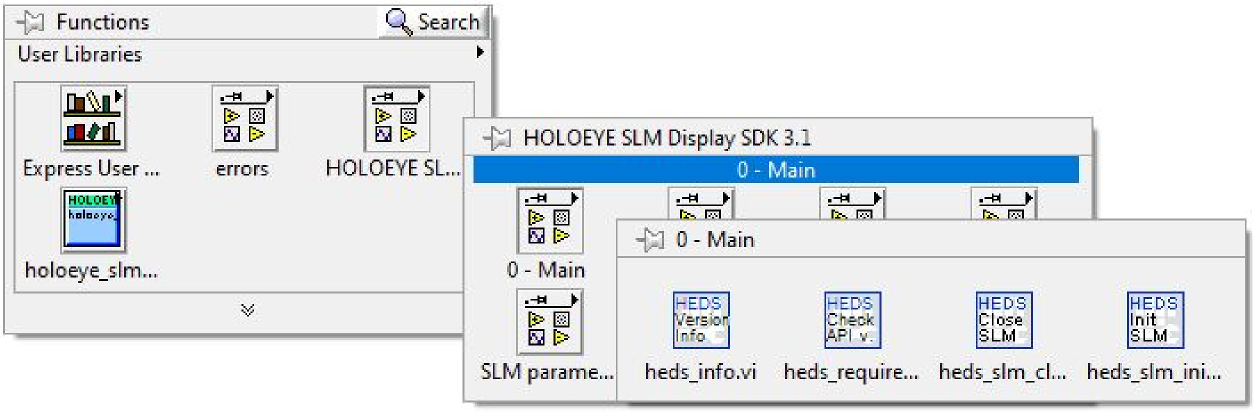


Figure 85: HOLOEYE SLM Display SDK access from LabVIEW.

The wrapper files (VIs) exist for all relevant ANSI C API functions and include the C-API help text. Some ANSI C API functions are combined into a single wrapper. For further documentation of HOLOEYE SLM Display SDK, the ANSI C (and C++) HTML documentation is installed together with the LabVIEW version, too. It can be accessed through the Windows-Start-Menu and is installed into the main installation folder ("C:\Program Files\HOLOEYE Photonics\SLM Display SDK (LabVIEW) v3.1\doc\ __index__.html"). This documentation is especially useful when adding library nodes inside LabVIEW directly into your code without using the wrapper VIs. This way the C API functions can be called directly.

Anyway, please have a look into the example VIs. Please start your own SLM Display SDK projects by just copying and then modifying one of the provided example files. This will make sure all the necessary initialization steps are done properly in your code. In addition, you may not need to read the ANSI C documentation at all.

If you already used an older 1.a.b.c or 2.a.b.c version of HOLOEYE SLM Display SDK for LabVIEW, then please note that the folder structure and the names of the wrapper VIs changed a little, together with all the changes made to the ANSI C API. The API wrapper VIs are now sorted into more subfolders and the naming was adapted to more relate to the ANSI C API function names, i.e. the spaces were replaced with underscores ('_'). For converting your own VIs, which made use of the old API functions, to be compatible with HOLOEYE SLM Display SDK v3.1, please select the corresponding new API wrapper VIs when LabVIEW asks you to provide the not found files. This is typically the case when you open your VI and the files of the older SDK are not available any more. If the old SDK is still installed and the old wrapper VIs are found (esp. Detect_HEDS_SDK_PATH....vi), then the new SDK is not used by your VI until you exchange the wrapper VIs correctly.

Here is a complete list of all LabVIEW wrapper VIs accessible through the LabVIEW User Libraries shown with the folder structure:

HOLOEYE SLM Display SDK 3.1

0 – Main

- heds_info.vi
- heds_requires_version.vi
- heds_slm_close.vi
- heds_slm_init.vi

1 – Show API

- **Built-in gratings**
    - heds_show_grating_horizontal_binary.vi
    - heds_show_grating_horizontal_blaze.vi
    - heds_show_grating_vertical_binary.vi
    - heds_show_grating_vertical_blaze.vi
- **Built-in image functions**
    - heds_show_blank_screen.vi
    - heds_show_dividedscreen_horizontal.vi
    - heds_show_dividedscreen_vertical.vi
- **Built-in phase functions**
    - heds_show_phasefunction_axicon.vi
    - heds_show_phasefunction_lens.vi
    - heds_show_phasefunction_vortex.vi
- **Data as gray values**
    - heds_show_data_from_file.vi
    - heds_show_data_grayscale_float.vi
    - heds_show_data_grayscale_uchar.vi
- **Data as phase values**
    - heds_show_phasevalues.vi

2 - Load-Show API (Advanced data handle)

- **Data handle**
    - heds_datahandle_apply.vi
    - heds_datahandle_init.vi
    - heds_datahandle_release.vi
    - heds_datahandle_release_all.vi
    - heds_datahandle_release_id.vi
    - heds_datahandle_statistics.vi
    - heds_datahandle_update.vi
    - heds_datahandle_waitfor.vi
    - heds_datahandle_waitfor_id.vi
- **Load data array**
    - heds_load_data_fromfile.vi
    - heds_load_data_grayscale_float.vi
    - heds_load_data_grayscale_uchar.vi

- **Load phase values**
    - heds_load_phasevalues.vi
- heds_show_datahandle.vi
- heds_show_datahandle_id.vi

Helper functions

- convert_2D_to_1D_array.vi
- Detect_HEDS_SDK_PATH_v3.vi
- heds_error_string.vi

SLM parameters

- heds_slm_pixelsize.vi
- heds_slm_refreshrate.vi
- heds_slm_size.vi
- heds_slm_wavefrontcompensation_clear.vi
- heds_slm_wavefrontcompensation_load.vi
- heds_slm_zernike_array.vi
- heds_slm_zernike_coefficients.vi

Types

- create_heds_data_flags.vi
- create_heds_datahandle_applyvalue.vi
- create_heds_slmpreviewflags.vi
- create_heds_wavefrontcompensationflags.vi
- heds_datahandle_applyvalue_typedef.ctl
- heds_datahandle_state_typedef.ctl
- heds_datahandle_typedef.ctl
- heds_loadflags_typedef.ctl
- heds_showflags_typedef.ctl
- heds_slmpreviewflags_typedef.ctl
- heds_wavefrontcompensationflags_typedef.ctl
- heds_zernikevalues_typedef.ctl

Utilities

- heds_utils_beam_lens_from_focal_length_mm.vi
- heds_utils_beam_lens_to_focal_length_mm.vi
- heds_utils_beam_steer_from_angle_deg.vi
- heds_utils_beam_steer_from_angle_rad.vi
- heds_utils_beam_steer_to_angle.vi
- heds_utils_slmpreview_move.vi
- heds_utils_slmpreview_set.vi
- heds_utils_slmpreview_show.vi
- heds_utils_wait_checked_ms.vi
- heds_utils_wait_ms.vi
- heds_utils_wait_until_closed.vi

The *.ctl files are controls which are used as strict type definitions representing the C API enums and structs.

6.2.4 Python

The installer for the HOLOEYE SLM Display SDK (Python) will install one additional subfolder called "python". In this subfolder there is another subfolder called "holoeye" with a subfolder called "slmdisplaysdk", which contains the Python files to access the DLL.

To be able to use these files, you need to add an import command to your Python scripts, like

```
from holoeye import slmdisplaysdk
```

However, this will not work until the "holoeye" subfolder would exist in the currently used Python installation folder in the subfolder "Libs/site-packages", or in your project directory.

To avoid installing the SDK into all your Python installations or into all your projects, we recommend using the following code to import the "holoeye" folder instead:

```
# Import the SLM Display SDK:
import detect_heds_module_path
from holoeye import slmdisplaysdk
```

This code can also be written as

```
# Import the SLM Display SDK:
sys.path.append(os.getenv("HEDS_3_PYTHON_MODULES", ""))
from holoeye import slmdisplaysdk
```

but it is recommended to use the script "***detect_heds_module_path***", which is installed into the examples folder. Using sys.path.append(somepath_to_sdk) manually is recommended only when you need to use a specific SLM Display SDK version, which is not available in the environment variables in Windows settings.

The code first adds the installation path of our modules to the current Python session and then imports the library as usual. The script "***detect_heds_module_path***" also handles errors in case the SDK folder could not be found.

Afterwards, you can open an SLM session with this command:

```
# Open the SLM window:
slm = slmdisplaysdk.SLMInstance()
# Check if the library implements the required version
if not slm.requiresVersion(3):
    exit(1)
error = slm.open()
assert error == slmdisplaysdk.ErrorCode.NoError, slm.errorString(error)
```

At the end of your script, you can close the SLM window by running

```
# Unload the SDK:
slm = None
```

For further usage and functionality, please have a look into the example scripts. Please always use the initialization code from the examples if you have any issues in your own code. If you have further issues running you code, please check if you can run an example before contacting HOLOEYE.

6.2.5 Octave

The Octave installer is very similar to the MATLAB installer, so please read the section for MATLAB users. However, the compilation of the mex files needs to be done again for each Octave version. Because of this, the installer is doing this compilation procedure during the installation automatically with the built-in compiler of Octave. During the automatic compilation, the installer may add the SDK install path to the Octave path persistently, so that you can start right away without calling the script “add_heds_path.m”.

This might not always work and can be done manually by calling “savepath;” in Octave. Anyway, it is recommended to start your scripts with calling “add_heds_path.m” like done in our examples to make sure the SDK files are found. Saving the path is more useful for direct usage in the command line.

The file structure of the installation is the same like for the MATLAB installer. All examples are compatible with MATLAB and Octave. You can use the integrated help, too.

6.3 SLM Initialization

Almost all API functions of this SDK require a properly connected and configured HOLOEYE SLM, which is supported by the SDK. The SLM needs to be set up as an extended desktop monitor.

When calling an API function, which requires a properly initialized SLM, the function will return an error code or invalid data (like a pixel number of 0).

6.3.1 SLM Device Detection

When you start the software, typically by running a program or script calling the API function

```
heds_slm_init()
```

a device detection dialog pops up which checks if a proper HOLOEYE SLM device is connected and if the system is configured correctly. You can find detailed information on the device detection in the chapter "EDID Device Detection" of this manual.

The HOLOEYE SLM Display SDK shows a tray icon as soon as the device detection opens.

Figure 86: Windows tray icon of HOLOEYE SLM Display SDK.

The icon is gray-colored until an SLM is successfully connected, or the previously connected SLM is lost. While an SLM is successfully connected, the icon is blue-colored, like shown in Figure 86.

By clicking the mouse on this icon (left, right or mid mouse button), a menu will pop up with all available options. The menu allows you to access the following:

- Open/Close SLM Preview window.
- Help:
    - Version and system information.
    - License.
    - SDK documentation (this PDF manual).
    - API documentation (HTML page).
- Check for updates.

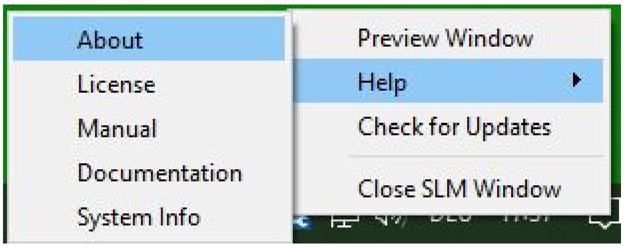


Figure 87: HOLOEYE SLM Display SDK menu. Please click on the tray icon to open.

6.3.2 SLM Full-Screen Support Within Extended Desktop

Since version 1.1 of the HOLOEYE SLM Display SDK, a Built-in SLM Preview Window was introduced to inspect the shown content on the SLM easily. However, this SLM preview window might have an impact on the performance of video-like data playback on the SLM. To get an SLM preview, which has almost no performance issues, there is still the possibility to connect an additional monitor with the same pixel count (resolution) like the SLMs pixel count and mirror it with the SLM. For example on a Pluto SLM, a FullHD (1920x1080 pixel) monitor can be used (see Figure 88).

The result will be one primary display, one display mirrored with the SLM and maybe more displays. This way, development gets much easier because you can inspect the content of the SLM very easily on the mirrored monitor. Please note that in the case of mirroring a monitor with the SLM, screen tearing on either the SLM and/or monitor might occur. This is a graphics adapter limitation.

Since version 2.0 of the SDK, the preview window will not have a big performance impact any more if the mode “Realtime Preview” and not “Capture SLM Screen” is selected.

Here are some more ways to inspect the content on the SLM:

1. Use the SLM preview window included in the SDK.

2. Use the “Save Data” button of the SLM preview window included in the SDK. You can save the frame generated by the SDK as well as the entire screen (dependent on the selected capture mode).
3. Use the screen magnifier of Microsoft Windows in “docked” mode and move the mouse to the SLM each time you need to look.
4. Press the “Print” key and paste the content to any image editing software, e. g. Microsoft Paint.
5. Use the SLM in amplitude modulation with a suitable polarizer configuration. A simple linear polarizer and sufficient light is typically sufficient to roughly inspect the content.

Please note that for holographic applications, a scaled preview, like the taskbar preview, is not sufficient. You will also not be able to see single line errors when using a polarizer, but such errors will impact the quality of the holographic images.

In such holographic applications, it is recommended to test the content of the SLM with an appropriate polarized laser and look onto the diffracted light.

Figure 88: SLM display configuration to be used as an extended screen with a mirrored additional monitor. “1” is the primary monitor, “2” and “3” are the SLM and the additional monitor. A decent graphics card might be required for this setup.

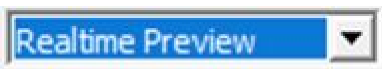
6.3.3 Built-in SLM Preview Window

The SLM preview can be opened either by using the popup menu of the tray icon from the already running SDK process or by using the API command inside the calling program

```
heds_utils_slm_preview_show(bool show = true);
```

The API command can be used to either show or close the SLM preview window. Please note that as long as the SLM preview window is opened, the performance of the program using the SLM through the SLM Display SDK can be influenced. The performance impact is much lower when operating the SLM preview in the default mode “Realtime Preview”, which uses the data directly from the GPU and just does another rendering into the SLM preview window.

Therefore, it can only capture the content shown through the SDK, and not any other windows, e.g. when another software tries to display data on the SLM and the SDK is not able to get in top of that window.



The capture mode “Capture SLM screen” can show the actual content exactly like shown by the graphics card on the SLM except the mouse cursor. In this mode, you will see all windows shown on the SLM screen, even if the SDK cannot get its content to the top level. However, this mode has much higher performance impact when running a video-like playback through the SLM Display SDK.

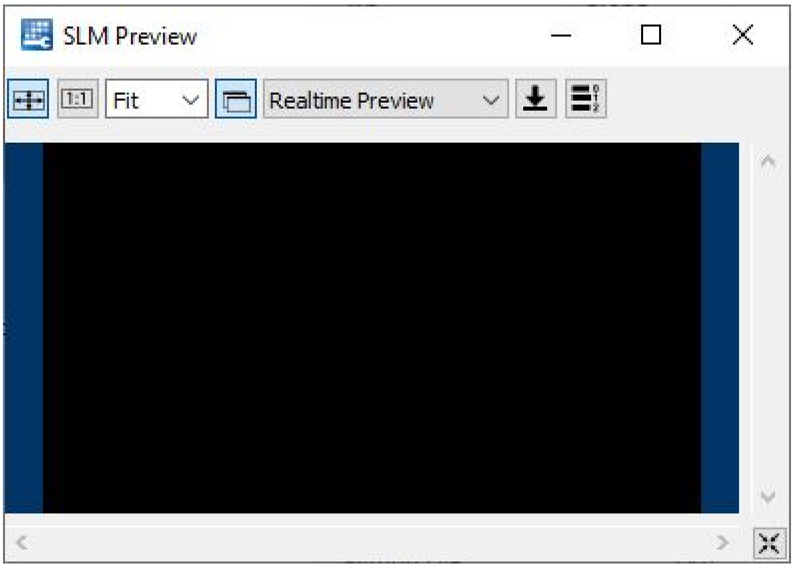


Figure 89: Default look of the SLM preview window. The blue part just fills empty space due to the window geometry and does not represent the SLM screen.

In the SLM preview the display scale can be selected. Valid options are “Fit” and any number in the format “1:1”, “x1”, and “/1”. The numbers can also include a point (comma). By default, it starts with the scale “Fit”, which means that the full SLM screen is scaled down so that nothing is cropped. Mode “1:1” has a separate button to easily switch. “1:1” means each pixel shown on the SLM is represented by one pixel in the SLM preview window.

The left most button on top of the window is a shortcut to the “Fit” scale, the next button is the shortcut to the “1:1” scale option and the drop-down-selector can be used to select any scale. Since SDK version 2.0, the scale along with other options can be set through the API function

```
heds_utils_slmpreview_set(flags, scale).
```

A scale of 0 will set to “Fit” option. With

```
heds_utils_slmpreview_move(x, y, w, h)
```

the preview window geometry can be changed through the API.

Please be very careful with the scale modes because strange results can happen when using misleading scale values. Please see Figure 90 for an example. All images in Figure 90 show the same content on the SLM, which is a vertical binary grating with a pixel width of 1 for the gray value 0 and also 1 for the gray value 255. Here is the API call used to show the grating:

```
heds_show_grating_vertical_binary(1,1,0,255).
```

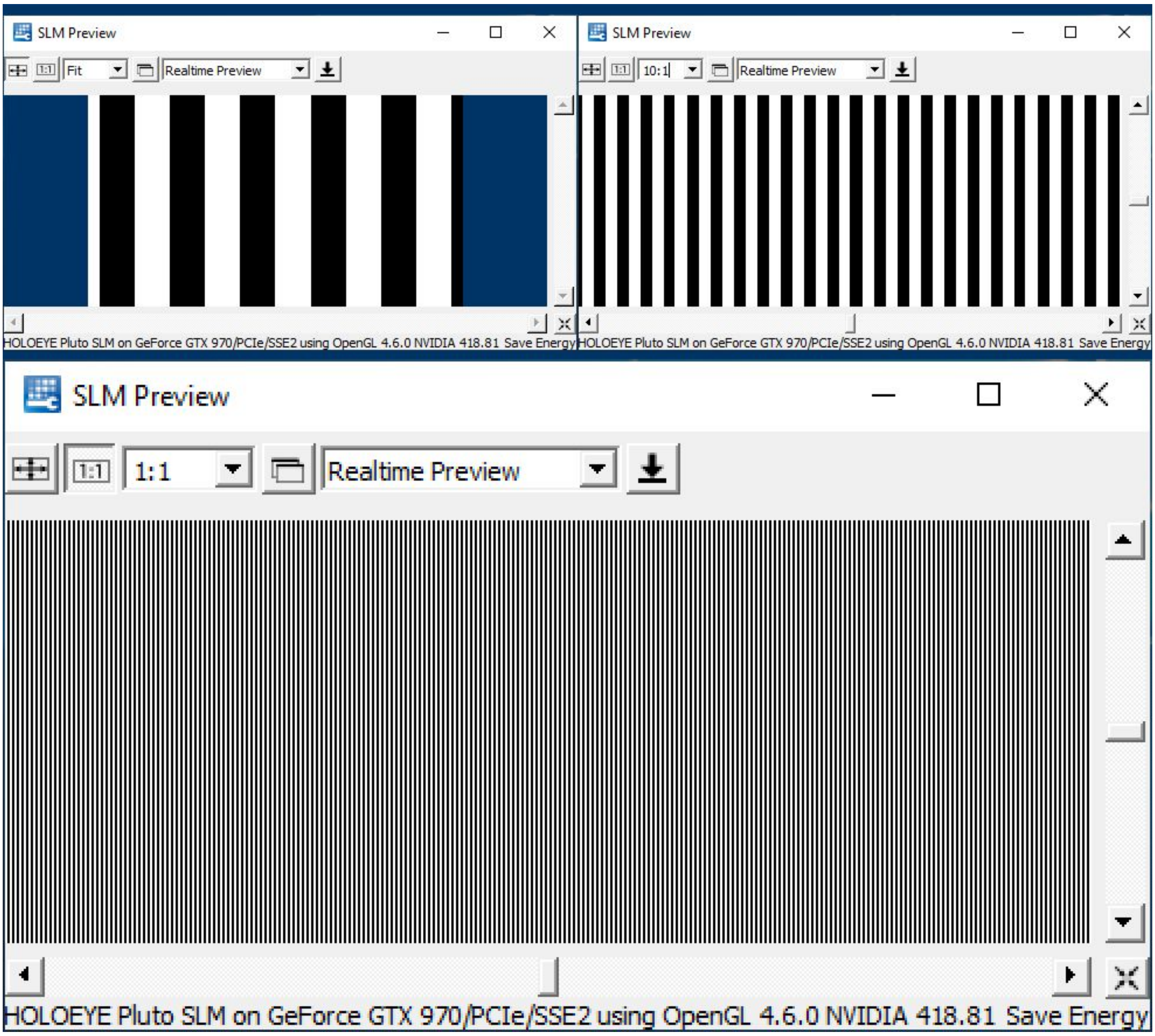


Figure 90: SLM preview window with scale "Fit" (top left), "1:1" (bottom), and "10:1" (top right). All three SLM previews show the same binary grating (1-1) on the SLM. The "Fit" scales down the pixels so much that a completely different looking image occurs. Please be careful with the scale modes which scale down (<1). The magnifying scale "10:1" means 10x10 pixel of the preview window show one pixel of the SLM screen.

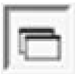
The top left picture in Figure 90 shows the grating in the scale mode "Fit", the larger bottom picture shows the SLM preview in mode "1:1", and the top right picture shows the SLM preview in scale mode "10:1", which is equal to "x10". The down sampling of the content on the SLM screen to the SLM preview results for this special content in a very different SLM preview image. The magnified scale mode is used ("x10") in the top right picture, which clearly shows that a 1-1 vertical binary grating is actually addressed on the SLM, and not the 180-180 grating appearing in “Fit” scale mode.

However, the “Fit” scale mode is very useful to get an overview of the content addressed on the SLM screen, and is therefore active by default.

In “Fit” or some smaller scale modes, areas in the SLM preview not filled with data from the SLM screen are shown in dark blue.

When the scaled SLM screen is larger than the SLM preview area, e.g. when using magnifying scale modes, a horizontal and a vertical slider is shown to move the position of the shown part of the SLMs content. The button in the bottom right corner can be used to reset both sliders back to the center position.

The “Stay on Top” button makes the SLM preview window stay on top of all other windows as long as this button is pressed down:



Since SDK version 2.0 this feature can also be set through the API function

```
heds_utils_slmpreview_set(flags, scale)
```

by using the flag “OnTop”.

By default, the position and size of the SLM preview window is set to the center of the main screen and can be modified either manually or since SDK version 2.0 by using the API function

```
heds_utils_slmpreview_move(x, y, w, h).
```

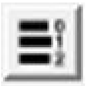
This API function is used across all examples by calling a separate example function for showing the preview. Please adapt this code if you wish a different default position and or size.

6.3.4 Additional Features in SLM Preview

6.3.4.1 SLM Data Handle Properties

The button “SLM Data Handle Properties” in the SLM preview window toolbar opens another window with all available properties of the currently visible data handle. If the same data handle was shown before, there is no new window opened, and for different data handles, new windows will appear.

The data handle properties editable through the API can be changed in this window, and the result will be visible on the SLM screen directly. This is helpful for example during development, and to try out some features of the data handle, like beam manipulations, data transformations and show flags. It can also be useful to easier access the timing statistics of the currently visible data field.



This button is not visible until any data or phasevalues are shown through an API function.

The window will always show the data handle visible on SLM screen when the button is pressed. Due to performance optimization, the SLM Data Handle Properties window will not update its values when new data is shown on the SLM screen or when the handle is changed. To update the window for a specific data handle, the data of this specific handle must be visible on screen again and then you need to press the button again.

The “SLM Data Handle Properties” button will open a new data handle properties window for not opened handles. That means you can edit multiple handles in parallel, but the windows will only update after pressing the button while the specific handle is addressed on the SLM screen. If the load functions were used to upload the data, the handle ID will be shown in the window caption.

Some selectable options might not make sense to combine, but this is also true when using the API functions to set these values.

Please refer to the API documentation of the data handle for more information about each option.

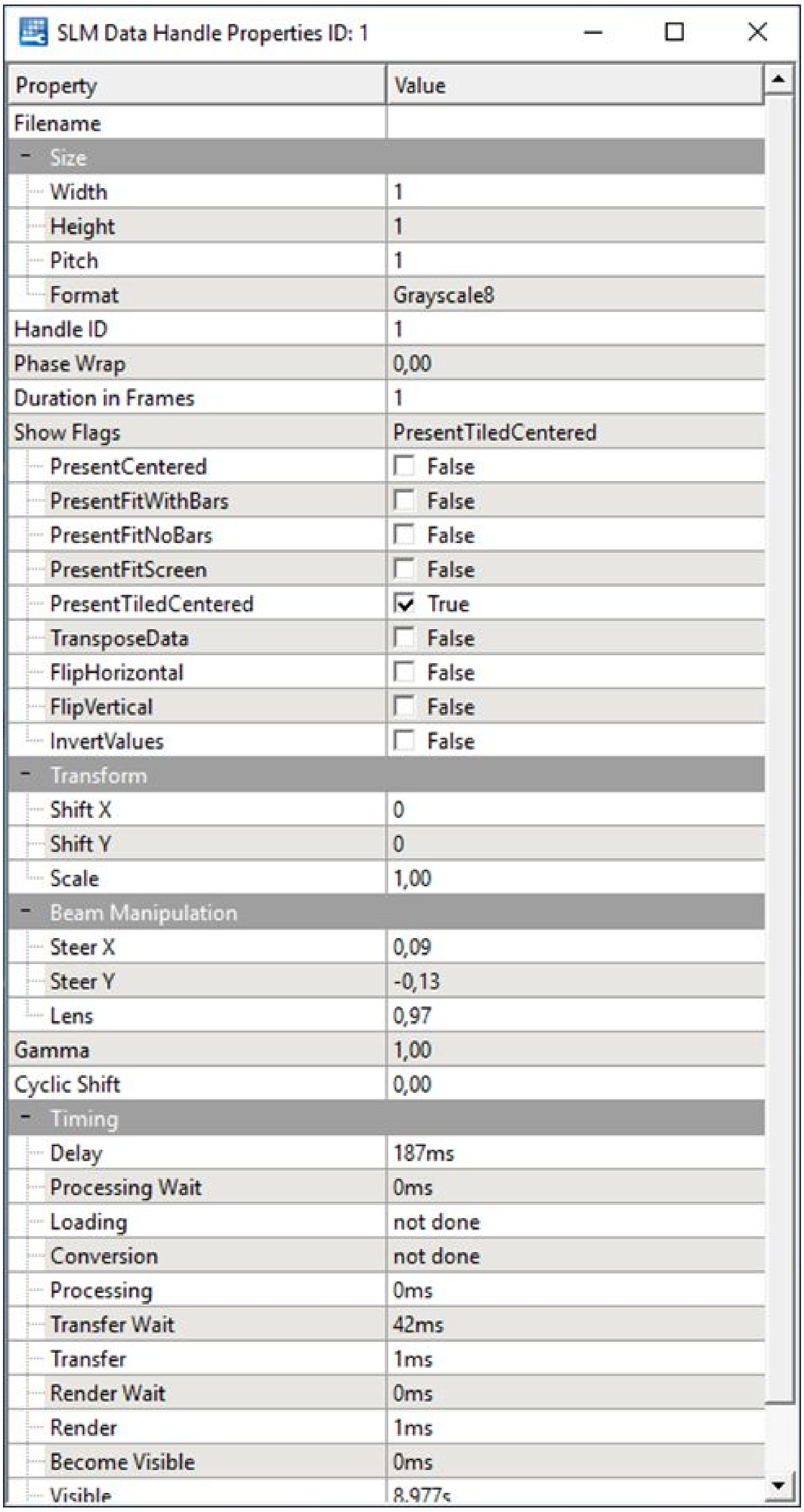


Figure 91: Data handle properties of the handle with the ID 1. The window allows inspecting and for some values also editing the available fields of the data handle.

6.3.4.2 Zernike Radius Indicator

The "Show Zernike Radius" button in the toolbar of the SLM preview can be pressed down to enable indication of the valid area for the currently set Zernike radius. In Figure 92 the button is pressed, and the Zernike radius is set to the half SLM height plus half a pixel.

This button only makes sense and is only shown when there are Zernike coefficients set to the SDK through the API function

```
heds_slm_zernike(const float *values, int valuesCount).
```

When the button is pressed down, only the SLM preview in mode "Realtime Preview" gets a red-colored overlay rendered into the shown data. That means the content on the SLM screen does not change when using this button, but the SLM preview indicates where the Zernike coordinates are out of the well-defined range. The Zernike radius is the first element of the Zernike values array passed to the API function.

The button is not pressed down by default, but can be enabled by using the flag "ShowZernikeRadius" in the API function

```
heds_utils_slmpreview_set(flags, scale).
```

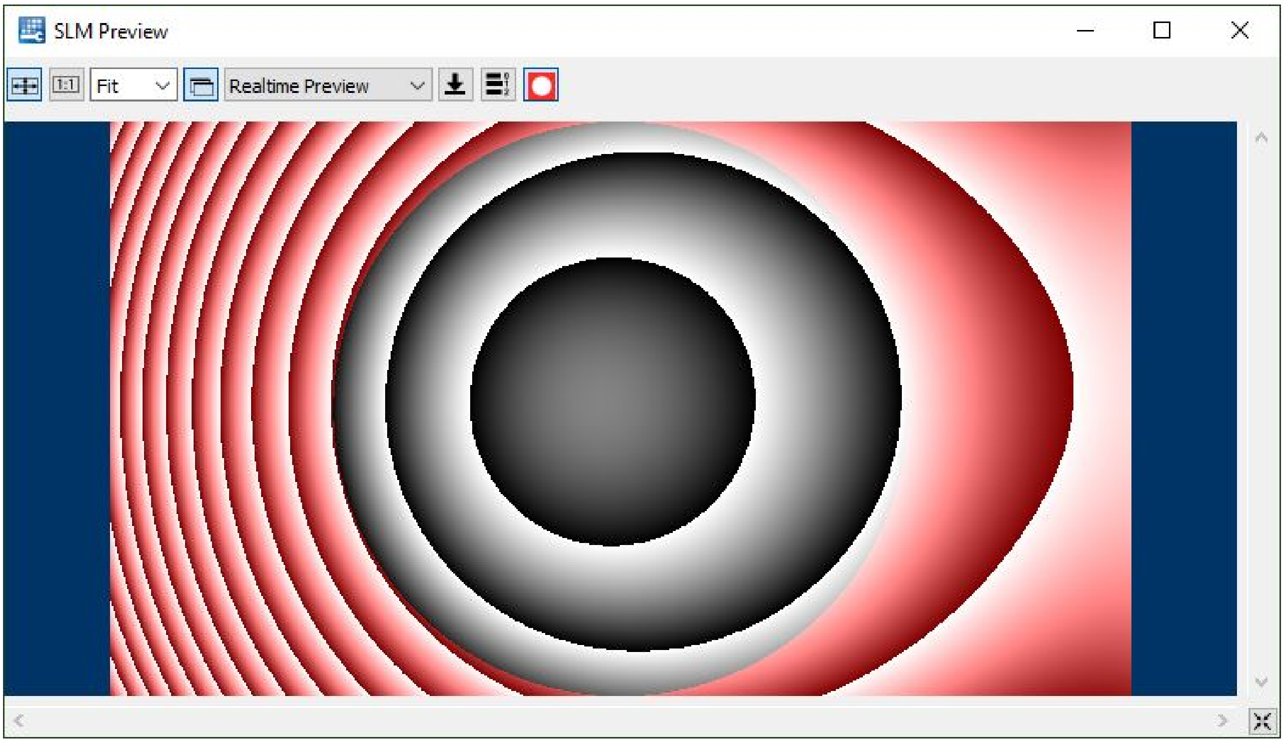
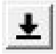


Figure 92: Data handle properties of the handle with the ID 0. The window allows inspecting and for some values also editing the available fields of the data handle.

The screenshot was created using the "phase_overlay_zernike" example shipped with the SDK.

6.3.4.3 Saving SLM Screen Data

Please use the "Save Data" button  in the toolbar of the SLM preview to save the entire SLM screens currently shown data to an image file. After pressing the button, a file selection dialog will open where you must select a file name and path to save the image file.

If time critical data is played on the SLM while using this feature, there will be some jitter added for a short period to the playback when the file dialog is opened.

The saved image file will not contain any indications added by the SLM preview. It will just contain the data like addressed to the SLM screen. Therefore, this feature is useful to inspect the SLM screen.

HOLOEYE Photonics AG

Volmerstr. 1

12489 Berlin, Germany

slm@holoeye.com

www.holoeye.com