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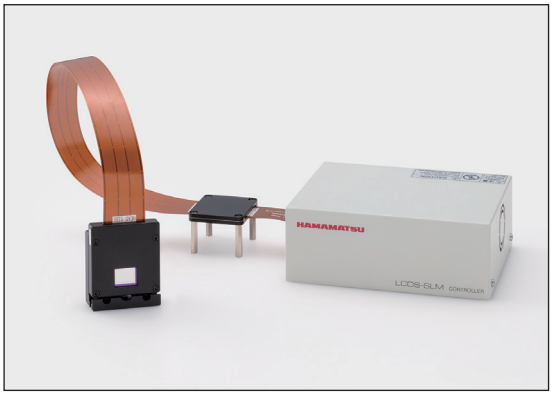
LCOS-SLM
X15213 series

■ 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

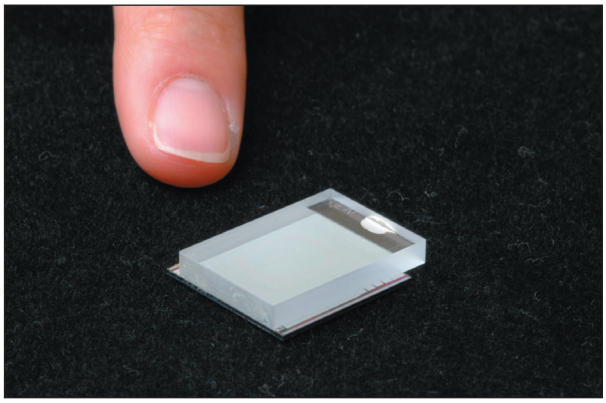
■ Applications

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

■ 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.
We also provide water-cooled types with a built-in water-cooled heatsink to improve power handling capability.

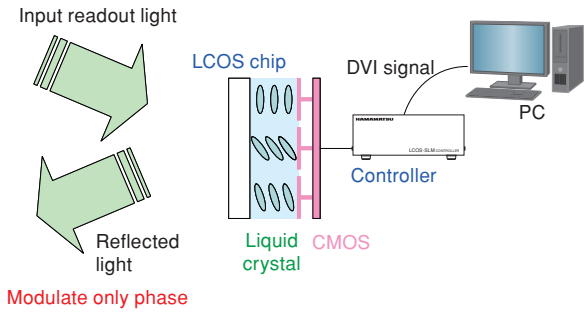
■ LCOS chip



■ 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



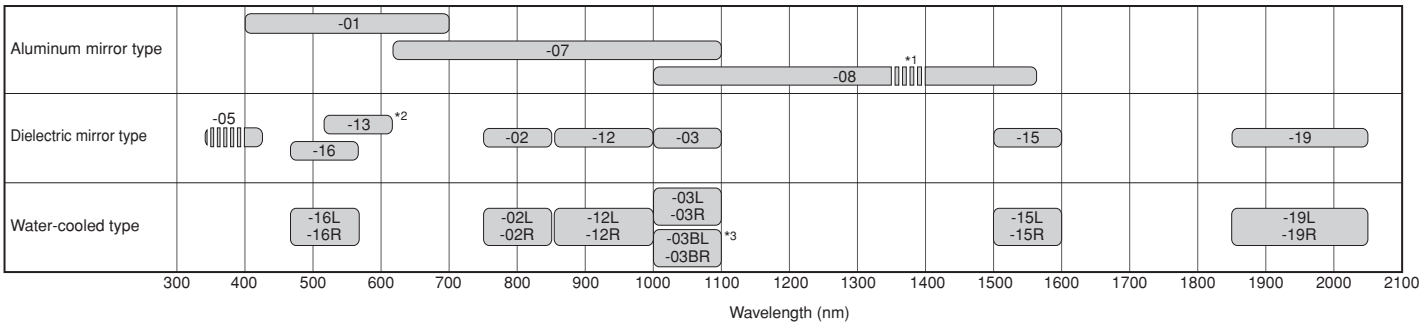
■ Supported wavelength range

There are 12 types in X15213 series, which cover different wavelengths of light sources.
All types have a glass substrate with an anti-reflection coating and a CMOS chip with a mirror.
They can be classified into aluminum mirror type and dielectric mirror type.

●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/-03/-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. This makes it possible to irradiate high power lasers.

●Water-cooled type (02L/-02R/-03L/-03R/-03BL/-03BR/-12L/-12R/-15L/-15R/-16L/-16R/-19L/-19R)
The dielectric multilayer mirror type head has a built-in water-cooled heat sink to suppress temperature rise due to laser irradiation and improve light resistance.



*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 -03BL/-03BR: As for the average laser power, their power handling capability is higher than the -03L/-03R.

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	150 (Water-cooled type: 550)	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	Digital video interface (DVI-D) / 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.
The characteristics of this product depend on temperature. Using this product at an ambient temperature of about 25 °C is recommended.
When there is a temperature difference between a product and the surrounding area in high humidity environment, dew condensation may occur on the product surface. Dew condensation on the product may cause deterioration in characteristics and reliability.

* 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 characterisitics

Parameter	-01	-02 /-02L/-02R	-03 /-03L/-03R /-03BL/-03BR	-05	-07	-08	Unit
Readout light wavelength	400 to 700	800 ± 50	1050 ± 50	410 ± 10	620 to 1100	1000 to 1550	nm
Light utilization efficiency (Typ.)	76 (633 nm)	97 (785 nm)	97 (1064 nm)	97 (405 nm)	80 (1064 nm)	86 (1550 nm)	%
Rise time *1 (Typ.)	5 (633 nm)	33 (785 nm)	27 (1064 nm)	7 (405 nm)	9 (1064 nm)	13 (1550 nm)	ms
Fall time *1 (Typ.)	21 (633 nm)	85 (785 nm)	83 (1064 nm)	17 (405 nm)	73 (1064 nm)	145 (1550 nm)	ms

Parameter	-12 /-12L/-12R	-13	-15 /-15L/-15R	-16 /-16L/-16R	-19 /-19L/-19R	Unit
Readout light wavelength	850 to 1000	530 to 635	1550 ± 50	510 ± 50	1850 to 2050	nm
Light utilization efficiency (Typ.)	97 (940 nm)	97 (532 nm)	97 (1550 nm)	97 (532 nm)	97 (1950 nm) *2	%
Rise time *1 (Typ.)	38 (940 nm)	10 (532 nm)	26 (1550 nm)	11 (532 nm)	30 (1950 nm)	ms
Fall time *1 (Typ.)	109 (940 nm)	21 (532 nm)	135 (1550 nm)	33 (532 nm)	155 (1950 nm)	ms

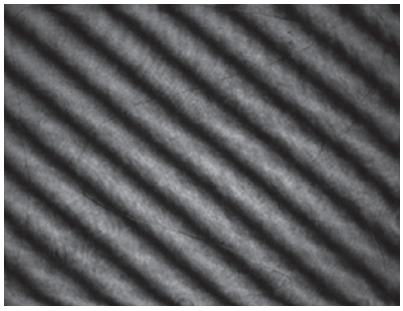
*1 Time required to change from 10 % to 90 % for 2π modulation.
*2 Design value
* Figures in parentheses indicate the wavelengths of the lasers used to measure light utilization efficiency, rise time, and fall time.

■ Operating characteristics

●High precision phase modulation

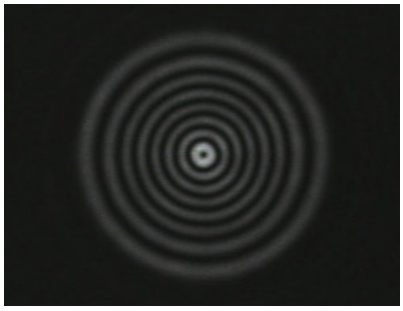
The X15213 series has high precision phase control and high diffraction efficiency, and is very suitable for holographic applications. Figure 2 (a) is a interferometer picture of the output wavefront with a flatness calibration. Figure 2 (b) is an example of a 1st order diffraction image obtained by 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

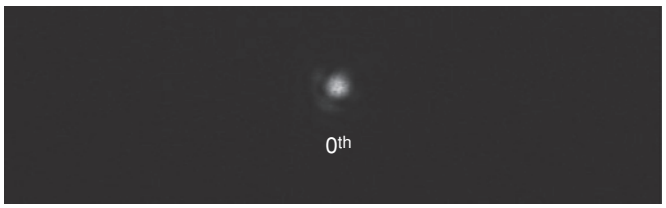


(c) LG beam

●High diffraction efficiency

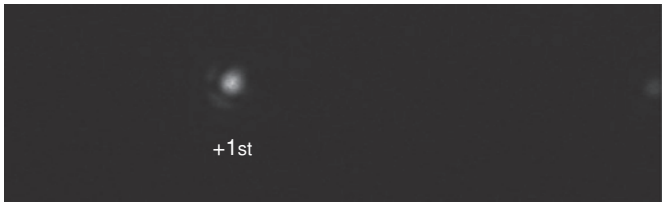
The X15213 series is a pure phase SLM with high precision phase control; therefore, it has high diffraction efficiency close to the theoretical values. Figure 3 shows images of diffracted spots when a multi-level phase grating is displayed on the X15213 series, and Figure 4 shows typical diffraction 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)



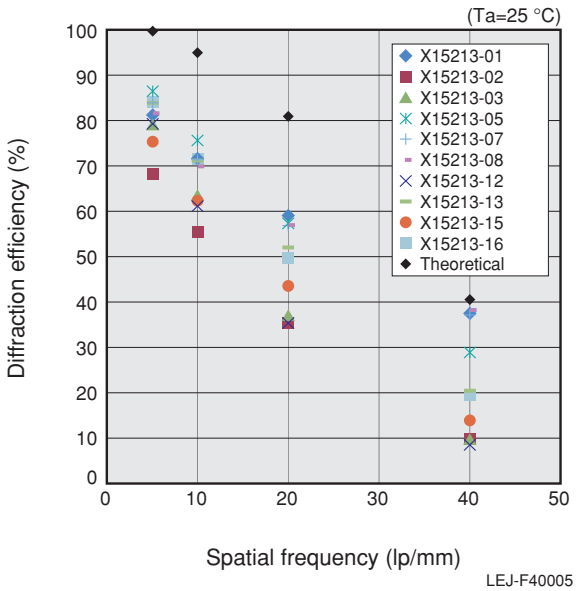
(a) No pattern

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



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

Figure 4: Diffraction efficiency (typical example)



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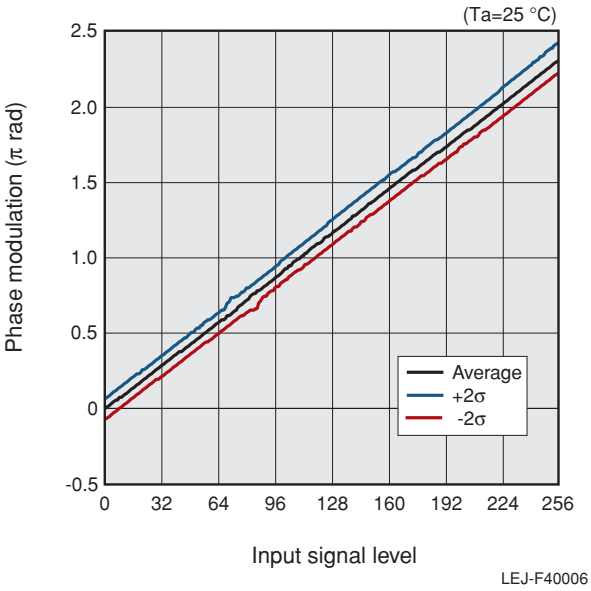
●High light utilization efficiency

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/-03/-05/-12/-13/-15/-16/-19 types 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 2π 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 2π 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 +/- 2σ, which indicates that the variation is so small.

Figure 5: Phase modulation (typical example)



■ 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.

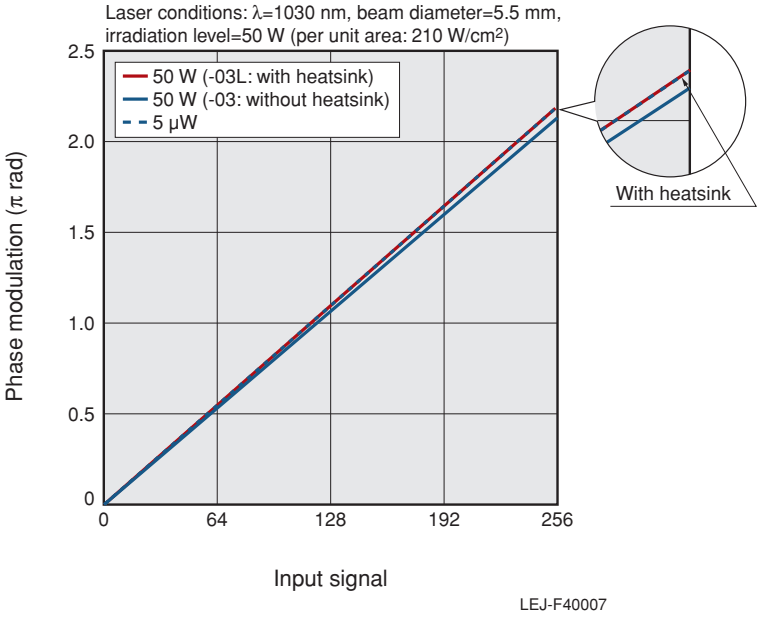
●Water-cooled type

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. In addition, the -03 type used for wavelength range 1050 nm ±50 nm offers a lineup of -03BL/-03BR with improved power handling capability compared to the conventional -03L/-03R by reviewing the circuit-design of the pixel electrode. Recommended beam diameter ($1/e^2$) is 8mm or more.

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

*1 500 mW/cm^2 or less per unit area is recommended.
*2 As it also depends on specifications such as wavelength, pulse width, and repetition frequency, please contact us for details.

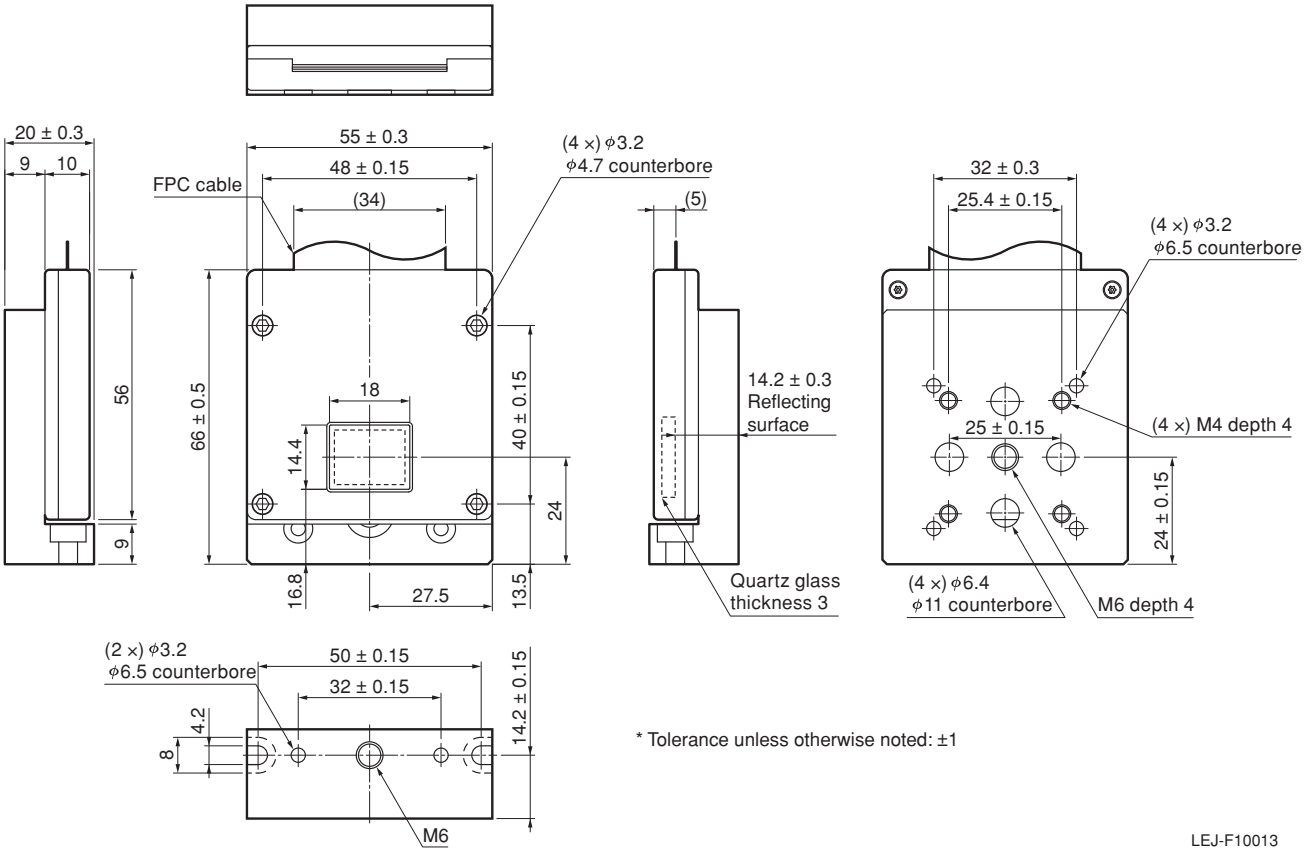
Figure 6: Laser irradiation test result



* Phase modulation does not change even when exposed to high power laser.

Figure 7: Dimensions (unit: mm)

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



* Tolerance unless otherwise noted: ±1

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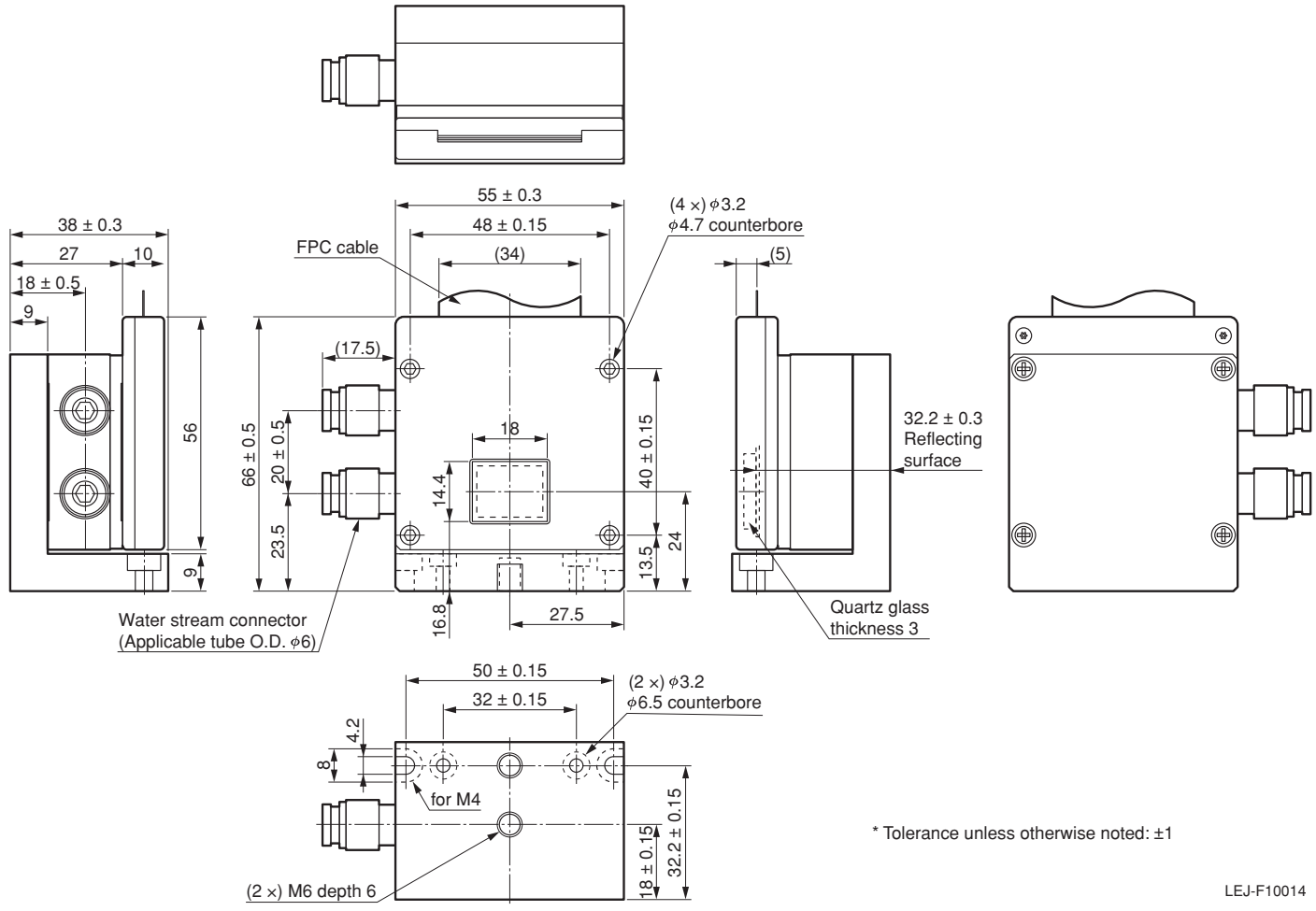
●Head (water-cooled type: X15213-02L/-03L/-03BL/-12L/-15L/-16L/-19L)



* Tolerance unless otherwise noted: ±1

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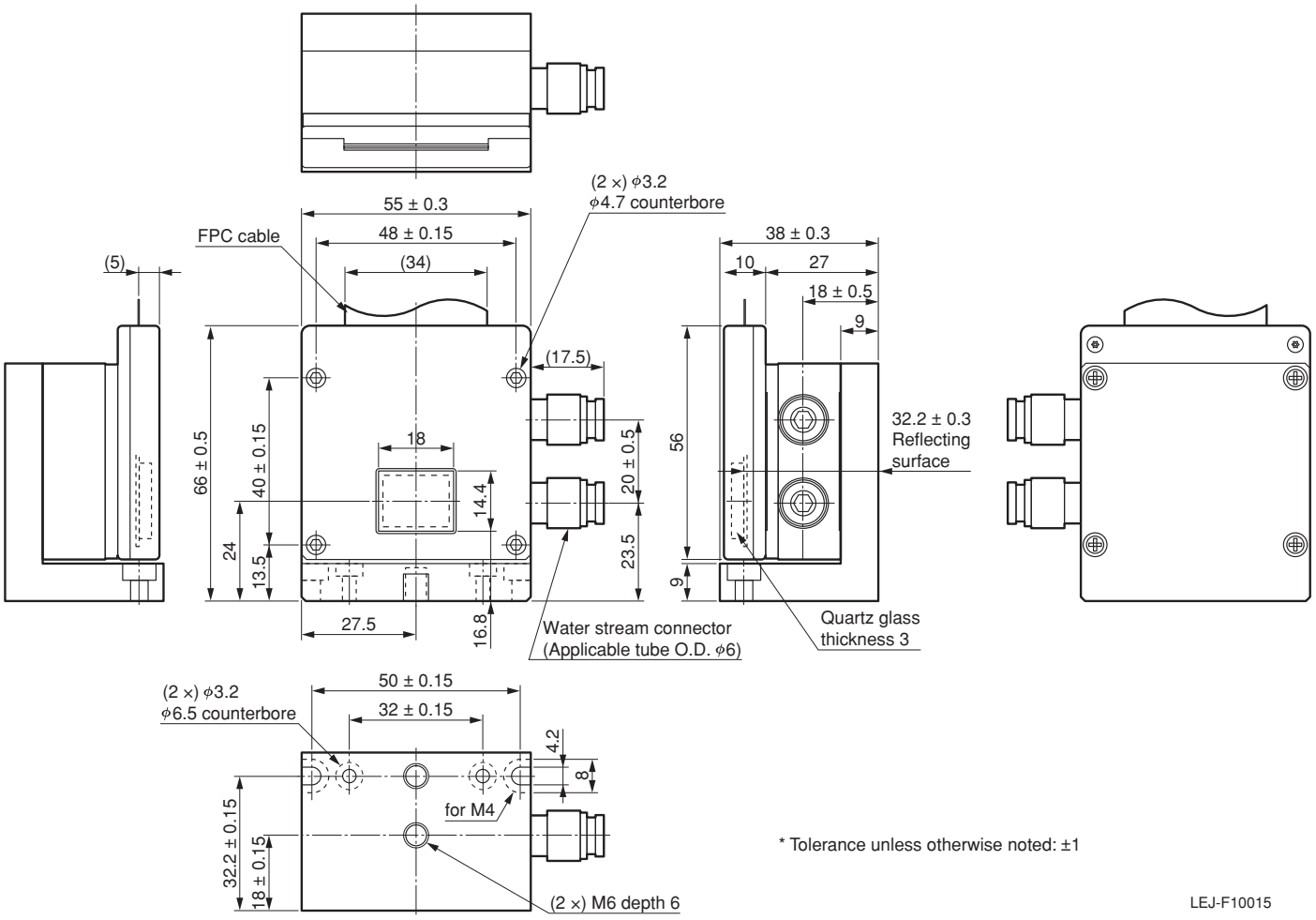
LCOS-SLM X15213 series

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



* Tolerance unless otherwise noted: ±1

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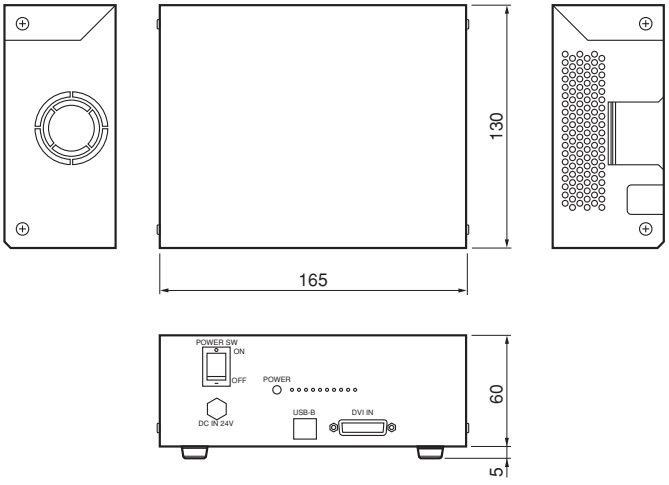
●Controller



* Tolerance unless otherwise noted: ±1

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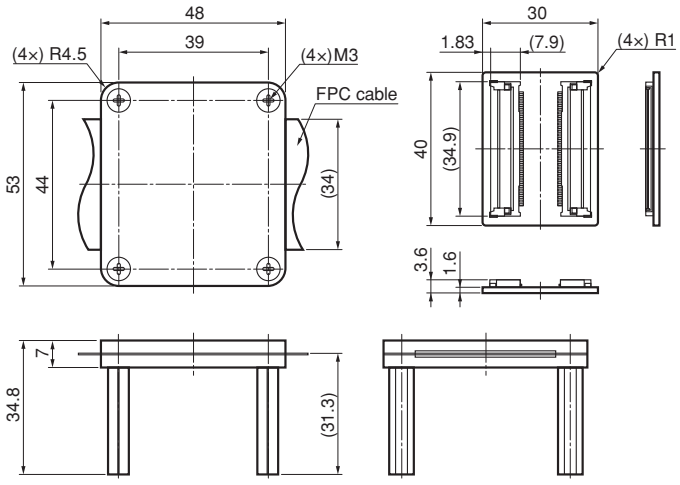
●Connection board



* Tolerance unless otherwise noted: ±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.

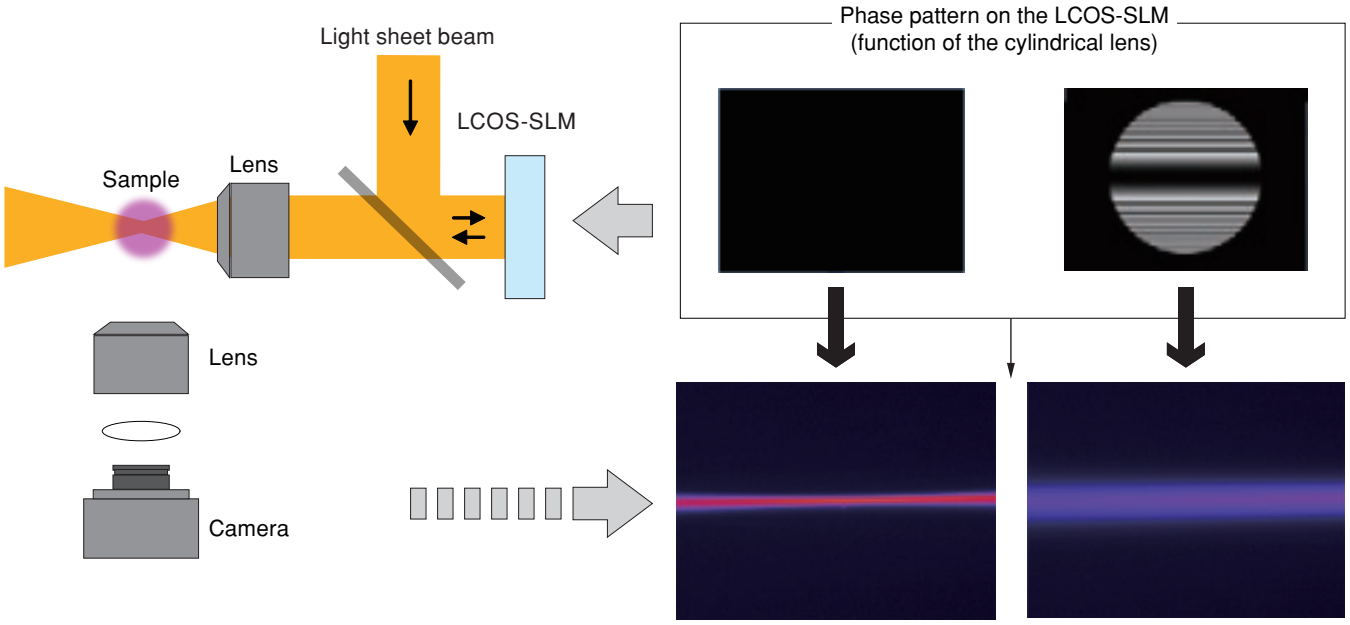
*1: The provided software that comes with the X15213 series has generating functions such as for a computer generated hologram (CGH).

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

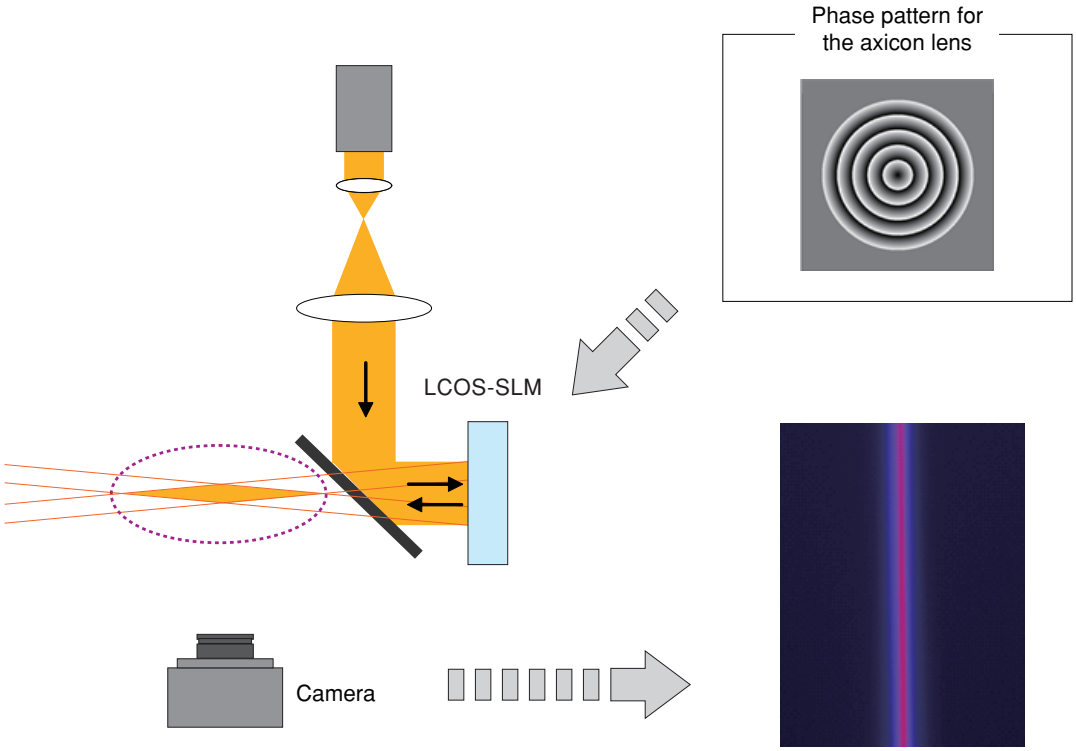
■ Application example 1: Beam control (lens function, nondiffracting beam generation)

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

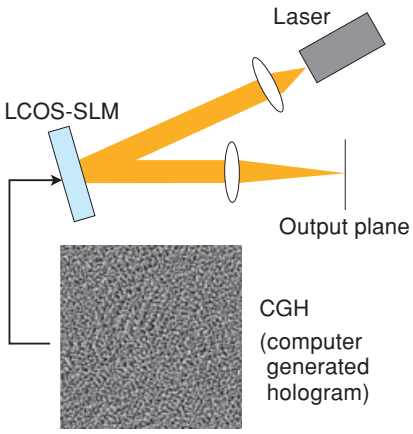


* Related patents of application example 1
US6710292, US7209279, US7527201, US8749463, US9415461, US9488831

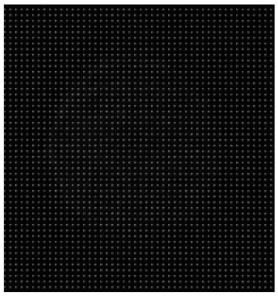
■ Application example 2: Light beam pattern generation

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 × 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 June 2022. Specifications are subject to change without notice.

HAMAMATSU PHOTONICS K.K. **www.hamamatsu.com**

Laser Promotion Division, Business Promotion G.
1-8-3, Shinmiyakoda, Kita-ku, Hamamatsu City, Shizuoka, 431-2103, Japan, Telephone: (81)53-484-1301, Fax: (81)53-484-1302, E-mail: sales-laser@lpd.hpk.co.jp

U.S.A.: HAMAMATSU CORPORATION: 360 Foothill Road, Bridgewater, NJ 08807, U.S.A., Telephone: (1)908-231-0960, Fax: (1)908-231-1218 E-mail: usa@hamamatsu.com
Germany: HAMAMATSU PHOTONICS DEUTSCHLAND GMBH.: Arzbergerstr. 10, 82211 Herrsching am Ammersee, Germany, Telephone: (49)8152-375-0, Fax: (49)8152-265-8 E-mail: info@hamamatsu.de
France: HAMAMATSU PHOTONICS FRANCE S.A.R.L.: 19, Rue du Saule Trapu, Parc du Moulin de Massy, 91882 Massy Cedex, France, Telephone: (33)1 69 53 71 00, Fax: (33)1 69 53 71 10 E-mail: infos@hamamatsu.fr
United Kingdom: HAMAMATSU PHOTONICS UK LIMITED: 2 Howard Court,10 Tewin Road, Welwyn Garden City, Hertfordshire AL7 1BW, UK, Telephone: (44)1707-294888, Fax: (44)1707-325777 E-mail: info@hamamatsu.co.uk
North Europe: HAMAMATSU PHOTONICS NORDEN AB: Torshamnsgatan 35 16440 Kista, Sweden, Telephone: (46)8-509 031 00, Fax: (46)8-509 031 01 E-mail: info@hamamatsu.se
Italy: HAMAMATSU PHOTONICS ITALIA S.R.L.: Strada della Moia, 1 int. 6, 20044 Arese (Milano), Italy, Telephone: (39)02-93 58 17 33, Fax: (39)02-93 58 17 41 E-mail: info@hamamatsu.it
China: HAMAMATSU PHOTONICS (CHINA) CO., LTD.: 1201 Tower B, Jiaming Center, 27 Dongsanhuan Beilu, Chaoyang District, 100020 Beijing, P.R. China, Telephone: (86)10-6586-6006, Fax: (86)10-6586-2866 E-mail: hpc@hamamatsu.com.cn
Taiwan: HAMAMATSU PHOTONICS TAIWAN CO., LTD.: 8F-3, No.158, Section 2, Gongdao 5th Road, East District, Hsinchu, 300, Taiwan R.O.C. Telephone: (886)3-659-0080, Fax: (886)3-659-0081 E-mail: info@hamamatsu.com.tw

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