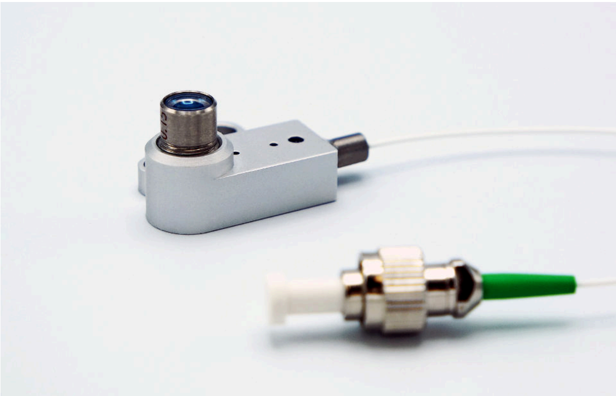
PicoScale Sensor Head PS-SH-F03



The F03 sensor head is intended for use with the **PICO**SCALE *Vibrometer* or the **PICO**SCALE *Interferometer*. The sensor head contains a Michelson interferometer and can be combined with various objectives to focus the measurement laser beam into a micrometer sized spot. This allows to measure displacements of microscopic targets at pm resolution. In combination with the **PICO**SCALE *Vibrometer*, the sensor head can also be used for high-resolution confocal microscopy.

1. OPTICAL SPECIFICATIONS

Interferometer

Figure 1 shows a simplified cross-section through the sensor head. The beam splitter divides the light into a measurement and a reference beam. The reference mirror is directly mounted on one exit of the beam splitter resulting in a short and very stable reference arm. After reflection, both beams travel back to the beam splitter where they recombine. The resulting interference signal is routed, via the optical fiber, to a photo diode within the system controller. Depending on the selected objective, the difference in path length between the reference and measurement arm is between 30 and 40 mm.

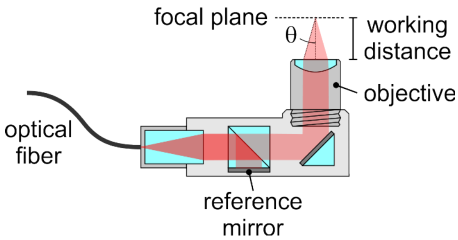


Figure 1. *Schematic drawing of the F03 sensor head. The light from the optical fiber is collimated and split into a reference and measurement beam. The measurement beam is turned by 90° and focused on the sample by the objective lens.*

Figure 2. *The objectives for the F03 sensor head are marked with their numerical aperture.*

Focusing optics

To create a small measurement spot, 3 objectives are available (Figure 2). Their numerical aperture ($NA = sin\theta$) specifies the maximum angle (θ) at which the objective lens can emit or collect light (Figure 1). The radius of the focused laser spot is inversely proportional with the NA. Table 1 provides an overview of the specifications. Due to the beam splitter, the output power will be half the input power of the 1550 nm laser source ($<$ 0.5 mW for the **PICO**SCALE *Vibrometer* and $<$ 0.2 mW for the **PICO**SCALE *Interferometer*). Figure 3 shows how the working range is defined.

Imaging performance

In the **PICO**SCALE *Vibrometer* the F03 sensor head can also be used as a confocal microscopy objective. The single mode optical fiber acts as pinhole which ensures that only light reflected from the focal volume is transferred back to the controller of the **PICO**SCALE *Vibrometer*. More information about the confocal microscopy mode of the **PICO**SCALE *Vibrometer* can be

Table 1. *Specifications of the 3 objectives in combination with the F03 sensor head.*

Numerical aperture (NA)	0.15	0.25	0.5
Spot radius at focus[1] [μm]	7	4	2
Working distance[2] [mm]	10	4.3	1.5
Working range[3] [μm]	90	35	7
Angular working range[4] [°]	±4	±6	±13

[1]Equals lateral imaging resolution.
[2]Distance between surface of objective lens and focal plane.
[3]Total range (around focal plane) at which detected signal exceeds half of its maximum value. Also provides axial imaging resolution
[4]Maximum tilt of sample at which detected signal exceeds half of its maximum value. In many cases vibration measurements are still possible at 1.5 x this angle.

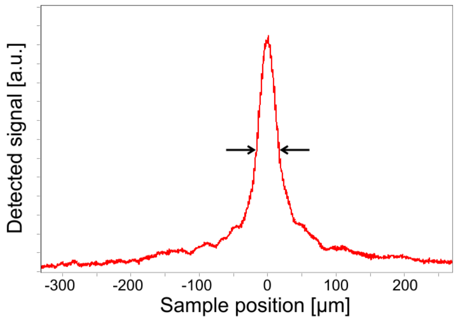


Figure 3. *Measuring the working range of an F03 sensor head with 0.25 NA objective. The reflected signal was recorded while moving the sample (a mirror) up and down. The signal, routed through the single mode optical fiber, was measured by the photo diode inside a **PICO**SCALE Vibrometer controller. Due to the confocal arrangement of the optical path, the recorded intensity peak is very sharp, resulting in a small working range. In this case, the full width at half maximum is 35 µm.*

found in a dedicated application note. The optical resolution is defined as the minimum distance between 2 points at which they can still be distinguished. The resolution that can be achieved with the objectives is approximately identical to the radius of the focused spot size. The highest lateral resolution of $\approx 2\,\mu m$ is obtained with the objective with the highest NA. Although it may appear tempting to choose for imaging applications the objective with smallest spot size, this is not always the best choice as demonstrated in Figure 4. Because of the very limited working range of the high NA objective, it becomes more difficult to ensure that the whole sample lies within the focal plane. For many samples better results are obtained with the 0.15 NA objective which also benefits from a longer working distance. Only for very small and flat structures, such as the one shown in Figure 5, the advantages of the high NA objective are fully exploited. Also in the axial direction (direction of the laser beam) the different objectives have a different resolution. In this case the size of the focused spot in the axial direction is described by Figure 3. In practice, planes within a sample that are at least the "full width at half maximum" apart can be clearly differentiated.
It should be noted that the imaging resolution is unrelated to the resolution of the interferometric displacement measurements. The latter is specified for the **PICO**SCALE at single pm for periodic displacements.

2. OPTICAL FIBER

The F03 sensor head is terminated with a short single-mode optical fiber (13 cm) and is connected through an additional single-mode patch cable to the **PICO**SCALE controller. The length of the patch cable affects the required laser modulation and must therefor be entered in the control software. For all optical fiber connections, FC/APC connectors are used (8° angled end face) to minimize back-reflections.

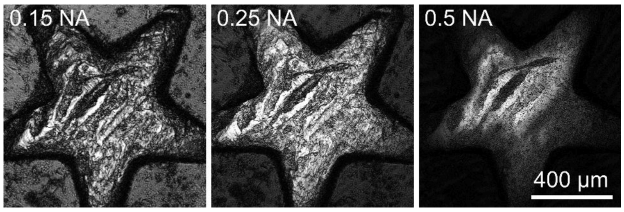


Figure 4. *Feature on a coin imaged with the different objectives. All images were recorded at 1 Megapixel and are unprocessed. Due to its larger working range, the 0.15 NA objective provides the image in which the ≈ 0.2 mm high structure can be best appreciated. In the images recorded with the objectives with a higher NA. the background remains dark and it becomes more difficult to recognize the structure.*

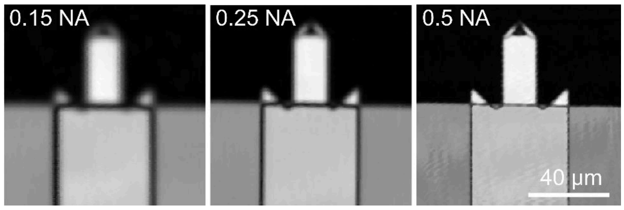


Figure 5. *Micro-cantilever imaged with the different objectives. In all images, recorded at 10 kilopixel and unprocessed, the 16 µm wide cantilever can be distinguished. The 0.5 NA objective provides the image with the highest resolution.*

3. HOUSING

Because of the micrometer sized laser spot and the very short working range it is recommended to mount the F03 sensor head on an XYZ translation stage to allow for an easy adjustment of its position with respect to the sample. The sensor head has a aluminum housing (Figure 6) which is designed to be mounted on the CLS 32 positioner from SmarAct GmbH, but can also be mounted on another flat surface with 2 M2 threads spaced 12.5 mm apart.

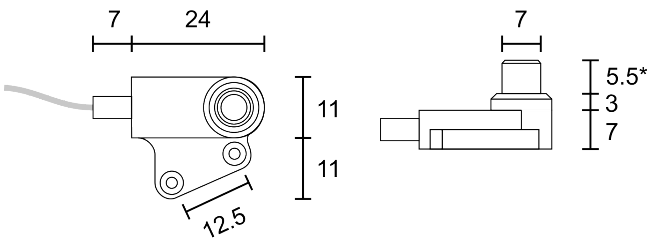


Figure 6. *Schematic drawing of the F03 sensor head with objective, the dimensions are in mm.*
** Because the different objectives have a slightly different height, the total height can vary by ± 0.5 mm.*

4. ORDER CODES

The order codes of the sensor head and its accessories are given in table Table 2. The F03 sensor head always comes with an NA 0.15 objective. Optionally, all 3 objectives can be ordered separately. The listed optical fiber patch cable is the default item used for the **PICO**SCALE *Vibrometer*, other patch cables are available on request.

Table 2. *Order codes for the sensor head and objectives.*

Order code	Description
PS-SH-F03	Sensor head including 0.15 NA objective
PS-ACC-OBJ-0.15	0.15 NA objective
PS-ACC-OBJ-0.25	0.25 NA objective
PS-ACC-OBJ-0.5	0.5 NA objective
PS-ACC-PAT-APC-1.1M-APC-B	Armored patch cable to connect sensor head to the controller

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