Wavefront Sensors: ShaH Family

ShaH-0620 sensor with telescope

ShaH-03500 high-speed wavefront sensor

A family of ShaH wavefront sensors represents recent progress of Del Mar Photonics in Shack-Hartmann-based technology. The performance of Shack-Hartmann sensors greatly depends on the quality of the lenslet arrays used. Del Mar Photonics developed a proprietary process of lenslet manufacturing, ensuring excellent quality of refractive lenslet arrays. The arrays can be AR coated on both sides without interfering with the micro-lens surface accuracy. Another advantage of the ShaH wavefront sensors is a highly optimized processing code. This makes possible real-time processing of the sensor data at the rate exceeding 1000 frames per second with a common PC. Due to utilizing low-level programming of the video GPU, it is possible to output the wavefront data with a resolution up to 512x512 pixels at a 500+ Hz frame rate. This mode is favorable for controlling modern LCOS wavefront correctors. The family of ShaH wavefront sensors includes several prototype models, starting from low-cost ShaH-0620 suitable for teaching laboratory to a high-end high-speed model, ShaH-03500. The latter utilizes a back-illuminated EM-gain CCD sensor with cooling down to -100 °C. This makes it possible to apply such a wavefront sensor in astronomy, remote sensing, etc.

Specification Table for ShaH wavefront sensors:

	ShaH-0620	ShaH-03500
Aperture dimension (diameter) [mm]	6	3
Number of subaperures for analysis	1000	250
Maximum tilt normal [rad]	±0.05	±0.05
Minimum measured curvature [m]	±0.06	±0.03
Repeatability RMS [2,3]	λ/100	λ/100
Absolute measurement accuracy RMS [2,3]	λ/25	λ/25
Relative measurement accuracy RMS [2,3]	λ/100	λ/100
Relative measurement accuracy P-V [12]	λ/20	λ/20
Tilt measurement sensitivity [rad]	3E-6	5E-6
Curvature measurement sensitivity [m]	500	140
Spatial resolution [mm]	0.15	0.15
Acquisition frequency [Hz]	20	500
Processing frequency [Hz]	20	500
Working wavelength [nm]	400 - 1000	400 -1000
Calibrated waveband [nm]	100nm	100nm
Working temperature [^{0}C]	+10 to +40	0 to +35
Weight (max) [Kg]	0.3	2
Dimensions (LxHxW)	155x55x55	258x174x139

[1] At maximum an gular source size 0.04 rad. [2] Within 90% of input aperture

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Main features of the ShaH software:

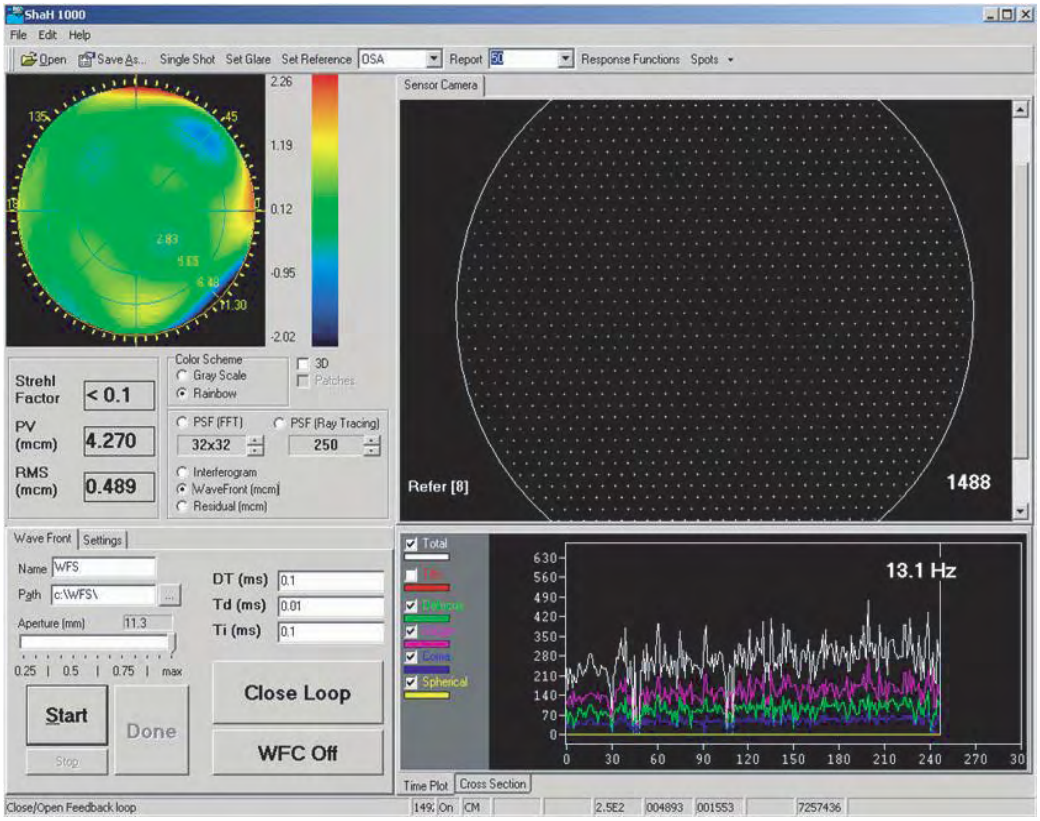
Wavefront acquisition: Continuous or external trigger mode; absolute (factory calibration) or referenced (user calibration) mode; background signal: save and subtract in real time. The time history is only limited by the free memory (approx. 50KB per frame). The stored data are available for retrospective display, processing, and analysis.

Real-time functions and displays: Wavefront display (units: microns or waves): 3D plot; 2D projection; synthesized interferogram; Zernike polynomial coefficients (up to 9th order); time history of 4 Zernike coefficients or orders; RMS and PV phase error.

Point Spread Function measurement: PSF display: 3D plot; 2D projection. Parameters: Strehl ratio; best focus plane; focal plane of ideal lens.

Retrospective functions and displays: All the functions available in real time, plus:
Wavefront display: 3D plot, 2D projection, and XY profile without tilt and/or focus and/or 3rd order aberrations; spot displacement map; residual zonal error of modal approximation.
Pupil calculation: automatic or manual.
MTF display: 2D or 3D plot; XY profile; best focus plane; user specified plane; focal plane of ideal lens.
Intensity display: 3D plot; 2D projection; XY profile; M^2 factor; intensity profile at given distance

ShaH Software Screenshot:



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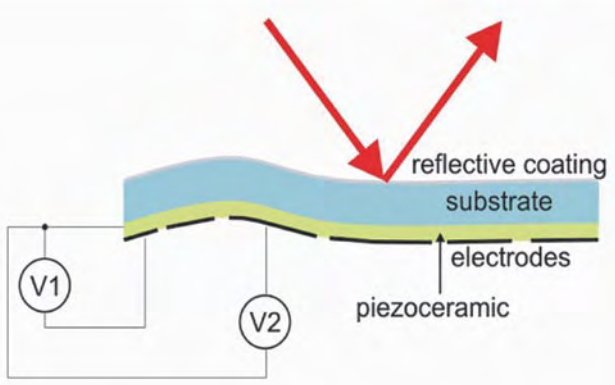
Unimorph Wavefront Corrections

Del Mar Photonics. has adopted and further developed technologies of mirror manufacturing initially proposed in Adaptive Optics Laboratory of Lomonosov Moscow State University. Recent advances in production technology allow us to manufacture a variety of deformable mirrors with 30-60mm aperture diameter, good surface quality, and record stroke for such type of the mirrors. With 30mm aperture, the maximum measured stroke is 50um. Unlike membrane mirrors, this type of wavefront correctors can bear an initial curvature. We have an experience in manufacturing the mirrors with an initial radius of curvature of 500mm. The reflective surface of the mirror can be cleaned by means of a conventional laboratory technique, which facilitates applications in university labs. The mirrors are shock- and vibration-resistant. In comparison with bimorph mirrors, our correctors demonstrate enhanced mechanical stability and better reliability. The mirrors are well-suited for compensation of low order aberrations (up to 4th order of Zernike polynomials).

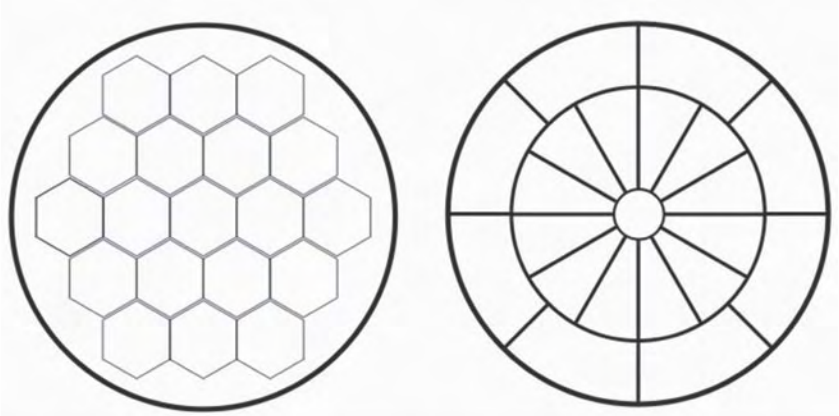


Responce functions

Principle of operation of unimorph mirrors

The unimorph mirror itself is constructed of a thin plate of piezo-electric material coupled to a substrate plate. The electrode pattern is deposited on the piezo-plate, which is then joined together with the substrate to form a sandwich structure. The ground plane is the back surface of the substrate in the unimorph. An optical surface is formed on the front surface of the substrate plate. The polarization of the piezo-electric plate is chosen so that to make the plate expand or contract when voltage is applied to the electrode. The differential expansion/contraction of the substrate and piezo-plates causes the unimorph to bend, much in the same way as a bi-metallic strip will bend when heated.

Typical electrode arrangement diagram for standard mirrors



19 electrodes HEX-arrangement

21 electrodes MDL-arrangement

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Typical specifications for unimorph deformable mirrors

Item	Value
Substrate	quartz, glass
Clear Aperture (diameter), mm	30-60
Stroke, μ	15-40
Number of control electrodes	13-36
Control voltage (max), V	± 300
Resonance frequency, Hz	> 2000
Reflecting coatings	protected Al, Ag, Cu, multilayer dielectric coating of reflectivity ρ≥99%
Optical Damage threshold in CW operation (up to), kW/cm² in pulsed operation (up to), J/cm²	 0.05 4
Surface quality (scratch-dig)	60-40
Hysteresis	<15 %
Operating temperature range °C	+10 +40
Storage temperature range °C	-30 / +70
Weight (max), Kg	0.1
Size, mm	Φ55x55

Control unit specification

Item	Value
Number of channels* (max)	32
Control interface	USB
Response delay (max), s	0.001
Output voltages, V	± 300
Control step, V	0.15
Standard frequency bandwidth at -3dB, 100nF load, Hz	> 500
Operating temperature range °C	-10 / +40
Storage temperature range °C	-10 / +70
Weight (max), Kg	8
Size, mm	440x400x140 (19" rack mountable)
Power supply	110-220V ; 50-60 Hz
Cable length between the amplifier and the adaptive mirror (standard), m	5

· Several units can be connected to the host computer for control mirrors with more than 32 electrodes.
· High voltage power supply is built in.

Control Software

Device drivers for Windows 2000/XP, diagnostic and control utility with graphic interface, SDK for C/C++.

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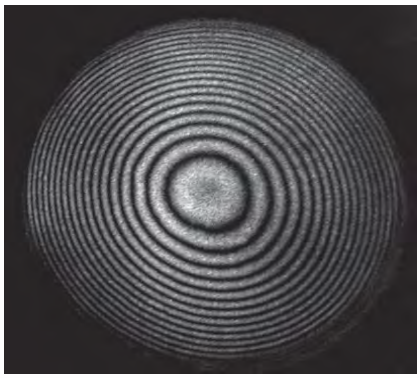
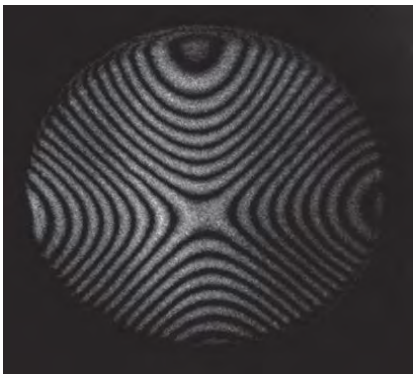
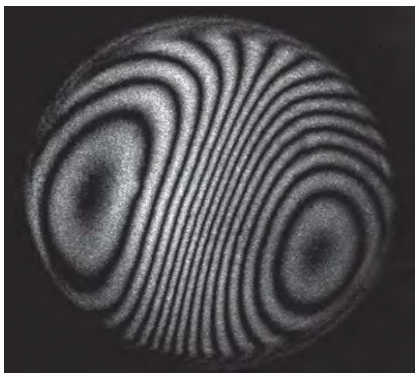
Some examples of mirror response functions measured with a Twyman-Green interferometer at λ=632.8nm, aperture 30mm



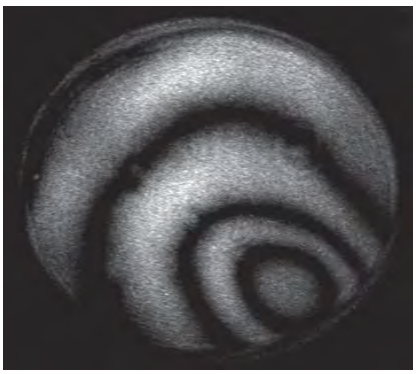
Defocus: +100V



Astigmatism: +200V

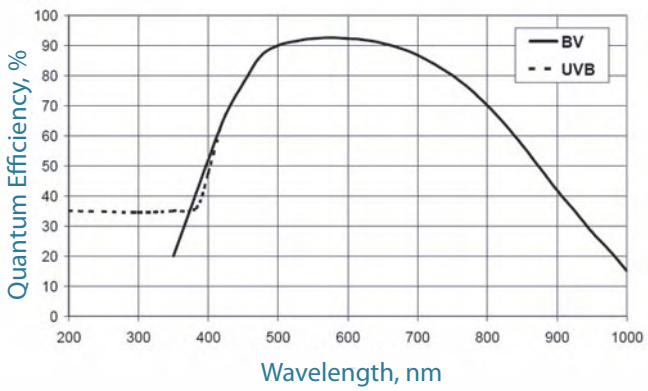


Coma: +200V



Electrode #4 (outer ring): +200V

QE spectral curve for ShaH-03500 high-speed wavefront sensor



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