PICOSCALE Interferometer: Measurement of radial run-out and wobble

Abstract
The **PICO**SCALE *Interferometer* is a displacement sensor with picometer resolution. It may be applied in industrial applications to measure (and eventually correct) the radial run-out of a rotating workpiece or spindle.

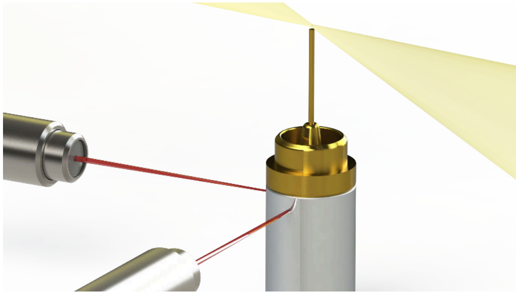

Figure 1. *Schematic view of the setup.* **PICO**SCALE *sensor heads are used to characterize the motion of a rotating target, which could be a sample holder in synchrotron beamlines.*

1. INTRODUCTION

In high precision engineering or in synchrotron end-stations the precise knowledge of the movement of a rotating target is of crucial interest. Radial run-out and wobble of a rotating spindle may have significant influence on the quality of a workpiece, and thus needs to be reduced. In synchrotron applications, tomography of crystal structures requires even higher precision to accurately position the sample. Thus the run-out and wobble need to be measured accurately. Subsequently, by applying adequate control loops or lookup-tables, the rotating target may be kept on the desired trajectory.

2. SETUP

The setup of this demonstrator is shown in Figure 2. A polished cylinder (stainless steel) was mounted on a SmarAct xy-stage as well as a rotary stage. The xy-stage can either be used to set a specific eccentricity to prove the capability of measuring large run-outs of up to 1 mm, or to correct for it. Two line focusing sensor heads (Order Code: PS-SH-L01) were assembled at a specific height with a 90° orientation to measure the eccentricity, and a third sensor head was mounted above the second one. The latter pair was used to infer the wobble of the cylinder. A **PICO**SCALE Controller with increased laser power was used for these experiments (Order Code: PS-CTRL-V1.4-HP), which is optimal for low-reflectivity or cylindrical targets.

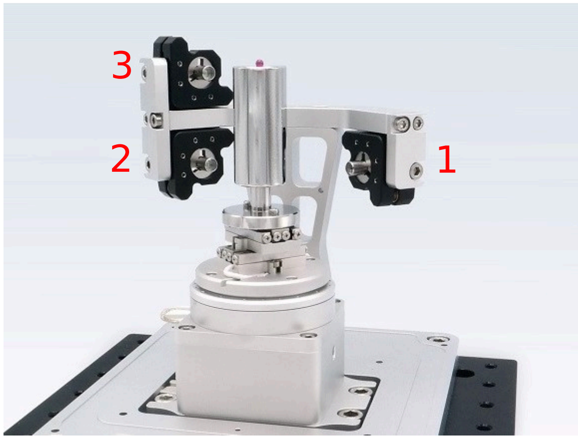

Figure 2. *Experimental setup. Three* **PICO**SCALE *sensor heads with line focused probe beam are targeting a polished cylinder, which is mounted on an xy- and a rotary stage. See text for details.*

3. MEASUREMENT PROCEDURE

The cylinder was rotated by small increments and at each angle the relative displacement of the target with respect to each sensor head was recorded. In Figure 3 the values for the x- and y-direction are shown. The 90° phase shifted signal is (in first order) interpreted as the eccentricity of the sample.
The wobble is calculated from the position data of sensor heads 2 and 3. Consequently, a numerical fit is applied to the data that incorporates the wobble of the pin. Thus the effect that each sensor head records the shape of an ellipse instead of a circle is taken into account. The residues from the pin are due to the non-perfect surface of the pin which is overlaid with bearing errors. Figure 4 shows these residues of sensor head 1, for all recorded angles between 0 and 360°. The residues are within ±1.5 µm.
The line focusing heads allowed to track eccentric movements of up to 1 mm while being insensitive to wobble. Thus, the **PICO**SCALE can be used in high

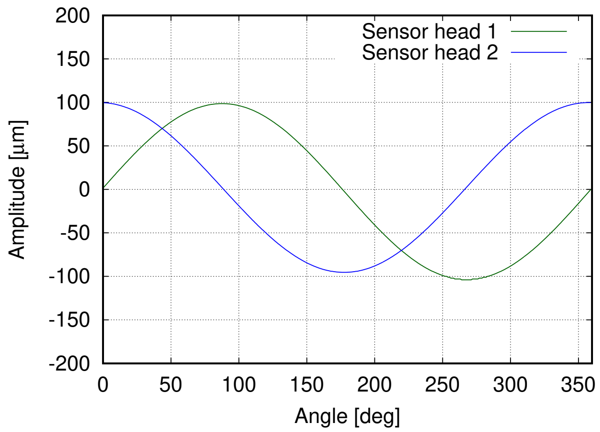

Figure 3. *Measurement of the eccentric movement. The x- and y-direction is shown, that are measured by sensor head 1 and 2, respectively.*

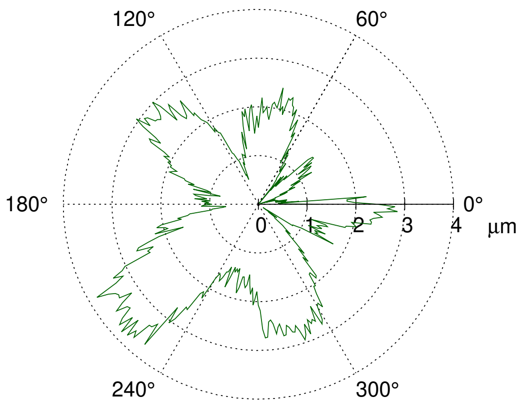

Figure 4. *Residues of the data measured by sensor head 1 after the calculated eccentric movement and wobble are subtracted.*

precision engineering or wherever radial run-out and wobble are crucial parameters.

4. VARIOUS PIN DIAMETERS

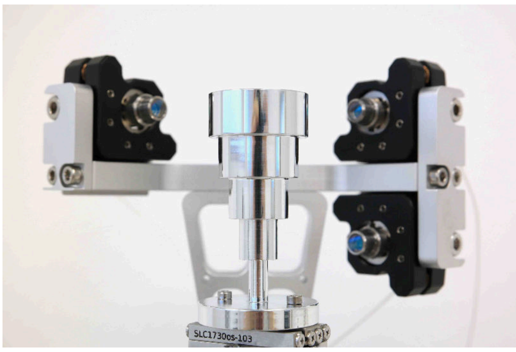

Figure 5. *Probe pin with different diameters ranging from 25 mm (top) down to 5 mm (bottom).*

The L01 sensor heads have been aligned to various diameters of a cylindrical surface, see Figure 5. The goal is to determine the maximum eccentric movement of the sensor head in dependence of the pin diameter. The results for the smallest pin diameter are shown in Figure 6. All measurements with larger diameters showed similar results, and maximum eccentricities of more than 0.7 mm were always possible. The surface quality of the pin was the limiting factor, which was polished aluminum.

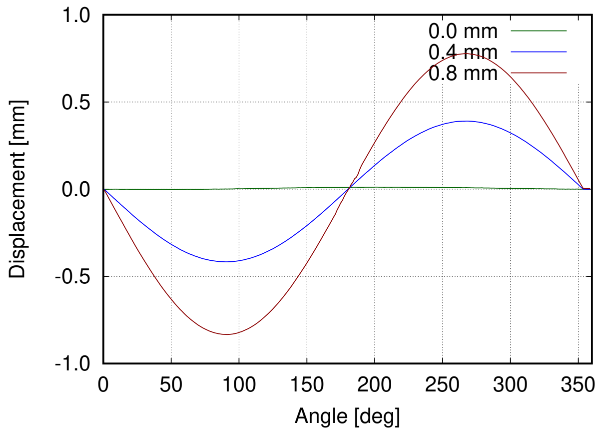

Figure 6. *Displacement measurements of a rotating pin with a diameter of 5 mm and some (artificially introduced) eccentricities. Eccentricities of 0.8 mm were tracked.*

A. ALIGNMENT OF THE SENSOR HEAD TO THE PIN

The alignment of the senor head to the target is crucial to obtain optimal performance, i.e. large lateral displacements of the pin with respect to the sensor head. As depicted in Figure 7, the cylinder lens is focusing the initially circular beam profile to a line. Directly at the exit pupil of the sensor head, the beam is nearly circular. In the focal plane, it is a thin line which must be oriented perpendicular to the pin's axis. Sometimes it can be easier to check the sensor heads orientation by viewing the beam profile in the far field, where the line is upright.

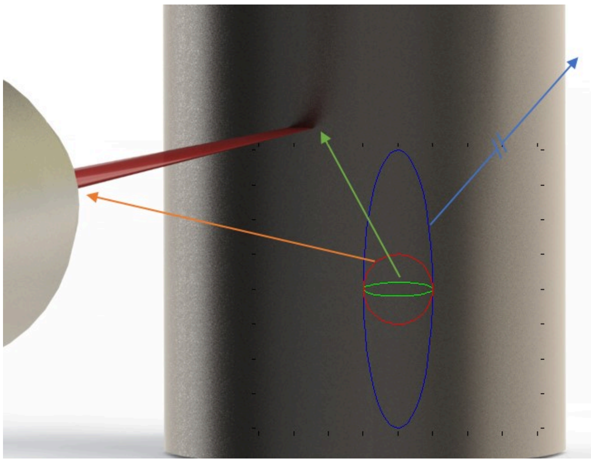

Figure 7. *Correct orientation of the sensor head: In the focal plane of the beam, the line is oriented perpendicular to the target cylinder's rotation axis (green). Thus, in the far field the line appears upright (blue) while directly at the exit pupil of the sensor head, the line focussing does not have any effect on the beam profile and the beam appears circular (red).*

Please note, that the measurement beam is infrared and cannot be seen with the eye. Thus, the pilot laser should be activated during alignment. However, for applications with line focusing sensor heads, a **PICO**SCALE with higher output power is recommended (-HP option), which does not have a pilot laser. Any other visible laser source may be used to obtain a visible indicator. Please contact SmarAct if you need support.

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