

### ■ Features

- High diffraction efficiency
- High light utilization efficiency
- High linear modulation characteristic
- High power handling capability
- Simple control via PC
- Suitable housing design for use on an optical table

### ■ Applications

- Optical beam pattern shaping
- Laser processing
- Laser marking
- Optical manipulation
- Optical tweezers
- Wavefront aberration correction
- Adaptive optics
- Optical vortex generation
- Pulse shaping
- Metal 3D printing

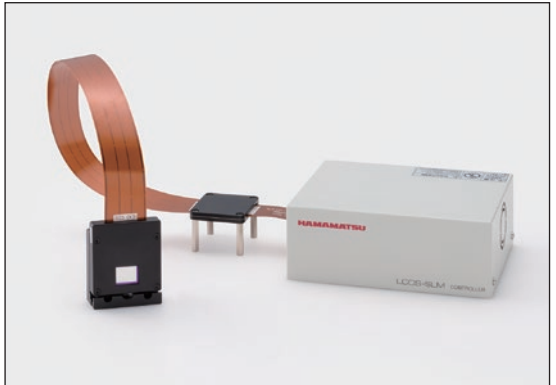
### ■ Outline

The X15213 series devices are LCOS-SLMs (Liquid Crystal On Silicon – Spatial Light Modulators) with a compact housing and AC adapter for power supply, suitable for use on an optical table. The LCOS-SLMs can modulate the wavefront of a light beam through a PC using Digital Video Interface (DVI), which is the standard interface for PC displays.

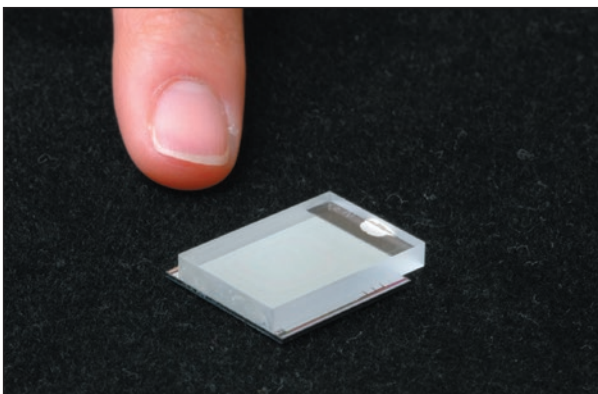
High-speed response and high-precision phase modulation are realized by directly controlling the liquid crystal (LC) with the voltage of the address part formed by applying CMOS technology.

The optimum optical design of the LCOS-SLM minimizes light loss to achieve high diffraction efficiency and high light utilization efficiency. In addition, high linear modulation characteristics can be obtained by digitally correcting distortion due to mirror surface distortion, non-uniformity of the thickness of the LC layer, and non-linear response of the LC.

In order to improve power handling capability, we also offer water-cooled types with a built-in water-cooled heatsink, and sapphire types using sapphire glass for the glass substrate.



### ■ LCOS chip

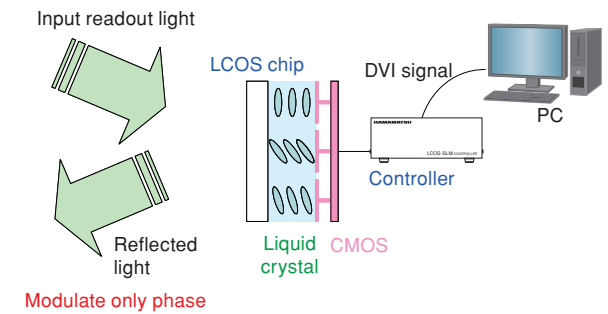


# LCOS-SLM X15213 series

## Principle of modulation

The LCOS chip has a parallel-aligned nematic LC layer between a CMOS chip and a glass substrate. Using the DVI signal sent from the PC to the controller, the CMOS pixel voltage can individually control the tilt of the LC molecules for each pixel. Since the refractive index of the LC layer changes according to the inclination of the LC molecules, the optical path length of the incident light passing through the LC changes, causing a phase difference. When the polarization direction of the incident light is aligned with the orientation direction of the LC molecule, it is possible to modulate only the phase of the light without changing the light intensity.

Figure 1: Principle of modulation



## Supported wavelength range

The X15213 series offers an extensive lineup to meet the needs of various wavelengths. All types have a glass substrate with an anti-reflection coating and a CMOS chip with a mirror. Recommended beam diameter ( $1/e^2$ ) is 8 mm or more.

### Aluminum mirror type (-01/-07/-08)

The aluminum mirror type uses the reflection from the aluminum electrode on the CMOS chip and has a wide reflection band, so it can be used in a wide wavelength range.

### Dielectric multilayer mirror type (-02/-03B/-05/-12/-13/-15/-16/-19)

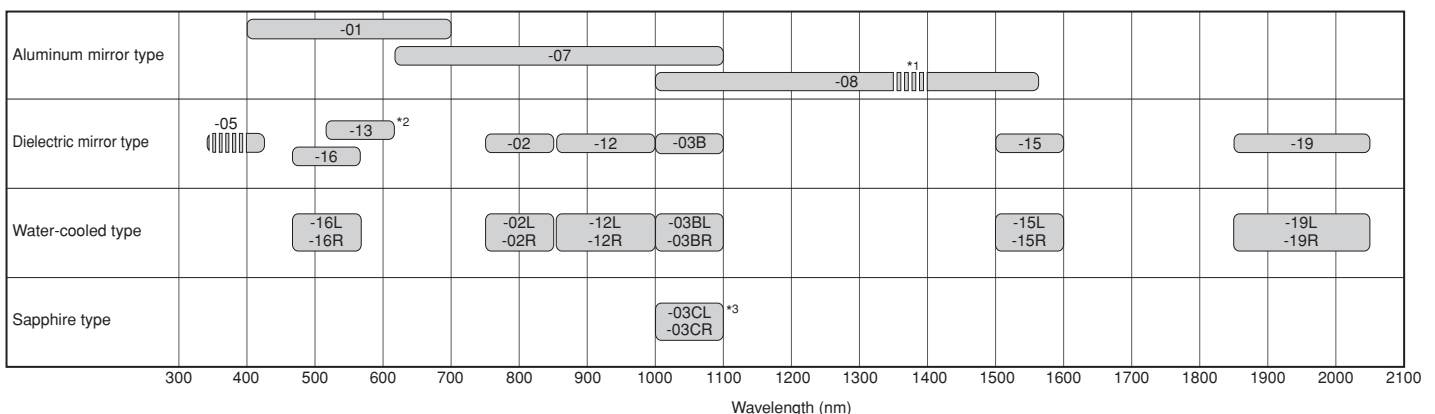
The dielectric multilayer mirror type has a specially designed dielectric multilayer film on the surface of the CMOS chip to support laser light sources of various wavelengths. Compared to the aluminum mirror type, the higher reflectivity achieved by the dielectric mirror decreases the internal absorption rate. High light utilization efficiency can be realized.

### Water-cooled type (-02L/-02R/-03BL/-03BR/-12L/-12R/-15L/-15R/-16L/-16R/-19L/-19R)

The dielectric multilayer mirror type head with a built-in water-cooled heat sink suppresses temperature rise due to laser irradiation and achieves high power handling capability.

### Sapphire type (-03CL/-03CR)

In addition to the water-cooled heat sink, sapphire glass is used for the glass substrate. As a result, the heat dissipation efficiency has been improved, leading to power handling capability of over 700 W.



\*1 -08: In the wavelength range of 1350 nm to 1400 nm, absorption by the glass substrate reduces reflectance by approximately 5%.

\*2 -13 and -16: They can be used for 532 nm band lasers. The -16 has higher power handling capability for short pulse lasers than the -13.

\*3 -03CL/-03CR: They have a very high power handling capability of over 700 W and are suitable for metal processing.

# LCOS-SLM X15213 series

## ■ Configuration

### ●Head

Parameter	X15213 series	Unit
Number of pixels	1272 × 1024	pixel
Pixel pitch	12.5	μm
Effective area size	15.9 × 12.8	mm
Fill factor	96.8	%
Weight	152 (Water-cooled type: 552 / Sapphire type: 557)	g

### ●Controller

Parameter	X15213 series	Unit
Power supply voltage (AC)	100 to 230	V
Power supply frequency	50 / 60	Hz
Power consumption (Typ.)	15	W
Input signal	DVI-D (Digital video interface) / USB-B (2.0 High-speed)	—
DVI signal format	1280 × 1024	pixel
DVI frame rate	60	Hz
Number of input signal gradations	256	level
Weight	910 (including accessories: 1350)	g

## ■ Absolute maximum rating

(Ta=25 °C)

Parameter	X15213 series	Unit
Operating temperature *1	+10 to +40	°C
Storage temperature *1	-20 to +55	°C
Withstand pressure of water stream connector	0.3 (Water-cooled type)	MPa

\*1 No condensation. Humidity may cause deterioration of characteristics, so be careful with the humidity.

\* Exceeding the absolute maximum ratings even momentarily may cause a drop in product quality. Always be sure to use the product within the absolute maximum ratings.

## ■ Electrical and optical characteristics

Parameter	Readout light wavelength (nm)	Light utilization efficiency (Typ.) (%)	Rise time *1 (Typ.) (ms)	Fall time *1 (Typ.) (ms)
X15213-01	400 to 700	76	5	21
X15213-02/-02L/-02R	800 ± 50	97	33	85
X15213-03B/-03BL/-03BR /-03CL/-03CR	1050 ± 50	97	27	83
X15213-05	410 ± 10	97	7	17
X15213-07	620 to 1100	80	9	73
X15213-08	1000 to 1550	86	13	145
X15213-12/-12L/-12R	850 to 1000	97	38	109
X15213-13	530 to 635	97	10	21
X15213-15/-15L/-15R	1550 ± 50	97	26	135
X15213-16/-16L/-16R	510 ± 50	97	11	33
X15213-19/-19L/-19R	1850 to 2050	97 *2	30 *2	155 *2

\*1 Time required to change from 10 % to 90 % for 2π modulation.

\*2 Design value for a laser with an oscillation wavelength of 1950 nm.

\* Lasers with the following wavelengths are used to measure light utilization efficiency, rise time, and fall time.

Laser emission wavelength 633 nm (X15213-01)

Laser emission wavelength 785 nm (X15213-02 series)

Laser emission wavelength 1064 nm (X15213-03B series/-07)

Laser emission wavelength 405 nm (X15213-05)

Laser emission wavelength 1550 nm (X15213-08/-15 series)

Laser emission wavelength 940 nm (X15213-12 series)

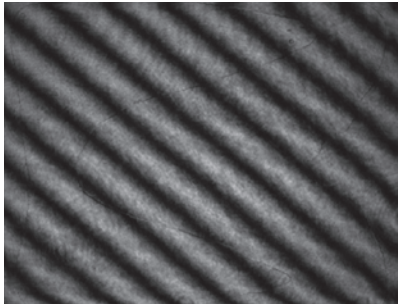
Laser emission wavelength 532 nm (X15213-13/-16 series)

## Operating characteristics

### High precision phase modulation

The X15213 series has high precision phase control and high diffraction efficiency, and is very suitable for holographic applications. Figure 2 (a) is a interferometer picture of the output wavefront with a flatness calibration. Figure 2 (b) is an example of a 1st order diffraction image obtained by reconstructing a computer generated hologram (CGH) using the Fourier transform optical system. Figure 2 (c) shows a clear Laguerre Gaussian (LG) beam of (0, 1) order.

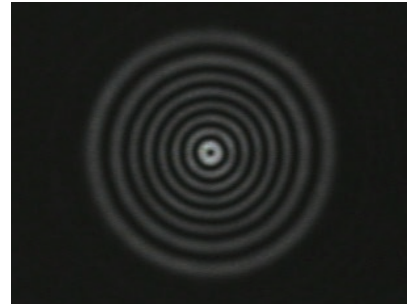
Figure 2: Output image examples



(a) Interferogram of output wavefront with calibration  
1272 × 1024 pixels  
RMS: 0.025 λ (λ=532 nm)



(b) Reconstructed image of CGH



(c) LG beam

### High diffraction efficiency

The X15213 series is a pure phase SLM with high precision phase control; therefore, it has high diffraction efficiency close to the theoretical values. Figure 3 shows images of diffracted spots when a multi-level phase grating is displayed on the X15213 series, and Figure 4 shows typical diffraction efficiency characteristics. Here, the diffraction efficiency is defined as  $I_1/I_0$ , where  $I_1$  is the intensity of the 1st order diffraction spot,  $I_0$  is the intensity of the 0th order light when no pattern is displayed.

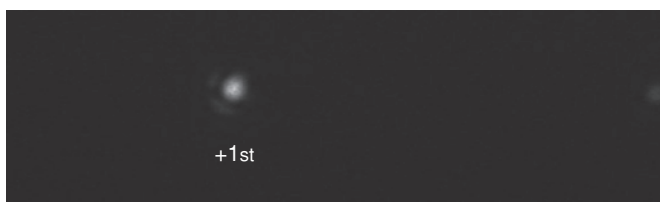
Figure 3: Diffracted spots images (typical example)



(a) No pattern

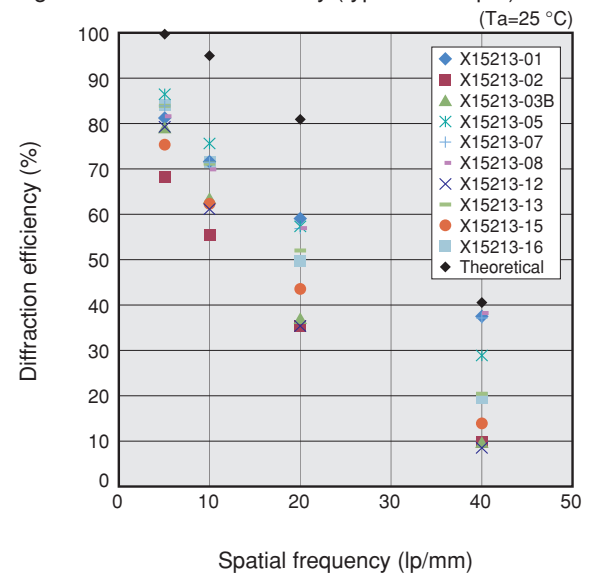


(b) 2-level grating (40 lp/mm)



(c) 4-level grating (20 lp/mm)

Figure 4: Diffraction efficiency (typical example)



# LCOS-SLM X15213 series

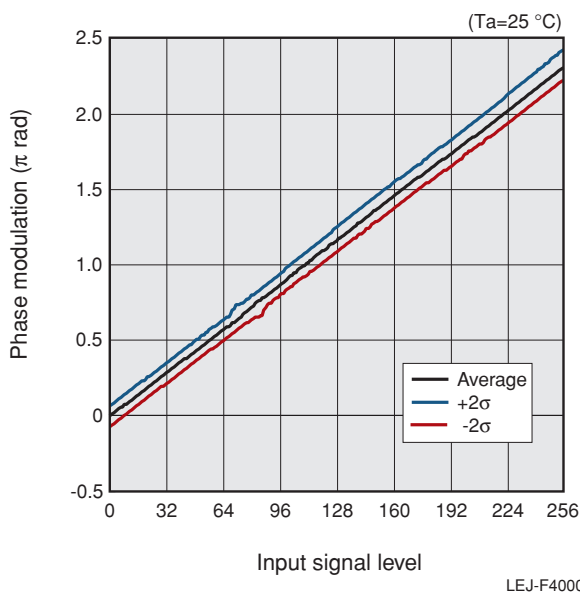
## ●High light utilization efficiency

The X15213 series have high light utilization efficiency, which is defined as the ratio of the 0th order diffraction light intensity to the input light intensity. The light utilization efficiency mainly depends on the reflectivity of the mirror, and the amount of diffraction loss caused by the pixel structure. We adopted advanced CMOS technology to make the diffraction loss smaller. As a result, the diffraction loss is less than 5 %. In particular, the -02/-03B/-05/-12/-13/-15/-16/-19 series have very high light utilization efficiency thanks to the highly reflective dielectric mirror.

## ●High linear phase modulation characteristics

The X15213 series can achieve phase modulation of more than  $2\pi$  radians over the 400 nm to 2050 nm readout wavelength range. Prior to shipment, each type is pre-calibrated at the factory to obtain high-precision and high-linear modulation characteristics for a specific wavelength range. Figure 5 shows typical phase modulation characteristics. A phase shift of  $2\pi$  radians or more and a linear phase response are achieved. The phase modulation curve of 95 % of the pixels in the effective area is within  $\pm 2\sigma$ , which indicates that the variation is so small.

Figure 5: Phase modulation (typical example)



# LCOS-SLM X15213 series

## ■ High power handling capability

Although the X15213 series achieves versatility and high reliability, there is a concern that characteristics may change depending on the peak power and average power of the incident light when irradiated with high power laser light. When the peak power is high, 2 photon absorption occurs in the LC layer, which leads to characteristic changes and damage. When the average power is high, a characteristic change occurs due to heat generation. The water-cooled type and the sapphire type with improved heat dissipation efficiency are effective in suppressing this characteristic change caused by heat generation.

### ●Water-cooled type

When irradiating a laser with high average power, heat generation can be suppressed and power handling capability can be improved by using a water-cooled type equipped with a water-cooled heat sink. Particularly, the nice power handling capability of -03BL/-03BR enables to be used with high power lasers up to average 200 W at 1050 nm wavelength.

### ●Sapphire type

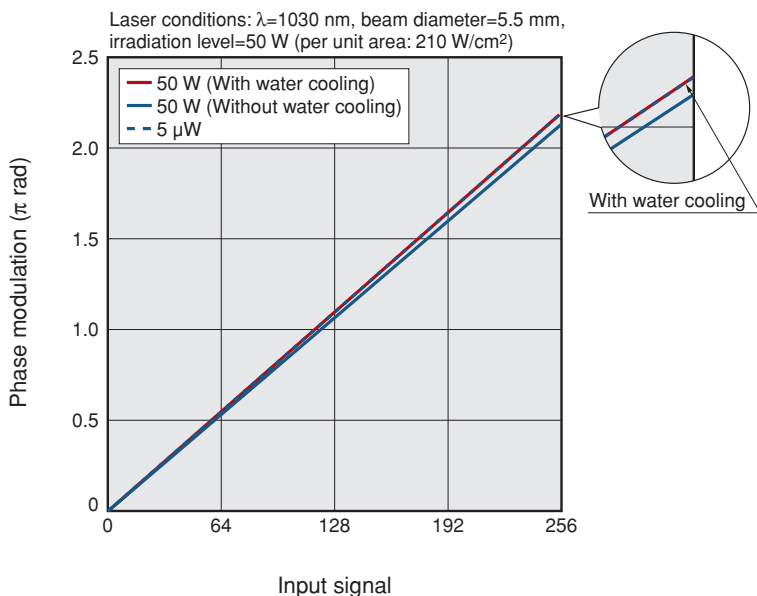
In addition to the water-cooled heat sink, the glass substrate is made of sapphire glass, which has approximately 30 times higher thermal conductivity than conventional materials. As a result, the heat dissipation efficiency has been improved. Furthermore, we have realized the power handling capability of over 700 W by enclosing high-thermal conductivity fillers inside LCOS-SLM packaging and optimizing the internal construction. It is possible to respond to high-power lasers required for metal processing.

Type	Type no.	Recommended average power
Aluminum mirror type	X15213-01/-07/-08	≤0.5 W *1
Dielectric mirror type	X15213-02/-03B/-05/-12/-13/-15/-16/-19	≤10 W
Water-cooled type	X15213-02L/-02R/-12L/-12R/ -15L/-15R/-16L/-16R/-19L/-19R	≤100 W
	X15213-03BL/-03BR	≤200 W *2
Sapphire type	X15213-03CL/-03CR	≥700 W *2

\*1 500 mW/cm<sup>2</sup> or less per unit area is recommended.

\*2 As it also depends on irradiation conditions, please contact us for details.

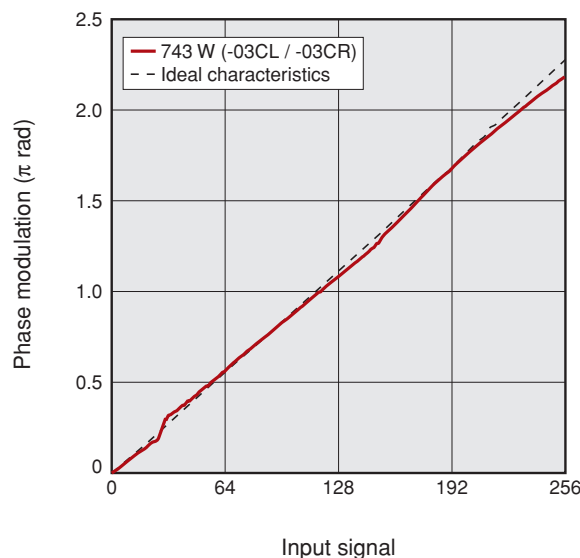
Figure 6: Laser irradiation test result



\* The data was acquired by the experiment with previous model. Successor model, -03BL and -03BR offer similar or better performance.

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Figure 7: Phase modulation characteristics of sapphire type



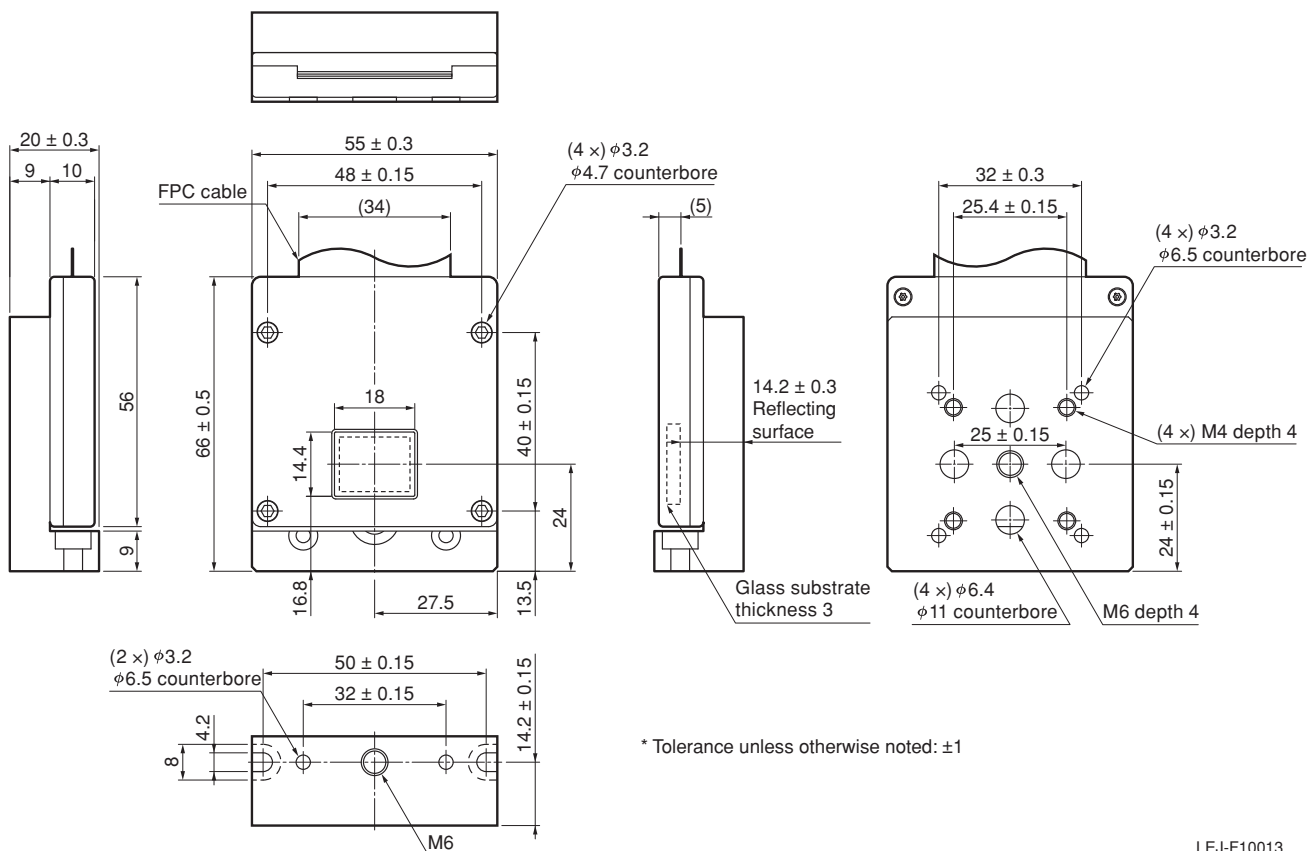
\* The phase modulation characteristics depend on water cooling conditions. Please contact us for details.

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# LCOS-SLM X15213 series

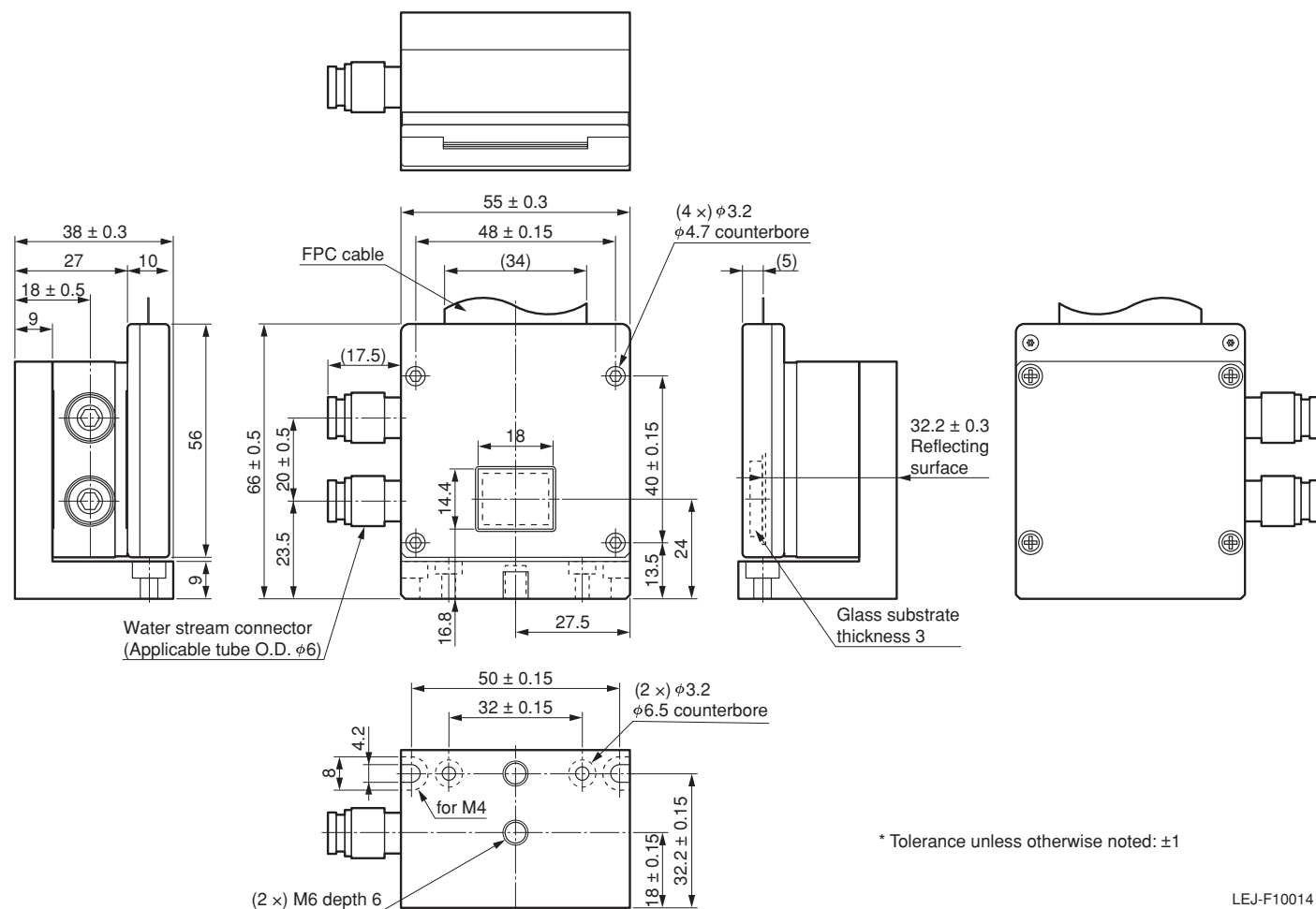
Figure 8: Dimensions (unit: mm)

●Head (X15213-01/-02/-03B/-05/-07/-08/-12/-13/-15/-16/-19)



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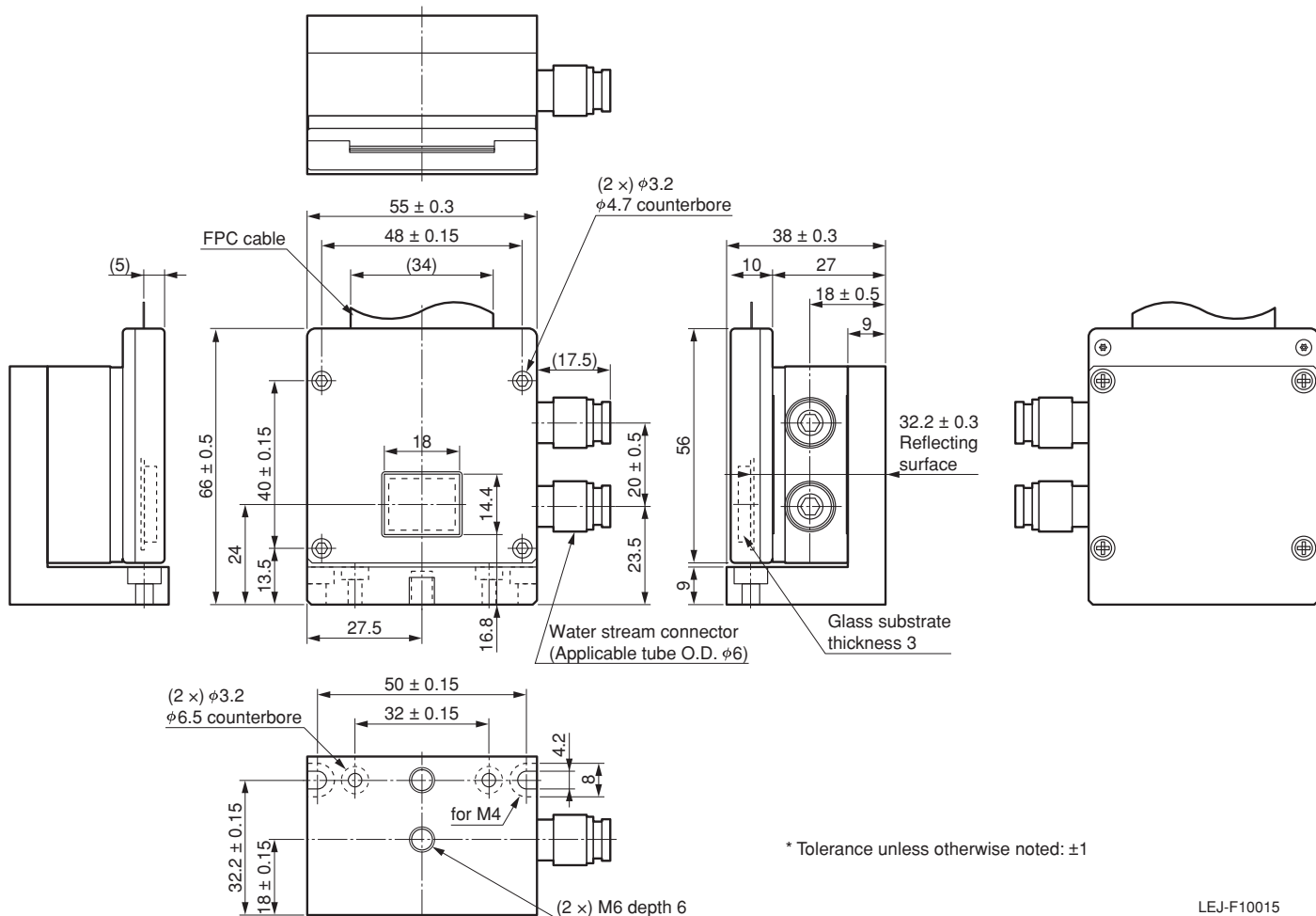
●Head (water-cooled type: X15213-02L/-03BL/-12L/-15L/-16L/-19L sapphire type: X15213-03CL)



LEJ-F10014

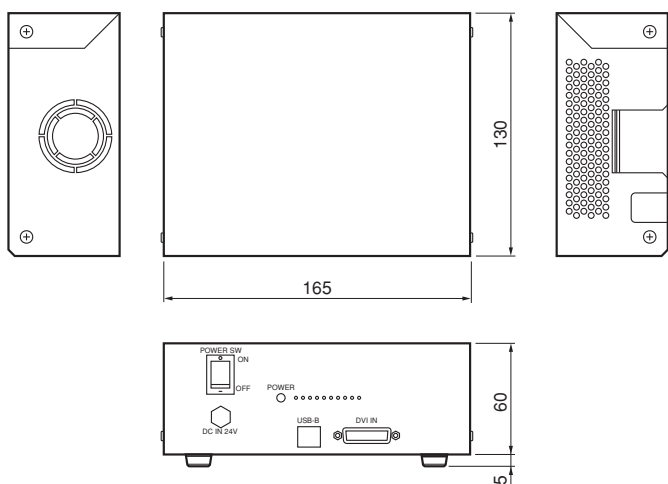
# LCOS-SLM X15213 series

●Head (water-cooled type: X15213-02R/-03BR/-12R/-15R/-16R/-19R sapphire type: X15213-03CR)



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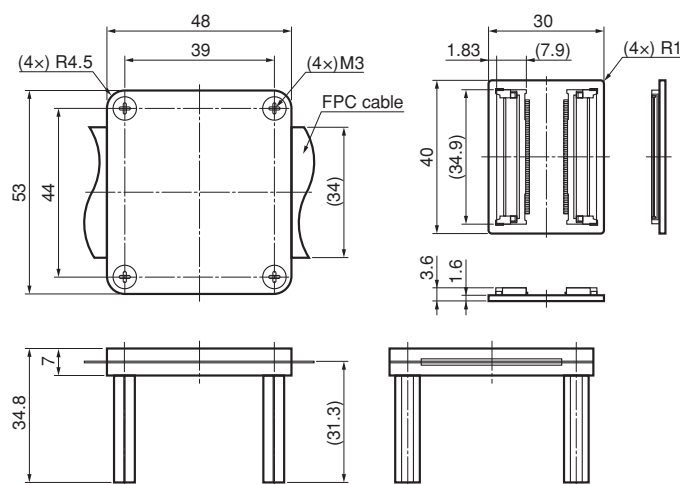
## ●Controller



\* Tolerance unless otherwise noted:  $\pm 1$

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## ●Connection board



\* Tolerance unless otherwise noted:  $\pm 1$

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The X15213 series does not include a PC. Prepare a PC by referring to the followings:

- OS that supports the provided software\*1 : Microsoft® Windows® 10
- The PC must have a DVI-D port or a DVI-D converter to connect the X15213 series to DVI.
- The provided software supports dual monitor control. The first monitor is for PC screen and the second one is for phase images on the X15213 series. In this case, the phase image displayed on the second monitor can be controlled by operation on the first monitor.
- When the X15213 series is connected to a PC via USB, the phase image can be displayed using the supplied software.

\*1: The provided software that comes with the X15213 series has generating functions such as for a computer generated hologram (CGH).

\* Microsoft, Windows are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.

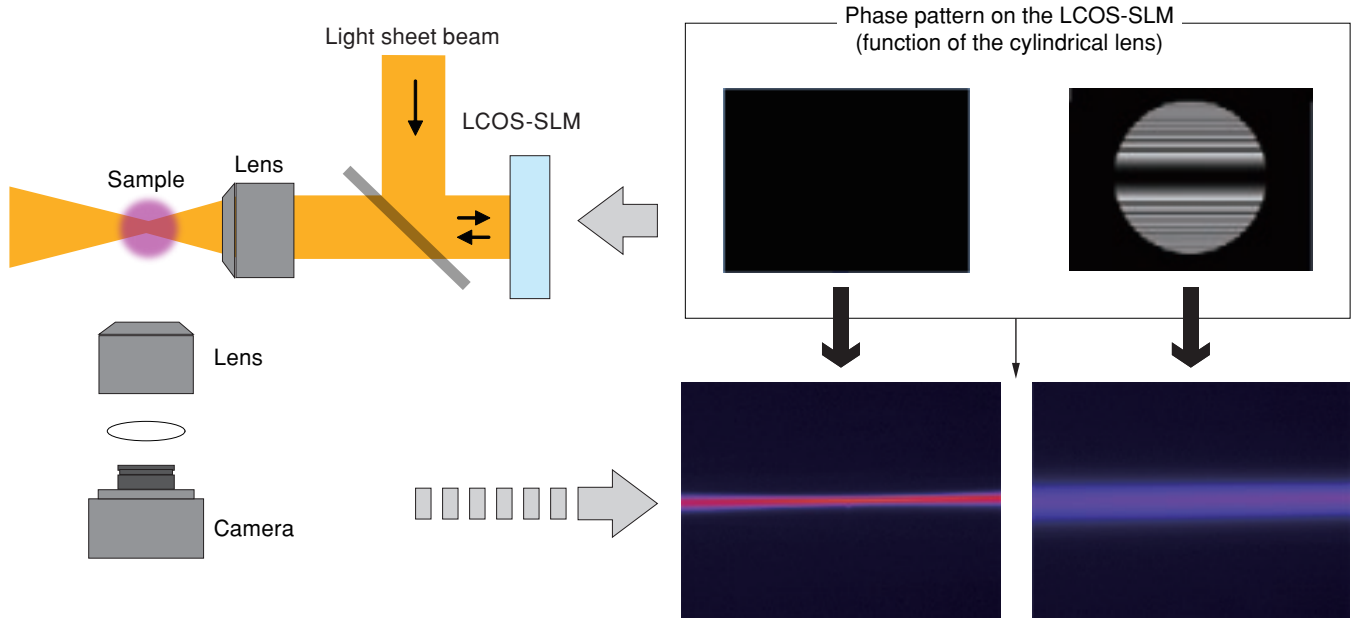


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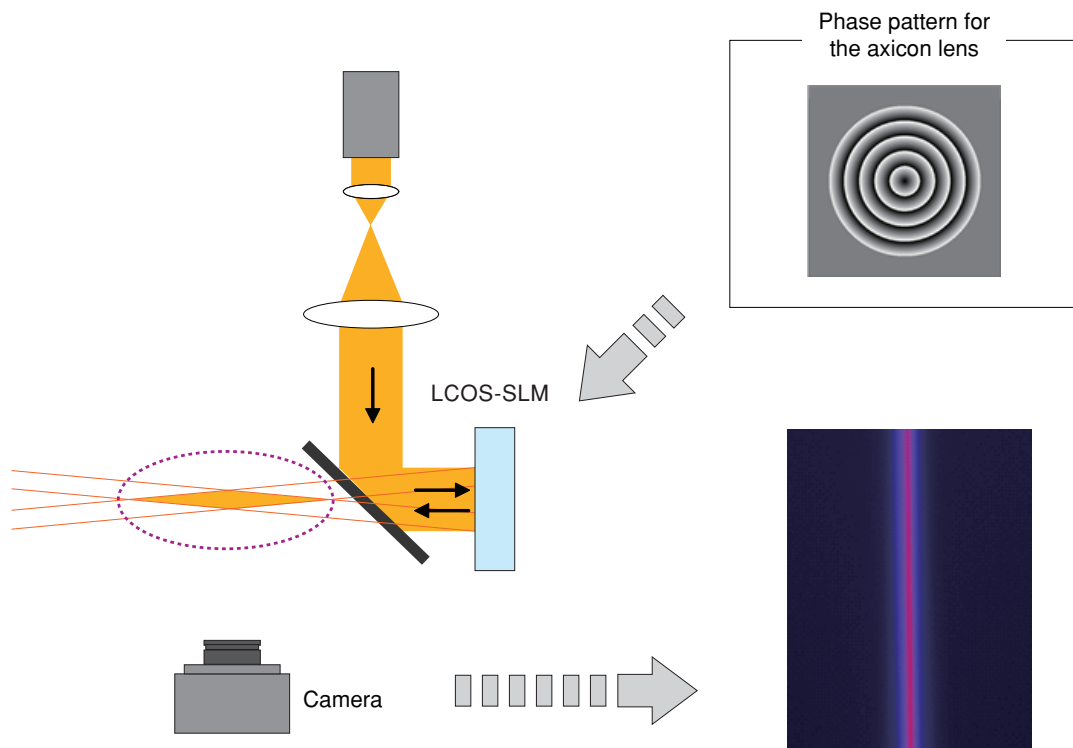
## Application example 1: Beam control (lens function, nondiffracting beam generation)

The LCOS-SLM can generate and control Bessel beams and other various beams based on phase images that have lens functionality. These beams are expected to be used in light sheet microscopy and other leading edge applications.

### Function of the cylindrical lens



### Nondiffracting beam generation



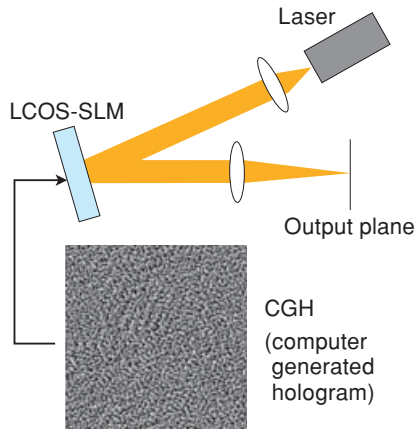
\* Related patents of application example 1  
US6710292, US7209279, US7527201, US8749463, US9415461, US9488831

# LCOS-SLM X15213 series

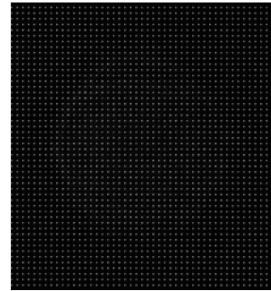
## Application example 2: Light beam pattern generation

This technology uses the LCOS-SLM to reproduce CGHs and generate arbitrary light patterns. Unlike the conventional intensity modulation system that shields light by masking to generate arbitrary light patterns, this technology features highly efficient pattern generation by distributing light using a CGH.

### Optical system



Clear CGH reproduced image (+1st order light)



50 x 50 point generation with 0th order suppressed



Text reproduction example (+1st order light)

\* Related patents of application example 2  
US6710292, US7209279, US7527201, US8749463

## Other related patents

US8576206, US9007286, US8553733, US7876405, US9250459, US9250458, US9223159

## Precautions

### Product-related precautions

<https://www.hamamatsu.com/all/en/support/disclaimer.html>

Information described in this material current as of May 2024. Specifications are subject to change without notice.

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