Quarterly Technical Summary

Advanced Electronic Technology

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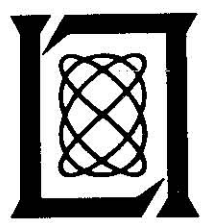

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INTRODUCTION

This Quarterly Technical Summary covers the period 1 November 1972 through 31 January 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
Joseph J. Whelan, USAF
Acting Chief, Lincoln Laboratory Liaison Office

CONTENTS

DATA SYSTEMS
DIVISION 2

INTRODUCTION

This section of the report reviews progress during the period 1 November 1972 through 31 January 1973 on Data Systems projects funded by the Air Force. We begin reporting here the new program in Speech Processors. Separate reports on Speech Understanding, Seismic Discrimination, Educational Technology, Radar Measurements, and FAA Interactive Graphics describe the work of Division 2 on these programs.

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I. INTRODUCTION

Fabrication of a high-speed 2-bit gated adder, which included the processing techniques of buried As collectors, epitaxy and two-level metalization, was accomplished during this quarter. Progress continued on all projects previously reported,* and new tasks were begun in packaging, three-level metal, TTL-circuit processing, and upgrading of the tester. Table I shows the status of various circuits in design, fabrication, or test.

TABLE I
STATUS OF LARGE-SCALE INTEGRATED DIGITAL CIRCUITS

Circuit	Status
3-input gate	Working circuits
16-transistor geometries	Measurements and comparative evaluation
Two-level metal	Part of standard process
Three-level metal	Initial experiments
ECL gate chain	In process
2-bit adder	Working circuits at design speeds
A/D converter	Mask design (new design with full decoding)
C-circuit Bit pipeline	Mask design
Basic arbiter	Experimental and theoretical evaluation
IC-tunnel-diode arbiter	Mask design
Submicron devices	Alignment technique developed – device fabrication
TTL gate chain	Circuit design

II. INTEGRATED CIRCUIT PROCESSING

A. Integrated Circuit Fabrication

Three runs each of 2-bit adder and 16-transistor array wafers have been processed. The 2-bit adder was fabricated with our own buried As collectors and epitaxial films.

Propagation delays of packaged adder circuits were in the range of 2.5 to 3.5 nsec. Current efforts are directed at process improvements to yield faster devices.

B. Metalization

A double-layer aluminum metalization process has been established which uses a 350°C substrate temperature during the two-level metal evaporation to produce a via resistance of less than 0.1 ohm.

In certain circuits, molybdenum metalization would be advantageous due to the absence of electromigration, negligible penetration into silicon, and the hillock-free surfaces which enable

*Advanced Electronic Technology Quarterly Technical Summary, Lincoln Laboratory, M.I.T. (15 November 1972), DDC AD-754945.

finer line widths and smaller via windows on the second-layer metal. The sheet resistivity of molybdenum is about three times higher than aluminum. Initial work on two-level molybdenum has been encouraging with via resistances of approximately 0.3 ohm.

C. Electron-Beam Pattern Definition

Three wafers containing a total of approximately 100 transistors with emitters defined by electron-beam illumination of an electron resist in a Scanning Electron Microscope are in the final stages of processing. The emitter-oxide-cut widths of these transistors range from 0.5 to 3.0 μm. Good progress has been made on a method of nondestructively detecting and aligning on silicon wafer bench marks in the SEM for the purpose of maintaining accurate registration for multi-level exposures with the electron beam.

III. PHOTOLITHOGRAPHIC INTERCONNECTION OF PLASTIC-EMBEDDED SEMICONDUCTOR CHIPS

A. Memory Arrays

Construction has begun on 8-chip abbreviated memory arrays, precursors to a 20-chip memory array which is the test vehicle for this chip interconnection procedure. Quantities of commercial memory, latch, and decoder chips have had aluminum pads metalized with nickel in preparation for incorporation into memory arrays.

Twelve Intel 3101A memory chips, individually packaged with photoformed and plated connections, are being cycled and checked with a "checkerboard" storage pattern. Operation has been error-free for 452 hours.

B. Electroless Metal Deposition

A new and simpler procedure for delineating and metalizing array wiring patterns has been developed and tested on single-memory-chip arrays. It is an additive process which produces all-nickel conductors from a neutral pH electroless bath operated at slightly above room temperature. Approximately 0.5-mil thickness of nickel is deposited in 1 hour. This conductor thickness has been determined sufficient for conductivity requirements with present conductor widths.

C. Batch Packaging

Initial design work is complete on a method of packaging 0.100-inch-square dice in standard DIP configurations at a cost low enough to permit testing after packaging, thus eliminating wafer probing and nearly all chip handling. Tape layouts are being made for photoetching of the lead frames, and potting molds are being designed.

IV. TESTING

A. Evaluation of 16-Transistor Test Groups

Two wafers of 16-transistor array chips have been made and partially evaluated. WF222.1 has back-collector contacts and no isolation. WF229.2 has an isolation region and top-collector contacts. A summary of the wafer parameters is given in Table II.

No base-resistance measurements have been made yet, and it is not clear how variations due to alignment problems compare with design variations. However, the following measurements are of interest and provide an indication of our current fabrication capability.

TABLE II

WAFER PARAMETERS

Wafer	WF222.1	WF229.2
Substrate	N+	P–
Epi	0.56 ohm-cm 3.5 μm	0.50 ohm-cm 3.0 μm
Collector	Substrate	Buried
Base inserts	103 ohms/square 1.5 μm	105 ohms/square 1.6 μm
Base	1100 ohms/square 0.71 μm	840 ohms/square 0.61 μm
Emitter	53 ohms/square 0.41 μm	41 ohms/square 0.32 μm
Collector contact	Bottom	Top

The array is made up of devices with various configurations and dimensions. The "standard" transistor has single base, emitter, and collector stripes. The base and emitter stripes are 0.1 × 0.6 mil separated by 0.1 mil. Unless noted, other configurations have the same dimensions. For the "back-collector" wafer, the standard transistor has a peak f_T of 2.6 GHz and a high-current 1.0-GHz f_T at 9 mA. A transistor with two emitter stripes and a center base stripe has a peak f_T of 3.1 GHz, the best we have achieved, and a 1.0-GHz f_T at about twice the current of the standard device. A transistor with a 0.4-mil-wide emitter and two base stripes has a peak f_T of 2.8 GHz and a 1.0-GHz f_T at almost four times the current of the standard device.

At f_T = 1.0 GHz, the "top-collector" transistors have, unexpectedly, about twice the current of the back-collector transistors. For this wafer, the peak f_T of the standard transistor is 2.3 GHz and the greatest improvement is obtained by adding a second collector contact which increases peak f_T to 2.7 GHz and doubles the current at f_T = 1.0 GHz.

B. Test Facility

The computer-controlled wafer test facility is now limiting wafer throughput. The control computer is the TX-2, a large-scale, experimental, time-shared system. Due to dedicated-machine usage and hardware improvement time, the TX-2 is available in the time-shared mode for about 24 hours during the normal work week. It is expected that a considerable increase in throughput can be made by using a dedicated small-scale computer for which hardware and software requirements are being determined.

V. APPLICATIONS AND DESIGN AIDS

A. Metastable States of Decision Circuits

A decision circuit (e.g., a flip-flop) can be excited into a metastable state, which is neither its 1 nor its 0 state, by the nearly simultaneous arrival of two unsynchronized signals. The time required for a bistable element to resolve to a stable state after being triggered into the vicinity of its metastable state has been characterized in terms of the electrical parameters of the circuit transistor. The effect of noise on the resolution time has been analyzed in terms of the probability that the bistable element will fail to decide for a stable state within a given time.

B. IC-Tunnel-Diode Arbiter

The decision circuit, or arbiter, with the shortest resolution time presently is provided by transistors feeding a tunnel-diode bistable circuit. Such a combination produces an order-of-magnitude improvement over high-speed ECL ICs. An integrated module is being designed which will provide a number of standard, high-performance interface circuits on a single chip which can be combined with tunnel diodes to form high-speed decision elements.

C. Double Raster Display System

The C4 computer has been running on a daily basis with the TX-2 APEX time-sharing system. Programming tools which will make possible the implementation of user-level programs for the display system are being developed. A debugging package has been completed, and a fast assembler which provides for macros and supplies full external linking is near completion.

Checkout of the display hardware is well advanced, and the system is expected to become operational during the next quarter.

D. Logic Design Graphics System

The graphics portion of the Lincoln On-Line Logic System (LOLLS) is developmentally operational on CP/CMS through an ARDS terminal. The simulation program has been written and is being debugged.

DIGITAL PROCESSORS
GROUP 24

Lincoln Laboratory's program in speech processors has the ultimate goal of specifying one or more appropriate hardware configurations of speech-compression systems for defense communications applications. Part of our effort is dedicated to the development of compact, cheap, fully digitized channel vocoders with configurations similar to the series of analog vocoders constructed at the Laboratory in the 1960's; these analog vocoders, operating at 2400, 4800 and 9600 bits per second (bps), resulted in good voice quality and reasonable speaker recognizability. The second feature of our effort is devoted to analysis and simulation of a new class of vocoders, introduced by Bishnu Atal of the Bell Telephone Laboratories and presently undergoing extensive study in many laboratories; the most common name for this class is "linear prediction vocoders" (LP vocoders).

For channel vocoders, the most important questions revolve around the hardware implementation. The probability exists that the relatively lenient requirements on the hardware speeds for digital realizations can eventually lead to a very highly integrated and hence small, cheap, and reliable system. Thus, one phase of our effort involves a preliminary hardware design of a channel vocoder with adjustable data rate, using digital Lerner bandpass filter banks as the basic analyzers and synthesizers, a Hademard transform as the coding scheme, and one of two versions of a pitch and buzz-hiss extractor previously developed at Lincoln Laboratory. Along with this, a complete simulation on the FDP (Fast Digital Processor) is being carried out to determine precisely the necessary register lengths for an all-digital construction.

Although much has been accomplished on the LP vocoder during the past few years with promising results, it remains relatively untested as a practical system relative to the channel vocoder. First, there exists no real-time device for conversational testing; second, testing with practical pitch extractors is just beginning; and third, a host of coding and implementation problems remains to be explored. With these facts in mind, our program must include first a sound theoretical understanding of the various proposed procedures as expounded by Atal, Markel, Itakura, etc., and second a reference simulation against which all ideas can be contrasted. To this end, we have programmed on the FDP a simulation using Atal's formulation to extract the coefficients of a 14th-order direct-form difference equation. This program includes a previously developed pitch and buzz-hiss algorithm.

The FDP is capable of real-time simulation of many vocoder systems, including LP vocoders. We believe that a comprehensive computer simulation should include both real- and non-real-time modes; in this way, tests can be made both microscopically and macroscopically (conversationally). One facet of our program will be devoted to the construction of both real- and non-real-time software systems within which different vocoder ideas can be simulated by workers both within and outside of Lincoln Laboratory.

COMPUTER SYSTEMS
GROUP 28

I. TIME-SHARED SERVICE

An IBM 3705 programmable Communications Controller has successfully replaced two IBM 2702 Transmission Control Units during this quarter. In addition to its cost savings, the 3705 provides a greater number and a greater variety of telecommunications access ports. While the work of refining the supporting software continues, effort is being concentrated on providing additional cable connections for the approximately eighty terminals installed throughout the Laboratory.

With an ever-increasing time-sharing load, work continues to improve the CP/CMS dispatching algorithm. The struggle to maintain a consistently low response time for interactive users becomes much more difficult when the system is saturated. To solve this problem, the dispatching algorithm was modified to provide variable or dynamic control of the length of execution pools to increase the system's throughput capability. The system can now take full advantage of the recent increase in real core size, and dynamically commit or decommit core depending on the variations in system load. A much more sensitive control of this vital resource (real core) is now possible. There has been a significant increase in system throughput, and system thrashing has been completely eliminated. Along with this change, a reassignment of the basic time quanta for particular types of time-sharing users has improved system response such that the interactive user requiring modest amounts of the CPU resource is absolutely guaranteed the time.

In order to gain additional efficiency, the paging algorithm has also been modified. It now has the capability of accurately recording the page reference pattern during the last execution interval. This facility is a necessary prerequisite for system pre-paging, post-paging, and automatic core-cleaning of virtual user's pages. The effect will be a significant lowering of system overhead due to paging.

Another means of controlling the I/O resource has been implemented which consists of using the system measurement facility (CPLOG) to monitor the number of I/O requests on each disk module in the system. The problem at hand was the verification of a load balance among the three selector I/O channels. A daily report is prepared listing the actual I/O counts on each disk module. It is now possible to mount the disk packs in an optimum order on the channels and obtain complete load balancing.

II. BATCH SERVICE

A great deal of effort has also been expended in measuring the efficiency of the batch processing system, OS/360. The issue here is the concurrent scheduling of jobs as a function of their main storage requirements. Since installation of the fifth storage box last quarter, CPU activity has risen by more than 10 percent to almost the 90-percent level. This is probably close to the point of diminishing returns. Although it is not correct to say that system efficiency is 90 percent because the CPU is active at that level, it does indicate that the scheduling mechanism properly balances job stream selection to minimize wait time. A modest effort in system tuning will be continued.

AIR TRAFFIC CONTROL
DIVISION 4

INTRODUCTION

The development activities in Air Traffic Control at Lincoln Laboratory for the Federal Aviation Administration and the Transportation Systems Center are described in separate reports. The status of several relatively small tasks being carried out for the Air Force are summarized in this report. These tasks include: studies of microwave landing systems in support of the NATO Industrial Advisory Group (NIAG), the construction and evaluation of a computer-driven airborne display for the SEEK BUS program, and 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

Lincoln Laboratory is participating as the U.S. technical representative to the NATO Industrial Advisory Group (NIAG) Subgroup (SG-1). Subgroup 1 is in the process of assessing several alternative concepts for advanced approach and landing systems for the post-1975 period. Some of these concepts are also being considered in the U.S. MLS program, but others are not.

A critical assessment of the various systems requires a detailed understanding of the effects of coherent (multipath) interference on system performance, and the efficient utilization of the available RF spectrum. These issues are being analyzed for each of the important MLS candidate systems.

II. AIRBORNE GRAPHICAL DISPLAY

The design and construction of experimental airborne graphical display equipment for the SEEK BUS program is continuing. All major subassembly designs have been completed and the units are being assembled. The data processing and control programs are in preparation. The programs will be compiled and tested on a minicomputer identical in operation with the airborne computer planned for editing data and for display formatting.

The graphical display will be installed in an Air Force C-131 aircraft that is currently equipped with a SEEK BUS airborne data link terminal. A computer associated with the display will extract the information from the SEEK BUS data base to provide the pilot with an edited and annotated situation display. The equipment will be available for installation on 30 June 1973.

III. TPN-19 (GCA) STUDIES

Several aspects of the TPN-19 and PAR radars have been investigated (for the ESD Terminal Control Program Office) to assess system performance in rain and clutter. Performance trade-off studies and the design of a digital doppler processor for the PAR have been examined. Work on these tasks is continuing.

SOLID STATE
DIVISION 8

INTRODUCTION

This section of the report summarizes progress during the period 1 November 1972 through 31 January 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.

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DIVISION 8 REPORTS
ON ADVANCED ELECTRONIC TECHNOLOGY

15 November 1972 through 15 February 1973

PUBLISHED REPORTS

Journal Articles*

JA No.			
3735	High-Pressure Synthesis	J. B. Goodenough J. A. Kafalas J. M. Longo	Chapter in Preparative Methods in Solid State Chemistry, P. Hagenmuller, Ed. (Academic Press, New York, 1972), p. 1
3826	Raman Spectroscopy of Solids	A. Mooradian	Chapter E8 in Laser Handbook, edited by F. T. Arecchi and E. O. Schulz-DuBois (North-Holland, Amsterdam, 1972), pp. 1409-1456
4016	Experimental Charge Density of Copper	R. J. Temkin V. E. Henrich P. M. Raccah	Phys. Rev. B6, 3572 (1972), DDC AD-753307
4043	Giant Quantum Oscillations in High-Purity Bismuth: Search for Hole-Fermi-Surface Anomalies	V. E. Henrich	Phys. Rev. B7, 602 (1973)
4048	Efficient Optically Pumped InP and $In_xGa_{1-x}As$ Lasers	J. A. Rossi S. R. Chinn	J. Appl. Phys. 43, 4806 (1972)
4068	Two-Phonon Deformation Potential in InSb	K. L. Ngai† E. J. Johnson	Phys. Rev. Letters 29, 160 (1972)
4081	Electric-Field-Induced Transient Spin-Flip Raman Laser Pulses in InSb	A. Mooradian S. R. J. Brueck E. J. Johnson J. A. Rossi	Appl. Phys. Letters 21, 482 (1972), DDC AD-753311
4083	Submillimeter Lasers Optically Pumped Off Resonance	H. R. Fetterman H. R. Schlossberg† J. Waldman	Opt. Commun. 6, 156 (1972)
4097	High Resolution Photoconductivity Studies of Residual Shallow Donors in Ultrapure Ge	S. D. Seccombe D. M. Korn	Solid State Commun. 11, 1539 (1972)

* Reprints available.

† Author not at Lincoln Laboratory.

JA No.			
4105	Dependence of the Insulator-Metal Transition in EuO on Magnetic Order	Y. Shapira* S. Foner* T. B. Reed H. Birecki* H. E. Stanley*	Physics Letters 41A, 471 (1972)
4107	Procedure for Polishing PbS and $PbS_{1-x}Se_x$	G. A. Ferrante M. C. Lavine T. C. Harman J. P. Donnelly	J. Electrochem. Soc. 120, 310 (1973)
4116	Growth of Crystals of V_2O_3 and $(V_{1-x}Cr_x)_2O_3$ by the Tri-Arc Czochralski Method	J. C. C. Fan T. B. Reed	Mater. Res. Bull. 7, 1403 (1972)

Meeting Speeches

MS No.			
3245	X-Ray Replication of Scanning Electron Microscope Generated Patterns	D. L. Spears H. I. Smith E. Stern	Electron and Ion Beam Science and Technology (Fifth International Conference), R. Bakish, Ed. (The Electrochemical Society, Inc., Princeton, New Jersey, 1972), p. 80
3344	Photothermal Ionization of Shallow Donors in GaAs	G. E. Stillman C. M. Wolfe D. M. Korn	Proceedings of the 11th International Conference on the Physics of Semiconductors, Vol. 2 (Polish Scientific Publishers, Warsaw, 1972), p. 863
3353	Dependence of Growth Temperature on Carrier Gas Velocity in Open Tube Transport	T. B. Reed W. J. LaFleur	J. Crystal Growth 17, 123 (1972)
3410	Bandpass Surface Wave Filters	J. Melngailis J. M. Smith J. H. Cafarella	Proceedings of Ultrasonic Symposium, Boston, 4-7 October 1972
3411	Analysis of Surface Wave Reflection from a Periodic Array of Grooves	R. C. M. Li	
3413	Ion Beam Etching of Reflective Array Filters	H. I. Smith R. C. Williamson W. T. Brogan	
3414	Measurement of the Propagation Characteristics of Surface and Bulk Waves in $LiNbO_3$	R. C. Williamson	

* Author not at Lincoln Laboratory.

UNPUBLISHED REPORTS

Journal Articles

JA No.			
4070	Optical Properties of Graphite	L. G. Johnson G. Dresselhaus	Accepted by Phys. Rev. B
4086	Role of Bulk and Surface Plasmons in the Emission of Slow Secondary Electrons: Polycrystalline Aluminum	V. E. Henrich	Accepted by Phys. Rev. B
4113	Stress-Induced Spin Flop in Cr_2O_3	J. W. Allen	Accepted by Phys. Rev.
4114	Interpretation of Structure and Magnetism in Transition-Metal Pnictides M_2X and $(M_{1-x}M'_x)_2X$	J. B. Goodenough	Accepted by J. Solid State Chem.
4130	Fast, Accurate Secondary-Electron Yield Measurements at Low Primary Energies	V. E. Henrich	Accepted by Rev. Sci. Instr.
4134	Discussion of "Chemical Vapor Deposited Polycrystalline Silicon"	C. M. Wolfe G. E. Stillman J. A. Rossi	Accepted by J. Electrochem. Soc.
4142	Effects of Mirror Reflectivity in a Distributed Feedback Laser	S. R. Chinn	Accepted by IEEE J. Quantum Electron.
4171	Interpretation of the Transport Properties of Ln_2NiO_4 and Ln_2CuO_4 Compounds	J. B. Goodenough	Accepted by Mater. Res. Bull.

Meeting Speeches*

MS No.			
3138C	Tunable Infrared Lasers and Their Applications	P. L. Kelley	IAP Lecture Series on Frontiers of Optics, M.I.T., 8 January 1973
3318D	High Resolution Infrared Spectroscopy with Tunable Semiconductor Lasers	K. W. Nill	Invited Talk, American Physical Society Meeting, New York, New York, 29 January – 1 February 1973
3421	Pressure Variation of the Curie Temperature and Spontaneous Magnetization in Fe_2P and $Fe_2P_{0.9}As_{0.1}$	J. B. Goodenough J. A. Kafalas K. Dwight N. Menyuk A. Catalano†	18th Annual Conference on Magnetism and Magnetic Materials, Denver, Colorado, 28 November – 1 December 1972
3502	Using Tunable Infrared Lasers in Pollution Monitoring	P. L. Kelley	Seminar, Spectroscopy Laboratory Symposium on Current Topics in Spectroscopy, M.I.T., 10 January 1973

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

† Author not at Lincoln Laboratory.

SOLID STATE
DIVISION 8

I. SOLID STATE DEVICE RESEARCH

$Pb_{1-x}Sn_xTe$ diode lasers at 10.6 μm with CW output power over 10 mW, single-longitudinal-mode power up to 6 mW, and incremental external quantum efficiencies up to 0.16 have been obtained using polished rather than cleaved end-mirrors. These results, which were obtained at liquid helium temperature, indicate that one of the major factors limiting the output power and external efficiency of these lasers is the optical quality of the mirrors. Low threshold powers and CW operation at wavelengths in the 10- to 11-μm range have also been observed in as-grown $Pb_{1-x}Sn_xTe$ laser samples optically pumped using a GaAs diode laser source. Laser emission has been observed at 3.4 μm in pulsed operation in $Pb_{1-x}Ge_xS$ diode lasers fabricated by diffusion using vapor-grown crystals.

The amphoteric behavior of Sn has been examined in vapor-epitaxial GaAs for Sn concentration from 5×10^{14} cm^{-3} to 5×10^{17} cm^{-3}. The compensation ratio N_A/N_D is found to remain constant at 0.23 for low concentrations, and to begin increasing in the 10^{16}-cm^{-3} range. This behavior is explained using a nonequilibrium impurity incorporation model which includes the effects of surface states. A quantitative fit to this model is obtained with a surface state density of 3×10^{11} cm^{-2}.

II. QUANTUM ELECTRONICS

Gallium arsenide double heterostructures have been fabricated for optical pumping. The structure consists of GaAs sandwiched between layers of $Ga_{1-x}Al_xAs$, allowing optical confinement of lasing modes to the GaAs region. Power-conversion efficiency of 10 percent has been observed for converting pump light into laser output. The power output and mode quality have been characterized as a function of pump and cavity geometry in both mesa and slab structures.

The theory of distributed feedback lasers has been extended to include the effects of finite reflectivity at the end faces. For zero reflectivity, modes further from the distributed feedback wavelength require higher gain. For finite reflectivity, the selectivity provided by distributed feedback decreases. As the distributed feedback parameter is reduced in the case of finite reflectivity, the modes and mode thresholds become those of the Fabry-Perot cavity.

Spectroscopy of xenon has been carried out with pressure-tuned GaAs lasers operating in the pulsed mode. Since the lasers frequency sweep (chirp) during current pulse, fast detection techniques are used to obtain Doppler-limited resolution. Nuclear hyperfine structure has been observed in $6s \rightarrow 6p$ transitions for Xe^{129} and Xe^{131}, and the levels involved have been identified.

The widths and intensities of 14 water-vapor transitions in the ν_2-band have been measured near 5 μm using tunable PbSSe diode lasers. Present results give additional confirmation to earlier tunable laser observations that the atmospheric widths of high rotational energy water-vapor transitions are considerably narrower than previously predicted. In addition, self-broadening coefficients, nitrogen and air shifts, and relative positions have been measured for several transitions.

III. MATERIALS RESEARCH

Transparent tube furnaces with constant temperature profiles have been constructed using resistance heater elements that supply additional power at the ends to compensate for the heat

losses there. In one furnace operating at 1000°C, the temperature is constant to within 1°C over 75 percent of the heater element length of 22.5 cm, and is constant to within 2°C over 85 percent of this length.

The phase diagram of the $KF-YF_3$ pseudobinary system has been investigated by powder x-ray diffraction studies on samples of various compositions prepared by solid state reaction between KF and YF_3. These studies show that the compound KY_7F_{22} does not exist; the phase previously reported to have this composition is actually YOF, which is obtained because of oxygen contamination.

Single-crystal x-ray diffraction data have been used to perform a crystal structure refinement on KY_3F_{10}. The compound has a cubic structure related to that of CaF_2, with Fm3m as the most probable space group.

IV. PHYSICS OF SOLIDS

Work on the rare-earth phosphors for near-infrared-to-visible upconversion continues. A new sample of the $NaYF_4$:Yb, Er system has been fabricated which exhibits a green upconversion efficiency a factor-of-two greater than our best previous sample. In the $NaYF_4$:Yb, Tm system, which has blue upconverter efficiencies comparable to the best blue phosphor systems reported in the literature, an experimental investigation of the factors involved in the upconversion response time has been initiated. At the same time, a set of differential equations has been formulated which relates the response times to the decay times of the excited levels and the Yb-Tm transfer functions. Another phosphor system being studied is KY_3F_{10}:Yb, Er; for a particular sample, with 20-percent Yb and 2-percent Er, the green light upconversion efficiency was found to be comparable to that of YF_3:Yb, Er, but not as high as that of $NaYF_4$:Yb, Er.

A study has been initiated of infrared (10.6-μm) stimulated, visible (red) luminescence in ZnTe:O. Based on the experimental results, a tentative model has been formulated which differs from that in ZnS principally in that the emitting and metastable states are of the same physical character in ZnS, but are fundamentally different from each other in ZnTe:O.

Investigation of sputtered films of Au-MgO cermet has been extended to a wide range of compositions and substrate temperatures. Emitters with peak yields $\delta > 8$, and crossover voltages as low as 17 V, have been produced.

Research continues on the program to obtain pseudopotentials for the transition metals. The concept of quantum defect has been extended to the transition metals; by setting up a transition-metal model pseudopotential to simulate the information about the atomic potential contained in the quantum defects, a measure of success has been achieved in a first principles calculation of the phonon spectra of ten transition metals.

In the last Solid State Research Report,* we reported the Zeeman effect of NO in the ($v = 0$, $J = 3/2$, M_J) → ($v = 1$, $J = 5/2$, $M_J + 1$) and ($v = 0$, $J = 3/2$, M_J) → ($v = 1$, $J = 3/2$, $M_J + 1$) transitions of the $^2\Pi_{3/2}$ state. A calculation of the spectrum has now been made, including off-diagonal as well as diagonal matrix elements of the Zeeman interaction, and good agreement with the observations has been obtained.

The first tunable laser absorption spectra of CO_2 have been obtained, using a CW tunable PbS semiconductor laser. Besides fundamental ν_3-band lines, a number of isotopic and/or hot lines from the bands with their center near 4.2 μm was observed.

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* Solid State Research, Lincoln Laboratory, M.I.T. (1972:4).

The spectral coverage of CW tunable lead-salt lasers has been significantly extended toward shorter wavelengths with the development of CW $Pb_{0.98}Cd_{0.02}S$ diode lasers operating near 2800 cm^{-1} (3.58 μm). This development should allow high-resolution studies of the hydrocarbon C-H stretch vibrations; preliminary absorption spectra of HCl and H_2CO confirm the narrow linewidth of these new sources.

Work continues on submillimeter lasers achieved by optically pumping molecules somewhat off their vibration-rotation resonances. By going to isotopic mixtures of $^{14}NH_3$ and $^{15}NH_3$, it has been possible to study further the conditions of off-resonant pumping, and to greatly increase the number of far-infrared transitions which lase at high-power levels.

V. MICROELECTRONICS

The program for developing silicon retinas for IR image conversion devices has expanded considerably during this past quarter, and presently requires interesting but rather unusual processing procedures to overcome existing material limitations and inherent packaging problems. The material must have a known low minority concentration (10^{14}P/cc) and a high majority doping concentration (10^{17}B/cc), and such material is neither easily produced nor easily measured for that matter. Furthermore, the possible tradeoffs between device requirements and material parameters is not yet well understood, so it is necessary to fabricate some devices with available but unsatisfactory material for a reference level. The low-temperature operation (4.2°K) of the relatively large area devices ($1\frac{1}{2}$-inch diameter) in more-or-less open packages (for illumination purposes) presents some serious thermal-mechanical design constraints.

The packaging program on the LES IMPATT diodes has received considerable attention recently because of mechanical and electrical instabilities which have occurred in packaging assembly. Some modifications in the processing procedure have been made to reflect recent changes by the designers of the diodes in the expectation of improving the yield. Continuing examination of all aspects of the assembly is under way to uncover any detrimental handling procedures.

The Electron Beam Semiconductor Program, as a result of the success at L-band, is now proceeding with the design and fabrication of high-power S-band devices.

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13. ABSTRACT

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14. KEY WORDS

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