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IDS Sensors

Real-Time Displacement Sensor for Machine Integration

attocube systems AG | Königinstrasse 11a | D - 80539 München | Germany
Tel.: +49 89 2877 809 - 0 | Fax: +49 89 2877 809 - 19 | info@attocube.com
www.attocube.com

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attoSENSORICS
Ultra Precision Sensors

Glossary

attoSENSORICS technical terms

Fabry-Pérot Interferometer

Our FPS and IDS Sensor Systems rely on a low-finesse fiber-based Fabry-Perot Interferometer. A great advantage of this technology over other displacement sensing techniques is their electronic-free sensor heads. The physical dimension of the sensor head is reduced to the millimeter range. This miniaturization makes the sensor ultra-compact and also compatible with extreme environments such as ultra high vacuum and low temperature.

The fiber-based design allows flexible alignment, thus making multiaxis measurements and large distances of fiber length (even covering kilometer long distances) an easy task.

Environmental Compensation Unit (ECU)

The ECU provides a fully automated refractive index compensation for contactless interferometric measurements at ambient conditions. Variations in air pressure, temperature, and humidity are recorded and used to automatically compensate for changes in the refractive index.

Focusing Sensor Head

The focusing sensor heads D4/F17 (sensor head diameter of 4 mm with a focal length of 17 mm), M12/F40, and D12/F2.8 are suitable to measure on a wide range of target materials as well as target surface qualities with low, medium, or high surface reflectivity. For example, the focusing sensor heads make it possible to measure on a BK7 glass object with a reflectivity of only 4 %. The sensor head M15.5/F40 includes a flexure structure to adjust the beam path angle with ±1°.

Collimating Sensor Head

The sensor head M12/C7.6 (sensor head with a M12 metric thread and a beam diameter of 7.6 mm) is suited with a collimating optics type especially designed for the use with retroreflectors. It is optimized to measure over longer distances.

Working Distance

Distance between the front side of the sensor head and the target where a continuous measurement is possible.

Absolute Distance

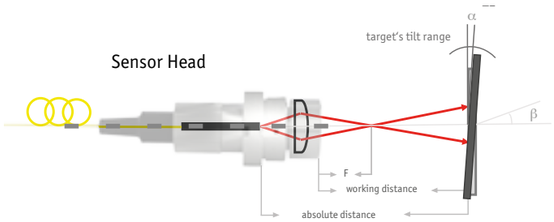
Distance between the end of the fiber, which is represented by the mechanical stop, and the target.

Focal Length

The focal length F is the distance between the front side of the sensor head and the focal point.

Alignment Tolerance

The angular alignment tolerance represents the target's tilt range in respect to the laser beam (α in the figure below). The laser beam might not be parallel to the central axis of the sensor head (β in the figure below). At retroreflectors, the center of roration is defined as the center of the retroreflector.

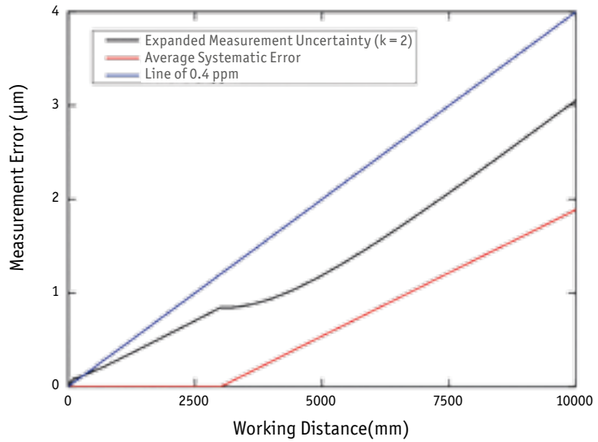


PTB-Certification for Interferometers

highest accuracy over long distances

attocube's interferometers have been tested by the National Metrology Institute of Germany (PTB). The accuracy of the interferometers has been confirmed at various pressure, humidity and temperature conditions over several days, thus also confirming the high performance and reliability of attocube's ECU (environmental compensation unit).

The IDS was checked over a working distance of 10 meters. The systematic error of measurement was quantified to 0.0 ppm between a working distance of 0 m and 3 m. The total expanded measurement uncertainty (k=2), consisting of the systematic and random measurement errors mostly remains under 0.4 ppm.



The figure above shows the systematic measurement error and the measurement uncertainty of the IDS as certified by the PTB. They depend on the working distance. The blue line represents a measurement error of 0.4 ppm that surrounds the other lines, while the average systematic error is always lower than 0.19 ppm.

Download the calibration certificate for the IDS/FPS at our website:

IDS certificate

Loan Service for IDS

testing the interferometer under real conditions

attocube's laser interferometer is suitable for a broad field of applications. Since each application case has its own constraints and interfaces, the real benefits of the IDS appear when it is used under real conditions.

For checking the applicability and performance of the laser interferometer, attocube offers a loan service for testing it. This allows to use the interferometer under real conditions and to estimate its benefits and accuracy.

Loan Period

The loan service allows to use and test the interferometer for up to 2 weeks.

Data for Installation/Integration

All documents, software and DLLs for using and integrating the device into the environment are provided with the loan package.

Expert Consulting for Installation

Our experienced team supports the whole process of installation and integration and provides advice for your projects.

Delivery Scope of Loan Package

1. IDS including accessories (e.g. power supply)
2. Environmental Compensation Unit (ECU)
3. Selection of collimating and focusing sensor heads for ambient conditions
4. Mounting Kits for aligning the sensor head
5. Optical items: glass target, plane mirror, and retroreflector
6. Fiber cleaning tool

CUSTOMER FEEDBACK

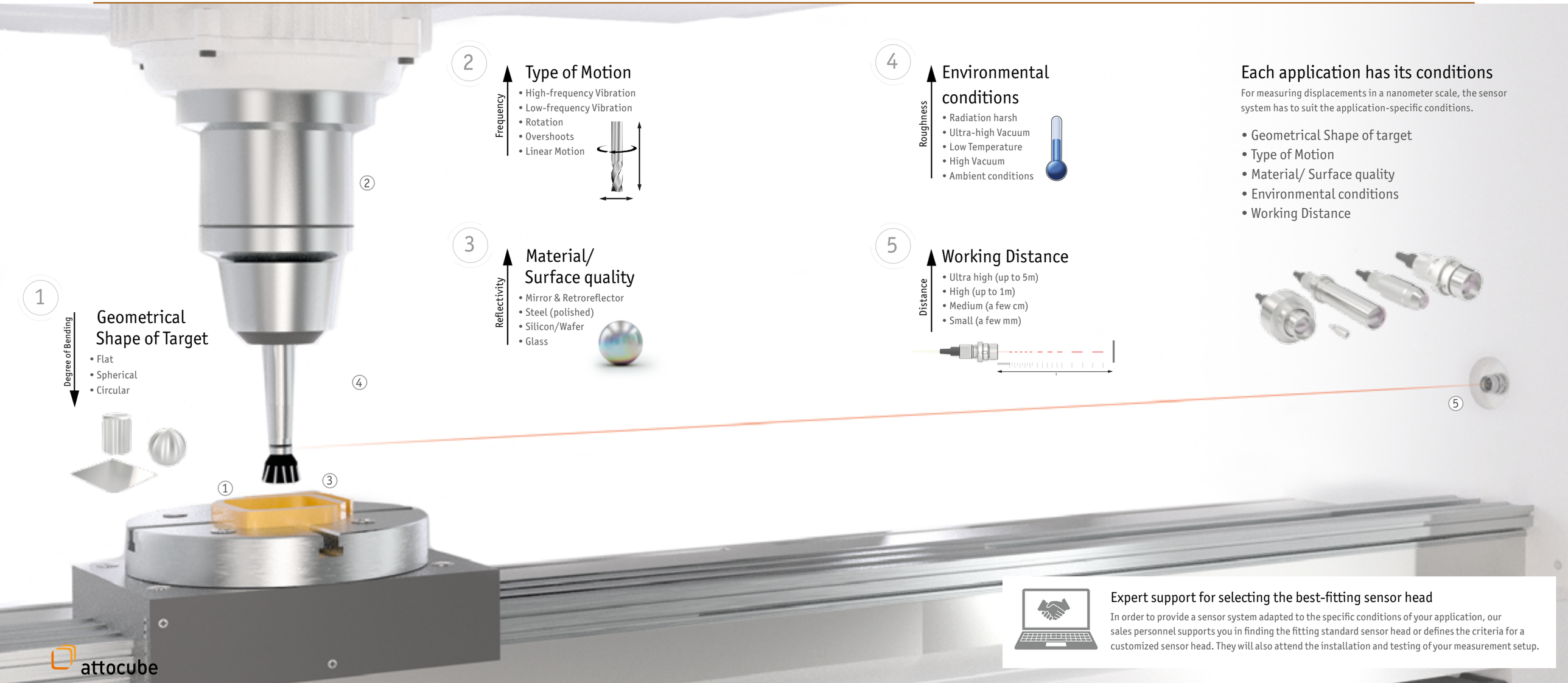
Dr. T. Zickler

Before purchasing a laser interferometer, we were not sure about the applicability of the interferometer for our requirements. During the short testing phase, we became familiar with the interferometer and its operation. While using the sensor for the intended application, we verified the advantages of the device and decided for purchasing it.

(CERN, Magnetic Measurement Section, Geneva, Switzerland)

IDS/FPS Sensor Heads

optimized for a broad range of applications



1 Geometrical Shape of Target

Degree of Bending

- Flat
- Spherical
- Circular

2 Type of Motion

Frequency

- High-frequency Vibration
- Low-frequency Vibration
- Rotation
- Overshoots
- Linear Motion

3 Material/ Surface quality

Reflectivity

- Mirror & Retroreflector
- Steel (polished)
- Silicon/Wafer
- Glass

4 Environmental conditions

Roughness

- Radiation harsh
- Ultra-high Vacuum
- Low Temperature
- High Vacuum
- Ambient conditions

5 Working Distance

Distance

- Ultra high (up to 5m)
- High (up to 1m)
- Medium (a few cm)
- Small (a few mm)

Each application has its conditions

For measuring displacements in a nanometer scale, the sensor system has to suit the application-specific conditions.

- Geometrical Shape of target
- Type of Motion
- Material/ Surface quality
- Environmental conditions
- Working Distance

Expert support for selecting the best-fitting sensor head

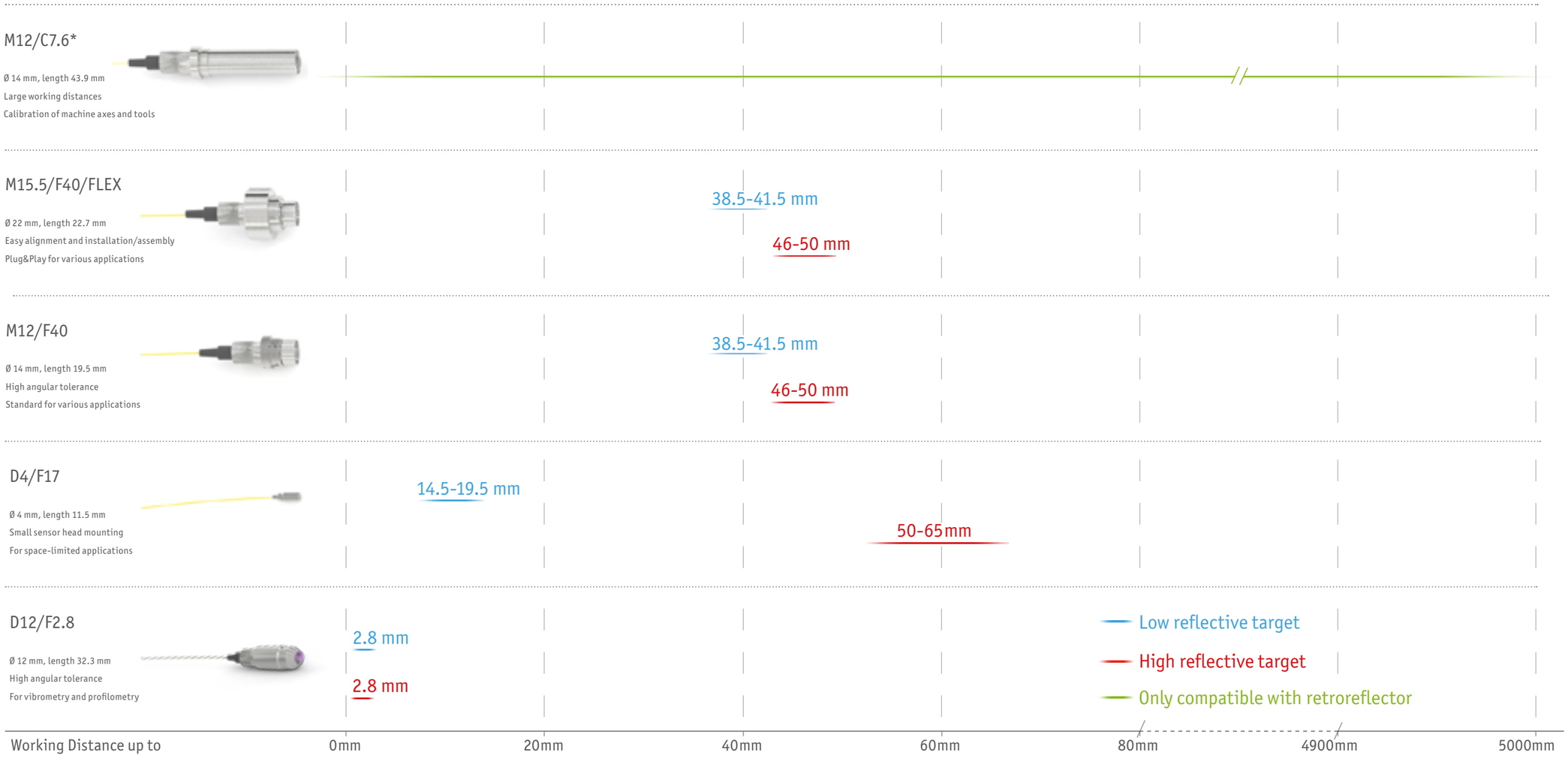
In order to provide a sensor system adapted to the specific conditions of your application, our sales personnel supports you in finding the fitting standard sensor head or defines the criteria for a customized sensor head. They will also attend the installation and testing of your measurement setup.

attocube

Sensor Head Overview

IDS & FPS

The IDS and FPS can be operated with different sensor heads: ultra compact heads for the most confined spaces or alternative designs where priority is given to easy alignment or to the compatibility with various target materials (glass, aluminum, ceramic, etc.).



*FPSH: 0..2000 mm; IDSH: 0..5000 mm
[1] By using special sensor heads, the IDS can realize measurement distances of up to 30 meters.

Sensor Head Specifications

IDS & FPS

Sensor Heads						
product name	D12/F2.8	D4/F17		M12/F40	M15.5/F40/FLEX	M12/C7.6
Modes of Operation						
optics type	focusing	focusing		focusing	focusing	collimating
dimensions	Ø 12 mm, length 32.3 mm	Ø 4 mm, length 11.5 mm		Ø 14 mm, length 19.5 mm	Ø 22 mm, length 22.7 mm	Ø 14 mm, length 49.2 mm
mounting	clamped	clamped		metric M12 x 0.5	metric M15.5 x 0.5	metric M12 x 0.5
focal length	2.8 mm	17 mm		40 mm	40 mm	infinity
connector	FC/PC	fiber glued		FC/PC	FC/PC	FC/PC
working environment	/RT, /LT/HV, /UHV, /RAD				/RT, /LT/HV, /UHV, /RAD	
benefits	short distance and wide angle	lower surface quality		broad variety of applications	easy to mount and easy to align	long distances and working ranges
exemplary applications	of various geometrical shapes	deformation monitoring of work pieces during manufacturing		concentricity tests, detection of imbalances	monitoring and diagnostics of machine tools components	calibration and synchronization of large-scale machine tools or coordinate measurement machines
Measurement Specifications						
working range (target: glass)	2.8 mm ± 4 µm	14.5..19.5 mm		38.5..41.5 mm	38.5..41.5 mm	-
alignment tolerance (target: glass)	± 4°	± 0.15°		± 0.35°	± 0.35°	-
working range (target: mirror)	2.8 mm ± 20 µm	50..65 mm		46..50 mm	46..50 mm	-
alignment tolerance (target: mirror)	± 10°	± 0.2°		± 0.35°	± 0.35°	-
working range (target: retroreflector)	-	-		-	-	up to 5000 mm
alignment tolerance (target: retroreflector)	-	-		-	-	± 15 °
lateral alignment tolerance (target: retroreflector)	-	-		-	-	± 2 mm
						

Compatible environments

/RT (ambient conditions):	0 .. 100 °C, 1x10^{-6} mbar .. 10 bar	/LT (low temperature):	mK .. 423 K (150 °C 1x10^{-6} mbar .. 10 bar
/HV (high vacuum):	0 .. 150 °C, 1x10^{-8} mbar .. 10 bar	/RAD (radiation hard):	0 .. 150 °C, up to 10 MGy radiation dose
/UHV (ultra high vacuum):	0 .. 150 °C, 1x10^{-10} mbar .. 10 bar		

Naming Scheme

F40:	focussing head with 40 mm focal length	D4:	4 mm mounting diameter
C7.6:	collimating head with 7.6 mm spot size	M12:	M12 x 0.5 metric thread mounting
FLEX:	flexure structure with integrated (theta, phi) adjustment range		

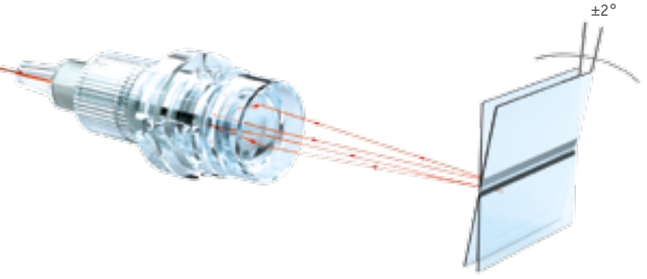
Customized Sensor Heads

Depending on your specific application, modifications concerning the type of optics, focal length, working environment or filter options are possible.

Customized Sensor Heads

customized sensor heads for specific applications

For measuring displacements in a nanometer scale, sensor heads must fit the application's characteristics. For applications exceeding the standard range of applications or sensor heads, attocube offers a customization service providing sensor heads adapted the specific application. This customization service includes the variation of the optics type, the focal length, the mounting, the connecting fiber, and the environment (see the page on the right). Our expert sales personnel will lead you through our process for characterizing your application and to find a suitable sensor head that will be produced for this specific applications.



Wide Angle Option

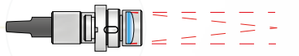
Applications requiring a wide angle tolerance can be realized by the customized M12/C1.6 sensor head. This collimating sensor head is compatible to the wide angle option that allows tolerance angles up to +-2° (depending on the working distance). The wide angle option can be activated via the webserver. The effect of the wide angle option is based on the dual pass mode because the laser beam is passing the cavity twice: after first time passing, the beam is reflected by the ferrule back to the target and then reflected to the fiber (see figure on the left...). This enables large working distances for a lower angle tolerance as well as a high angle tolerance for smaller working distances.

Customized Sensor Head for Space-limited Applications

Machine-integrated measurements do not provide a lot of space for conventional measurement systems. Realizing measurements in space-limited applications requires a compact design of sensor heads and electronics. The customized sensor heads with a diameter of 1.2 mm fulfill those requirements of lowest space consumption. The small size of the sensor head is possible because the sensor heads include no electronic parts or beam splitters. Furthermore, this sensor head is available with different focal lengths.

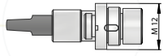
Customized Sensor Head Focusing Directly on Buckled Guide Rails

To identify the positioner accuracy of a linear stage, the motion of the linear stage is tracked by a laser interferometer. The buckled guide rails make the stage tilting while moving which requires a high angle tolerance for the measurement system. If the measurement setup requires a direct measurement on the stage without mounting a retroreflector, the sensor head M12/C7.6 is not suitable because it is only applicable to retroreflectors. The customized sensor head M12/C1.6 has a collimating optics with a beam diameter of 1.6 mm and fulfills the requirements of high angle tolerance combined with the capability of measuring on non-mirror surfaces.



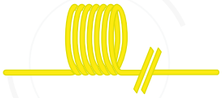
• Optics type
collimating or focusing

• Focal length
7 mm - 25 0 mm



• Mounting
clamped or metric thread from 1.2 mm diameter to M15.5 x 0.5 metric thread

• Environment
RT, HV, LT, UHV, RAD



• Connected fiber
length, bending radius, metal tubing

IDS Sensors

displacement sensing for industry & synchrotron

Some of the most important tasks in industrial metrology applications are contactless measurements of distances and displacements, the detection of vibration amplitudes of machine components and tools, and the ultra-precise survey of rotationally symmetric parts. Fields of application are extremely versatile and range from ultra-precision machining to semiconductor technology.

Requirements on accuracy, flexibility, and interconnectivity are constantly increasing and ask for ever more sophisticated solutions. These solutions are supposed to combine highest precision, speed, and reliability - while providing remote access and software maintenance from virtually anywhere on the planet. attocube's IDS3010 sensor has been specifically designed for challenging OEM and synchrotron applications and fulfills future requirements on precision already today.

Accurate

The built-in DFB laser of the IDS 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. (see page 379)

Ultra fast

All IDS Sensors measure the position of the target with a bandwidth of 10 MHz and a resolution of 1 pm. At the same time, the sensor is compatible with displacement velocities of up to 2 m/s.

Machine integrable

Due to its compact size (55mm x 52mm x 195mm) and its passively cooled housing, IDS Sensors can be directly integrated into milling machines, coordinate measurement machines, and semicon equipment. Adapter plates enable the integration into electric control cabinets.

Industrial interfaces

IDS sensors are compatible with a multitude of interfaces.
As standard interfacing, IDS Sensors provide real-time digital (HSSL, AquadB) and analog (sin/cos, linear) position data. Alternatively, the IDS can optionally be upgraded with BiSS-C.
In addition, IDS devices interface with field busses such as CANopen, Profibus, Profibus RT, and EtherCAT (on request).

Measurement software WAVE

The optional software package WAVE provides a fast and easy data visualizing and post-processing. Multiple functions like zooming, pausing, or a live Fast-Fourier-Transformation enable a live analysis of measurement data.

Multi axis operation up to 5m

The IDS offers three measurement axes which operate simultaneously, enabling tracking target displacements in three degrees of freedom over dynamic travel ranges of up to 5 m.

Environmental compensation

IDS sensors can be equipped with an optional environmental compensation unit (ECU). The ECU enables the operation of IDS sensors at ambient conditions while maintaining an accuracy guaranteed ± 1ppm (up to 5 m) and expected ± 0 ppm (up to 4.2 m) under a wide range of pressure, temperature, and humidity values.

VIS alignment laser

All IDS sensors are equipped with an integrated visible alignment laser (650 nm). The alignment laser can be software enabled during mechanical installation of the sensor, greatly reducing setup duration. An alignment software tool simplifies the process further.

For information on further accessories (fibers, targets, software upgrades...), please visit www.attocube.com

IDS3010

integrated displacement sensing

With its slim size, the IDS can be directly integrated into machines for free-beam operation and is the product of choice for challenging OEM & synchrotron applications. A passively cooled housing prevents contamination of optical and electrical components. For even more confined applications, sensor heads can be remotely operated and interconnected via glass fibers. Due to an integrated webserver, the sensor can be aligned, initialized and (re-) configured remotely at any time.

A broad spectrum of digital and analog real-time interfaces and protocols enables the simple transmission of position data to the receiver such as CNC controllers or RTOS computers. The further support of the most common industrial networks such as CANopen, Profinet, Profinet RT, and EtherCAT enable the integration into broader industrial and synchrotron networks.

Environmental Compensation Unit – ECU

The environmental compensation unit enables sub-ppm accuracy in ambient conditions

CUSTOMER FEEDBACK

Dr. Stefan Kubsky

An intense and ongoing scientific exchange with the attocube-development team permitted us to obtain new functionalities and highest precision. Our system, being inherently non-standard, profits greatly from the compactness and modularity of the sensor heads. We rapidly managed to file a patent application implying interferometric metrology.

(Synchrotron Soleil St. Aubin, France)

CUSTOMER FEEDBACK

Nicolas Stübe, Dr. Alke Meents

Due to the fast adjustment and precise sub-nanometer resolution of the sensor, we are able to easily identify trajectories and eigen frequencies for the optimization of flexure based components. The combination of the digital interfaces with our motion control system allows most accurate closed-loop control for scanning applications. With the closed-loop integration of the IDS3010 in our X-Ray microscope by the end of this year, we feel confident to get the first 3-D tomographic pictures of biological samples with a resolution of 20 nm within the beginning of 2016.

(DESY/suna-precision GmbH, Hamburg, Germany)

Fields of Applications - Examples

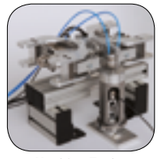
Coordinate Measurement

Real-Time Vibration Detection

Semiconductor Technology

Synchrotron Applications

Drive Technology



Machine Tools Calibration

Sensor	
number of sensor axes	3
working distance	0...5000 mm (depending on sensor head)
sensor resolution	1 pm
sensor repeatability	2 nm[1)]
max. target velocity	2 m/s
measurement bandwidth	10 MHz
signal stability (WD: 77 mm)	0.110 nm (2σ)
Modes of Operation	
measurement modes	displacement
remote operation	integrated webserver
output signal: electronics	sin/cos, AquadB, HSSL, linear analog (optional), field bus systems on request
output signal: displacement measurement	laser light (IR)
output signal: alignment laser	laser light (VIS)
sensor alignment	via integrated webserver or DLLS (C, C#)
sensor initialization	via integrated webserver or DLLS (C, C#)
Interfaces	
analog interfaces (real time)	sin/cos, linear analog (optional)
digital interfaces (real time)	AquadB, HSSL
field bus interfaces (optional)	Biss-C
field bus interfaces (on request)	EtherCAT, CANopen, Profinet, Profinet RT
Controller Hardware	
chassis	55 x 52 x 195 mm³
weight	730 g
power supply	12 V DC
power consumption	8 W
Measurement Laser	
laser source	DFB laser (class 1)
laser power	400 µW
laser wavelength	1530 nm
wavelength stability	50 ppb

1) at 10 mm working distance in vacuum conditions, +/-1ppm in ambient conditions with ECU.

IDS Sensors – Interfaces

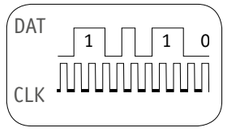
real-time digital and industrial connectivity

The IDS3010 is delivered with a standard set of high-speed interfaces for real-time data communication with FPGA-based or RTOS receivers. These interfaces consist of an incremental AquadB, a proprietary serial word (HSSL), a synthetic analog sin/cos, and a linear analog output signal. All signals can be outputted as either single-ended (LVTTL) or differential (LVDS). Interface parameters can be configured in the web interface section of the IDS.

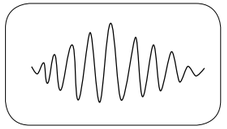
Alternatively, the IDS can optionally be upgraded with BiSS-C, an open standard sensor interface optimized for multi-device usage. All interfaces provide maximum bandwidth at highest resolution. For OEM customers, interconnectivity with other industrial networks such as Ethernet (TCP/IP), EtherCAT, CanOPEN, Profinet, and Profinet RT can be implemented on request.

① GPIO – General Purpose Input/Output: BiSS-C (real-time)
② Main Power
③ Ethernet
④ HSSL, AquadB, sin/cos, linear analog (real-time)
⑤ ECU

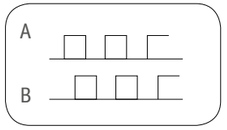
Interface Specifications					
target velocity [m/s]	0.0001	0.001	0.1	1	2
resolution HSSL (abs.) 8-48 bit, up to 25 MHz [nm]	0.001	0.001	0.001	0.001	0.001
resolution AquadB (inc.) at 25 MHz [nm]	0.004	0.04	4	40	80
resolution Sin/Cos (inc.) at 25 MHz [nm]	0.004	0.04	4	40	80



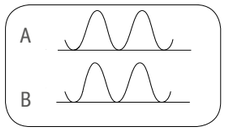
HSSL (digital; bandwith up to 25 MHz and 8-48 bit resolution): attocube's proprietary serial word protocol provides absolute position information - both in terms of the protocol and the measurement itself. The HSSL interface consists of one data and one clock signal (single ended or differential); position information is packed into one container of user-defineable bit-length, synchronization with the receiver is accomplished using the clock signal.



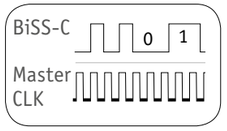
Linear Analog Output (analog; bandwidth up to 25 MHz; resolution freely assignable, 1pm - 2^{12} pm, optional): The linear analog output interface is a digitally synthesized analog signal for high-frequency vibrometry applications. It enables the direct post-processing of measurement data with a, AC-coupling of 1.7 V. An adaptable high-pass filter prevents a drifting of the signal. The linear analog output is best used with differential signaling.



AquadB (digital; bandwith up to 25 MHz; resolution freely assignable): The AquadB interface provides incremental displacement information on target displacement. Position resolution and (maximum) clock rate can be user defined using the IDS web interface.
For maximum data bandwidth, the AquadB interface is best used with differential signaling.



Sin/cos (analog; bandwith up to 25 MHz; resolution freely assignable, 1pm - 2^{24} pm): The sin/cos signal is a digitally synthesized analog signal which provides incremental position information. As with the digital AquadB signal, the increment (i.e. resolution) is user-definable in the system's web interface. For maximum data bandwidth, the sin/cos signal is best used with differential signaling.



BiSS-C (digital; bandwidth up to 10 MHz; resolution freely assignable, 1pm – 2^{15} pm) is available as an own version of the interferometers. It provides point-to-point topology for data communication with motion controllers and is especially suitable for the easy integration of several sensors to an external master clock at multi device facilities such as synchrotrons and spallation sources. BiSS-C signals are routed through the 14 pin GPIO connector (all other real-time interfaces are disabled in this mode) and they are based on the differential RS-422 standard.

Industrial Interfaces on request

Other industrial interfaces can be implemented on request, please contact info@attocube.com

EtherCAT (Ethernet for Control Automation Technology) is an open, real-time Ethernet-based fieldbus network. It is used for machine control and regulation as well as for multi-channel, synchronous measurement devices.

Profinet is a protocol based on industrial Ethernet according to IEEE 802. It connects devices, systems, and cells, facilitating faster, safer, less costly and higher quality manufacturing.

Profinet RT is the real-time derivative of Profinet.

CANopen is a communication protocol based on CAN (Controller Area Network) which is used for the interconnection of complex, embedded systems used in automation.

WAVE: Measurement Software Package

realtime data processing for IDS

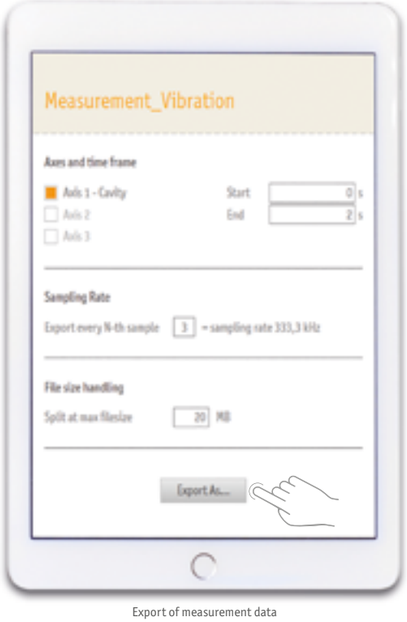
With the new software tool for measurement processing, WAVE, attocube offers an extensive software package for a broad variety of features: e.g. configuring the interferometer device, displaying and saving measurement data, or a real-time Fast-Fourier Transformation. The software package WAVE is optinally available for all IDS devices.

Device overview and alignment

The software tool WAVE displays all IDS devices that are connected to the computer (directly or via network). Furthermore, the alignment routine is also included.

Alignment of optical setup

Device overview



Export of measurement data

simply click to export data

Post-processing in CSV-file

CSV-Export: Easy data post-processing

For a further post-processing of measurement data, WAVE enables to export measurement data to CSV-files for software tools like Microsoft Excel, Matlab, or Origin.

WAVE: Functions for Data Analysis

saving and visualizing displacements and vibrations

1 Stopping and continuing data displaying

WAVE includes a function that stops the current displacements display to enable users to zoom into past data. The FFT plot automatically adapts to the zoomed time period.

2 Time and displacement zoom: analyzing while measuring

The streaming function facilitates users to zoom into past measurements for a more detailed investigation of the captured motions.

3 Displacement data visualization: time-saving measurements

The window for showing the displacements includes data of the last 5 seconds at a bandwidth of up to 1 MHz (for one axis).

4 FFT Analysis: analyzing vibrations and overshoots

The real-time Fast-Fourier Transformation (FFT) enables frequency analyses of displacement data that are used for detecting the resonance frequency of components or for analyzing the spreading of mechanical oscillations.

Environmental Compensation Unit

accurate interferometrical measurements in ambient environment

ECU/IDS3010

In order to reduce position inaccuracy due to air-induced variations of the index refraction, attocube supplies an environmental compensation unit (ECU). By locally measuring environmental parameters, an accuracy of typically better ± 1 ppm can be achieved in air. The ECU is plug and-play compatible with all IDS models and can be screw mounted.

IDS ECU

Technical Specifications	Art. No.
art. no.	1010698
dimensions	28 x 61 x 20.5 mm³
weight	41.5 g
integrated sensors	T, p, rH
interface	RJ12 connector
sensor mount	screw mount
working environment	non condensing
cable length	1,83 m
Measurement Accuracy (Sensors)	
T-sensor	±0.1°C (0..50°C)
p-sensor	±1 hPa (300..1100 mbar)
rH-sensor	±2% (10..90%)
typ. accuracy setup	guaranteed ± 1.0 ppm up to 5m; expected ± 0.0 ppm up to 4,2 m

iF Design Award for IDS3010

compact design at highest functionalities

The iF Design award 2017 goes to...

The iF Industrie Forum Design e.V. represents the oldest independent design institution in the world. The annual iF Design awards honor products from various branches. An international expert committee evaluates product's design excellence based on criteria like usability, innovation, or spatial concept. Out of 5500 submissions in 2017, the IDS3010 was certified in the category "industry/skilled trades".

Elaborated Spatial Concept

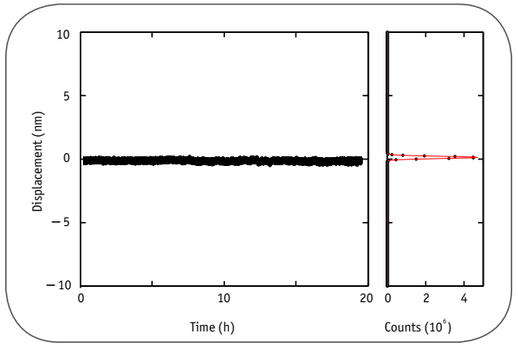
One challenge in the design of the IDS3010 was the compact size in combination with a highest level of functionalities. While other laser interferometers exceed the size of the IDS3010 by ten times or more, the compact design enables the IDS3010 for machine integration or space-limited applications. Since the sensor heads get along without electronic components, they have lower spatial requirements and they are more robust against harsh environments.

Usability emphasizes outstanding functionality

The iF Design award indicates outstanding functionality coming along with a highest level of aesthetics and design quality. While the passive cooling fulfills an essential function of the devices, it also serves as a design element supporting the aesthetic appearance and usability of the product. The IDS combines highest technology and ease of use in one device.

Selected Measurements

unrivaled accuracy for different environments



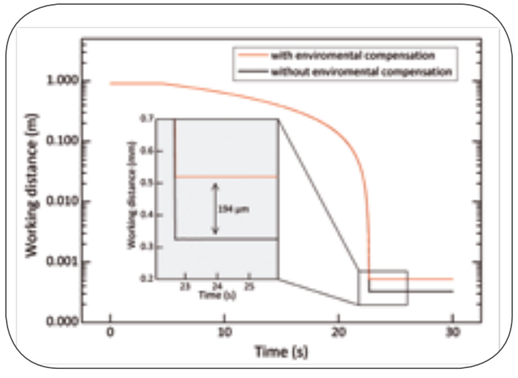
Long-term signal stability as demonstrated on a 77 mm long cavity cooled to liquid helium temperature (-269 °C) in order to minimize thermal expansion/contraction.

Proven Sub-Nanometer Signal Stability

The intrinsic signal stability of the IDS – equivalent to its positional repeatabilty – is unheard of in position sensing. While being specified to achieve a repeatability of 2 nm at 20 mm working distance and 100Hz measurement bandwidth (in vacuum), the IDS routinely achieve significantly better performance.

The actual measurement on the left shows positional stability as measured on a titanium cavity cooled to liquid helium temperature (-269 °C), temperature stabilized to few milli-degrees. The plot shows position sensing data recorded on a 77 mm long cavity during a 20 hour period of time, measured at 100 Hz bandwidth. The standard deviation of the above shown measurement is 55 picometer!

(attocube applications labs, 2015)



Displacement measurements as performed at variable sensor/target separation in constant conditions. The plot shows the displacement sensing error of 246 µm over 1 meter travel range (uncompensated) vs <1 µm (compensated).

Environmental Compensation (optional)

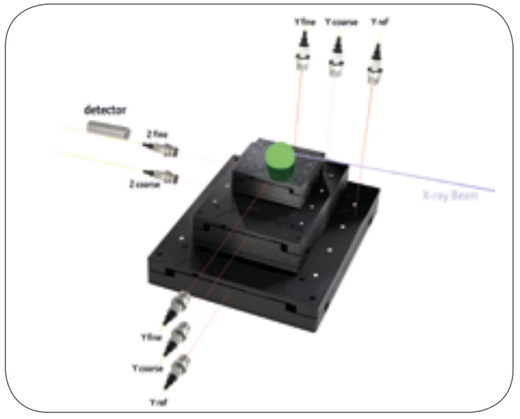
Any interferometric device operated in environmental conditions is negatively influenced by index of refraction fluctuations, caused by air temperature, pressure, and humidity variation. The influence of these parameters is significant and can reach deviations in measurement of up to 500 ppm, equivalent to a deviation of 500 µm per meter.

To compensate these errors, attocube offers an environmental compensation unit (ECU) which precisely measures environmental parameters and determines the actual index of refraction n(t). This measurement allows to compensate environmental influences down to better 1 ppm and enables highly precise, accurate measurements in air.

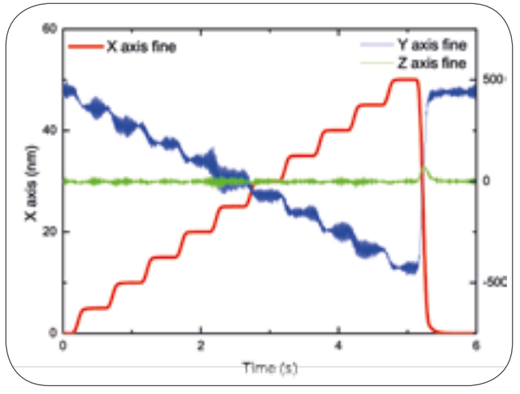
(attocube application labs, 2017)

Selected Applications

IDS Sensors



Rough sketch of the setup. The eight sensor heads M12/C1.6 are shown monitoring the 3 modules, each module consist of 3-dimentional X, Y, and Z movements. The complete setup is in high vacuum.



The parasitic movement during the incremental steps of the X-axis (red line) is shown for disabled axes Y (blue line) and Z (green line).

Synchronous Data Acquisition for Detecting Vibration Propagation

In high precision systems for moving objects in nanometer ranges, error motions and vibration propagation are crucial information for the motion accuracy. Due to this, synchrotron facilities continue to develop and upgrade different components to keep pace with the latest available technologies. The beamline I08 recently upgraded the end-station using attocube interferometers IDS3010 with BiSS-C interface. An experimental setup at the Diamond Light Source is synchronously triggering and tracking the movement of eight different linear axes. These eight axes were controlled by the Delta Tau "GeoBrick" controller, which ensures the accurate timestamped data from all eight axes, i.e. three IDS3010 devices.

The setup consists of three motion modules as shown in a simplified version in the upper figure: from the bottom one manual positioner, on top of it one stepper motor for more coarse adjustments, and finally on top of that one piezo-based positioner for fine motions. All three modules can move in X-, Y-, and Z-direction, i.e. the complete setup consists of 9 linear movements, and is being tracked by 8-axes consisting of M12/C1.6 high vacuum compatible sensor heads. Since the sample's position is relevant for each movement of the three modules, every motion axis needs to be tracked. There are two kinds of error motions (parasitic movements) relevant for the sample's position: vibrations caused by moving the positioner that spread to connecting positioners and the sample, as well as uneven motions caused by non-parallel mountings between the positioners.

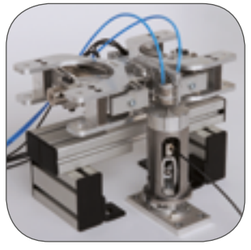
One measurement example is shown in the lower figuer, which only involves the X, Y, and Z piezo-based positioners in the upper module. The two parasitic movements are shown while moving the fine piezo positioner in the X-direction using 5 nm step sizes. The red line (X-axis) shows the positioner moving in one direction, after 10 steps, the positioner is moving back with one 50 nm step. The blue line (Y-axis) shows the error motions of the fine positioner orthogonal to the motion of the positioner in the horizontal level. The noised oscillations are caused by vibration propagation emerging from the positioner's motions. This line shows a linear offset of 100 pm for every step. This offset originates from the not perfect parallel mounting between the X- and Y- positioners. This non orthogonal mount can be compensated using the information for the other axes. The green line (Z-axis) shows the vertical movements of the fine positioner. Only the last step of 50 nm shows a significant change of the vertical position, presumable due to a rapid vibration.

(Diamond Light Source Limited, 2017)

Contactless Frequency Analysis of Motor Vibrations

To monitor the health status of a gear or machine, attocube's IDS3010 can be used to track machine vibrations. To improve the vibration behavior of a machine, its motor was rotated at different speed levels and the motor's vibrations were measured on the outer shell of the motor. Conducting a live Fast-Fourier-Transformation (FFT) showed that the motor rotating with 2000 rpm generated vibrations at 270 Hz which in turn amplified a system resonance at 345 Hz, and therefore drastically increased the overall vibration amplitude. At this system status, the vibrations amplitude was identified to be more than 150 nm, while the maximum acceptable amplitude was set to 100 nm. This crucial information enabled the system's manufacturer to minimize the system response to vibrations and prevented potential failure.

(attocube application note SEN13, 2014)

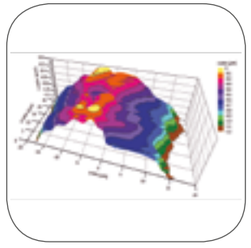


Highly Precise Micro Manufacturing

Ever increasing requirements for precision and size of machined parts have driven the development of highest-precision machining tools. The Square Foot Manufacturing concept separates well-known machining centers into small-sized sub-groups having standardized interfaces not only for power and data transmission but also for the transmission of processing forces and moments. Laser interferometry plays a key role in the piezo-based feed units of this concept as well as in the measurement of the reproducibility of these interfaces. A special differential technique allows for precise characterization of translational and rotational errors, which, in this case, are better than 0.16 µm and 8.22 arc seconds (3 sigma) respectively.

(attocube application note SEN07, 2013)

Selected Applications
IDS Sensors



Profilometry on Micron-Sized Objects

Ultra-precise and contactless surface analyses are of major interest in order to guarantee the quality of the material in many research and industrial applications. The large acceptance angle is one of the main strong benefits of attocube's Industrial Displacement Sensor (IDS). Due to its proprietary patented techniques, the system allows for measurements on surfaces with more than 10° inclination with respect to the measurement direction. The actual measurement shows nanometer precise 3D profilometry data of micron-sized metal cylinders. Several deformations can be seen: In the center position the object profile clearly shows a dent on its surface with a depth of around 400 nm. In addition the diameter contour in the front part near x = 0 has a plateau over a length of approximately 10 µm.

(attocube application note SEN14, 2016)

Ultra Precise Contactless Detection of Bearing Errors

Error motions of rotating objects are far-reaching issues in high precision mechanical engineering. In case of a high speed spindle, even sub-nm deviations from a perfect rotation can create undesired vibrations or error movements. Monitoring error motion with sub-nm resolution is therefore of prime necessity from state of the art mechanical engineering to nanotomography research. Since vibrations and error motions limit the maximum accuracy of high precision machine tools, the IDS is the first step to increase manufacturing accuracy by acquiring error motions of different dimensions in a sub-nm resolution. The IDS can be used for calibrating spindles in machine tools or for detecting bearing errors of small shafts. The small sensor heads enable inline measurements of rotating shafts for tracking error motions.

(attocube application note SEN08, 2013)