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FAST Z-SHIFTER BASED ON A UNIMORPH DEFORMABLE MIRROR

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Abstract

The project **eVerest** is geared towards developing a laser micromachining technique for structuring of large-size moulding tools with µm-sized precision and ablation depth of several millimeters. This process requires guiding the focus of a laser beam along the contours of the workpiece in three dimensions.

State-of-the-art galvo scanners already provide highly dynamic and precise x-y beam deflection. However, focus shifters ("z-shifters") relying on conventional optics are restricted to a fairly limited bandwidth of a few 100 Hz. In this project we develop a fast z-shifting mirror with high surface fidelity and stroke of several µm which allows for an actuation rate of 2 kHz.

Mirror Design

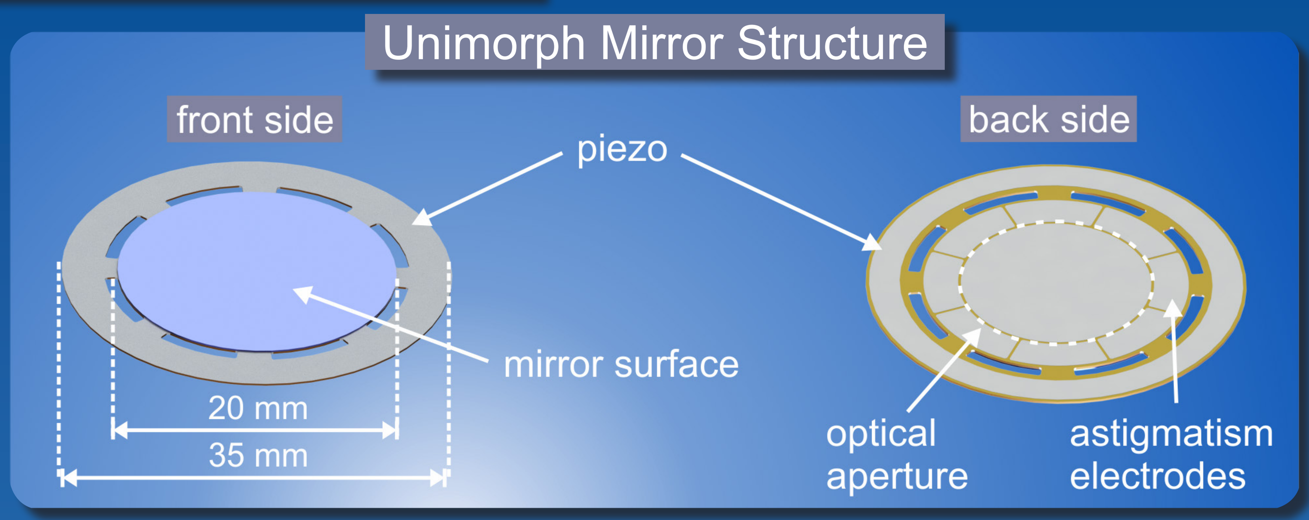

Fig. 1 Mirror structure with reflective mirror surface (front side) and structured electrode (back side).

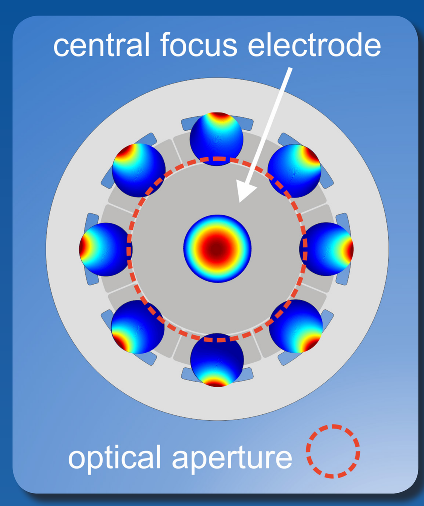

Fig. 3 Influence functions.

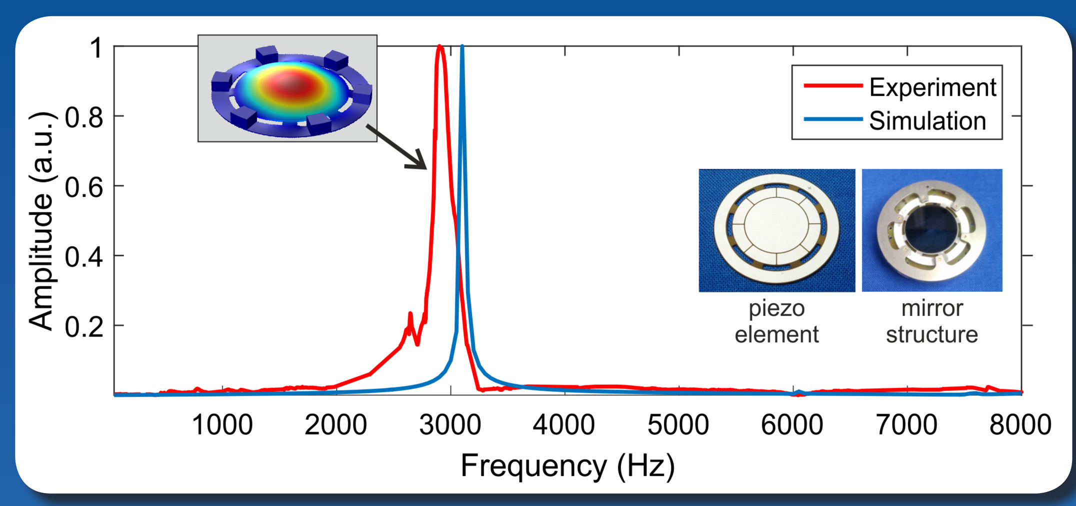

Fig. 5 Measured and calculated frequency response.

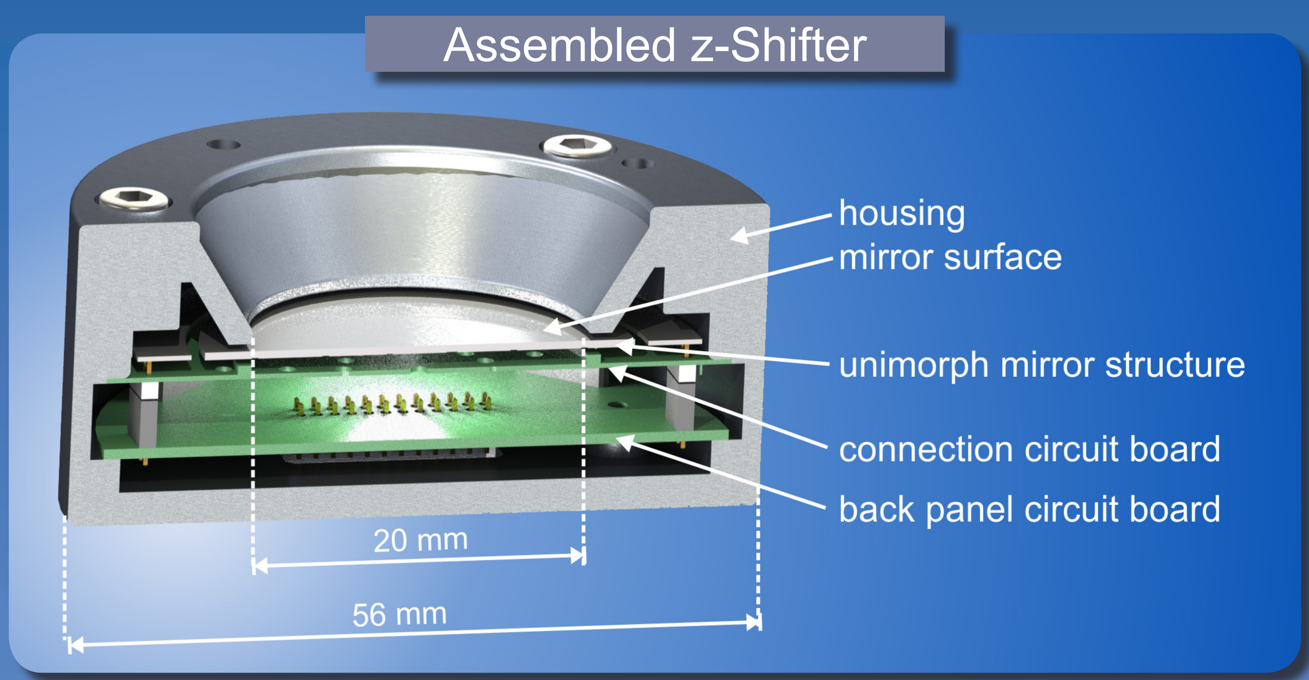

Fig. 2 Cross-sectional view of the assembled mirror.

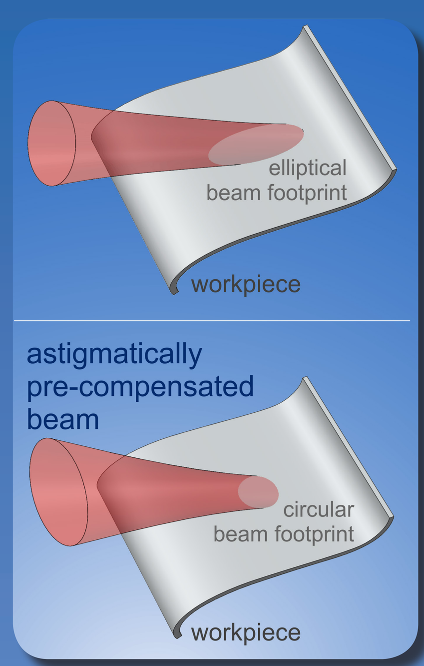

Fig. 4 Astigmatism compensation.

Specifications:

- super-polished N-BK10 substrate (RMS < 1.0 Å)
- HR dielectric coating: R > 99.998 %
- optical aperture: Ø 14 mm
- actuation speed: up to 2kHz
- stroke: +/- 6 µm (PV)
  ⇒ +/- 25 mm focus shift
  (by using a 250 mm F-Theta lens)
- dynamic astigmatism control to compensate for elliptical beam footprint

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Bundesministerium für Bildung und Forschung

Mirror Characterization

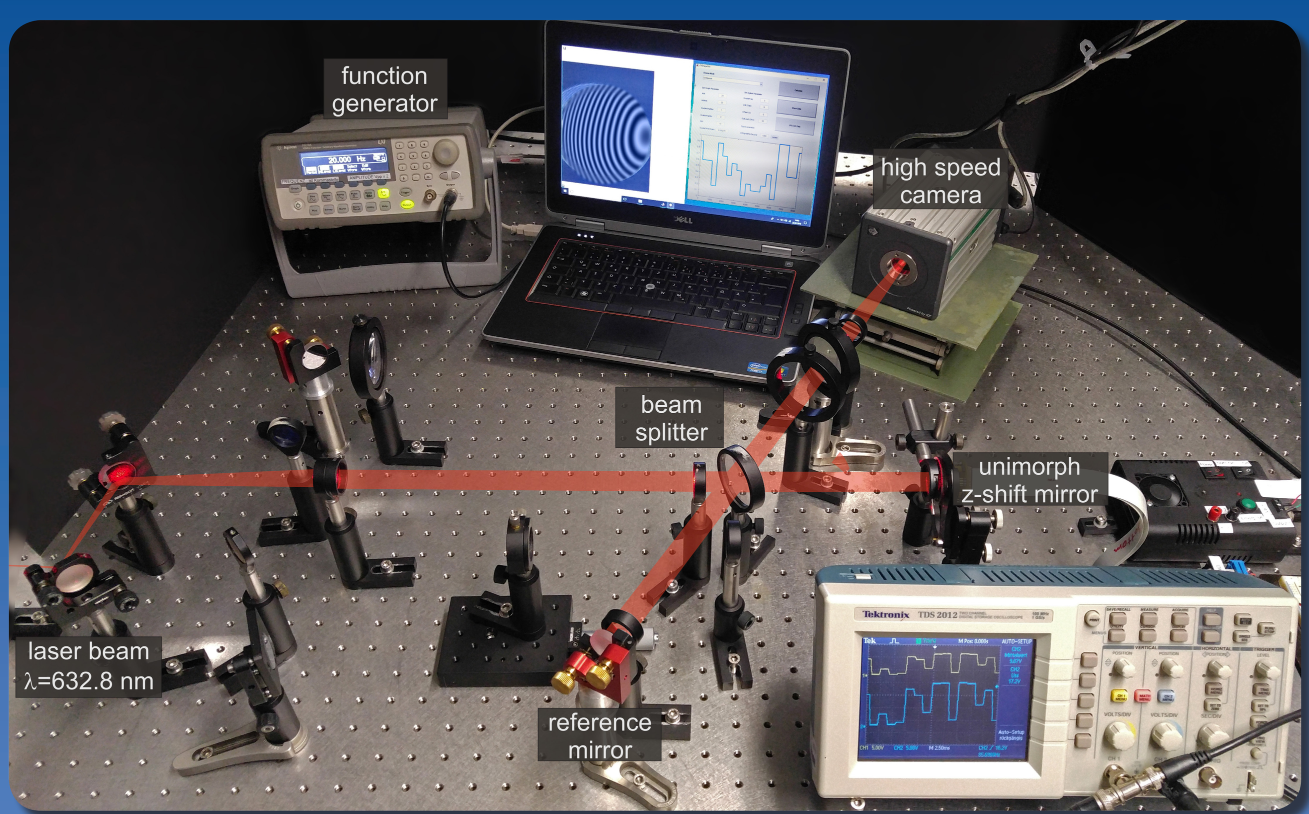


Fig. 6 Interferometric setup for high-speed surface metrology. Interferograms are recorded with 200000 frames/s.

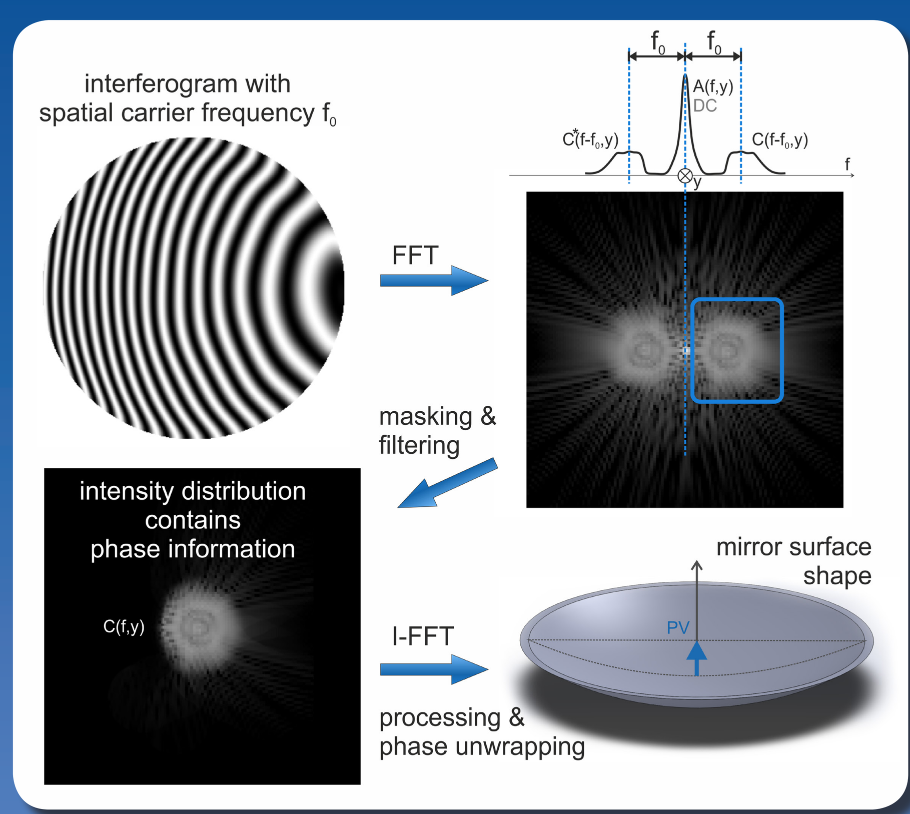
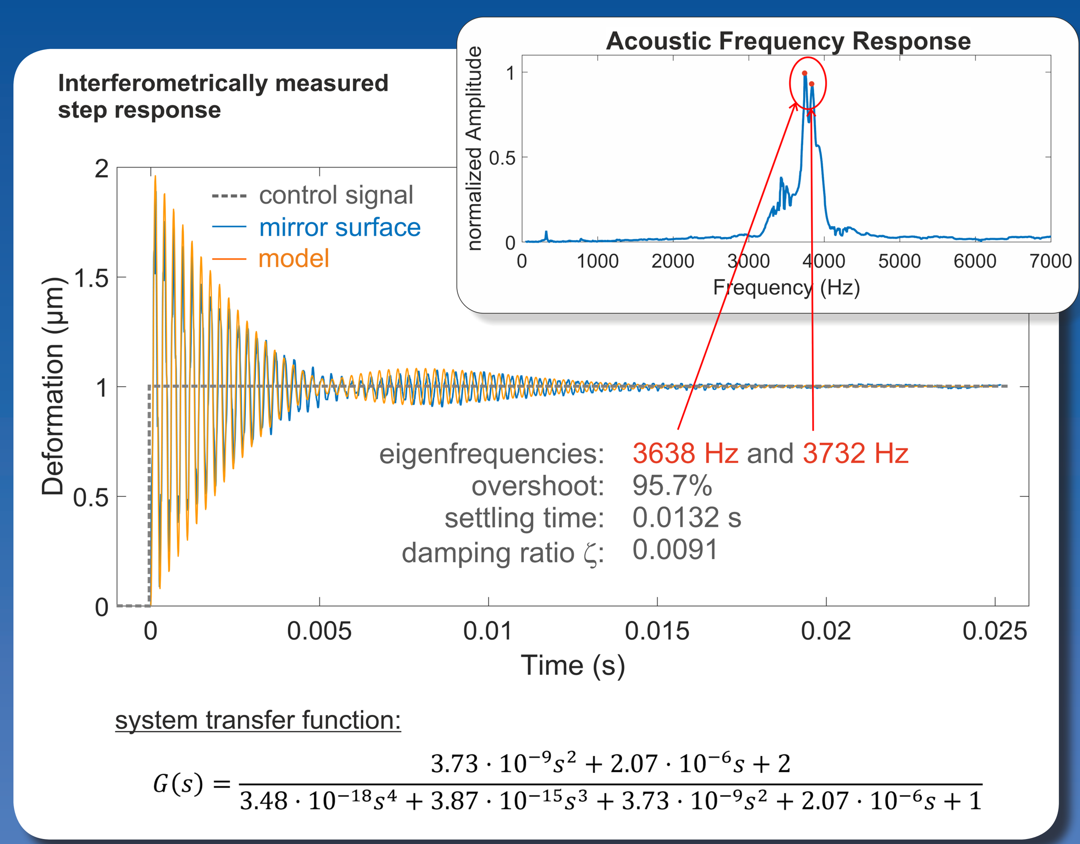


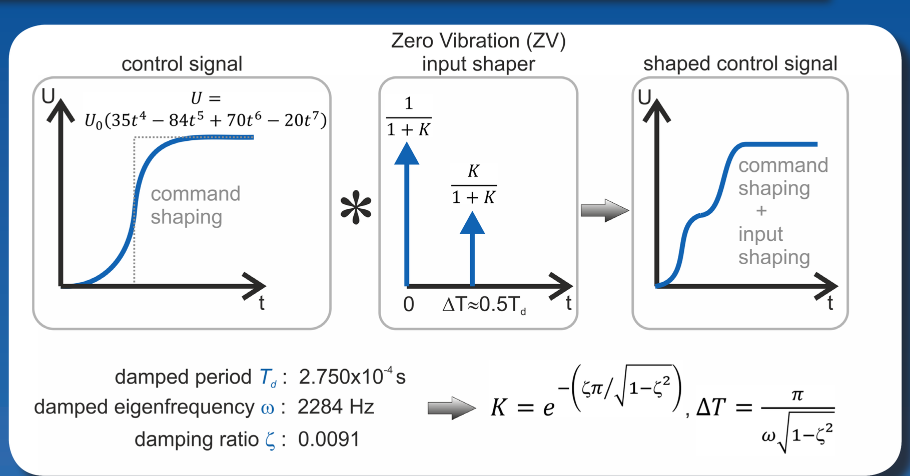
Fig. 7 Interferograms are evaluated by Fourier-transform fringe pattern analysis.

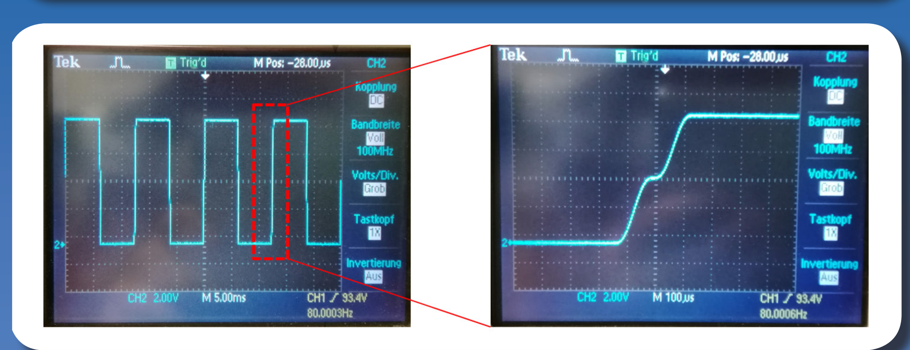


$$G(s) = \frac{3.73 \cdot 10^{-9} s^2 + 2.07 \cdot 10^{-6} s + 2}{3.48 \cdot 10^{-18} s^4 + 3.87 \cdot 10^{-15} s^3 + 3.73 \cdot 10^{-9} s^2 + 2.07 \cdot 10^{-6} s + 1}$$

Fig. 8 Optically measured step response of the z-shift mirror. The inset shows the mirror´s frequency response under acoustic excitation.

Open-Loop Control





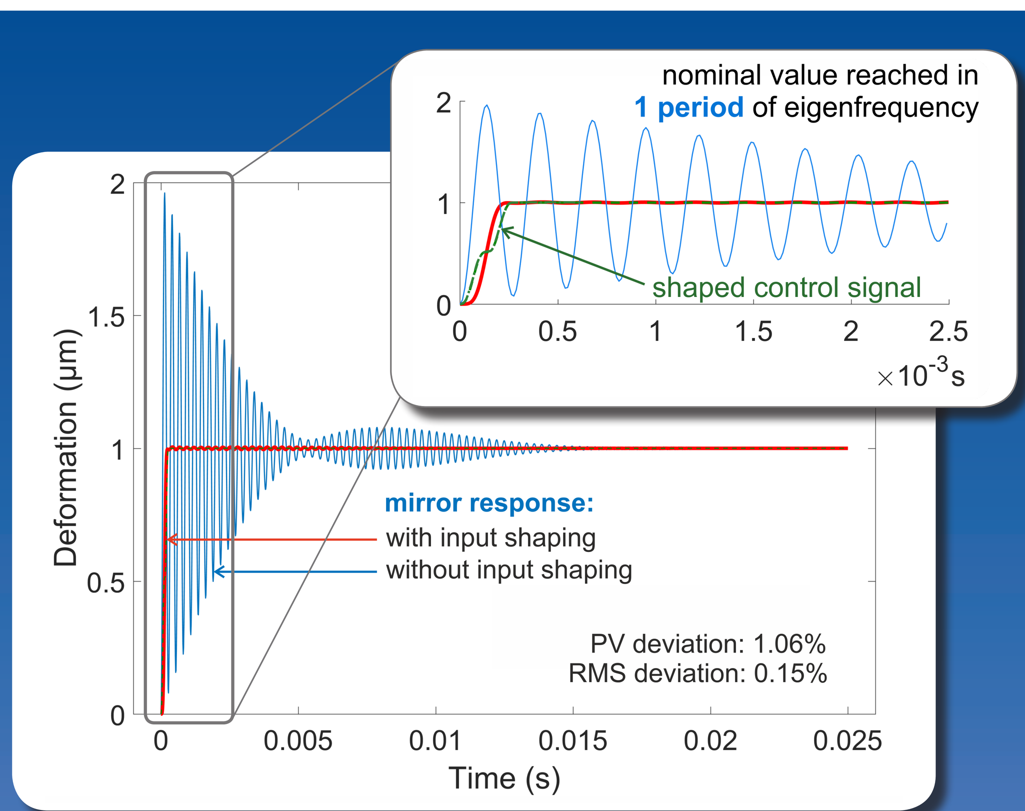


Fig. 9 Simulation of the step response with activated and deactivated input shaping.

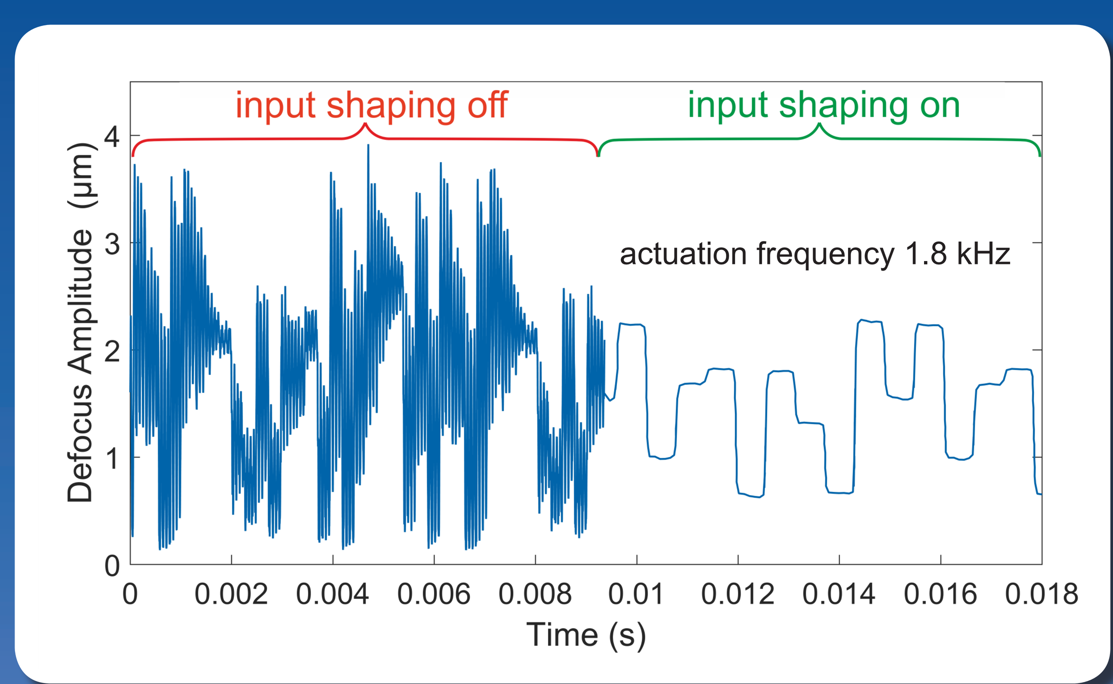


Fig. 10 Measured mirror response to random voltage steps with activated and deactivated input shaping.

Conclusion: The combination of command shaping and input shaping methods effectively suppresses the oscillation characteristic of the mirror´s step response. The settling time is reduced from 13.2 ms to 0.3 ms, allowing the mirror to be actuated with up to 2 kHz.

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