ATTOMETROLOGY
FOR EXTREME ENVIRONMENTS

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ACCURATE ROBUST SIMPLE

Real Time Interferometric Sensor

*FPS*3010 | *FPS*1010

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High-Precision, Real Time Interferometric Sensor.

Exceptionally Innovative. Surprisingly Simple.

MEASURE DISPLACEMENTS WITH PICOMETER RESOLUTION AND 10 MHz SAMPLING RATE

The FPS sensor family sets new standards in industrial displacement measurement applications. Based on attocube's patented fiber interferometer technology, FPS sensors can be applied to multipurpose displacement measurements – such as needed in extreme environmental positioning applications, coordinate measurement machines or micromachining applications. Real time interfaces and true standalone capabilities make the FPS sensors preferential for many high-bandwidth feedback and monitoring applications.

Ease of use

Sensors of the FPS family are unsurpassed in their ease of use and level of automation. A simple signal strength indicator makes alignment of the sensor a straightforward task, while a fully automated software routine calibrates and initializes the sensor on the fly.

Fast

All FPS sensors measure the position of the target with a bandwidth of 10 MHz and a resolution of 25 pm. At the same time, the sensor is compatible with displacement velocities of up to 1 m/s.

Real time interfaces

Built-in *AquadB* and serial word interfaces (high-speed serial link, *HSSL*) allow real-time position output at 10MHz bandwidth. This makes the sensor particularly useful for feedback applications and real-time position monitoring.

Multi axis

The FPS3010 provides three fully independent measurement axes, allowing parallel displacement measurements, data processing, and position output of three targets in real time. The one axis version FPS1010 is a cost-efficient single-axis version of the FPS3010.

Accurate

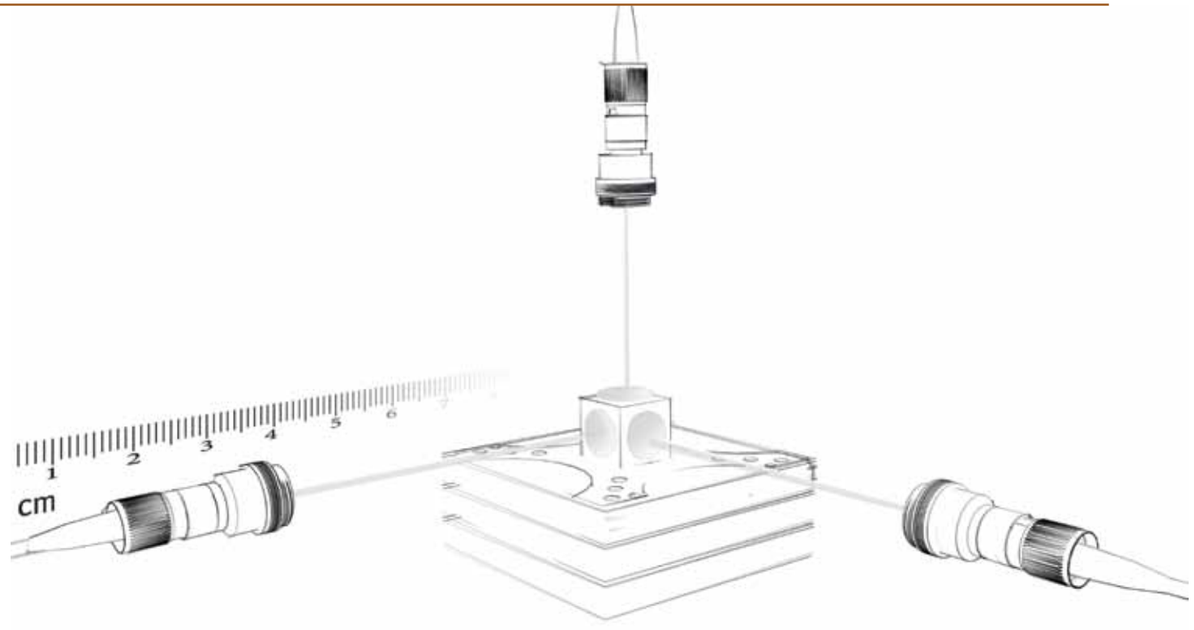
The built-in laser source of the FPS is locked to a molecular absorption frequency reference, making the detected displacement traceable to international length standards. All measurements are therefore truly accurate in a metrological sense.

Non-invasive

With a laser power of 75 µW per measurement axis, the FPS sensor family is considered truly non-invasive. There are hardly any other devices on the market, dissipating less energy at the target location while providing a similarly accurate position/displacement information.

Miniature

With a standard sensor head size of 15mm diameter and 12mm length, sensors of the FPS family belong to the smallest interferometric sensors available on the market. Fabricated from grade two Titanium, FPS sensors are compatible with various environments ranging from ultra-low temperature to high magnetic fields. Customized sensor head designs are available upon request.



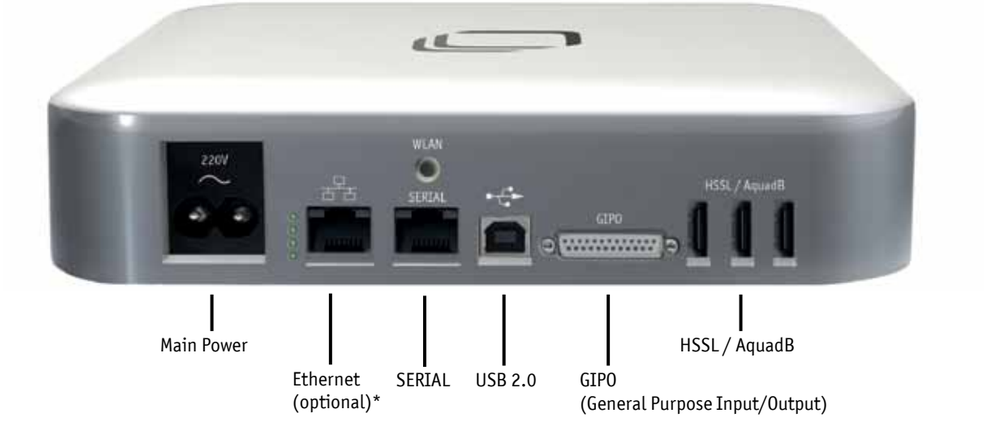
PRODUCT KEY FEATURES

> Multi-axis interferometer
> Standalone, turnkey operation
> Real-time digital interfaces
> High-speed FPGA electronics
> 10 MHz sampling rate
> 1 m/s maximum target velocity
> single-mode fiber-based sensors
> vacuum & extreme environment compatible

BENEFITS

> High bandwidth displacement detection
> Closed-loop motion control
> Vibrometry measurements at MHz range
> Thermal load on target << 75 µW
> No electrical connections to sensor head
> Cost-effective technology
> Industrial design and reliability

Real-Time Digital Interfaces.



High-speed digital serial and incremental interfaces.

The FPS sensor family of sensors is designed for standalone operation. While signals can be transferred to and stored on a personal computer using USB, all units are equipped with high-speed, digital interfaces for real-time position sensing and feedback applications. For each interferometer axis, an incremental *AquadB* and an absolute 48 bit high speed serial (*HSSL*) interface with 10 MHz bandwidth are available. The resolution of the *AquadB* interface is user-adjustable.

*Note: Ethernet option available in conjunction with /SYNC version. The Ethernet option is delivered with EPICS driver set.

Interface Specifications

target velocity [m/s]	resolution USB (abs.) 32 bit, 400 kHz [nm]	resolution HSSL (abs.) 48 bit, 10 MHz [nm]	resolution AquadB (inc.) 10 MHz [nm]
0.00001	0.025	0.025	0.025
0.0001	0.025	0.025	0.025
0.001	0.025	0.025	0.1
0.01	0.025	0.025	1
0.1	0.025	0.025	10
1	0.025	0.025	100

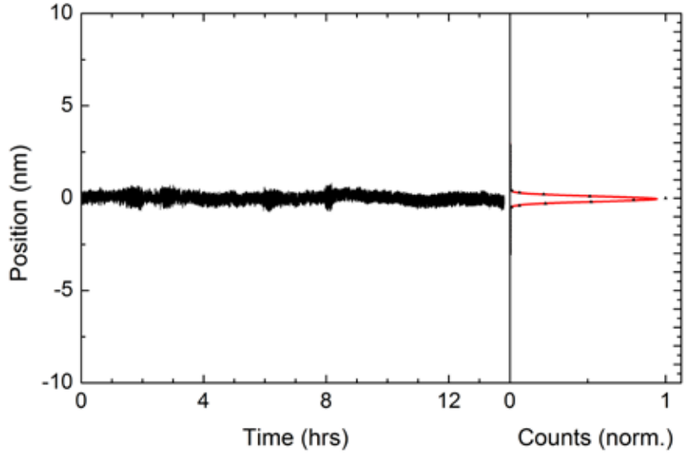
Simple Alignment. Turnkey Operation.

FPSensor iPad App

Ease of sensor alignment

Both FPS3010 and FPS1010 sensors are equipped with a sensor alignment algorithm. In alignment-mode, the sensor automatically measures the interferometric signal quality, quadrature shape, and other crucial parameters while the angular orientation of the sensor head is adjusted by the operator. This information, along with other parameters acquired by the interferometer hardware, are used to compute a simple signal strength value. This process makes alignment of the sensor a straight forward, single-parameter process. A patented technology enabling alignment tolerances of +/- 0.4° further simplifies this process.

Unsurpassed Signal Stability.



Measured Signal Stability	
working distance	2σ
[mm]	[nm]
20	0.286
70	0.530
120	1.035

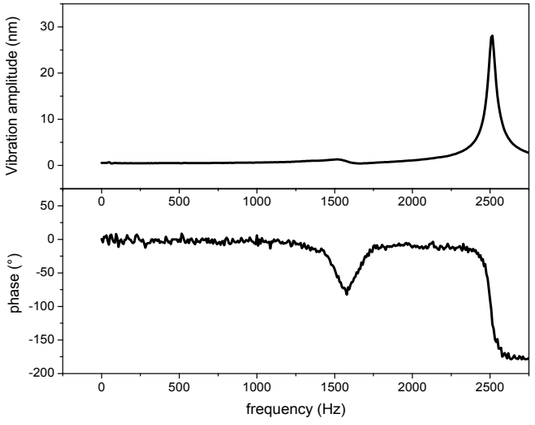
Long-term FPS signal stability as demonstrated on a 20 mm long Titanium vacuum reference cavity. The cavity is cooled to liquid Helium temperature (-269 °C) in order to minimize thermal expansion/compression effects. 68% of all position measurement data points lie within 286 pm, as measured at a 100 Hz bandwidth over 12 hrs.

Long-term picometer stability - demonstrated.

The intrinsic position signal stability of the FPS is unsurpassed - making it challenging to demonstrate the performance of the FPS sensors with standard tools and equipment. The measurements shown above were therefore recorded on an evacuated reference cavity with a relative length stability $\Delta l/l$ well below 10^{-8}. This stability was achieved by temperature stabilizing the Titanium cavity within few millikelvin at liquid Helium temperature (-269°C).

Due to the low coefficient of thermal expansion at said temperature, the Titanium cavity provides a reference in length approximately 10 times more stable than a corresponding ultra-low-expansion glass (ULE) cavity at ambient conditions. The plot shows position sensing data recorded on a 20 mm long cavity during a 12 hour period of time. The bandwidth of the measurement was 100Hz.

Real-Time Vibrometry Measurements.



Vibrometry measurement on a prototype xyz positioner measured with the FPS3010 and a piezo for excitation purpose. The excitation amplitude of the piezo was approximately 0.5nm.

Vibrometry measurements made simple.

The FPS3010 is not only a very capable real-time displacement sensor but it also serves the user as a powerful vibrometer. With its built-in fast-Fourier algorithm (FFT), the FPS-series directly detects the distribution of vibrational amplitudes in frequency space. Frequency and phase information of resonance peaks can be live-viewed on the iPad or PC-based FPS application tool. This live-view mode is available for measurements in a 1MHz bandwidth.The data above demonstrate the suitability of the FPS sensor for this type of application. In this specific case, the resonance frequency of a protoype xyz positioning stack was measured by exciting the stack with broad-band noise and detecting the mechanical response of the stack using the FPS3010. While the amplitude is already a good indicator as to whether or not resonance occurs, the phase relation between excitation and detection signal is the most robust measure of a resonance condition. In this case, the phase shift of 180° at approximately 2.5 kHz indicates the first normal-mode resonance of this mechanical system.

Specifications

FPS1010

FPS3010

	FPS1010		FPS3010	
Sensor				
number of axes	1		3	
working distance	0-400	mm	0-400	mm
digital sensitivity	25	pm	25	pm
maximum target velocity	1	m/s	1	m/s
repeatability	2	nm*	2	nm*
measurement bandwidth	10	MHz	10	MHz
Usability				
sensor alignment	semi-automated via WLAN, Ethernet, or USB			
sensor initialization	fully automated, turnkey			
realtime interfaces	digital AquadB output 48 bit serial word (HSSL)			
interface bandwidth	10 MHz			
other interfaces	USB, Ethernet, or WLAN			

	FPS1010		FPS3010	
Laser				
laser source	DFB laser		DFB laser	
wavelength	1530	nm	1530	nm
wavelength stability	20	ppb	20	ppb
laser power	75 typ.	µW	75 typ.	µW
Physical Properties				
sensor head dimensions *standard*	Ø 15/12 mm, l = 12 mm		Ø 15/12 mm, l = 12 mm	
sensor head dimensions *others*	on request		on request	
sensor head material	stainless steel, titanium		stainless steel, titanium	
optical fiber	Ø 250 µm, plastic or metallic coating		Ø 250 µm, plastic or metallic coating	
temperature range	mK ..373 K (100 °C)		mK ..373 K (100 °C)	
pressure range	$1x10^{-10}$ mbar .. 10 bar		$1x10^{-10}$ mbar .. 10 bar	
operation and mounting	any direction		any direction	
compatibility options	/LT/HV/UHV		/LT/HV/UHV	
ambient compensation	optional		optional	

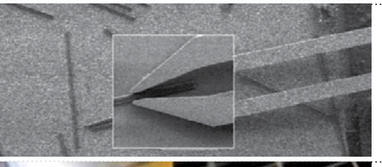
* @ 10 mm working distance (WD), 5 nm @ 100 mm WD

Attocube's Fiber Optical Sensor.

ENABLING NEW INDUSTRIAL AND RESEARCH APPLICATIONS

INDUSTRIAL MICROMACHINING
- Ultra-fast, absolute position control of cutting tools
- closed-loop sample motion with highest feedrates
- fast optical inspection of work pieces with nm accuracy
- circularity and straightness analysis of work pieces
- in-situ wear & tear and vibration measurements of high-speed cutting tools

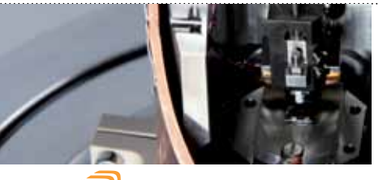
ULTRA-HIGH FREQUENCY POSITION DETECTION IN AEROSPACE INDUSTRY
- axial runout detection at MHz sampling rate with nm resolution
- blade clearance and deformation/growth detection
- vibration level measurements
- circularity analysis
- clearance measurement under extreme environment (heat)



STATE OF THE ART NANOTECHNOLOGY APPLICATIONS
- Multi-axis wafer stepper positioning
- Interferometric table for lithography applications in Scanning Electron Microscopes
- Highest-accuracy positioning of manipulators, probes, and other tools
- Vibrometry measurements on quantum optomechanical resonators and other micro- or nanometer sized objects

GENERAL INDUSTRIAL APPLICATIONS
- Optical roughness detection
- Profilometry and surface topography measurements
- Portable calibration and routine performance checking of machines
- Straightness and circularity measurements
- Traceable absolute distance measurements

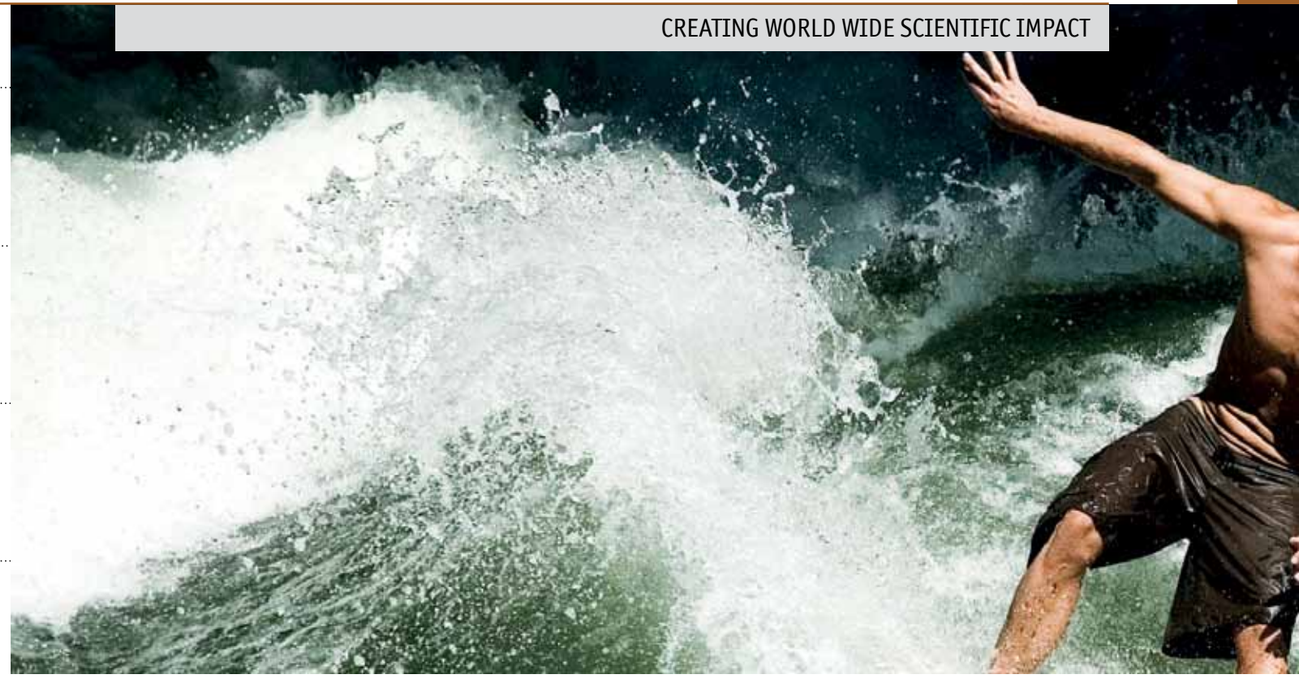
RESEARCH APPLICATIONS
- Measurements of thermal expansion of low expansion materials
- Interferometric measurements of seismic waves
- Absolute force detection for tensile studies over large ranges using AFM cantilevers
- Highest-accuracy active positioning of lenses and samples in x-ray, synchrotron, and visible-light optics applications



CLOSED-LOOP NANOPOSITIONING FOR EXTREME ENVIRONMENTS
- Sample / sensor positioning with highest stability & resolution
- Stitching functionality in lithography and scanning applications
- Large range closed-loop scanning with no hysteresis or creep
- High speed nanofocusing
- Coarse positioning for AFM, STM, SNOM,...

Satisfied Customers.

CREATING WORLD WIDE SCIENTIFIC IMPACT



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