HAMAMATSU
PHOTON IS OUR BUSINESS

LCOS-SLM (Liquid Crystal on Silicon - Spatial Light Modulator)

X10468/X13267/X13138 series

Control your light !
Shape your beam !
Improve your image !

The X10468/X13267/X13138 series devices are a reflective type of pure phase Spatial Light Modulators (SLMs), based on Liquid Crystal on Silicon (LCOS) technology in which liquid crystal (LC) is controlled by a direct and accurate voltage, and can modulate a wavefront of light beam. The LCOS-SLMs are carefully designed to achieve high light utilization efficiency from various points of view, such as reflectivity, aperture ratio and diffraction noise due to the pixel structure.
The X10468/X13267/X13138 series can be controlled via a PC using the Digital Video Interface (DVI), which is a standard interface for PC displays. The distortions in the LCOS chip, such as wavefront distortion and non-linear response of the LC, are efficiently compensated by the controller.
Easy PC control, precise and linear phase modulation characteristics can be accomplished with the X10468/X13267/X13138 series. They can also provide high diffraction efficiency and high light utilization efficiency. We also provide water cooled types with a built-in water-cooled heat sink for improved power handling capability.

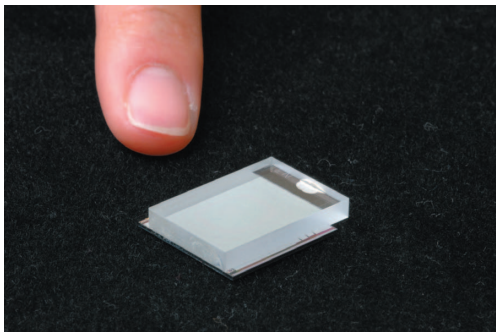
Features

- **Pure, linear and precise phase control**
- **High light utilization efficiency**
- **High diffraction efficiency**
- **High power handling capability**
- **Ease of use (DVI compatible)**
- **Reflective type**

Applications

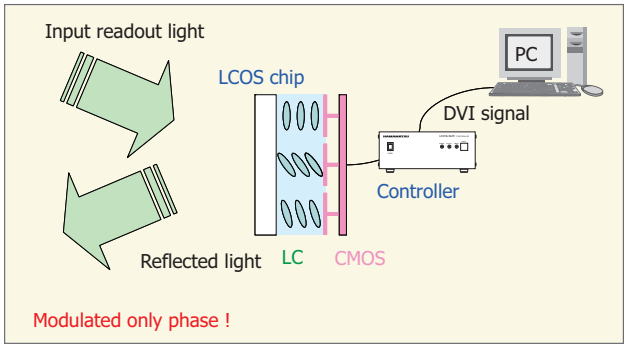
- **Laser material processing**
- **Optical manipulation**
- **Wavefront correction**
- **Pulse shaping**
- **Optical testing**

LCOS chip inside the head



Principle of modulation

The LCOS chip has a parallel-aligned nematic liquid crystal layer to modulate light. It only changes the phase of light without any change of intensity and rotation of polarization state. Phase modulation is changed according to the alignment of the LC. The LC alignment is controlled, pixel by pixel, using a CMOS backplane and a DVI signal via a PC.



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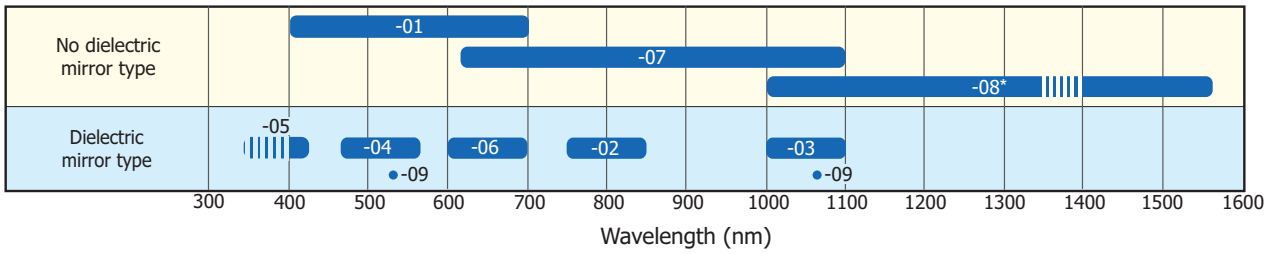
Selection guide

Each of the X10468/X13267/X13138 series consists of nine types. Types -01, -07, and -08 are those without a dielectric mirror. The device reflectance is inferior, but their diffraction efficiency is higher and can be used in a wide spectral range. Types -02, -03, -04, -05, and -06 types contain a dielectric mirror suitable for 800-nm band femtolaser, 1064-nm band YAG laser, 532-nm band YAG second harmonic, 405-nm band LD, and 633-nm band He-Ne laser, respectively,while type -09 has a dielectric mirror suitable for both 1064-nm band YAG laser and 532-nm band YAG second harmonic. They provide high reflectance. Figure 1 shows the wavelength ranges that each type covers. Note that the wavelength range below 400 nm is the UV region and may damage the X10468-05. For details on using it at 400 nm or less, contact us. Water cooled types have WL or WR (where WL and WR indicate the water stream connector positions left and right, respectively) appended to the number -03 or -04, which indicates the wavelength range.

[Figure 1] Spectral response



* For the wavelength band between 1350 and 1400 nm on the -08 type, the reflectance degrades about 5% due to the absorption by the glass substrate.

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Absolute maximum ratings

Parameter	Operating temperature (°C)	Storage temperature (°C)
X10468 series	+10 to +40*1	-20 to +55*1
X13267 series		
X13138 series		

*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.

Note: 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.

Structure

Head

Parameter	Number of pixels (pixels)	Pixel pitch (µm)	Effective area size (mm)	Fill factor (%)	Weight (g)
X10468 series	792 × 600	20	15.8 × 12	98	350 (Water cooled type: 650)
X13267 series	792 × 600	12.5	9.9 × 7.5	96	
X13138 series	1272 × 1024		15.9 × 12.8		

■ Controller

Parameter	Supply voltage AC (V)	Power supply frequency (Hz)	Weight		Input signal	DVI signal format (pixels)	Input signal level (levels)	DVI frame rate		Power consumption (VA)
			Main unit (g)	Including cables (g)				Typ. (Hz)	Max. (Hz)	
X10468 series	100 to 230	50/60	3300	4200	Digital Video Interface (DVI-D)	800 × 600	256	60	120	50
X13267 series										
X13138 series						1280 × 1024			-	

Electrical and optical characteristics

Parameter	Readout light wavelength (nm)	Light utilization efficiency typ. (%)	Rise time*2 (ms)	Fall time*2 (ms)
X10468-01	400 to 700	79 (633 nm)	5 (633 nm)	25 (633 nm)
X10468-02	800 ± 50	97 (785 nm)	30 (785 nm)	80 (785 nm)
X10468-03/-03WL/-03WR	1050 ± 50	97 (1064 nm)	20 (1064 nm)	80 (1064 nm)
X10468-04/-04WL/-04WR	510 ± 50	97 (532 nm)	10 (532 nm)	25 (532 nm)
X10468-05	410 ± 10	97 (405 nm)	10 (405 nm)	20 (405 nm)
X10468-06	650 ± 50	97 (633 nm)	10 (633 nm)	30 (633 nm)
X10468-07	620 to 1100	82 (1064 nm)	10 (1064 nm)	80 (1064 nm)
X10468-08	1000 to 1550	82 (1550 nm)	30 (1550 nm)	140 (1550 nm)
X10468-09	532 ± 1	96 (532 nm)	20	35
	1064 ± 5	97 (1064 nm)	25	80
X13267-01	400 to 700	76 (633 nm)	5 (633 nm)	25 (633 nm)
X13267-02	800 ± 50	97 (785 nm)	30 (785 nm)	80 (785 nm)
X13267-03/-03WL/-03WR	1050 ± 50	97 (1064 nm)	25 (1064 nm)	80 (1064 nm)
X13267-04/-04WL/-04WR	510 ± 50	97 (532 nm)	10 (532 nm)	25 (532 nm)
X13267-05	410 ± 10	97 (405 nm)	10 (405 nm)	20 (405 nm)
X13267-06	650 ± 50	97 (633 nm)	10 (633 nm)	30 (633 nm)
X13267-07	620 to 1100	80 (1064 nm)	10 (1064 nm)	80 (1064 nm)
X13267-08	1000 to 1550	80 (1550 nm)	30 (1550 nm)	140 (1550 nm)
X13267-09	532 ± 1	96 (532 nm)	15	35
	1064 ± 5	97 (1064 nm)	20	80
X13138-01	400 to 700	76 (633 nm)	5 (633 nm)	25 (633 nm)
X13138-02	800 ± 50	97 (785 nm)	30 (785 nm)	80 (785 nm)
X13138-03/-03WL/-03WR	1050 ± 50	97 (1064 nm)	25 (1064 nm)	80 (1064 nm)
X13138-04/-04WL/-04WR	510 ± 50	97 (532 nm)	10 (532 nm)	25 (532 nm)
X13138-05	410 ± 10	97 (405 nm)	10 (405 nm)	20 (405 nm)
X13138-06	650 ± 50	97 (633 nm)	10 (633 nm)	30 (633 nm)
X13138-07	620 to 1100	80 (1064 nm)	10 (1064 nm)	80 (1064 nm)
X13138-08	1000 to 1550	80 (1550 nm)	30 (1550 nm)	140 (1550 nm)
X13138-09	532 ± 1	96 (532 nm)	15	35
	1064 ± 5	97 (1064 nm)	20	80

*2: Time required to change from 10% to 90% for 2π modulation (typical value)

Operating characteristics

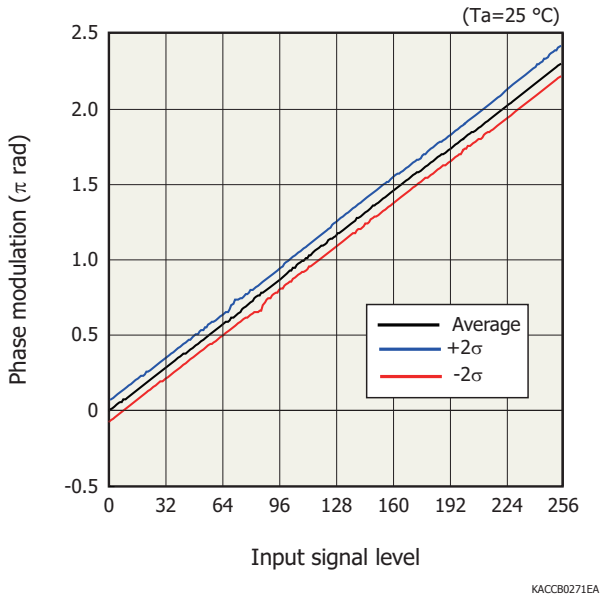
Light utilization efficiency

The X10468/X13267/X13138 series have high light utilization efficiency, which is defined a ratio of the 0th order diffraction light level to the input light level. The high light utilization efficiency mainly depends on reflectivity, 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%. The -02/-03/-04/-05/-06/-09 types have a dielectric mirror which has high reflectivity. Therefore, these types have very high light utilization efficiency. The -01/-07/-08 types have relatively low light utilization efficiency compared to the ones with the dielectric mirror but have wide spectral response characteristics.

Phase modulation

The X10468/X13267/X13138 series can achieve phase modulation of more than 2 π radians over the 400-1550 nm readout wavelength range. The X10468/X13267/X13138 series comes pre-calibrated from the factory for a specified wavelength range to have more than 2 π radians of phase modulation and its linear characteristics. Figure 2 shows typical phase modulation characteristics. A phase shift of 2 π radians or more and a linear phase response are achieved. The phase modulation curves for 95% pixels lies within +/- 2 σ.

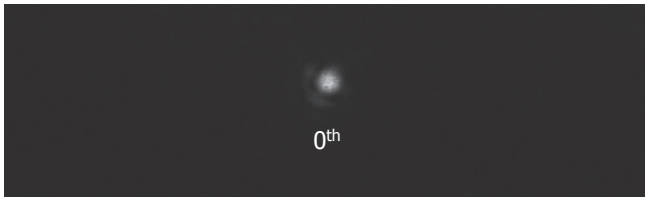
[Figure 2] Phase modulation (typical example)



Diffraction efficiency

The X10468/X13267/X13138 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 formed in the X10468 series and Figure 4 shows typical diffraction efficiency characteristics. Here, the diffraction efficiency is defined I_1/I_0, I_1 is 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)



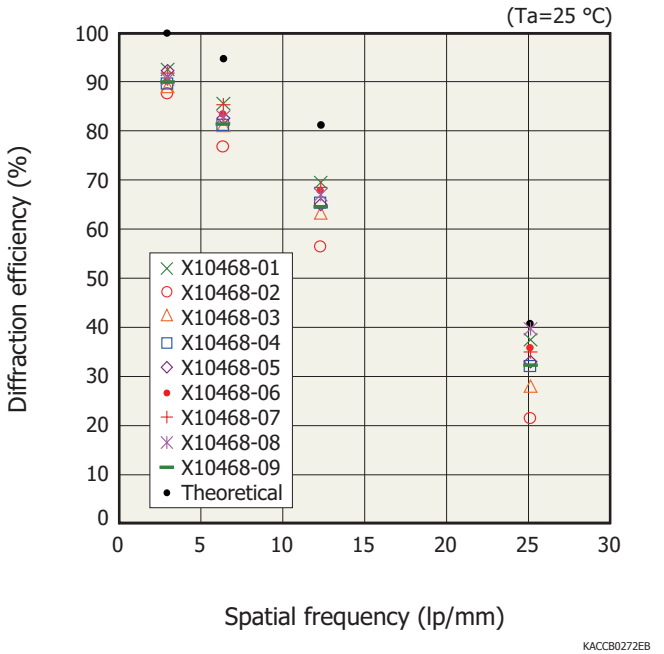
(a) No pattern

(b) 2-level grating (25 lp/mm)

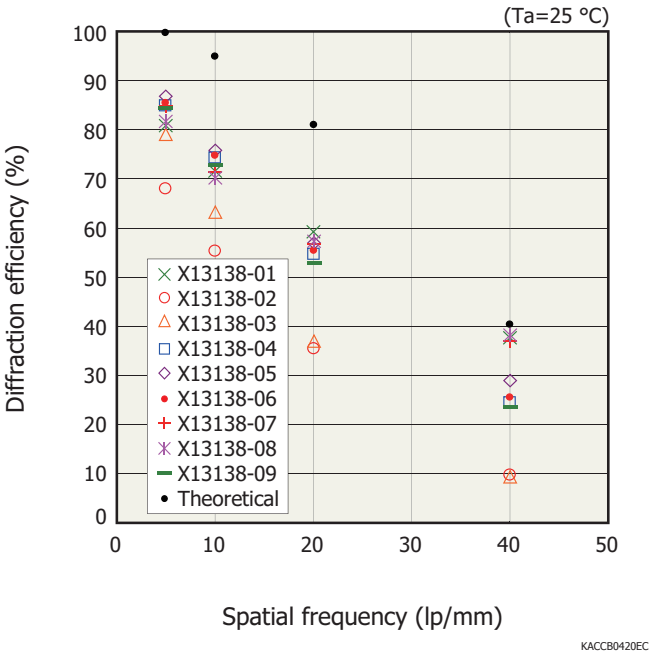
(c) 4-level grating (12.5 lp/mm)

[Figure 4] Diffraction efficiency (typical example)

X10468 series



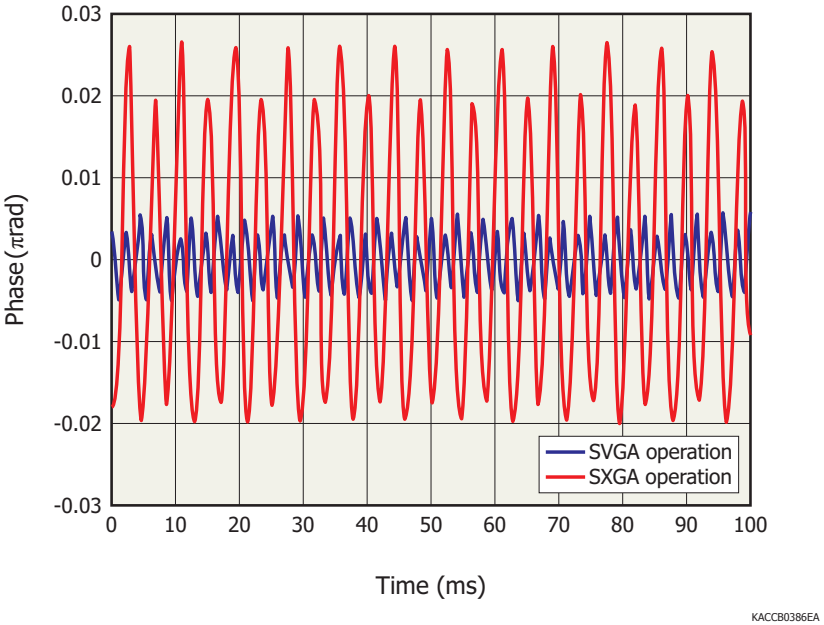
X13267/X13138 series



Phase fluctuation

As the LCOS-SLM is driven by AC power, the output light will fluctuate according to the drive frequency even when a uniform pattern is displayed over the entire surface. Figure 5 shows an example of the phase fluctuation for the -04 types. The drive frequency is 120 Hz for SXGA operation (X13138-04) and 240 Hz for SVGA operation (X10468/X13267-04). In SXGA operation, which operates at low frequency, the phase fluctuation is about four times greater than that in SVGA operation.

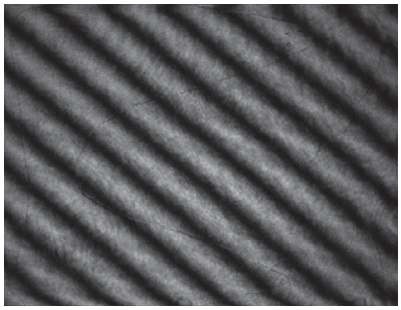
[Figure 5] Phase fluctuation (typical example)



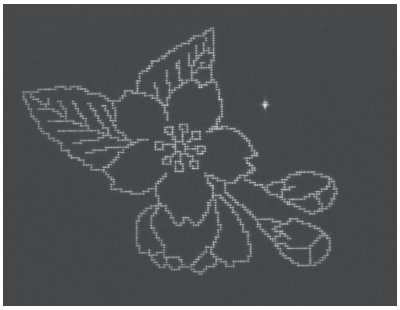
Output image examples

The X10468/X13267/X13138 series has high precision phase control and high diffraction efficiency, and is very suitable for holographic applications. Figure 6 (a) is a interferometer picture of the output wavefront with a flatness calibration. The image in Figure 6 (b) was reconstructed as the 1st diffraction order of the phase hologram through the Fourier transform optics. Figure 6 (c) shows a clear Laguerre Gaussian (LG) beam of (0, 1) order.

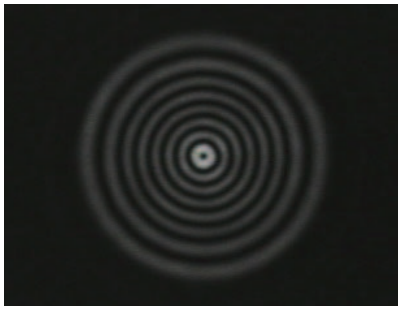
[Figure 6] Output image examples



(a) Interferogram of output wavefront with calibration
800 × 600 pixels
RMS: 0.025 λ (λ=532 nm)



(b) Reconstructed image of CGH

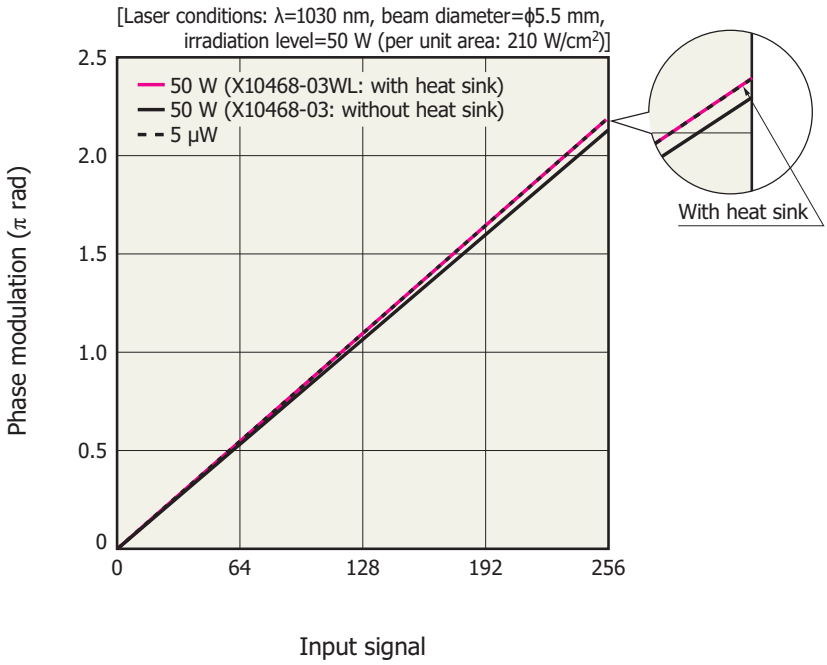


(c) LG beam

Light resistance

The LCOS-SLM features versatility and high reliability, but exposure to high power laser light increases the temperature and may cause characteristic degradation or damage. Water cooled types (-03WL, -03WR, -04WL, -04WR) have built-in cooling heat sink in the head section to improve the light resistance by suppressing temperature increases caused by laser irradiation.

[Figure 7] Laser irradiation test result



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

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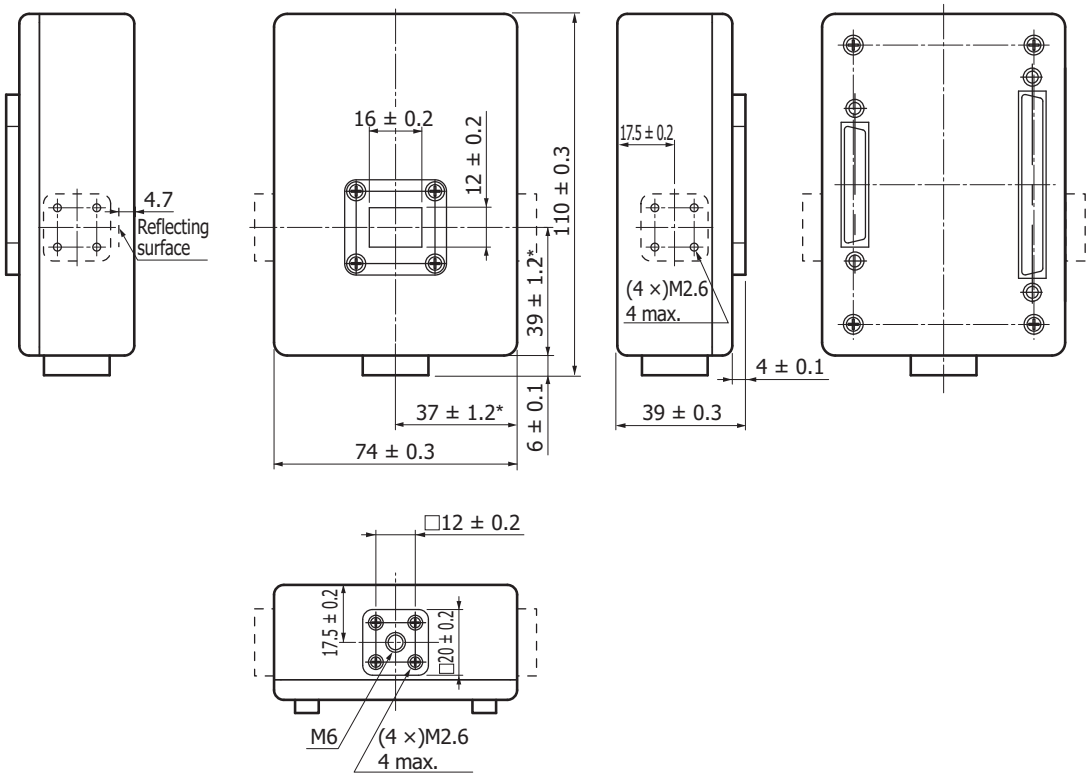
Dimensional outlines (unit: mm)

Head

-01 to -09



* Although the center of the LCOS effective area may deviate due to production tolerance, the aperture and the LCOS effective area are aligned.

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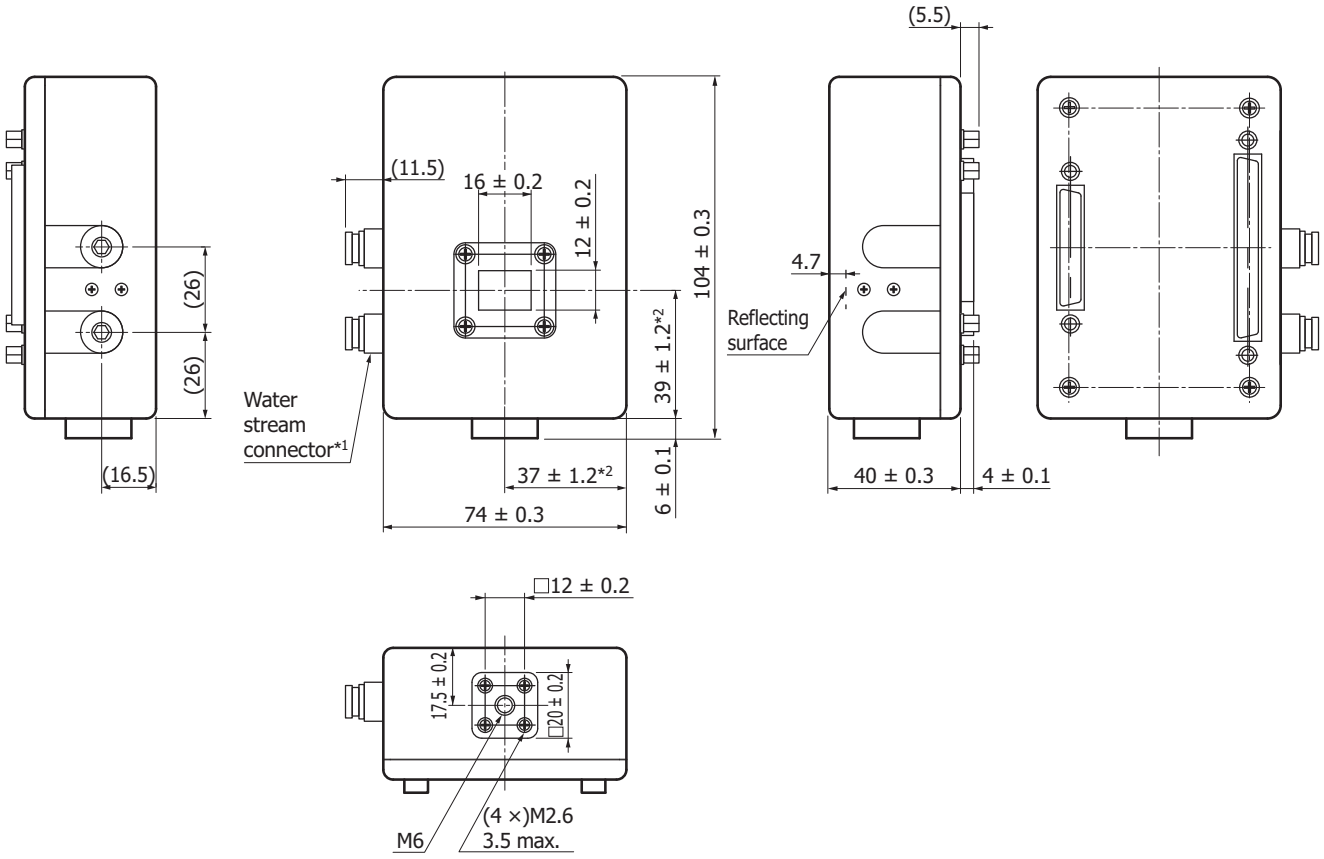
■ -03WL, -04WL



*1: KQB2S06-01S SMC, compliant tube outer diameter: ϕ6
*2: Although the center of the LCOS effective area may deviate due to production tolerance, the aperture and the LCOS effective area are aligned.

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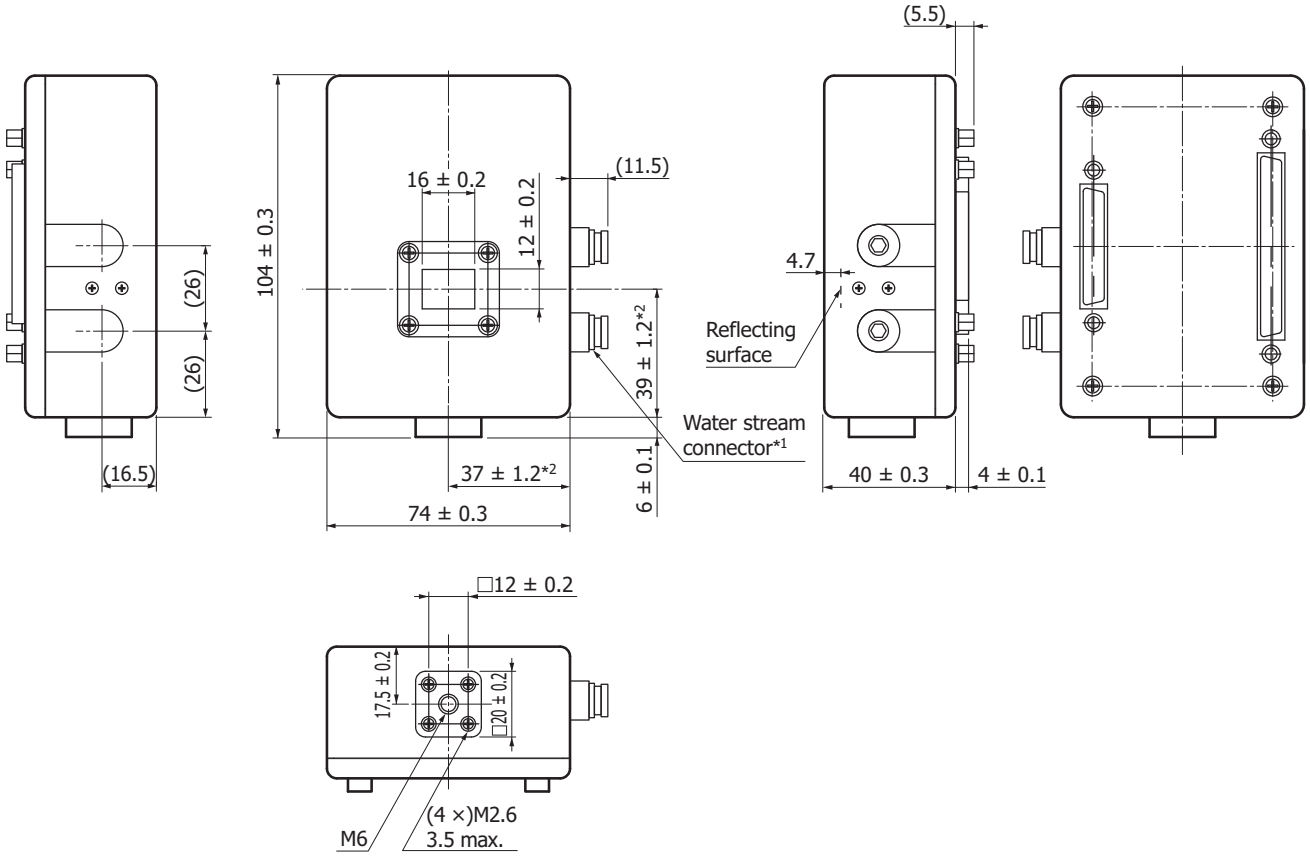
■ -03WR, -04WR



*1: KQB2S06-01S SMC, compliant tube outer diameter: ϕ6
*2: Although the center of the LCOS effective area may deviate due to production tolerance, the aperture and the LCOS effective area are aligned.

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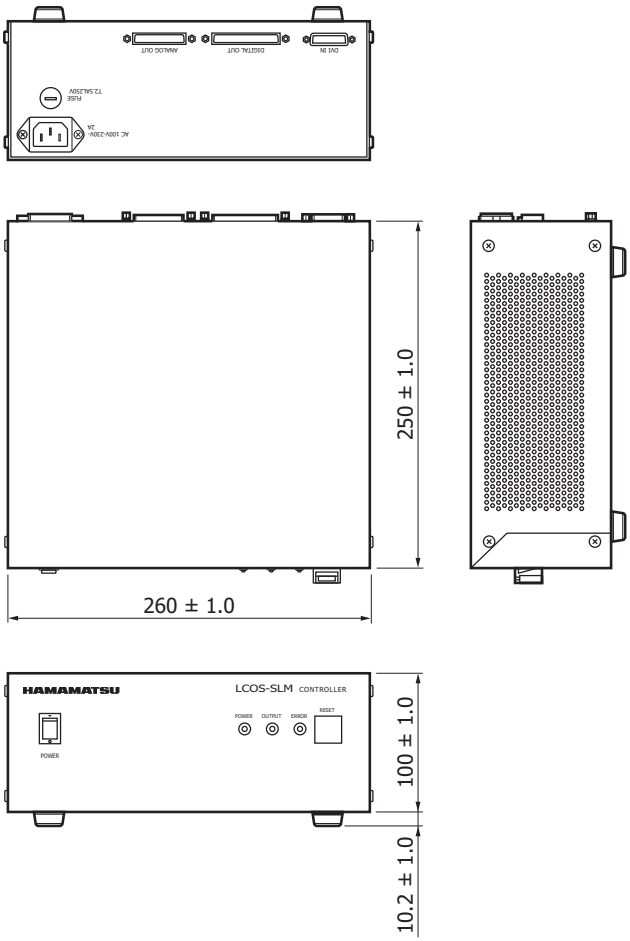
Controller



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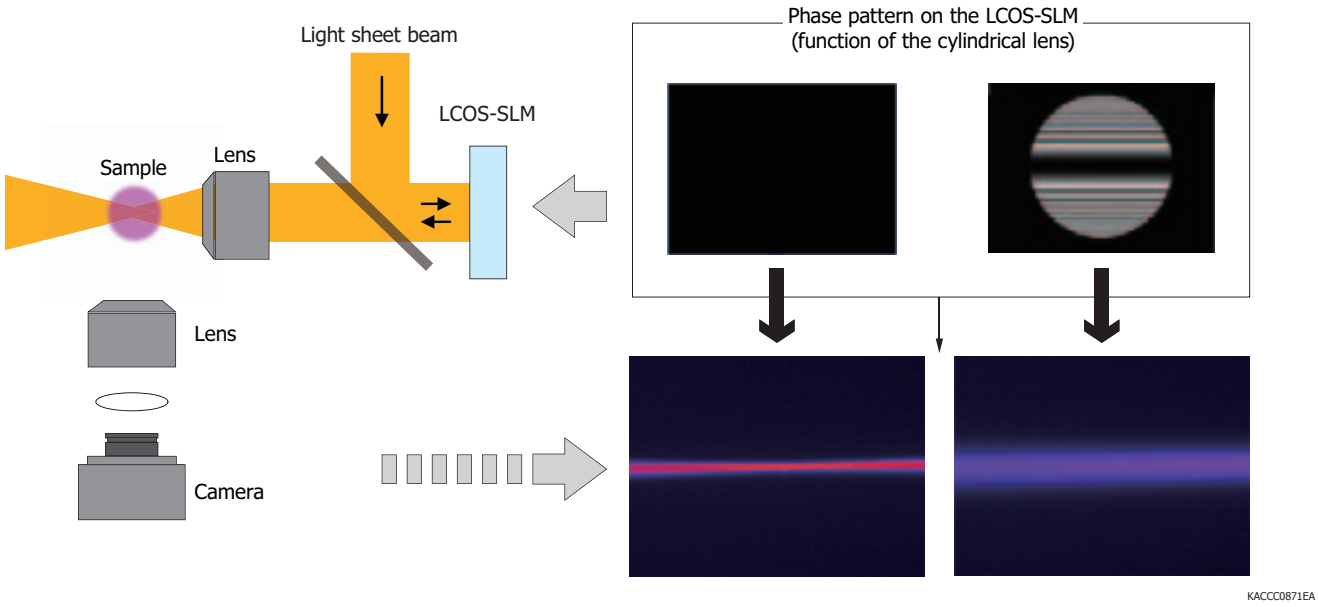
The X10468/X13267/X13138 series does not include a PC. Prepare a PC by referring to the followings:
· OS that supports the provided software*3 : Microsoft® Windows® XP/7/8/10
· PC must have a DVI-D port for connecting to the X10468/X13267/X13138 series.
· The provided software supports dual monitor control. The first monitor is for PC screen and the second one is for phase images on the X10468/X13267/X13138 series. In this case, the phase image displayed on the second monitor can be controlled by operation on the first monitor. Note that you need a dual ported DVI-D display card to perform this operation.

*3: The provided software that comes with the X10468/X13267/X13138 series has generating functions such as for a computer generated hologram (CGH).
Note: Microsoft, Windows are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.

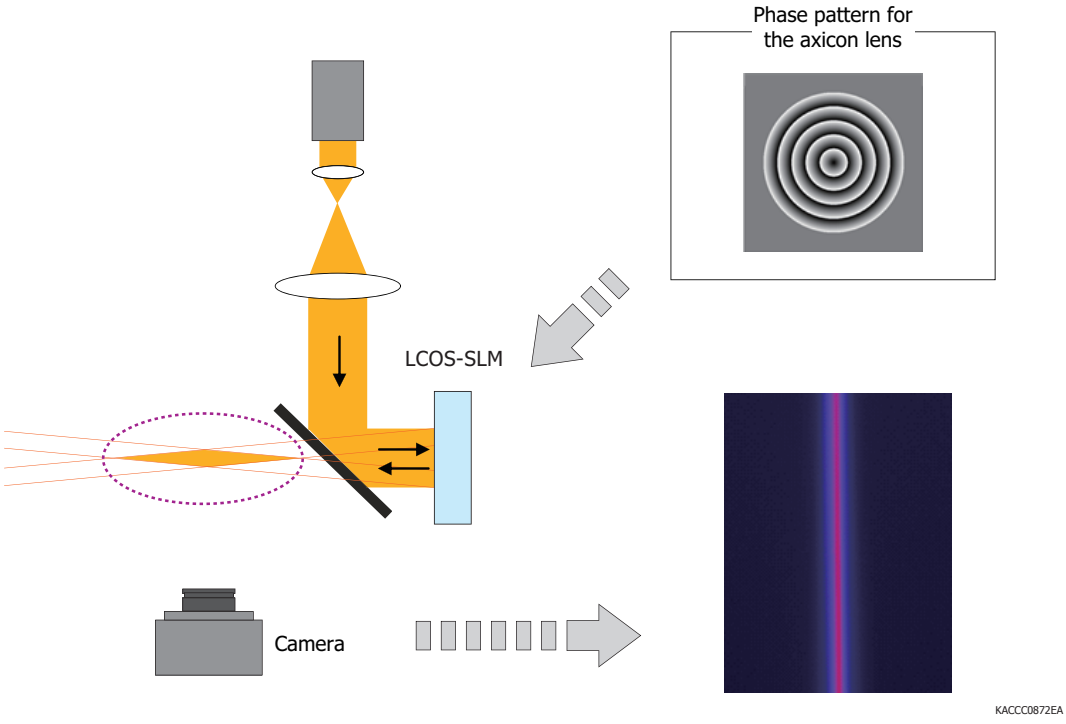
Application example 1: Beam control (lens function, nondiffracting beam generation)

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



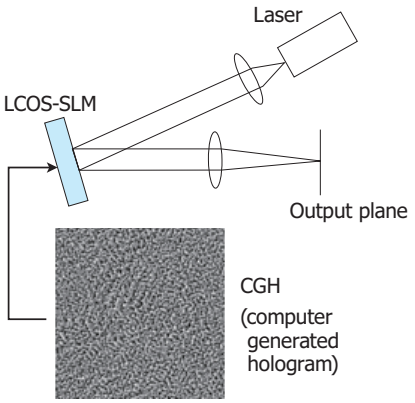
- Related patents of application example 1

US6573953, US6710292, US7209279, US7527201, US8749463, US9415461, US9488831

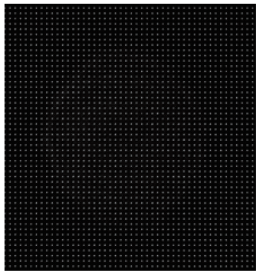
Application example 2: Light beam pattern generation

This technology uses the LCOS-SLM to reproduce phase type holograms 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 phase type hologram.

■ Optical system



Clear CGH reproduced image
(+1st order light)



50 × 50 point generation
with 0th order suppressed

Text reproduction example
(+1st order light)

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■ Related patents of application example 2

US6573953, US6710292, US7209279, US7527201, US8749463

Other related patents

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

Related information

www.hamamatsu.com/sp/ssd/doc_en.html

■ Precautions

· Disclaimer

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