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STUDY OF OPTICAL SOUND GENERATION AND AMPLIFICATION(U)
MISSISSIPPI UNIV UNIVERSITY PHYSICAL ACOUSTICS RESEARCH
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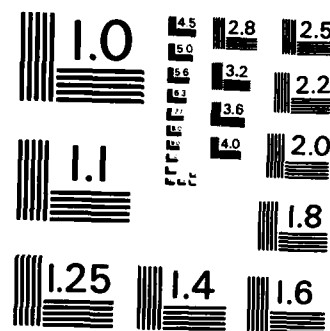
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER PARGUM 85-05	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) Study of Optical Sound Generation and Amplification		5. TYPE OF REPORT & PERIOD COVERED Annual Report	
		6. PERFORMING ORG. REPORT NUMBER University of Mississippi	
7. AUTHOR(s) Henry E. Bass, Lawrence A. Crum and F. Douglas Shields		8. CONTRACT OR GRANT NUMBER(s) N000114-84-C-0193	
		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Program Element No. 61153N Project-Task RR 011-08-01 Work Unit No. NR 384-936	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Physical Acoustics Research Laboratory The University of Mississippi University, MS 38677		11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Arlington, VA 22217	12. REPORT DATE 1 November 85
		13. NUMBER OF PAGES	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified	
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
16. DISTRIBUTION STATEMENT (of this Report) "Approved for public release; distribution unlimited"			
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)			
18. SUPPLEMENTARY NOTES			
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Acoustic amplification; opto-acoustic effect			
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This project involves four separate tasks with the following titles: Task I Generation of low frequency sound from optical pulses; Task II Propagation of sound through a gas with an overpopulation of vibrationally excited states; Task III Opto-acoustic studies in liquids and Task IV Nonlinear oscillation of gas bubbles. The first three tasks, funded by the physics division of ONR, represent a three pronged study of the generation of sound by the absorption of light. The fourth task, funded by the mathematics division of ONR, is a continuing study of cavitation in liquids.			

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Study of Optical Sound Generation and Amplification

Annual Report

1 November 1984 - 31 October 1985

by

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General Comments

During the period covered by this contract, the Physical Acoustics Research Laboratory awarded four Ph.D.'s and another student completed all requirements for the Ph.D. Two of these students plus a former Ph.D. candidate (Detsch) accepted positions with the U.S. Navy during the past year. The laboratory currently has six Ph.D. candidates and six M.S. candidates. Two M.S. students are not U.S. citizens.

Plans to move the Physical Acoustics Research Laboratory into contiguous space still awaits state approval. A Long Range Plan for development of the laboratory has been completed. Copies are available upon request.

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Task 1

Generation of Low Frequency Sound from Optical Pulses

H.E. Bass

The objective of this task is to generate audible frequency sound from a series of short optical pulses modulated in time and amplitude.

During the past year, our studies of the pulsed spectrophone in a highly absorbing gas (SF_6) were completed. The study of SF_6 which is being prepared for publication in a special issue of IEEE Transactions on Sonics and Ultrasonics proved to be quite interesting. At low pressures, the optoacoustic signals get progressively smaller, go to zero (at about 200 mtorr), then change sign. A theoretical model to explain this unusual behavior was very successful. This observation demonstrates one of the problems which can be encountered in photoacoustic spectroscopy. There are no further plans for additional studies in the gaseous phase.

During the next year, this task will focus on sound generation at a darkened surface using a specially designed high power strobe lamp. This light system will produce variable intensity pulses at rates up to 2 kHz. When driven by a low frequency oscillator, the lamp intensity and pulse repetition frequency vary in proportion to the instantaneous amplitude from the oscillator. Since the pulse repetition frequency is at a frequency higher than the oscillator frequency the total energy impinging on the surface is controllable. This source will allow us to experimentally explore the pulse modulation schemes suggested by Visiting Professor Lafleur during the summer of 1985 (see last year's report).

Task 2

Propagation of Sound Through a Gas with an Overpopulation of Vibrationally Excited States

F. Douglas Shields

This task is a study of sound amplification from controlled excitation reactions (SACER). An experimental system has been built for passing an electrical discharge through gases at reduced pressures. By terminating the discharge on a screen a short distance from one end of the tube a sound wave is generated that reflects back and forth in the tube. In N_2 and a few other gases, practically all of the discharge energy deposited in the gas very quickly winds up as molecular vibrational energy. In this way it is possible to obtain non-equilibrium states where the vibrational temperature is thousands of degrees above the translational temperature. Theoretical predictions indicate that a sound wave propagating in a gas in such a "metastable" state will be amplified.

Dadang Iskandar completed his PhD in March of this year and his dissertation was distributed as a technical report. Since he left we have made something of a "breakthrough" in observing "SACER". Dadang made most of his measurements in a tube 1/2 inch in diameter and was trying to see amplification of waves of 2 to 6 kHz frequency. He was Fourier analyzing the sound pulse each time it passed the microphone as it reflected back and forth in the tube. He had observed a decrease in absorption at these frequencies but the effect was not sufficient to produce an actual amplification in the wave. Last summer we increased the amount of energy in the electrical discharge and went to a 1 inch tube. Doubling the tube radius increased the thermal diffusion time by 4. In addition, instead of looking at Fourier components in the pressure pulse we set our filter to select out the resonant frequency of the closed tube. The result was very gratifying. After having predicted the effect theoretically several years

ago and looking for it experimentally for two years, suddenly the expected gain was clearly evident. The resonant sound vibration built in amplitude for 10 or 20 periods before beginning to die away.

We have spent the last few months developing the technique and computer programs for extracting as much information as possible from the pulses. First it was necessary to correct the absorption and velocity for the tube wall losses. We have also empirically determined the end losses so that we can now, with these corrections, get the gain due to the Sacer effect to compare with theoretical predictions. We are now plotting both the translational temperature (as determined from the sound velocity measurements) and the gain as a function of time following the discharge. We have measured the effect of changing the gas pressure, gas composition, electrical discharge energy, and sound frequency on these curves and are seeking to correlate the dependence of the temperature and absorption curves upon these parameters with a theoretical model for the relaxation process. The prospects are good for eventually getting physical properties of the gases not accessible from other types of measurements. For example, the gain should be very sensitive to the temperature dependence of the v - t transition rate. There is considerable debate over the temperature dependence of the H_2O/N_2 v - t rate. By comparing the gains in N_2/H_2O and N_2/H_2 mixtures it should be possible to get much-needed and difficult-to-measure information about the temperature dependence of the N_2/H_2O rate.

Our recent results will be reported in a paper given at the November meeting of the Acoustical Society of America.

Task 3

Opto-Acoustic Studies of Liquids

H.E. Bass

The goal of this task is to identify the microscopic mechanism for pressure generation when a liquid absorbs a laser pulse. This work is similar to the spectrophone studies in the gas phase except on a much shorter time scale consistent with the shorter time between interactions characteristic of liquids.

Our initial goal is to reproduce the recent work by Tam of IBM. He subjected a liquid to a pulse from an N_2 laser with a pulse length ~ 1 nsec and observed structural relaxation. His electronics limited resolution to a few nsec. Though we now have electronics capable of resolution to 50 psec, we will initially restrict our attention to the 1-100 nsec time regime. In this time regime, we will examine the effect of laser power density on the amplitude of the observed pressure pulse. If Tam was observing structural relaxation, we would expect to see step-like behavior as the laser pulse energy becomes sufficient to detach one, two, three, etc. molecules from the cluster. Macroscopically, this would be seen as a non-linear behavior of the thermal expansion coefficient and corresponding improved optical to acoustic conversion efficiency.

All experimental equipment has been received and initial signals have been observed. Due to jitter in the laser firing circuit, capture of the signal proved to be a major problem. This was resolved by acquiring a second 50 GHz photo-detector to provide a signal pulse from the N_2 laser pulse. The opto-acoustic signals recorded to date show the proper time delay when excitation and probe beams are moved apart but the signal strength is not yet great enough to accurately measure waveshapes (or amplitudes). The key to increased signal strength is to focus the excitation beam down to a smaller volume. This initially proved difficult but we

were able to track the problem back to a bad dye cell and have recently succeeded in reducing the N_2 laser spot size down to $\sim 20\mu$ in diameter. This should provide sufficient intensity for the purpose of our work.

Task 4

Nonlinear Oscillations of Gas Bubbles

Lawrence A. Crum

The goal of this task is to examine the dynamics of gas bubbles driven at large acoustic pressure amplitudes.

We are pleased to report a very successful summer, with the completion of a Ph.D. dissertation, three technical reports, four research publications and some exciting advances in our research efforts.

Working with A. Prosperetti, we now have a computer code that permits us to describe the nonlinear oscillations of gas bubbles at large driving amplitudes. Comparison with our data taken a few years ago assures us that the code quite accurately describes the behavior of these bubbles. Interestingly, comparison of our model with models currently accepted in the literature indicates that these previous models are considerably inaccurate for a wide variety of regions of interest. The student who has been working on these problems, K. Commander, has completed his Ph.D. and is now working for the Naval Coastal Systems Laboratory.

We have also made some progress in our studies of cavitation nucleation. A technical report was issued in January, a paper was written in July, and a review article is planned for the coming Spring. The student involved in these studies, A. Atchley, is also working for the Navy, having accepted a position at the Naval Postgraduate School. (He is currently on leave from the NPS to work at Yale having been awarded the Hunt Fellowship from the Acoustical Society of America.)

We are now building a sophisticated light scattering technique to study bubble oscillations directly and we anticipate moving into the area of deterministic chaos, vis a vis bubble dynamics, in the coming year.

Finally, L. Crum is on sabbatical in London and wishes to report progress in a number of areas. A detailed list of publications and external reports will be sent at the end of the contract year.

OFFICE OF NAVAL RESEARCH

PUBLICATIONS / PATENTS / PRESENTATIONS / HONORS REPORT

for

1 October 1984 through 30 September 1985

for

Contract N000114-84-C-0193

Task No. NR 384-936

Study of Optical Sound Generation and Amplification

Henry E. Bass, Lawrence A. Crum and F. Douglas Shields

Physical Acoustics Research Laboratory

The University of Mississippi
University, Mississippi 38677

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PAPERS SUBMITTED TO REFEREED JOURNALS
(not yet published)

L. A. Crum, A. Prosperetti, and K. W. Commander, "Nonlinear Bubble Dynamics", submitted to the Journal of the Acoustical Society of America.

L. A. Crum and J. B. Fowlkes, "Cavitation Produced by Short Acoustic Pulses", accepted and published in ULTRASONICS.

G. Reynolds, L. A. Crum, and A. J. Walton, "Image Intensifier Studies of Sonoluminescence From Liquids Subjected to Low Level Ultrasonic Pressure Amplitudes", to appear in IEEE Transactions on Nuclear Science.

L. A. Crum and J. B. Fowlkes, "Acoustic Cavitation Generated by Micro Second Pulses of Ultrasound", accepted for publication in NATURE.

R. Roy, A. Atchley, L. A. Crum, J. B. Fowlkes, and J. Reidy, "A Precise Technique for the Measurements of Acoustic Cavitation Threshold and Some Preliminary Results", accepted in the Journal of Acoustical Society of America.

A. Atchley and A. Prosperetti, "The Critical Radius Approach to the Crevice Model of Cavitation Nucleation", submitted to the Journal of the Acoustical Society of America.

PAPERS PUBLISHED IN REFEREED JOURNALS

Richard M. Detsch and Henry E. Bass, "Sound Amplification from Controlled Excitation Reactions: Experimental Observations in Chemically Reacting H_2/Cl_2 Mixtures," Journal of the Acoustical Society of America, Vol. 77, pages 512-519 (1985).

L. A. Crum and G. Reynolds, "Sonoluminescence from Stable Cavitation", Journal of the Acoustical Society of America, Vol. 78, pages 137-139 (1985).

L. A. Crum and G. Hansen, "The Use of a Mie Scattering Technique for the Sizing of Bubbles", Applied Optics, Vol. 24, page 3214, (1985).

F. D. Shields, "The Propagation of Sound Through a Gas With an Overpopulation of Excited States", Journal of the Acoustical Society of America, Vol. 76, pages 1749-1754 (1984).

BOOKS (AND SECTIONS THEREOF) SUBMITTED FOR PUBLICATION

L. A. Crum, "Nucleation, Rectified Diffusion, Stable Cavitation and Experimental Measurements", Chapter 2 in BIOLOGICAL EFFECTS OF ACOUSTIC CAVITATION (monograph to be published).

A. Atchley and L. A. Crum, "Acoustic Cavitation and Bubble Dynamics" a chapter in ULTRASOUND: CHEMICAL, PHYSICAL AND BIOLOGICAL EFFECTS by Velag Chemie International, Inc.

BOOKS (AND SECTIONS THEREOF) PUBLISHED

N/A

PATENTS FILED

N/A

PATENTS GRANTED

N/A

INVITED PRESENTATIONS AT TOPICAL OR
SCIENTIFIC/TECHNICAL SOCIETY CONFERENCES

L. A. Crum and J. B. Fowlkes, "Cavitation Produced by Short Acoustic Pulses", presented at ULTRASONICS INTERNATIONAL, London, England, July 3, 1985.

HONORS / AWARDS / PRIZES

Dr. Anthony Atchley was awarded the prestigious Hunt Fellowship in Acoustics for 1985-86.

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