meadowlark optics
polarization solutions

LCoS 反射型液晶空間光変調器　SLM-LCoS

シリコンに液晶をコーティングした (LCoS) 技術を採用した反射型 SLM は純粋な位相アプリケーション用のユニークな設計。またそれと独立して常に新しいレートで直接アナログデータを届けるアナログドライブ技術により、リップルの殆どない安定した位相安定性を得ることが可能。
スペクトルのチューニング他、各種応用に使用でき 400nm ～ 1650nm まで対応可能。

ピクセル構成	応答時間	ピクセル幅	回折効率	光利用効率	可動域 (mm)	コントローラ
高速 1920 x 1152	1.4 ～ 5.0 ms	9.2 x 9.2 μm	88%	95.7%	17.6 x 10.7	PCIe
1920 x 1152	6 ～ 33ms	9.2 x 9.2 μm	88%	95.7%	17.6 x 10.7	HDMI
512 x 512	3 ～ 130ms	15 x 15 μm	61.5 ～ 99%	83.4 ～ 100%	7.68 x 7.68	PCIe, DVI
リニアー 1 x 12,288	4.5 ～ 30ms	1.6 μm x 19.7mm	80 ～ 95%	100%	19.7 x 19.7	

①LCoS反射型２軸液晶空間光変調器　SLM-LCoS-XYseries

LCoS 反射型 SLM の２軸 (XY) シリーズは一般的なラボの環境下で各種応用に簡単に使用出来るように設計されており、主要な幾つかの決められた波長の 1 つで反射した時にフルウェーブ (2π) の位相ストロークを提供するように最適化されている。入射光が水平軸に対してリニアー偏光の時にのみ位相変調できる。振幅は位相変調されたリニアー入射光が 45 度回転した場合、変調可能になる。

◆LCoS 高解像度・高速型　SLM-1920 x 1152

LCoS 反射型 SLM の高解像度型で 1920 x 1152 ピクセルの特大液晶板（シリコンバックプレーン）により、高出力レーザビームにも対応でき、高い回折効率でリップルが殆どない高性能の安定した位相変調が高速で可能。
PCIe コントローラー採用の高速タイプ (>714Hz) 新登場

◆LCoS 標準・万能型　SLM- 512 x 512

LCoS 反射型 SLM ー XY シリーズの標準型。アナログドライブ技術により低位相リップルで高い位相安定性がえられ、高リフレッシュレートで高速位相変調が可能な SLM。　応答時間が 3ms に短縮している。高い回折効率でリップルの殆どない安定した位相変調が高速で可能。

用途　●ビームステアリング（ホログラム等）　●回折光学素子
　　●スペクトルチューニング

②LCoS反射型リニアー液晶空間光変調器　SLM-LCoS-Linear

◆LCoS リニアー型　SLM-Linear-1 x 12,288

LCoS 反射型 SLM の中で高光分解能のリニアーアレイを採用しているモデル。高いリフレッシュレートのアナログシリコンバックプレーンにより、最良の位相安定性が得られる。最高の充填率（100%）と高回折効率で光学精度の高い安定した位相変調又は振幅変調が可能。

用途　●プログラマブル位相格子　●偏光光学　●プログラマブル振幅格子

特長

◆LCoS 反射型2軸 SLM

＊LCoS : シリコンに液晶をコーティング

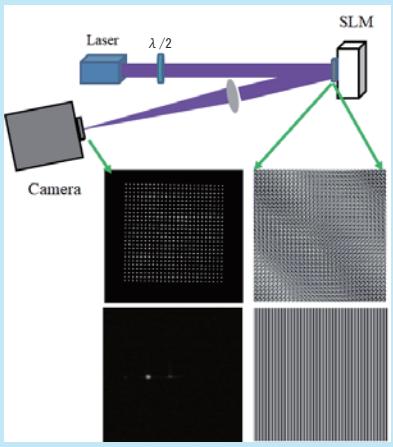
- LCoS 技術・PCIe 制御により最短応答時間 >1.4ms
- アナログドライブ技術により位相安定性が極めて高い
- 紫外 (>365nm) ～中赤外 (3-5μm) の広帯域に対応

◆LCoS 反射型リニア 1 軸 SLM

- 高分解能のリニアアレイを採用
- 高位相安定性で高精度変調が可能
- 位相変調または振幅変調が可能

用途

1D/2D/3D ビームステアリング

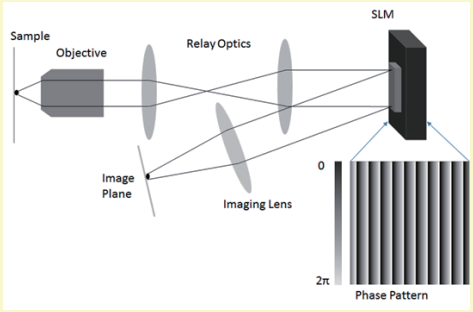


波面の位相変調に最適

1D : SLM-1x12288
2D&3D : SLM-1920x1152/512x512

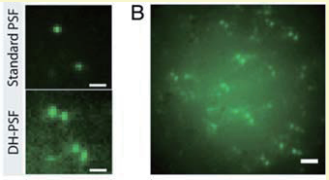
レーザ通信・光ピンセット・光遺伝学等に応用可能

顕微鏡における光波シンセシス (PSF-Engneering)



顕微鏡内位相イメージの変調に最適

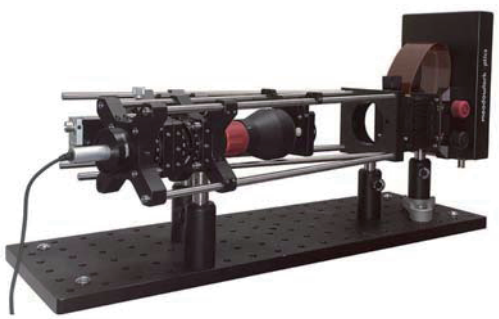
PSF : SLM-512x512



高解像度イメージング
コントラスト増強

＊オプティクスキット

このキットには精密なリニアポラライザー、 半波長リターダー、 レンズ等 SLM のアライメントを素早く出来る為のすべての光学系が含まれており、 非常に簡単にシステムアップできる。
このキットを使用することで、 SLM 使用の各種応用・実験等に必要なシステムアップに要する時間が短縮でき、 光学系の影響を最小限にすることが可能。



- Half-Wave Retarder,
- a pair of Linear Polarizers
- Beam expander
- Lenses
- Tip/tilt stage
- Base plate and posts
- Laser and camera (optional)

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SPATIAL LIGHT MODULATORS

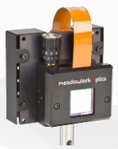
Reflective Analog SLMs

All of Meadowlark's liquid crystal on silicon (LCoS) backplanes incorporate analog data addressing with high refresh rates to provide the lowest phase ripple SLMs available. User's can select standard or high speed liquid crystal for optimal performance. Liquid cooling systems are available to remove heat via the back of the SLM chip in order to maximize optical power handling capabilities.

1920 x 1152 – New! This SLM offers large format, high fill factor (high optical efficiency), high-speed (as fast as 1.4 ms), low phase ripple (.2 – 3%), high optical power handling (up to 15 GW/cm^2 peak power density), and high refresh rate. This analog, high voltage SLM produces very stable phase patterns, coupled with fast liquid crystal response times.

Small 512 x 512 – Entry Level – Educational – Economical
Our legacy SLM is now available as our E-Series model. It is ideally suited for labs with a limited budget or researchers who do not require the high speed or high efficiency features of our premium SLMs, yet still demand high performance. This entry-level SLM is affordably priced without sacrificing quality.

1 x 12,288 – The only high resolution linear array on a silicon backplane available on the market. The high refresh rate analog backplane provides excellent temporal stability. Our production process results in 100% fill factor, giving high optical efficiency.



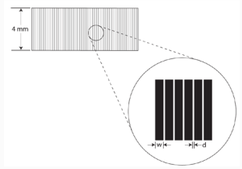
Optics Kit –Includes optics & mounts for simple phase or amplitude experiments. Available pre-aligned and ready to use over 405 - 1550 nm. Available with optional camera and laser.

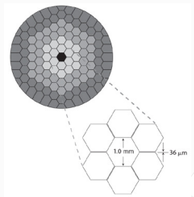
SPATIAL LIGHT MODULATORS

Transmissive SLMs

All of Meadowlark's liquid crystal on glass (LCoG) SLMs provide precision retardance control for spatially varying phase or amplitude requirements. Each pixel is independently addressed, acting as a separate variable retarder. These SLMs are easily incorporated into optical systems requiring programmable masks and variable input / output devices.

1 x 128 – The Linear SLM has a linear pixel array geometry. This system can be used to alter the temporal profile of femtosecond light pulses via computer control. Applications requiring these short pulses include analysis and quantum control of chemical events, optical communication and biomedical imaging. This linear SLM offers high fill factor, and good transmitted wavefront distortion.





Hex-127 – Our two dimensional hexagonal pixel transmissive SLMs are designed for adaptive optics applications. The SLM acts as a real time programmable phase mask for wavefront correction of a linear polarized source. Unwanted aberration effects are removed by introducing the opposite phase shift through the Hex SLM. The most common applications involve high-resolution imaging where viewing through an aberrant medium is unavoidable.

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SPATIAL LIGHT MODULATOR

SELECTION GUIDE

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SG10.19

Why Choose Meadowlark Reflective SLMs?

High Voltage Backplanes = Fastest Response Times Meadowlark Optics SLMs use custom backplanes, and proprietary drive schemes to achieve response times down to 1 ms (wavelength dependent). Most other liquid crystal spatial light modulators utilize display backplanes built with standard Nematic liquid crystal, limiting response time to >30 ms.

Highest Phase Stability Commercially Available - Our backplanes are custom designed to allow high refresh rates (up to 6 kHz), and direct analog drive schemes. Refreshing the voltage at the pixel at rates far surpassing the response time of the liquid crystal ensures high temporal phase stability. Further, use of direct analog drive schemes, as opposed to digital dithering, reduces optical flicker as low as 0.1% (0.001 π radians).

Low Inter-pixel Cross Talk - Our backplanes are custom designed to offer high voltage at the pixel (5 – 10 V). Further, our SLMs are built with Meadowlark Optics proprietary liquid crystal which minimizes the required thickness of the LC layer in the SLM. By maximizing the ratio of pixel pitch to LC thickness we are able to offer SLMs with minimal inter-pixel effects.

Broad Wavelength Capabilities - Meadowlark Optics is the only SLM supplier capable of offering SLMs designed for use from UV (>365 nm) up to the MWIR (3 - 5 µm).

Analog is Better - All Meadowlark SLMs have been designed for phase modulation. Unlike many display LCoS backplanes which require a pulse width modulation (PWM) scheme, Meadowlark backplanes utilize analog voltages at each pixel. This results in a very stable phase response over time.

High Bit Depth Controllers - Meadowlark offers 8, 12, and 16-bit controllers to provide the most linear resolvable phase levels commercially available (up to 500). Fast transfer speeds from the computer to the SLM are offered up to 2 kHz.

1920 x 1152 Analog Spatial Light Modulator

Resolution: 1920 x 1152 **Fill Factor**: 95.7%
Array Size: 17.6 x 10.7 mm **Diffraction Efficiency***: 88%
Pixel Pitch: 9.2 x 9.2 µm **Controller:** PCIe 8/12-bit, HDMI 8/12-bit

Wavelength	Wavefront Distortion	Liquid Crystal Response Time (Standard / Mid / High Speed)			AR Coatings (Ravg <1%)
		Model P1920	Model MSP1920	Model HSP1920	
405 nm	λ/3	6.0 ms	3.0 ms	N/A	400 – 800 nm
532 nm	λ/5	9.0 ms	4.5 ms	1.4 ms	400 – 800 nm
635 nm	λ/6	12.0 ms	5.9 ms	1.8 ms	400 – 800 nm
785 nm	λ/7	19.0 ms	10.0 ms	2.3 ms	600 – 1300 nm
1064 nm	λ/10	25.0 ms	13.0 ms	3.3 ms	600 – 1300 nm
1550 nm	λ/12	33.0 ms	24.8 ms	4.7 ms	850 – 1650 nm

*Silicon backplane, performance varies as a function of wavelength.

Small 512 x 512 Analog Spatial Light Modulator

Resolution: 512 x 512 **Fill Factor**: 83.4 - 100%
Array Size: 7.68 x 7.68 mm **Diffraction Efficiency***: 61 - 99%
Pixel Pitch: 15 x 15 µm **Controller:** PCIe 8-bit, PCIe 16-bit, DVI 16-bit

Wavelength	Wavefront Distortion	Liquid Crystal Response Time (Standard Efficiency / High Efficiency)			AR Coatings (Ravg <1%)
		Model E512/PDM512	Model HSP512/HSPDM512	Model ODP512/ODPDM512	
405 nm	λ/5	25.0 ms / 33.3 ms	N/A	3.0 ms / 4.0 ms	400 – 850 nm
532 nm	λ/7	33.3 ms / 45.0 ms	7.0 ms / 10.0 ms	3.5 ms / 4.5 ms	400 – 850 nm
635 nm	λ/8	33.3 ms / 45.0 ms	12.0 ms / 16.7 ms	4.0 ms / 5.0 ms	400 – 850 nm
785 nm	λ/10	55.5 / 80.0 ms	17.2 ms / 22.2 ms	4.5 ms / 5.5 ms	600 – 1300 nm
1064 nm	λ/10	66.7 / 100.0 ms	10.0 ms / 16.7 ms	5.0 ms / 6.0 ms	600 – 1300 nm
1550 nm	λ/12	100.0 / 130.0 ms	20.0 ms / 28.5 ms	6.0 ms / 7.0 ms	850 – 1650 nm

*Silicon backplane, performance varies as a function of wavelength.

1 x 12,288 Analog Spatial Light Modulator

Resolution: 1 x 12,288 **Fill Factor**: 100%
Array Size: 19.66 x 19.66 mm **Diffraction Efficiency***: 99%
Pixel Pitch: 1.6 µm x 19.66 mm **Controller:** PCIe 16-bit

Wavelength	Liquid Crystal Response Time	AR Coatings (Ravg <1%)
	Model HSP12K	
405 nm	N/A	N/A
532 nm	4.5 ms	400 – 850 nm
635 nm	5.0 ms	400 – 850 nm
785 nm	8.5 ms	600 – 1300 nm
1064 nm	15.0 ms	600 – 1300 nm
1550 nm	30.0 ms	850 – 1650 nm

*Silicon backplane, performance varies as a function of wavelength.

Transmissive Spatial Light Modulator

Modulation: Phase or Amplitude **Wavelength Range:** 405 – 1800 nm
Retardance Uniformity: ≤ 2% rms variation over clear aperture
Transmission: >90% (without polarizers)

Pixel Format	Response Time	Pixel Pitch	Efficiency	Fill Factor	Active Area (mm)
1 x 128	35 – 70 ms	100 µm	85 - 92%	98.0%	12.80 x 5.00
Hex	35 – 70 ms	1 mm	> 90%	93.1%	12.00 Ø

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Spatial Light Modulator

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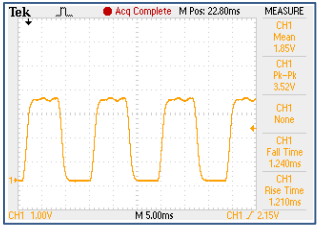
High Resolution

1920 x 1152 SLM

COMPACT DESIGN
SLM with attached
PCIe Control Electronics

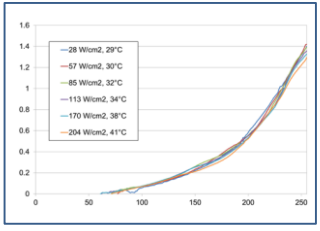
NEW

High Speed



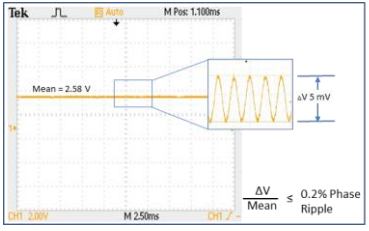
Up to 714 Hz

High Power



Up to 15 GW/cm²

Low Phase Ripple



As low as 0.2%

Resolution: 1920 x 1152
Array Size: 17.6 x 10.7 mm
Pixel Pitch: 9.2 x 9.2 µm

Fill Factor: 95.7%
Diffraction Efficiency*: 88%
Controller: HDMI 8/12-bit, PCIe 8/12-bit

Wavelength	Wavefront Distortion	Standard Liquid Crystal Response Time	High Speed Liquid Crystal Response Time	AR Coatings (Ravg <1%)
405 nm	λ/3	6.0 ms	N/A	400 – 800 nm
532 nm	λ/5	9.0 ms	1.4 ms	400 – 800 nm
635 nm	λ/6	12 ms	1.8 ms	400 – 800 nm
785 nm	λ/7	19 ms	2.5 ms	600 – 1300 nm
1064 nm	λ/10	25 ms	3.3 ms	600 – 1300 nm
1550 nm	λ/12	33 ms	5.0 ms	850 – 1650 nm

*Silicon backplane, performance varies as a function of wavelength.

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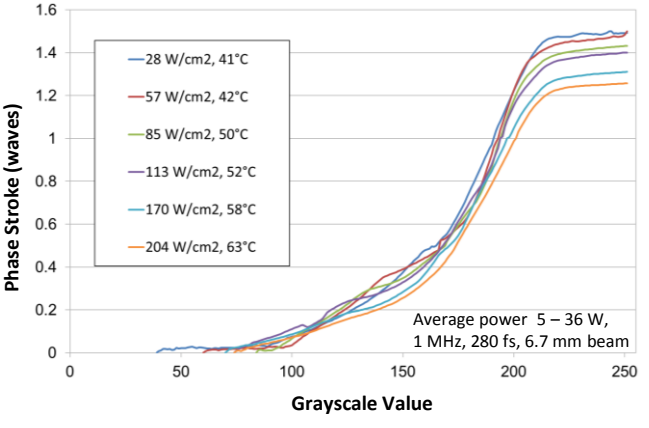
SLM capable of >200 W/cm^2 with peak powers up to 15 GW/cm^2

Optional water cooling system maintains consistent temperature and phase stroke when using high power lasers.

Standard 1920 x 1152 SLM

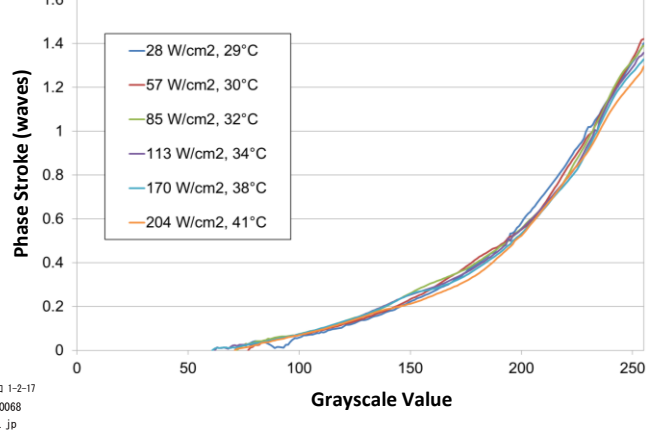


Tested with Coherent Monaco Laser

- High Power Femtosecond Industrial Laser
- 40W, 1 - 50 MHz Rep Rate, <400 fs to >10 ps
- Exceptional Beam Quality
- Single-box Solution

COHERENT.

Cooled 1920 x 1152 SLM



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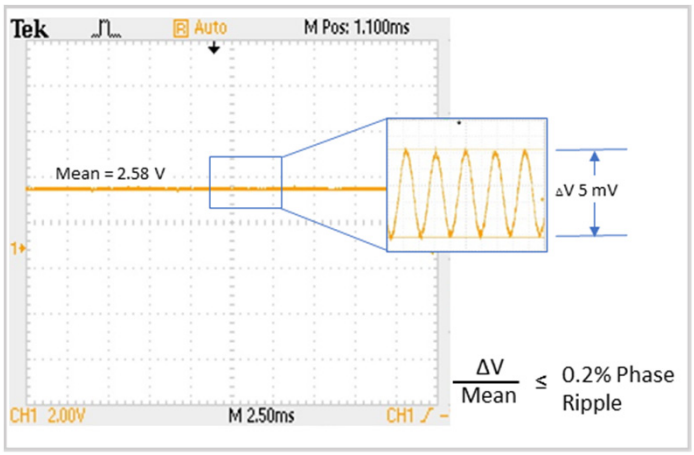
Spatial Light Modulator – 1920 x 1152

Meadowlark Optics Liquid Crystal on Silicon (LCoS) Spatial Light Modulators (SLMs) are uniquely designed for pure phase applications and incorporate analog data addressing with high refresh rates. This combination provides users with the fastest response times and highest phase stabilities commercially available. Meadowlark offers both transmissive and reflective SLMs in either one- or two dimensions. Phase-only SLMs can also be used for amplitude-only or a combination of both. The 1920 x 1152 SLM is good for applications requiring high speed, high diffraction efficiency, low phase ripple and high-power lasers.

High Phase Stability - Meadowlark Optics' SLMs are known for having the highest phase stability on the market. Our backplanes are custom designed with high refresh rates and direct analog drive schemes resulting in phase ripple as low as 0.2% (0.002 π radians) for standard speed, and as low as 0.5% (0.005 π radians) for high-speed. Phase ripple is quantified by measuring the 1st order ripple as compared to the mean intensity while writing a repeating linear phase ramp to the SLM.

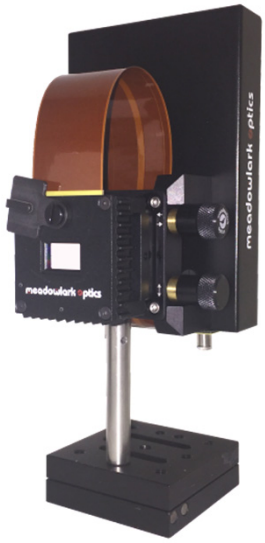


1st order Intensity when writing a phase ramp to the SLM

Hardware Interface Options - Meadowlark Optics' SLMs come with multiple hardware interface options. For customers that prefer the computer to view the SLM as a secondary monitor, we offer a HDMI controller with optional output trigger for synchronization. For customers that require high speed operation, we offer PCIe controllers with input and output triggers and low latency image transfers.

HDMI Controller

PCIe Controller to support high frame rates (up to 844 Hz)



SLM Features

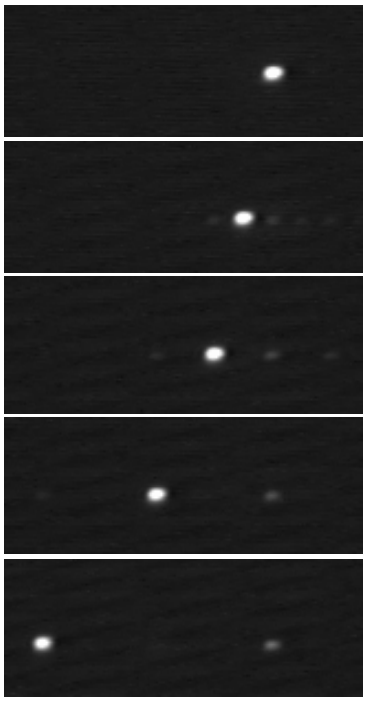
- High resolution
- High speed
- High Phase Stability
- Pure analog phase control
- High first order efficiency
- High reflectivity
- High power handling
- Compact design
- Wavelengths from 400-1650 nm

Software Features

- Input and Output Triggers
- Image Generation
- Automated Sequencing
- Wavefront Calibration
- Global and Regional Look Up Tables

Diffraction Efficiency (1st-order) - This is the percentage of light measured in the 1st-order when writing a linear repeating phase ramp to the SLM as compared to the light in the 0th order when no pattern is written to the SLM. Diffraction efficiency varies as a function of the number of phase levels in the phase ramp. An example measurement, taken at 1064 nm is shown below left, for phase ramps with 4 to 32 phase levels between 0 and 2π. The plot below right shows sample 1st order diffraction efficiency measurements, as a function of the phase ramp period, taken at various wavelengths.

Measured 1st Order Diffraction Efficiency



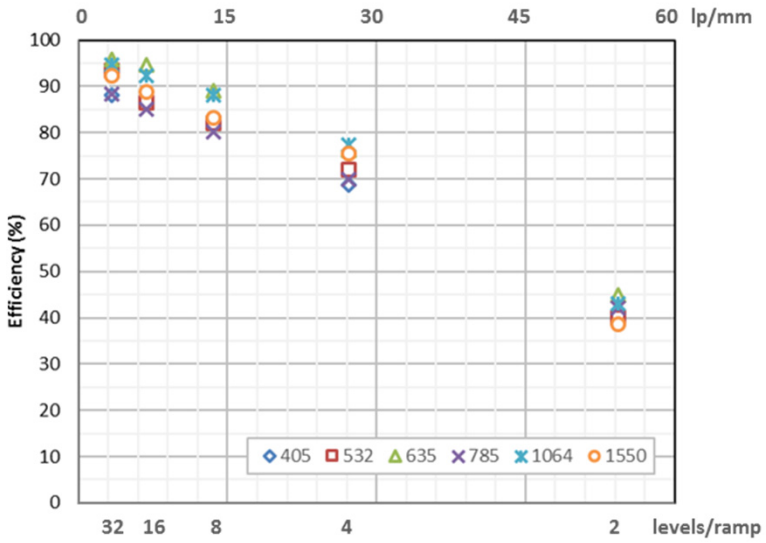
0th Order

32 phase levels, 0.2°
1st Order Diffraction
Efficiency: 94.6%

16 phase levels, 0.4°
1st Order Diffraction
Efficiency: 92.4%

8 phase levels, 0.8°
1st Order Diffraction
Efficiency: 88.0%

4 phase levels, 1.6°
1st Order Diffraction
Efficiency: 77.4%



Software - Meadowlark Optics' SLMs are supplied with a GUI and software development kits that support LabVIEW, Matlab, and C++. The software allows the user to generate images, to correct aberrations, to calibrate the global and/or regional optical response over 'n' waves of modulation, to sequence at a user defined frame rate, and to monitor the SLM temperature.

Global or Regional Calibrations - Regional calibrations provide the highest spatial phase fidelity commercially available by regionally characterizing the phase response to voltage and calibrating on a pixel by pixel basis.

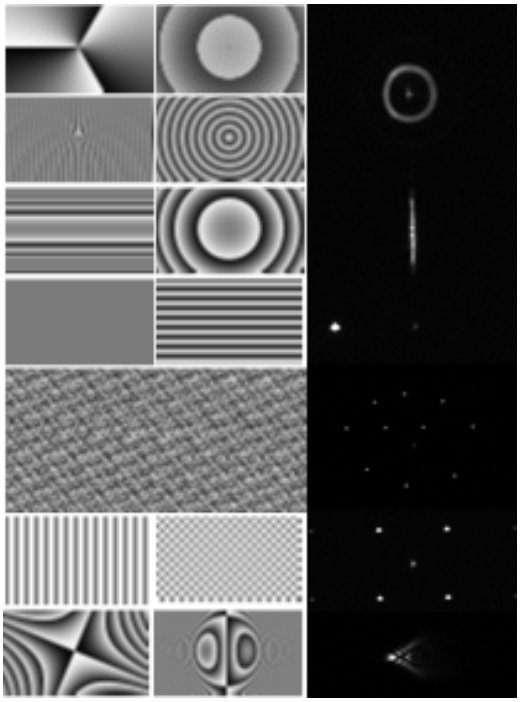


Image Generation Capabilities

Bessel Beams: Spiral Phase, Fork, Concentric Rings, Axicons
Lens Functions: Cylindrical, Spherical
Gratings: Blazed, Sinusoid
Diffraction Patterns: Stripes, Checkerboard, Solid, Random Phase
Holograms, Zernike Polynomials, Superimpose Images

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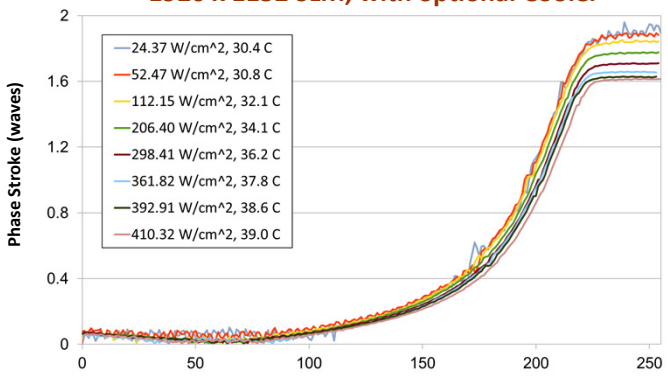
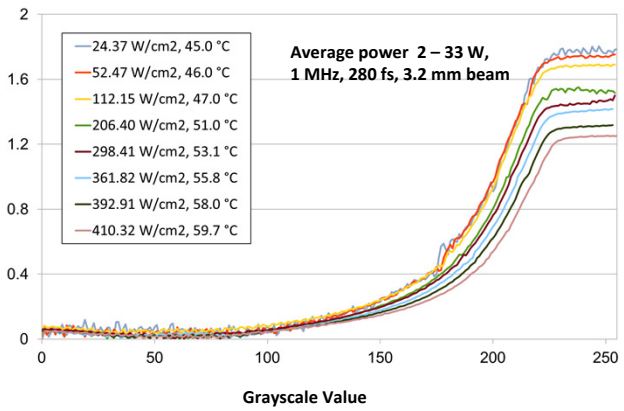
High Power Capability - Meadowlark Optics' Spatial Light Modulators have been tested for compatibility with high power pulsed and CW lasers. In the graphs below, the optical response of the 1920 x 1152 pixel SLM with and without liquid cooling was measured as the incident power was incremented up to 15 GW/cm^2 peak power or 410 W/cm^2 average power.

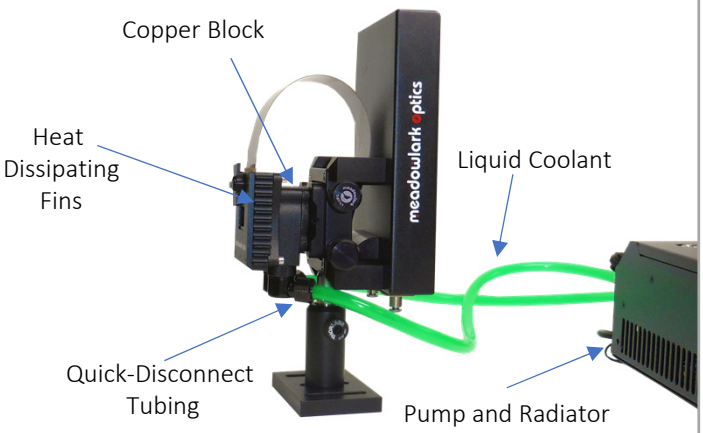
1920 x 1152 SLM, with optional Cooler



1920 x 1152 SLM, Uncooled

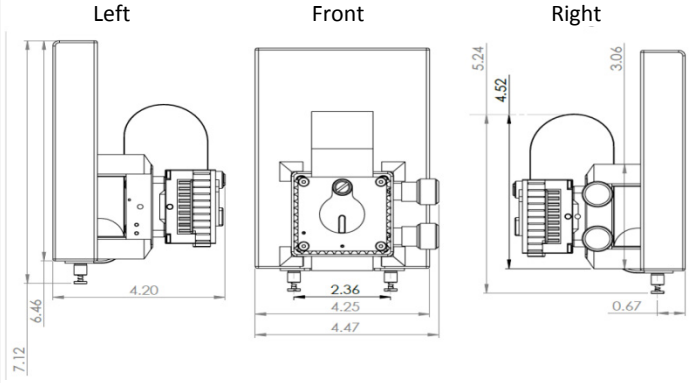


Liquid Cooling System
Part Number WCS1

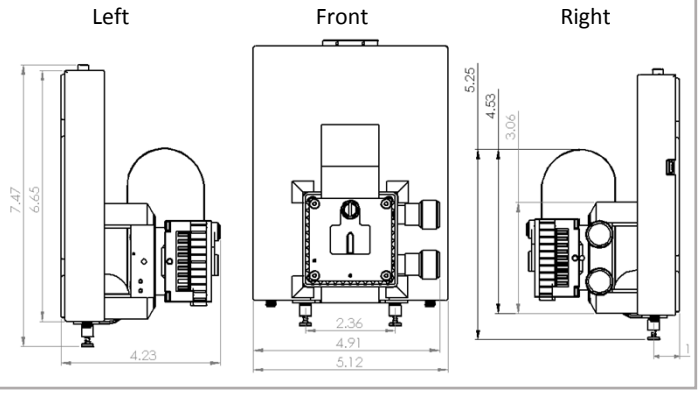


A copper block is attached to the back of the SLM to draw heat out of the SLM. The copper block is attached with 2 meters of quick-disconnect tubing to cooling unit containing an external pump, radiator, and fan to cool the liquid down to ambient temperature. Includes one bottle of liquid coolant.

HDMI 1920 x 1152 System Dimensions



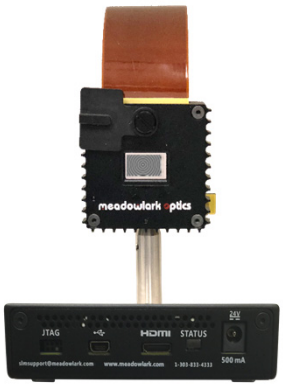
PCIe 1920 x 1152 System Dimensions



1920 x 1152 Analog Spatial Light Modulator Specifications

Resolution: 1920 x 1152
Fill Factor: 95.7%
Array Size: 17.6 x 10.7 mm
Pixel Pitch: 9.2 x 9.2 µm
Zero-Order Diffraction Efficiency*: 88%
Controller: HDMI 8/12-bit, PCIe 8/12-bit

Standard Speed System - Standard Liquid Crystal with HDMI Controller

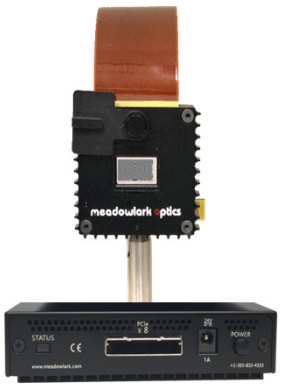


Specify Calibration Wavelength	Wavefront Distortion	LC Response Time / System Frame Rate	AR Coatings (Ravg <1%)	Reference this Model Number when Ordering
405 nm	λ/3	6 ms / 31 Hz	400 – 800 nm	Model P1920-400-800-HDMI
532 nm	λ/5	9 ms / 31 Hz	400 – 800 nm	
635 nm	λ/6	12 ms / 31 Hz	400 – 800 nm	
785 nm	λ/7	19 ms / 31 Hz	600 – 1300 nm	Model P1920-600-1300-HDMI
1064 nm	λ/10	25 ms / 31 Hz	600 – 1300 nm	
1550 nm	λ/12	33 ms / 31 Hz	850 – 1650 nm	Model P1920-850-1650-HDMI

Mid Speed System - Standard Liquid Crystal with High Speed PCIe Controller

Specify Calibration Wavelength	Wavefront Distortion	LC Response Time / System Frame Rate	AR Coatings (Ravg <1%)	Reference this Model Number when Ordering
405 nm	λ/3	3.0 ms / 281.6 Hz	400 – 800 nm	Model MSP1920-400-800-HSP8
532 nm	λ/5	4.5 ms / 211.1 Hz	400 – 800 nm	
635 nm	λ/6	5.9 ms / 169.0 Hz	400 – 800 nm	
785 nm	λ/7	10.0 ms / 93.7 Hz	600 – 1300 nm	Model MSP1920-600-1300-HSP8
1064 nm	λ/10	13.0 ms / 76.8 Hz	600 – 1300 nm	
1550 nm	λ/12	24.8 ms / 40.2 Hz	850 – 1650 nm	Model MSP1920-850-1650-HSP8

High Speed System – High Speed Liquid Crystal with High Speed PCIe Controller



Specify Calibration Wavelength	Wavefront Distortion	LC Response Time / System Frame Rate	AR Coatings (Ravg <1%)	Reference this Model Number when Ordering
532 nm	λ/5	1.4 ms / 422.4 Hz	488 – 800 nm	Model HSP1920-488-800-HSP8
635 nm	λ/6	1.8 ms / 422.4 Hz	488 – 800 nm	
785 nm	λ/7	2.3 ms / 422.4 Hz	600 – 1300 nm	Model HSP1920-600-1300-HSP8
1064 nm	λ/10	3.3 ms / 281.6 Hz	600 – 1300 nm	
1550 nm	λ/12	4.7 ms / 211.2 Hz	850 – 1650 nm	Model HSP1920-850-1650-HSP8

*Silicon backplane, performance varies as a function of wavelength.

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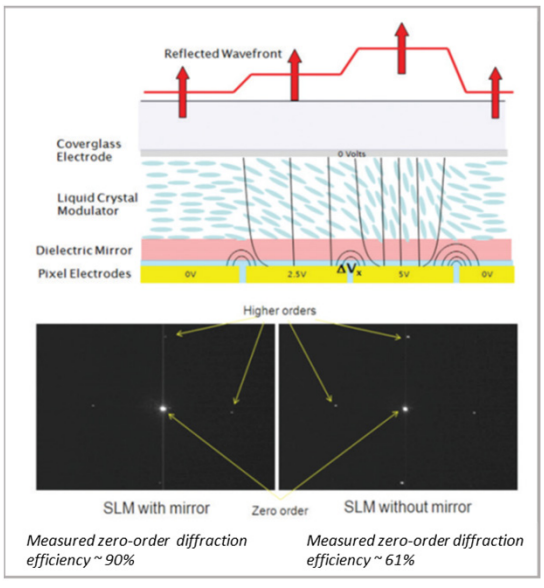
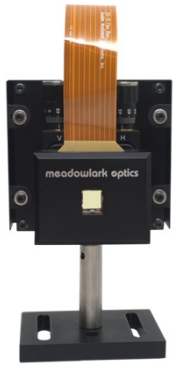
Spatial Light Modulator – 512 x 512

Meadowlark Optics Liquid Crystal on Silicon (LCoS) Spatial Light Modulators (SLMs) are uniquely designed for pure phase applications and incorporate analog data addressing with high refresh rates. This combination provides user's with the fastest response times and highest phase stabilities commercially available. Meadowlark offers both transmissive and reflective SLMs in either one or two dimensions. Phase-only SLMs can also be used for amplitude-only or a combination of both. The 512 x 512 SLM is good for applications requiring high speed, with synchronization / triggering capabilities. The optional dielectric mirror coating provides users with 100% fill factor, which increases optical efficiency.

High Efficiency

All of the light reflecting off of the SLM is modulated – including the light between the aluminum pixel electrodes. The reflective pixel structure associated with a Liquid Crystal (LC) on Silicon SLM backplane acts as an amplitude grating that diffracts some light into higher orders. To eliminate this loss of light, Meadowlark has developed a process for removing the grating effects due to the pixel structure. Optically, the active area of the backplane is converted into a flat dielectric mirror by depositing planar dielectric layers to eliminate the amplitude and optical path variations associated with the underlying aluminum pixel structure. The dielectric stack is kept thin to minimize any drop in electric field across the LC layer as shown in the figure below. In other words, there are no abrupt changes in phase modulation (such as dead zones) between pixels due to the smoothing (low pass spatial filtering) which results from separating the LC modulator from the driving electrodes.





Key Features

- High speed
- Pure analog phase control
- High bit-depth controllers (high phase resolution)
- High reflectivity option
- High power handling
- Synchronization / Triggering
- Wavelengths from 400-1650 nm

Applications

- Adaptive Optics
- Optical Trapping
- Multi-Spot Volumetric Beam Steering
- Optical Vortices
- Pulse Shaping
- Spectral Shaping
- Tunable Lens

SLM Family

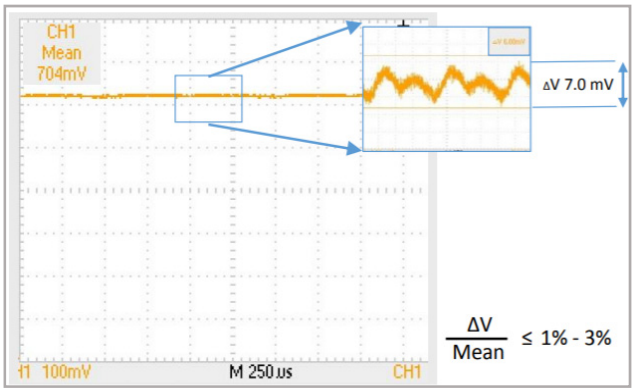
- 1920 x 1152
- 1 x 12,288
- E-Series 512 x 512
- 1 x 128
- Hex 127

High Phase Resolution

Meadowlark offers the industry's only 16-bit controllers for LCoS SLMs. With 16-bit voltage resolution these controllers provide unsurpassed phase resolution. When properly calibrated the SLMs typically have more than 10,000 unique pixel values over a 2π phase stroke. This high resolution is necessary when working with broad wavelength ranges, or large phase stroke SLMs in order to accurately hit the desired retardance at the operating wavelength. High phase resolution is also necessary in applications where the SLM is combined with polarizers to achieve amplitude modulation. With this approach, achieving good contrast ratio requires hitting the exact phase value yielding the darkest "off" state.

Low Phase Ripple

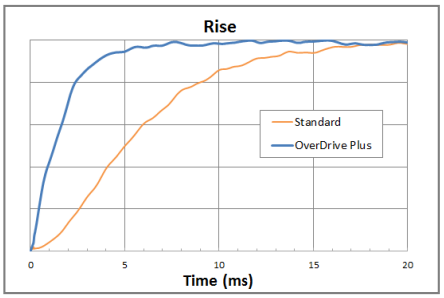
Meadowlark loads every pixel with 8-bit or 16-bit data several times per millisecond. This high speed addressing scheme eliminates phase ripple as demonstrated in the figure to the right. Meadowlark Optics' SLMs have been tested for compatibility with high power pulsed and CW lasers. In the measurements shown, the optical response of the 512 x 512 pixel SLM was measured as the incident power was incremented up to a peak power density of 112 MW/cm^2. Thermal effects resulted in a reversible reduction in modulation depth, and no permanent damage.

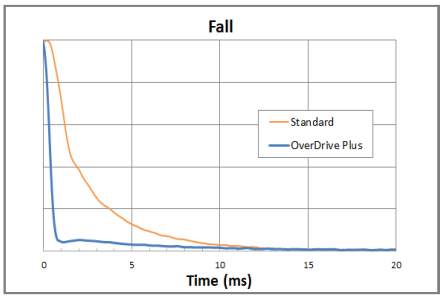


High Speed

The use of OverDrive Plus has shown reductions of the liquid crystal response times by a factor of up to 8x through use of the transient nematic effect, phase wrapping, and regional calibrations. The base technology is the transient nematic effect, utilizing intermediate transition voltages beyond the target voltage needed to achieve the desired phase value. The second technology development is the use of phase wrapping, which is based on the cyclical nature of light wherein adding or subtracting 2π from any phase value in a hologram results in an equivalent hologram. Often times it is faster to switch from phase1 → phase2 ± 2π instead of switching from phase1 → phase2. ODP automatically implements the faster of the two transitions, based on the calibration data. The third technology development is the utilization of regional calibrations of an SLM. Because most optical applications require precision on the order of a fraction of a wavelength, nearly all SLMs will have some inherent phase errors across the aperture that may impact the performance of the optical system. OverDrive Plus utilizes the phase modulation capabilities of the SLM to calibrate these errors out of the reflected wave, while also utilizing the regional calibrations when determining the length of time required for the transient nematic effect on a pixel by pixel basis.

OverDrive Plus for Ultra-High Speed Modulation





512 x 512Analog Spatial Light Modulator Specifications

Resolution: 512 x 512 **Array Size:** 7.68 x 7.68 mm **Zero-Order Diffraction Efficiency***: 61 - 95%
Fill Factor: 83.4 - 100% **Pixel Pitch**: 15 x 15 µm **Controller:** PCIe 8-bit, PCIe 16-bit, DVI 16-bit

Wavelength	Wavefront Distortion	Liquid Crystal Response Time (Standard Efficiency / High Efficiency)			AR Coatings (Ravg <1%)
		P512/PDM512	HSP512/HSPDM512	ODP512/ODPDM512	
405 nm	λ/5	25 ms / 33.3 ms	N/A	3 ms / 4 ms	400 – 850 nm
532 nm	λ/7	33.3 ms / 45 ms	7 ms / 10 ms	3.5 ms / 4.5 ms	400 – 850 nm
635 nm	λ/8	33.3 ms / 45 ms	12 ms / 16.7 ms	4 ms / 5 ms	400 – 850 nm
785 nm	λ/10	55.5 / 80 ms	17.2 ms / 22.2 ms	4.5 ms / 5.5 ms	600 – 1300 nm
1064 nm	λ/10	66.7 / 100 ms	10 ms / 16.7 ms	5 ms / 6 ms	600 – 1300 nm
1550 nm	λ/12	100 / 130 ms	20 ms / 28.5 ms	6 ms / 7 ms	850 – 1650 nm

*Silicon backplane, performance varies as a function of wavelength.

Hardware Interface Options - Meadowlark Optics' SLMs come with multiple hardware interface options. For customers that prefer the computer to view the SLM as a secondary monitor, we offer a 16 bit DVI controller. For customers that require high speed operation and 16 bit addressing, we offer a PCIe 16-bit controller. For customers that require low latency transfers for OverDrive Plus we offer a PCIe 8-bit controller.


DVI 16-bit


Pcle 16-bit


Pcle 8-bit

512 x 512 Controller Models

Model	PCIe 8-bit	PCIe 16-bit	DVI 16-bit
Controller Phase Levels	256 / 8-bits	65,536 / 16-bits	65,536 / 16-bits
CPU to Controller Transfer Time (Computer Dependent)	0.6 ms	2.1 ms	16.7 ms

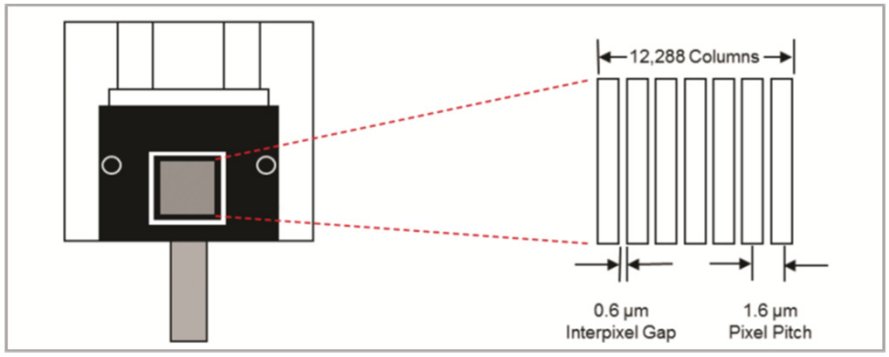
Spatial Light Modulators – 1 x 12,288

A Spatial Light Modulator (SLM) is a device that modulates light according to a fixed spatial (pixel) pattern. SLMs have an expanding role in several optical areas where light control on a pixel-by-pixel basis is critical for optimum system performance. SLMs are typically used to control incident light in amplitude-only, phase-only or the combination (phase-amplitude).

Meadowlark Optics (Meadowlark) manufactures and sells liquid crystal based Spatial Light Modulators for a variety of applications. Meadowlark SLMs operate in both reflection, (liquid crystal on silicon (LCoS)) and transmissive (glass-on-glass) modes. The 1x12,288 is based on our reflective LCoS technology.

Key features of our SLMs include high speed phase or amplitude modulation, high efficiency operation, and a complete, user-friendly graphical software interface.

Several parameters help define SLM characteristics. Pixel pitch is defined as the center-to-center spacing between adjacent pixels. Interpixel gap describes the edge-to-edge spacing between adjacent pixels.



Interpixel gap describes the edge-to-edge spacing between adjacent pixels. The chart below illustrates basic specifications used to describe our reflective SLM products.

Key Features

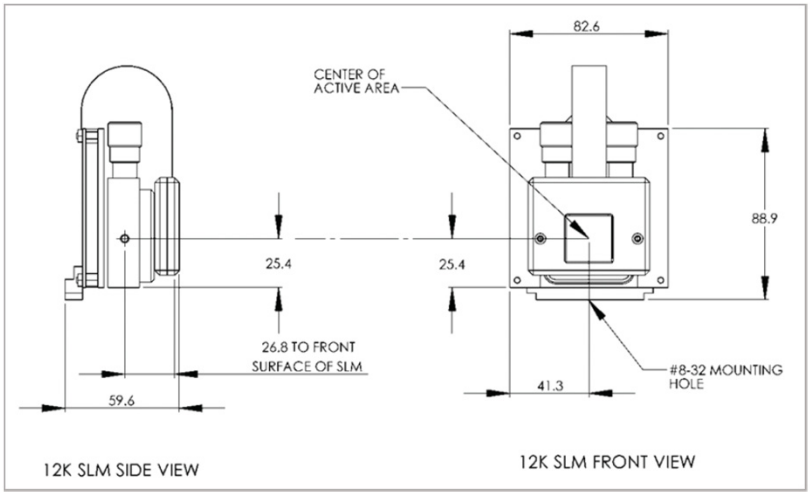
- High optical efficiency
- No mechanical motion
- High speed phase control
- Safe, low-voltage operation
- User-friendly graphical interface

Applications

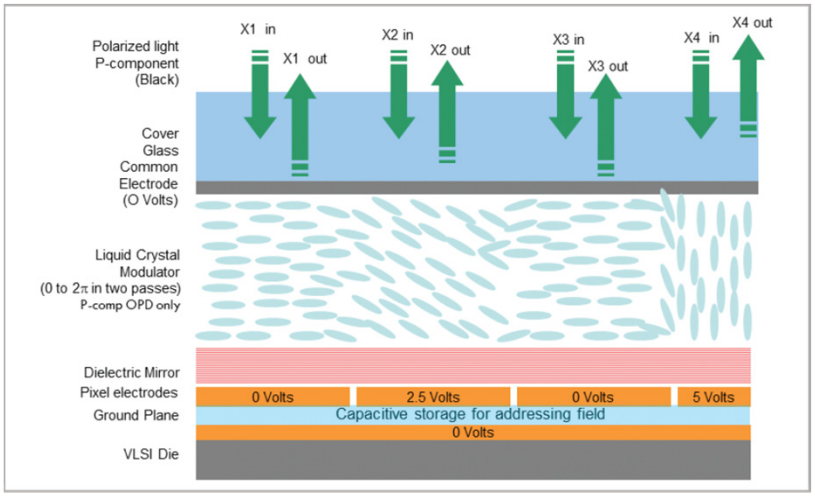
- Beam Steering
- Diffractive optics
- Ultra-fast pulse shaping
- Spectral tuning / processing
- Programmable phase gratings
- Programmable amplitude gratings

SLM Family

- 1920 x 1152
- 512 x 512
- 1 x 128
- Hex 127
- E-Series 512 x 512



Outline drawing showing front and side views of 1x12,288 Optical Head. Dimensions in millimeters.



Cross Section of Optically-efficient Phase Only LCoS SLM

1 x 12,288 Analog Spatial Light Modulator Specifications

Resolution: 1 x 12,288 **Array Size:** 19.66 x 19.66 mm **Diffraction Efficiency***: 99%
Fill Factor: 100% **Pixel Pitch**: 1.6 µm X 19.66 mm **Controller:** Pcle 16-bit

Wavelength	Liquid Crystal Response Time	AR Coatings (Ravg < 1%)
Model HSP12K		
405 nm	N/A	N/A
532 nm	4.5 ms	400 – 850 nm
635 nm	5 ms	400 – 850 nm
785 nm	8.5 ms	600 – 1300 nm
1064 nm	15 ms	600 – 1300 nm
1550 nm	30 ms	850 – 1650 nm

*Silicon backplane, performance varies as a function of wavelength

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