Height and vibration measurements of spiral-shaped accelerometers

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INTRODUCTION

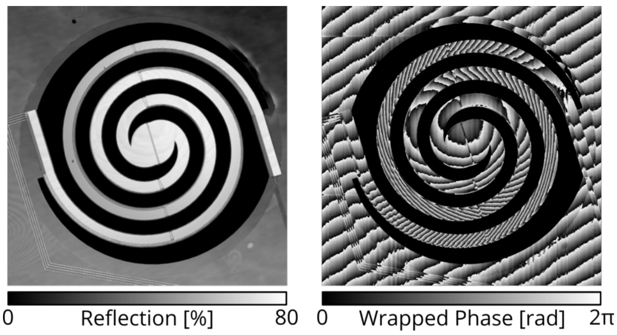
In this application note, we demonstrate the capabilities of SmarAct's **PICO**SCALE *Vibrometer* to measure the topography and vibrational modes of a prototypic spiral-shaped acceleration sensor. Both pieces of information can be used to validate fabrication processes or to calibrate the electric response of such sensors.

RESULTS

Height measurement

With interferometry, displacements can be measured with very high accuracy which is the foundation for vibration measurements. However, also when the sample is stationary, the interferometer will still report a displacement when the measurement laser moves from one pixel to the next. This displacement reports the difference in height between both pixels (more accurately, the difference in distance between the sensor head and each of the pixels). When the sample is continuous and reflective it is in principle possible to track the changes in distance and to reconstruct a height image. In practice this method is prone to errors because the correlation between the pixels is often lost due to discontinuities and non-reflective parts in the sample. The information that remains is a so-called wrapped height image, in which each pixels has a height from 0 to 2π (which can be mapped from zero to half the laser wavelength). Through phase unwrapping algorithms, also used in the topographic mapping from radar interferometry data, it is possible to resolve the 2π ambiguity and to reconstruct the height image. In the **PICO**SCALE *Vibrometer* VIEW software, efficient phase unwrapping algorithms are included which allow the reconstruction of an height image with one mouse-click. Figure 1a shows a reflection image of the spiral-shaped accelerometer and the original wrapped recording and Figure 1b shows the reconstructed height image. It can be seen that the accelerometer is not flat: the outer arms of the spiral are about 25 μm higher than the substrate while the spiral core extends about 10 μm above it.

(a) Microscopy images of the accelerometer.



(b) Height unwrapping.

Figure 1. ***a****) The size of the scan is 2.5x2.5 mm. Left: reflection image, Right: wrapped height image. This interferometric image was recorded simultaneously with the reflection image.* ***b****) the reconstructed height image obtained by a phase-unwrapping algorithm. The spiral is not flat, the center extends about 10 μm above the surrounding substrate, whereas the outer arms of the spiral are about 25 μm higher.*

Vibration measurement

Accelerometers measure acceleration, information that allows to understand the surrounding of the device. For sensitive applications, these sensors have to be fully characterized to minimize the chance of misinterpreting the data. SmarAct's **PICO**SCALE *Vibrometer*, in combination with the standard shaker stage, is a great tool to do just that. Here, the accelerometer was positioned on top of the active surface of the stage which was then excited using the internal signal generator of the vibrometer. After measuring the local vibrations of the sensor at its center, few resonances were visible and we moved on in performing modal analyses. A standard modal analysis consists in exciting the sample at one specific frequency while imaging the amplitude and phase of vibrations on-the-fly using the internal lock-in amplifier. For this application, the accelerometer was actuated successively at 2 kHz, 4 kHz, 14 kHz and 46 kHz. While trained users can directly correlate the amplitude and phase images to a given vibrational mode, it is sometimes easier to first combine both pieces of information and reconstruct a deflection image. Figure 2 shows the deflection images for each resonance as reconstructed by the **PICO**SCALE *Vibrometer* VIEW software. The first bending mode was retrieved at 2 kHz which defines the actual bandwidth of this prototype.

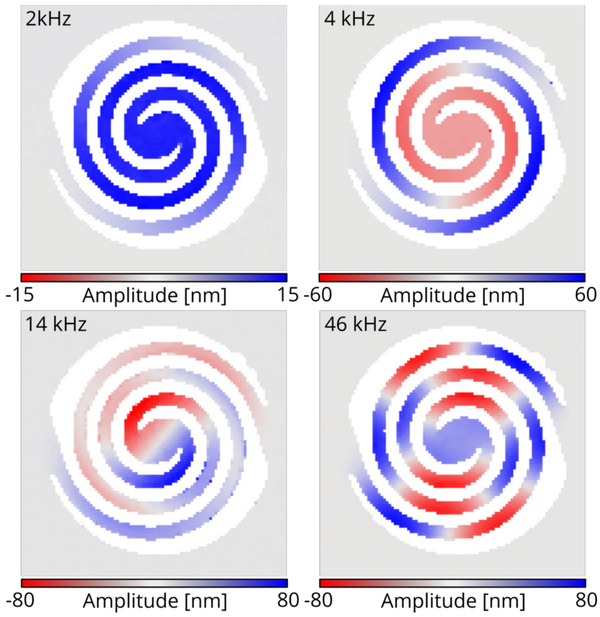


Figure 2. *Modal analyses of a spiral-shaped accelerometer. The deflection images combine both amplitude and phase images that are recorded on-the-fly while imaging.*

Conclusion

Height measurements in correlation with modal analyses allow to further characterize and specify vibrating structures. During the prototyping process, these pieces of information are crucial to actually confront simulations which are usually based on models that do not necessarily comply with the sample shape nor behavior.

In an iterative process, the simulations can be refined and the production optimized, leading inevitably to increased performances.

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