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CALENDAR OF ULTRASONIC EVENTS

Acoustical Society of America, November 6–9, 1963, University of Michigan, Ann Arbor, Michigan

1963 Ultrasonic Symposium, December 4-6, 1963, Marriott Motor Hotel, Washington, D. C.

1964 IEEE International Convention. Under the new organization of the IEEE Convention, technical sessions will not be organized by specific Professional Technical Groups. Instead, papers will be grouped according to general technical areas. For detailed information see Proceedings of the IEEE, Volume 51, Number 8, August, 1963, Page 16A. Deadline for abstracts is October 18, 1963.

Acoustical Society of American, New York City, May 6-9, 1964.

1963 ULTRASONIC SYMPOSIUM, DECEMBER 4-5-6 MARRIOTT MOTOR HOTEL, WASHINGTON, D.C.

A preliminary announcement of the Technical Program is contained in this newsletter. In addition to the technical sessions, a social hour and banquet at the Marriott Motor Hotel have been planned for Thursday evening, December 5. Prof. Robert T. Beyer of Brown University will be the banquet speaker.

Banquet tickets will be on sale up to the close of the afternoon session on Wednesday, December 4. Those wishing to purchase banquet tickets in advance should send a check for $8.00 per ticket to Dr. William P. Raney, National Academy of Science, Washington, D.C. Checks should be payable to "1963 Ultrasonic Symposium."

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Preliminary Program for 1963 Ultrasonics Symposium

nesday, December 4
8:30 AM Registration
9:30 AM Session A
Invited Papers: de Klerk, Shiren
Contributed Papers: Tepley, Strandberg, Auld, Dobrov

2:00 PM Session B
Invited Papers: Rollins, Mayer
Contributed Papers: Bricout, Dombek, Kelton, Spears, Sullivan, Lindberry, Porter, Fry, Fry, Leichner

Thursday, December 5
9:00 AM Session C
Invited Papers: Wanuga, Brouillette, Foster
Contributed Papers: Hayre, Vilkelis, Land, Smith, Westgate, Burlage

2:00 PM Session D
Invited Papers: Bolef, Litovitz
Contributed Papers: Abeles, Keller, Crabbe, Prohofsky, Kroger

Evening Social hour and Banquet

Friday, December 6
9:00 AM Session E
Invited Papers: Morgenthaler, Schloemann
Contributed Papers: Quate, Haydl, Strauss, Babcock, Vorie, Henry, Sparks, Higgins

2:00 PM Session F
Invited Papers: Mason, Bateman, Pomerants
Contributed Papers: Papadakis, Fraser, LeCraw, McSkimin, Chambers, Spencer, Coquin, Meeker, Meitzler

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Session A - Wednesday Morning, December 4, 9:30 AM -
Invited Papers

A1. Recent Advances in Microwave Phonon Generation and Detection and Their Application to the Study of Phonon-Phonon Interactions in Quartz - J. de Klerk, Westinghouse Research Laboratories, Pittsburgh 35, Penna.

The use of an oblique E-field for surface excitation of quartz can produce uniform excitation of the end surface of the quartz rod, with a resultant reduction of undesirable modulation of the echo envelope. Further recent advances include the use of tunable resonant coaxial cavities in the frequency range 600 to 8000 mc/s and stub stretcher probes for use in a helium cryostat. Attenuation of microwave phonons in quartz at low temperatures as functions of temperature, power and pulse repetition rate will be described.

Contributed Papers

A2. Parametric Interactions of Microwave Acoustic Travelling Waves in M_gO. - N.S. Shiren, Thomas J. Watson Research Center IBM Corporation, Yorktown Heights, N.Y.

Non-linear interactions between co-linear microwave acoustic waves have been observed in single cyrstal M_gO. The waves are non-linearly coupled through the third (or higher) order term in the anharmonic lattice energy. Since the crystals are normally non-dispersive for acoustic frequencies, the input energy is converted to all sum and difference combinations of the input frequencies, and energy conversions of 70% have been observed. Because the interaction path lengths are large (10^4 wavelengths) the experimental results may be compared with the theory of travelling wave parametric interactions.

Paramagnetic impurities in the crystals provide a means of obtaining frequency selective dispersion through spin-phonon interactions. The dispersion has been used to identify the generated frequencies. It may also be used to supptess the generation of undesir frequency components or, conversely, to allow normally forbi interactions. Applications to acoustic parametric devices will be considered.

Session A - Wednesday Morning, December 4, 9:30 AM - Contributed Papers

A3. Magnetoacoustic Measurements in Metals at Nine Gigacycles * Norman Tepley ** and M.W.P. Strandberg, Dept. of Physics and Research Lab. of Electronics, MIT, Cambridge 39, Mass.

An application of microwave frequency ultrasonic techniques to the observation of magnetoacoustic oscillations in metals is reported. These oscillations in the ultrasonic attenuation in a metal occur when the dimension of an extremal cyclotron orbit of conduction electrons is an integral multiple of the ultrasonic wavelength; the period of the oscillations in H^{-1} gives information on the extension of the Fermi surface. To observe these oscillation, it is necessary that the electronic mean free path in the metal be greater than the ultrasonic wavelength, while the observation of a related phenomenon, ultrasonic cyclotron resonance, requires that the electronic mean free path be more than 1000 times the ultrasonic wavelength, so that the use of microwave ultrasonics is desirable. A method for overcoming difficulties in making single-crystal metal samples suitable thin and flat and with sufficiently parallel faces for such experiments and for bonding them to quartz transducers is described. Some preliminary results of such studies on gallium are discussed.

*This work was supported in part by the U.S. Army, the Air Force Office of Scientific Research, and the Office of Naval Research; and in part by the Signal Corps under Contract No. DA36-039-sc-87376.

** esent address: Dep. of Physics, Wayne State University, De t 2, Mich.

A4. Ultrasonic Instabilities in Solids - B.A. Auld, Microwave Lab., W.W. Hansen Labs. of Physics, Stanford Univ., Stanford, Calif.

A survey is made of various methods for parametrically pumping ultrasonic instabilities in solids. The basis for the discussion of instability mechanisms in magnetic materials is taken to be a simple two-dipole model for magnetostriction in a saturated ferromagnet. Similar models are given for electrostriction and piezoelectricity in a saturated ferroelectric, and it is shown that the electrostrictive and magnetostrictive mechanisms are entirely analogous. On the basis of these simple models estimates are made of the instability thresholds for a number of magnetic and nonmagnetic materials, and comparisons are made, where possible, with measured thresholds reported in the literature. Possible applications of these pumping mechanisms in ultrasonic amplifiers are discussed.

A5. Acoustic Absorption Coefficients are Paramagnetic Resonance* W.I. Dobrov, Lockheed Research Labs., Palo Alto, Calif.

In order to evaluate and design experiments and devices based on interactions between microwave ultrasonics and electron spins at magnetic resonance (acoustic masers), it is necessary to know the dependence of a particular type of interaction on direction of magnetic field, direction of wave propagation and on polarization for various crystalline symmetries. The form of the equations describing the spin transition probabilities and thus the acoustic absorption at paramagnetic resonance depends explicitly on the form of the magnetoelastic matrix whose elements couple spins to ultrasonics. Having obtained magnetoelastic matrices for all crystal classes we have derived acoustic absorption coefficients due to $\Delta M = 1$ and $\Delta M = 2$ spin transitions in terms of magnetoelastic const s for arbitrary direction of external magnetic field, for any pol tion and any direction of wave propagation in the crystal. These expressions were derived for iron group and S-state ions in the two cases, namely when spinultrasonics interaction is linear and quadratic in spin variables. It turns out that the angular dependence of the absorption coefficients in the two cases is substantially different only in anisotropic cases. Some of these theoretical conclusions are compared to the results of our experiments in which paramegnetic absorption coefficients were obtained as functions of various parameters by measuring attenuation of 10 kmc ultrasonics at magnetic resonance.

* Supported by the Lockheed Independent Research fund.

Session B - Wednesday Afternoon, December 4, 2:00 PM - Invited Papers

B1. The Generation of Ultrasonic Beams by Wave Interaction in Nonlinear Solids* - Fred Rollins, Jr., Midwest Research Institute, Kansas City, Mo.

The interaction of thermal phonons in solid materials has been discussed for many years with very little direct experimental evidence of such phenomena. The temperature dependence of hypersonic wave attenuation, generally attributed to wave interaction with thermal phonons, has been a major contribution to this field of study.

Recent ultrasonic experiments in the low megacycle range have produced more direct evidence that elastic waves do interact in some solids. The intersection of two ultrasonic beams under resonant conditions can lead to the generation of a third beam which has a frequency $(\omega_1 \pm \omega_2)$ and wave vector $(\bar{k}_1 \pm \bar{k}_2)$. Interaction experiments can thus be used to generate ultrasonic beams of either longitudinal or transverse mode and the beam origin may be varied throughout the volume of relatively large specimens.

In this paper, both theoretical and experimental aspects of ultrasonic beam interaction will be presented. These will include conditions of resonance, intensity relationships, beam collimation properties, and frequency dependence. Potential applications of interaction phenomena will also be discussed.

* This work was supported by the Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio.

B. 2 Mode Conversion of Ultrasonic Waves at Flat Boundaries - Walter G. Mayer, Physics Dept., Michigan State University, East Lansing, Michigan.

A historical introduction is given illustrating the work performed during the 19th century which led to the present formalism describreflection and refraction of ultrasonic waves at boundaries. Special attention is given to solid-liquid and liquid-solid boundaries. Various factors influencing energy partition are examined, and certain applications are discussed.

Session B - Wednesday Afternoon, December 4, 2:00 PM Contributed Papers

B. 3 Sonic Wind Velocity Measurements Without Local Sensor * P.A. Bricout, E. Dombek, and G. Kelton, RADCOM; Div. of the Systems Group, Litton Industries, Inc., College Park, Md.

Continuous recordings of wind speed and direction at a distance of 70 feet from the sonic source (20 feet above ground) have been achieved by measuring the frequency of sonic waves scattered from a narrow beam generated by a powerful whistle at 11 kilocycles. Parabolic reflectors are used for concentrating the source energy within $\pm$ 3degrees HPBW and for providing the analyzing microphones with a high gain. All reflectors are aimed at the observation point.

The analysis of the sound receiver by the microphones and strongly amplified (100 db) shows that: a) the amplitude of the scattered sound fluctuates continuously depending on weather and wind conditions, and b) its frequency can differ from source frequency suggesting the existence of a doppler effect produced by scattering centers carried by the wind.

A theory of the measurement for various configurations of the source and receivers has been fully confimed experimentally. Tracking oscillators locking automatically on the frequency of scat tered signals compensate for fading. The use of two receivers in orthogonal directions respective to the source give continuous readings of the orthogonal components of wind velocity. A series of over 300 sonic measurements on winds from 3 to 25 miles per hour show average difference readings with a Bendix Aerovane anemometer not larger than ± 1.0 miles per hour for speed nor ± 4.5 degrees for direction. Hence, a high degree of correlation is shown to exist between the sonic and the commonly used anemoneter readings.

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* This work was supported by the Department of the Navy, Bureau of Ships, under Contracts NObs-84140 & NObs-86855.

B4. Ultrasonic Cleaning - Destructive or Selective? - Seymour Spears and Robert Sullivan, Reliability Section, ARMA Division American Bosch Arma Corp., Garden City, New York.

Ultrasonic Cleaning of printed circuit assemblies for high reliability missile equipment is the preferred means for the effective removal of solder flux, dirt, grease and other foreign materials deposited on these assemblies as a result of normal assembly processes.

The affect of this cleaning process on semiconductors devices has been a controversial issue among producers of military electronic equipment and agencies of the Department of Defense. The controversy is centered on a series of tests performed by military agencies and equipment producers to find the cause of semiconductor failures which occurred in electronic equipment during exposure to high level acoustic noise. The published results of many of these tests indicated that ultrasonic cleaning had created breaks in internal connections within the semiconductor. Based on this conclusion many producers of high reliability military electronic equipment discontinued the use of ultrasonic cleaners substituting other cleaning processes. The Department of Defense has not only sanctioned these changes, but recommended that contractors still using ultrasonic cleaning suspend its use.

Arma performed a number of tests to investigate the cause and mechanism of acoustic noise failures of diodes. The results of these tests produced failures of the same type as reported in the other studies. But Arma carried their study far enough so that initial conclusions can be reached that indicate that with the proper use of ultrasonics, incipient failures of this type can be "screened-" from assemblies with large numbers of semiconductors. This ..eening process must be completed by testing the equipment under environmental conditions as severe as any environment the equipment will experience during its life.

This paper will describe the tests performed, the mechanisms of failure as observed and the resulting data to support the thesis that ultrasonics used properly will improve the reliability of any system that must operate in high level acoustics and vibration environments.

B.5 Generation of Ultrasonic Power with Rotating Machinery - J.R. Lindberry and E. Porter, Electronics Div., VARO Inc. Santa Barbara, Calif.

Generation of ultrasonic frequency power by rotating machinery is not new, however it is not the common method of generating ultrasonic power. Alexanderson is probably the first man to have accomplished this feat in the year 1906 with his rotating machine which produced power at 100 kc for radio transmission.

The development effort on such machines has been limited by the demand.

Recent developments in the field of ultrasonics have increased the demand for low cost, high reliability sources of ultrasonic power. The motor generator system offers some distinct advantages from both of these standpoints and also has the advantage of simplicity and ease of maintenance. The average maintenance personnel are familiar with this type of equipment. There are no extremely high voltages and the factor of personnel safety is greatly improved.

There are, however, certain limitations in the application of this type of machine which should not be overlooked. Such things as adjustment of nominal output frequency and frequency stability may limit the utility of performance of the machines in certain areas. Some of the inherent advantages and disadvantages, design con- ration and application considerations will be presented along pictures and performance data on a 1.5 kw 21.2 kc electromechanical generator.

B6. System Design for Ultrasonic Modification of Brain - William J. Fry, Francis J. Fry and Gene H. Leichner, Biophysical Research Laboratory, University of Illinois, Urbana, Ill.

The established capability for sophisticated modification of brain structures by intense ultrasound can only be achieved by employing relatively elaborate systems for implementing the use of this form of energy. In addition to the design and development of ultrasonic instrumentation and directly associated equipment - focusing transducers, stable probes of high resolution, cavitation-free axes tracking those employed in landmark coordinate determination and electronic driving and timing equipment for supplying power to the transducers - it was also necessary to engage in an extensive series of programs to develop new supporting methods and instruments. For example, much greater accuracy in the determination of the coordinate positions of sites in selected brain structures was required than standard methods could provide. This required the development of more rigid headholders, with higher repostioning accuracy incorporating roentgenographic systems for precision ventriculography, for both the experimental animal and for the human work. In addition, it was necessary to develop for the experimental animal work an instrument for determining when a cannula penetrates the ventricular wall. A second development was new ultrasonic field calibration instruments to make possible, over long periods of time, duplication of the levels of acoustic field parameters with the precision necessary for the production of predictable selective action on the tissue. A third program was concerned with the design of electronic instruments for stabilizing transducer driving voltages and for providing in routine use an order of magnitude greater accuracy in the linear scaling of such voltages than is possible with present vacuum tube voltmeters. Since the dosage of ultrasonic radiation required to induce selective action is markedly dependent on the temperature of the tissue, a fourth area of development involved the problem of maintaining brain temperature, in the anesthetized experimental animal, at prescribed fixed values throughout an irradiation sequence. The indicated major supporting subsystems are essential parts of the ultrasonic irradiation facilities of this laboratory. With such a system of instrumentation, controlled effects of great utility in basic studies of brain and in applied neurology can be produced by ultrasonic energy.

This paper outlines specific requirements that must be satisfied by a system of the type described and it also indicates how these requirements are realized in systems used by the authors and collaborators. In addition, some of the directions of system development indicated for the immediate future are discussed. Finally, the paper stresses the importance, to the designer of such instrument systems, of understanding what ultrasonic energy methods can provide toward the elucidation of structure and function of the central nervous tem so that the equipment that comes into use in the immediate future is not simply apparatus to provide only another method of inducing the relatively primitive types of changes that can be produced by methods in common use - irreversible changes produced by probes employing electrical, thermal and chemical means.

Session C - Thursday Morning, December 5, 9:00 AM
Invited Papers

C1. Generation and Attenuation of Ultrasonic Waves in the Megacycle to Kilomegacycle Frequency Range - S. Wanuga and W. Brouillette, General Electric Company, Electronics Lab., Syracuse, New York

In general, conventional methods of exciting ultrasonic waves in this frequency range utilize bonded transducers. This involves difficult bonding techniques and causes errors in experimental measurements. These are due mainly to impedance mismatch between the transducer, bond and specimen. More reliable results were obtained using thin film magnetostrictive transducers and surface excited piezoelectric crystals using specially designed coupling structures.

Thin film magnetostrictive transducers have been used for generating ultrasonic waves in crystalline quartz and ruby. These samples were studied in the frequency range 350 to 3,000 megacycles/sec. at room temperature. Generation and propagation in silicon, germanium, gallium arsenide and cadmium sulfide were also studied at 1,000 to 3,000 megacycles/sec. at liquid helium temperatures using magnetostrictive excitation.

Direct excitation of piezoelectric crystals such as quartz, cadmium sulfide and gallium arsenide was investigated. Microwave phonon generation was observed in quartz and cadmium sulfide at liquid helium temperatures using reentrant cavities. Ultrasonic propagation was observed in these crystals at 30 megacycles using tranmission line structures. While the overall insertion loss of such a structure tends to be quite high, the bonding problem is elimina broadband characteristics are obtained and hence, this sc ie is useful as an analytical tool.

Experimental results are presented with regard to methods of generation, mode propagation, attenuation and structure configuration for various crystals, temperatures and transducers.

This work was supported by U.S. Army Signal Research and Development Laboratory, Fort Monmouth, New Jersey, Contract No. DA-36-039-sc-87209, and U.S. Air Force, Rome Air Development Center Research and Technology Division, Griffiss Air Force Base, New York, Contract No. AF 30(602)-2230.

C2. High Frequency Transducers from Piezoelectric Semiconductors - N. F. Foster, Bell Telephone Labs., Inc., Murray Hill, New Jersey

ABSTRACT

The work on cadmium sulphide diffusion layer transducers initially reported last year has been extended to higher frequencies and to include shear, in addition to longitudinal, mode operation. Fundamental mode operation from below 100 to above 1,900 Mc has been obtained. Operation in each mode has been examined both in structures consisting of a single piece of cadmium sulphide and in structures consisting of small CdS samples bonded to quartz bars. A variety of bonding procedures involving indium, indium alloys and nonmetallic materials have been investigate.

A new type of transducer also using piezoelectric semiconductor materials has been fabricated which is particularly suited to operation in the higher frequency ranges from several hundred to perhaps several thousand megacycles.

Session C - Thursday Morning, December 5, 9:00 AM
Contributed Papers

C.3 Non-Linear Ultrasonic Simulation of Radar Return * - H.S. Hayre, Dept. of EE, Kansas State University, Manhattan, Kansas

In linear acoustic modeling electromagnetic wave-backscatter from a surface, when the transmitter is in motion with respect to the latter, a range factor, acoustic to electromagnetic wave velocity factor, and the resulting time factor are employed in construction of a laboratory model. In case of planetary bodies, the range scale factor becomes too large to be used in modeling such surfaces. It is therefore necessary to introduce two separate scale factors, one for range H, and another for surface heights in such a way that the ultrasonic simulated return yields the same information as would a linear model. These scale factors are neither related to each other nor to the velocity and time scale factors. This paper gives theoretical and experimental justification for the use of such a complex non-linear acoustic simulation technique.

Theoretical justification for the use of reduced-range-factor is provided by the fact that the average power return from a rough surface at large distances varies as h^{-n}, where n is approximately 4. If the modeled range is sufficiently large to result in such range variation of the average return power, then a further increase in the modeled range would result in attenuation of the return power, which can be corrected.

The use of reduced-scale-factor for surface heights in an ultrasonic model using flat-disc type sonic transducers, may be discussed using the far-field expression for pressure p as $p=p_o(\frac{1}{R}) \exp(-j)(wt-kh)$ for small angle of incidence, which is the case when the planetary surfaces are modeled. P_o is a transducer constant for a given set of conditions, w is the frequency in radians/sec and k is the wave number 2π/wavelength. The effect on average return power due to change in range, caused by the surface heights is negligible if such heights are insignificant as compared to the range, but the change in phase of the return pressure due to surface heights is significant. Then it is reasoned that if the actual surface heights are reduced by integral number of half-wavelengths, the net phase of the back-scattered pressure wave will be identical to that obtained u: linear model. Thus it is established that integral number of ha.. wavelengths-reduced-surface height-model, even though it introduces non-linear factor in modeling should yield proper simulated return with a fixed amplitude attenuation factor.

Moreover, acoustic simulation of the lunar radar return using this type of non-linear modeling techniques has been successful and accomplished, thus supporting theoretical justification given above.

* This work was supported by National Aeronautics and Space Administration under Grant NsG 129-61.

C4. Torsional Mode Ceramic Transducer - W. V. Vilkelis Components Lab., International Business Machines Corp. Poughkeepsie, New York

Piezoelectric ceramic transducers have been developed that can excite torsional waves in cylindrical structures. These transducers can be used to replace the magnetostrictive transducer longitudinal to torsional mode converter combinations commonly used in magnetostrictive delay lines. The transducers can also be mounted upon fiber delay lines, made for example of fused silica.

Two configurations of the transducer and the means used to polarize the ceramic in the appropriate direction will be described in the paper. Techniques for bonding the transducer to the delay media will be discussed.

Electrical impedance measurements of free and mounted transducers have been made which show the effect of a mechanical load upon the ceramic transducer. The ceramic transducers have been made with resonant frequencies up to 8 Mcps. The material used to make the transducers is PZT-7 ceramic obtained from the Clevite Corporation.

C5. The Dependence of the Small-Signal Parameters of Ferroelectric Ceramic Resonators Upon State of Polarization * - C. E. Land, G. W. Smith, and C. R. Westgate, Sandia Lab., Alburquerque, N. M.

Some general results of a study of polarization dependence of the small-signal parameters of hot-pressed, lead-zirconate-titanate ceramic bar and disk resonators are discussed in this paper. Measurements were made of both the free admittance loci in the vicinity of principal resonance and the high-frequency clamped impedence as the polarization was varied in increments from negative to positive saturation remanence. The results of these measurements are presented in terms of the variation of equivalent circuit parameters as functions of the polarization. From the established relationships between resonator equivalent circuit parameters and material properties, it is shown that the significant polarization dependent material properties are piezoelectric coupling, complex permittivity and complex stiffness. Piezoelectric coupling and complex stiffness vary directly with polarization; complex permittivity is inversely proportional to polarization. For some lead-zirconate titanate compositions measured, piezoelectric coupling and complex permittivity are essentially anhysteretic functions of polarization; whereas, for these same compositions, the relationship between complex stiffness and polarization exhibits detectable hysteresis. The possibility of using ferroelectric ceramic resonators as multistate memory devices with constant, small-signal, nondestructive readout is discussed briefly.

* This work was done under the auspices of the U. S. Atomic Energy Commission.

C6. The Dependence of Elastic Constants on Polarization in a Ferroelectric Ceramic - S. R. Burlage, Clevite Corp., Electronic Res. Div., Cleveland, Ohio

The variations of the elastic constants c_{11}^E, c_{44}^D, c_{44}^E, c_{33}^D and c_{66} with polarization have been measured on a rhombohedral ferroelectric Pb (Ti, Zr, Sn) O_3 composition near the tetragonal antiferroelectric boundary. The measurements were made using the pulse echo method with a fused silica buffer rod and 10 Mc X- or Y-cut quartz transducers. Time delays were determined by a simultaneous display of 1 μsec reference time marks. The polarization was continuously varied and measured with a manually operated polarization-electric field hysteresis loop recorder.

From the curves of c_{44}^D and c_{44}^E the polarization dependence of the electromechanical shear coupling coefficient k_{15} is found directly. The variation of c_{33}^E cannot be measured with the pulse echo method; however, since the thickness coupling coefficient k_t is known to be an approximately linear function of polarization * the c_{33}^E dependence on polarization can be inferred.

Since mainly 180° domain reorientation occurs during the hysteresis loop only a slight variation would be expected in c_{11}, which is found to be the case for c_{11}^E. The dependence of c_{11}^D is essentially identical since the piezoelectric constant e_{31} has ·n measured and found to be nearly zero. The variation of c_{66} n polarization is then due mainly to c_{12}^E where $c_{12}^E \cong c_{12}^D$ for the reason mentioned above.

* D. Berlincourt, to be published.

Session D - Thursday Afternoon, December 5, 2:00 PM
Invited Papers

D1. Nuclear Spin-phonon Interactions by User of Ultrasonic Techniques - D.I. Bolef, Washington University, St. Louis, Missouri

A brief review will be given of the theory and of the experimental techniques for observing acoustic spin-phonon absorption. The measured acoustic absorption coefficient and resonance line shapes will be discussed in their relation to nuclear electric quadruple interactions and exchange interactions in solids. Particular emphasis will be placed on spin-phonon interactions in metals and in III-V semiconductors and their relation to spin-lattice relaxation mechanisms.

The cw ultrasonic techniques used in the nuclear spin-phonon work enable one to measure changes of acoustic attenuation of parts per million. A description of the extension of these techniques to UHF frequencies spin-phonon interactions at low temperatures will be given.

D2. Comparison of Ultrasonic and Dielectric Relaxation in Liquids - T.A. Litovitz, Physics Dept., Catholic University of America, Washington, D. C.

The use of ultrasonic absorption and velocity measurements to investigate the dynamics of liquid structure will be considered. ' -luded in this will be a discussion of the mechanism of molecular ✓ which determines the structural relaxation time obtained from tne ultrasonic data. It will be shown how the dielectric relaxation time in a liquid is related to the ultrasonic relaxation time and how measurements of each of these phenomena lead to a better understanding of the other.

Session D - Thursday Afternoon, December 5, 2:00 PM
Contributed Papers

D3. Excitation and Propagation of Microwave Phonons in GaAs and InSb * - B. Abeles and K.R. Keller, RCA Labs., Princeton, N. J.

Sound waves at frequencies of 0.6, 3 and 10 Gc were propagated along the (110) direction in optically finished rods of semi-insulating GaAs and pure InSb. Direct surface excitation was used, or alternatively, the samples were bonded to quartz rods which were surface excited. The sound attenuation was measured in the temperature range 2° -300°K. A discussion of the results is given.

*This research was sponsored in part by the Advanced Research Project Agency of the Department of Defense under Contract No. SD-182.

D4. Oscillation in CdS Ultrasonic Current Limiters - J.S. Crabbe Texas Instruments, Inc., Dallas, Texas

An idealized model of an ultrasonic current limiter predicts current saturation for fields which tend to cause electrons to drift faster than the piezoelectrically coupled ultrasonic wave. Data is presented which illustrates that the limiting field of 0.5 - 5.0 ohm cm CdS samples increases for decreasing sample thickness. ·ical values for field, current density and power at the limiting ...eshold are also presented.

Measurements of the current limiting properties of CdS samples at liquid nitrogen temperature have shown a sustained oscillation in the current flowing through the CdS sample upon application of fields in excess of those required to induce current limiting. The thickness of the current limiter sample corresponds closely to the half wavelength of the coupled ultrasonic wave at the oscillation frequency. Data is presented which shows the effect of applied drift field and terminating impedance on the oscillation frequency.

D5. Phonon Emission by Supersonic Electrons and Collective Phonon Propagations.- E.W. PROHOFSKY, Sperry Rand Res. Center, Sudbury, Mass.

The emission of piezoelectrically active phonons by electrons with drift velocity greater than the velocity of sound is studied in the quantum limit. This interaction is found to be very strong, as the electrons have a momentum space population inversion and are prone to undergo "Cerenkov-like" radiation. The most probable frequencies of emitted phonons are 10^{10} - 10^{11} CPS. In the presence of this stimulated emission, the crystal momentum losses for this band of phonons may be overcome, and collective propagations by the phonons become possible. The collective waves in the "phonon gas" are much like an ordinary sound wave in a molecular gas. A similar propagation among thermal phonons is thought to be the mechanism for second sound phenomena in superfluid liquid helium.

D6. Experimental Observation of Collective Phonon Propagation in CdS - H. Kroger, Sperry Rand Res. Center, Sudbury, Mass.

Experimental observations of collective phonon waves in cadmium sulfide under acoustic gain (supersonic electron drift velocities) conditions are described. These include measurements of the velocity of collective waves in the 10-100 Mc/sec frequency band. The possible relation between collective phonon modes and nonohmic behavior of piezoelectric crystals under acoustic gain conditions is discussed. Two types of spontaneous current oscillations are described. The experimental arrangement was similar to that of Hutson, McPhee and White.[1] The period of one type of oscillation is exactly the transit time of piezoelectrically active sound wave across the crystal. The period of the other type of oscillation is not determined by the size of the crystal alone but also depends upon light intensity and voltage. Experiments are described which suggest that the latter mode of oscillation is related to the generation of collective electron-phonon waves.

[1] A.R. Hutson, J.H. McPhee and D.L. White, Phys, Rev. Letters 7, 237 (1961)

Session E - Friday Morning, December 6, 9:00 AM
Invited Papers

E1. Magnon-Phonon Instabilities Associated with the Exchange Branch in Ferrimagnetic Crystals * - Frederic R. Morgenthaler, Dept. of EE and Lab. for Insulation Res., MIT, Cambridge, Mass

The spectra of the microwave and exchange magnons that are associated with a two sublattice ferrimagnetic crystal will be reviewed, and their modification due to magnetoelastic energy terms considered. It will be shown that the degree of magnon-phonon interaction for each of the magnon branches depends upon a different combination of sublattice components of the magnetoelastic energy. Measurements of the magnon-phonon splitting of both branches should allow one to decompose the usual magnetoelastic energy coefficients (such as b_2) into their sublattice components; this is not possible from the microwave measurements alone.

The possibilities and criteria for magnon-phonon instabilities involving the microwave branch will be reviewed and the theory extended to include the exchange branch. The instabilities will be considered as providing possible phonon sources and/or amplifiers, and as the basis of a nonlinear spectrometer used to measure a variety of fundamental properties of magnetoelastic systems.

* This research was sponsored by the USAF under Contract AF 33(616) 8353

Session E - Friday Morning, December 6, 9:00 AM
Contributed Papers

E3. Coupling to Hypersonic Waves with Piezoelectric Insulators
C. F. Quate and W. H. Haydl, Stanford University, Stanford, Calif.

Piezoelectric discs can be used for efficient couplers for longitudinal waves in the microwave range if they are properly matched to the microwave circuit with acoustic impedance transformers.

We have considered insulating discs several odd half-wavelengths in thickness which are coupled to the acoustic transmission medium by "double layer" of quarter wave films. The quarter wave films are of alternately high and low impedance material and serve to transform the acoustic impedance of the acoustic medium to a value that is appropriate for matching to the electromagnetic circuit. This is in direct analogy to the use of "double layers" of quarter-wave films which are commonly used in optical devices.[1]

In this paper, the principles of such couplers together with the associated transformers are presented together with some initial results which lead to couplers with a power conversion efficiency of 10% and metallic band losses of less than 2 db over a narrow band at 600 Mc.

Such couplers are conveniently incorporated into acoustic wave amplifiers and the properties of such amplifiers using CdS as the active medium will be included in the discussion.

[1]M. Born and E. Wolf, Principles of Optics, Pergammon Press (1959), P. 65.

E4. A New Approach to High Frequency Delay Lines, Walter Strauss, Bell Tel. Labs., Inc., Murray Hill, N.J.

In the construction of high frequency delay lines one usually encounters problems because of: (1) a need for optically flat and parallel surfaces, (2) high sonic loss at room temperature, and (3) poor electromechanical conversion efficiency. Recent observation of magnetoelastic waves by the author together with the work of Schloemann[1] and Eshbach[2] suggest that some of the above difficulties may be overcome. Magnetoelastic pulses propagating parallel to axis of a rod of yttrium iron garnet were observed at microwave frequencies. Input power was in the milliwatt range. The travel time of these pulses was varied by adjustment of the applied magnetic field. A proposed magnetoelastic delay line will have the feature of variable delay time. Since the magnetoelastic wave will be launched inside the sample, surface conditions should be only of secondary importance. Other characteristics and design problems of a magnetoelastic delay line will be discussed.

[1]E. Schloemann, Advances in Quantum Electronics, edited by J. R. Singer (Columbia University Press, New York, 1961), p. 444, Sec. 5

[2]J. R. Eshbach, J. Appl. Phys. 34, 1298 (1963)

E5. A Birefringent Scanner Concept - R. T. Babcock and G. C. Vorie, Computer Research Department, Cornell Aeronautical Lab., Buffalo, N. Y.

A concept under investigation at CAL for image dissection takes advantage of ultrasonically induced birefringence in photoelastic delay lines, The rotation of polarized light in the presence of a stress wave in two-orthogonal delay lines to use in conjunction with polarizing elements and optics to create an image dissector which may have camera and display application. From an electronics viewpoint, the advantages are that no vacuum tubes or high voltages are required and the device will probably not be limited by extreme environmental stresses of shock temperature, and nuclear radiation.

The paper describes the image dissector concept, together with results of a theoretical and experimental research program being conducted to investigate important questions concerning the technical feasibility of the scanner concept. Preliminary results of the resolution, sensitivity, and other characteristics of the birefringent scanner are presented, and the requirements of future research are indicated. These preliminary results indicate that this new scanning concept has the greatest potential application for displays.

E6. Orthogonal Ultrasonic Signals * - E. E. Henry, Institute of Science and Technology, The University of Michigan, Ann Arbor, Michigan

An ultrasonic light modulator is one good means of introducing an active signal into a beam of light for computing various logic functions such as Fourier transforms of the signal. A possible method of increasing the information capacity of the modulator is to introduce two signals perpendicularly, if the intermixing effect is negligible. To determine this effect, a water cell has been constructed with two quartz transducers mounted into two sides of the unit so as to produce two perpendicular ultrasonic wave trains with a common area of interaction. Each crystal is driven separately. They They are energized both singly and simultaneously with pure resonant frequency excitation and amplitude modulation as well. The cell isinserted into a collimated beam of light to form the diffraction pattern (or Fourier transform) of the signal. The effect of introducing various signals is found by studying the diffraction pattern of the composite signal. Studies to date of the optical effects indicate that the ultrasonic signals are orthogonal (that is, free from frequency mixing) when various modulations are used. This paper describes the equipment used and the results which have been achieved with this equipment.

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E7. An L-Band Permanent Magnet Type Yttrium Iron Garnet Delay Line - R. A. Sparks and E. L. Higgins, RADCOM, Div. of Litton Systems, Inc., College Park, Md.

The results of using single crystal yttrium iron garnet as a delay line at ultra high frequencies have been previously reported by Eggers and Strauss.[1] In this paper the preliminary results of an investigation at L-band frequencies are presented also using YIG as the delay medium. The novel feature to be noted in these studies, in addition to extending the frequency range of operation, is the use of a permanent magnet biasing field to raise the polished and faces of the YIG bar into the neighborhood of ferromagnetic resonance. The (100) oriented crystals were first evaluated in a DC field provided by an electromagnet and then placed in the center of a cylindrical type permanent magnet. A special in-line coaxial crystal holder was constructed to maintain orientation concentric with the axial magnetic field. The r-f energy was coupled to the YIG using the nonresonant technique that has been described by Denton and Spencer[2]. Two areas of investigation have been examined for specific device applications. Maximum delays, corresponding to several round trip reflections in the medium, can be obtained by properly orienting the crystal with respect to the incident r-f magnetic field. Alternately, conditions can be established to suppress the multiple reflections and enhance the one way transmitted signal. A new configuration under development uses a C-type permanent magnet and a strip line matching section combined with the input and output coupling loops to provide a compact, light weight, low power device.

[1]F. G. Eggers and W. Strauss, J. A. P., 34, pt. 2, 1180 (1963)

[2]R. T. Denton, and E. G. Spencer, NEREM Record, 44, (1962)

Session F - Friday Afternoon, December 6, 2:00 PM
Invited Papers

F1. Ultrasonic Wave Propagation in Pure and Doped Silicon and Germanium - Warren P. Mason and T. B. Bateman, Bell Tel. Labs. Inc., Murray Hill, N. J.

Ultrasonic attenuation and velocity measurements have been made in pure germanium and silicon (doping $< 10^{14}$ impurity atoms per cc) and in doped silicon and germanium having doping values of p-and n-type impurities in the range from 5×10^{17} up to 3×10^{19} doping atoms. The attenuation in pure material shows a continuous decrease as the temperature is decreased and an almost complete absence of attenuation below 20°K. These results indicate that the energy losses are accounted for entirely by phonon-phonon interactions. A calculation has been made of these losses using a model based on the Akheiser effect and incorporating the recently measured th order elastic moduli of silicon and germanium. For both mate the calculated values agree with the measured values within 50 percent for both shear and longitudinal waves.

The effect of doping silicon and germanium with p-and n-type impurities is to increase the attenuations and to decrease the velocities. The n-type material produces a constant loss independent of the temperature at low temperatures. This loss can be used to evaluate the intervalley relaxation time associated with the motion of electrons from one valley to another. The corresponding intersurface relaxation time measured for p-silicon doped with boron shows an activation energy effect which is believed to be caused by the capture of the hole by the boron atom. This energy disappears for high doping levels.

F2. Propagation of Microwave Phonons in Germanium * - M. Pomerantz, International Business Machines Corp. Thomas J. Watson Res. Center, Yorktown Heights, N. Y.

The effect of various kinds of interactions on the propagation of 9 Gc/s microwave phonons in germanium have been studies experimentally. We will discuss phonon interactions (a) with conduction electrons in degenerate n-Ge, which produces attenuation of waves of specific polarization in particular directions of propagation, (b) with microwave phonons, which gives nonlinear effects, (c) with thermal phonons, which gives temperature dependent ultrasonic attenuation.

* This research has been supported in part by the U. S. Army Electronics Research & Development Lab., Fort Monmouth, N. J.

Session F - Friday Afternoon, December 6, 2:00 PM
Contributed Papers

F Simulation of Crystal Symmetries Through Working Polycrystalline Metals: Ultrasonic Applications and Experiment on Tool Steel - Ammanuel P. Papadakis, Bell Tel. Lab., Inc., Allentown, Penna.

Plastic deformation of polycrystalline metals produces preferred orientation among the crystallites. The effect is to align certain crystallographic axes in the grains with the directions and planes in the specimen characterizing the mechanical working (e.g., drawing axis, rolling place and direction, etc.). The anisotropic elastic moduli of the grains impart to the finished specimen as elastic anisotropy characteristic of the metal and its deformation. Certain crystal symmetries such as hexagonal, orthorhombic, and tetragonal can be simulated in worked metals. The degree of anisotropy can be controlled through the degree of working and subsequent heat treatment. This simulation will be useful in ultrasonic wave propagation studies since diffraction, double refraction, conical refraction, wave surfaces, and other phenomena could be investigated in specimens fabricated to order. Ultrasonic devices may be devised to utilize anisotropic materials. Several experiments are suggested. An experiment was performed on rolled bars of tool steel both before and after hardening to study this hexagonal crystal facsimile. The five elastic moduleswere found from absolute measurements of the ultrasonic wave velocities while the velocity surfaces were investigated by twin-sample ultrasonic interferometry and ultrasonic double refraction. Surprisingly, hardening changed the anisotropy very little while lowering all the elastic module somewhat.

F4. A Novel Method of Measuring Elastic and Anelastic Properties of Solids - D. B. Fraser and R. C. LeCraw, Bell Tel. Labs., Inc., Murray Hill, N. J.

A technique has been devised whereby the elastic and anelastic perties of solids can be measured both as a function of frequency temperature. A small sphere, of the order of 5mm or less in diameter, is placed without bonding on a ceramic shear mode transducer. The transducer is pulsed at one of the sphere's resonant frequencies and the free decay of vibrations is observed by feeding the transducer signal to a receiver. From the decay of the vibrations the internal friction, Q^{-1}, may be determined. Various series of modes may be excited and from comparison with the calculated mode spectra of an isotropic solid, the Lame constants, and μ, and Poisson's ratio may be computed directly. Measurements have been made over a range of temperatures from $1.4^{\circ}K$ to $400^{\circ}K$, the present upper limit being set by the solder connections to the transducer. Several materials have been tested and results for two single crystal garnet spheres will be given as representative of the capabilities of the technique for reasonably isotropic substances. The range of Q^{-1} that has been measured extends from 2.5×10^{-7} to 5×10^{-4}, and in this range the loss appears to be independent of the transducer.

F5. Methods of Measuring Mechanical Properties of Plastics with High Frequency Ultrasound - H. J. McSkimin and R. P. Chambers Bell Tel. Labs., Inc. Murray Hill, N. J.

Two methods are described for measuring ultrasonic wave velocities and attenuation in plastics. The first is a variation of the "water immersion" method, and involves measuring the differential loss and phase shift resulting from removal of the specimen from the ultrasonic beam. Longitudinal wave data can be obtained to about 100 Mc. For the second method, which is applicable to both shear and longitudinal waves, the specimen, is cemented between two solid rods of quartz, and the desired quantities are obtained from measurement of wave amplitudes as a function of frequency.

Preliminary results for polystyrene indicate that measurements for this low loss material can be made at frequencies as high as 500 Mc; however, special attention must be paid to precise mechanical alignment of component parts.

F6. Modes in Circular AT Quartz Plates - W. J. Spencer, Bell, Tel. Labs., Allentown, Penna.

A complete analysis of acoustic modes in an anisotropic disc is not presently available. To circumvent this problem and to provide a tool for mode analysis of circular AT cut quartz discs, a study of high frequency shear and flexure modes in these plates has been made by x-ray diffraction. The x-ray technique depends on the reduction of primary extinction in a Laue diffraction due to the lattice curvature associated with various acoustic modes. The curvature tensor $\underline{K}$ related to the strain tensor by $\underline{K} = \nabla \times \underline{S}$ indicates from which planes the x-rays should be diffracted to obtain a maximum intensity. Diffraction patterns give a direct picture of the acoustic mode without resorting to analysis. Results may be used to determine the nature of spurious responses and coupled modes in AT quartz plates of any geometry whose fundamental frequency is above 800 kc. Generally, mode patterns in complete devices are obtainable.

F7. Attenuation of Longitudinal and Flexural Wave Motions in Strips - G. A. Coquin, T. R. Moeker, and A. H. Meitzler, Bell Tel. Labs., Inc. ABSTRACT

The frequency variation of the attenuation per unit length for elastic waves travelling in strips has been observed experimentally to depend markedly upon the particular longitudinal or flexural mode of propagation involved. Experimental and theoretical studies have been carried out on the lowest three longitudinal and lowest three flexural modes in strips of polycrystalline aluminum. Although a medium of this form has many possible loss producing mechanisms, a theory for wave propagation in a plate of viscoelastic material provides a useful basis for interpreting a number of the details observed for loss measurements in the frequency range of 1 to 35 Mc. Applications of the results of this work to the design of ultrasonic strip delay lines will be discussed, with particular attention paid to the way in which the frequency dependent loss characteristics of the lowest longitudinal mode and the two lowest flexural modes affect the design of dispersive strip delay lines.
