SPATIAL LIGHT **MODULATORS**

HOLOEYE **Pioneers in Photonic Technology**

HOLOEYE Spatial Light Modulators

HOLOEYE provides a wide range of Spatial Light Modulators. Each SLM type offers unique features which are beneficial for specific applications:

- Resolutions from 1920×1080 up to 4160×2464 pixel
- Pixel pitches from 8 µm down to 3.74 µm
- Fast SLMs
- Small form factor of the SLM device
- Versions featuring a dielectric mirror for higher power lasers

For most SLM types, we offer versions optimized for different wavelength ranges, typically a VIS version (420–650 nm), a NIR Version (650–1064 nm), and a version for the C-Band around 1550 nm for telecommunication applications.

PLUTO-2.1 and ERIS-1.1 also feature a flexible broadband version covering the range from 420–1064 nm.

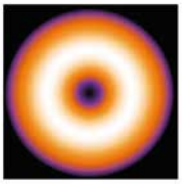
For the PLUTO-2.1, there are versions available for the UV (355–420 nm) and a version covering the range from 1700 nm up to 2,500 nm.

Additionally, the PLUTO-2.1 series includes versions featuring a dielectric mirror coating for use with high-power lasers.

All HOLOEYE SLMs come with an extensive software package that includes a Pattern Generator software, a Slideshow Player software, a convenient Configuration Manager, and an SDK for different programming environments.

SLM Applications

- Holography (AR/VR/MR/ Holographic Display, Digital- /Computer Holography, CGH)
- Quantum Optics / Optical Computing
- Deep Learning/Neural Networks Higher Order Modes/Optical Vortex/AOM
- WSS – Wavelength Selective Switching
- Microscopy
- Bessel- /Airy Beams
- Material Processing
- Optical Trapping / Tweezers
- Laser Pulse Modulation
- Image Processing
- Interferometry
- Lithography
- Polarization Generation



ERIS-1.1 SLM

Analog Phase Only
Spatial Light Modulator Series

The analog ERIS Spatial Light Modulator shows extreme phase stability, low latency and the display architecture allows low crosstalk LCOS-cell designs.

The ERIS Phase Only Spatial Light Modulator is based on a 0.717" LCOS microdisplay with a resolution of **1920×1200 px** and 8 µm pixel pitch. The SLM provides 8-bit phase levels but can also be operated in 10-bit phase mode.

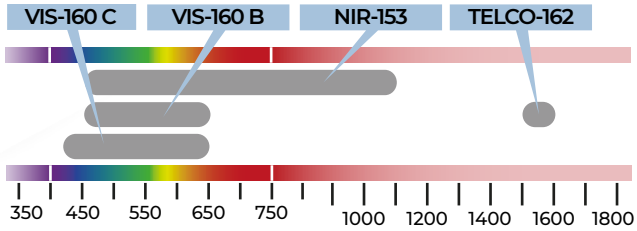
Display Type	Reflective LCOS
Resolution	1920 × 1200 px
Pixel Pitch	8.0 µm
Active area / Diagonal	15.42 × 9.66 mm / 0.717”
Fill Factor	>92%
Addressing Bit Depth	8 Bit / 10 Bit
Input Frame Rate	60 Hz / 120 Hz*
Signal Format	HDMI

**Please note that this is the input frame rate. The actual reponse time of the LC material depends on the version and configuration.*

ERIS-1.1 SLM Series Versions

The ERIS series covers **4** versions optimized for different wavelength ranges.

- The ERIS-VIS-160 B **(450 to 650 nm)** is optimized for high refresh rates (120 Hz) at low power.
- The ERIS-VIS-160 C **(420 to 650 nm)** can handle higher power at 60 Hz.
- The ERIS-NIR-153 version covers a broad wavelength range from **450 to 1100 nm**.
- The ERIS-TELCO-162 version is designed for typical telecommunication wavelengths in the area of **1400–1600 nm (e.g., C-Band 1550 nm)**.



Device	λ Range	Max. Phase	Avg. Refl.
VIS-160B	450–650 nm	3.2 π @ 633 nm	85 %
VIS-160C	420–650 nm	2.4 π @ 633 nm	89 %
NIR-153	450–1100 nm	2.4 π @ 1064nm	76–90 %
TELCO-162	1400–1600 nm	2.3 π @ 1550 nm	90 %

ERIS-1.1 120 Hz Mode

The ERIS SLM offers a real 120 Hz operation mode. The refresh rates for both, input frames via the HDMI graphics interface and the output, are boosted to 120 Hz.

The mode between standard 60 Hz and 120 Hz can simply be changed by configuring the HDMI graphics adapter to the desired frame rate or by selecting the mode at the HOLOEYE SLM Software.

PLUTO-2.1 SLM

Phase Only Spatial Light Modulator Series

The PLUTO Spatial Light Modulator is the **all-rounder** within our product range. It is the **best qualified** and **diversified** SLM platform with many versions optimized for specific requirements, including high reflectivity versions featuring a dielectric mirror for high power applications.

Furthermore, the PLUTO hardware is already implemented in different industrial applications.

Display Type	Reflective LCOS
Resolution	1920 × 1080 px
Pixel Pitch	8.0 µm
Active area / Diagonal	15.36 × 8.64 mm / 0.7”
Fill Factor	93%
Addressing Bit Depth	8 Bit
Input Frame Rate	60 Hz*
Signal Format	HDMI - HDTV Res.

**Please note that this is the input frame rate. The actual reponse time of the LC material depends on the version and configuration.*

Pluto-2.1 Series Versions

The PLUTO-2.1 series covers different versions optimized for different wavelength ranges between:

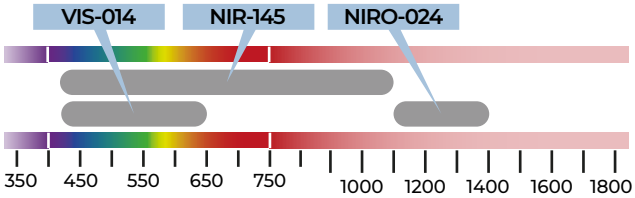
350 nm and 2500 nm

Besides the **standard versions**, we offer **high retardation** versions and **high reflectivity** versions for highly specialized requirements and applications.

Standard Versions

The standard PLUTO-2.1 devices include one version for the visible range, a flexible version for the near Infrared up to 1100 nm (which can also be used at the visible range), and a version centered for the O-band.

All standard versions provide at least 2π phase retardation for the specified wavelength range.

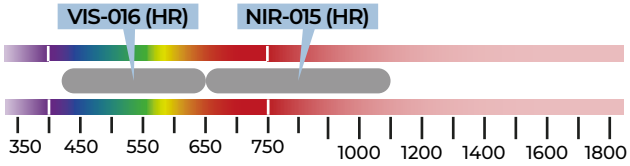


Device	λ Range	Max. Phase	Avg. Refl.
VIS-014	420–650 nm	3.1 π @ 633 nm	65 %
NIR-145	420–1064 nm	2.2 π @ 1064 nm	80 %
NIRO-024	1064–1400 nm	4.2 π @ 1300 nm	82 %

High Retardation Versions

The high retardation versions (VIS and NIR) enable a modulo 4 π or 6 π encoding of optical functions depending on the wavelength.

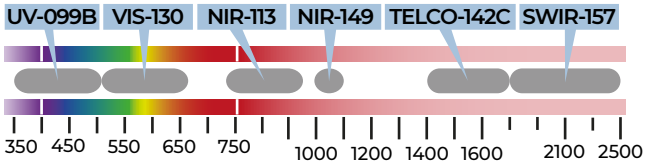
These versions can also be used to minimize phase flicker effects by driving the high retardation display with low voltage settings for 2 π phase retardation, although compromising the response time.



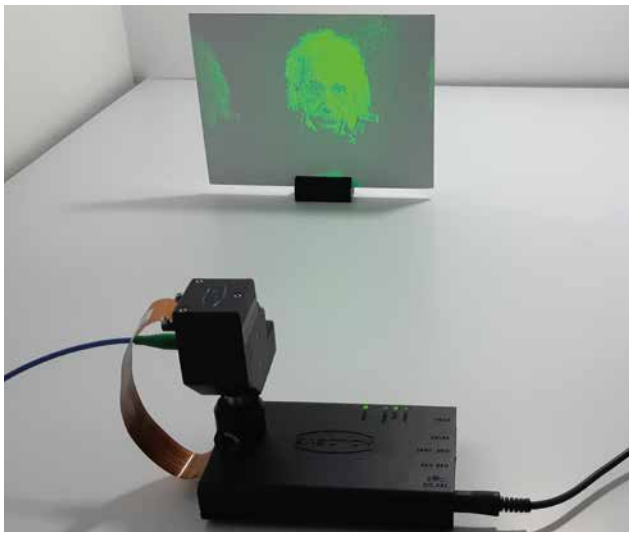
Device	λ Range	Max. Phase	Avg. Refl.
VIS-016	420–650 nm	5.2 π @ 633 nm	67 %
NIR-015	650–1100 nm	3.6 π @ 1064 nm	65-75%

High Reflectivity Versions

Some PLUTO-2.1 SLM display versions are equipped with a dielectric mirror coating to increase the reflectivity. Due to the increased reflectivity less absorption occurs and these versions can be used with higher incident laser power compared to the standard versions.



Device	λ Range	Max. Phase	Avg. Refl.
UV-099B	350–500 nm	4.9 π @ 405 nm	80 %
VIS-130	500–670 nm	2.5 π @ 633 nm	94 %
NIR-113	730–940 nm	2.5 π @ 800 nm	95 %
NIR-149	1000–1100 nm	2.9 π @ 1064 nm	93 %
TELCO-142C	1400–1700 nm	3.1 π @ 1550 nm	>90 %
SWIR-157	1700–2500 nm	2.0 π @ 2500 nm	90 %



Pluto-2.1 Flexible Driver

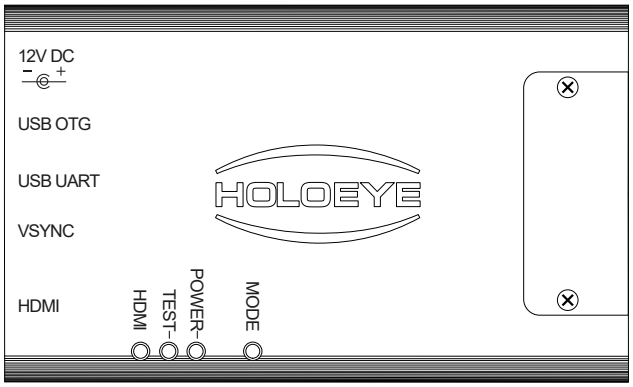
All PLUTO phase display versions can be driven with the same PLUTO-2.1 driver unit. This provides the flexibility to upgrade / adapt the SLM device to another version for different applications without the need to purchase a complete new SLM kit.

The PLUTO-2.1 driver uses an HDMI interface for addressing phase functions and an USB connection to communicate with the driver (to change the voltage vs. gray level distribution (gamma control) and dynamic range (voltage across the LC cell) in order to calibrate the SLM for different wavelengths).

The driver has a trigger sync output to synchronize the device with external devices.

The PLUTO-2.1 driver features a dual-core ARM® Cortex™-A9 processor which includes on-chip memory. This enables the user to program additional functionality which is directly processed on the SLM device.

The dual-core system runs an embedded LinuxTM SMP operating system and includes a library which provides full control and supervision of the display and driver board.



GAEA-2.1 SLM

Phase Only Spatial Light Modulator Series

The GAEA SLM offers **the highest resolution on the market** with an extremely small pixel pitch.

The GAEA-2.1 phase modulators are based on reflective LCOS microdisplays with 4160 × 2464 pixel resolution and 3.74 µm pixel pitch. The device also offers a fast mode at 3840 × 2160 pixel or 4000 × 2464 pixel resolution.

Display Type	Reflective LCOS
Resolution	max. 4160 × 2464 px
Pixel Pitch	3.74 µm
Active area / Diagonal	15.56 × 9.22 mm / 0.7”
Fill Factor	90%
Addressing Bit Depth	8 Bit
Input Frame Rate:*	
3840 × 2160 Pixel	60 Hz / (180 Hz - CFS)*
4000 × 2464 Pixel	60 Hz / (180 Hz - CFS)*
4160 × 2464 Pixel	58 Hz / (174 Hz - CFS)*
Signal Format	HDMI

**Please note that this is the input frame rate. The actual reponse time of the LC material depends on the version and configuration.*

High Spatial Resolution

The small pixel pitch of 3.74 µm enables high diffraction angles and results in a high effective spatial resolution at 133.5 lp/mm.

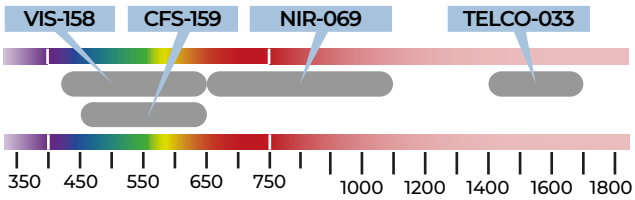
WL	Period | Angle		Period | Angle		Period | Angle	
1550 nm	2 px	11.96°	4 px	5.95°	8 px	2.97°
633 nm	2 px	4.85°	4 px	2.43°	8 px	1.21°
532 nm	2 px	4.08°	4 px	2.04°	8 px	1.02°
450 nm	2 px	3.45°	4 px	1.72°	8 px	0.86°

Color Sequential Mode

The GAEA-2.1 SLM driver is prepared to work in Color-Field-Sequential (CFS) mode by addressing 3 × 8 bit within a frame (180 Hz). The device features an LED-connector which can be used to synchronize the light source (color-switchable RGB lasers or LED lighting) with the device.

GAEA-2.1 Series Versions

- The GAEA-2.1-VIS-158 version can be used between **420 and 650 nm**.
- The GAEA-2.1-CFS-159 is designed for **color-field-sequential (CFS) operation**.
- The GAEA-2.1-NIR-069 version is optimized for **650 to 1100 nm**.
- The GAEA-2.1-TELCO-033 version is designed for typical telecommunication wavelengths in the area of **1400–1700 nm.**



Device	λ Range	Max. Phase	Avg. Refl.
VIS-158	420–650 nm	2.2 π @ 633 nm	78 %
CFS-159	450–650 nm	min 2 π @ CFS	76 %
NIR-069B	650–1100 nm	2.4 π @ 1064 nm	68 %
TELCO-033	1400–1700 nm	2.6 π @ 1550 nm	72 %

GAEA-C SLM

Phase Only Spatial Light Modulator Series

The GAEA-C SLM is a compact version of the 4K GAEA SLM with a **cost optimized driver solution and enhanced phase stability**.

The GAEA-C phase modulators are based on reflective LCOS microdisplays with **4094 × 2400** pixel resolution and 3.74 µm pixel pitch.

Display Type	Reflective LCOS
Resolution	4094 × 2400 px
Pixel Pitch	3.74 µm
Active area / Diagonal	15.56 × 9.22 mm / 0.7”
Fill Factor	90%
Addressing Bit Depth	8 Bit
Input Frame Rate:*	30 Hz
Signal Format	HDMI

**Please note that this is the input frame rate. The actual reponse time of the LC material depends on the version and configuration.*

High Spatial Resolution

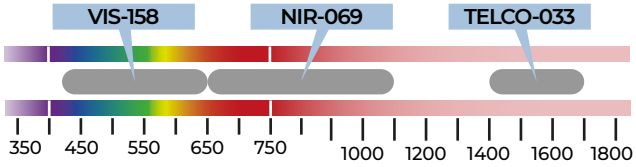
The small pixel pitch of 3.74 µm enables high diffraction angles and results in a high effective spatial resolution at 133.5 lp/mm.

WL	Period	Angle	Period	Angle	Period	Angle
1550 nm	2 px	11.96°	4 px	5.95°	8 px	2.97°
633 nm	2 px	4.85°	4 px	2.43°	8 px	1.21°
532 nm	2 px	4.08°	4 px	2.04°	8 px	1.02°
450 nm	2 px	3.45°	4 px	1.72°	8 px	0.86°

GAEA-C Series Versions

The GAEA-C Spatial Light Modulator series covers **3** versions optimized for different wavelength ranges.

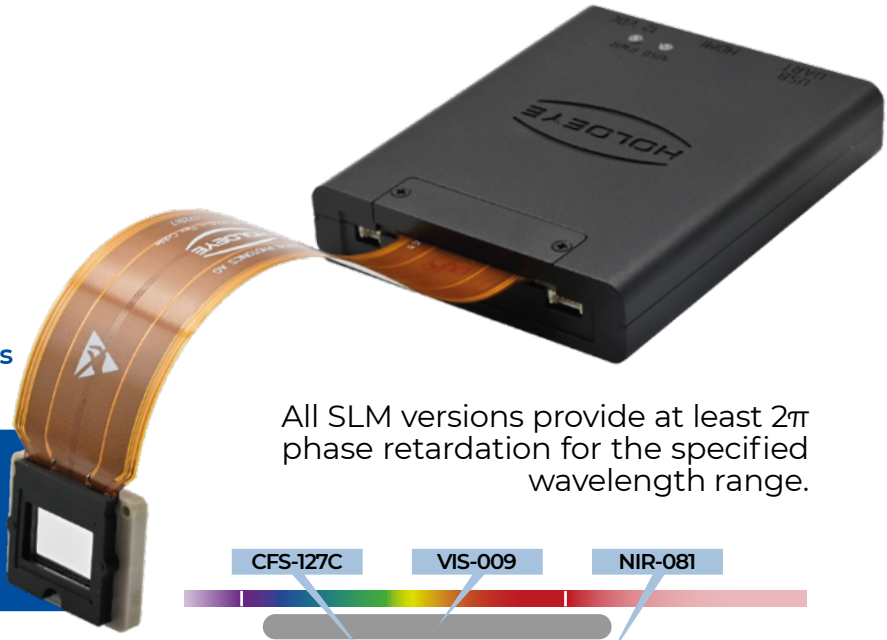
- The GAEA-C-VIS-158 version can be used between **420 and 650 nm**.
- The GAEA-C-NIR-069 is optimized for **650 to 1100 nm**.
- The GAEA-C-TELCO-033 version is designed for typical telecommunication wavelengths in the area of **1400–1700 nm (e.g., C-Band 1550 nm)**.



Device	λ Range	Max. Phase	Avg. Refl.
VIS-158	420–650 nm	2.2 π @ 633 nm	78 %
NIR-069B	650–1100 nm	2.4 π @ 1064 nm	68 %
TELCO-033	1400–1700 nm	2.6 π @ 1550 nm	72 %

LETO-3 SLM

Phase Only Spatial Light Modulator Series



The LETO Spatial Light Modulator is our fast SLM platform with high bandwidth. The SLM is capable of **color sequential operation**.

The LETO-3 phase modulator is based on reflective LCOS microdisplays with 1920×1080 pixel resolution. With a pixel pitch of only 6.4 µm and small interpixel gaps of 0.2 µm, the LETO-3 SLM provides a high fill factor of 93%.

Display Type	Reflective LCOS
Resolution	1920 × 1080 px
Pixel Pitch	6.4 µm
Active area / Diagonal	12.29 × 6.91 mm / 0.55”
Fill Factor	93%
Addressing Bit Depth	8 Bit
Input Frame Rate	60 Hz / (180Hz - CFS)*
Signal Format	HDMI - HDTV Res.

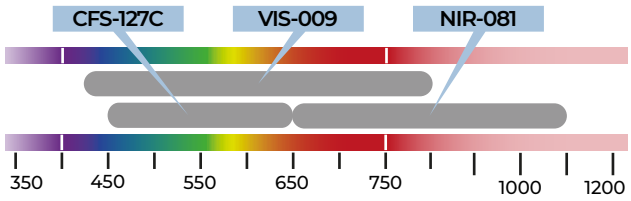
**Please note that this is the input frame rate. The actual reponse time of the LC material depends on the version and configuration.*

LETO-3 Series Versions

HOLOEYE offers **3** different LETO-3 Spatial Light Modulator versions which are optimized for use at different wavelength ranges or for different applications.

- The LETO-3-VIS-009 version is optimized for **420 to 800 nm.**
- The LETO-3-NIR-081 version covers the wavelength range from **650 to 1100 nm**.
- The LETO-3-CFS-127 version is designed for **color-field-sequential (CFS) operation**.

All SLM versions provide at least 2π phase retardation for the specified wavelength range.



Device	λ Range	Max. Phase	Avg. Refl.
CFS-127C	450–650 nm	min 2 π @ (CFS)	56-78 %
VIS-009	420–800 nm	2.8 π @ 633 nm	60-75 %
NIR-081	650–1100 nm	2.4 π @ 1064 nm	80 %

Color Sequential Mode

The LETO-3 SLM driver is prepared to work in Color-Field-Sequential (CFS) mode by addressing 3×8 bit within a frame (180 Hz).

The device features an LED-connector which can be used to synchronize the light source (color-switchable RGB lasers or LED lighting) with the device.

LETO-3-CFS-127 version is especially optimized for fast response times for use in color-field-sequential mode.

LETO-720 SLM

Phase Only Spatial Light Modulator Series

The LETO-720 phase only modulator is the fastest option we currently offer.

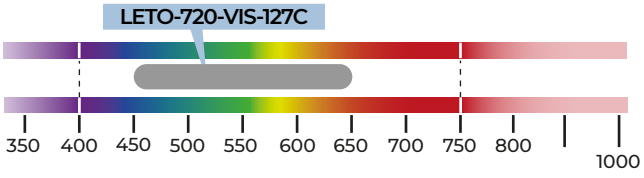
The fast LETO-720 phase only modulator is based on reflective microdisplays with 1920 × 1080 pixel resolution and a pixel pitch of only 6.4 µm.

Display Type	Reflective LCOS
Resolution	1920 × 1080px
Pixel Pitch	6.4 µm
Active area / Diagonal	12.29 × 96.91 mm / 0.55”
Fill Factor	93%
Addressing Bit Depth	6 Bit
Input Frame Rate:*	240 fps*
Signal Format	HDMI - HDTV Res.

**720 Hz modulation possible using RGB color channels.*

LETO-720 Version

Due to limitations in response times for LC based devices, we currently offer one version optimized for the VIS range between 450 to 650 nm.



Device	λ Range	Max. Phase	Avg. Refl.
VIS-127C	450–650 nm	2.4 π @ 635 nm	62-72 %

The LETO-720 combines the high data bandwidth and low latency of the HOLOEYE 4K resolution GAEA-2.1 (4k - 60fps - RGB888) driver and a fast display version of the LETO-3 SLM with a resolution of 1920 × 1080 pixels (~1 ms response-time at 520 nm).

LETO-720 Modes

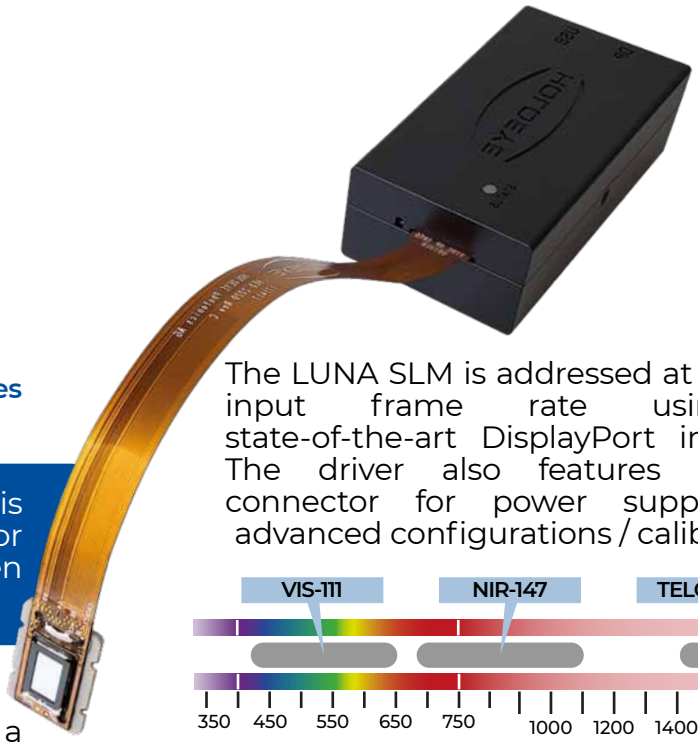
The SLM offers two modes:

240 Hz mode: This mode utilizes the high video data bandwidth of the driver to address real 240 Hz data on the SLM. The refresh rates for both, input frames via the HDMI graphics interface and the output, are boosted to 240 Hz.

720 Hz modulation (RGB coded): This mode makes use of the RGB color channels in addition to the 240 Hz mode. Three consecutive monochrome images are stacked in one full-color image.

LUNA
SLM

Phase Only Spatial Light Modulator Series



The LUNA Spatial Light Modulator is our most compact SLM platform for integration into **small-sized** or even **portable solutions**.

The LUNA SLM is based on a small sized 0.39" LCOS microdisplay with a resolution of 1920 × 1080 pixels and 4.5 µm pixel pitch. The small pixel pitch of 4.5 µm enables high diffraction angles and a spatial resolution of 111 lp/mm.

Display Type	Reflective LCOS
Resolution	1920 × 1080 px
Pixel Pitch	4.5 µm
Active area / Diagonal	8.64 × 4.86 mm / 0.39”
Fill Factor	91%
Addressing Bit Depth	8 Bit
Input Frame Rate	60 Hz / (180Hz - CFS)*
Signal Format	DisplayPort - HD Res.

**Please note that this is the input frame rate. The actual reponse time of the LC material depends on the version and configuration.*

LUNA Series Versions

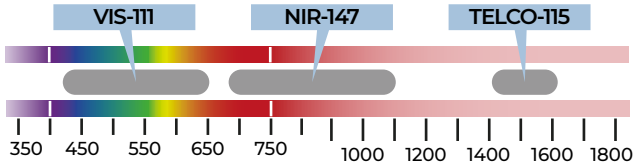
HOLOEYE offers **3** versions of the LUNA Spatial Light Modulator optimized for different wavelength ranges.

The LUNA-VIS-111 version is optimized for **420 to 650 nm** and **CFS** mode.

The LUNA-NIR-147 version covers the wavelength range from **680 to 1100 nm**.

The LUNA-TELCO-115 version is designed for typical telecommunication wavelengths in the area of **1400–1600 nm**.

The LUNA SLM is addressed at a 60 Hz input frame rate using a state-of-the-art DisplayPort interface. The driver also features a USB connector for power supply and advanced configurations / calibrations.



Device	λ Range	Max. Phase	Avg. Refl.
VIS-111	420–650 nm	2.4 π @ 635 nm	61-67 %
NIR-147	680–1100 nm	2.3 π @ 1064 nm	60-75 %
TELCO-115	1400–1700 nm	2.3 π @ 1550 nm	70 %

Small Design & Integrated ASIC

For the LUNA Spatial Light Modulator series, the driver ASIC is embedded in the LCOS microdisplay itself. This saves board space which enables a very compact driver, makes integration more convenient, and enables implementation into small-sized and portable solutions. The standard driver box has a size of only 85 × 47 × 28.8 mm.

The microdisplay can even accept video data input via a 4-lane MIPI DSI. This novel approach brings phase only Spatial Light Modulator technology to a new level of potential for industrial implementations.

LC-2012

Translucent Spatial Light Modulator

The LC-2012 is our most basic Spatial Light Modulator system based on a translucent liquid crystal microdisplay with a resolution of 1024×768 pixels (XGA). The device is mainly intended for **proof of concepts and education**.

The LC 2012 can be used for phase (phase mostly) and amplitude modulation applications in the visible range. The mode is defined by the configuration / incident polarization and polarizer-analyzer settings. The LC 2012 provides a phase shift of about 2 π at 450 nm, about 1.8 π at 532 nm and around 1 π at 800 nm.

Display Type	Translucent LC
Resolution	1024 × 768 px
Pixel Pitch	36 µm
Active area / Diagonal	36.9 × 27.6 / 1.8”
Fill Factor	55%
Transmittance	25%
Addressing Bit Depth	8 Bit
Input Frame Rate	60 Hz
Signal Format	HDMI - XGA Res.

The microdisplay and drive electronics are packaged into a compact box for easy integration into optical setups. The device is addressed using a standard HDMI interface and brightness and contrast settings can be performed using an USB interface.

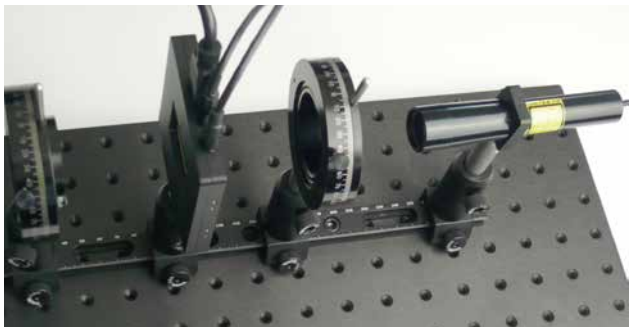
OPTIXPLORER

The OptiXplorer is an educational kit for both introductory and advanced laboratory courses in optical physics. The kit is based on the **LC 2012 SLM**. Additionally, **a laser module, two rotatable polarizers** and some **optomechanical components** are included in the kit.

The main topics covered in the six experimental modules listed below are polarization effects, amplitude modulation, phase modulation and Fourier Optics.

Topics & Experiments

- **AMP** – Using an SLM as an amplitude modulator for image projection experiments
- **JON** – Measurement of the Jones matrix components of the TN-LC cells of the SLM and derivation of the cell parameters
- **LIN** – Using an SLM to create binary linear and 2D-separable beam-splitter gratings
- **RON** – Measurement of the phase modulation of the SLM using dynamically addressed Ronchi gratings
- **CGH** – Computer generated holograms with included lens and prism phase functions
- **INT** – Interferometric fringe-shift measurement of the phase modulation of the SLM



Together with a theoretical introduction in the handbook and the provided references to additional literature, the six experimental modules make the Optixplorer a powerful and low-cost educational tool that enables the demonstration and active exploration of a wide range of optical phenomena.

TMS Thermal Management Systems

SLM Thermal Management Solutions

HOLOEYE SLMs are based on Liquid Crystal microdisplays. Physical properties of LC materials show a certain temperature dependence and a change in temperature may influence different optical SLM properties (phase shift, switching speed, phase stability...). SLM displays have their own power dissipation which varies between products and configurations.

To keep the performance / temperature stable, an active thermal management system should be used.

Dependent on the device model and its power dissipation, the device version's reflectivity and the laser power used, HOLOEYE offers a thermal management system with passive heat sink or a system based on an active water cooling.

All HOLOEYE LCOS SLM displays feature an integrated temperature sensor. A USB connection is used to connect the temperature control unit to the PC.

The SLM Configuration Manager software can be used to read out the microdisplay temperature and keep it stable at a defined temperature.

TMS 001

The TMS 001 thermal management system is based on a Peltier element which is a thermoelectric cooler, in combination with a passive heat sink and can both cool and heat up the SLM display.

TMS 002

Even using HOLOEYE's high reflectivity SLM versions (with dielectric mirror), an active thermal management is required for high laser power applications. The TMS 002 thermal management system with active water cooling is especially designed for use with higher laser power.

The up-to-date display versions of all these SLM platforms use a standardized display packaging with a ceramic stiffener / back plate with excellent thermal conductivity.

The displays can be mounted using the integrated magnets or by screws if required.

SLM SOFTWARE

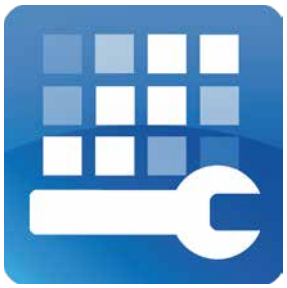
Software for HOLOEYE Spatial Light Modulators

All HOLOEYE Spatial Light Modulators are addressed like a monitor via standard HDMI or DisplayPort. Meaning the SLM actually acts like a standard monitor device and no special software or drivers are necessary to operate the SLM (standard image viewer software can be used).

For an easy start and even more convienent operation, HOLOEYE provides a Pattern Generator software (for calculation of different optical functions), a Slideshow Player software (for easy addressing of precalculated functions or images on the SLM) and an SDK for different programming environments.

The SLM Display SDK also supports the use of multiple SLMs simultaneously and offers a canvas mode to address different functions/content on a tiled SLM display area.

Of course, also a convenient Configuration Manager software for configuration, calibration and temperature management is delivered with each SLM Device.

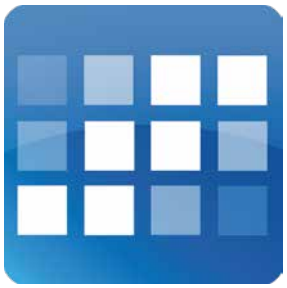


SLM DISPLAY SDK

SDK for LabView, Matlab, Python Octave and GCC environments

SLM CONFIGURATION MANAGER

Software for device configuration and calibration



SLM PATTERN GENERATOR

Generation of different optical functions

SLM SLIDESHOW PLAYER

Image slideshow software for HOLOEYE SLMs

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HOLOEYE

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SLM – Rev15.5 – Specifications are subject to change without notice