Testing ultrasonic transducers with vibrometry

INTRODUCTION

Ultrasonic transducers convert electrical signals into ultrasound and *vice versa* and are widely used in diagnostic devices. By detecting the reflected ultrasound, features within the human body can be imaged as well as artifacts in solid materials. The acoustic pressure wave that travels through the material is generated by the mechanical motion of the transducer. To optimize a transducer for a specific application it is important to have methods to test the conversion of electrical into mechanical energy. Here, we show how SmarAct's **PICO**SCALE *Vibrometer* can be used to measure the mechanical response to an electrical input pulse directly on the ceramic surface of an ultrasonic transducer. Furthermore, by scanning the laser beam, the spatial distribution of the motion can be imaged.

METHODS

Measurements were performed with a standard **PICO**SCALE *Vibrometer*. Thanks to the integrated confocal microscope, the position for vibration measurements can be accurately selected.

To excite the transducer with a custom waveform, the **PICO**SCALE *Vibrometer* was connected to an arbitrary waveform generator. Here, we used an Agilent 33220A, which was set to play a single waveform (at 20 Vpp) upon receiving a trigger signal. The triggers were generated by the **PICO**SCALE *Vibrometer* and are automatically configured by the software.

When measuring very small displacements it is essential to increase the signal-to-noise ratio by averaging multiple measurements. Because the waveform generator is synchronized with the vibrometer through the trigger pulses, the averaging procedure can be performed online.

Alternatively, it is possible to perform the measurements with a **PICO**SCALE *Interferometer*, SmarAct's universal displacement sensor. In this case, more user actions are required to configure the trigger signals and to position the laser beam onto the transducer.

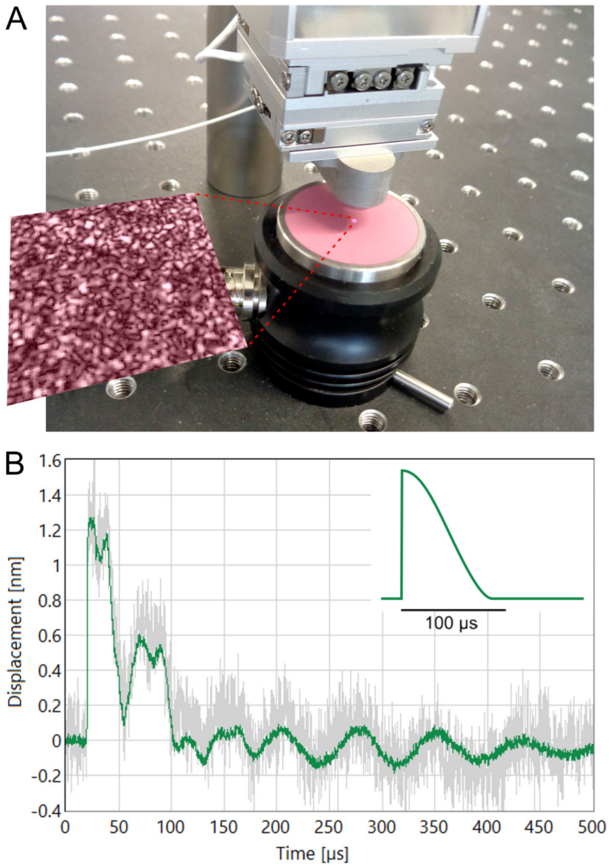

Figure 1. Measuring motion with interferometry. *A) A commercially available transducer was placed under the scanning head of the vibrometer. The bright spot of the pilot laser in the middle of the pink ceramic disc indicates the measurement position. Inset: 200 x 200 µm microscopy image showing the detailed structure of the ceramic surface. B) Average from 2000 displacement measurements (green curve), sampled at 10 MHz. Details of less than 0.1 nm can be easily distinguished including the reverberation after the pulse end at ≈100 µs. Average from 50 measurements (gray), many details are still buried in noise. Inset: Electrical excitation pulse.*

RESULTS

Ultrasonic transducers are commonly coated with a ceramic or plastic layer which are poor reflectors for light. Thanks to the confocal measurement principle of the **PICO**SCALE *Vibrometer* it is possible to directly measure on such surfaces. Thus, a reflective coating, which could affect the performance of the transducer, is not required. Figure 1A shows the microscopic structure of the transducer surface recorded with the microscopy imaging mode of the **PICO**SCALE *Vibrometer*.

To measure the mechanical motion of the transducer, the measurement laser was positioned on one of the bright spots visible in the microscopy image. A repetitive series of interferometric measurements was performed while exciting the transducer with an electrical pulse. Figure 1B shows the measured averaged response, the inset shows the excitation pulse. The RMS noise after 2000 averaging cycles is ≈20 pm at a 10 MHz sampling rate. Further noise reduction can be achieved by increasing the number of averages or by low pass filtering of the data.

In order to measure spatial variations in mechanical motion, the measurement was repeated at different positions on the ultrasonic transducer. A circular pattern of positions was defined through the software. Figure 2 reveals a clear correlation between position and measured response. A total of 16 measurements were performed, each consisting of 2000 averages. Curves on the same circle were again averaged to get the response at 1.3 mm (green) and 10 mm (blue) from the transducer centre. Due to the averaging procedure, the remaining RMS noise was less than 10 pm at a 10 MHz sampling rate. The measured motion is clearly different when measured further away from the centre. The differences between measurements on the same circle were negligible (data not shown).

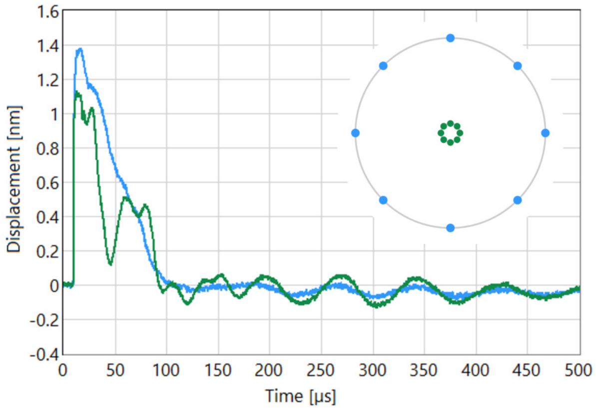

Figure 2. Measuring motion at different positions. *Inset: 16 measurement positions located on 2 concentric circles with radii of 1.3 and 10 mm, respectively. The graphs show the averaged response from all measurements performed at 1.3 mm (green) and 10 mm (blue) from the transducer centre.*

CONCLUSION

Both SmarAct's **PICO**SCALE *Interferometer* and **PICO**SCALE *Vibrometer* allow to record motion in the time domain at high temporal resolution. By averaging multiple recordings, the RMS noise can be reduced to less than 10 pm at 10 MHz sample rate. In the **PICO**SCALE *Vibrometer* all steps to measure multiple points on a sample are automated through the software, which allows for a complete characterization of the dynamic response upon stimulation with a pulse-like signal. These capabilities are exemplified on an ultrasonic transducer but are applicable to a wide range of different samples.

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