

# SLM

## Spatial Light Modulators



# PLUTO-2.1

## Phase Only Spatial Light Modulator Series



The PLUTO-2.1 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.

Also the PLUTO hardware is already implemented in different industrial applications.

Display Type	Reflective LCOS
Resolution	1920 x 1080 Pixel
Pixel Pitch	8.0 $\mu\text{m}$
Active Area / Diagonal	15.36 x 8.64 mm / 0.7"
Fill Factor	93%
Addressing Bit Depth	8 Bit
Input Frame Rate	60 Hz / (180 Hz)
Signal Format	HDMI - HDTV Res.

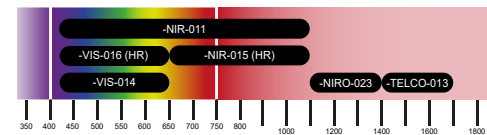
The PLUTO-2.1 series covers different versions optimized for different applications and wavelength ranges from 350 nm up to 1700 nm.

Furthermore high retardation display versions are available (VIS and NIR) which enable a modulo  $4\pi$  or  $6\pi$  encoding of optical functions depending on the wavelength. These versions can also be used to minimize phase flicker effects by driving the high retardation displays with low voltage settings for  $2\pi$  phase retardation, however compromising the response time.

All different phase display versions can be driven with the same PLUTO-2.1 driver units. 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 also 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 Linux™ SMP operating system and includes a library which provides full control and supervision of the display and driver board.

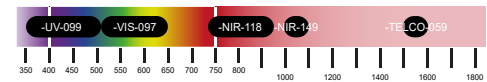
### Standard Versions



Device	$\lambda$ Range	Maximum Phase	Average Refl.
VIS-014	420-650 nm	$3.1\pi$ @ 633 nm	65%
VIS-016	420-650 nm	$5.2\pi$ @ 633 nm	65%
NIR-011	420-1100 nm	$2.3\pi$ @ 1064nm	65-75%
NIR-015	650-1100 nm	$3.6\pi$ @ 1064 nm	65-75%
NIRO-023	1100-1400 nm	$4.2\pi$ @ 1300 nm	74%
TELCO-013	1400-1700 nm	$3.9\pi$ @ 1550 nm	80%

### 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 display versions can be used with higher incident laser power compared to the standard versions.



Device	$\lambda$ Range	Maximum Phase	Average Refl.
UV-099	350-500 nm	$4.9\pi$ @ 405 nm	90%
VIS-097	515-650 nm	$2.7\pi$ @ 633 nm	95%
NIR-118	730-950 nm	$3.1\pi$ @ 800nm	95%
NIR-149	1000-1100 nm	$2.9\pi$ @ 1064 nm	93%
TELCO-059	1500-1600 nm	$3.1\pi$ @ 1550 nm	90%

# GAEA-2

## Phase Only Spatial Light Modulator Series



**The GAEA-2 Spatial Light Modulator is the highest resolution SLM on the market with extremely small pixel pitch.**

The GAEA-2 phase modulators are based on reflective LCOS microdisplays with 4160 x 2464 pixel resolution and 3.74  $\mu\text{m}$  pixel pitch. The phase displays can be addressed at 3840 x 2160 pixel or 4000 x 2464 pixel resolution at 60 Hz. The full physical resolution of 4160 x 2464 pixel can be used at 58 Hz frame rate.

Display Type	Reflective LCOS
Resolution	max. 4160 x 2464 Pixel
Pixel Pitch	3.74 $\mu\text{m}$
Active Area / Diagonal	15.32 x 9.622 mm / 0.7"
Fill Factor	90%
Addressing Bit Depth	8 Bit
Input Frame Rate	3840 x 2160 Pixel @ 60 Hz 4000 x 2464 Pixel @ 60 Hz 4160 x 2464 Pixel @ 58 Hz
Signal Format	HDMI

## High Spatial Resolution

The small pixel pitch of 3.74  $\mu\text{m}$  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°

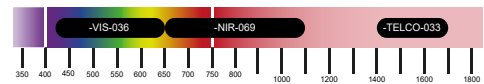
## GAEA-2 Series Versions

The GAEA-2 series covers 3 versions optimized for different wavelength ranges.

The GAEA-2-VIS-036 version can be used between 420nm and 650nm. The display is equipped with an AR coating that gives a front reflection less than 0.5% in this range. The LC cell enables at least  $2\pi$  phase retardation up to 650nm.

The GAEA-2-NIR-069 version is optimized for the wavelength range 650nm to 1100nm. The device provides at least  $2\pi$  phase retardation up to 1064nm.

The GAEA-2-TELCO-033 version is designed for typical telecommunication wavelength in the area of 1400 - 1700 nm (e.g. C-Band 1550 nm). The display provides  $2\pi$  phase shift up to at least 1550nm.



Version	$\lambda$ Range	Maximum Phase	Average Refl.
VIS-036	420-650 nm	$3\pi$ @ 633nm	62 %
NIR-069	650-1100 nm	$2.4\pi$ @ 1064nm	60 %
TELCO-033	1400-1700 nm	$2.6\pi$ @ 1550nm	72 %



# LETO

## Phase Only Spatial Light Modulator Series



**The LETO Spatial Light Modulator is our fast SLM platform due to the high band width. The SLM is capable for color sequential operation.**

The LETO phase modulator is based on reflective LCOS microdisplays with 1920 x 1080 pixel resolution. With a pixel pitch of only 6.4  $\mu\text{m}$  and small interpixel gaps of 0.2  $\mu\text{m}$  the LETO SLM provides a high fill factor of 93%.

Display Type	Reflective LCOS
Resolution	1920 x 1080 Pixel
Pixel Pitch	6.4 $\mu\text{m}$
Active Area / Diagonal	12.5 x 7.1 mm / 0.55"
Fill Factor	93%
Addressing Bit Depth	8 Bit
Input Frame Rate	60 Hz / (180 Hz)
Signal Format	HDMI - HDTV Res.

### LETO Series Versions

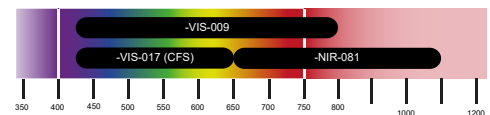
HOLOEYE offers three different LETO Spatial Light Modulator versions which are optimized for the use at different wavelength ranges / for different applications.

One SLM version is optimized for the visible range, one version for the near IR range up to 1100 nm and a third version is optimized for fast response (180 Hz) and use for color-field-sequential (CFS) operation in the visible range with color-switchable RGB Laser (different pulse-code programming / calibration is necessary).

The LETO-VIS-009 SLM version can essentially be used between 420 nm and 1064 nm. The display has an AR coating that gives a front reflection less than 0.5% in this range. However, the phase shift above 800 nm will be limited (below 2 Pi).

The LETO-NIR-081 version is equipped with an AR coating for the range of 650 nm to 1100 nm and provides 2 Pi phase shift up to 1100 nm.

The LETO-VIS-017 Spatial Light Modulator version is optimized for fast response times for the use at color field sequential operation in the visible range. The LETO SLM driver is prepared to work in color-field-sequential (CFS) mode e.g. with color-switchable lasers or LED lighting and the device features an LED-connector which can be used to synchronize the light source with the device.



Version	$\lambda$ Range	Maximum Phase	Average Refl.
VIS-017	420-650 nm	min 2 $\pi$ @ (CFS)	75 %
VIS-009	420-800 nm	2.8 $\pi$ @ 650nm	75 %
NIR-081	650-1100 nm	2.4 $\pi$ @ 1064nm	62-70 %



# LUNA

## 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 x 1080 pixels and 4.5  $\mu\text{m}$  pixel pitch. The small pixel pitch of 4.5  $\mu\text{m}$  enables high diffraction angles and a spatial resolution of 111 lp/mm.

Display Type	Reflective LCOS
Resolution	1920 x 1080 Pixel
Pixel Pitch	4.5 $\mu\text{m}$
Active Area / Diagonal	8.64 mm x 4.86 / 0.39"
Fill Factor	91%
Addressing Bit Depth	8 Bit
Input Frame Rate	60 Hz / (180 Hz)
Signal Format	DisplayPort - HD Res.

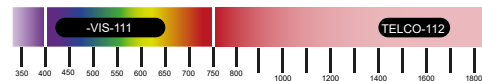
### LUNA Series Versions

HOLOEYE offers two different LUNA Spatial Light Modulator display versions which are optimized for the use at different wavelength ranges / for different applications.

One SLM version is optimized for the visible range and provides a linear phase shift of at least 2  $\text{Pi}$  at 420-650 nm.

The other version is especially designed for the telecommunication waveband and provides a phase shift of 2  $\text{Pi}$  up to 1550 nm.

The LUNA SLM is addressed at 60 Hz input frame rate using an up-to-date DisplayPort interface. The driver also features an USB connector for power and advanced configurations / calibrations.



Version	$\lambda$ Range	Maximum Phase	Average Refl.
VIS-0111	420-650 nm	2.4 $\pi$ @ 635nm	61-67 %
TELCO-112	1400-1700 nm	2.3 $\pi$ @ 1550nm	70 %

### Small Design & Integrated ASIC

At 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 x 47 x 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 x 768 pixel (XGA). The device is mainly intended for proof of concepts and education.

The Spatial Light Modulator can be used for phase (phase mostly) or amplitude modulation applications in the visible range. The mode depends on the configuration / incident polarization and polarizer-analyzer settings. The LC 2012 provides a phase shift (phase mostly) of about  $2\pi$  at 450 nm, about  $1.8\pi$  at 532 nm and around  $1\pi$  at 800 nm.

Display Type	Translucent LC
Resolution	1024 x 768 Pixel
Pixel Pitch	36 $\mu$ m
Active Area / Diagonal	36.9 x 27.6 mm / 1.8"
Fill Factor	55 %
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 Education Kit

The OptiXplorer is an educational kit for both introductory and advanced laboratory courses in optical physics. The kit is based on the LC 2012 Spatial Light Modulator.

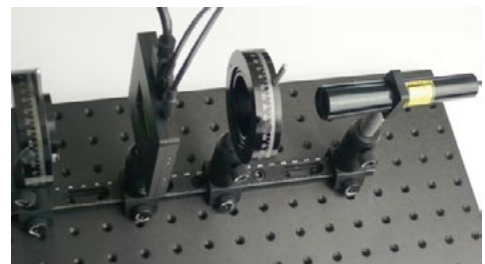
Additionally a laser module, two rotatable polarizers and some optomechanical components are included in the kit.

## OPTIXPLORER

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 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.

# SLM Software

## Software for HOLOEYE Spatial Light Modulators

All HOLOEYE Spatial Light Modulators are addressed like a monitor via standard HDMI or DisplayPort. This means 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 convenient 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.

Of course also a convenient Configuration Manager software for configuration, calibration and temperature management is delivered with each Spatial Light Modulator device.



### SLM CONFIGURATION MANAGER

Software for device configuration and calibration



### SLM SLIDESHOW PLAYER

Image slideshow software for HOLOEYE SLMs



### SLM PATTERN GENERATOR

Generation of different optical functions



### SLM DISPLAY SDK

SDK for LabView, Matlab, Python Octave and GCC environments

SLM – Rev. 9.1 – Specifications are subject to change without notice