Spatial Light Modulator Principles

Meadowlark Optics award-winning Spatial Light Modulators (SLMs) provide precision retardance control for spatially varying phase or amplitude requirements. Our SLMs consist of liquid crystal (LC) pixels, each independently addressed, acting as separate variable retarders. These SLMs are easily incorporated into optical systems requiring programmable masks and variable input/output devices. Applications include correlation, spectroscopy, data storage, ultrafast pulse shaping, optical computing, beam steering and wavefront correction for active and adaptive optics.

Basic construction and operation of an SLM is similar to our standard LC Variable Retarder described on pages 49-50. The ITO transparent conductor is photolithographically patterned into individual electrodes, creating independently controllable pixels. Standard SLM geometries are shown on page 65.

Minimizing pixel spacing is critical to optimize performance and resolution. Proprietary designs and techniques enable Meadowlark Optics to offer tight interpixel spacing. Custom pixel configurations are possible.

Spatial Light Modulator Applications
Spatial Light Modulators are being used in a diverse range of new applications including:
- **Microscopy**
- **Imaging polarimetry**
- **Optical data storage**
- **WDM gain flattening**
- **Wavefront correction**
- **Arbitrary pulse shaping**
- **Optical transform masks**
- **WDM add/drop modulators**
- **Multi-channel PMD correction**
- **Beam steering for live cell manipulation**
- **Holographic Displays**
- **Cinematography**
- **Optical Tweezers**
- **Astronomical Observation**
- **Fluorescence Photomasking**

Phase Control

Spatial phase control or modulation is accomplished without altering the intensity profile of an incident beam. Light linearly polarized parallel to the extraordinary axis of the LC material is phase modulated by the voltage applied across individual pixels. An optical path difference between adjacent pixels, tunable to one full-wave, is easily accomplished, as shown in figure 6-1.
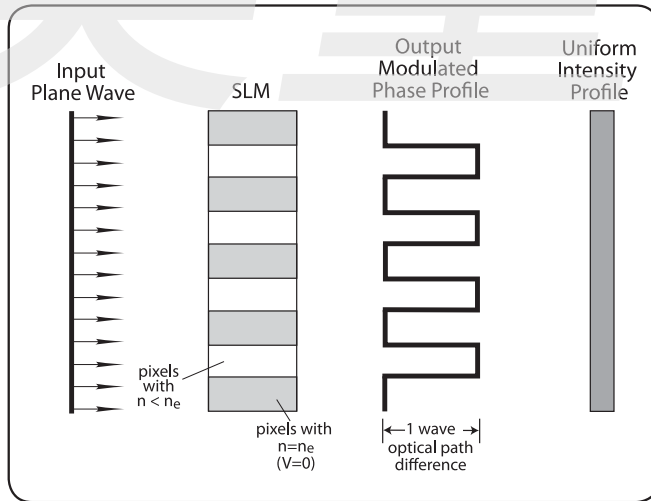
Amplitude Control

Spatial Light Modulators are also used for amplitude control or modulation. Here, the SLM modifies the beam intensity, but also spatially alters the phase profile, which may be undesirable. Correction is accomplished by using two spatial light modulators in series. The first performs the necessary amplitude modulation, also introducing a phase change. The second SLM restores the original, or desired phase relationship between pixels. Polarizers are optional with an amplitude SLM. These polarizers are both rotatable and removable from the SLM housing.

The compact optical head is designed so that two units can be placed back-to-back, minimizing the path distance between modulators. Electrical connections exit one side of the optical head for convenience in handling and mounting.

All Meadowlark Optics SLMs conveniently interface with Model D3128 Controller described on page 67.

Fig. 6-1 With phase modulation, an optical path difference of up to one full-wave is produced between adjacent pixels of the Spatial Light Modulators. The output intensity remains uniform.

Spatial Light Modulators

Key Benefits

- **High transmission**
- **Compact optical housing design**
- **Computer controlled**
- **Phase or amplitude modulation**
- **Uses model D3128 SLM Controller**

Meadowlark Optics Spatial Light Modulators (SLMs) consist of patterned arrays of independently controlled liquid crystal (LC) variable retarders. Our high-resolution SLMs are electronically programmable and interface to our Model D3128 SLM Controller. Meadowlark Optics offers both linear and hexagonal pixel geometries.
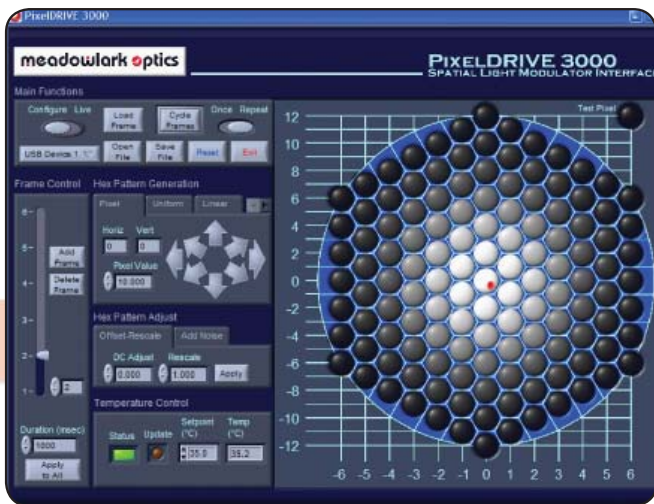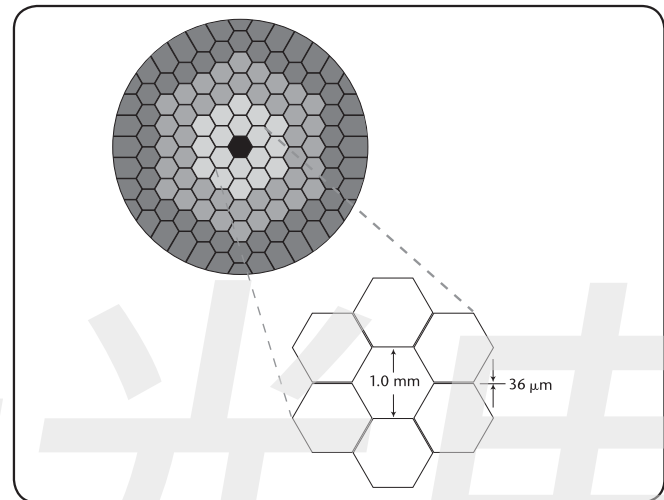
Hex Spatial Light Modulator

Our two dimensional SLMs are designed for adaptive optics applications. A two dimensional array of Liquid Crystal Variable Retarders 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. Examples include astronomical imaging with ground-based telescopes and medical imaging through body fluids. High-energy laser users also benefit from active phase compensation for beam profile correction.

Linear Array Spatial Light Modulator

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. These SLMs find use in other applications including Hadamard spectroscopy, optical data storage and wavefront compensation.

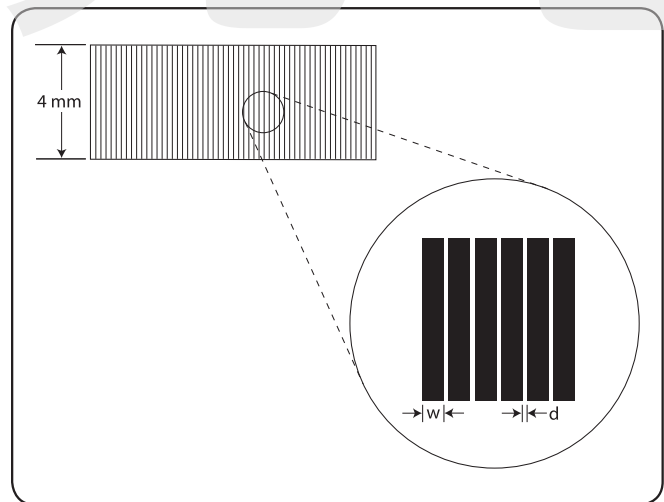**Fig. 6-2**   Hexagonal SLM pixel geometry

Fig. 6-3   Linear SLM pixel geometry
w = 98 um and d = 4 um

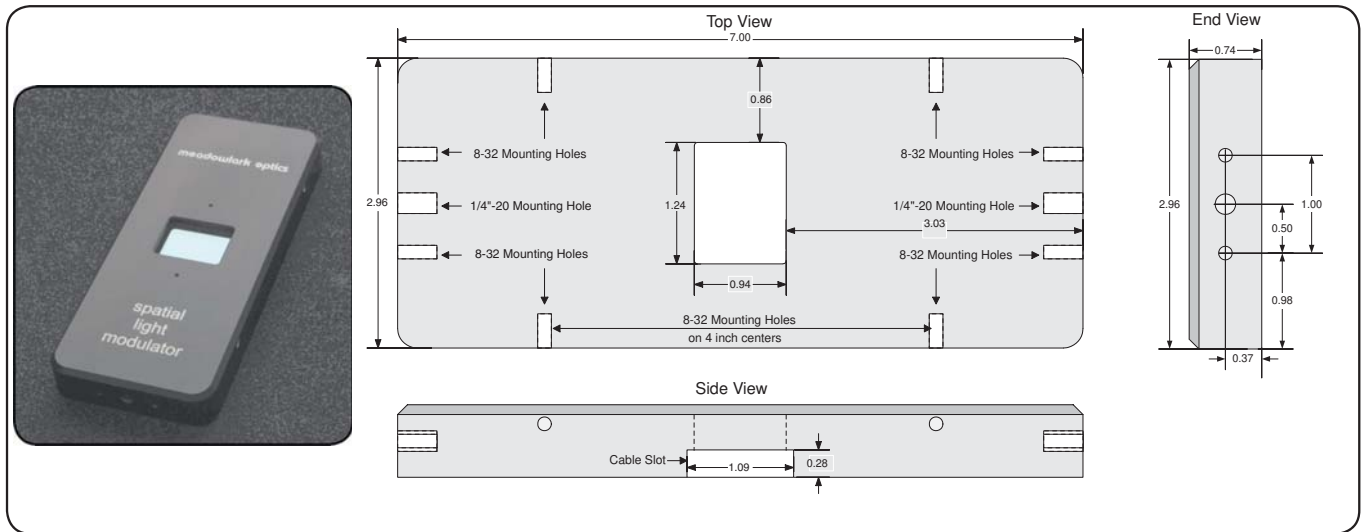*Custom Spatial Light Modulators are available.*

Spatial Light Modulators

Fig. 6-4   Spatial Light Modulator Mechanical Drawing

SPECIFICATIONS

Retarder Material	Nematic liquid crystal
Substrate Material	Optical quality synthetic fused silica
Center Wavelength	450-1800 nm (specify)
Modulation Range	
Phase (minimum) Amplitude	1λ optical path difference 0-100%
Retardance Uniformity	≤ 2% rms variation over clear aperture
Transmitted Wavefront Distortion (at 632.8 nm)	≤ λ/4
Surface Quality	40-20 scratch and dig
Beam Deviation	≤ 2 arc min
Transmittance	> 90% (without polarizers)
Reflectance (per surface)	≤ 0.5% at normal incidence
Dimensions (L x W x H)	7.00 x 2.96 x 0.74 in.
Recommended Safe Operating Limit	500 W/cm^2, CW 300 mJ/cm^2, 10 ns, 532 nm
Temperature Range	10° C to 45° C

Note that the D3128 is included with purchase of the SLM system, see page 67 for specifications

ORDERING INFORMATION

Name Pixel Width (µm)	Pixel Geometry	Version	Part Number
1 x 128	98µm x 4mm linear	Phase	SSP - 128P - λ
		Amplitude	SSP - 128A - λ
Hexagonal 127	1mm across	Phase	Hex - 127P - λ
		Amplitude	Hex - 127A - λ

Please specify your operating wavelength λ in nanometers when ordering.

Two year and three year extended warranty options available, please contact your Meadowlark Optics sales engineer

OPTIONAL POLARIZERS

Type	Wavelength Range (nm)	Part Number
Visible	450 - 700	SDP - VIS
Near Infrared 1	775 - 890	SDP - IR1
Near Infrared 2	890 - 1800	SDP - IR2

Spatial Light Modulator Controller

Meadowlark Optics Spatial Light Modulator Controller allows for independent voltage control of up to 128 liquid crystal cells or pixels.

The SLM Controller connects via USB cable to a Windows™ based computer. Supplied software allows for convenient setting of individual pixel retardance and for the programming of retardance profiles across a pixelated device. Custom software can be written using the included LabVIEW™ Virtual Instrument Library to allow for integration into custom applications.

ORDERING INFORMATION

Item	Output Channels	Part Number
SLM Controller	128	D3128

SPECIFICATIONS

Output Voltage	2 kHz ac square wave digitally adjustable 0-10 V rms
Voltage Resolution	2.44 mV (12 bit)
Computer Interface	USB
Power Requirements	100-240 V ac 47-63 Hz 1 A
Dimensions (L x W x H)	9.50 x 6.25 x 1.50 in.
Weight	2 lbs.

Minimum System Requirements
- PC with Pentium III class processor
- 64 MB RAM
- CD ROM drive
- 40 MB hard drive space
- USB Port
- Windows™ 98/ME/2000/XP/Vista
- Use of LabVIEW Instrument Library requires LabVIEW version 6.1 or higher

Please note that the D3128 is included with purchase of the SLM system, see page 66 for specifications