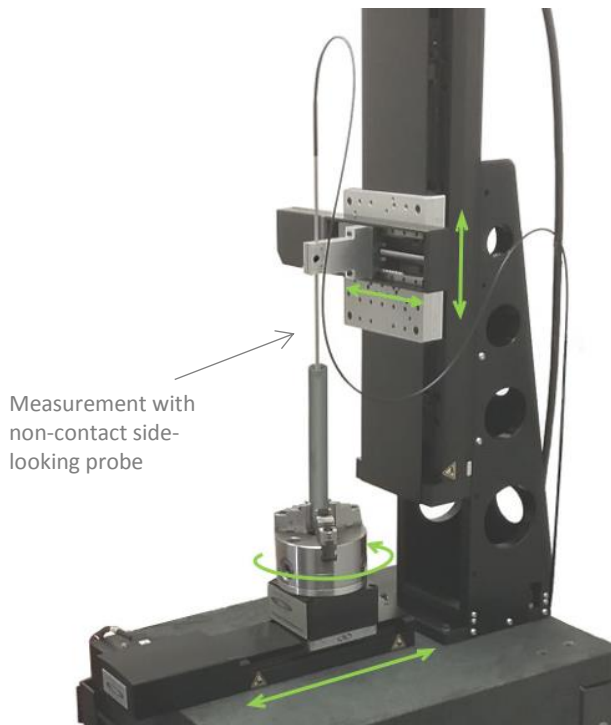
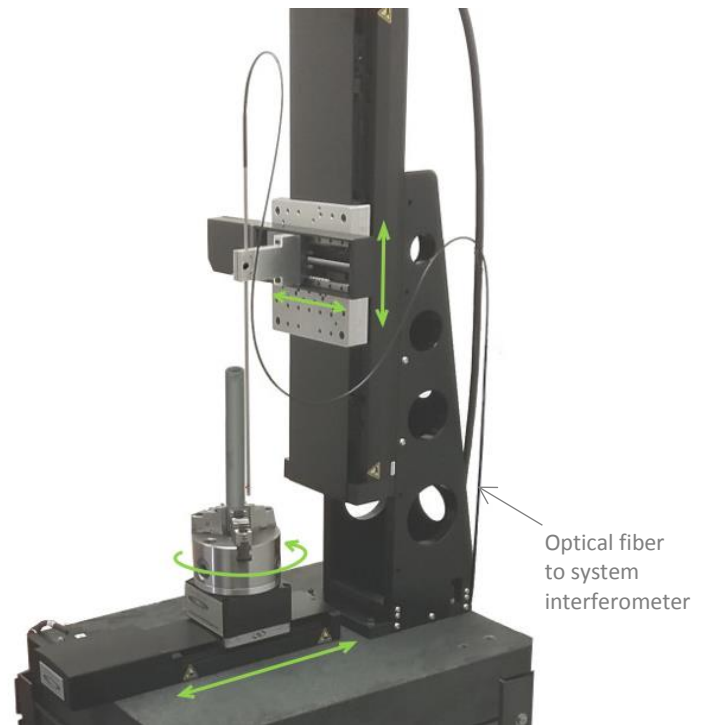


TUBEINSPECT™ system

For non-contact 3D metrology of tube ID and OD



Inside diameter measurement



Outside diameter measurement

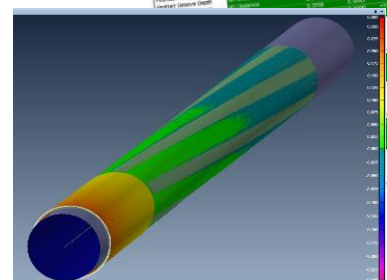
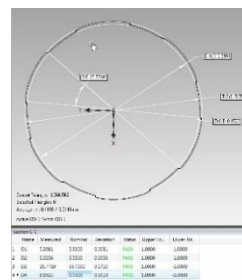
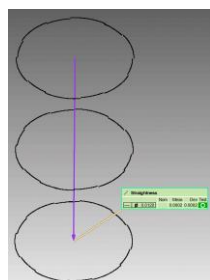
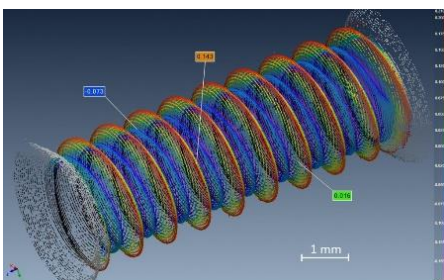
✓ Wide range of micron-precision 3D measurements of tube interiors and exteriors

- **3-dimensional geometry (GD&T)** of inside and outside surfaces
- **Chatter** measurement
- **Roughness** measurement
- **Defect detection** - porosities, cracks, scratches
- **Thickness** measurement of semi-transparent material coatings

✓ Fully configurable automated inspection

✓ Easily integrated in fully automated inspection setups

Measure	Dimension	Mean	Min	Max	Dev	Unit
Profiled Lead	1.5000	1.5000	1.5000	1.5000	0.0000	mm
Profiled Lead	1.5000	1.5000	1.5000	1.5000	0.0000	mm
Profiled Lead	1.5000	1.5000	1.5000	1.5000	0.0000	mm
Profiled Lead	1.5000	1.5000	1.5000	1.5000	0.0000	mm
Profiled Lead	1.5000	1.5000	1.5000	1.5000	0.0000	mm
Profiled Lead	1.5000	1.5000	1.5000	1.5000	0.0000	mm
Profiled Lead	1.5000	1.5000	1.5000	1.5000	0.0000	mm
Profiled Lead	1.5000	1.5000	1.5000	1.5000	0.0000	mm
Profiled Lead	1.5000	1.5000	1.5000	1.5000	0.0000	mm
Profiled Lead	1.5000	1.5000	1.5000	1.5000	0.0000	mm



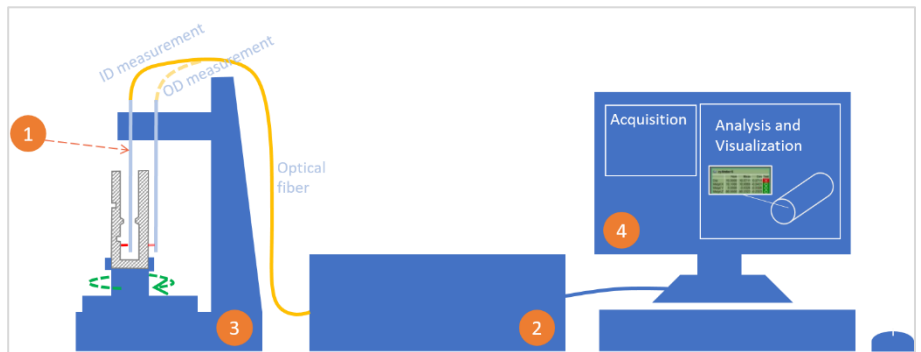
System Benefits

- ✓ **3D measurements of diameter, circularity, cylindricity, parallelism, taper, runout, straightness, cone angle, concentricity of ID & OD surfaces, roughness, chatter, defects, etc.**
- ✓ **Measures high-aspect-ratio features such as undercuts, cross-holes, chamfers, rifling, threads, O-ring grooves, and edges**
- ✓ **Reduced inspection cycle time:** up to 100,000 measurements per second, each representing a 3D topographic point
- ✓ **Flexible options for evaluating inspected parts with third party software:** measured features can be compared to CAD or to user-defined set of locations, nominals, and tolerances
- ✓ **Simple scan definition and execution:** The scanning sequence defined by teaching the system with a joystick
- ✓ **Time-saving automated reporting:** Following a scan, go-no-go reports can be produced automatically, and results logged in a manner compatible with industry-standard mechanisms
- ✓ **Adaptable to hostile environments:** radioactive, very hot, cryogenic, vacuum, etc.
- ✓ **No need for expensive consumables:** Optical probes do not wear out like contact probes.

System components

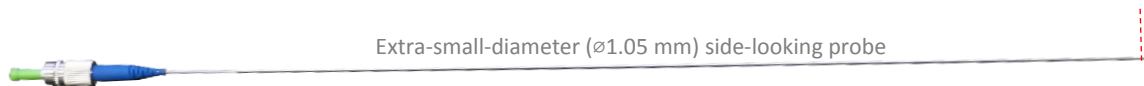
NOVACAM™ TUBEINSPECT™ system is a fiber-based modular system comprising:

- (1) Optical side-looking probe
- (2) MICROCAM interferometer
- (3) Inspection station
- (4) PC
- (5) Motion controller(s) (not shown) and, optionally,
- (6) multiplexing hardware (not shown)

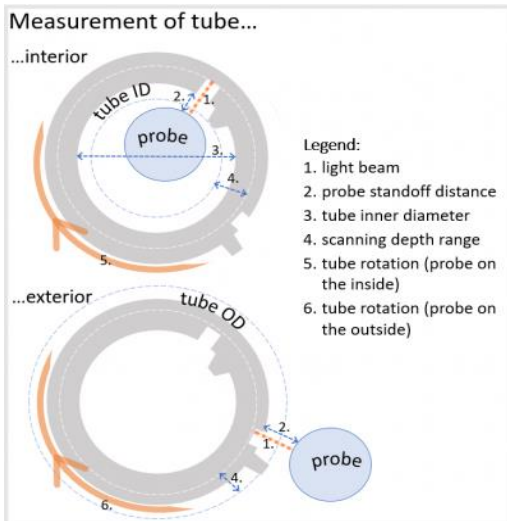


1 Optical probe

The side-looking optical probe reaches inside the spinning tube to scan its complete inside geometry in a spiral pattern. The same probe may be used to measure a range of tube diameters. The same probe may be moved to the OD measurement position to scan the outside of the tube.



Top view of scanning setup



Standard probe characteristics*

Probe diameter (mm)	Maximum standoff distance (mm)	Typical spot size (µm)	Probe length (mm)
0.55	0.5	15 - 35	50-1000**
1.05	1		
2.4	1.3		
3.05	4.8		
4.6	15		
17.8	54		

* Custom probes with non-standard diameters (such as ø8.8 mm or ø30.5 mm), lengths, spot sizes, and light beam angles (i.e., different from the standard 90°) are built upon request. Custom probes for extreme temperatures, high pressures, or other hostile environments are also built upon request.

** Maximum probe length may be limited by mechanical constraints. Custom probes as long as 2 m have been built.

2

MICROCAM™ interferometer

The interferometer provides the light source to the optical probe and processes the optical signal received from the probe. The probe and the interferometer are connected with an optical fiber.



MICROCAM interferometer models

	MICROCAM-3D		MICROCAM-4D
General characteristics			
Technology	low-coherence interferometry		
Light wavelength	1310 nm, infrared		
Size of interferometer enclosure box (depth x width x height)	4U rackable enclosure 445 x 445 x 178 mm		
Non-contact measurements			
Scanning depth range options*	3.5 mm	7 mm	5 mm
Acquisition (A-scan) rate	2.10 kHz	1.05 kHz	100 kHz
Axial (Z-axis) resolution	< 0.5 μ m		
Light spot size (Lateral [XY-axis] resolution)	4.1 - 146 μ m, typically 15 - 35 μ m		
Standoff distance	0.5 - 100 mm for standard probes, up to 1 m for non-standard probes		
Repeatability**	< 1 μ m		
Thickness measurements			
Thickness measurement range (optical in air)	10 μ m - 3.5 mm	10 μ m - 7 mm	20 μ m - 5 mm
Typical materials for thickness measurements	glass, polymers, multi-layer films, coatings, plastics, silicone, liquids, specular or non-specular		
Sample reflectivity	0.1 - 100%		

* To further increase maximum scanning depth, a mechanical displacement axis is available.

** The stated repeatability pertains to a system where the optical sensor is not moving with respect to the measured surface. The repeatability of the motion mechanism is usually bigger; this can be effectively addressed by the use of a glass reference plate.

3

Inspection station

Inspection station configurations are application-dependent and can be supplied by Novacam. Fixturing for the part is not included.

For lab and shop floor inspection, TUBEINSPECT system inspection stations typically include probe displacement in 2, 3, or 4 axes, and a motorized spinning fixture for the inspected tube. Granite tables are optionally available and recommended for some applications.

For automated inline industrial inspection, TUBEINSPECT system probes may be integrated with precision stages, third-party CMMs (coordinate-measuring machines), CNC (computer numerical control) machines, or robots to support high-volume continuous flow manufacturing.

Alternative inspection station configurations: Standard “probe-on-top” configuration is the most common. In the “probe-below” configuration shown on the right, the rotational stage with the tube fixture is on top of the inspection table, and the probe enters the spinning tube from below.



TUBEINSPECT system inspection station with “probe-below” configuration prevents unintended operator contact with the probe in a shop environment.

4

PC, monitor and joystick

The TUBEINSPECT system comes with a PC, monitor, mouse, and joystick.

5

Motion controller(s)

Motion controllers are included. Depending on the number of additional motion axis required, the motion controller(s) are housed in a 2U, 3U, or 4U rackable enclosure.

6

Hardware for multiplexing support (optional)

Optical switches are available for multiplexing up to 8 probes to a single Microcam interferometer. Multiplexed probes may be used one at a time. This option brings additional return on investment (ROI) to many installations.

System software

The TUBEINSPECT system comes with NOVACAM high-performance data acquisition software, which is PC, Windows®-based, and user-friendly for scan programming. The TUBEINSPECT system simultaneously generates 3 data sets from the same scan: 3D point cloud, light intensity image, and height image. The height and light intensity images facilitate defect detection. STL file format is also available.

An application programming interface (API) is available for system integrators and OEMs to accommodate a wide variety of online and offline applications. Exported results may be integrated with data loggers and SPC software.

A turnkey solution for full GD&T analysis of measured parts is available with InnovMetric PolyWorks® Inspector metrology software that may be purchased with the system. Go-no-go reporting is easily programmed and automated. Operators benefit from capabilities such as a quick visual comparison (deviation map) of the acquired part measurements to pre-specified tolerances or to the CAD of the part.

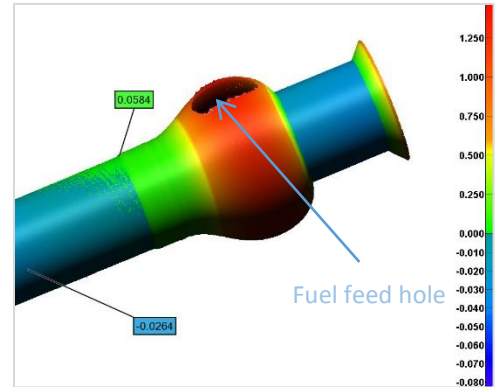
Visualizing the scan data may be accomplished by importing the data into third party visualization and numerical analysis software such as PolyWorks Inspector, Geomagic, ImageJ, SolidWorks, Octave, MatLab, Mathematica, IDL, or IGOR Pro.

Deriving application-specific measurements from the 3D point cloud is available through a selection of in-house and third-party software. Novacam supports the following options:

Data processing options

	Novacam in-house software	3 rd party software, such as
Dimensional measurements (GD&T parameters)		PolyWorks Inspector (turnkey solution), Geomagic
Roughness and surface analysis	✓	TrueSurf, MountainsMap
Thickness	✓	
Chatter (vibration)	✓	
Volume loss	✓	
Defects	Custom-developed*	

* Novacam offers the option of custom data processing, reporting, and defect detection programs that can be written based on client requirements.



ID of fuel injector nozzle (ID ϕ 4.04 mm), 3D point cloud viewed with PolyWorks® Inspector

Standard system configuration

- MICROCAM-3D interferometer
- 1 standard 4.6 mm-diameter side-looking probe (for inspection of bores up to 300 mm (12") deep)
- 3-axis inspection station and 3-axis motion controller
- 1 chuck with motor and motion controller for rotating the inspected tube
- PC with NOVACAM acquisition software
- 1-year warranty

Instrument safety

NOVACAM TUBEINSPECT systems feature an in-probe red laser pointer (650 nm wavelength) for alignment purposes. They systems are Class 1M Laser products, with < 20 mW of infrared and < 5 mW of in-probe laser pointer.

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