sample surface, which is coupled to a glass prism with a thin water film, using a camera instead of a point detector (photodiode) [Paltauf].

The pressure distribution at the sample surface as a function of time as input allows a 3-D reconstruction of the reinforcement. If the time-dependent 2D pressure distribution measurement is not available as a noise-free function in space and time (which is the case in practice), the estimation gets more involved and unstable. In this situation there is no explicit inversion formula available. Numerical simulations provide insight in the instability issue and the quality of measurement data, and thus they can be used to design “optimal” measurement devices.


Session: 4C

PHYSICAL ACOUSTICS I
Chair: S. Zerong
Schlumberger-Doll Research Center

4C-1 4:30 p.m.
(Invited)
AIR-COUPLED ULTRASOUND AND APPLICATIONS TO RAPID ELASTIC PROPERTY CHARACTERIZATION
D. E. CHIMENTI*, S. D. HOLLAND, and D. FEI, Iowa State University, Ames, IA.
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Plate-wave dispersion spectra have been inferred directly in a single air-coupled coordinate scan using mirror-focussed broadband air-coupled acoustic beams on both transmitting and receiving transducers. The Lamb mode spectra are extracted in a two-dimensional FFT of the measured broadband focused air-coupled signal. To enhance the typically weak air-coupled signal, we have employed a novel signal coding scheme using a random-phase analog burst 200 microsec in length. Subsequent correlation yields the system impulse response, from which we obtain the processed results as a wavenumber-versus-frequency plot. Comparison of the inferred dispersion curves with calculated spectra using nominal stiffness values, shows excellent mode separation and good agreement with predictions. Experimental results are presented for isotropic media such as Lucite and aluminum, but also for anisotropic plates such as composite laminates and wood. Some results using water-coupling are also presented, including a graphic demonstration of electromechanical reciprocity.
DYADIC GREEN’S FUNCTION OF A LAMINAR PLATE
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Surface Green’s functions, that relate displacements to stresses at the surface of a semi-infinite or multilayered substrate, are a powerful tool for the study of wave propagation. They have proven efficient in elastic surface wave analysis where they enable the characterization of modes. They are also used in mixed Finite Element Method / Boundary Element Method (FEM/BEM) for a fast and efficient calculation of the electromechanical behavior of a complex structure. In classical models, surface Green’s functions are calculated assuming either a semi-infinite or a finite laminar substrate. In the later case, one of the sides of the plate is assumed stress free.

We focus on the Green’s function of a laminar plate. The aim of this function is to link generalized displacements (mechanical displacements together with electric potential) on both sides of a plate to the generalized stresses (mechanical stresses together with electric displacement) applied on the boundaries of the structure. There are 8 components for both these vectors (4 components for each side of the plate). Hence, the Green’s function is a 8x8 matrix of Green’s functions, or dyadic.

In this paper we first expose the theoretical calculation of the Green’s function of a laminar plate. This is performed using a scattering-matrix model for simulating the electromechanical behavior of a multilayer structure including piezoelectric, dielectric, metal and fluid layers which has already been described at last year’s symposium. The scattering matrix model was originally developed to account for the Green’s function of one side of a plate with the assumption of a stress-free condition on the other side. We show how this basic solution can be used to obtain the dyadic Green’s function of the laminar plate. We then give results for academic examples: a solid plate excited longitudinally, a plate excited transversely by two inter-digitated transducers located on each of its faces for example, and a Bragg mirror as the ones used to isolate the two resonators in a Coupled Resonator Filter.

DETERMINATION OF LATERAL MODE DISPERSION FROM FULL-FIELD IMAGING OF FILM BULK ACOUSTIC RESONATOR MOTION
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A full-field view laser ultrasonic imaging method has been developed that measures acoustic motion at a surface without scanning. Images are recorded at normal video frame rates and heterodyne principles are used to allow operation at any frequency from Hz to GHz. Both acoustic amplitude and phase are recorded allowing Fourier transformation of the displacement images to provide a mapping of excited mode wavenumbers at each frequency. Measurements as a function of frequency provide a means for mode identification and a direct measure of the lateral mode dispersion. Results are presented at frequencies near the first longitudinal thickness mode (900 MHz) demonstrating simultaneous excitation of lateral modes with nonzero wavenumbers in an electrically driven AlN thin film bulk acoustic resonator. Discussion and analysis are presented illustrating identification of specific lateral modes and illustration of the effects of physical dimensions and material elastic properties on the measured dispersion relations.

4C-4  5:30 p.m.

BOREHOLE DIPOLE AND QUADRUPOLE MODES IN ANISOTROPIC FORMATIONS
B. SINHA*, J. PABON, and C.-J. HSU, Schlumberger-Doll Research, Ridgefield, CT.
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Sonic measurements while drilling are made in the presence of a drill collar that provides an additional path for the acoustic energy propagating from the transmitter to an array of receivers. Low-frequency asymptotes of both dipole and quadrupole modes yield the formation far-field shear slowness. Intrinsic or stress-induced anisotropy of surrounding formation in a vertical well is generally investigated by a wireline sonic tool using a borehole dipole mode that exhibits cosθ azimuthal dependence in their associated acoustic field propagating along the borehole axis. The fast and slow dipole shear polarizations are orthogonal to one another in the presence of any azimuthal anisotropy. However, borehole quadrupole modes appear to be more promising for estimating the far-field formation shear slowness in the presence of a drill collar. Formation anisotropy can also be investigated using such quadrupole modes that exhibit cos2θ azimuthal dependence in their acoustic field propagating along the borehole axis. The two canonical quadrupole modes are excited by rotating the quadrupole transmitter by 45° from one of the primary shear polarization directions. Borehole flexural dispersions exhibit a crossover in the presence of a uniaxial stress in the azimuthal plane. In contrast, a perturbation analysis of quadrupole modes in the presence of a uniaxial stress does not show any such crossovers. Both the orthogonal quadrupole modes corresponding to the transmitter oriented parallel and 45° to the uniaxial stress direction asymptote to the same shear slowness at low frequencies. This shear slowness is the same as the fast shear slowness measured by a dipole transmitter parallel to the uniaxial stress direction. However, there are increasing differences between the two orthogonal quadrupole mode slownesses at higher frequencies. Quadrupole waves with positive polarization parallel to
the uniaxial stress direction always exhibit larger slownesses than those polarized $45^\circ$ to the uniaxial stress direction. Although stress-induced anisotropy in shear slownesses at low frequencies is not predicted for the orthogonal quadrupole modes, discernible differences at higher frequencies can be used as an indicator of stress-induced anisotropy.

Session: 5C

SAW ACOUSTIC EFFECTS
Chair: V. Plessky
GVR Trade SA

5C-1 4:30 p.m.

ACOUSTICALLY DRIVEN NEMS RESONATORS
F. W. BEIL\textsuperscript{1}, R. H. BLICK\textsuperscript{2}, and A. WIXFORTH\textsuperscript{*3}, \textsuperscript{1}Center for NanoScience, Munich, Germany, \textsuperscript{2}University of Wisconsin, Madison, \textsuperscript{3}University of Augsburg, Germany.
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Surface acoustic waves (SAW) are used to coherently excite nanofabricated free standing beam resonators. Typical resonator sizes are $L = 3.5 \ \mu m$, $w = 300nm$, and $h = 200nm$, resulting in mechanical eigenfrequencies of the order of 100 MHz. Depending on the ratio between the resonator eigenfrequency and the frequency of the driving SAW, and depending on the SAW amplitude, we observe a complex interaction spectrum like mode locking or parametric oscillations of the NEMS beam. We give a detailed description of our experimental findings in terms of a theoretical model. Moreover, we demonstrate that our unique experiment can even yield insight into the microscopic distribution of lattice defects and their dynamics in a nanometer size mechanical single crystal resonator. 

Acknowledgement: We gratefully acknowledge financial support by the Deutsche Forschungsgemeinschaft DFG.

5C-2 4:45 p.m.

SAW DEVICE ANALYSIS USING A COMBINATION OF FEM/BEM CALCULATION AND SCANNING INTERFEROMETER MEASUREMENTS
S. CHAMALY\textsuperscript{*1}, R. LARDAT\textsuperscript{1}, T. PASTUREAUD\textsuperscript{1}, W. STEICHEN\textsuperscript{1}, O. HOLMGREN\textsuperscript{2}, M. KUITUNEN\textsuperscript{2}, J. V. KNUUTTILA\textsuperscript{2}, and M. M. SALOMAA\textsuperscript{2}, \textsuperscript{1}Temex Microsonics, Sophia-Antipolis, France, \textsuperscript{2}Helsinki University of Technology, Finland.
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Recently, scanning laser interferometry \cite{1} has enabled the identification of new acoustic loss phenomena \cite{2}. It is a challenge to provide a rigorous physical interpretation of the measured acoustic field distribution. With the help of