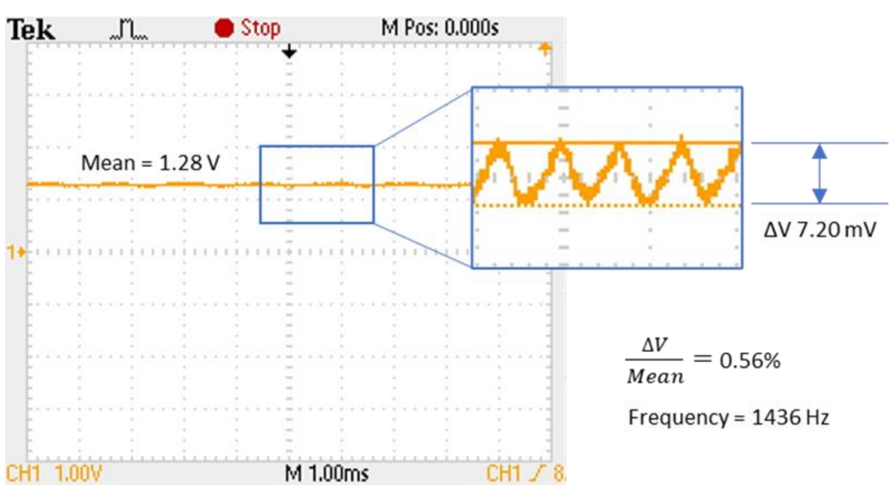
Spatial Light Modulator – 1024 x 1024

High Speed Analog, Phase Only – up to 2 kHz

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 (1400 Hz). This combination provides users with the fastest response times with high phase stability. The 1024 x 1024 SLM is good for applications requiring high speed, high diffraction efficiency, low phase ripple and high-power lasers.

High Phase Stability – Making an LCOS SLM faster usually means the phase stability is worse. However, we've combined our traditional analog drive scheme with new proprietary technologies to suppress phase instabilities to 0.05% to 2.0% without compromising speed. Phase ripple is quantified by measuring the variation in intensity of the 1st order diffracted spot as compared to the mean intensity while writing a blazed phase grating to the SLM. Since phase stability varies as a function of pixel voltage, this measurement approach is an average and does not represent all scenarios. If your application requires extremely low phase ripple, please contact a Meadowlark Solutions Engineer for more information on the 19x12 SLM



Typical data showing phase stability of the HSP1K-488-800 at 532 nm

SLM Features

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High resolution

High speed

High Phase Stability

Pure analog phase control

High first order efficiency

High reflectivity

High power handling

On-board Memory

Wavelengths from 488-1650 nm

Software Features

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Input and Output Triggers

Image Generation

Automated Sequencing

Wavefront Calibration

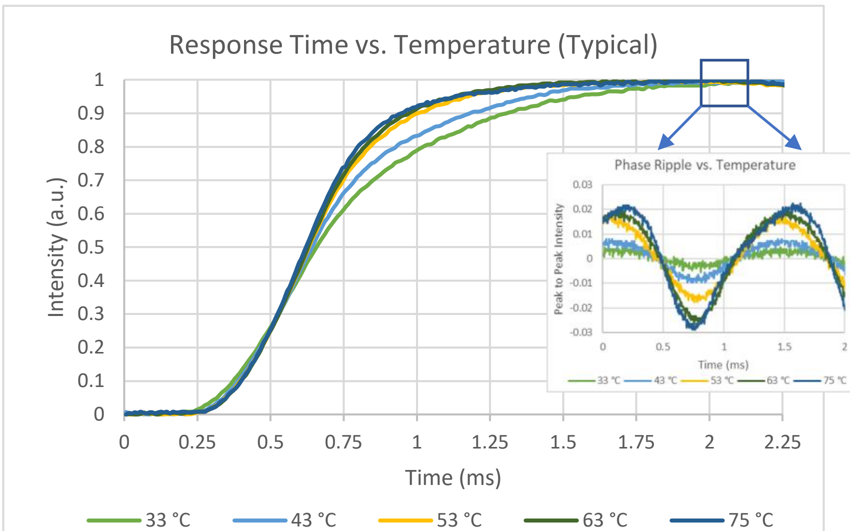
Global and Regional Look Up Tables

Temperature Monitoring

Look-up-table Calibration Kit

High Speed with High Phase Stability - Great care was taken in the design of the 1024 x 1024 silicon backplane to enable high speed operation while simultaneously maximizing phase stability. The 1024 x 1024 SLM is incredibly fast with liquid crystal response times ranging from 0.6 to 8 ms (wavelength dependent) for a full wave of modulation. In our ultra-high speed model customers can control the temperature set point to find the perfect balance between switching speed and phase stability.

Tunable temperature control to balance speed and stability

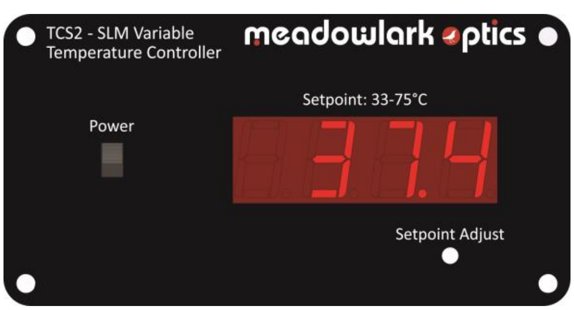


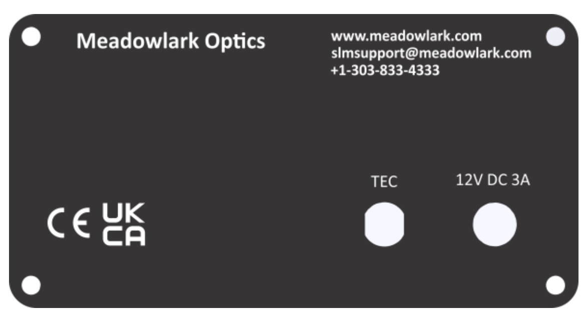
Sub-millisecond liquid crystal response times are measured in the far field. Images applied to the SLM are toggled between an 8-pixel, 2π phase grating and a solid image. Data captured while operating from 33°C to 75°C, using 10 to 90% reference levels. Results show typical switching speeds and phase stability at 532 nm.

TEC Heater

Part Number TCS2

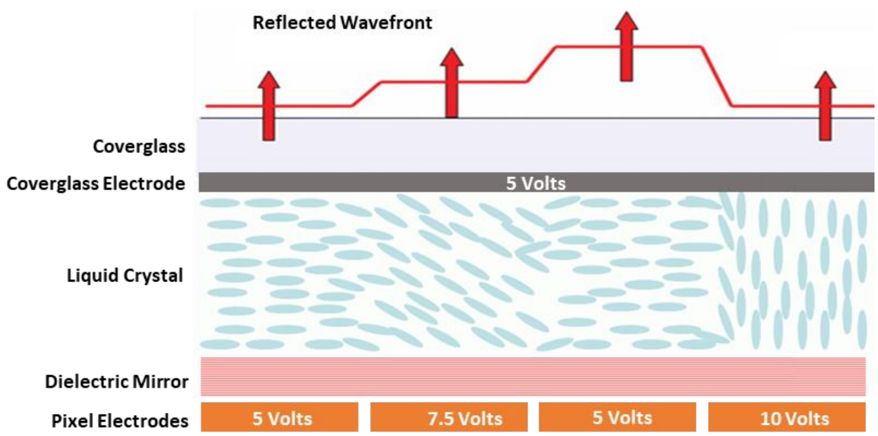
Thermoelectric Cooler (TEC) gives the user control over the temperature in which to operate the SLM. Heating the liquid crystals increase the switching speed, and cooling the liquid crystals improves phase stability.

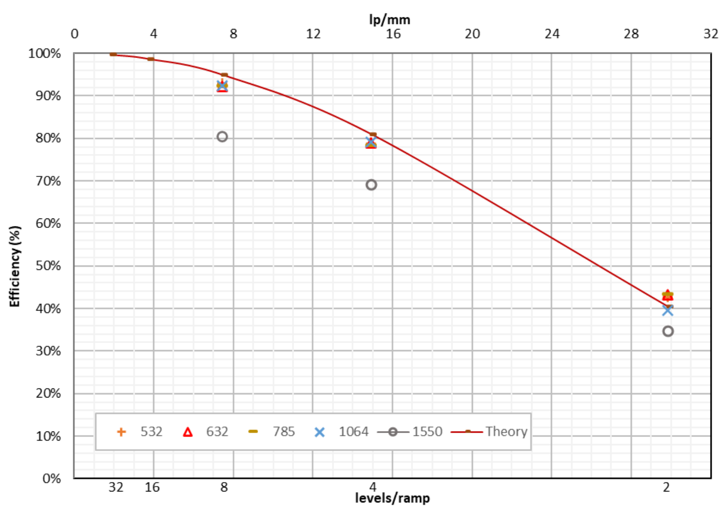




Diffraction Efficiency (0th-order) – This is the amount of light retained in the 0th-order (dc) when writing solid grayscale images to the SLM as compared to the amount of light in the 0^{th} order when the SLM is replaced with a reference mirror. This measurement quantifies losses in the coverglass coatings, losses due to wavelength dependent reflectivity of the pixel pads, as well as losses to diffraction from reflecting off the pixilated structure of the backplane. In the case of a dielectric mirror coated model, the measurement accounts for losses due to imperfect reflectivity of this dielectric mirror coating. The 0^{th} order diffraction efficiency will vary as a function of wavelength due to differences in coating materials and designs. It will also vary with pixel value due to the inherent change in the index of refraction of the liquid crystal that results in a change in the Fresnel reflections inside the liquid crystal cell. Most standard SLMs will range from 70 – 90%, while the dielectric mirror coated models will range from 92 – 98%.

High Efficiency Dielectric Mirror Coating – Optically, the backplane is converted into a flat dielectric mirror by depositing 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.

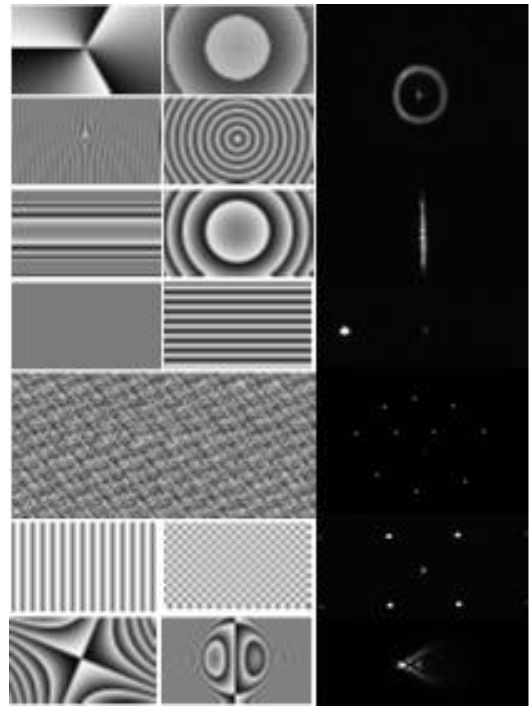




Typical Measured 1st Order Diffraction Efficiency

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 0^{th} order when no pattern is written to the SLM. 1^{st}-order diffraction efficiency varies as a function of the number of phase levels, or pixels, in the phase ramp. Example measurement data taken at various wavelengths is shown below for phase ramps with 2 to 8 phase levels between 0 and 2π.

Software - Meadowlark Optics' SLMs are supplied with a graphical user interface and software development kits that support LabVIEW, Matlab, Python, 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.

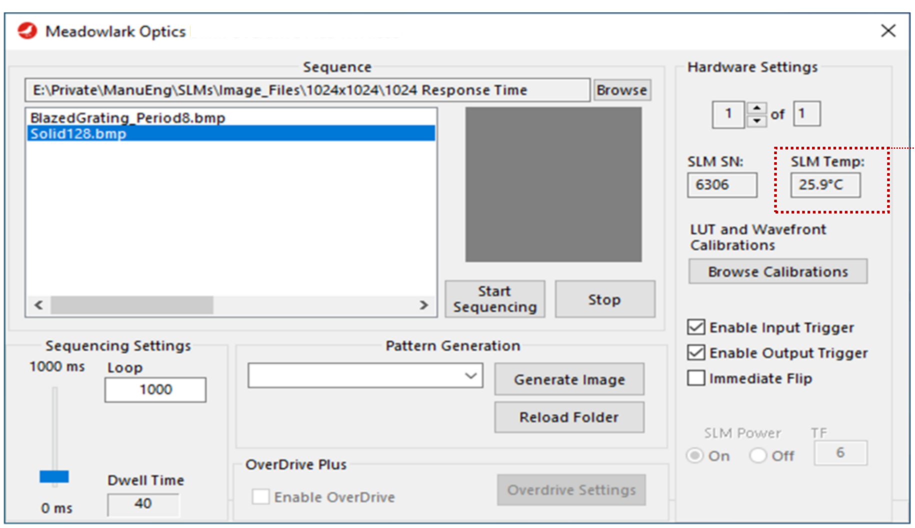


Global or Regional Calibrations - Regional calibrations provide the highest spatial phase fidelity commercially available by regionally characterizing the phase response to voltage and calibrating on a pixel-by-pixel basis.

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

Optional Look-Up-Table Calibration Kit (Part Number LUT1)
Meadowlark includes a calibrated LUT at one of our standard test sources (405, 532, 635, 785, 1064, or 1550 nm). If the user wants to work at a different wavelength, we recommend purchasing our Look-Up-Table Calibration Kit. It provides the tools needed to create a custom LUT based on the user's wavelength and operating temperature for optimal performance. The kit is shipped with software and a National Instruments NI-6000 data acquisition card. The user only needs to provide a photodetector at their desired wavelength.

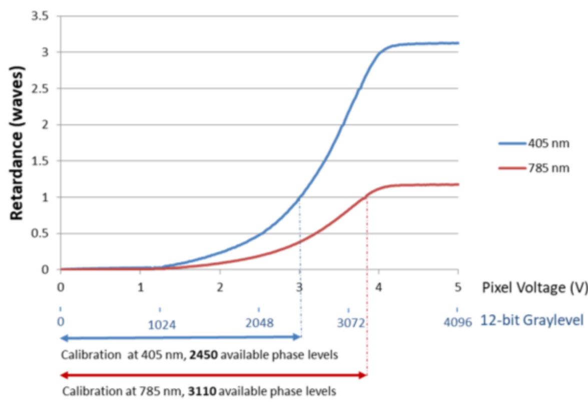


On chip temperature sensors allow the user to monitor the SLM temperature either through the example program or the software developer kits.

Hardware Interface - The 1024 x 1024 SLM system includes a Gen3 x8 PCIe controller with input and output triggers and low latency image transfers. Triggering can be performed on SLM chip refresh period boundaries of 696 µs, or even in the middle of refresh periods for applications requiring the SLM be tightly synchronized to external hardware. The controller also includes 752 frames of internal memory that can be loaded in advance, then sequenced at full speed in order to minimize traffic on the PCIe bus during operation. Using the 8-bit input/12-bit out design enables the SLM to support a broad wavelength range without sacrificing linear phase levels

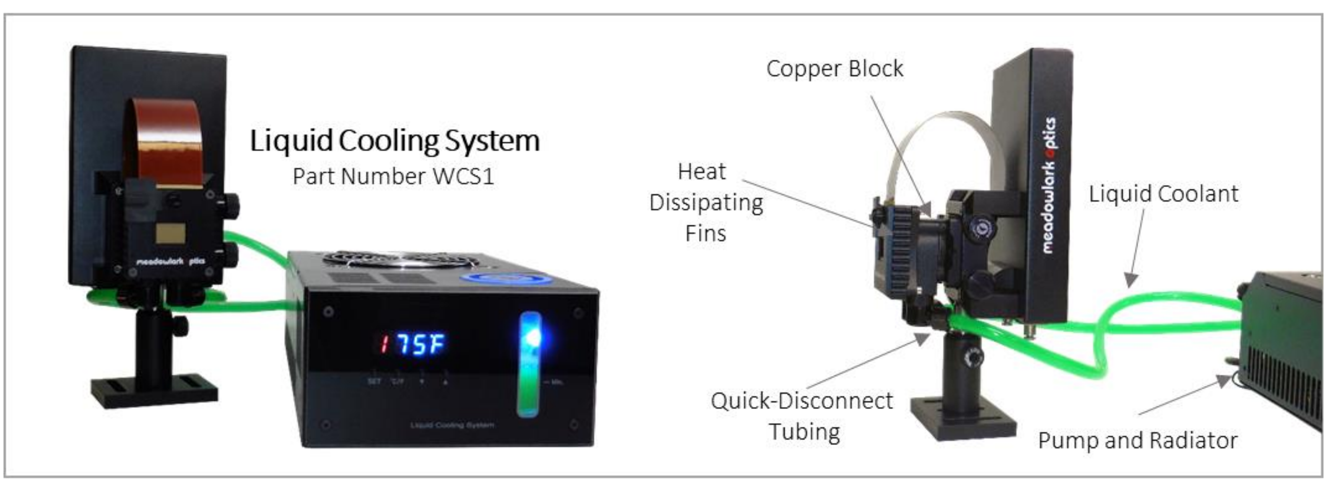
ONE SLM supports a broad wavelength range without losing linear phase levels

PCIe Controller supports high frame rates (up to 1436.1 Hz)



High Power Capability - Meadowlark SLMs are designed for compatibility with high power lasers through use of low absorption materials, large pixel pads, dielectric mirror options, and liquid cooling. If you are using a high power laser please contact Meadowlark with more information about your average power, pulse width, repetition rate, and beam diameter incident on the SLM. We will compare your laser specifications to our catalog of collected measurements and make a recommendation for the power handling limit of your optical system.

Liquid Cooling System - A copper block is attached to the back of the optical head to draw heat out of the SLM chip. The copper block is coupled via 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. The liquid cooling system not only pulls heat away from the SLM, it also keeps the SLM at a consistent temperature to ensure no change in modulation occurs as temperature varies.



1024 x 1024 Analog Spatial Light Modulator Specifications

Resolution: 1024 x 1024
Fill Factor: 97.2%
Array Size: 17.40 x 17.40 mm
Pixel Pitch: 17 x 17 µm
Zero-Order Diffraction Efficiency: 75 - 87%
With Dielectric Mirror Coating: 92 – 98%

HIGH SPEED

Standard Calibration Wavelengths	HIGH SPEED Liquid Crystal Response Time			Calibrated Wavefront Distortion
	AR Coating Range 488 – 850 nm	AR Coating Range 500 – 1200 nm	AR Coating Range 850 – 1650 nm	
532 nm	≤ 1.0 ms	≤ 1.4 ms	–	λ/5
635 nm	≤ 1.3 ms	≤ 1.8 ms	–	λ/6
785 nm	≤ 1.8 ms	≤ 2.4 ms	–	λ/7
1064 nm	–	≤ 3.4 ms	≤ 5.5 ms	λ/10
1550 nm	–	–	≤ 8.0 ms	λ/12

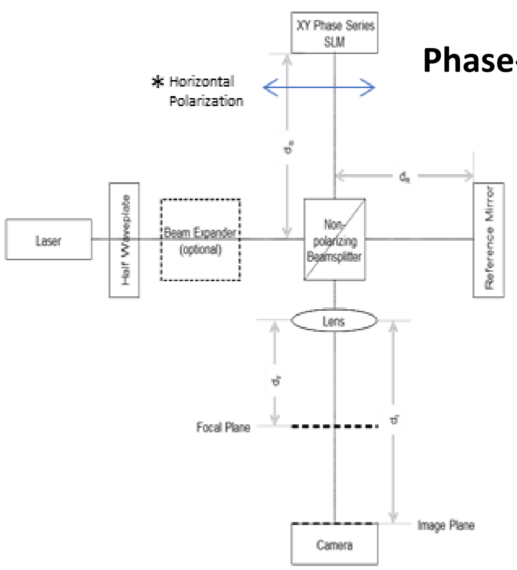
ULTRA HIGH SPEED

Standard Calibration Wavelengths	ULTRA HIGH SPEED Liquid Crystal Response Time			Calibrated Wavefront Distortion
	AR Coating Range 488 – 850 nm	AR Coating Range 500 – 1200 nm	AR Coating Range 850 – 1650 nm	
532 nm	≤ 0.6 ms	≤ 0.7 ms	–	λ/5
635 nm	≤ 0.7 ms	≤ 0.9 ms	–	λ/6
785 nm	≤ 0.9 ms	≤ 1.2 ms	–	λ/7
1064 nm	–	≤ 1.7 ms	≤ 2.0 ms	λ/10
1550 nm	–	–	≤ 3.9 ms	λ/12

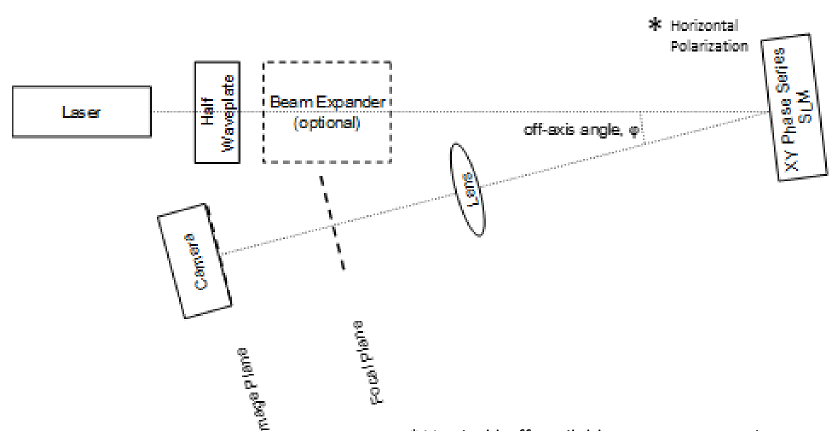
Model Number Guide:

UHSPDM-1K-488-850-PC8-WCS1

U: Ultra (optional)
HSP: High Speed
DM: Dielectric Mirror (optional)
1K: Resolution
488-850: Wavelength Range
PC8: Controller Type
WCS1: Temperature Control (optional)



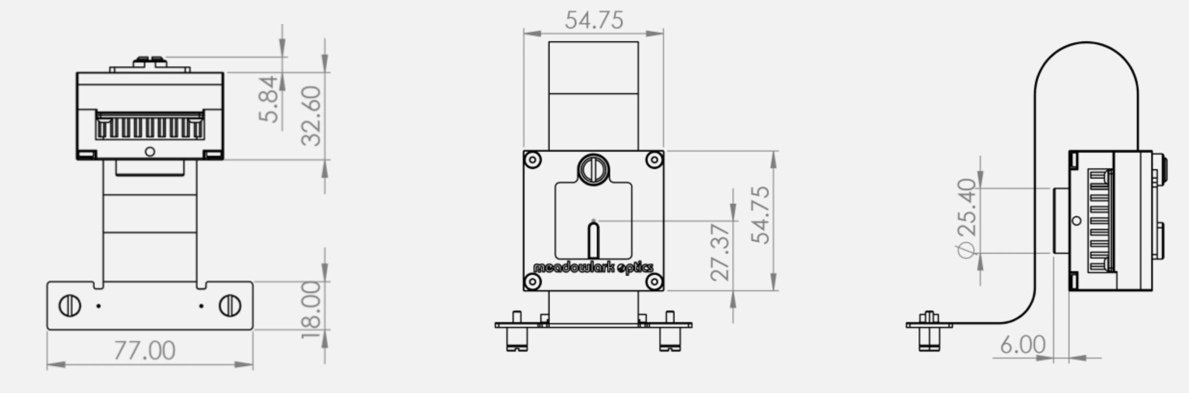
Phase-only Optical Test Setups



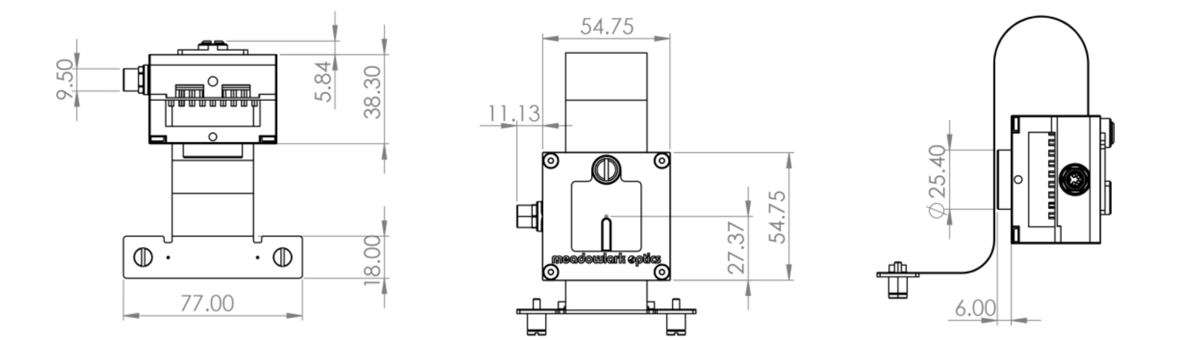
* Vertical buff available as a custom option.

1024 x 1024 Spatial Light Modulator Component Dimensions

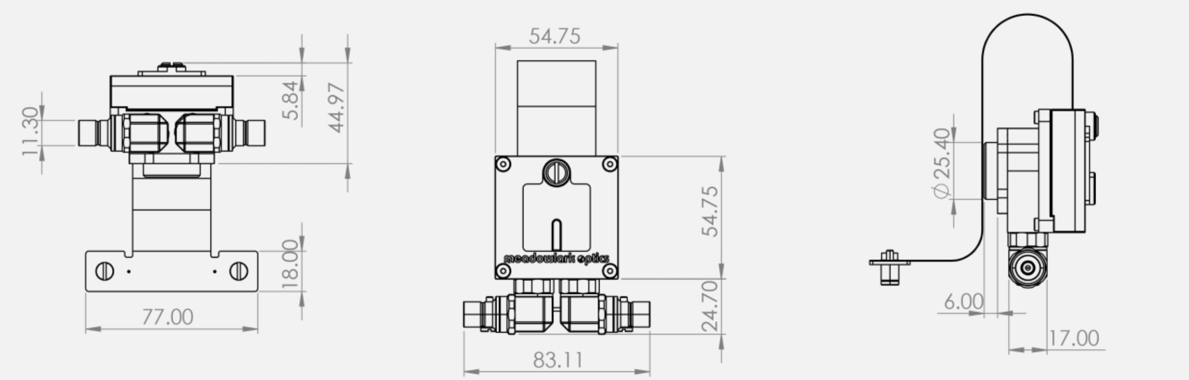
HSP1K Optical Head



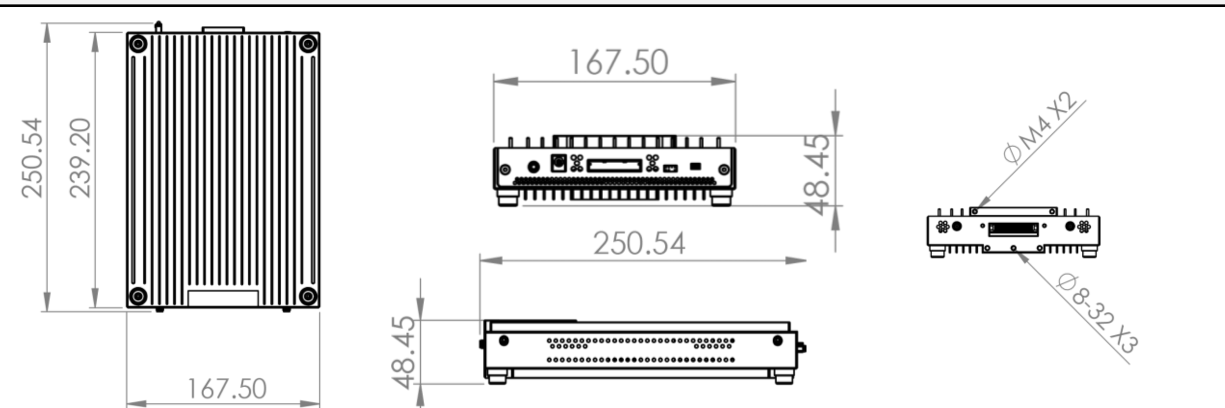
UHSP1K Optical Head



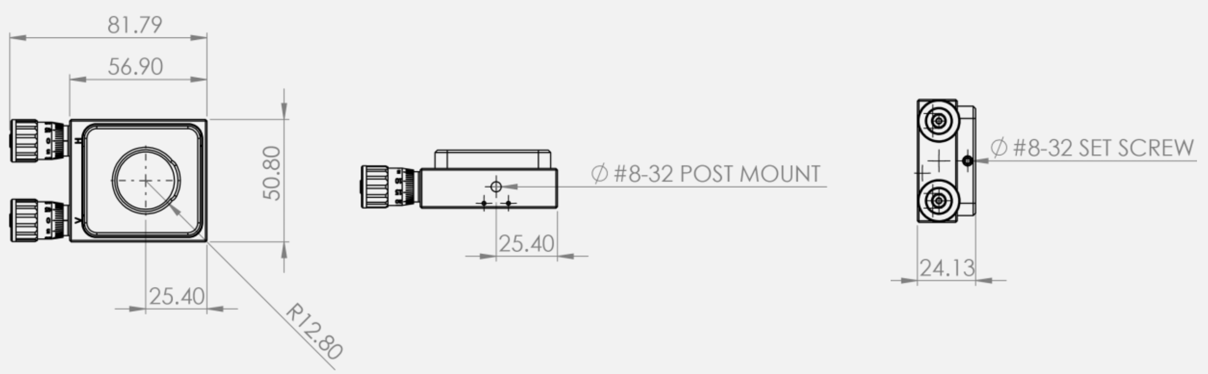
Liquid Cooled Optical Head



PCIe Controller



Tip/Tilt Stage Dimensions

VM1 Tip/Tilt Stage	
Siskiyou Tip/Tilt Stage