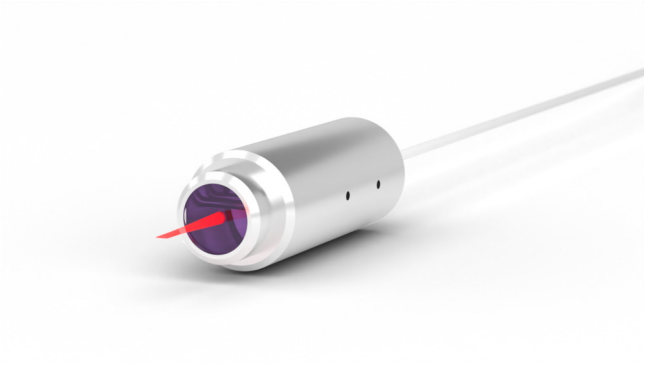
PicoScale sensor head type L01



The L01 is a sensor head for the **PICO**SCALE laser interferometer. The target beam is focused along only one axis with a cylinder lens so that a line focus is generated. This way, the sensor head has a relatively large angular working range along the focused axis while having a large diameter along the orthogonal axis. Typically, these sensor heads are used to measure eccentric movements of rotating cylindrical objects and being insensitive to their wobble, i.e. tip/tilt of the axis of rotation.

Table 1. *Summary of optical properties (for a typical sensor head with a focal distance of 30 mm).*

Property	Value
Wavelength	1550 nm
Laser output mode	single mode
Focal distance (F)	30 mm
Working distance (WD)	39 mm - 57 mm
Working range	±1.4 mm
Beam geometry	line focused
Focused axis	
Beam waist diameter (d_0)	50 µm
Beam divergence half-angle	19.74 mrad
Minimum angular working range	±0.506°
Collimated axis	
Beam waist diameter (D_0)	1600 µm
Beam divergence half-angle	0.62 mrad
Minimum angular working range	±0.016°

OPTICAL SPECIFICATIONS

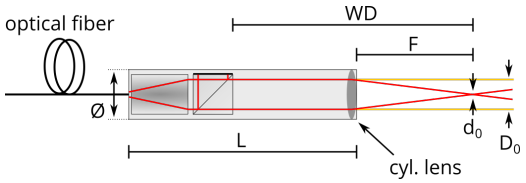


Figure 1. *Schematic drawing of the sensor head L01.*

Each sensor head is based on two main components (cf. Figure 1): the lens system, collimating the fiber output beam, and the beam splitter, which splits the beam into a reference and probe beam. The reference beam is reflected off an internal reference mirror, coated to one side of the beam splitter cube. The probe beam exits the head and is reflected off the target surface in order to track its relative displacement. The front surface of the beam splitter marks the absolute zero position of every **PICO**SCALE measurement as here the probe and reference beams are of equal length and thus the working distance is always defined relative to this point. In the L01 sensor head type, the probe beam is then enlarged by telescope optics and subsequently focused by a cylinder lens. Along one axis, the beam gets focused, while staying collimated along the orthogonal axis.

Beam properties

The probe beam has its waist at the focal length of the cylinder lens, which is 30 mm. In the focused axis, the beam has a beam waist diameter of about 50 µm, and in the collimated axis it is about 1600 µm. The beam exhibits a large divergence and the beam diameter increases significantly if the target is away from the focal point, cf. Figure 2.

Working distances (WD)

The **PICO**SCALE sensor head L01 is optimized for cylindrical probe close to the focal point. Due to the inevitable divergence of the laser beam, the optical power collected by the sensor head decreases if the target moves away from the focal point. Figure 3 shows the expected optical signal for varying distances. We recommend operation within ±9 mm around the specified focal length.

Working range

The working range of the sensor head is defined as the distance relative to the focus position at which the

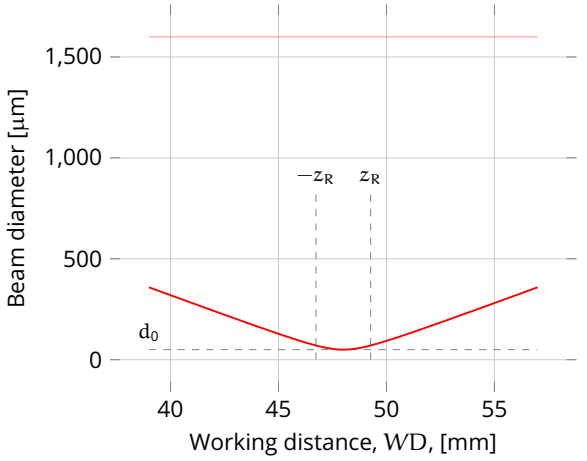


Figure 2. *Beam diameter versus distance, modeled as a Gaussian beam* $d(z) = d_0\sqrt{1+\left(\frac{z-z_0}{z_R}\right)^2}$ *with* $z_R = \frac{\pi w_0^2}{\lambda}$. *Solid: focused axis; semi-transparent: collimated axis.*

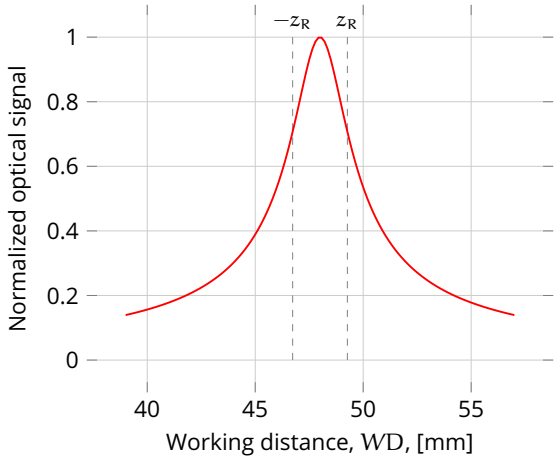


Figure 3. *Normalized interferometric signal versus working distance, modeled from Gaussian beam divergence assuming power coupling into the sensor head* $S(z) \propto \eta(z)$ *with* $\eta(z) = \left[1+\left(\frac{z-z_0}{z_R}\right)^2\right]^{-1/2}$.

PICOSCALE detects a "beam interrupt" event[1]. This event corresponds to approximately 33 % of the optimum interferometric signal amplitude.

> Owing to dynamic signal correction, the usable working range typically extends beyond the specified value.

Angular working range

The optimal performance of the sensor head is obtained when the maximum optical power is returned from the target mirror. This occurs for normal incidence of the probe beam. If the mirror is tilted with respect to the beam axis, the coupling efficiency into the fiber decreases and the interferometric signal amplitude is reduced. Figure 4 shows the angular working range of typical L01-30 sensor heads, defined as the tilt angle at which the **PICO**SCALE detects a "beam interrupt" event[1]. The beam interrupt threshold corresponds to approximately 33 % of the optimum interferometric signal amplitude.

[1] The **PICO**SCALE controller provides an event notification system and can alert the user if the signal quality drops below a defined threshold.

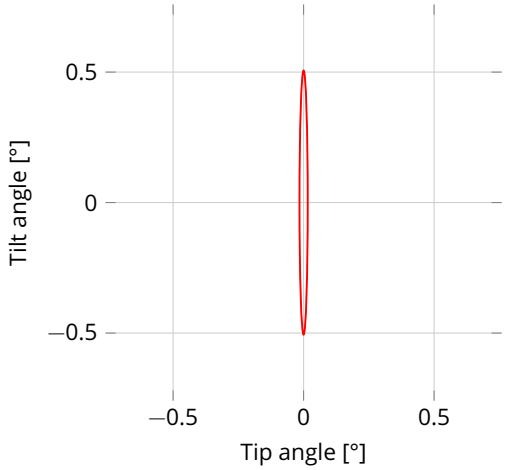


Figure 4. *Angular working range of the sensor head. The normalized interferometric signal amplitude versus target mirror tilt angle* θ_m *is modeled by Gaussian angular coupling of the returned beam,* $S(\theta_m) = \exp\left[-\frac{1}{2}\left(\frac{\pi d_0 \theta_m}{\lambda}\right)^2\right]$, *where* d_0 *is the* $1/e^2$ *beam waist diameter and* λ *is the wavelength. The angular working range is defined by the tilt angle at which the interferometric signal amplitude decreases by 33 % relative to its maximum value (i.e.,* $S = 0.67$*). Solid: typical; shaded: tolerance range.*

> Owing to dynamic signal correction, the usable angular working range typically extends beyond the specified value.

VACUUM COMPATIBILITY

The standard sensor heads are designed to operate in ambient conditions. However, all sensor heads can optionally feature high vacuum, ultra-high vacuum. The high-vacuum option (-HV) can be used in vacuum conditions with pressures as low as 10^{-6} mbar.
The ultra-high vacuum option (-UHV) is required if the sensor heads are used at pressures as low as 10^{-11} mbar. They are specified for bake-out temperatures up to 120 °C for 72 h.

OPTICAL FIBER

The sensor head L01 is interfaced with the **PICO**SCALE controller via an optical fiber with an FC/APC connector (8° angled end face to minimize back-reflections). By default, the sensor heads are equipped with a 900 µm fiber, which is 1.5 m long.

Both the fiber length and the actual fiber type can be customized, please refer to „Order Code“.

HOUSING

A standard L01 sensor head has a titanium housing with a diameter of 6 ± 0.05 mm and 20.6 mm length, as shown in Figure 5. Its weight is approximately 1.6 g.

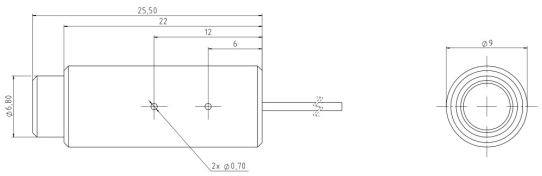
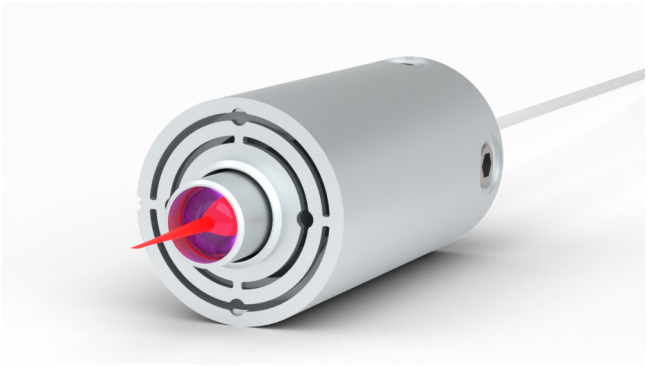


Figure 5. *CAD drawing of the sensor head L01 (General tolerances: ISO 2768-fH).*

Manual alignment option (MAM)



The MAM (manual alignment mount) option allows easy integration of a sensor head into an existing setup. The housing can simply be clamped in an appropriate bore hole, for example. Fine adjustment screws are used to manually align the sensor head to the target.

Property	Value
Outer diameter	12.7 mm (1/2”)
Length	30.5 mm
Alignment range (tip/tilt)	>±4°
Alignment resolution	0.5° per revolution

Piezo-actuated alignment option (PAM)

The PAM (piezo-actuated alignment mount) option allows remote alignment of the sensor heads. The housing can simply be clamped in an appropriate bore hole, for example. The PAM option is available as open-loop actuator (”-PAM“). Please contact SmarAct for availability of this variant.

ORDER CODE

The order code of the sensor heads is built as follows:

PS - SH - L01 ***- A - B - E - F - G - H - I***

The placeholders can be replaced by the respective option code. These codes are given in the table below. If you do not specify an option, the default value is used.

Category	Shortcut	Description
-A: Focal length	-X.xx	Focal length in mm (measured from housing). Standard: 30 mm
-B Vacuum/cryostat option	No entry/default	Operation in ambient conditions. Maximum temperature: 90 °C.
	-HV	High vacuum compatibility; down to 10^{-6} mbar. Maximum temperature: 90 °C.
	-UHV	Ultra-high vacuum compatibility; down to 10^{-11} mbar. Maximum temperature: 90 °C. Bake-out temperature: up to 120 °C for 72 h.
-E: Fiber length	No entry/default	1.5 m fiber length
	-3.0	3.0 m fiber length.
	-X.xx	Custom lengths on request
-F: Fiber type	No entry/default	900 µm jacket recommended minimal bending radius: 20 mm (ambient/HV); 30 mm (UHV)
	-B	3 mm stainless steel tubing recommended minimal bending radius: 30 mm
	-E	900 µm, 5mm bending radius
-G: Housing options	No entry/default	Standard size, 6 mm diameter, 20.6 mm length; weight 1.6 g
	-MAM	Manual alignment option, 12.7 mm diameter, 30.5 mm length
	-PAM	Piezo-actuated alignment option. Please contact SmarAct.
-H: Polarization Option	No entry/default	Single-mode non-polarized
	-PM	Single-mode Polarization Maintaining PANDA
-I: Particle Cleanliness	No entry/default	Items are visually checked and cleaned accordingly
	-PRT6	Items are checked using a x2 microscope and cleaned accordingly

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