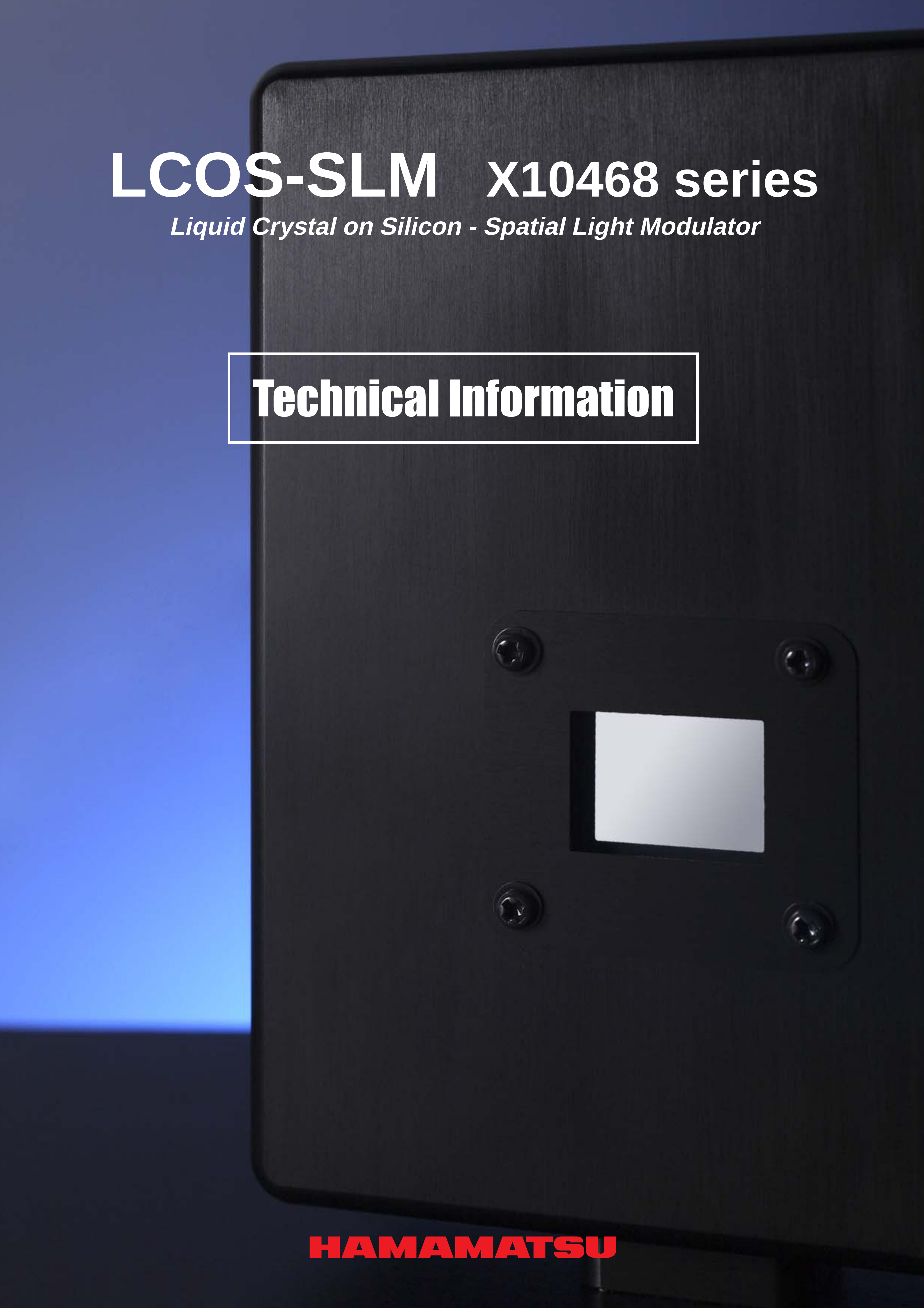
LCOS-SLM X10468 series

Liquid Crystal on Silicon - Spatial Light Modulator

Technical Information



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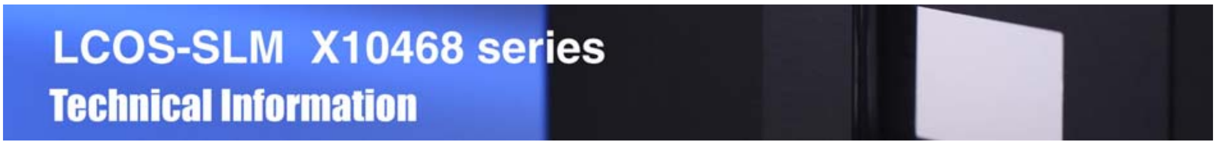

Technical Information 1

An Introduction to High Power Laser Applications

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1. Intoroduction

X10468 series spatial light modulators (SLMs) may be damaged when the SLM is operated with excessive readout laser power. We have measured some excessive readout laser power handling capabilities at several representative wavelengths.

1.1. General cautions

There are three kinds of damages;

1) Thermal damage of liquid crystal (LC),
2) Abrasion damage of dielectric or aluminum surfaces,
3) Photochemical damage of LC molecules.

The thermal damage will be caused when the average power of readout light is too high. The cause for thermal damage is as follows;

1) some material in the SLM may absorb some light energy,
2) the absorbed energy may heat up liquid crystal,
3) LC birefringence will decrease as the temperature increases,
4) LC birefringence will disappear when the temperature of LC reaches the isotropic phase temperature,
5) in the extreme case, liquid crystal may boil and undergo irreversible change.

This thermal damage can be prevented by monitoring the characteristic change in birefringence as described in Step 3.

The abrasion damage will be caused when the peak power density of readout light is too high. Once the peak power density of readout light exceeds the abrasion threshold, the SLM will be damaged.

The photochemical damage is caused by absorption of ultra-violet (UV) light by the LC. Absorption coefficient of the LC increases at wavelengths less than 350 nm. Absorption of such UV light can breakdown the liquid crystal molecules. One should not allow readout surface of SLM to be exposed to UV light.

2. Prevention of thermal damage with birefringence change detection

The phase (birefringence) change in SLMs due to temperature rise can be detected with a simple experimental setup in which a polarized laser light is used with an analyzer. By monitoring the phase change, users can find a safe laser power level.

2.1. Experimental setup

Figure 1 shows an example of setup. A laser beam is linearly polarized by a polarizer and incident obliquely to an X10468 SLM. The beam reflected on the SLM passes through an analyzer and then is detected by a photo detector. The SLM is located as its LC alignment direction is parallel to the paper. The polarizer and analyzer are aligned as their polarization directions make an angle of 45 degree with respect to the LC alignment direction. When you take an oblique incident setup shown in Fig. 1, please keep the incident angle, θ, less than 10 degree to maintain good phase modulation linearity.

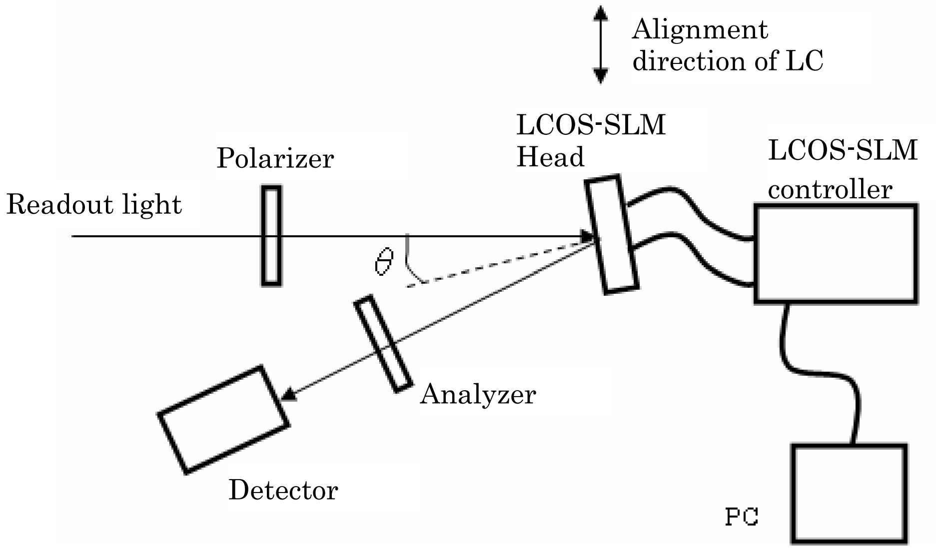


Fig. 1. A setup example to detect LC birefringence change.

Notes:

- Please keep the incident angle, θ, less than 10 degree to maintain good phase modulation linearity.
- Please keep the laser power very weak until you find a safe level through the procedures described in Section 2.3.
- It is recommended to use a collimated laser beam because narrow laser beams have high power density and is danger to the SLM.

2.2. Preparation

In this alignment, the phase change created in the SLM is converted to intensity change. The grey level should be set appropriately for sensitive phase change detection. Figure 2 is an example of intensity detected by the photo detector when uniform images of various grey levels are displayed onto the SLM. While the phase modulation is almost linear to the grey level, the intensity modulation detected with the photo detector forms a sinusoidal curve. The intensity change is very small at the maximum and minimum of the sinusoidal curve. To make the detection sensitive, users must set the output grey level in a region where the intensity change is large.

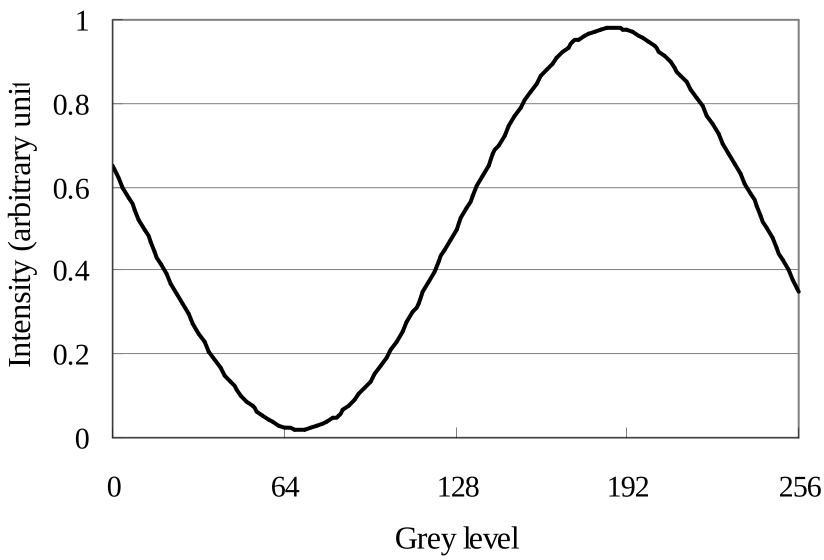


Fig. 2. Intensity change detected in the setup shown in Fig. 1.

2.3. Finding the safe level of laser power

The procedures to find a safe level of laser power as follows.

1. Set the laser power at the level which makes the detection possible and gives no damage to the SLM.
2. Search a proper grey level as described above.
3. Display the uniform image having the grey level found in the former step.
4. Observe the output intensity of the photo detector as increasing the laser power gradually. Be careful not to increase it rapidly.
5. Stop increasing when the intensity change occurs.
6. Decrease the laser power slightly.
7. Keep the laser power at the same level and continue observing the intensity output in a period enough long for your application.
8. Stop the procedure if there is no further intensity change. Or return to Step 6 if there is any intensity change

The laser power at the last step does not cause any rise in the SLM temperature and is a very safe level from thermal damage.

3. Power Handling Capability

Light source A: 1064 nm CW YAG laser
Light source B: 1064 nm Pulse YAG laser (pulse width: 100-200 ns, repeat frequency: 80 KHz)
Light source C: 1030 nm Short-pulse laser (pulse width: 11.4 ns, repeat frequency: 10 KHz)
Light source D: 1030 nm Short-pulse laser (pulse width: 1.37 ps, repeat frequency: 30 KHz)
Light source E: 1030 nm Short-pulse laser (pulse width: 670 fs, repeat frequency: 1 KHz)
Light source F: 800 nm Short-pulse Ti: S laser (pulse width: 100 fs, repeat frequency: 1 KHz)
Light source G: 800 nm Short-pulse Ti: S laser (pulse width: 50 fs, repeat frequency: 1 kHz)
Light source H: 800 nm Short-pulse Ti: S laser (pulse width: 30 fs, repeat frequency: 10 Hz)
Light source I: 532 nm CW YAG laser (SHG)
Light source J: 515 nm Short-pulse laser (pulse width: 14.4 ns, repeat frequency: 10 KHz)
Light source K: 515 nm Short-pulse laser (pulse width: 0.91 ps, repeat frequency: 30 KHz)
Light source L: 365 nm UV-LED

Type -01: aluminum mirror for 400 nm to 700 nm
Type -02: with a dielectric mirror for 750 nm to 850 nm
Type -03: with a dielectric mirror for 1000 nm to 1100 nm
Type -04: with a dielectric mirror for 460 nm to 560 nm
Type -05: with a dielectric mirror for 350 nm to 420nm
Type -07: aluminum mirror for 620 nm to 1100 nm

Light source / Type	Average power	Peak power	Illumination area	Results
A/ -03	2.5 W	2.5 W	X: 3.05 mm Y: 3.11 mm (*1)	No damage and no phase modulation change observed for three-hour exposure.
A/ -03	2.0 W	2.0 W	X: 2.44 mm Y: 2.50 mm (*1)	No damage and no phase modulation change observed for one-hour exposure.
A/ -03	3.5 W	3.5 W	X:2.44 mm Y: 2.50 mm (*1)	No damage but phase modulation change observed for a few minutes exposure.
B/ -03	2.0 W		X:2.44 mm Y: 2.50 mm (*1)	No damage and no phase modulation change observed for one-hour exposure.
B/ -03	3.5 W		X:2.44 mm Y: 2.50 mm (*1)	No damage but phase modulation change observed for a few minutes exposure.
C/ -03	17.4 W	152 KW	ϕ 13.0 mm (*2)	No damage and no phase modulation change observed for eight-hour exposure
D/ -03	5.2 W	120 MW	ϕ8.11 mm (*2)	No damage and no phase modulation change observed for eight-hour exposure
E/ -03	0.578 W	0.86 GW	ϕ4.5 mm (*2)	No damage and no phase modulation change observed for ten-hour exposure.

*1: measured with M2BOX by SPIRICON
*2: defined as $1/e^2$ with the assumption of the Gaussian profile

Light source / Type	Average power	Peak power	Illumination area	Results
F/ -07	0.33 W	3.3 GW	ϕ11 mm (*2)	No damage and no phase modulation change observed for seven-hour exposure
F/ -07	0.57 W	5.7 GW	ϕ11 mm (*2)	No damage but phase modulation change observed for seven-hour exposure
G/ -02	2.73 W	54 GW	ϕ9 mm (*2)	Liquid crystal layer start to melt down at the center portion of the illuminated area for three-hour exposure.
G/ -02	2.73 W	54 GW	ϕ11 mm (*2)	No damage and no phase modulation change observed for ten-hour exposure.
H/ -02	52 mW	173 GW	ϕ18 mm (*2)	No damage and no phase modulation change observed for six-hour exposure.
I/ -01	0.025 W	0.025 W	Approx. ϕ1 mm (*3)	No damage occurred for five-hour exposure.
I/ -04	0.075 W	0.075 W	Approx. ϕ0.4 mm (*3)	No damage and no phase modulation change occurred for three-hour exposure.
J/ -04	4.3 W	30 KW	ϕ 9.1 mm (*2)	No damage and no phase modulation change observed for eight-hour exposure
K/ -04	1.8 W	65 MW	ϕ 9.1 mm (*2)	No damage and no phase modulation change observed for eight-hour exposure
K/ -04	3.2 W	115 MW	ϕ 9.5 mm (*2)	No damage but phase modulation change observed for eight-hour exposure

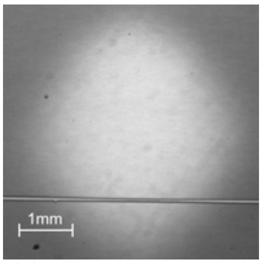
*2: defined as $1/e^2$ with the assumption of the Gaussian profile

*3: visually measured and simply calculated with the reduction ratio

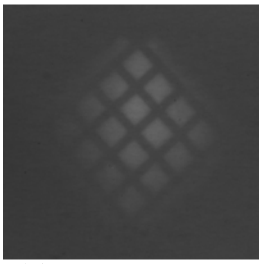
Light source / Type	Average power	Results
L/ -05	0.5 W/cm^2	No damage and no phase modulation change observed for 1000-hour exposure.
L/ -05	0.5 W/cm^2	No damage but phase modulation change observed for 2000-hour exposure. (*4)
L/ -05	1.0 W/cm^2	No damage and no phase modulation change observed for 500-hour exposure.
L/ -05	1.5 W/cm^2	No damage but phase modulation change observed for 500-hour exposure. (*4)
L/ -05	2.0 W/cm^2	No damage but phase modulation change observed for 100-hour exposure. (*4)

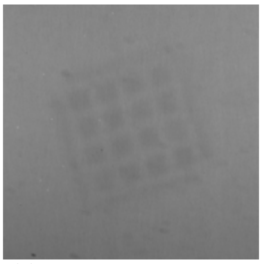
*4: Observed changes

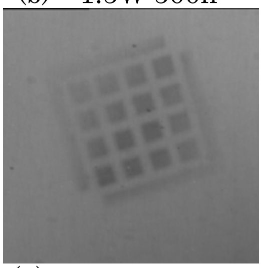
The phase modulation changes after UV-LED irradiation are shown. These are observed in an intensity modulation setup (Fig.1). The observed phase modulation changes are corresponding to the irradiation pattern of the UV-LED which is a set of square distribution. The absolute degree of the changes is not evaluated. (The horizontal line in figure (a) is owing to a line defect of the chip.)



(a) 0.5W 2000h


(b) 1.5W 500h


(c) 2W 100h


(d) 2W 200h

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