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Quarterly Technical Summary

Advanced Electronic Technology

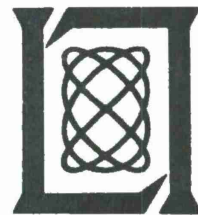
15 November 1975

Prepared for the Department of the Air Force
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Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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ADVANCED ELECTRONIC TECHNOLOGY

QUARTERLY TECHNICAL SUMMARY REPORT
TO THE
AIR FORCE SYSTEMS COMMAND

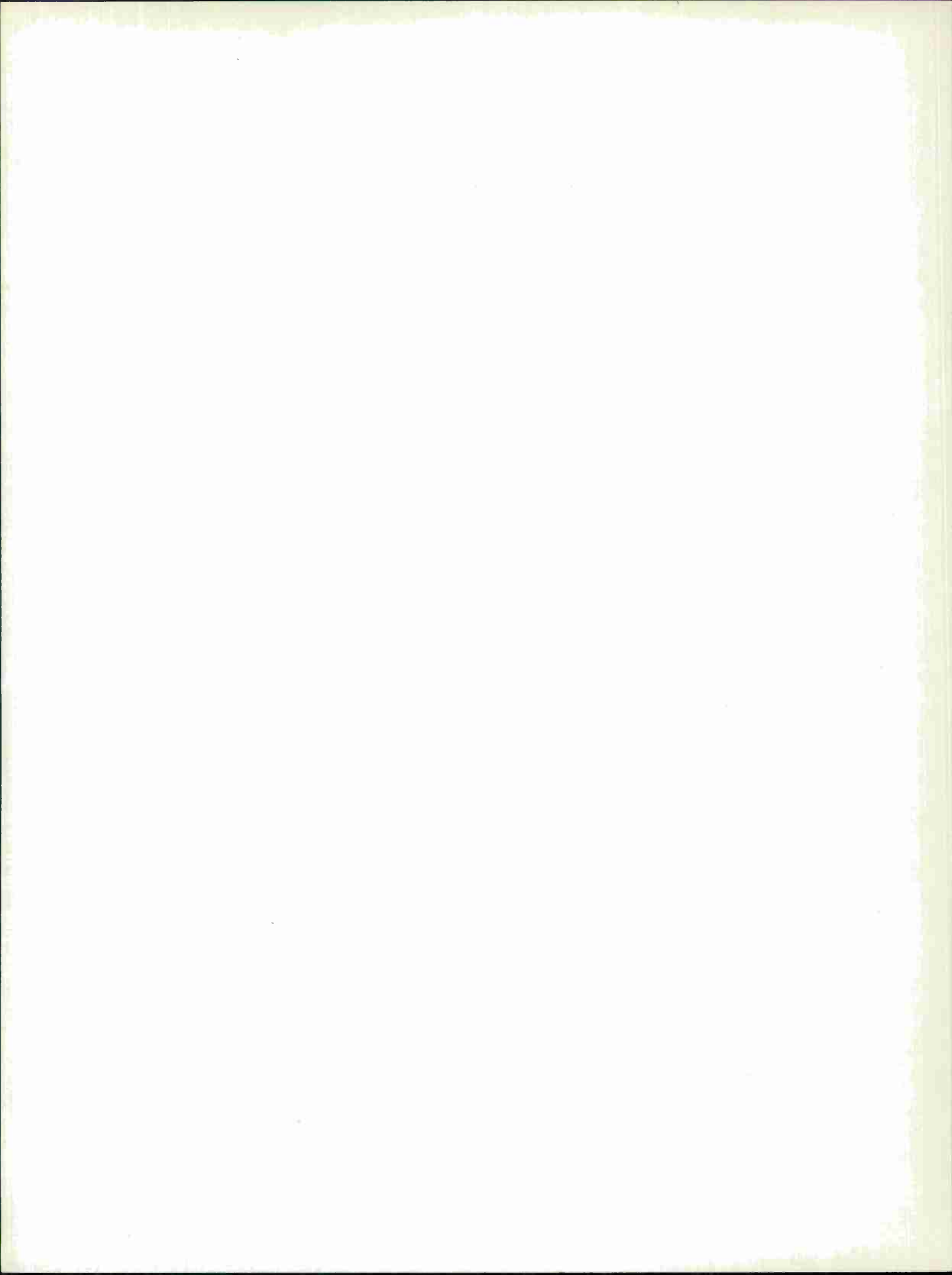
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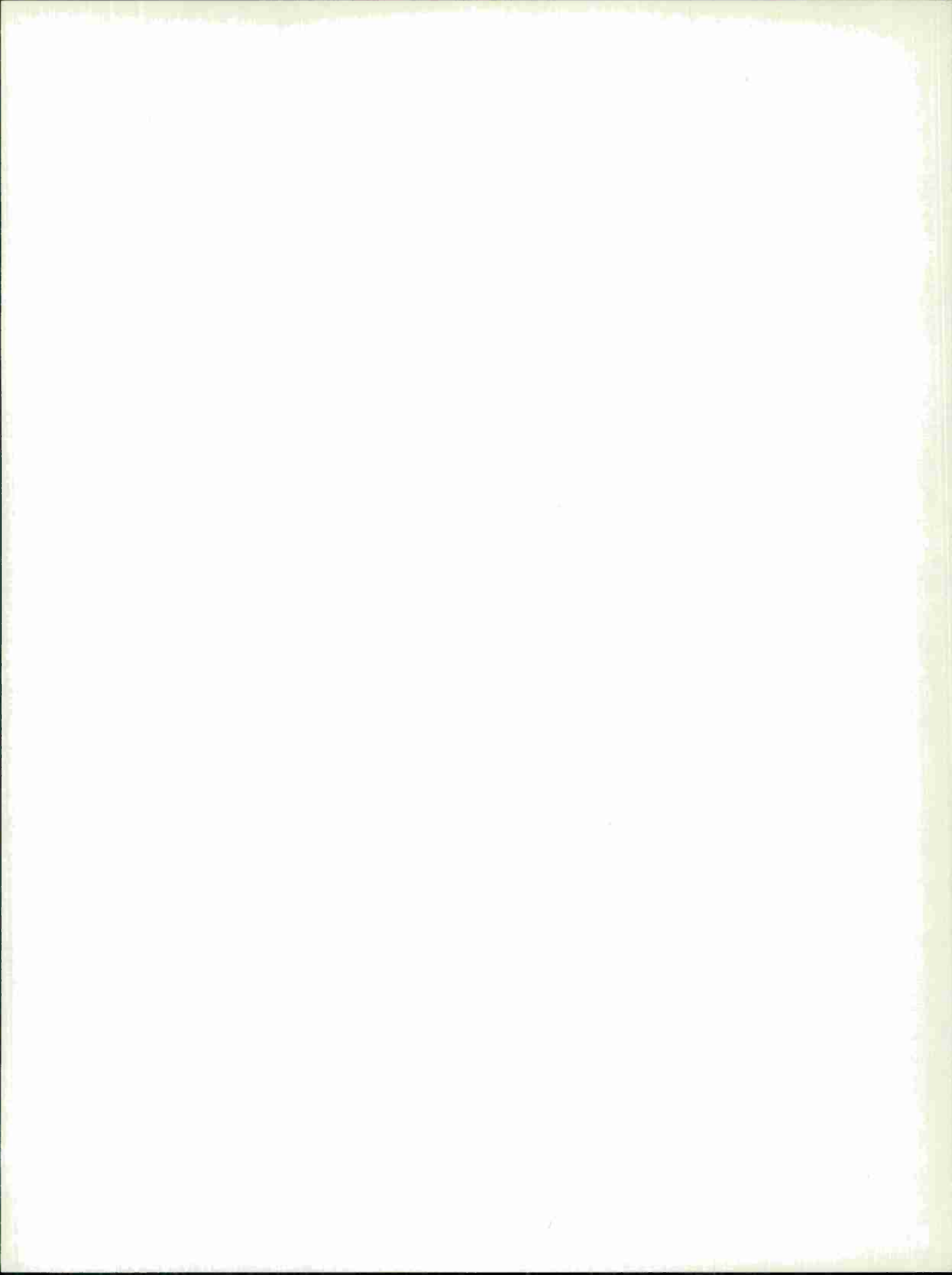
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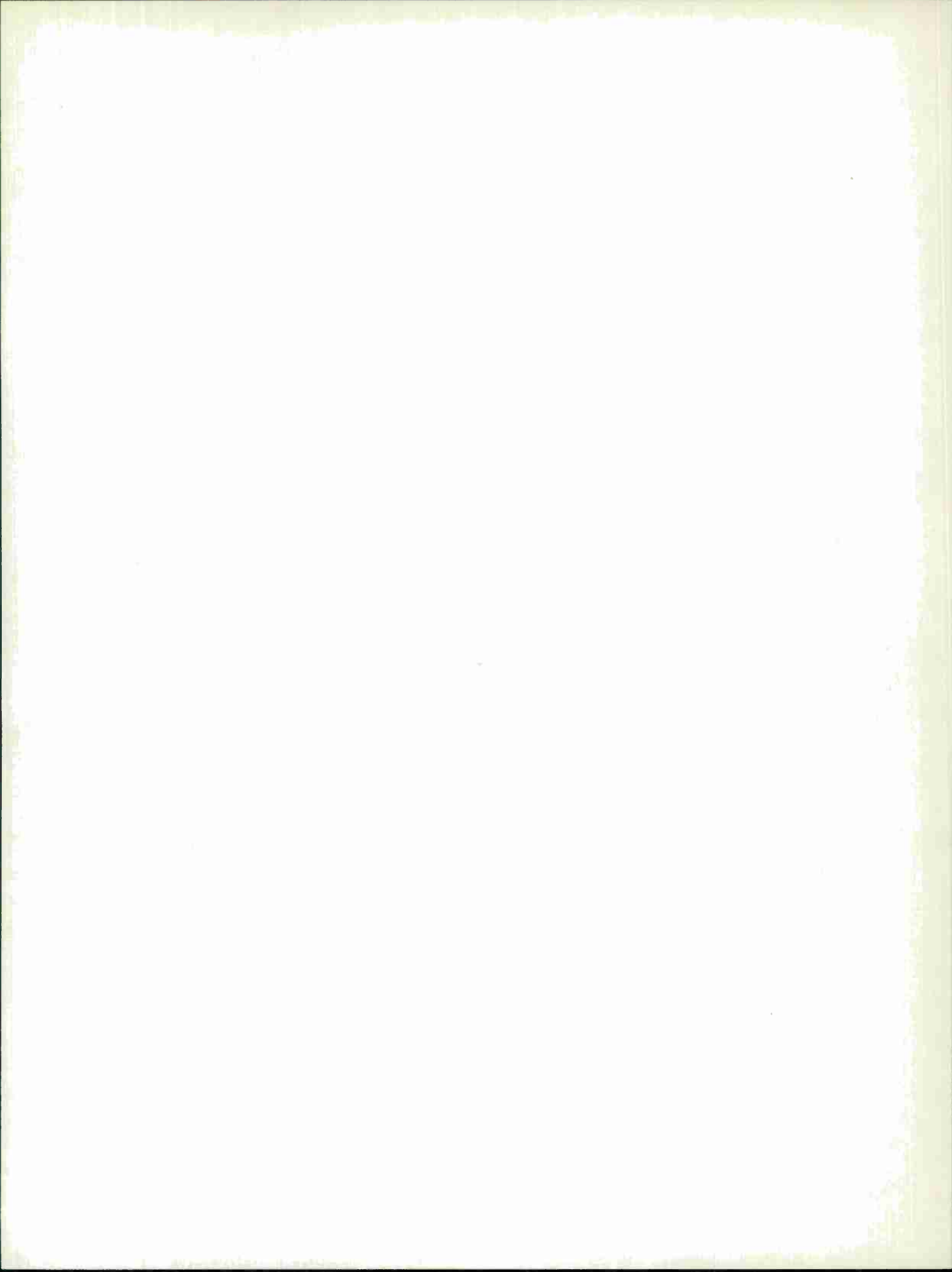
INTRODUCTION

This Quarterly Technical Summary covers the period 1 August through 31 October 1975. It consolidates the reports of Division 2 (Data Systems) and Division 8 (Solid State) on the Advanced Electronic Technology Program.



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DATA SYSTEMS DIVISION 2

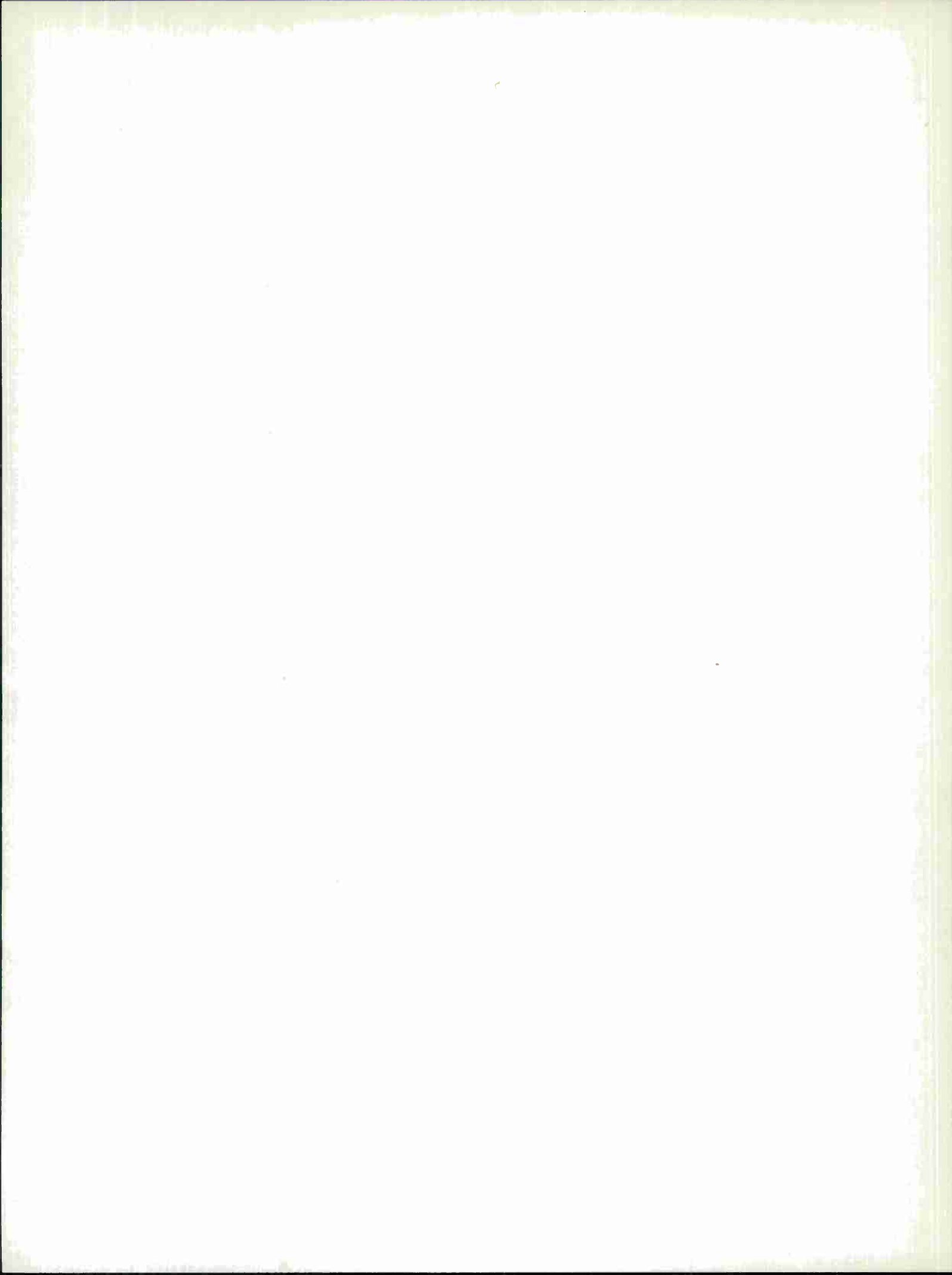
INTRODUCTION

This section of the report reviews progress during the period 1 August through 31 October 1975 on Data Systems. Separate reports describing other work of Division 2 are issued for the following programs:

Seismic Discrimination	ARPA
Educational Technology	NSF, Bureau of Mines
Speech Evaluation	OSD-DCA
Digital Voice Terminal	ESD
Packet Speech	ARPA
Airborne Command and Control	ARPA
Radar Signal Processing Technology	BMDATC

M. A. Herlin
Head, Division 2

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DIGITAL COMPUTERS

GROUP 23

I. INTRODUCTION

Application studies of the gate array for both speech and radar signal processing have been initiated involving six possible parts in various stages of design. Eighteen 4×4 multipliers have successfully passed wafer probe; fault and yield diagnosis continues.

II. APPLICATIONS

A. 4×4 Multiplier Gate Array

Seven devices which tested good from one wafer were packaged and delays were measured. The delays were close to those reported in the last Quarterly Technical Summary.* A new multiplier has been designed with additional pulldown resistors on the longer metal runs to reduce delay. Samples soon will be ready for testing. A 20×20 multiplier has been designed for use in the FDP computer.

B. Multiplier Control Gate Array

The multiplier control chip which multiplexes inputs and stores outputs from a multi-phase reclocked multiplier has been built. Partially good chips have been made, but results are inconclusive due to problems with the tester.

C. Phase Generator Gate Array

A circuit for controlling and generating a four-phase clock has been designed and breadboarded, and the interconnection is now being laid out. Based on our experience with the multiplier, some care is being taken to minimize lead length.

D. 250-MS/sec 8-Bit A/D Converter

The possibility of using a two-stage system for an 8-bit 250-megasample/sec (MS/sec) A/D converter is being explored. A "thermometer-code" D/A converter in the first stage and an error correction in the second are two features believed to be essential to such an approach. Coaxial cable is being investigated as a signal-storage medium, and a chip has been fabricated containing four differential switches for D/A conversion which will be measured for high-speed transient behavior.

E. Sequential Radar Data Memory Circuit

A very-high-speed, 1024-bit, block-oriented, random-access-memory circuit chip is being designed. It will be used to collect data from the output of the 250-MS/sec A/D converter. The block diagram of the memory circuit chip is shown in Fig. 1. Data will be shifted serially into the 16-bit shift register at 250 MHz, transferred to the buffer register, and then written in the memory while the following 16 bits are being assembled in the shift register. Readout will operate in a reverse fashion. The combination of storage and serial-to-parallel formatting on one

*Advanced Electronic Technology Quarterly Technical Summary, Lincoln Laboratory, M.I.T. (15 August 1975), p.2, DDC AD-A016399.

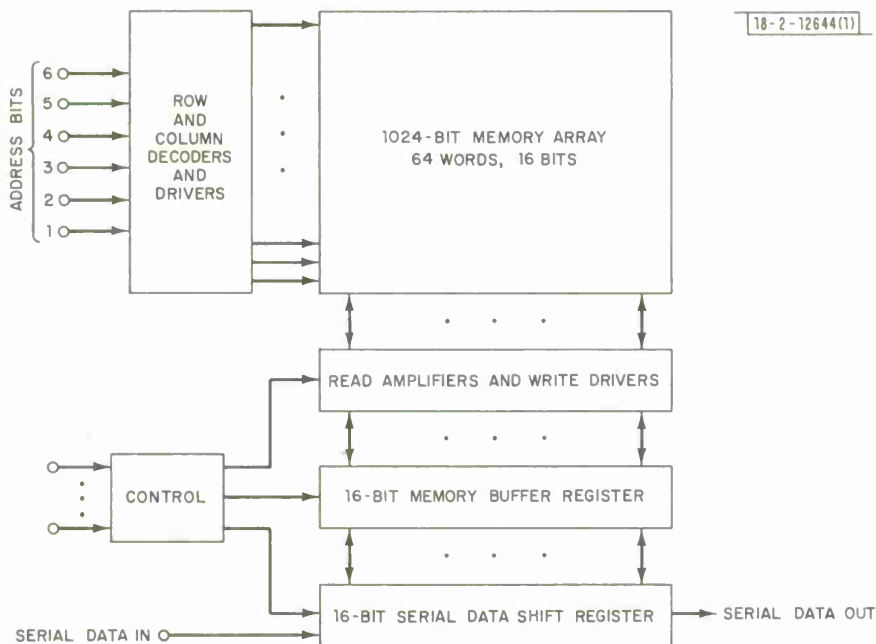


Fig. 1. Sequential radar data memory chip.

chip reduces package and pin count from a multiplexing approach. The memory will use dual-emitter nonsaturated bipolar-transistor static memory cells. The shift register and buffer register will use emitter-function logic for reduced power dissipation. In/out circuits will be MECL 10K compatible. A circuit evaluation chip has been designed and is in processing. The design and layout of a prototype memory circuit chip are partially completed and await testing of the evaluation chip and completion of a study of the entire memory system configuration and interfacing.

F. MNOS Charge Storage

An investigation of MNOS charge storage devices for ultrahigh density memory applications has been initiated due to the essentially nondissipative characteristics of these devices. Silicon nitride electrical conduction properties vs deposition conditions have been studied in order to properly fabricate structures in which charging of the nitride oxide interface occurs by conduction through the nitride layer. Single-shot test equipment has been constructed, and a fully dynamic test apparatus is under construction to test the storage characteristics of MNOS capacitor test devices. One problem which we have observed with these devices is that one polarity of writing voltage generates a thick silicon depletion layer immediately underlying the nitride oxide layers. This depletion layer results in a large reduction of the applied electric field in the nitride and oxide, thus resulting in an inability to charge the device for that polarity except for extremely long writing times (≥ 10 msec). This problem is not observed in transistors where an adjacent metallurgical region of the opposite conductivity type (i.e., the source or drain) provides electrical contact to the inversion layer. Various schemes to circumvent this problem in capacitors are currently under investigation.

III. INTEGRATED CIRCUIT PROCESSING

A. ECL Gate Array

To date, 18 good 4×4 multiplier chips have been produced from 12 runs having a total of 1536 dice. Additionally, a run of 6 wafers having the control array metalization has been made and is undergoing evaluation.

Metal-to-metal via resistance variation has been eliminated by correcting the second-level metal deposition temperature and adding a 455°C , 10-min. sinter step following second-level metalization. Typically, the resistance is $0.2\Omega/\text{via}$ with a spread of $\pm 0.2\Omega$.

B. Array Failure Mechanisms

A device yield analysis program was initiated to define the major yield detractors and direct process improvement activities. The results indicate that emitter-to-collector leakage is the chief mechanism degrading low-frequency transistor performance, and the leakage is primarily a bulk phenomenon. Diagnostic tests after first-level aluminum etching and at wafer probe test have been implemented to screen out defective wafers and provide the detailed information required to locate the leakage sources.

C. Oxide Isolation

The new nitride reactor was brought to satisfactory operating condition, and the deposition of nitride from silane and ammonia and of oxide from silane and carbon dioxide was characterized under normal deposition conditions. Nitride and oxide layers under conditions of thick oxide layer growth are being characterized to eliminate the mechanical failures which have been occurring.

IV. DESIGN AND TESTING

A. Calma Design System

One defect of the Calma software as purchased was the poor sorting done on tapes for a Mann 1600 pattern generator. Mann exposure times for our array masks were of the order of days. A sort program, which runs on the Calma machine, was written to correct this problem and patterns can now be exposed overnight.

B. IC Process Simulation

Diffusion coefficient modeling in the simulation program was changed to include concentration dependence.

C. Quantizer Circuit Modeling

A project to verify circuit modeling capabilities was undertaken. The approach was to model the quantizer, compute its input impedance in the VHF range, and measure the input impedance in the same range looking for agreement. Accurate prediction of input impedance would be a valuable indicator of potential instability. Thus far adequate agreement, defined as 20- to 30-percent difference, has not been obtained although a reproduction of the general shapes of curves has been obtained. Simpler circuits are being modeled and measured to try to verify the procedure. The circuit packages have substantial and complex parasitics in the range of measurement which is possibly a source of large error. The effort is aimed now at trying to gain some understanding of these parasitics.

D. Gate Array Packaging

Fifty-pin and 64-pin flat packs with 300-mil chip cavities have been procured. Experiments on heat dissipation of the 3.5-W chip in these packages will soon begin. Adaptor boards have been designed so that the packages can be plugged into a wire-wrap-socket board. While multi-layer printed-circuit boards are probably a preferred construction method, these adaptors will facilitate breadboarding of small systems.

E. Chip Probing

The chip prober with probe card and two manual probers has been useful for diagnostic probing of wafers and packaged chips, and even permits some probing of dynamic signals.

F. SEM Voltage Contrast Experiments

In order to permit more nondestructive diagnostic information of packaged devices, a Coates and Welter scanning electron microscope is being modified to operate in the voltage contrast mode. In this mode the brightness of a surface feature is dependent upon its voltage so that a voltage map of a surface of a functioning device can be obtained.

PROCESSOR AND EDUCATION TECHNOLOGY
GROUP 27

AFCS MAINTENANCE TRAINING SYSTEM

Evaluation of the LTS-3S currently is under way at Robins AFB. Minor ambiguities have been corrected in the performance procedures, and a booklet showing the setup of test equipment has been provided.

A qualified crewman has gone through the four performance procedures using the LTS-3S. He experienced no difficulties and required 20 min. for each of three procedures, and 45 min. for the other. The total, 105 min. establishes a baseline against which to judge performance of inexperienced crewmen.

To date, six personnel without prior qualification have performed these four procedures once, and one has done them three times. The time required by these inexperienced personnel on the first try is consistently three times that of the experienced crewman. They exhibit considerable, not unexpected difficulty in the use of test equipment, test leads, etc. In the one case with repetition, the time decreased to about twice that of the experienced crewman on both repetitions and there was a substantial decrease in the number of interactions with the supervisor.

These results are consistent with the view that new personnel aided by the LTS can carry out performance check procedures with reasonable proficiency, without prior training and with little supervisory support. This evaluation will continue at least through the end of November 1975.

COMPUTER SYSTEMS

GROUP 28

As previously reported, work is in progress to replace the VS2 batch processing system with a version known as VS1. The objective is to provide a more efficient system to run in combination with the VM time-sharing system. Both versions of VS are associated with subsystems which provide a job-handling interface for users and operators. Although neither subsystem directly affects program execution, both are involved in the way that users and operators see and control the system. The subsystem currently installed with VS2 and known as HASP has not heretofore been available with VS1. This fact has slowed progress in converting to VS1. During this quarter, a version of HASP, modified to work with VS1, has been received from Duke University. After some initial debugging and testing, this version seems capable of being brought up to an operational level. This should mean that the VS1 conversion can proceed more easily and quickly, with very little impact on users or operators.

To further support the use of VS for batch processing under the VM time-sharing system, interface routines have been developed which permit VS Fortran programs to read and write VM/CMS files. Because the file structure of VS and VM differ, users who need to work back and forth between the two must maintain two different versions of their files. This new facility will make it possible to eliminate the VS version. In addition, a terminal support system for VS users has been developed which provides access to all the resources of VS and a significant subset of the resources of VM/CMS. This capability is not associated with the Time Sharing Option regularly provided with VS, but it is available with VS running alone or under VM.

Several successful tests of remote-terminal transmissions at various speeds and distances have been made using modifications of the EIA RS232 interface but without modems of any kind. Tests at 4800- and 9600-baud rates have simulated synchronous modems by sending the computer's timing signal to the remote terminal and also feeding it back to the computer's telecommunications port. Using AWG #22 twisted pairs, this method has been successful at 4800 baud for distances up to 2000 feet and at 9600 baud up to 1000 feet. Work is in progress to increase these distances by conditioning the line to reduce capacitance. Terminals operating at 300 baud at distances up to 3700 feet have now successfully simulated the Bell 103A modem using only two directly connected twisted pairs. This is a savings over the previous three-pair connection. In all the direct-wire modem simulations, the data terminal ready signal (EIA 20) from the remote terminal is fed back to the terminal itself as clear to send (EIA 5), data set ready (EIA 6), and data carrier detect (EIA 8). It is also sent to the computer on a single line where it is put in common with these same three pins at the computer end. The introduction of 300-baud terminals has reduced the daily median response time by 1 sec and increased the number of user interactions by 6000. A change in the handling of 1200-baud terminals increased daily interactions by 3000, with no increase in median response time.

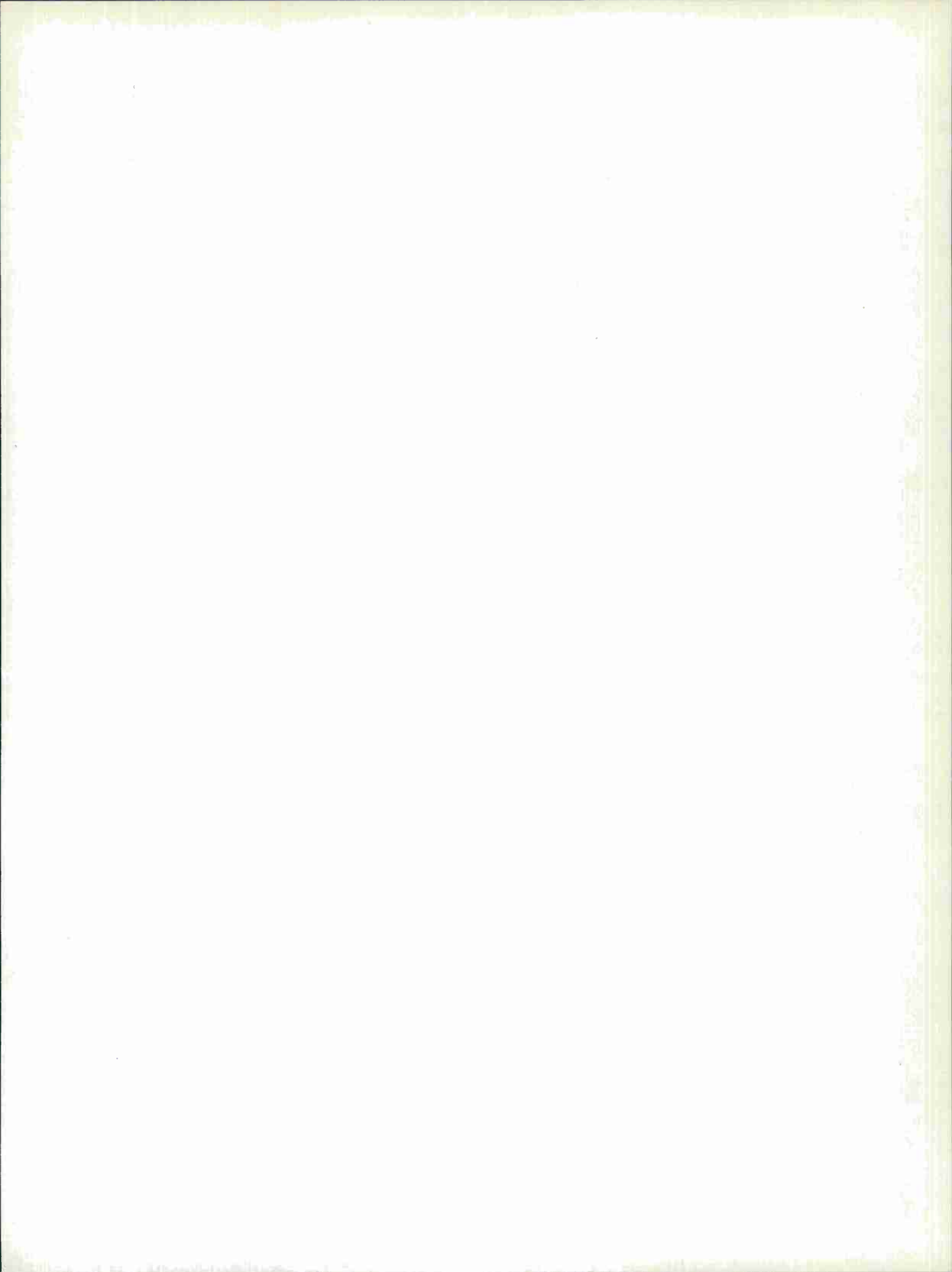
SOLID STATE
DIVISION 8

INTRODUCTION

This section of the report summarizes progress during the period 1 August through 31 October 1975. The Solid State Research Report for this same period describes the work of Division 8 in more detail. Funding is provided primarily by the Air Force, with additional support provided by the Army (BMDATC), ARPA (MSO, IPTO), NSF, and ERDA.

A.L. McWhorter
Head, Division 8

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Associate Head



DIVISION 8 REPORTS
ON ADVANCED ELECTRONIC TECHNOLOGY

15 August through 15 November 1975

PUBLISHED REPORTS

Journal Articles

JA No.

4339	Many-Body Treatment of Pressure Shifts Associated with Collisional Broadening	R. W. Davies	Phys. Rev. A <u>12</u> , 927 (1975), DDC AD-A017353
4453	Etude des Proprietes Magnetiques, Electriques et Optiques des Phases de Structure Perovskite $\text{SrVO}_{2.90}$ et SrVO_3	P. Dougier* J. C. C. Fan J. B. Goodenough	J. Solid State Chem. <u>14</u> , 247 (1975)
4469	Low-Threshold, Transversely Excited $\text{NdP}_5\text{O}_{14}$ Laser	S. R. Chinn J. W. Pierce H. Heckscher	IEEE J. Quantum Electron. <u>QE-11</u> , 747 (1975), DDC AD-A017355
4503	Integrated GaAs-AlGaAs Double-Heterostructure Lasers	C. E. Hurwitz J. A. Rossi J. J. Hsieh C. M. Wolfe	Appl. Phys. Lett. <u>27</u> , 241 (1975), DDC AD-A016699
4511	Crystallization of Amorphous Silicon Films by Nd:YAG Laser Heating	J. C. C. Fan H. J. Zeiger	Appl. Phys. Lett. <u>27</u> , 224 (1975), DDC AD-A016696
4524	Coherent Integration and Correlation in a Modified Acousto-electric Memory Correlator	K. A. Ingebrigtsen E. Stern	Appl. Phys. Lett. <u>27</u> , 170 (1975), DDC AD-A016688
4531	Optically Pumped Infrared V-V Transfer Lasers	H. Kildal T. F. Deutsch	Appl. Phys. Lett. <u>27</u> , 500 (1975)
4537	Photoelectrolysis of Water in Cells with TiO_2 Anodes	J. G. Mavroides D. I. Tchernev J. A. Kafalas D. F. Kolesar	Mater. Res. Bull. <u>10</u> , 1023 (1975), DDC AD-A017419
4543	Crystal Structure of Potassium Neodymium Metaphosphate, $\text{KNdP}_4\text{O}_{12}$, A New Acentric Laser Material	H. Y-P. Hong	Mater. Res. Bull. <u>10</u> , 1105 (1975), DDC AD-A017268

*Author not at Lincoln Laboratory.

Meeting Speeches

MS No.

- | | | | |
|------|---|--|---|
| 3720 | GaAs Schottky Barrier Avalanche Diodes for Integrated Waveguide Photodetectors at 0.905 μm | G. E. Stillman
C. M. Wolfe
J. A. Rossi
J. L. Ryan | In <u>Optical and Acoustical Microelectronics</u> , J. Fox, Ed. (Polytechnic Press, Brooklyn, New York, 1975), p. 543 |
| 3979 | Surface-Wave Resonators Using Grooved Reflectors | R. C. M. Li
J. A. Alusow
R. C. Williamson | Proc. 29th Annual Symposium on Frequency Control, Atlantic City, 28-30 May 1975, pp. 167-176, DDC AD-A017356 |

* * * * *

UNPUBLISHED REPORTS

Journal Articles

JA No.

- | | | | |
|-------|--|---|---|
| 4443 | Frequency Stabilization and Absolute Frequency Measurements of a cw HF/DF Laser | R. S. Eng
D. L. Spears | Accepted by Appl. Phys. Lett. |
| 4461 | External Cavity CO ₂ Pumped InSb Spin-Flip Laser | S. R. J. Brueck
A. Mooradian | Accepted by IEEE J. Quantum Electron. |
| 4465 | The Molecular Contribution to the Infrared Laser Transmittance of the Natural Atmosphere | P. L. Kelley
R. A. McClatchey*
R. K. Long*
A. Snelson* | Accepted by Optical and Quantum Electronics |
| 4469A | Low-Threshold, Transversely-Excited NdP ₅ O ₁₄ Laser | S. R. Chinn
J. W. Pierce
H. Heckscher | Accepted by Appl. Opt. |
| 4487 | Properties of Sn-Doped In ₂ O ₃ Films Prepared by RF Sputtering | J. C. C. Fan
F. J. Bachner | Accepted by J. Electrochem. Soc. |
| 4488 | Optically Pumped 15.90 μm SF ₆ Laser | H. R. Fetterman
H. R. Schlossberg*
W. E. Barch | Accepted by Opt. Commun. |
| 4496 | Applications of Infrared Lasers to Spectroscopy | A. H. M. Ross*
P. L. Kelley
K. W. Nill | Accepted in <u>Applications of Lasers to Atomic and Molecular Physics</u> (North-Holland Publishing Company, Amsterdam) |
| 4528 | The Application of Moiré Techniques in Scanning Electron Beam Lithography and Microscopy | H. I. Smith
S. R. Chinn
P. D. DeGraff | Accepted by J. Vac. Sci. Technol. |

* Author not at Lincoln Laboratory.

JA No.

4532	Prospects for X-Ray Fabrication of Silicon IC Devices	H. I. Smith S. E. Bernacki	Accepted by J. Vac. Sci. Technol.
4541	CW Laser Action in Acentric $\text{NdAl}_3(\text{BO}_3)_4$ and $\text{KNdP}_4\text{O}_{12}$	S. R. Chinn H. Y-P. Hong	Accepted by Opt. Commun.
4545	Spiking Oscillations in Diode-Pumped $\text{NdP}_5\text{O}_{14}$ and $\text{NdAl}_3(\text{BO}_3)_4$ Lasers	S. R. Chinn H. Y-P. Hong J. W. Pierce	Accepted by IEEE J. Quantum Electron.
4547	Isotope Separation Involving Photoinduced Changes in the Electric and Magnetic Properties of Molecules and Atoms	P. L. Kelley N. M. Kroll* C. K. Rhodes*	Accepted by Opt. Commun.
MS-4067	Recent Advances in Tunable Infrared Lasers	A. Mooradian	Accepted by Soviet J. Quantum Electron.

Meeting Speeches†MS No.

3467A	Electron Delocalization in the Solid State	J. B. Goodenough	Symposium on Delocalized Electrons in Solids, Brown University, 24 August 1975
4059A	Photoelectrolysis of Water on Semiconducting Surfaces	D. I. Tchernev	Seminar, I.B.M., Yorktown Heights, N.Y., 1 October 1975; Brown University, 6 November 1975
4062	Nucleation and Surface Morphology of LPE GaAs and GaAlAs Grown from Supercooled Solutions	J. J. Hsieh	148th Meeting of the Electrochemical Society, Dallas, Texas, 5-10 October 1975
4088	Experimental Exploration of the Limits of Achievable Q of Grooved Surface-Wave Resonators	R. C. M. Li J. A. Alusow R. C. Williamson	1975 IEEE Ultrasonics Symposium, Los Angeles, 22-24 September 1975
4090	BGO Reflective-Array Compressor (RAC) with 125 μsec of Dispersion	V. S. Dolat R. C. Williamson	
4091	Measurement of Impedance Mismatch and Stored Energy for Right-Angle Reflection of Rayleigh Waves from Grooves on Y-Cut LiNbO_3	J. Melngailis R. C. M. Li	
4093	Stable CW Operation of Gap-Coupled Silicon-on-Sapphire to LiNbO_3 Acoustoelectric Amplifiers	R. W. Ralston	

* Author not at Lincoln Laboratory.

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

MS No.

4098	Programmable Matched Filtering with Acoustoelectric Convolvers in Spread-Spectrum Systems	J. H. Cafarella J. A. Alusow W. M. Brown E. Stern	1975 IEEE Ultrasonics Symposium, Los Angeles, 22-24 September 1975
4100	Holographic Storage of Acoustic Surface Waves with Schottky Diode Arrays	K. A. Ingebrigtsen E. Stern	
4101	Acoustic Memories	E. Stern	
4104	Reflective-Array Matched Filter for a 16-Pulse Radar Burst	R. C. Williamson V. S. Dolat J. Melngailis	
4094	GaAs-Based Integrated Optical Circuits	I. Melngailis	Electro-Optics '75, Anaheim, California, 11-13 November 1975
4128, 4128A	GaAs-Based Integrated Optical Circuits	C. E. Hurwitz	Seminar, American Vacuum Society, Lexington, Massachusetts, 1 October 1975; Optics Seminar, M.I.T., 16 October 1975
4137	Measurement of Vibrational-Vibration Exchange Rates for Excited Vibrational Levels in Hydrogen Fluoride Gas	R. M. Osgood, Jr.	Army Symposium on High Energy Lasers, Redstone Arsenal, Alabama, 3-4 November 1975

SOLID STATE
DIVISION 8

I. SOLID STATE DEVICE RESEARCH

Single-mode GaAs $p^+-n^-n^+$ optical striplines have been fabricated with a loss coefficient of 1.2 cm^{-1} at $1.06 \text{ }\mu\text{m}$. The p^+-n^- junctions have shown sharp reverse-bias breakdown characteristics at average electric fields in the n^- guiding layer of $1.5 \times 10^5 \text{ V/cm}$. These results suggest the feasibility of developing GaAs modulators, directional couplers, and optical switches having lower loss than those reported previously.

Sheet carrier concentration and mobility for various implant temperatures have been determined for GaAs samples implanted with 1×10^{13} and $1 \times 10^{14} \text{ Sn ions cm}^{-2}$. For $1 \times 10^{14} \text{ Sn ions cm}^{-2}$ and implant temperatures in the range 100° to 500°C , the sheet carrier concentration and mobility were $1.8 \times 10^{13} \text{ cm}^{-2}$ and $2400 \text{ cm}^2/\text{V-sec}$, respectively.

CW operation of a tunable PbSnTe double-heterostructure (DH) laser grown by molecular-beam epitaxy has been obtained for heat-sink temperatures just above 77 K . The emission wavelength of this DH diode laser varies from $10.1 \text{ }\mu\text{m}$ at liquid helium temperature to $8.29 \text{ }\mu\text{m}$ at 77 K , giving a temperature tuning range of $1.81 \text{ }\mu\text{m}$ over the region of CW operation.

Large bulk single crystals of PbS with carrier concentrations as low as $2.8 \times 10^{16} \text{ cm}^{-3}$ have been prepared by using a two-temperature zone annealing technique. Evidence for a relatively high degree of carrier concentration homogeneity was obtained from CO_2 laser transmission scans.

II. QUANTUM ELECTRONICS

Room-temperature operation has been obtained in two new stoichiometric neodymium materials: $\text{NdAl}_3(\text{BO}_3)_4$ and $\text{KNdP}_4\text{O}_{12}$. As with neodymium pentaphosphate ($\text{NdP}_5\text{O}_{14}$), the high Nd concentration allows miniature laser operation. In addition, the lack of inversion symmetry makes possible harmonic generation and electro-optic modulation in the laser crystal.

Photoluminescence due to recombination of excitons bound to Te impurities in CdS was studied. Spectra and time decays were observed for excitons bound to single Te impurities as well as for excitons bound to nearest-neighbor pairs of Te impurities.

Nearly 75 mW of CW second-harmonic power has been obtained on doubling CO_2 radiation in CdGeAs_2 . The crystals were antireflection coated with ZnS on the entrance and exit faces. Most samples withstood CW power densities in excess of $2 \times 10^5 \text{ W/cm}^2$.

Tripling of CO_2 laser radiation has been observed in SF_6 , BCl_3 , and CO . In the case of SF_6 and BCl_3 , a vibration fundamental was resonant with the first harmonic of CO_2 , while for CO the fundamental was resonant with the second harmonic. Frequency, pressure, and pump dependences were studied.

The vibrational relaxation time of liquid nitrogen has been measured to be $\sim 70 \text{ sec}$ and is limited mainly by radiative processes. The collisionally induced N_2 absorption band was pumped by an HBr laser, and the fluorescence decay time of CO added to the N_2 was measured as a function of CO concentration.

The technique for generating step-tunable CW far-infrared radiation from non-collinear difference-frequency mixing of radiation from two CO_2 lasers in a GaAs crystal has been used

to make high-resolution transmission measurements as a function of pressure of the rotational spectrum of water vapor in the 55- to 56-cm⁻¹ and 62- to 63-cm⁻¹ regions.

III. MATERIALS RESEARCH

Room-temperature operation, with pulsed thresholds as low as 2.8 kA/cm² for broad-area devices, has been achieved for Ga_{1-x}In_xAs_{1-y}P_y/InP double-heterostructure diode lasers emitting at 1.1 μm, where optical fibers have their minimum transmission loss. With thresholds in this range, it should be possible to produce stripe-geometry lasers capable of continuous operation at room temperature, which would be of particular interest for optical communication systems.

Detailed measurements on the photoelectrolysis of water in cells with single-crystal n-type SrTiO₃ anodes have shown that the photoelectrolytic quantum efficiencies obtained in the absence of a bias voltage are about an order-of-magnitude higher for SrTiO₃ than for TiO₂. In addition to confirming that TiO₂ is not unique in its ability to catalyze the photodecomposition of water, these results show that both electron affinity and energy gap must be considered in the search for practical electrode materials to be used in the conversion of solar energy by means of photoelectrolysis.

By determining the angle-of-incidence and primary-electron-energy dependences of the reflection electron energy loss spectra of MgO, it has been possible to distinguish two type of electronic transitions: from Mg core levels to bulk excitonic states like the excited states of the free Mg²⁺ ion, and from the core levels to excitonic states of the surface Mg²⁺ ions that are Stark-split by the intense Madelung electric fields at the surface. Application of this improved technique to TiO₂ and SrTiO₃ should contribute to an increased understanding of the surface electronic states of these compounds that are involved in catalyzing the photoelectrolysis of water.

A new type of transparent heat mirror has been produced by etching a microgrid of square holes 2.5 μm on a side, separated by lines 0.6 μm wide, in a thin film of Sn-doped In₂O₃. The solar transmission is significantly higher for the microgrid than for the original continuous film; but the infrared reflectivity becomes significantly lower, indicating that films with higher conductivity will probably be required in order for the microgrid technique to result in improved heat-mirror performance for solar-energy applications.

IV. MICROELECTRONICS

A prototype, 30- × 30-element, CCD imaging array has been fabricated and tested as part of the development effort aimed at realizing a 100- × 400-element CCD array for the GEODSS (Ground Electro-Optical Deep Space Surveillance) Program. Tests on this prototype have revealed difficulties in transferring charge for test purposes through the channels between the input (test) and output registers and the CCD array, and problems with the level of the output signal caused by a large capacitance in the diode-MOSFET preamplifier structure. Somewhat imprecise optical measurements have indicated that these devices have transfer inefficiencies of less than 10⁻³. Two redesigned 30 × 30 prototypes are being fabricated which will incorporate changes in structure and processing to reduce the charge transfer problem between the registers and the CCD array, and to increase the output signal by reducing the capacitance in the output circuitry.

The detector being built for use at the prime focus of a 31-inch telescope in the GEODSS Program will be a hybrid integrated circuit consisting of sixteen 100- × 400-element, CCD imaging arrays mounted on an alumina interconnect substrate. The individual arrays must be aligned on

the substrate to within 0.0005 in. and be parallel to within 0.03°. The hybrid will be fabricated on a multilevel interconnect substrate. The individual arrays will be located and placed using a modified x-y coordinator with 0.0002-in. accuracy, and die attachment will be accomplished with an anerobic, fast-setting adhesive.

An electronically variable attenuator has been built as a chip-and-wire hybrid for use in the UHF receiver of the proposed LES-10 satellite. The circuit is a bridged-T attenuator whose basic components are two PIN diodes which function as current-controlled, variable resistors, and two Ta₂N₃ thin-film resistors. This circuit in hybrid form has at least 25 dB of attenuation between 30 and 400 MHz, as opposed to the discrete version of the same circuit which had a maximum of 18 dB of attenuation at 400 MHz.

The mask-making facility of the Microelectronics Group requires software to be used in conjunction with the IBM 370/168 and the Calma interactive graphic design system to provide input to a D. W. Mann Model 1600 pattern generator. Two important programs, CALMASRT and MANNPLOT, have been written and updated, respectively, to improve the operation of the facility. CALMASRT takes the data from the Calma system and sorts the data to minimize the running time of the pattern generator. MANNPLOT is a user-oriented program that allows patterns to be designed on the 370/168 system, and then creates the file or files needed to generate the mask on the pattern generator.

V. SURFACE-WAVE TECHNOLOGY

The Rayleigh-wave reflection coefficient of shallow grooves has been measured on Y-cut LiNbO₃ for waves reflected from the Z- to the X-direction. This 90° reflection geometry is used in surface-acoustic-wave (SAW) devices such as the reflective-array compressor (RAC) and the burst matched filter. The reflection coefficient of each edge of a groove has a real and an imaginary part. The real part is proportional to groove depth and contributes mainly to the amplitude of reflections, while the imaginary part is proportional to the square of the groove depth and leads to phase shifts on transmission.

A burst matched filter has been designed and fabricated using the reflective-array technology. The device is a 15-cm-long LiNbO₃ crystal with an input and an output transducer and 16 pairs of shallow gratings in its surface. The gratings selectively reflect SAWs whose wavelength satisfies a Bragg condition. The impulse response of the device is a train of 16 linear-FM subpulses. The filter compresses a Doppler-sensitive radar waveform to which the filter is matched. It can resolve a Doppler shift of 20 kHz.

Linear-FM pulse expanders and compressors in the reflective-array configuration have been fabricated on bismuth-germanium-oxide substrates. The low surface-wave velocity on this material and the folded RAC configuration allow 125 μsec of dispersion over the 2.5-MHz bandwidth to be obtained in a compact device. Controlled spatial variations in reflectivity achieved by etching gratings to varying depths were employed to provide spectral weighting in the frequency response of the devices. Special procedures for ion-beam etching, metalization, and bonding were developed for use on bismuth-germanium-oxide.

Acoustoelectric amplifiers have been developed to provide distributed on-substrate loss compensation of very long SAW delay lines as a means of maintaining wide bandwidth and large dynamic range. The gap-coupled silicon-on-sapphire (SOS) to LiNbO₃ configuration is the first SAW amplifier which exhibits stable DC operation with gain and noise performance that matches theoretical predictions. Optimum performance results because traps within the SOS film prevent intense fringing fields from distorting the homogeneity of the electron sheet.

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