Dissecting the dynamic response of an ultra-fast actuated mirror

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Abstract
The behavior of piezo-based actuators does not only rely on the dynamic response of the piezoelectric element itself. Both the packaging and the mounting conditions of the piezo contribute to the actuator's performance. Here, we used SmarAct's **PICO**SCALE *Vibrometer* to directly visualize the vibrational modes of the different building blocks of an ultra-fast actuated mirror. Thus, particular resonance peaks can be attributed to specific components of the assembly.

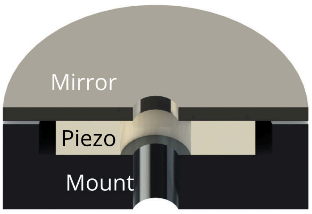


Figure 1. *Cross-sectional drawing of the ultra-fast actuated mirror. The piezo ring is sandwiched between a polished titanium mirror and a cup-shaped titanium mount.*

1. INTRODUCTION

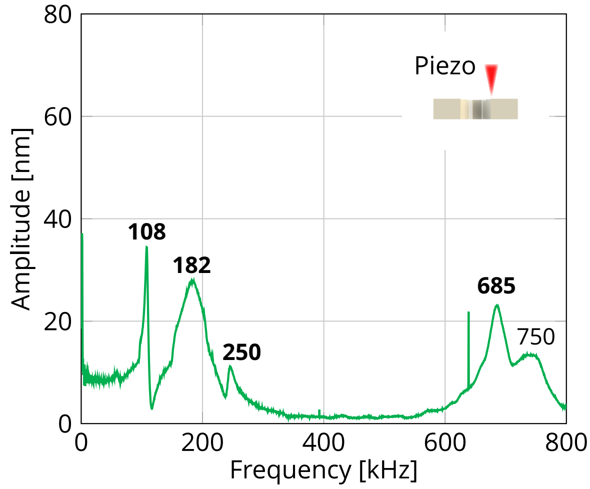
The dynamic response of a piezo-actuated assembly does not only depend on the chosen piezoelectric element but also on the other components such as the housing, the actuated object and on how these parts are connected. The resulting system response can be notoriously difficult to predict. Finite element analysis is regularly used but production tolerances and mounting stresses are difficult to include. Also, complex assemblies can be very time consuming to simulate.
The actual measurement of vibrations of piezo-actuated systems remains essential to characterize their real-world performance. Here, we employed the **PICO**SCALE *Vibrometer* to image mechanical resonance modes of an ultra-fast actuated mirror (**Figure 1**). We measured the response of an unmounted piezo element and compared this with the dynamic response of the complete assembly.

2. RESULTS

To determine the resonance frequencies of the system, the electric output signal of the function generator of the **PICO**SCALE *Vibrometer* was connected to the piezo element. A frequency sweep was performed from 10 kHz to 800 kHz at constant amplitude. The displacements were measured at a single point and Fourier transformed to show the amplitude in the frequency domain.

Dynamics of piezoelectric element: First, the response of the bare piezo ring was measured. The ring was resting on a sorbothane sheet in order to mechanically isolate it from its surroundings. The manufacturer specified a resonance frequency of 515 kHz. Figure 2a reveals multiple resonance peaks, three of which occur at frequencies lower than the stated resonance frequency. To visualize the bending modes of the piezo ring, it was actuated at the respective resonance frequencies while raster scanning the laser beam over the surface. Thanks to the integrated lock-in amplifier, the bending modes can be directly visualized and are shown in Figure 2b.

(a) Amplitude spectrum of the piezo



(b) Deflection images of vibrational modes

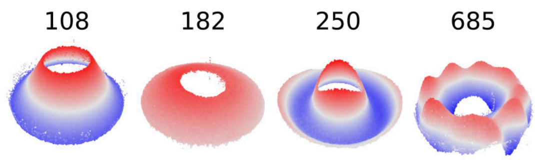


Figure 2. ***(a)*** *Frequency response of the ring piezo (inset figure).* ***(b)*** *Deflection images of the bending modes at the indicated frequencies.*

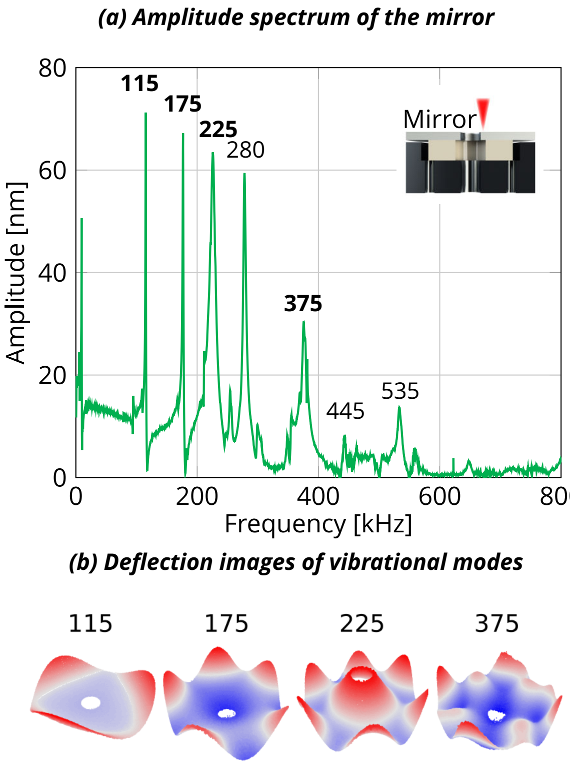


__Figure 3. (a)__ Frequency response of the polished titanium mirror (inset figure). __(b)__ Deflection images of the bending modes at the indicated frequencies. The complexity of the modes increases with the frequency of excitation.

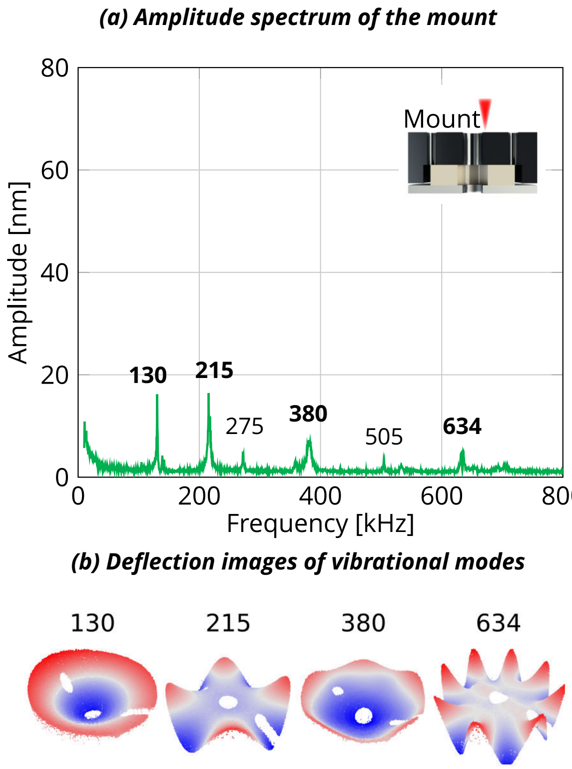


__Figure 4. (a)__ Frequency response of the titanium mount (inset figure). __(b)__ Deflection images of the bending modes at the indicated frequencies.

Dynamics of the mirror surface: Next, the complete mirror assembly was investigated. The measurement laser was focused on the mirror near the center of the device. Figure 3a reveals multiple resonance peaks which show no resemblance with the amplitude spectrum of the ring piezo. Also the bending modes appear very different (Figure 3b). Clearly, the dynamic response of the thin mirror itself leads to multiple additional peaks with a high amplitude that dominate the measured response.

Dynamics of the titanium mount: Finally, the response of the titanium mount was measured. To this end, the assembly was turned around and the measurement laser was focused on the mount, near the center. Figure 4a shows less resonance peaks and lower amplitudes as compared to the amplitude spectrum of the mirror. This is likely due to the larger mass of the mount and its more complex shape. Figure 4b shows the corresponding bending modes.

3. CONCLUSION

With SmarAct's **PICO**SCALE *Vibrometer* it is possible to characterize the dynamic response of an ultra-fast actuated mirror. By performing measurements on different parts of the assembly, the influence of the mirror and housing on the dynamic performance can be clearly seen. Such measurements as essential to optimize the design of actuators that operate under dynamic challenging conditions.

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