Subproject B1: “Sensor / Actor Arrays based on PVDF Film“ Flow measurement in liquids

- **Prof. Dr. Wolfgang Manthey**
- **Prof. Dr. Gunter Ebest**
- **Prof. Dr. Dietmar Müller**

Author: Marko Adam

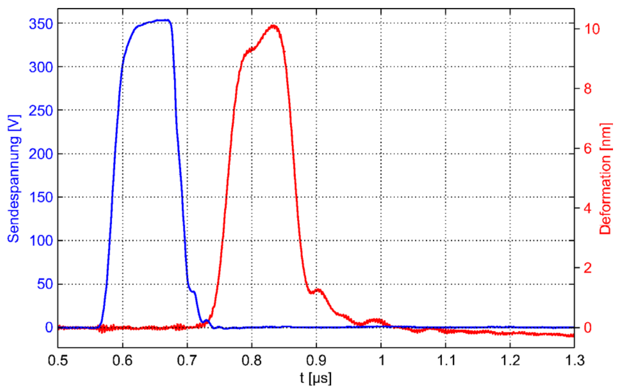
Ultrasonic sound is used in many scopes of technology, such as medicine and measurement of flow rates. The developed ultrasonic transducers arrays are able to pan a sound beam in an arbitrary direction in fluids and can therefore be justified mounted without vortex for flow measurement. In this project the usability of the beam drift method for measurement of flow rates in fluids is analysed.

Transducer principle and technology

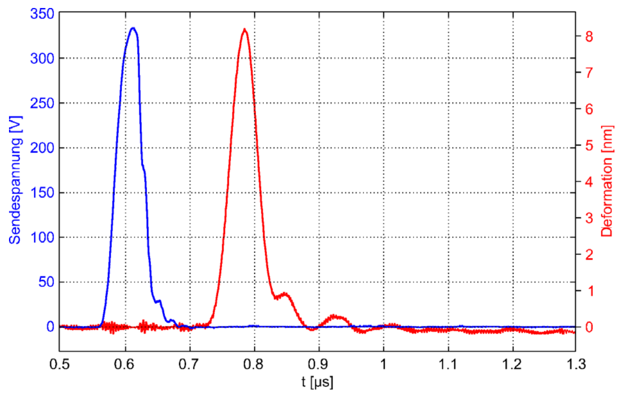
The operating principle of the developed micromachined ultrasonic transducers is known as “phased array“ but the very broadband PVDF film is driven by short time shifted pulses. The ultrasonic transducer array is based on a structured silicon substrate metallised with a electrode structure and a top mounted PVDF film, which is metallised on the upper side. A silicone or epoxy layer protects the transducer array. One element of the array is formed by a single electrode (width 20 to 100 µm) on top of the silicon chip and the opposite gold electrode of the PVDF film. The transducer element works as a thickness vibrator by applying a voltage between these electrodes.

Characterisation of ultrasonic transducers

An important characteristic value is the upper edge frequency. Figure 1 shows the deformation of the used PVDF film (red) as reaction on the electrical stimulation (blue).



a)



b)

Figure 1: Electrical high voltage stimulation (blue) of a) 150 ns and b) 60 ns width and the reaction of the PVDF-Film (red)

The deformation was measured using a laser vibrometer, which is able to measure exclusively the deformation in thickness direction. Because of the higher edge frequency of the PVDF-film and the low mechanical quality factor, the deformation of the PVFD-film follows the electrical stimulation nearly exact. The time shift of about 200 ns between stimulation and deformation is caused by a time shift inside the electronical circuit of the laser vibrometer.

Flow measurement in liquids

The used measurement arrangement consists of two transducer arrays facing each other – a sound emitter and a sound receiver. The transducer arrays can be displaced parallel. The distance between the transducers cannot be less then 60 mm.

The developed measurement circuit (Figure 2) was build to show signals of the elements time shifted on the screen of the oscilloscope. Therefore it is necessary to multiplex the single element signals. The multiplexed signal is then amplified for the peak-detection, which provides the desired output signal. A delay unit is needed to detach undesired parts of the received signal.

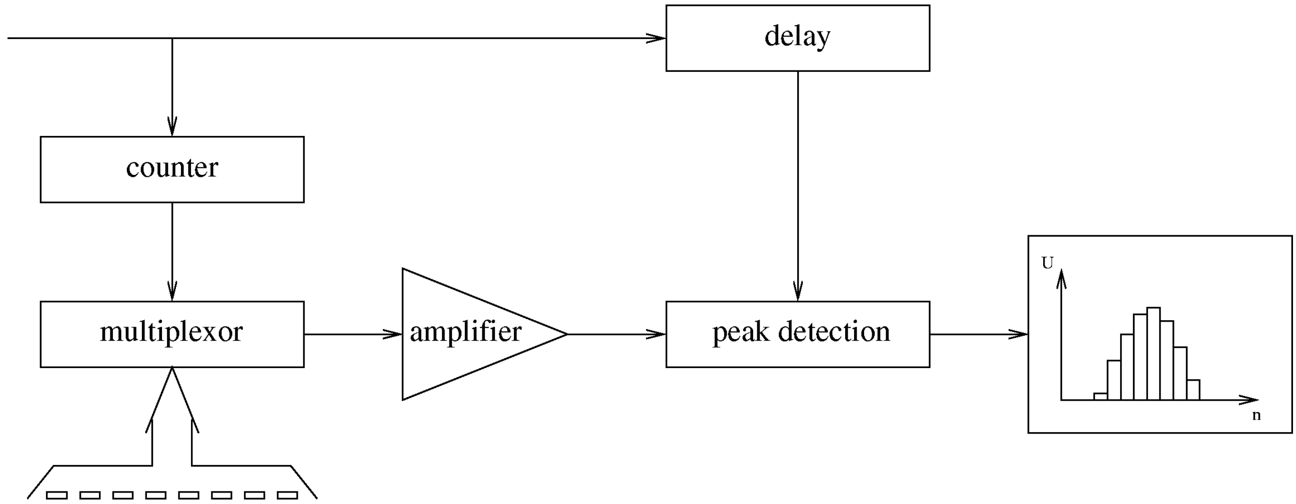
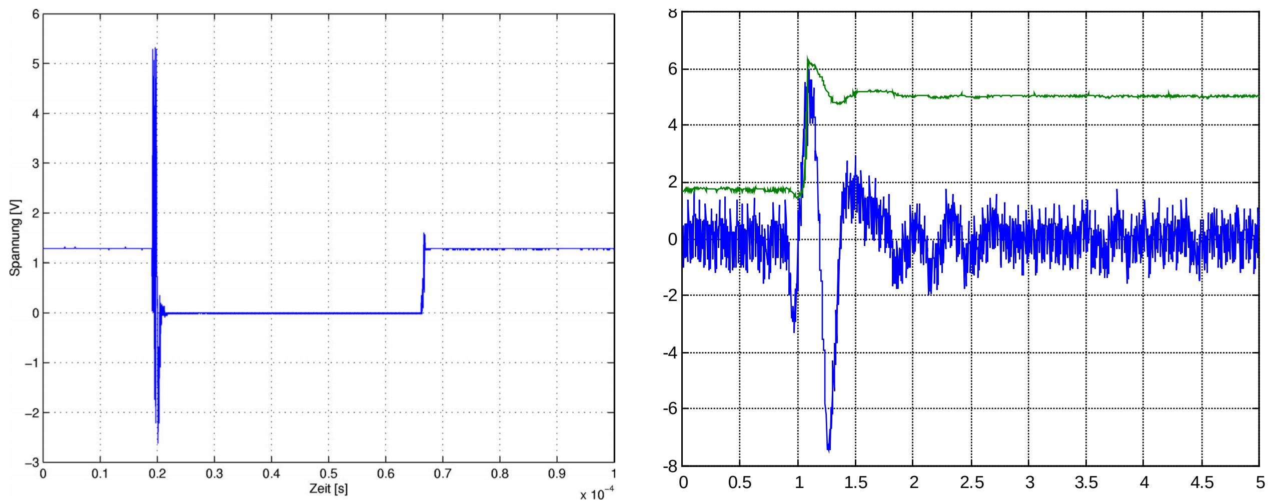


Figure 2: Measurement circuit for time shifted display of element signals

The detection of the peak values was first done using a sample and hold unit. This unit has a detection delay of about 20 ns. During this time, the input signal amplitude decreases significantly due to the high frequency used (Figure 3). Therefore another measurement circuit was build, which uses a capacitor to hold the peak value. This arrangement causes a signal drop as well, but this drop in contrast to the first arrangement does not depend on the frequency of the signal. This drop is caused by the electrical characteristics of the diode.



a) b)

Figure 3: Detection of peak values using a) a sample and hold unit and b) a capacitor

The peak value with an amplitude of about 5 V shown in Figure 3 a is not caused acoustically and needs to be neglected.

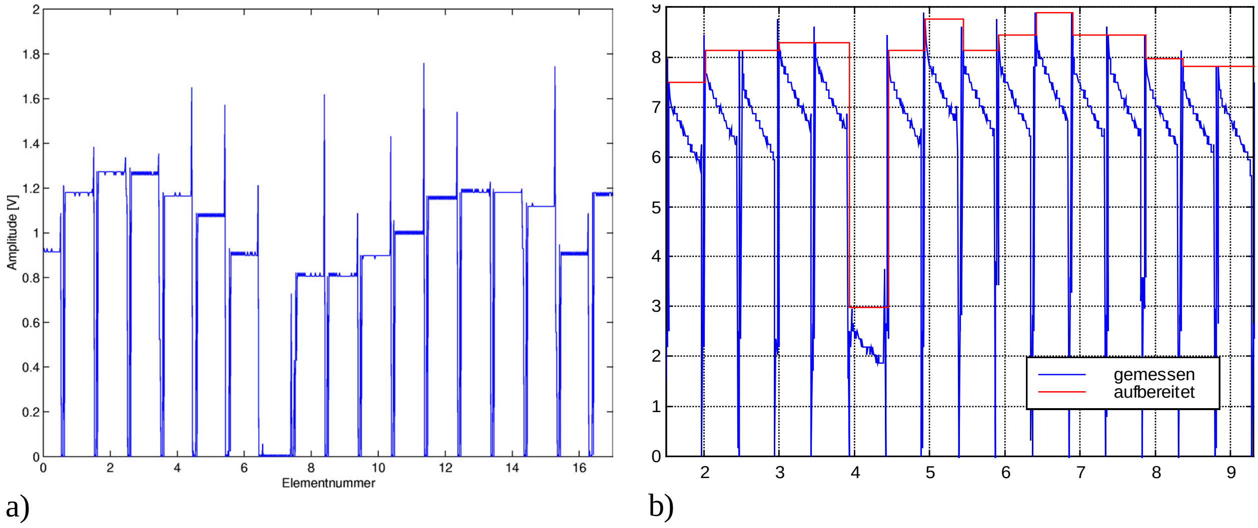


Figure 4: 16 elements displayed as step function measured using a) a sample and hold unit and b) a capacitor

Figure 4 shows measurements where the peak values are being held until the next trigger pulse. The integrated sample and hold circuit has a better ability to hold the voltage level for a long time, the capacitor slowly discharges. But the frequency dependent detection of the sample and hold unit causes a reduced amplitude around element 8, where higher frequencies appear due to the angle dependent frequency characteristics of the transducer array. Figure 5 shows the frequency included in the time signals over a displacement. Parts of the spectrum with frequencies of 8-10 MHz with significant amplitudes can only be seen between -5 mm and 0 mm The realisation of the measurement circuit with a capacitor does not show this effect.

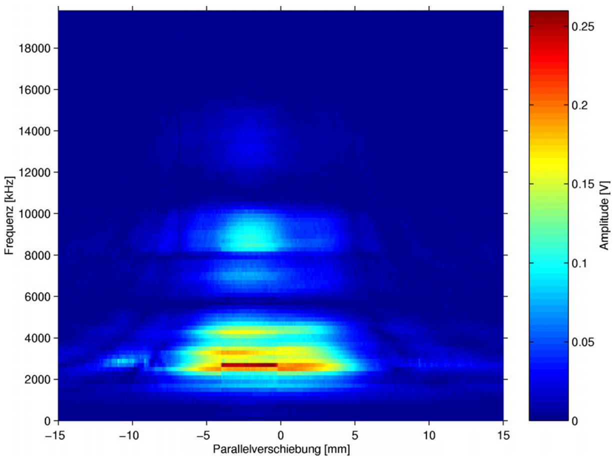


Figure 5: Displacement dependend frequency of a transducer array

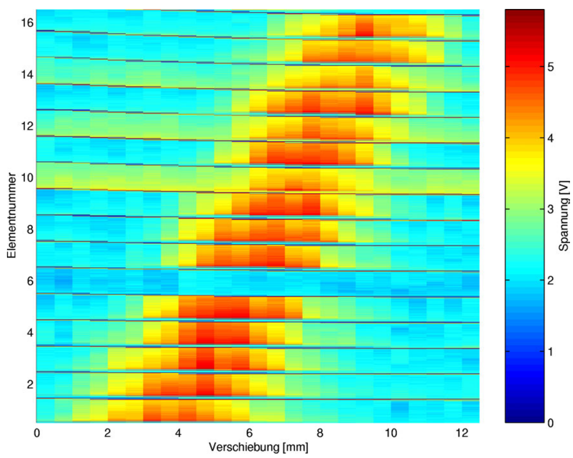


Figure 6: Complete measurement of amplitude over displacement

A complete measurement is shown in Figure 6. The elements of the receiving transducer have width of 300 µm and a pitch of 100 µm. With a growing parallel displacement of the receiving transducer the elevation of voltage crosses the elements of the receiving transducer. A parallel displacement change of about 1 mm causes a displacement of the elevation of about 3 elements.