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LARGE ANGLE ACOUSTIC BEAM STEERING IN ACOUSTICALLY ANISOTROPIC CRYSTAL

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Recently acoustic beam steering and scanning by electronic techniques to replace mechanical scanning of acoustic beams have become important for medical diagnosis and nondestructive testing imaging systems. The usual electronic beam steering techniques have been by means of phased transducer array methods. A linear array of ultrasonic transducers is electronically phased with proper time-delayed pulses to each transducer so that the overall wavefront of the transducer array can be scanned or focused. In order to obtain real time scanning, sophisticated controls for handling the signal inputs and adjustments to the transducers are needed.[1] For linear acoustic scanners, there have been grating acoustic scanners[2,3] which are based on the scattering of a propagating surface acoustic wave into the bulk of the substrate by a grating on the substrate surface. As the surface acoustic wave pulse propagates along the substrate, the scattered beam scans at the fixed speed of the surface acoustic wave velocity. In this paper, we have demonstrated a unique scheme for electronically steering an acoustic beam over an angle larger than 70^o in a TeO_2 crystal. The idea is based on the principle that the acoustic energy flow direction is always normal to the slowness curve in an acoustically anisotropic crystal. In the plane normal to the c-axis of a TeO_2 crystal and around the (110) axis, the shear wave acoustical energy flow directions can have a swing of more than 70^o (from the (110) axis) by changing the wave vector direction only 3^o from the (110) axis. Using a grating to diffract a shear wave propagation direction around the (110) axis, we have observed the wide angle acoustic beam steering effect by a laser probe. It is well known that the energy flow direction in a crystal is always normal to the surface of slowness curve (inverse of the acoustic velocity).[4] In a highly anisotropic crystal such as TeO_2, the acoustic velocities change drastically as a function of crystalline orientation. Figure 1 shows the slowness curves of acoustic waves in TeO_2 in the plane normal to the c-axis. The quasi-shear wave along the (110) axis has a velocity of 6.17×10^4 cm/sec and becomes a longitudinal wave with a velocity of 3.049×10^5 cm/sec along the (100) axis. There is a factor of about five in velocity change from the waves propagating along (110) to (100) axes. If the shear wave is propagating exactly along the (110) axis, the energy flow direction coincides with the k-vector direction. If there is a small angular deviation of the shear wave k-vector from the (110) axis (a small angle θ), the energy flow direction, which is normal to the curve, has a large angular swing angle α as shown in Figure 1. We have experimentally demonstrated the anisotropic beam steering technique in TeO_2 with an angular scan of more than 70°. A grating was used to steer the shear wave propagation directions around the (110) axis of the TeO_2 crystal. By electronically changing slightly the input acoustic frequencies, the energy flow direction of the shear wave beam can be scanned by as much as 70° from the (110) axis. A laser probe based on acousto-optic Bragg diffraction[5] was used to detect the scanning acoustic beam. We believe that this anisotropic beam steering technique is unique and may have applications in medical ultrasonic, non-destructive testing and acousto-optic devices. Detail experimental results and possible applications will be discussed.

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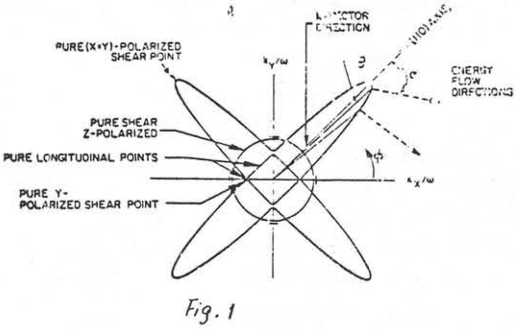

Fig. 1

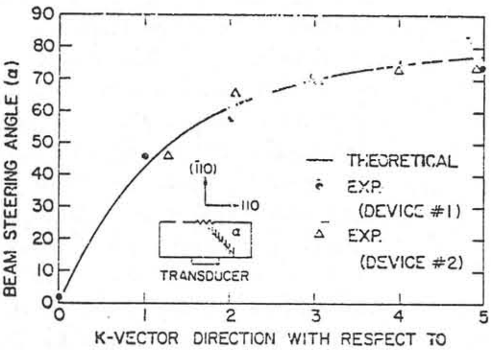

Fig. 2

Figure 1.

Slowness curves (inverse of acoustic velocity curves) of acoustic waves in the plane normal to the c-axis of a TeO_2 crystal. The energy flow direction for a shear wave propagating along θ with respect to the (110) axis is normal to the slowness curve and has an angle α with respect to the (110) axis.

Figure 2

Theoretical curve and experimental points of the energy flow directions of the TeO_2 anisotropic acoustic scanner as functions of the k-vector direction θ with respect to the (110) axis and the percentage acoustic frequency increase from the center frequency f