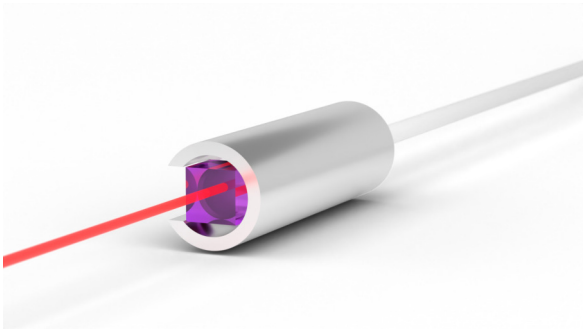
PicoScale sensor head type C04



The C04 is the standard sensor head type for the **PICO**SCALE *Interferometer*. Due to its collimated output beam, the compact form factor and the various customization options, it is appropriate for most common applications.

OPTICAL SPECIFICATIONS

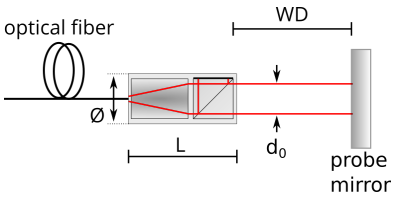


Figure 1. *Schematic drawing of the sensor head C04.*

Each sensor head (see Figure 1) uses a lens system to collimate the fiber output beam and a beam splitter to separate it into a reference and a 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 beam are of equal length.

Beam properties

The probe beam has its waist approximately at the front surface of the beam splitter cube, where the beam has a diameter of about 360 µm. Beyond approximately twice the Rayleigh range, $2 \cdot z_R = 131.34$ mm, the beam propagation is dominated by divergence and approaches far-field behavior, with a far-field half-angle of 2.74 mrad, as shown in Figure 2.

Working distances (WD)

The **PICO**SCALE sensor head C04 is specified for working distances between 13 and 460 mm. Due to the divergence of the laser beam and the finite collection efficiency of the sensor head, the returned interferometric signal level decreases with increasing working distance. In Figure 3, the optical signal is shown as a function of the working distance. For the C04, we recommend working distances below 250 mm. Larger working distances are possible, but the achievable signal-to-noise performance will be limited.

Table 1. *Summary of optical properties (typical).*

Property	Value
Wavelength	1550 nm
Laser output mode	single mode
Beam waist diameter (d_0)	360 µm
Waist position	0 mm
Beam divergence half-angle	2.74 mrad
Working distance	13-460 mm
Beam geometry	circular
Minimum angular working range	±0.070°

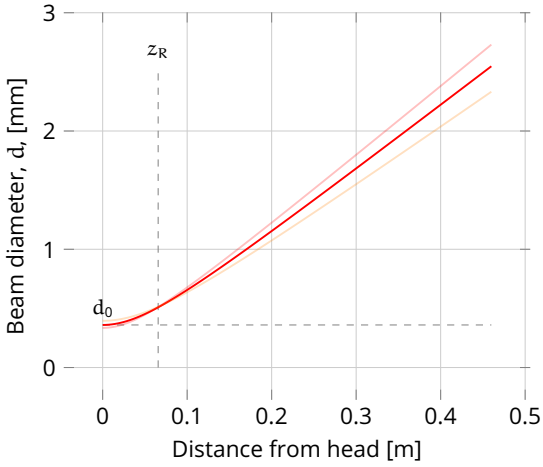


Figure 2. *Beam diameter versus distance, modeled as a Gaussian beam* $d(z) = d_0\sqrt{1+\left(\frac{z-z_0}{z_R}\right)^2}$ *with* $z_R = \frac{\pi w_0^2}{\lambda}$. *Solid: typical; shaded: tolerance range.*

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

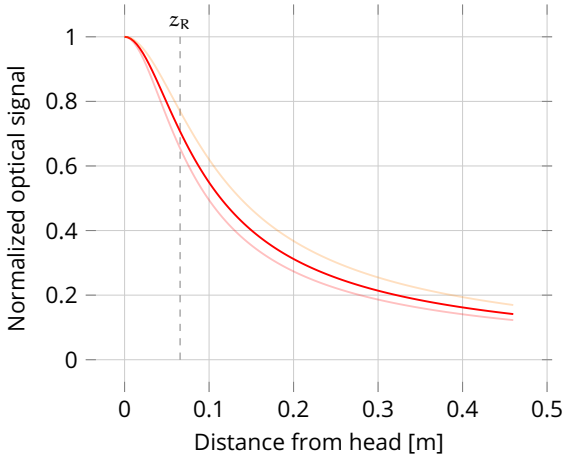


Figure 3. *Normalized interferometric signal versus working distance, modeled from Gaussian beam divergence assuming power coupling into the sensor head* $S(z) \propto \eta(z)$ *with* $\eta(z) = \left[1 + \left(\frac{z-z_0}{z_R}\right)^2\right]^{-1/2}$. *Solid: typical; shaded: tolerance range.*

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 C04 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.

> For a collimated probe beam, the angular working range is determined by Gaussian mode overlap during return coupling and depends on the beam waist at the sensor head. It is therefore independent of the working distance within the specified range.

Options

The C04 sensor heads can be equipped with different beam splitters, allowing to customize the optical properties.

Reference mirror at the front face

In a standard C04 sensor head the reference mirror is coated to one of the side faces of the beam splitter. In setups with specific space constraints it can be advantageous to use a beam splitter with the reference mirror coated to its front face, so that the probe beam exits the head perpendicularly.

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

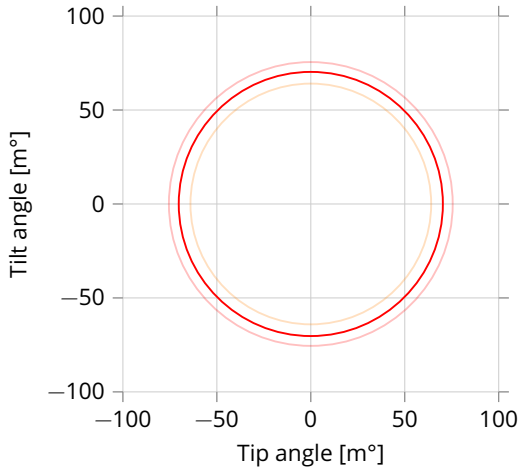


Figure 4. *Angular working range of the sensor head. The normalized interferometric signal amplitude versus target mirror tilt angle* θ_m *is modeled by Gaussian angular coupling of the returned beam,* $S(\theta_m) = \exp\left[-\frac{1}{2}\left(\frac{\pi d_0 \theta_m}{\lambda}\right)^2\right]$, *where*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

No reference mirror - differential measurements

Generally, the reference mirror is directly coated to the beam splitter. However, sensor heads are available without any reference mirror. In this case, the user has to provide an additional mirror to be used as reference. This setup allows to measure relative displacements of two targets.

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 or cryostat compatibility. For the high-vacuum option (-HV), the sensor heads 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.

HOUSING

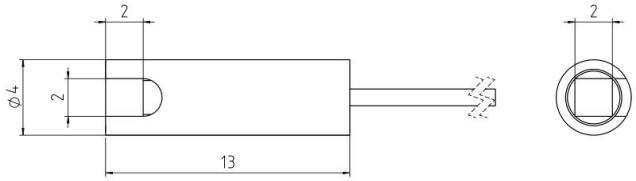


Figure 5. *CAD drawing of the sensor head C04 (General tolerances: ISO 2768-fH).*

A standard sensor head C04 has a titanium housing with a diameter of 4 ± 0.05 mm and 13 mm length, as shown in Figure 5. Its weight is approximately 0.5 g. Furthermore, the sensor heads can be delivered without protective housing (-NO). In this case, a 2.85 mm diameter glass sleeve can be used for mounting and its weight reduces down to approximately 0.2 g.

OPTICAL FIBER

The sensor head C04 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".

Stainless steel tubing

The protective fiber tubing from stainless steel requires special fixture to the sensor head. Thus, directly behind the sensor head the fiber is rigid and should not be bent, cf. Figure 6.

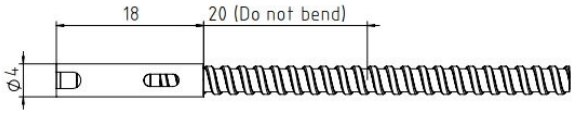
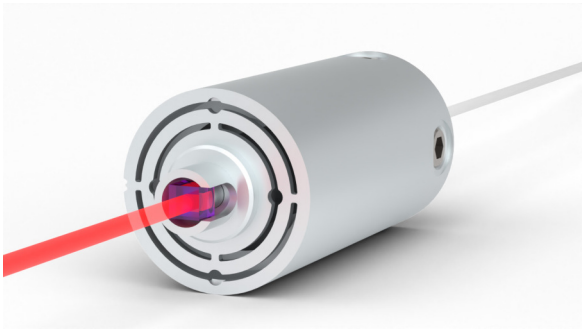


Figure 6. *Sensor head with stainless steel tubing.*

Please note, that the tubing is intended to protect the fiber over its length. The sensor head with its (glass) optics inside becomes the weakest part and strong forces in any direction must be avoided at the interface between the tubing and the sensor head's cover. If strong forces are unavoidable in the vicinity of the sensor head, SmarAct recommends to clamp the tubing separately in order to obtain a strain relief of the sensor head. Please contact SmarAct for recommendations in your specific setup.

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.

Table 2. *Summary of specifications of the MAM option.*

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 - C04 ***- B - C - 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
-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.
	-CRYO	Cryogenic compatibility; down to 4k. Please contact SmarAct.
-C Reference mirror position	No entry/default	Reference mirror on side surface of beam splitter; probe beam exits at front of sensor head
	-FR	Reference mirror on front surface of beam splitter; probe beam exits perpendicular
	-ER	External reference mirror; two probe beams exit sensor head for differential measurements
-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/Cryo)
	-B	3 mm stainless steel tubing recommended minimal bending radius: 30 mm
	-E	900 µm, 5 mm bending radius
-G: Housing option	No entry/default	Titanium housing (⌀ = 4 mm, L = 13 mm, m = 0.5 g)
	-NO	No housing; glass sleeve only (⌀ 2.85 mm, m = 0.2 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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