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# Visualization of ultrasonic waves in piezoelectric materials

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## 1. Introduction

Lead Zirconate Titanate $(Zr_xTi_{1-x})O_3$ (PZT) play a vital role in several industrial and military applications including biomedical devices, actuators, optoelectronic, telecommunication, structural health monitoring and green energy harvesting devices [1, 2]. PZT has several inherent advantages like excellent electromechanical coupling, broad-band operational frequency, low power consumption, and impedance matching with several substrates. These qualities make them popular choice as transducers in several applications. The visualization of bulk and shear acoustic waves in piezoelectric crystal is one of the fundamental problems of physical acoustics. The generation and detection of acoustic waves in piezoelectric materials with the aid of an inter-digital transducer (IDT) has attracted widespread scientific interest for signal processing and filtering applications [3].

Mechanical waves are generated and detected by point contact like field probes via piezoelectric coupling on a PZT sample (3mm thick). Due to the high dielectric constant of PZT, the electric field at the contact area is concentrated sufficiently to represent in that respect an almost ideal point like point spread functions for the wavelength observed here concerning generation and detection[4-9]. Such excitation technique enables a wideband excitation and detection in the absence of mechanical, geometrical, and electrical resonances. It requires low dynamical force for an effective acoustic coupling without damaging the surface. Here, we utilize the point contact excitation and detection method to visualize the transport phenomena of the shear waves in shear PZT ceramic and show a comparison with the bulk guided waves in bulk PZT. In this technique, the electric field is converted into mechanical vibrations via the excitation of phonons, enabling the spatial-temporal imaging of the bulk and shear guided waves by point contact excitation and detection.

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## 2. Experiment

Two small pieces (~2 cm) of fiber optical cable was glued on a plastic board (6x4 cm$^2$) forming a triangular cantilever structure, controlling the applied pressure to enhance the coupling of the electric field. A steel sphere (diameter 2.57 mm) serving as a Coulomb probe was attached with epoxy glue on the tip of the triangle.

A copper wire was adhered to this steel ball using conducting silver epoxy (EPO-TEK; solidifying epoxy by heating for 2 hours at 90˚C). This Coulomb probe was used for generation of shear and guided ultrasonic waves in PZT ceramics. A similar probe was fabricated and placed in a metal box serving as a Faraday cage and acting as the receiver for acquisition of propagated ultrasonic waves [7]. Simultaneous excitation and detection of bulk and shear waves in PZT samples is conducted in conjunction of these two probes. **Fig. 1** illustrates the experimental setup for point contact excitation and detection in bulk and shear PZT samples.

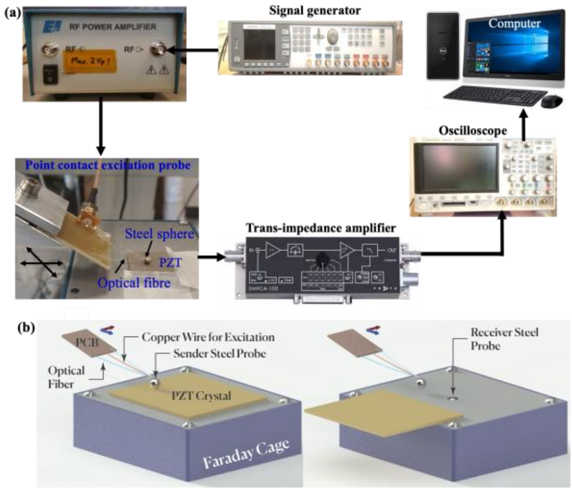


Fig. 1 (a & b) Experimental setup for point contact excitation and detection scheme for visualization of ultrasonic waves in piezo ceramics.

An arbitrary function generator (Agilent 81150A) generated excitation pulse (75 ns time) and the signal was amplified by a radio frequency amplifier (Electronics & Innovation: 403LA, New York, USA). The amplified signal was then supplied to Coulomb probe which was gently in contact with the surface of the PZT sample. The excited signal generates the shear and guided waves that propagate through the thickness of the PZT ceramic. The second probe placed on the opposite side of the PZT sample acquired the propagated signal, which was further amplified using a trans-impedance amplifier (DHPCA-100). This oscilloscope performs averaging of 256 pulse shootings and digitizes the signal which is then recorded. The mechanical scanner's XY motion is controlled using a computer program with step size 50 µm in both directions and scanning area of 10×10 $mm^2$.

## 3. Results and discussion

**Fig. 2** represents the time domain signal for longitudinal and shear PZT. The Time domain signal was recorded employing the point contact excitation and detection method. The ultrasonic waves were excited by a Ricker wave. The transient signal was recorded at the center of the scan, where the sender and receiver probes were placed opposite to each other.

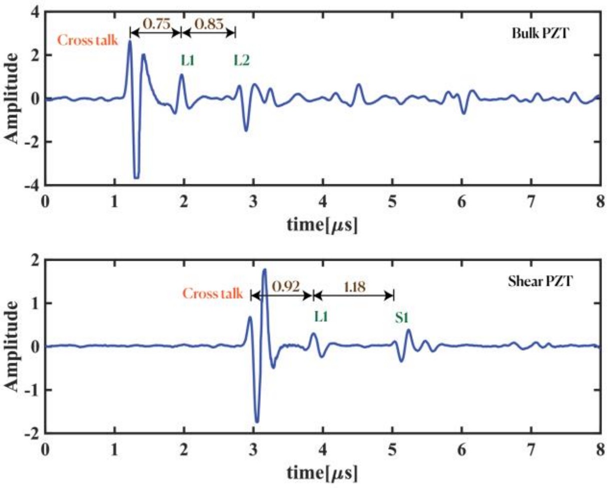


Fig. 2: Transient signal amplitude recorded at the center of the scanning area with a steel sphere, acting as a receiving electrode positioned on the opposite side of the bulk and shear PZT ceramic sample.

The time-sequential images in **Fig. 3** represents the development of acoustic waves in the piezoelectric sintered PZT-ceramic plate. In fig. 3 (a, b) demonstrate the first longitudinal waves in bulk PZT which is mark in fig. 2 ($L_1$). On the other hand, in fig. 3 (c, d) represents the shear wave in shear PZT and marked in fig. 2 as $S_1$. Scanning parameter of the experiments were kept constant for both type PZT ceramics and the scanning area of the experiments were 10 ×10 $mm^2$.

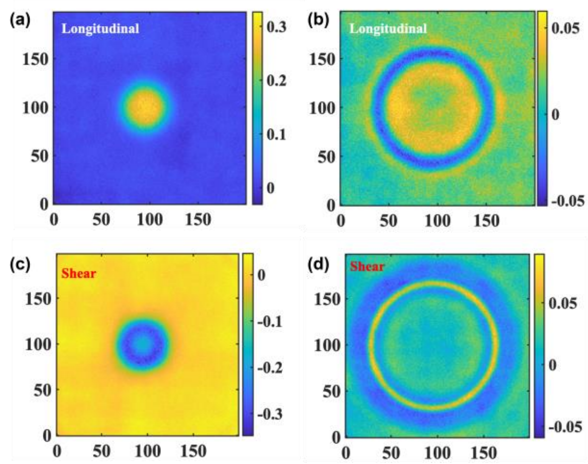


Fig. 3: Time sequential images of acoustic waves evolving in a 3 mm thick sintered bulk and shear PZT ceramic plate, (a, b) represents the longitudinal mode in bulk PZT and (c, d) represents the shear mode in shear PZT.

## 4. Conclusion

The point contact excitation and detection method utilized for visualizing the propagation of the shear and guided waves in the PZT ceramic for the first time. Through the experimental evidence, we can conclude that with such simple technique it is possible to visualize the acoustic wave propagation in piezoelectric materials. The simplicity of this technique is that it can produce a broadband frequency spectrum and wide directional wave vector.


## Acknowledgment

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