Quarterly Technical Summary

Advanced Electronic Technology

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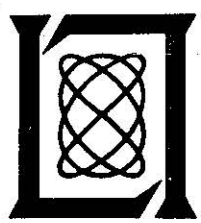

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INTRODUCTION

This Quarterly Technical Summary covers the period 1 May through 31 July 1973. It consolidates the reports of Division 2 (Data Systems), Division 4 (Air Traffic Control), and Division 8 (Solid State) on the Advanced Electronic Technology Program.

Accepted for the Air Force
Eugene C. Raabe, Lt. Col., USAF
Chief, ESD Lincoln Laboratory Project Office

CONTENTS

DATA SYSTEMS
DIVISION 2

INTRODUCTION

This section of the report reviews progress during the period 1 May through 31 July 1973 on Data Systems. Separate reports on Speech Understanding, Seismic Discrimination, Educational Technology, Radar Measurements, FAA Interactive Graphics and ATC Surveillance and Communication describe the work of Division 2 on these programs.

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I. INTRODUCTION

Circuits with higher f_T were fabricated and tested this quarter. Static and dynamic measurements were made on the first comparator circuits and the mask set for an evaluation wafer was designed.

II. INTEGRATED CIRCUIT PROCESSING

A. Integrated Circuit Fabrication

Two-bit adder and gate-chain wafers have been fabricated with thinner bases. Earlier adders with thicker bases had f_T of 1 to 1.5 GHz and circuit delays of 1.3 nsec. The f_T with thinner bases is 2.5 to 3 GHz and the circuit delay is about 1.0 nsec. Gate-chain circuits with thick bases had stage delays of 0.8 to 0.9 nsec. The thin-base wafers have not yet been measured. It is uncertain whether base width or capacitance is now limiting speed but work is being done to reduce both.

A technique has been developed for removing second-level metal without damaging the underlying first-level metal that is exposed in the vias. Thus, we were able to quickly revise circuit interconnection by simply stripping and repatterning previously metallized wafers.

B. Metallization

Double-layer molybdenum test structures have shown no failures due to electromigration, even at ten times the mean time to failure for similar aluminum devices. On test wafers the contact resistance of moly films compared favorably with aluminum. However, when a wafer with circuits was metallized with molybdenum the emitter and base contacts were low resistance and the collector contacts high resistance. We have not been able to explain this result. Further tests are in progress.

C. Dielectric Isolation

Deep isolation moats pose several problems for photoresist technology. First, it is difficult to coat the upper corners of these deep cuts with resist that is thin enough to permit 0.1-mil pattern resolution. Secondly, the spacing between bottom of the moats and the exposure mask is too large to permit less than 0.3-mil line definition due to light undercut. A number of possible conventional solutions to these problems, such as oxide backfilling and double photoresist exposures, are being explored. However, recent preliminary experiments have raised the possibility of a simpler, more effective technique for providing isolation than any of the methods presently in use. The process uses the selective growth of high-resistance polycrystalline isolation regions during the epitaxial collector formation. Fully processed wafers are undergoing test and detailed results will be described in the next QTS.

III. PHOTOLITHOGRAPHIC INTERCONNECTION OF PLASTIC-EMBEDDED SEMICONDUCTOR CHIPS

A. Memory Arrays

The second and third 20-chip, 1024-bit memory arrays have been constructed. On each array one inter-level wiring short caused by a plated void (bubble) in the resin dielectric layer

was successfully removed. The second array was then partially operational and the third fully operational until either it or the tester failed. The cause of failure will be located.

Test chips containing a total of 16 nickel-aluminum interfaces have been on test at 300°C for 83 days with no significant change in appearance or electrical resistance.

B. Batch Packaging

Prototype packages were successfully made using the batch packaging technique. Wafer strips, each eight die long, were potted with lead frames, interconnections between leads were made across the dice, the strip was separated into single units, and each unit potted into a dual inline package. The polyester-electroless plating technique produced 100 percent good interconnections with acceptably low resistance. Work is being done on simplification of certain process steps.

IV. TESTING

The Data General Nova 1230 computer was delivered and the interface hardware to connect the computer to the integrated circuit test equipment has been built and checked out. Software is being written in multi-task Fortran to run the test facility. As with the present TX-2 system, it will be highly operator-program interactive.

V. APPLICATIONS AND DESIGN AIDS

A. High-Speed Comparator

The first wafer of the LL206 latched voltage comparator had f_T = 1.5 GHz rather than the design goal of 2 GHz, resistor values about 40 percent above nominal and collector-base capacitances about twice the estimated value. The dynamic performance was: small-signal rise time of 1.5 nsec, slew rate of 1 V/nsec, turn-on regenerative time constant of 0.5 nsec, and a minimum acceptable unlatch pulse width of 3 nsec. These values are significantly slower than the design goal.

Input offset voltages have shown standard deviations of 3 to 6 mV about means of up to 14 mV, the nonzero means attributable to a correctable layout error that made offset sensitive to mask alignment. The design goal of a standard deviation of 1 mV requires larger input devices. A new chip consisting of matched pairs of transistors and resistors is being produced to make possible a determination of the trade offs involved in a lower offset.

B. Circuits for "Butterfly Box"

Four 9 × 9 array multipliers utilizing 144 of our 2-bit adders will be assembled in FY 74 to produce a butterfly box for performing the complex multiplications and additions required for high-speed convolution in the ABMDA Digital Signal Processor Development Program.

C. Double-Raster Display System

The double-raster system program was extended to allow higher level commands and operations. The TX-2 refresh-scope command handler was incorporated into the system.

D. Propagation Delay of an ECL Gate

In order to obtain optimum circuit performance from our process, it is necessary to have a good analytical understanding of circuit behavior.

An expression for the per stage small-signal propagation delay (τ_{pd}) of an inverting ECL gate chain has been derived. For a fan-in and fan-out of one and employing standard notation, τ_{pd} is given by the following expression

$$\tau_{pd} = \frac{r'_{bi}}{\omega_{ti} r'_{ei}} + R_c \left[\left(1 + \frac{r'_{bi}}{r'_{ei}} \right) C_{ci} + C_{iso} + 1/2\ C_{R_c} \right] + (R_c + r_{b_f}) \left[C_{c_f} + \frac{1}{\omega_{tf}(R_e + r'_{ef})} \right]$$

$$+ \frac{R_e r'_{ef}}{R_e + r'_{ef}} \left[1/2\ C_{R_e} + 1/2\ \frac{1}{\omega_{ti} r'_{ei}} + 1/2\ \frac{R_c}{r'_{ei}} C_{ci} \right] \quad ,$$

where the subscript, i, refers to the inverter transistor and the subscript, f, refers to the emitter follower transistor in the ECL gate. The first term in this expression for τ_{pd} represents the delay through the inverter transistor. The second term is the delay due to the charging of the capacitance associated with the collector of the inverting transistor through the collector load resistance R_c. The third term is the delay through the emitter follower transistor. Finally, the fourth term is the delay due to the charging of the capacitance associated with the emitter of the emitter follower through the output resistance of the emitter follower, $R_e r'_{ef}/(R_e + r'_{ef})$.

DIGITAL PROCESSORS
GROUP 24

I. SPEECH PROCESSORS

The Lincoln Laboratory Speech Processor program continues toward the goal of specifying appropriate vocoder hardware configurations for defense communication applications. Part of our effort is directed toward fully digitized versions of analog vocoders designed and constructed at Lincoln Laboratory for use at 2400, 4800, and 9600 bits per second (bps). These vocoders were successfully used in various experiments, and the digitized versions will be compact and low priced. A second part of the effort is directed toward implementation of Linear Predictive Coding (LPC) vocoders for operation in the 2400- to 4800-bps range. A third part of the effort is concerned with accurate pitch and voicing information extraction from the input speech waveform; a necessary procedure for both channel and LPC vocoder realizations.

The digital filter channel vocoder design simulation effort is continuing. The basic vocoder simulation without coding has been debugged, and the coding for 4800- and 2400-bps output is being debugged. Issues of scaling and gain between stages are under investigation to maximize signal-to-noise ratios in the simulation and following hardware. The basic arithmetic element of the vocoder design, a serial multiplier driven by an MOS register for state storage, has been breadboarded. The element works as designed, performing a 12-bit by 16-bit multiply in 1.6 μsec, adequately fast for the vocoder realization.

Simulation studies of LPC vocoders continues. A study of the coding of the roots of the predictor polynomial aimed at 4800 bps LPC is now being programmed. Some preliminary work in coding vowel segment formants with linear approximations appears very promising for high-compression or variable-rate coding. An alternate iterative solution technique for predictor coefficients is under study for possible use in variable-rate coding.

Finally, a more elaborate time domain pitch extractor has been coded and runs in simulation on the FDP. This extractor was implemented and used in several Lincoln Laboratory vocoders. Under careful examination it yields a very accurate pitch track with low incidence of doubling or halving pitch period but suffers from small delays and anticipations in producing voiced-unvoiced boundaries. These errors seem to be magnified when such a pitch track is used to synthesize LPC speech. As a result we are studying improvements in Buzz-Hiss boundary detection in the present extractor. A hardware design study is under way to reduce this extractor to an MOS realization. Since the original implementation was designed as a serial device running at a one-microsecond clock, MOS implementation makes sense for a lower power, cheaper, smaller realization. Some of the subunits of the extractor have been tested in MOS logic and function as required.

In order to accommodate increasing user demand for on-line storage, three direct-access storage devices were installed during this quarter. The total capacity of the system for this kind of secondary storage is now 800 million bytes. Also in response to user requirements the capacity of the communications controller was increased by providing eight more lines and additional facilities for medium-speed display devices.

The capability of recovering from permanent errors on the system paging drum has been added to the time sharing system, CP/67. This function insures continued operation even though there is an I/O error on the backing store device. Instead of the whole system becoming inoperative, only the user whose virtual storage resides on the bad drum record is affected. This technique will provide much greater reliability to time-sharing operations.

In preparation for an "exclusive use" secure mode of time-sharing operation, a special version of CP/67 has been generated. While it is functionally similar to the standard version a number of restrictions and limitations have been included. Several changes in the physical arrangement of the computer room and in operating procedures have also been completed for the purposes of security. Current users of the secure-batch system, which is a special restricted version of IBM's Operating System/360, are being assisted in converting to the secure time-sharing system. On completion of this activity all requirements for classified data processing are expected to be handled by the special version CP/67. As an accommodation for current users of secure OS/360 who encounter conversion problems, work is in progress to improve the efficiency of operating OS/360 on a virtual machine provided by the secure version of CP/67.

The Laboratory has entered into an arrangement with a computer center operating an IBM 370/165, to provide computing services in the event of major damage to Lincoln's installed IBM 360/67 or to handle short-term overloads. Since the use of such services would be only temporary and would come with little advance notice a high degree of program compatibility is necessary. This can best be provided by preparing the Laboratory's own version of OS/360 for use at the backup facility.

To generate this system a special system of OS and HASP was required along with minor modification to the catalogued procedures, organization of data sets on system disk packs, the system accounting routine, HASP, and system initialization routines. The backup system consists of the same release of HASP and OS used at the Laboratory with additional IBM fixes. The major difference between the two is in the support of the operator console. In the Lincoln system the operator console is under the control of OS (HASP cannot support the console for the 370/165). Preparation of the backup system is nearly complete and testing should begin soon.

AIR TRAFFIC CONTROL
DIVISION 4

INTRODUCTION

The Air Traffic Control Division at Lincoln Laboratory is engaged in studies and development programs for the Federal Aviation Administration and the Transportation Systems Center of the Department of Transportation. These activities are described in other reports. In addition, three small tasks being conducted for the Air Force are reported herein: (1) studies of microwave landing systems in support of the NATO Industrial Advisory Group (NIAG), (2) the construction of a computer-driven airborne display for the SEEK BUS program, and (3) studies of the TPN-19 system for the Terminal Control Program Office at ESD.

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AIR TRAFFIC CONTROL
DIVISION 4

The following three tasks are being carried out with Air Force Support.

I. APPROACH AND LANDING SYSTEMS

Effort in support of Lincoln Laboratory's participation as a U.S. technical representative to the NATO Industrial Advisory Group (NIAG) Subgroup 1 (SG-1) ended with the forwarding of five SG-1 recommendations to the Conference of National Armaments Directors (CNAD) and the NATO Air Force Armaments Group (NAFAG) in August 1973. Subgroup 1 had been instructed to advise on a NATO requirement for an approach and landing system for the post-1975 period.

It had been originally hoped that, on the basis of paper studies [including coherent interference (multipath) simulations], SG-1 could identify a single "best" concept to meet the NATO requirement from the 16 systems proposed by various firms. However, SG-1 did not settle on a single concept and has recommended to CNAD a follow-on evaluation program consisting of flight tests between the more promising concepts together with studies to refine the user requirements.

Initially, it had been thought in the U.S. aeronautical community that the "air-derived" systems under active development in the U.S. MLS program would emerge as the most promising candidates. However, it became evident during the assessment period that advances in signal-processing technology, especially for digital signals, had made practical a group of "ground-derived" systems which perform direction finding (e.g., by interferometric techniques) on a signal emitted by the aircraft and then transmit its coordinates to the aircraft via a digital data link. On the basis of the current operational requirement and the data available, SG-1 was not able to express a preference for either ground- or air-derived concepts.

II. AIRBORNE GRAPHICAL DISPLAY

The airborne graphical display equipment, the flyable mini-computer, and all the control boxes were interfaced in the Laboratory with the SEEK BUS terminal. Software and hardware debugging was accomplished and the pilot's control box and the display were shipped to RADC for installation in the C-131 aircraft which is equipped with a SEEK BUS terminal.

A large monitor display and interface hardware will be shipped early in the next quarter for installation in the aircraft. This hardware includes the airborne mini-computer, power distribution equipment, etc. This equipment will be located in the passengers' compartment of the C-131 and the large display will provide a repeat of what is displayed to the pilot.

Flight tests are expected to begin in September.

III. TPN-19 (GCA) Studies

The study of possible improvements to the Precision Approach Radar (PAR) was continued until the end of the fiscal year. The principal proposed improvement was the addition of a Doppler filter bank in each range gate. With the threshold adaptively adjusted in each Doppler filter, a great advantage will be gained in the rejection of rain clutter. A similar approach has been implemented on an S-band Airport Surveillance Radar and is under test here at Lincoln Laboratory.

To improve TPN-19 radar performance in weather necessitates the collection of data from more pulses than in the present design. Studies were made of the best radar tradeoffs to achieve this objective. A report is in progress covering study work during the period of the contract.

SOLID STATE
DIVISION 8

INTRODUCTION

This section of the report summarizes progress during the period 1 May through 31 July 1973 on Solid State Research projects funded primarily by the Air Force. The Solid State Research Report for the same period describes this work of Division 8 in more detail.

A. L. McWhorter
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P. E. Tannenwald
Associate Head

DIVISION 8 REPORTS
ON ADVANCED ELECTRONIC TECHNOLOGY

15 May through 15 August 1973

PUBLISHED REPORTS

Journal Articles*

JA No.			
4029	High-Pressure Technology and Magnetism	J. B. Goodenough	Opportunities in High-Pressure Technology – A Report of the National Materials Advisory Board (Publication NMAB 303, January 1973), p. 175
4057	Exploring the $A^{+}B^{5+}O_3$ Compounds	J. B. Goodenough J. A. Kafalas	J. Solid State Chem. 6, 493 (1973)
4061	Inhomogeneous Line Broadening in Donor Magneto-Optical Spectra	D. M. Larsen	Phys. Rev. B 8, 535 (1973)
4086	Role of Bulk and Surface Plasmons in the Emission of Slow Secondary Electrons: Polycrystalline Aluminum	V. E. Henrich	Phys. Rev. B 7, 3512 (1973)
4089	Exciton Levels in a Magnetic Field	N. Lee† D. M. Larsen B. Lax†	J. Phys. Chem. Solids 34, 1059 (1973)
4094	Theory of the Spontaneous Spin-Flip Raman Line Shape in InSb	R. W. Davies	Phys. Rev. B 7, 3731 (1973)
4113	Stress-Induced Spin Flop in Cr_2O_3	J. W. Allen	Phys. Rev. B 7, 4915 (1973)
4119	Electron Radiation Damage and Annealing of $Hg_{1-x}Cd_xTe$ at Low Temperatures	J. Melngailis J. L. Ryan T. C. Harman	J. Appl. Phys. 44, 2647 (1973)
4122	Line Shape of the Doppler-Limited Infrared Magnetic Rotation Spectrum of Nitric Oxide	F. A. Blum K. W. Nill A. J. Strauss	J. Chem. Phys. 58, 4968 (1973)
4124	Near-Resonance Spontaneous-Spin-Flip Light Scattering in InSb	S. R. J. Brueck A. Mooradian F. A. Blum	Phys. Rev. B 7, 5253 (1973)

* Reprints available.

† Author not at Lincoln Laboratory.

JA No.

4134	Discussion of "Chemical Vapor Deposited Polycrystalline Silicon"	C. M. Wolfe G. E. Stillman J. A. Rossi	J. Electrochem. Soc. 120, 848 (1973)
4142	Effects of Mirror Reflectivity in a Distributed-Feedback Laser	S. R. Chinn	IEEE J. Quantum Electron. QE-9, 574 (1973)
4143	High-Power Output in $Pb_{1-x}Sn_xTe$ Diode Lasers with Improved Mirror Quality	J. N. Walpole A. R. Calawa R. W. Ralston T. C. Harman	J. Appl. Phys. 44, 2905 (1973)
4148	Backward Stimulated Light Scattering and the Limiting Diameters of Self-Focused Light Beams	P. L. Kelley T. K. Gustafson*	Phys. Rev. A 8, 315 (1973)
4151	Pressure-Tuned GaAs Diode-Laser Absorption Spectroscopy of Xenon Hyperfine Structure	A. S. Pine C. J. Glassbrenner J. A. Kafalas	IEEE J. Quantum Electron. QE-9, 800 (1973)
4157	Tunable Laser Measurements of Water Vapor Transitions in the Vicinity of 5 μm	R. S. Eng P. L. Kelley A. Mooradian A. R. Calawa T. C. Harman	Chem. Phys. Letters 19, 524 (1973)
4168	Infrared Reflectivity of Paratellurite, TeO_2	D. M. Korn A. S. Pine G. Dresselhaus T. B. Reed	Phys. Rev. B 8, 768 (1973)
4175	High-Efficiency Secondary-Electron Emission from Sputtered MgO-Au Cermets	V. E. Henrich J. C. C. Fan	Appl. Phys. Letters 23, 7 (1973)
4181	Tunable cw $Pb_{0.98}Cd_{0.02}S$ Diode Lasers Emitting at 3.5 μm: Applications to Ultrahigh-Resolution Spectroscopy	K. W. Nill A. J. Strauss F. A. Blum	Appl. Phys. Letters 22, 677 (1973)
4182	High-Power, Narrow-Linewidth Operation of GaAs Diode Lasers	J. A. Rossi S. R. Chinn H. Heckscher	Appl. Phys. Letters 23, 25 (1973)

Meeting Speeches

MS No.

3350	Small Bandgap Lasers and Their Uses in Spectroscopy	A. R. Calawa	J. Luminescence 7, 477 (1973)
3351	Small Bandgap Semiconductor Infrared Detectors	I. Melngailis	J. Luminescence 7, 501 (1973)

* Author not at Lincoln Laboratory.

MS No.			
3373	The Structure of La_2CuO_4 and $LaSrVO_4$	J. M. Longo P. M. Raccah	J. Solid State Chem. 6, 526 (1973)
3391	Narrow-Gap Semiconductor Lasers and Detectors	I. Melngailis	Proc. 4th Conf. on Solid State Devices, Tokyo, 1972 (The Japan Society of Applied Physics, Tokyo, 1973) [J. Jap. Soc. Appl. Phys. 42, supplement, 1973], p. 3
3454	Structural Studies in the System $KF-YF_3$	J. W. Pierce H. Y-P. Hong	Proceedings of the Tenth Rare Earth Research Conference, Vol. 1, C. J. Kevane and T. Moeller, Eds. (United States Atomic Energy Commission CONF-730402-P1, 1973), p. 527

* * * * *

UNPUBLISHED REPORTS

Journal Articles

JA No.			
4149A	Simple Modification to Commercial Michelson Transform Spectrometer for Increased Resolution	D. M. Korn	Accepted by Rev. Sci. Instr.
4152	The Stress Dependence and the Latent Heat of the Morin Transition in Fe_2O_3	J. W. Allen	Accepted by Phys. Rev. B
4153	Electronic Structure of Transition Metals. I: Phonon Spectra	A. O. E. Animalu	Accepted by Phys. Rev. B
4158	Electronic Structure of Transition Metals. II: Quantum Defects, Old and New	A. O. E. Animalu	Accepted by Phys. Rev. B
4184	Stark Effect on Donor Transitions in High Purity GaAs	D. M. Korn D. M. Larsen	Accepted by Solid State Commun.
4189	EuO. I. Resistivity and Hall Effects in Fields up to 150 kOe	Y. Shapira* S. Foner* T. B. Reed	Accepted by Phys. Rev. B
4190	EuO. II. Dependence of the Insulator-Metal Transition on Magnetic Order	Y. Shapira* S. Foner* R. L. Aggarwal* T. B. Reed	Accepted by Phys. Rev. B

* Author not at Lincoln Laboratory.

JA No.			
4194	Spontaneous Spin-Flip Raman Linewidth and Nonlinear Processes in InSb	S. R. J. Brueck A. Mooradian	Accepted by Opt. Commun.
4197	The Josephson Current in Tunneling Between Coupled Superconductors	A. O. E. Animalu	Accepted by Phys. Rev. B
4208	Observation of Strong Nonlinearities in the High Field Zeeman Spectrum of NO at 1876 cm^{-1}	H. J. Zeiger F. A. Blum K. W. Nill	Accepted by J. Chem. Phys.
4209	Crystal Chemistry in the System $MSbO_3$	H. Y-P. Hong J. A. Kafalas J. B. Goodenough	Accepted by J. Solid State Chem.
4216	Threshold, Spectral and Output Power Characteristics of $GaAs/Ga_{1-x}Al_xAs$ Single Heterostructure Diode Lasers	J. A. Rossi H. Heckscher S. R. Chinn	Accepted by Appl. Phys. Letters
4217	Time Delays and Q-Switching Effects in $GaAs/Ga_xAl_{1-x}As$ Single Heterostructure Diode Lasers	J. A. Rossi H. Heckscher G. E. Stillman S. R. Chinn	Accepted by Appl. Phys. Letters
4225	Experimental and Theoretical Charge Density in Aluminum	R. J. Temkin* V. E. Henrich P. M. Raccah*	Accepted by Solid State Commun.
4240	Effect of Pb- and Te-Saturation on Carrier Concentrations in Impurity-Doped PbTe	A. J. Strauss	Accepted by J. Electron. Mater.
4254	Applications of Phase Transitions in Materials Science	J. B. Goodenough	Accepted by Mater. Res. Bull.

Meeting Speeches†

MS No.			
3175A	The Electronic Properties of Oxides	J. B. Goodenough	Conference on Peculiar Properties of Oxides, Argonne National Laboratories, Argonne, Illinois, 18-19 May 1973
3337G, I	Tunable Semiconductor Lasers and Their Applications	A. Mooradian	Physics Colloquium, Pennsylvania State University, Phillipsburg, 29 May 1973; Lasers and Optics for Applications, Summer Course, M.I.T., 31 July 1973

* Author not at Lincoln Laboratory.

† Titles of Meeting Speeches are listed for information only. No copies are available for distribution.

MS No.			
3337H	Tunable Semiconductor Lasers and Their Applications	A. Mooradian	Laser Spectroscopy Conference, Vail, Colorado, 25-29 June 1973
3428C	High Resolution Infrared Spectroscopy Using Tunable Semiconductor Lasers	F. A. Blum K. W. Nill	
3615	Advances in Tunable Lead-Salt Semiconductor Lasers	I. Melngailis	
3474B	Free Energy Model of High Temperature Metal-Insulator Transitions in Ti_2O_3 and V_2O_3	H. J. Zeiger	Conference on Phase Transitions and Their Applications in Materials Science Conference, Pennsylvania State University, 23-25 May 1973
3561	Phase-Transition Mechanisms	J. B. Goodenough	
3515	Advances in Lead Salt Tunable Diode Laser Performance	J. N. Walpole	1973 IEEE/OSA Conference on Laser Engineering and Applications, Washington, D. C., 30 May – 1 June 1973
3592	Efficient Doubling and CW Nonlinear Mixing in the Infrared Using Chalcopyrites	H. Kildal J. C. Mikkelsen S. R. J. Brueck	
3527A	High-Efficiency Secondary-Electron-Emission from Sputtered MgO-Au Cermets	V. E. Henrich J. C. C. Fan	IEEE Device Research Conference, Boulder, Colorado, 26-28 June 1973
3562	External Cavity Operation of GaAs Diode Lasers	J. A. Rossi S. R. Chinn H. Heckscher G. E. Stillman	
3583	High CW Output-Power in Stripe-Geometry PbS Diode Lasers	R. W. Ralston J. N. Walpole A. R. Calawa T. C. Harman J. P. McVittie	
3584	High Speed HgCdTe Photodiodes at 10.6 μm	D. L. Spears I. Melngailis C. Freed T. C. Harman	
3585	High-Speed, High-Gain 1.06 μm Avalanche Photodiodes	G. E. Stillman C. M. Wolfe A. G. Foyt W. T. Lindley	
3589	Single Heterojunction $Pb_{1-x}Sn_xTe$ Diode Lasers	J. N. Walpole A. R. Calawa R. W. Ralston T. C. Harman J. P. McVittie	
3607	Electron and Hole Impact Ionization Rates in GaAs	G. E. Stillman C. M. Wolfe J. A. Rossi A. G. Foyt	

MS No.			
3532	Apparent Mobility Enchancement in Semiconductors with Metallic Inclusions	C. M. Wolfe G. E. Stillman	Electrochemical Society Meeting, Chicago, 13-18 May 1973
3536	Tunable Laser Measurements of Water Vapor Transitions in the Vicinity of 5 μm	R. S. Eng P. L. Kelley A. Mooradian A. R. Calawa T. C. Harman	28th Annual Symposium on Molecular Structure and Spectroscopy, Ohio State University, Columbus, 11-15 June 1973
3554A, B,C	Pulsed Lead-Salt Diode Lasers for Atmospheric Absorption Spectroscopy	E. J. Johnson	Seminar, Los Alamos Scientific Laboratory, 18 June 1973; Seminar, Phillips Research Laboratory, Briar Manor, New York, 26 June 1973; Seminar, 3M Corporation, St. Paul, Minnesota, 14 August 1973
3575	The Use of Tunable Lasers in Infrared Atmospheric Spectroscopy	P. L. Kelley	5th Conference on Laser Radar Studies of the Atmosphere, Williamsburg, Virginia, 4-6 June 1973
3591	Photo- and Electroluminescence and Lasers of GaAs and Related Materials	J. A. Rossi	Seminar, General Motors Research, Warren, Michigan, 15 June 1973
3598	What the Future Holds for Ambient Air and Stack Testing	P. L. Kelley	38th Midyear Meeting of Division of Refining (American Petroleum Institute), Philadelphia, 15 May 1973
3640	Growth Problems and Methods for Growth of Rare-Earth Chalcogenides	T. B. Reed	Gordon Research Conference on Crystal Growth, Tilton School, Tilton, New Hampshire, 2-6 July 1973
3656	Radiation Insulation for Energy Conservation and Generation	T. B. Reed	Gordon Research Conference on Solid State Studies in Ceramics, Kimball Union Academy, Meriden, New Hampshire, 6-10 August 1973

I. SOLID STATE DEVICE RESEARCH

The simultaneous operation of a $Hg_{1-x}Cd_xTe$ photodiode as an optical heterodyne receiver and a varactor microwave harmonic mixer has made possible the detection of CO_2 laser beats to beyond 60 GHz. A microwave local oscillator pump was fed into the photodiode which mixed with the high-frequency optical beat signal, generating a strong difference-frequency signal. Although the photodiode was designed for a 1-GHz heterodyne receiver at 10.6 μm, its simultaneous use as a microwave mixer greatly improves its performance well above the roll-off frequency.

Single heterojunction diode lasers have been fabricated by vacuum deposition of an n-type PbTe film onto a p-type $Pb_{0.88}Sn_{0.12}Te$ substrate. The devices obtained show significantly lower threshold current densities and CW operation at higher temperatures than homojunction devices in this material. Optical coatings have been applied to the cavity end faces of high-power PbS stripe-geometry diode lasers in order to increase the single-ended output power and measurements have been made of emission spectra, field patterns, and efficiencies.

Uniform Schottky-barrier avalanche photodiodes with gains greater than 250, rise times less than 200 psec, and quantum efficiencies over 40 percent at 1.06 μm have been fabricated in $In_xGa_{1-x}As$ alloys. The material used for these devices was grown epitaxially on GaAs substrates using an $AsCl_3$-H_2Ga-In vapor-phase system which permitted grading the epitaxial layers from GaAs to the desired composition.

II. QUANTUM ELECTRONICS

Studies have been carried out of the wavelength dependence of GaAs laser threshold injection current as well as the wavelength dependence of power output versus current level. A grating-tuned external cavity was used to select the operating wavelength. A sharp increase in threshold current was found as the output photon energy was decreased below the band gap. An initially gradual rise was found as the output photon energy was increased above the gap with the slope of this rise increasing as the output photon energy increased.

The CW InSb spin-flip Raman laser has been operated in a gradient-field permanent magnet. For CO laser pumping near the band gap, up to five Stokes and two anti-Stokes components were observed. Tuning was achieved by moving the magnet along the field gradient. With the magnet alone a first-Stokes tuning range of 1.3 cm^{-1} was obtained; external coils increased the tuning range to 1.9 cm^{-1} and could be used for accurate fine tuning. Doppler-limited spectra of NO were taken by driving current in the coils as well as by moving the sample in the field gradient.

This spin-flip laser system has been stabilized by driving the magnet coils with a reference signal obtained by heterodyning the spin-flip output against a stable CW CO laser. Stabilities of better than 100 kHz were obtained for 1 second. This is in the stability range required for nonlinear spectroscopy.

Work has continued on evaluating and using chalcopyrite nonlinear optical materials. Fifteen-percent conversion efficiency was obtained in $CdGeAs_2$ for doubling CO_2 radiation. Difference-frequency outputs between 11.4 and 16.8 μm were obtained on a CW basis using the outputs from grating-tuned CO and CO_2 lasers. The absolute value of the nonlinear susceptibility of $AgGaSe_2$ was also measured.

Absolute measurements of CO laser lines have been made with an accuracy of about 5 MHz. These measurements were made by mixing in a high-speed HgCdTe photodiode CW radiation from a stable CO laser with doubled radiation from a stable CW CO_2 laser. Detector output signals of up to 11 GHz have been measured by heterodyning this output with an external microwave oscillator. The measurements give values of CO frequencies which average several tens of megahertz below the previous values.

A hot-band ($2\nu_2 \leftarrow \nu_2$) water vapor transition has been measured relative to a CO laser transition with an accuracy of 30 MHz. A PbSSe diode laser was tuned to the peak of this absorption line and then heterodyned in a fast HgCdTe detector with the P(17) line of the 7-6 band of a CO laser. Using recently obtained values of CO laser frequencies, a value of the water vapor line frequency was found which compares reasonably well with the value inferred from measurements of other transitions.

Low-chirp PbSSe diode lasers operating at 77 K have been pressure tuned to obtain nearly Doppler-limited spectra of both CO at 4.8 μm and NO at 5.3 μm. The technique is capable of covering even more extensive wavelength ranges. Using a pressure-tuned diode operating in a single mode near threshold, spectra were obtained without the necessity of a spectrometer for filtering out extraneous modes.

III. MATERIALS RESEARCH

In order to determine the effects of changes in the Pb/Te ratio on the carrier type and concentration in impurity-doped PbTe, Hall coefficient measurements have been made on as-grown, Pb-saturated, and Te-saturated samples doped with one of 7 impurities: Cu, Ag, In, Tl, As, Sb, and Bi. Both Ag and As are definitely amphoteric impurities in PbTe, while less conclusive evidence of amphoteric behavior is obtained for Cu and Sb.

A new ternary compound, Ag_9GaSe_6, has been prepared by fusion of the elements in stoichiometric proportions. X-ray diffraction data indicate that the new compound is not the second phase that currently limits the optical quality of $AgGaSe_2$ crystals grown for nonlinear applications.

The crystal structure of neodymium ultraphosphate, NdP_5O_{14}, has been determined by analysis of single-crystal x-ray diffraction data. This structure, in which the Nd atoms are isolated from each other by PO_4 tetrahedra, appears to account for the small Nd-Nd pair interactions revealed by fluorescence decay measurements.

The efficiency of green emission from $NaYF_4$:Yb,Er and YF_4:Yb,Er upconverting phosphors excited by a GaAs:Si light-emitting diode has been measured as a function of diode current. The overall power efficiency for the phosphor-diode combinations varies from $\sim 5 \times 10^{-5}$ to $\sim 1 \times 10^{-4}$ as the diode current is increased from 100 to 500 mA.

IV. PHYSICS OF SOLIDS

Lifetimes of the neodymium $^4F_{3/2}$ states in the metaphosphate series $Nd_xLa_{1-x}P_3O_9$ and the ultraphosphate series $Nd_xLa_{1-x}P_5O_{14}$ have been measured. Because these materials can be doped with Nd out to $x = 1$ without complete quenching of the luminescence, they are of potential interest as optically pumped laser materials.

In connection with the metal-insulator transition program, an experimental investigation is being carried out on the temperature dependence of the sound velocity in V_2O_3. So far, a room-temperature longitudinal velocity of 7.85×10^5 cm/sec, which is within 10 percent of that in Ti_2O_3, has been measured.

Calculation of the phonon spectra of transition metals continues. In the case of vanadium, excellent agreement between theory and experiments is obtained with V^{5+}, but as the chemical valence is decreased this agreement is lost.

An experimental study of optically pumped molecular systems lasing CW in the submillimeter region has shown that the limitations caused by a need for close resonance of pump and molecular absorption frequencies can be largely overcome through Stark-tuning of the absorption. Specifically, CW submillimeter lasing has been observed in NH_3 by Stark-shifting three absorption lines of NH_3 into resonance with CO_2 laser lines.

V. MICROELECTRONICS

Two silicon EBS diodes have been successfully mounted into two high-frequency metal-ceramic gridded triode tubes. These tubes are currently being evaluated for vacuum integrity and electrical performance. Because of some problems encountered in earlier tubes of shortened tube life due to low-temperature bakeout, the upper temperature limits to which the current EBS devices may be processed are now being investigated.

An experimental and theoretical study was carried out to evaluate the possible use of silicon Schottky-barrier diodes as EBS targets. The results of the study indicated that a metal-semiconductor barrier height of 0.73 eV was necessary to prevent thermal runaway in the present application.

The fabrication of the silicon membranes which are used as mask substrates in the x-ray lithographic process is presented in detail.

The capabilities of the mask-making laboratory have continued to be expanded and refined. A particular recent refinement is a program for easily digitizing the layout of a meandering line.

The MANNPLOT mask layout program can now send displays to any scope attached to the 360 computer, a capability which greatly improves the pattern generation procedure.