

A close-up photograph of a black, rectangular Shack-Hartmann wavefront sensor. The sensor has a central circular lens with a white concentric circle pattern. There are four screws on the front face, one in each corner. The background is a dark, textured surface.

ALPA0

Leading the light

**Shack-Hartmann
Wavefront Sensors**



Our Company

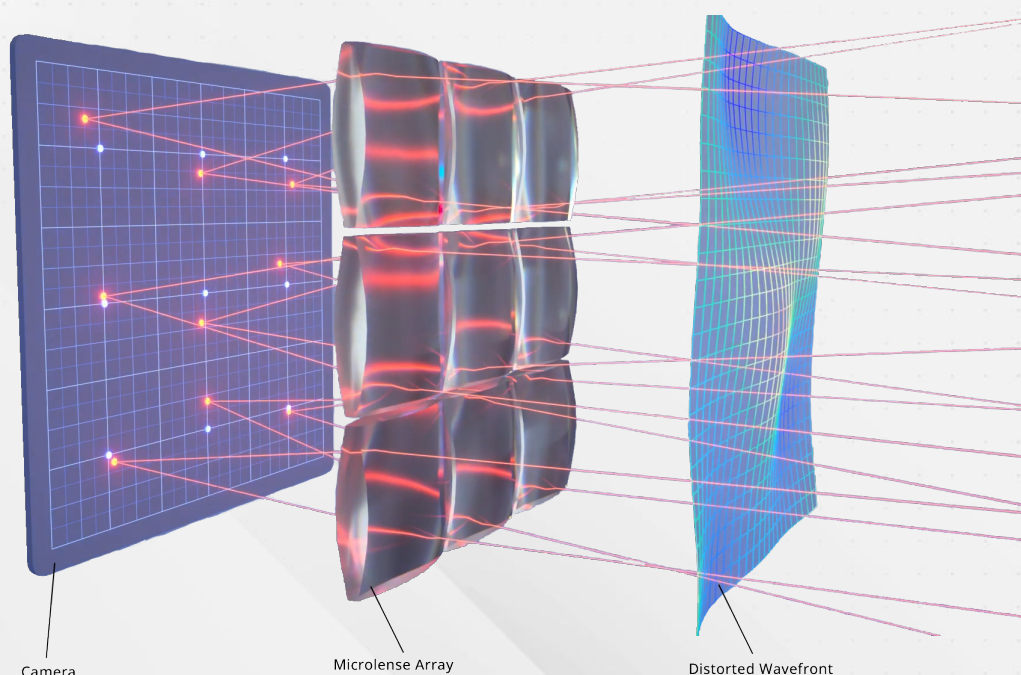
Experience the cutting edge of Adaptive Optics technology with the industry standard in design and manufacture of high-performance components for Adaptive Optics systems.

Since its inception in 2007, ALPAO has been consistently revolutionizing the field, offering innovative solutions tailored to a wide range of applications. With a strong commitment to research and development, ALPAO is at the forefront of optical technology, delivering unparalleled performance, reliability, and precision to its customers around the world.

Our Technology

ALPAO's Wavefront Sensors employ the Shack-Hartmann technology. This technology employs an array of micro-lenses to precisely analyze incoming light waves, converting local wavefront slopes into accurate wavefront reconstructions.

The result is a high-resolution, real-time assessment of optical aberrations, allowing users to achieve unparalleled levels of precision and image quality. Whether it's for research, industry, or advanced applications, Shack-Hartmann Wavefront Sensors offer a robust, reliable, and efficient solution that will elevate your optical performance to new heights.





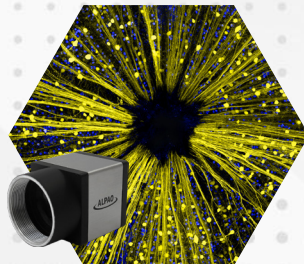
Key Features and Benefits

- Widest range of WFS optimized for Adaptive Optics
- Shack-Hartmann configuration for enhanced wavefront measurement accuracy
- Several spectral ranges covered: UV - Visible - NIR - SWIR
- High speed reduces the time needed for corrective actions
- High sensitivity allows for the correction of the slightest irregularities
- Low latency provides immediate feedback on wavefront distortions

Applications



Astronomy



Vision Science



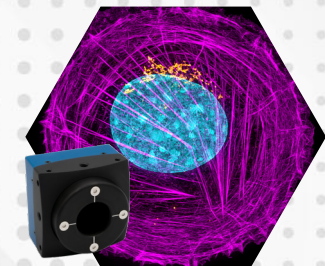
FSO - QKD - SSA



Space



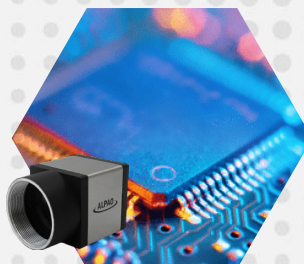
Laser



Microscopy



Defense



Microelectronics



Physics



Shack-Hartmann CMOS (SH-CMOS)

The SH-CMOS, ALPAO's Shack-Hartmann CMOS Wavefront Sensor is a highly effective and versatile tool that brings together the best in Adaptive Optics technology at an affordable price point. It offers users an accessible yet powerful solution for achieving exceptional levels of precision and image quality.

One of the standout features of the SH-CMOS is its integration of advanced CMOS technology with the trusted Shack-Hartmann configuration. This combination results in a high-speed, high-resolution sensor capable of accurately measuring and correcting complex optical aberrations in real-time. Its impressive sensitivity and dynamic range make it suitable for low-light conditions, while its rapid response time ensures excellent performance in time-sensitive applications.



In addition to its technical prowess, the SH-CMOS is designed with affordability in mind, making advanced wavefront sensing technology more accessible than ever before. Its seamless compatibility with ALPAO's comprehensive suite of Adaptive Optics components and software allows users to create a tailored, cost-effective solution to meet their specific needs. The exceptional support provided by ALPAO's team of experts further ensures a smooth implementation process and ongoing assistance throughout the product's lifecycle.

Its combination of advanced technology, ease of integration, and cost-effectiveness make it a compelling choice for researchers and industry professionals alike. By investing in the SH-CMOS, you gain access to a high-performance wavefront sensing solution backed by ALPAO's expertise and commitment to customer satisfaction.



SH-CMOS Technical Specifications

Number of sub-apertures	50x50
Microlens pitch (μm)	96.6
Pupil Diameter full ROI (mm)	4.83

Lowest acquisition frequency (Hz)	118
Highest acquisition frequency full ROI (Hz)	477

Peak quantum efficiency (%)	67
Photons for SNR=1 (ph/frame/sub-aperture)	100
Read-out noise (e ⁻ RMS)	2.1

Tip-Tilt range full ROI ($\mu\text{m PV}$)	62
Defocus range full ROI ($\mu\text{m PV}$)	15
Repeatability (nm RMS)	2
Optical spectral range (nm)	VIS

WFS sub-aperture ROI	8x8	10x10	15x15	16x16	19x19	23x23	31x31	50x50	63x63
Compatible DM (Fried geometry)	DM69	DM97	DM192	DM241	DM292	DM468	DM820	-	DM3228

Camera acquisition frequency (Hz)	477	417	317	302	266	229	179	118	n/a
Read-out latency (μs)	5000	5000	5000	5000	5000	5000	5000	5000	n/a
Tip-Tilt range ($\mu\text{m PV}$)	7	10	16	17	21	26	37	61	n/a
Defocus range ($\mu\text{m PV}$)	1	2	4	4	5	6	9	15	n/a

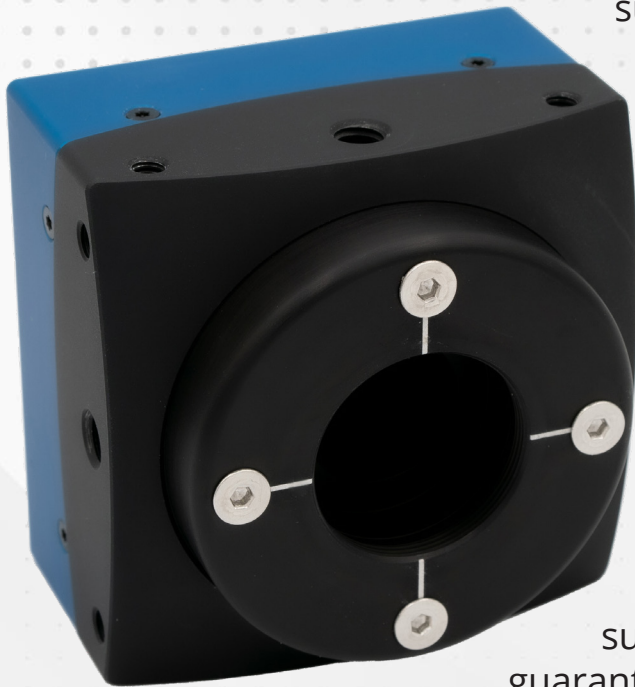


Shack-Hartmann CMOS fast (SH-CMOS fast)

The SH-CMOS fast, ALPAO's Shack-Hartmann CMOS Wavefront Sensor, designed for those seeking superior performance in time-sensitive applications. This variant of the SH-CMOS offers users an advanced solution for achieving exceptional levels of precision and image quality, with the added benefit of an enhanced acquisition frequency.

The SH-CMOS Fast maintains the same successful integration of advanced CMOS technology and trusted Shack-Hartmann configuration found in the original SH-CMOS. This pairing yields a high-speed, high-resolution sensor capable of accurately measuring and correcting complex optical aberrations in real-time. Its

superior acquisition frequency more than compensates for this, making it ideal for demanding applications where speed is crucial.



The SH-CMOS fast upholds ALPAO's commitment to making advanced wavefront sensing technology accessible. The sensor's seamless compatibility with ALPAO's comprehensive suite of Adaptive Optics components and software allows users to build a tailored, high-performance solution to meet their specific needs. Furthermore, the exceptional support provided by ALPAO's team of experts guarantees a smooth implementation process and ongoing assistance throughout the product's lifecycle.

By choosing the SH-CMOS fast, researchers and industry professionals can enjoy the perfect balance of cutting-edge technology, ease of integration, and superior acquisition frequency. This investment not only grants access to an advanced wavefront sensing solution, but also to ALPAO's expertise and unwavering commitment to customer satisfaction.



SH-CMOS fast Technical Specifications

Number of sub-apertures	64x64
Microlens pitch (μm)	112
Pupil Diameter full ROI (mm)	7.17

Lowest acquisition frequency (Hz)	1730
Highest acquisition frequency full ROI (Hz)	28140

Peak quantum efficiency (%)	50
Photons for SNR=1 (ph/frame/sub-aperture)	1000
Read-out noise (e^- RMS)	37

Tip-Tilt range full ROI ($\mu\text{m PV}$)	96
Defocus range full ROI ($\mu\text{m PV}$)	24
Repeatability (nm RMS)	2
Optical spectral range (nm)	VIS

WFS sub-aperture ROI	8x8	10x10	15x15	16x16	19x19	23x23	31x31	50x50	63x63
Compatible DM (Fried geometry)	DM69	DM97	DM192	DM241	DM292	DM468	DM820	-	DM3228

Camera acquisition frequency (Hz)	28140	22080	14660	13010	10020	8000	5220	2620	1730
Read-out latency (μs)	10.7	11.2	12.48	12.79	13.78	15.3	18.9	31.1	42.2
Tip-Tilt range ($\mu\text{m PV}$)	9	12	19	21	25	31	43	72	91
Defocus range ($\mu\text{m PV}$)	2	3	4	5	6	7	10	18	22



Shack-Hartmann EMCCD (SH-EMCCD)

The SH-EMCCD, ALPAO's high sensitivity Shack-Hartmann Wavefront Sensor, representing a significant step forward in Adaptive Optics technology. This sensor offers users an advanced solution for achieving exceptional levels of precision and image quality in even the most challenging conditions.

A standout feature of the SH-EMCCD is its integration of cutting-edge EMCCD technology with the trusted Shack-Hartmann configuration. This combination results in a high-speed, high-resolution sensor capable of accurately measuring and correcting complex optical aberrations in real-time. The exceptional sensitivity and dynamic range of the SH-EMCCD makes it the ideal choice for demanding applications. Additionally, its rapid response time ensures excellent performance in time-sensitive situations.



The SH-EMCCD is designed for those who require the utmost in wavefront sensing technology, without sacrificing ease of integration. Its seamless compatibility with ALPAO's comprehensive suite of Adaptive Optics components and software allows users to create a tailored, high-performance solution to meet their specific needs. The exceptional support provided by ALPAO's team of experts further ensures a smooth implementation process and ongoing assistance throughout the product's lifecycle.

By choosing the SH-EMCCD Wavefront Sensor, researchers and industry professionals can access a cutting-edge wavefront sensing solution that combines advanced EMCCD technology, ease of integration, and superior sensitivity compared to other technologies. This investment not only grants access to a high-performance wavefront sensor but also to ALPAO's expertise and unwavering commitment to customer satisfaction.



SH-EMCCD Technical Specifications

Number of sub-apertures	16x16
Microlens pitch (μm)	192
Pupil Diameter full ROI (mm)	3.07

Lowest acquisition frequency (Hz)	1004
Highest acquisition frequency full ROI (Hz)	1838

Peak quantum efficiency (%)	95
Photons for SNR=1 (ph/frame/sub-aperture)	3
Read-out noise (e ⁻ RMS)	0.1

Tip-Tilt range full ROI ($\mu\text{m PV}$)	13
Defocus range full ROI ($\mu\text{m PV}$)	3
Repeatability (nm RMS)	2
Optical spectral range (nm)	VIS

WFS sub-aperture ROI	8x8	10x10	15x15	16x16	19x19	23x23	31x31	50x50	63x63
Compatible DM (Fried geometry)	DM69	DM97	DM192	DM241	DM292	DM468	DM820	-	DM3228

Camera acquisition frequency (Hz)	1838	1004	1004	1004	n/a	n/a	n/a	n/a	n/a
Read-out latency (μs)	69	68	64.8	64.2	n/a	n/a	n/a	n/a	n/a
Tip-Tilt range ($\mu\text{m PV}$)	5	6	10	11	n/a	n/a	n/a	n/a	n/a
Defocus range ($\mu\text{m PV}$)	1	1	2	2	n/a	n/a	n/a	n/a	n/a



Shack-Hartmann EMCCD fast (SH-EMCCD fast)

The SH-EMCCD fast, ALPAO's high sensitivity Shack-Hartmann Wavefront Sensor with enhanced acquisition frequency, representing a significant advancement in Adaptive Optics technology. This sensor offers users an advanced solution for achieving exceptional levels of precision and image quality in even the most challenging conditions, while excelling in time-sensitive applications.



A standout feature of the SH-EMCCD fast is its integration of cutting-edge EMCCD technology with the trusted Shack-Hartmann configuration. This combination results in a high-speed, high-resolution sensor capable of accurately measuring and correcting complex optical aberrations in real-time. While the SH-EMCCD Fast does exhibit a higher read-out noise, its superior acquisition frequency compared to the SH-EMCCD makes it the ideal choice for demanding applications that require rapid responses.

The SH-EMCCD Fast is designed for those who require the utmost in wavefront sensing technology, without sacrificing ease of integration. Its seamless compatibility with ALPAO's comprehensive suite of Adaptive Optics components and software allows users to create a tailored, high-performance solution to meet their specific needs. The exceptional support provided by ALPAO's team of experts further ensures a smooth implementation process and ongoing assistance throughout the product's lifecycle.

By choosing the SH-EMCCD Fast Wavefront Sensor, researchers and industry professionals can access a cutting-edge wavefront sensing solution that combines advanced EMCCD technology, ease of integration, and unparalleled acquisition frequency compared to the standard SH-EMCCD. This investment not only grants access to a high-performance wavefront sensor but also to ALPAO's expertise and unwavering commitment to customer satisfaction.



SH-EMCCD fast Technical Specifications

Number of sub-apertures	24x24
Microlens pitch (μm)	192
Pupil Diameter full ROI (mm)	4.61

Lowest acquisition frequency (Hz)	2067
Highest acquisition frequency full ROI (Hz)	2067

Peak quantum efficiency (%)	95
Photons for SNR=1 (ph/frame/sub-aperture)	4
Read-out noise (e ⁻ RMS)	0.3

Tip-Tilt range full ROI (μm PV)	32
Defocus range full ROI (μm PV)	8
Repeatability (nm RMS)	2
Optical spectral range (nm)	VIS

WFS sub-aperture ROI	8x8	10x10	15x15	16x16	19x19	23x23	31x31	50x50	63x63
Compatible DM (Fried geometry)	DM69	DM97	DM192	DM241	DM292	DM468	DM820	-	DM3228

Camera acquisition frequency (Hz)	2067	2067	2067	2067	2067	2067	n/a	n/a	n/a
Read-out latency (μs)	43	43	43	43	43	43	n/a	n/a	n/a
Tip-tilt range (μm PV)	8	11	18	19	23	29	n/a	n/a	n/a
Defocus range (μm PV)	2	2	4	4	5	7	n/a	n/a	n/a



Shack-Hartmann InGaAs fast (SH-InGaAs fast)

The SH-InGaAs fast is ALPAO's state-of-the-art NIR Shack-Hartmann Wavefront Sensor. Featuring an enhanced acquisition frequency, which marks a significant breakthrough in Adaptive Optics technology. This sensor provides users with a sophisticated solution for attaining remarkable precision and image quality in the challenging NIR domain, while excelling in time-critical applications.



The SH-InGaAs Fast distinguishes itself through the seamless fusion of advanced InGaAs technology and the reliable Shack-Hartmann configuration. This synergy results in a swift, high-resolution sensor that accurately assesses and rectifies intricate optical aberrations in real-time within the NIR spectrum. Although the SH-InGaAs Fast presents a higher read-out noise, its exceptional acquisition frequency, compared to the standard SH-InGaAs, positions it as the go-to choice for applications demanding prompt responses.

Designed to cater to those who seek the pinnacle of NIR wavefront sensing technology without compromising on integration, the SH-InGaAs Fast is effortlessly compatible with ALPAO's all-encompassing suite of Adaptive Optics components and software. This allows users to develop a customized, high-performance solution tailored to their specific requirements. Moreover, the outstanding support offered by ALPAO's team of experts guarantees a seamless implementation process and ongoing assistance throughout the product's lifecycle.

By choosing the SH-InGaAs fast Wavefront Sensor, researchers and industry professionals can access a cutting-edge wavefront sensing solution that combines advanced InGaAs technology, ease of integration, and unparalleled acquisition frequency compared to the standard SH-InGaAs. This investment not only grants access to a high-performance wavefront sensor but also to ALPAO's expertise and unwavering commitment to customer satisfaction.



SH-InGaAs fast Technical Specifications

Number of sub-apertures	64x64
Microlens pitch (μm)	120
Pupil Diameter full ROI (mm)	7.68

Lowest acquisition frequency (Hz)	690
Highest acquisition frequency full ROI (Hz)	9596

Peak quantum efficiency (%)	80
Photons for SNR=1 (ph/frame/sub-aperture)	400
Read-out noise (e ⁻ RMS)	40

Tip-tilt and defocus range full ROI ($\mu\text{m PV}$)	123
Defocus range full ROI ($\mu\text{m PV}$)	30
Repeatability (nm RMS)	2
Optical spectral range (nm)	NIR

WFS sub-aperture ROI	8x8	10x10	15x15	16x16	19x19	23x23	31x31	50x50	63x63
Compatible DM (Fried geometry)	DM69	DM97	DM192	DM241	DM292	DM468	DM820	-	DM3228

Camera acquisition frequency (Hz)	9590	6510	4760	4760	3650	2900	1970	960	715
Read-out latency (μs)	23.3	23.1	22.9	22.8	22.7	22.4	22	21	20.2
Tip-Tilt range ($\mu\text{m PV}$)	11	15	25	27	32	40	56	92	118
Defocus range ($\mu\text{m PV}$)	2	3	6	6	8	10	14	23	29



Shack-Hartmann sCMOS (SH-sCMOS)

The SH-sCMOS, ALPAO's high-sensitivity Shack-Hartmann CMOS Wavefront Sensor, a superior and multifaceted tool that leverages the best in Adaptive Optics technology. This premium version of the SH-CMOS offers users a more sensitive and potent solution, further enhancing precision and image quality while maintaining an attractive price point.

The SH-sCMOS stands out with its blend of cutting-edge CMOS technology and the reliable Shack-Hartmann configuration. This fusion leads to a high-speed, high-resolution sensor capable of measuring and correcting complex optical aberrations in real-time with even greater sensitivity than its predecessor, the SH-CMOS. Its remarkable dynamic range and enhanced sensitivity make it ideal for low-light conditions, and its swift response time ensures exceptional performance in time-sensitive scenarios.



Just like its predecessor, the SH-sCMOS also prioritizes affordability, making state-of-the-art wavefront sensing technology even more attainable. Its seamless compatibility with

ALPAO's comprehensive suite of Adaptive Optics components and software enables users to create a customized, cost-effective solution that fits their unique needs. As always, ALPAO's team of experts provide unrivaled support, ensuring a seamless implementation process and ongoing assistance throughout the product's lifecycle.

The SH-sCMOS embodies a perfect blend of advanced technology, easy integration, and cost-effectiveness, making it an appealing choice for researchers and industry professionals. By choosing the SH-sCMOS, you are investing in a superior wavefront sensing solution, backed by ALPAO's expertise and unwavering commitment to customer satisfaction.



SH-sCMOS Technical Specifications

Number of sub-apertures	n/a
Microlens pitch (μm)	n/a
Pupil Diameter full ROI (mm)	n/a

Lowest acquisition frequency (Hz)	n/a
Highest acquisition frequency full ROI (Hz)	n/a

Peak quantum efficiency (%)	n/a
Photons for SNR=1 (ph/frame/sub-aperture)	n/a
Read-out noise (e ⁻ RMS)	n/a

Tip-tilt and defocus range full ROI ($\mu\text{m PV}$)	n/a
Defocus range full ROI ($\mu\text{m PV}$)	n/a
Repeatability (nm RMS)	n/a
Optical spectral range (nm)	n/a

WFS sub-aperture ROI	8x8	10x10	15x15	16x16	19x19	23x23	31x31	50x50	63x63
Compatible DM (Fried geometry)	DM69	DM97	DM192	DM241	DM292	DM468	DM820	-	DM3228

Camera acquisition frequency (Hz)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Read-out latency (μs)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Tip-Tilt range ($\mu\text{m PV}$)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Defocus range ($\mu\text{m PV}$)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a



Shack-Hartmann sCMOS UV (SH-sCMOS UV Ext.)

The SH-CMOS high-sensitivity UV Extended, ALPAO's specialized Shack-Hartmann CMOS Wavefront Sensor designed for UV applications, an effective and unique tool in ALPAO's WFS catalogue. This UV-specific sensor brings the best of Adaptive Optics technology into the UV spectrum, providing an accessible yet powerful solution for achieving exceptional levels of precision and image quality.

The SH-CMOS UV Extended is notable for its integration of advanced CMOS technology with the trusted Shack-Hartmann configuration, specifically adapted for UV operations. This results in a high-speed, high-resolution sensor capable of accurately measuring and correcting complex optical aberrations in real-time within the UV spectrum.



Its impressive sensitivity and dynamic range make it suitable for UV-light conditions, while its rapid response time ensures excellent performance in time-sensitive applications.

Keeping with ALPAO's commitment to affordability and accessibility, the SH-CMOS UV Extended is designed to bring advanced UV wavefront sensing

technology within reach. Its seamless compatibility with ALPAO's comprehensive suite of Adaptive Optics components and software allows users to create a tailored, cost-effective UV solution to meet their specific needs. The exceptional support provided by ALPAO's team of experts further ensures a smooth implementation process and ongoing assistance throughout the product's lifecycle.

The SH-CMOS UV Extended stands out with its advanced UV-specific technology, ease of integration, and cost-effectiveness, making it an attractive choice for researchers and industry professionals working in the UV spectrum. By investing in the SH-CMOS UV Extended, you gain access to a high-performance UV wavefront sensing solution backed by ALPAO's expertise and commitment to customer satisfaction.



SH-sCMOS UV Ext. Technical Specifications

Number of sub-apertures	n/a
Microlens pitch (μm)	n/a
Pupil Diameter full ROI (mm)	n/a

Lowest acquisition frequency (Hz)	n/a
Highest acquisition frequency full ROI (Hz)	n/a

Peak quantum efficiency (%)	n/a
Photons for SNR=1 (ph/frame/sub-aperture)	n/a
Read-out noise (e ⁻ RMS)	n/a

Tip-tilt and defocus range full ROI ($\mu\text{m PV}$)	n/a
Defocus range full ROI ($\mu\text{m PV}$)	n/a
Repeatability (nm RMS)	n/a
Optical spectral range (nm)	n/a

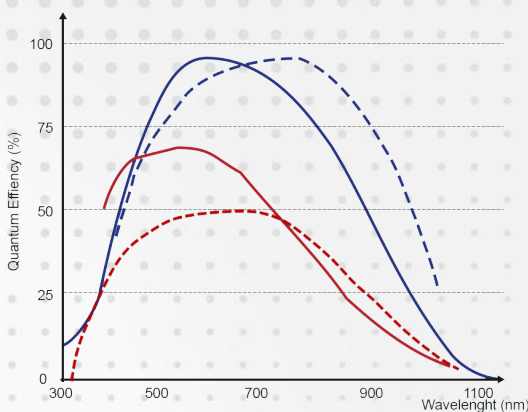
WFS sub-aperture ROI	8x8	10x10	15x15	16x16	19x19	23x23	31x31	50x50	63x63
Compatible DM (Fried geometry)	DM69	DM97	DM192	DM241	DM292	DM468	DM820	-	DM3228

Camera acquisition frequency (Hz)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Read-out latency (μs)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Tip-Tilt range ($\mu\text{m PV}$)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Defocus range ($\mu\text{m PV}$)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

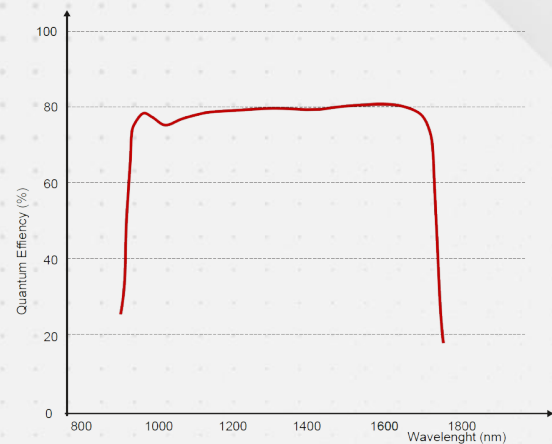


Complete Coverage of Spectral Ranges

The ALPAO SH-CMOS and SH-EMCCD wavefront sensors offer a wide spectral range of 350 to 1110 nm. We also offer the ALPAO SH-InGaAs fast sensor, specifically designed for the 950 to 1700 nm range. With our diverse range of wavefront sensors, we provide comprehensive coverage of spectral ranges, ensuring that we have the perfect solution for every application, in every spectral range.



Typical Quantum Efficiency of SH-EMCCD (in blue), SH-EMCCD fast (in dash blue), SH-CMOS (in red) and SH-CMOS fast (in dash red)



Typical Quantum Efficiency of SH-InGaAs fast (at 20°C, in red)

Software and Drivers

ALPAO WFS are designed to work with the ALPAO Core Engine (ACE) or the ALPAO RTC. These are not included and need to be purchased separately.

The ALPAO RTC includes the necessary hardware. The minimum configuration for ACE is 4Gb RAM, 100MB disk space, MATLAB® R2017a or higher.



Fast Wavefront Sensing

For atmospheric perturbation correction, kHz frequency wavefront sensors are needed. ALPAO WFS can be run up to 5 kHz.

Beyond frequency, latency is a key parameter for real time compensation of the perturbations. ALPAO WFS interfaces are designed for extremely low latency.

Thanks to their speed and low latency, those wavefront sensors are associated with the ALPAO Real-Time Computer (RTC) and ALPAO DM can reach AO bandwidth greater than 100Hz.

High Sensitivity Wavefront Sensors

Our SH-EMCCD and SH-EMCCD fast wavefront sensors are perfect for microscopy and astronomy applications, offering high sensitivity for exceptional performance. With EMCCD technology and low read-out noise, these sensors detect subtle wavefront distortions with precision.

Experience breakthroughs in these fields with our wavefront sensors, leveraging their high sensitivity and low read-out noise for remarkable results.

Customization Options

Our wavefront sensors can be customized for your particular needs, including real-time Adaptive Optics with pyramid wavefront sensors. If you have any question regarding a product and its specifications, please feel free to contact us, we will reply within the slightest of delays.



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