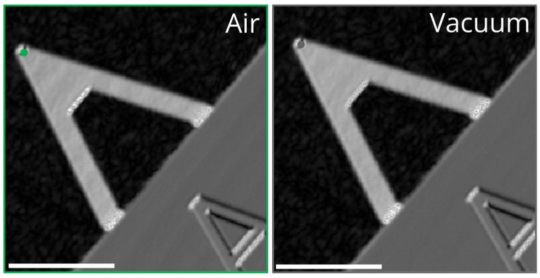
Measuring vibrations in vacuum

The dynamic behavior of structures can depend strongly on the surrounding medium. This application note deals with the measurement of vibrations in air and in vacuum. In air, the vibrations of a micromechanical structure will be damped, which generally leads to a downshift of the resonance peak and a reduction of its quality factor as compared to the situation in vacuum. For this reason, many MEMS sensors are packaged in vacuum to improve their performance.
The ability of Smaract's **PICO**SCALE *Vibrometer* to work in a variety of environments, including vacuum, opens up new ways for the characterization of micromechanical systems. For example, the effects of production steps that take place in vacuum, such as thin film deposition, can be directly measured. Furthermore, the performance of MEMS that are designed to work in vacuum can be tested at different pressures *before* they are packaged. In this context, also the capability of the **PICO**SCALE *Vibrometer* to measure vibrations through a silicon package with an infrared laser beam should be mentioned, since this allows to measure vibrations of MEMS sensors *after* they have been packaged.

Here, we show how the vibrational behavior of a micro-cantilever is strongly affected by air damping. For this, we studied the vibrations that are induced by the thermal energy in the system, so in the absence of active actuation of the cantilever. For the experiment, the **PICO**SCALE *Vibrometer* (excluding controller, PC and operator) was placed in a vacuum chamber. Figure 1a shows the recorded microscopy images of the cantilever. As expected, their appearance is identical. In order to measure the amplitude spectra, the measurement laser beam was positioned near the free end of the cantilever as indicated in figure 1a. Here, the displacements were measured and Fourier transformed to reveal the amplitude spectra around the resonance frequency (figure 1b). In vacuum, the curve has a much higher quality factor as under ambient conditions in air. In addition, the resonance frequency in air is reduced by about 0.3 kHz.

These results confirm the importance of measuring the dynamic performance of micromechanical structures under the right environmental conditions. Thanks to compact dimensions of the **PICO**SCALE *Vibrometer* it can be fitted in most vacuum chambers and electron microscopes.
Methods. The experiments were performed with a standard **PICO**SCALE *Vibrometer* placed inside a Vega3 electron microscope (Tescan, Brno, Czech Republic). The MSCT chip (Bruker, Billerica, USA) was fixed on the sample holder using vacuum grease and cantilever A was investigated (manufacturer specifications: resonance frequency 22 kHz, spring constant 0.07 N /m). The amplitude spectra were obtained by averaging 50 FFTs, each converted from a 1 s recording at a sampling frequency of 5 MHz. Due to this long measurement time it cannot be excluded that some extra energy was added to the system by the fraction of the measurement laser light that was adsorbed by the cantilever.

(a) Microscopy images



(b) Amplitude spectra

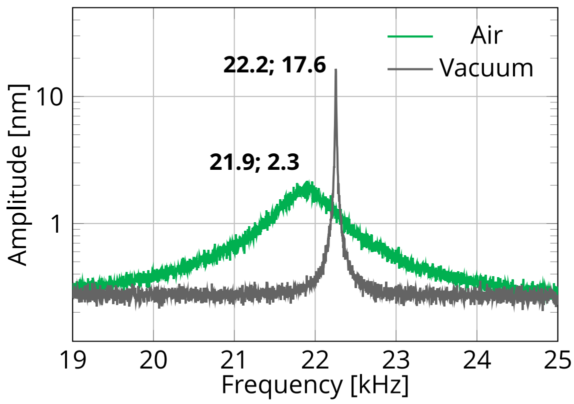


Figure 1. Vibrometry measurements in air and in vacuum. *The AFM cantilever was measured in a scanning electron microscopy chamber, either at 1.0 × 10^3 mbar (ambient air pressure) and 3.6 × 10^{-3} mbar (vacuum pressure). First, microscopy images were recorded.* ***(a)*** *Confocal reflection images in air and in vacuum. The dot shows the position of the measurement laser for the recording of the thermal vibrations.* ***(b)*** *The amplitude spectra in air and in vacuum. The curve in vacuum is much sharper and shows an higher resonance frequency as in air.*

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