Measuring Brownian Motion of Commercial Micro-Cantilevers

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Frequency analysis is a standard method to study demanding applications and measure the frequency dependent mechanical motion of machine parts and workpieces.

Measuring vibrations with amplitudes of only few picometers is very challenging, exceeding the capabilities of other commercially available measurement techniques. To demonstrate that attocube's fiber-based Industrial Displacement Sensor (IDS) not only has high-resolution but also a very low noise floor, we measured the resonant vibrations of micro-sized cantilevers which were excited only by their thermal energy at ambient conditions.

The experimental setup is shown in Figure 1: The cantilevers were fixed to a stack of attocube positioners to allow alignment movements in x-, y-, and z-directions. A sensor head with a fixed focal length of 2.8 mm (D12/F2.8) was used to focus the light to a spot size below 2 µm in diameter on the cantilevers.

The bandwidth of the digital signal output of 5 MHz (AquadB) allows a Fast Fourier Transform (FFT) analysis up to 2.5 MHz. We studied two different cantilevers of the same length (225 µm), but different thicknesses and widths: 3x28 µm (thin cantilever A) and 7x38 µm (thick cantilever B).

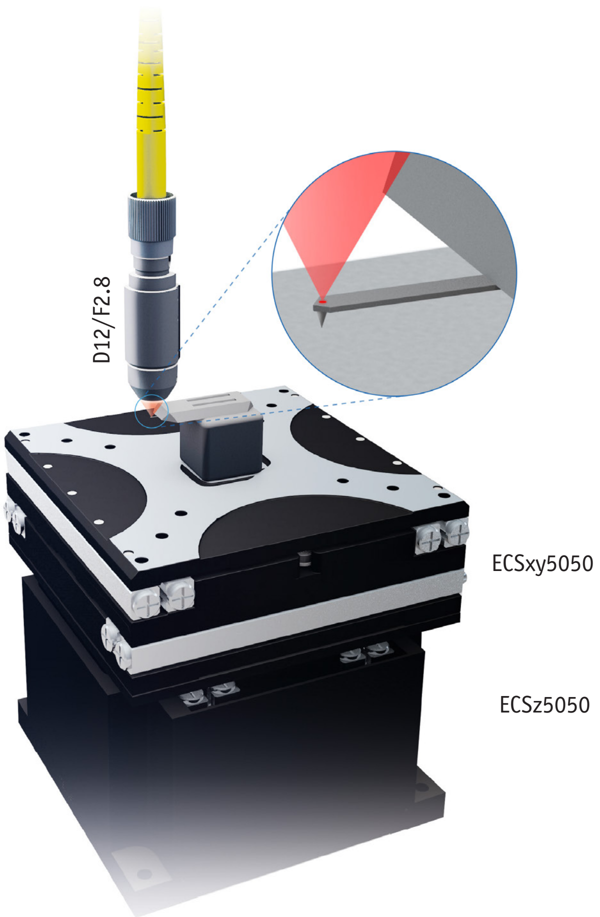

Figure 1: *A stack of three attocube x-, y-, and z-positioners was used to align the D12/F2.8 sensor head onto the micro-cantilever. The distance between the objective and the cantilever was about 2.8 mm.*

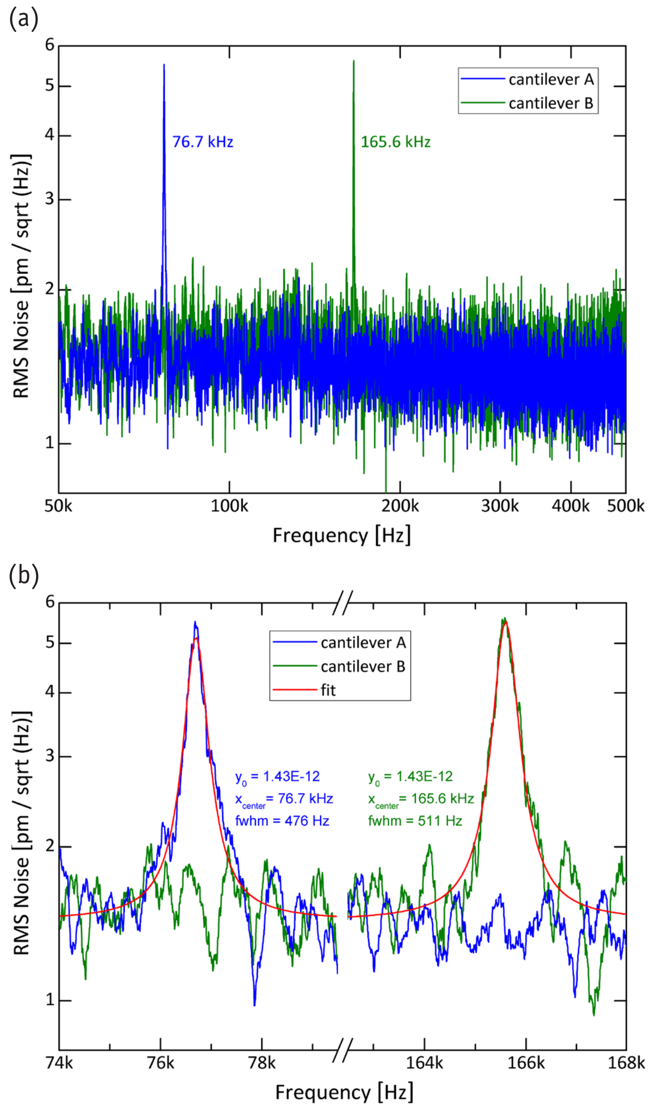

Figure 2: *The figures (a) and (b) show the FFT analysis of the two different cantilevers under investigation. The resonant frequencies of the cantilevers can be seen at 76.7 kHz (thin cantilever A) and 165.6 kHz (thick cantilever B).*

We received clear, high-contrast alignment signals from the cantilevers. This signal was subsequently FFT-analyzed to visualize the mode spectrum. Figure 2(a) shows the FFT result of the two cantilevers in a frequency range between 50 and 500 kHz. The cantilevers show strong individual resonance peaks. These resonance peaks at 76.7 kHz and 165.6 kHz, respectively, are only excited due to Brownian motion as no other excitation was present in the setup.

Moreover, the noise floor in the frequency range from 50 and 500 kHz is around 2 pm/sqrt(Hz). The red curves in Figure 2(b) represent the Lorentz fits of the two resonance peaks and, from this plot, the quality-factors of 161 for cantilever A and 324 for the cantilever B have been calculated.

In summary, this report demonstrates the resolution capability of the IDS by measuring the Brownian motion of micro-sized cantilevers at ambient conditions.

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