FPS3010: towards long range - high precision wobble characterization

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Introduction

The FPS3010 is a 3-axis miniaturized interferometric displacement sensor. Its outstanding performance allows compatibility with target displacement velocities of up to 1 m/s whilst offering sub-nm repeatability. Moreover, the patented [1] FPS all-optical fiber based standard sensing

Figure 1: *The real-time displacement FPS3010 sensor equipped with 3 channels using single mode fibers and compact sensor units.*

head enables the application in extreme environments (i.e. low temperature, high- and ultra-high vacuum). The FPS3010 is further plug-and-play compatible thanks to its large angular alignment tolerance.

In many applications - such as wobble characterization of piezo stages, tilt and pitch detection of bearings, measurement of piezo deformation - it is not only a linear sensing technology which is required but also the feasibility for angular measurement.

In this application note, attocube's R&D lab demonstrates the possibility of detecting small angular displacements (within few degrees) using the standard FPS3010 technology.

The FPS3010 measurement principle is as follows: a fiber-coupled, wavelength stabilized DFB laser diode sends light at 1535nm wavelength to the FPS sensor head. The laser beam is out-coupled and free-beam collimated towards a high reflectivity target to enable displacement measurement over long working distances of several tens of cm. The light is subsequently reflected twice between fiber end and target before it is finally coupled back into the fiber. Thus, a low finesse double path Fabry-Perot interferometer cavity is created and a signal modulation due to the interference can be detected when the target is displaced. Real time electronic processing is used to output the target's relative displacement with sub-nm repeatability.

Proof of principle

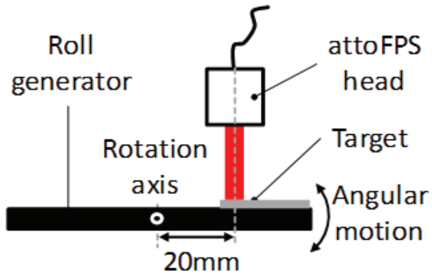

Figure 2: *Schematic of the proof of principle setup.*

To demonstrate the ability of the FPS to comply with small angular displacements, a high reflectivity target is mounted on top of a roll generator. This system generates a controlled angular displacement around a defined axis of rotation, see Figure 2. The FPS head is mounted 20mm de-centered from the rotation axis normal and allows measurement of the out-of-plane motion at the target location. From this linear motion, the roll angle can be deduced – provided the roll angle is smaller than the sensor head's acceptance angle.

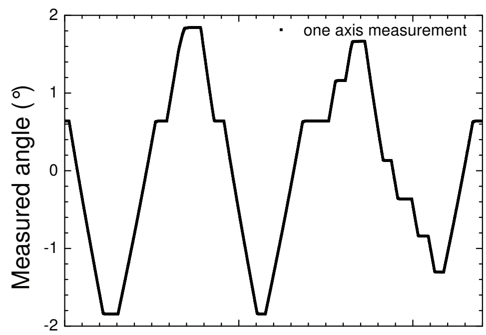

Figure 3: *Typical angle measurement range of a single standard FPS head in a setup as depicted in figure 2. The actual angle is deduced from a linear displacement as measured off-centered from the axis of rotation. The roll generator was consecutively set to values between -1.85°and 1.85, yielding the step pattern in the graph.*

For the setup as depicted in Figure 2, we have found that an angular motion of more than 3.5° (equal to 210 arc minutes) can be continuously detected if the distance between sensor head and target is set to approx. 3 mm, see Figure 3. This angular range is large compared to many laser interferometers available on the market, where angular ranges are typically – but not always – limited to .1° or even less.

Dual-beam setup

In a second setup – as depicted in Figure 4 – we have focused on measuring small angular displacements without having to precisely position the sensor head at a (known) distance L to the rotation axis. The setup consists of two sensing heads mounted normal to the roll generator in loose fashion. The optical centers of the two sensor heads are spaced 16 mm apart, see Figure 4. While the generator was rotated over a range from -1.7° to 0.8°, both linear position displacements of the two sensors were recorded, the angle calculated, and the results compared to an electronic angle sensor embedded in the roll generator.

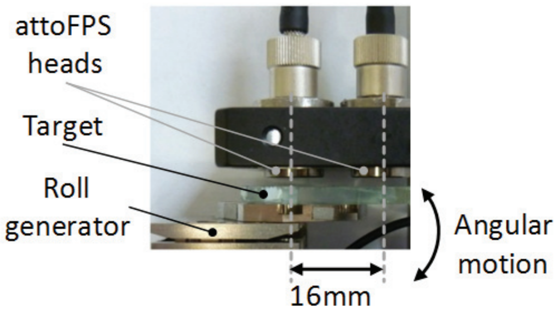

Figure 4: *Photograph of the second experiment setup. A high reflectivity target is mounted onto a roll generator. Two sensing heads are mounted roughly normal to the target at a working distance of a few mm.*

Measurement Results

We have calculated the angle of the roll generator through $\alpha = \arctan(\Delta P/L)$, where ΔP is the numerical difference between the indicated position of both FPS sensors and L the distance between the FPS heads, in this case 16mm. The angle α is then plotted versus the number of commanded steps of the table in Figure 5(a) (red dots). The internal roll generator sensor angle measurement is plotted as black open squares in Figure 5 (b). It is apparent that both signals are correlated with high accuracy confirming a good agreement between the two sensors.
To study more precisely the difference between the two detection methods, the difference between the measurements divided by the travel range is plotted in Figure 5(c). It can be noted that the measurement difference over the travel range is better than +/-0.2%, which is within the generator embedded sensor accuracy limit.

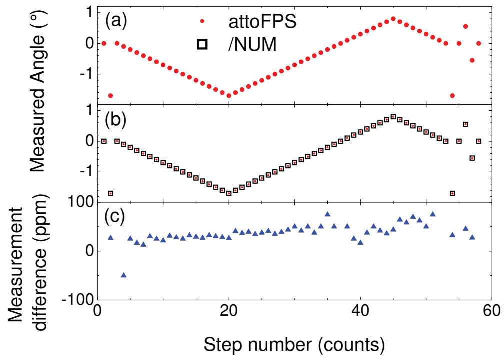

Figure 5: **(a)** *Angular position of the roll generator as measured by(a) FPS (red dots) and (b) embedded sensor (black open squares) and FPS (red dots) simultaneously. (c) Difference between the two measurement methods.*

Summary

We have demonstrated the capability of the FPS to detect angular displacements of up to 3.5° (210 arc minutes), in both single axis and differential measurement setups.

In contrast to conventional angular measurements employing e.g. LVDT's or optoelectronic sensors, angular measurements performed with the FPS provide highest angular resolution and repeatability, while creating least impact onto the target . Compared to the best optoelectronic sensors currently available, the FPS dissipates about one thousand times less energy at the sample location while being approx. a thousand times more accurate. Further to this, the FPS enables (angular) measurements in extreme environments such as low temperature and high/ultra-high vacuum; its compactness and simple operation further benefit the user.

attocube currently develops advanced sensor heads and according software designed and optimized for angular measurements which will be available by the end of 2012.

References

[1] K. Karrai and P.-F. Braun, EP2363685 (A1), 2011.

The measurements were performed by P.-F. Braun in attocube application labs.