PicoScale sensor head type F01

The F01 is a sensor head type with focused probe beam. This allows to measure displacements of small targets. Furthermore, the sensor heads provide high angular tolerances.

Table 1. *Summary of optical properties (for a typical sensor head with a focal distance of 10 mm).*

Property	Value
Wavelength	1550 nm
Laser output mode	single mode
Focal distance (F)	10 mm
Beam waist diameter (d_0)	28 µm
Beam divergence half-angle	35.24 mrad
Beam geometry	circular
Working distance (WD)	20.5 mm - 26.5 mm
Minimum working range	±0.4 mm
Minimum angular working range	±0.904°

OPTICAL SPECIFICATIONS

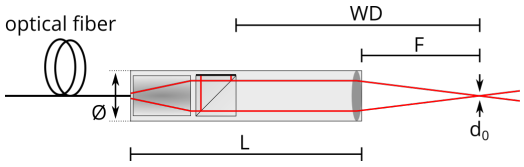

Figure 1. *Schematic drawing of the sensor head F01.*

After pre-collimation, an integrated beam splitter splits the light into a reference and probe beam as shown in Figure 1. The reference beam is reflected off the reference mirror which is coated to one side of the beam splitter cube. The probe beam is focused by a lens system and exits the head. The front surface of the beam splitter marks the absolute zero position of every **PICO**SCALE measurement as here the probe and reference beam are of equal length. Thus, the working distance (WD) is not equal to the distance from the head (i.e. focal length F) since the lens system is only integrated into the probe beam.

Beam properties

The probe beam has its waist at a customizable focal distance. The resulting beam diameter is dependent on the focal distance of the lens system and is typically in the range of 28 µm to 84 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.

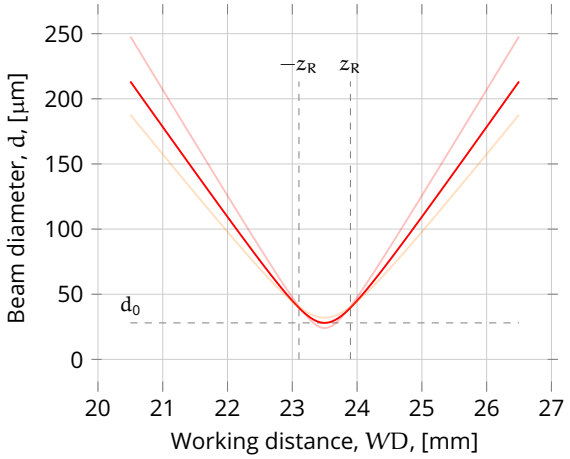

Figure 2. *Beam diameter versus distance, modeled as a Gaussian beam* $d(z) = d_0\sqrt{1+\left(\frac{z-z_0}{z_R}\right)^2}$ *with* $z_R = \frac{\pi w_0^2}{\lambda}$. *Solid: typical; shaded: tolerance range.*

Working distances (WD)

The **PICO**SCALE sensor head F01 is optimized for probe mirrors 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 ±3 mm around the specified focal length.

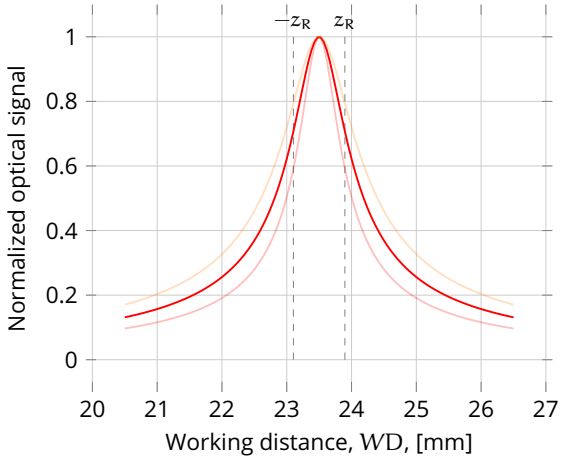

Figure 3. *Normalized interferometric signal versus working distance, modeled from Gaussian beam divergence assuming power coupling into the sensor head* $S(z) \propto \eta(z)$ *with* $\eta(z) = \left[1 + \left(\frac{z-z_0}{z_R}\right)^2\right]^{-1/2}$. *Solid: typical; shaded: tolerance range.*

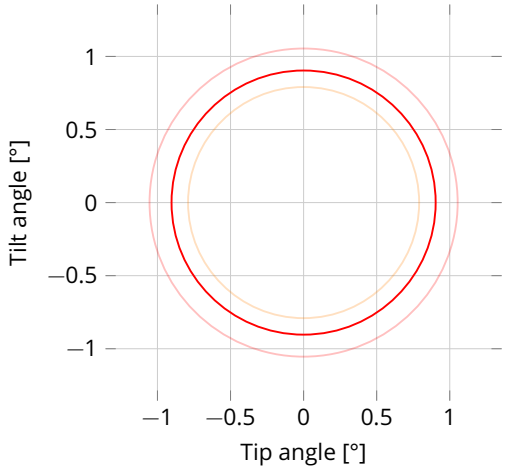

Figure 4. *Angular working range of the sensor head. The normalized interferometric signal amplitude versus target mirror tilt angle* θ_m *is modeled by Gaussian angular coupling of the returned beam,* $S(\theta_m) = \exp\left[-\frac{1}{2}\left(\frac{\pi d_0 \theta_m}{\lambda}\right)^2\right]$, *where* 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.*

Working range

The working range of the sensor head is defined as the distance relative to the focus position at which the **PICO**SCALE 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 F01-10 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.

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

Focal length

Each F01 sensor head is built with a customized focal length, which in turn determines the minimum achievable spot size. Figure 5 gives an overview of possible focal distances and corresponding focus diameters. Please note, that a smaller spot size increases the angular working range (also given in the plot), but reduces the linear working range correspondingly. The focal distance needs to be specified in the order code (see below).

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

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 F01 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".

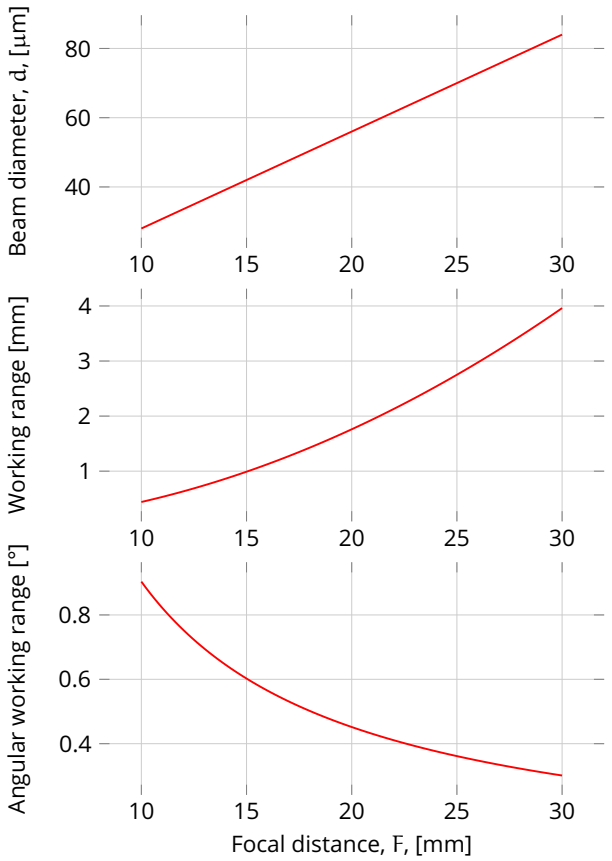

Figure 5. *Beam diameter, axial working range (33 % threshold), and angular working range of sensor head F01 versus focal length* F. *The beam diameter scales with* F, *the axial working range with* F^2, *and the angular working range with* $1/F$, *illustrating the inherent trade-offs between spot size and tolerance.*

HOUSING

A standard F01 sensor head has a titanium housing with a diameter of 6 ± 0.05 mm and 20.6 mm length, as shown in Figure 6. Its weight is approximately 1.6 g.

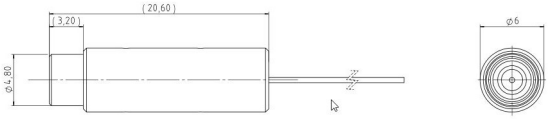

Figure 6. *CAD drawing of the sensor head F04 (General tolerances: ISO 2768-fH).*

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 - F01 ***- 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: 10 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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