Quarterly Technical Summary

General Research

15 August 1967

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Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Lexington, Massachusetts

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INTRODUCTION

This Quarterly Technical Summary covers the period from 1 May through 31 July 1967. It consolidates the reports of Division 2 (Data Systems), Division 3 (Radio Physics), Division 4 (Radar), Division 7 (Engineering), and Division 8 (Solid State) on the General Research Program at Lincoln Laboratory.

Accepted for the Air Force
Franklin C. Hudson
Chief, Lincoln Laboratory Office

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DATA SYSTEMS
DIVISION 2

INTRODUCTION

This section of the report reviews progress during the period 1 May through 31 July 1967 for the General Research Program of Division 2. Separate progress reports on Ballistic Missile Re-entry Systems, Graphics, and Project PRESS describe other work in the Division. All the work of Groups 21 and 22 and some of the work of Groups 23, 25, and 28 is therefore reported separately.

F. C. Frick
Head, Division 2

V. A. Nedzel
Associate Head

DIVISION 2 REPORTS ON GENERAL RESEARCH

15 May through 15 August 1967

PUBLISHED REPORTS

Technical Notes

TN No.				DDC and Hayden Nos.
1967-21	Wave Optical Aspects of Lorentz Microscopy	M. S. Cohen	10 May 1967	DDC 652497 H-845

Journal Articles*

JA No.			
2790	Finite Temperature Theory for the Attenuation of Quasi-Particle Excitations in Real Metals	R. W. Davies	J. Phys. Chem. Solids 28, 1001 (1967)

* * * * *

UNPUBLISHED REPORTS

Journal Articles

JA No.			
3004	The Oxidation of Aluminum Films in Low-Pressure Oxygen Atmospheres	C. T. Kirk, Jr. E. E. Huber, Jr.	Accepted by Surface Sci.
3028	New Variational Approach in the Transport Theory of the Coupled Electron-Phonon System	R. W. Davies	Accepted by Phys. Rev.
3058	Proposal for a Magnetic-Film Memory Accessed by Combined Photon and Electron Beams	D. O. Smith	Accepted by IEEE Trans. Magnetics
3063	Books and Conference Proceedings	K. J. Harte D. O. Smith	Accepted by Magnetic Materials Digest, 1967
3083	Changes in the Work Function of Aluminum During and Following Low-Pressure Oxidation at Room Temperature	E. E. Huber, Jr. C. T. Kirk, Jr.	Accepted by Surface Sci.

* Reprints available.

Division 2

MS No.			
1757	Two Basic Pattern Recognition Problems in Computer Aided Design	W. R. Sutherland	Accepted for Conference Record of IEEE Pattern Recognition Workshop, Puerto Rico, 1966

Meeting Speeches*

MS No.			
1541A	Seeing Solid	R. N. Davis H. E. Meily	Seminar on Computerized Imaging Techniques, Society of Photo-optical Instrumentation Engineers, Washington, D. C., 26-27 June 1967
2003	The Oxidation of Aluminum Films in Low-Pressure Oxygen Atmospheres	C. T. Kirk, Jr.	American Vacuum Society, New England Chapter, Thin Film Division, Lexington, Massachusetts, 24 May 1967
2005	Generalized Superposition and Picture Processing	T. G. Stockham	University of Illinois, 15 May 1967
2021	On the Construction of Graphics Software Packages	W. R. Sutherland	IEEE Workshop on Computer Aided Design Technology, Burlington, Vermont, 11 – 12 July 1967
2054	Handling Complex Structures	W. R. Sutherland	Conference on Computer Animation, Education Development Center, Watertown, Massachusetts, 17 – 18 July 1967
2060	High Quality Movies from Electronic Computers	R. N. Davis	

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

DIGITAL COMPUTERS
GROUP 23

I. COMPUTER SYSTEMS

A. New Display Sequence

A stroke-writing character generator is being added to the new conic generator display sequence. This generator provides the TX-2 Lincoln Writer with characters set in three forms: normal size, large size and slanted form. The existing control logic has been modified to incorporate the generator into a test-page writing mode, so that the generator programming is very much like that for our typewriter. In addition, carriage-return and line feed are automatically executed when a preset page width is exceeded and a normal word ending, such as space or tab, is specified. Therefore, it is relatively easy to move texts on the display CRT without recomputing the boundaries of individual lines in the texts.

B. Nine-Track Magnetic Tape Sequence (46)

A new input-output sequence, the Nine-Track Magnetic Tape Sequence (46) has been installed in TX-2 to replace the older IBM Magnetic Tape Sequence (45). The new sequence operates an IBM System 360-2400 series Magnetic Tape Control Unit, to which are attached three Model 2 Tape Drives. The sequence and the associated IBM equipment allow writing and reading on magnetic tape in the new IBM standard nine-track format (8-bit information byte + parity). Since the new Tape Sequence has its own self-contained Tape Control Unit (the old sequence depended on program timing for its control), it will be possible to operate the new Magnetic Tape Sequence (46) in the time-sharing system (Apex). The average data word transfer rate to or from TX-2 is 12,000 or 15,000 or 20,000 words/sec depending on the data format chosen.

The design of the new sequence simulates to some degree an IBM System 360 I/O Selector Channel and therefore, with minor hardware and software changes, may operate any of the IBM System 360 peripheral I/O devices.

C. Teletype Terminals

A Type 103A Data Set has been interfaced to a TX-2 data channel to allow a remote teletype with a similar data set to be used as a TX-2 console. Software in APEX provides ASC II/Lincoln Writer code conventions.

D. TX-2 Memory Speed-up

Much of the work has been completed which will permit a minimum of 1.2-μsec main frame cycle time for TX-2. This will represent a 5:1 speed-up over the original TX-2 design speed.

Construction is also under way on the hardware which will interface TX-2 and the memory bus switch with the long-word, large-capacity film memory (LCM). Although this hardware is designed to provide TX-2 with one standard 38-bit word in each 1.2-μsec memory cycle, it can also take advantage of the long-word character of the LCM and send all eight 38-bit words in one

long word through the memory bus switch in the same time. This considerably increases the speed of a potential processor with this memory.

E. Multiplexer Expansion

The V-memory multiplexer was expanded by twelve registers, and each console area was provided with an individual (not console-multiplexed) 36-bit input register to be used for such devices as WANDS and tablets.

F. Typewriter and Input Keyboard

Logic design for a golfball output typewriter has been completed. Design of the keyboard interface is complete up to the detailed interface with the keyboard itself.

G. Encoded Interrupt Sequence

A new I/O unit has been installed on TX-2 which will accept assorted interrupt signals from peripheral equipment. Each input is stored, gated by a program-variable mask bit, synchronized, and then applied to a priority net. The Sequence Control monitors all synchronizers; when one or more are set, it determines which has highest priority and encodes its number. This number is presented to TX-2, and that interrupt storage cleared. Inputs come from 1-Hz and 60-Hz pulse generators, light pens, console help-request buttons, the WAND, the RAND tablet, the Analog Comparator, Mag tape alarms, and program-generated pulses. The sequence provides for up to 64 interrupts.

H. Networking

The initial PDP 338 software package has been completed and checked out. TX-2 messages can be exchanged both ways between TX-2 and the PDP 338 and graphic information can be displayed at the PDP 338. The machine will be shipped to Washington in August and will be used there as a remote TX-2 console.

II. MAGNETIC FILM ENGINEERING

A. Large Capacity Memory (LCM)

Exerciser:– The timing control for the LCM and an exerciser to operate the complete memory and error check its readout have been built. One fourth (one byte) of the digit electronics has been constructed and will be connected to the control and exerciser. Other bytes will be added as they are ready.

Film Testing:– Thirty-six composite layer substrates have been completely processed up to final testing and inspection. Five have been tested, yielding two possible memory substrates.

Stack for TX-2:– The stack structure for use in TX-2 is assembled and is being wired. It differs from the prototype only in detail. Plated button contacts for word-line connection will be used.

Extended LCM Stack:– Experiments involving fabrication of digit lines for a 52-word substrate stack are proceeding. Splicing of 192-line segments into a 6-foot long digit mat appears

feasible using induction heating of a solder-plated double lap joint. All connections will be formed simultaneously without overheating the fibreglass-epoxy base material.

B. Pattern Scribing

Efforts are being directed toward producing much narrower word lines for magnetic memory. Data are being gathered to determine optimum values of scribing parameters for diamond tools with cutting edges 0.1 mil (2.5 micron) in width. Apparatus is being constructed to facilitate microscopic inspection of cutting edges to determine degree of tool wear and to predict tool useful life. No results on etchability of these narrow conductors are available at this time.

Signal and Noise:– The two-layer Co-Ni-Fe and Ni-Fe films provide an improved signal amplitude, typically 28 times sense-amplifier random noise and quite uniform over a word substrate. The minimum signal/random-noise ratio for reliable triggering is about 10, so determinate noise may be up to 65 percent of signal amplitude.* The threshold of the improved strobe circuit is negligible with respect to the sense-amplifier output amplitude, so the significant sources of determinate noise are the digit transient, the group-select transient, and word transient. The first two of these determine cycle and access time, respectively; for reasonable times, on the order of 1.0 and 0.5 μsec, respectively, they will total less than 20 percent of signal amplitude. This leaves a word-noise margin of about 45 percent of signal amplitude. In the present stack assembly there are many locations with word noise of up to 30 percent of signal amplitude, but few with noise beyond the 45 percent limit. The principal source of word noise, inductive coupling between word and digit line caused by line-edge defects or dirt between word and digit pieces, is being reduced by more careful line manufacture and cleaner stack assembly.

Peripheral Circuits:– All but one of the five circuits to provide an interface between TX-2 logic and the control and buffer-storage terminals of the digit cards are under construction; the remaining circuit is being designed.

C. New Film Preparation Techniques

Silica has been successfully evaporated by a new technique, and the evaporant has been shown to provide adequate smoothing for permalloy films on copper conductors and to be easily etchable in HF.

Experiments to evaluate how well sandwich films provide closure are in progress.

D. Optical B-H Looper

The prototype of the optical looper has been improved. The area of thin magnetic film whose B-H loop it can display has been reduced from 0.125 to 0.050 inch in diameter.

All plans for the final version of the optical looper have been completed and it is being machined. Its principal advantages over the flux loopers now in use are:

(1) It can examine a single film layer in a multilayer structure.

(2) It can examine a small region of a film layer.

(3) Its signal does not decrease with decreasing film thickness nearly as rapidly as that from the flux looper.

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* General Research Quarterly Technical Summary, Lincoln Laboratory, M.I.T. (15 November 1966), p. 6, DDC 645776.

III. SYSTEM PROGRAMMING

A. Applications Programming

During the past quarter a prototype system for integrated circuit mask design has been programmed and a film made showing its operation. This program allows a mask designer to sketch in a circuit diagram using the new Sylvania tablet. The computer will convert the circuit diagram to a mask diagram and the user can rearrange the components in an attempt to find a satisfactory layout. The only input to this program is the tablet stylus position. A very simple symbol recognizer has been programmed and this system is controlled by drawing appropriate marks on the tablet. A user can draw rough symbols for NPN transistors in four orientations, resistors (any orientation), capacitors (horizontal and vertical), terminals, wires, positive and negative sources, and ground. The computer will add a precisely drawn part to the drawing after the user has finished his rough symbol stylus motion. Commands for moving and deleting parts, and changing from circuit to mask symbols are also provided.

B. The Display of SNAT Data Structures

A program has been written to exhibit as a graph the structure of a SNAT 62 display file. This program, called DISPLAY DISPLAY, automatically forms a tree representation of the "group" and "use" structure existing in some user programs. Interrogation of specific groups to ascertain the names and properties of contained items (blocks) will be under simple user control.

Typical operating procedure when debugging a display program written in a VITAL language would be:

(1) Interrupt the program by hitting HELP.

(2) Type 5DD, causing DISPLAY DISPLAY to replace the user's display with the graph of the SNAT structure at the instant of interruption.

(3) Obtain detailed information by target-controlled interrogation.

(4) Type a terminating phrase followed by 5 RESUME, thereby returning to the identical prior state of the display program.

C. Program for Constraint Satisfaction

Work has been progressing on development and implementation of a new mathematical approach to a common problem in engineering design, namely constraint satisfaction. The problem is to determine the values of an interrelated collection of variables, given the values of a subcollection. When no solution exists, the need is to quickly discover this fact and offer justifiable strategies for modifying values or relations.

Difficult constraint problems have been shown to be solvable by the new methods. Moreover, it has been shown that it is possible to obtain solutions in milliseconds rather than seconds. The increase in speed makes it feasible to obtain real-time dynamic displays of highly constrained systems. For example, such a capability might facilitate design of mechanical systems; it also could help a computer animation system under current development to attain high levels of generality. Several other areas of application are presently being considered.

D. Display Executive

The major development effort on the display exeeutive this quarter has gone into the new eonie seope seetion and modifieation to the present exeeutive for the 338 remote display eonsole. The eonie seope is on-line in an interim eonneetion and programs have been written and run in time-sharing for eonie seetion display.

E. Languages

VITAL aetivity this past quarter has eentered around the design of the new VITAL II compiler-compiler system. This system is planned for both the TX-2 and the IBM 360/67. The initial formalities for aeeessing the 360 as a time-shared user have been eompleted and next quarter the neeessary 360 programming will be under way.

The development of the Language for Expressing Associative Proeedures (LEAP) under the existing VITAL I system has eontinued. VITAL I has also been used to make a TX-2 assembler for PDP-8 machine code. This assembler took a total of 30 man-hours to complete.

F. IBM Tape

The installation of the new Nine-Traek Magnetic Tape System in TX-2 required extensive modifieations to MK4 and to the tape reading and writing program. The program whieh backs up the drum onto tape was eompletely redone. The emergeney all-tape operating system for use when the drum is down was redesigned, eoded and tested. Finally, tapes were copied over from the old units to the new nine-traek format.

IV. CIRCUIT AND NEW MACHINE DEVELOPMENT

A. Microsystems

Numerous diffieulties have been eneountered in produeing the 27-bit parity array, most of them assoeiated with the move of the Philco-Ford development laboratory from Lansdale to Blue Bell, Pennsylvania. Sueeess so far has been limited to the 3-bit array.

In an effort to capitalize on the work whieh has gone into the basic wafer, we have designed a binary combinatorial multiplier, whieh uses the same basie wafer as the parity eireuits. Only the two upper metal patterns are ehanged. The initial work will be aimed at produeing a single multiplier eell. After initial studies the effort will be shifted to a 1×4 array whieh will be slightly less complex than the 27-bit parity array. This multiplier should form the product of two 10-bit numbers in less than 25 nsee.

B. Machine-Aided Design

Mueh of the work with the 360 version of CIRCUS has eonsisted in discovering and eliminating minor errors in this version of the program. This has enabled us to run a two-stage version of the SMX-4 eurrent-mode gate. Attempts to run a three-stage problem, whieh might be compared with actual measurements, are still unsueeessful.

The problems assoeiated with large seale array mask design have been studied with regard to possible utilization of the TX-2 graphies system for automating parts of the design process.

C. Associative Memory Array

A complete set of 20 drawings, detailing the associative memory array design, has been sent to Philco-Ford at Blue Bell for mask cutting. This is probably the first example of a design of this complexity (750 components and 3 levels of metallization) which has been executed outside of the semiconductor industry. The interface problems encountered during its development have been very useful in establishing possible uses for computer-aided graphics.

COMPUTER COMPONENTS
GROUP 24

I. MAGNETIC FILMS

A. Anisotropy Spectrum of Magnetic Films

Rotating magnetic annealing studies of nonmagnetostrictive Permalloy films have revealed a relaxation peak at 40°C, with the same relaxation time as process 1 of Smith, Weiss and Harte,[1] but of only one-tenth the magnitude. In fact, the total contribution to the uniaxial anisotropy field H_K from all reversible low-temperature processes observed to date is only ~2 percent. Since ~25 percent of H_K was re-oriented or removed in previous hard-axis annealing studies,[1] we conclude that the processes previously observed were almost completely irreversible and therefore are not detectable by the rotating anneal method. Studies are continuing at higher temperatures.

B. Lorentz Microscopy

The stability of the electron microscope has now been improved so that over 25 fringes have been obtained in Lorentz micrographs of convergent domain walls. In addition, Fresnel fringes originating from divergent walls have been observed for the first time. Difficulty has been experienced in obtaining sufficient contrast in the photographic plates to enable meaningful microphotometer traces to be made, however, and experiments involving higher speed photographic plates and developing techniques have therefore been initiated. Some progress has been made in producing a computer program which will plot theoretical intensity curves which can be matched with the experimental microphotometer traces.

II. MAGNETO-OPTICS

A. Magnetic-Film Memory Accessed by Combined Phonon and Electron Beams

A magnetic film memory accessed by combined photon and electron beams has been proposed.[2,3] Experimental and continued theoretical work is in progress to investigate the feasibility of such a memory.

Theoretically the necessary temperature dependence of the magneto-optical coefficient and the coercive force can be obtained by using composite films made from layers having different Curie points.[3] Experiments are in progress to fabricate such composite films using doped EuO as one of the layers.

A severe limitation on the system signal-to-noise ratio arises due to the shot noise generated by the DC background light which reaches the detector in the usual magneto-optical read-out schemes. This difficulty can be overcome by using an interferometer to separate the magneto-optical signal from the background.[3] Elimination of the background light will also result in improved visual contrast which should make magneto-optical display systems a practical possibility.

III. ELECTRON TRANSPORT

A. Mean Free Path of Hot Electrons

The mean free path of hot electrons in aluminum has not been measured previously in metal-metal oxide barrier devices. Recent results, however, show a smoothly decreasing functional dependence of the saturated α of a metal-insulator triode upon base thickness. A similar dependence has been found between the photocurrent in metal-insulator diodes and the thickness of the metal layer exposed to the light. The apparent reproducibility of these initial results should permit a mean free path determination and this is currently in progress.

B. Collection Efficiency in a Metal-Insulator Triode

The collection efficiency α of a metal-insulator triode appears to obey the empirical expression

$$\alpha = \alpha_{\epsilon}\, e^{-W_b/L_b}\, \alpha_c$$

where α_{ϵ} is the collisionless or ballistic α of the triode, $\exp(-W_b/L_b)$ represents the collision losses in the base, and α_c accounts for the losses in the collector. Two possible sources of loss associated with α_c are: (1) transmission at the base-collector insulator interface, and (2) collision losses within the collector insulator itself due most likely to the generation of polar, optical-phonons. At present, however, no satisfactory theoretical model for α_c incorporating either or both of these effects has been constructed which explains the experimentally observed behavior of α_c.

Preliminary measurements of the collected photocurrent in photo diodes indicate a very high ratio (≈ 1) of collected electrons to photo excited electrons having the proper energy to cross the barrier. The discrepancy between this high quantum yield value in photo diodes and the low saturated α values of $10^{-2} - 10^{-3}$ in triodes presents an interesting dilemma.

C. Theory of the Surface Potential in Metals

The theory of the surface potential in metals has a rather long history, dating back to Bardeen's calculation[4] of the work function in a free electron metal. Bardeen considered a model consisting of a fixed uniform positive step charge density occupying half of space, plus a system of neutralizing mobile electrons. Carrying out a Hartree-Fock analysis, with a crude allowance for correlation corrections, Bardeen concluded that "the barrier at the surface is due largely to exchange and polarization forces (i.e., correlation effects) rather than ordinary electrostatic (or Hartree) forces."

In 1953, Juretschke[5] reexamined the exchange potential for a simplified model in which the surface is represented by an infinite barrier at $x = 0$. Juretschke's calculation revealed that the exchange potential in the interior is not monatonic, but, rather, shows oscillatory structure.

More recently, Loucks and Cutler[6] have used the Bohm-Pines decoupling scheme to investigate the effects of correlation in Juretschke's model. We are presently considering the same problem, employing, instead, an RPA analysis of the exchange-correlation potential. Our tentative conclusions are that, in relation to the shape of the surface potential curves, Loucks' and Cutler's treatment tends to somewhat overestimate the effects due to correlation.

REFERENCES

1. D. O. Smith, G. P. Weiss and K. J. Harte, J. Appl. Phys. 37, 1464 (1966).
2. General Research Quarterly Technical Summary, Lincoln Laboratory, M.I.T. (15 May 1967), p. 8, DDC 653862.
3. D. O. Smith, IEEE Trans. Magnetics (to be published December 1967).
4. J. Bardeen, Phys. Rev. 49, 653 (1936).
5. H. J. Juretschke, Phys. Rev. 92, 1140 (1953).
6. T. L. Loucks and P. H. Cutler, J. Phys. Chem. Solids 25, 105 (1964).

PSYCHOLOGY
GROUP 25

I. MAN-MACHINE INTERACTION ON THE TX-2 COMPUTER

A. APEX

In the past quarter there has been little external change in the APEX time-sharing system. There has been some internal reorganization in preparation for a change in the logic of scheduling and for improvements in the handling of interrupts. A teletype console has been added to the system, and the connection to a remote PDP-8/338 computer has been brought to operational status. The system still lacks routines for handling magnetic tapes, but the new tape units are now operating and the routines should be available within the coming quarter.

B. Coherent Programming

The service routines that a programmer may use to inspect the string of instructions to his program have been revised and consolidated to make it easier for him to achieve the "coherence in calling" discussed in the last Quarterly Technical Summary.*

A first attempt to set down an orderly exposition of coherent programming has been made.†

C. Speech Recognition

Work on computer recognition of speech has been suspended since early 1964 because of commitments to the APEX time-sharing system for TX-2. Now that the effort devoted to APEX can be reduced, the speech work is being resumed. The speech-recognition programs are being revised to operate in the time-sharing environment, and the large body of speech samples that were digitally recorded and analyzed is now being recovered and reformatted. The design and construction of a new speech-input facility that will make the analyzer output of the Lincoln Vocoder available to time-shared programs on TX-2 in real-time has been undertaken.

II. MAN-MACHINE INTERACTION ON THE IBM 360 MODEL 67

A. Editor System for the 360/67

Mod 1 of the Character Stream Editor is nearing completion. The Character Stream Editor is a basic, general editor that the on-line user will probably use only on rare occasions – for example, when he needs to override the limitations of special editors such as those for Fortran source-language or English text. However, it includes the fundamental functions on which the special editors will rely.

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* General Research Quarterly Technical Summary, Lincoln Laboratory, M.I.T. (15 May 1967), DDC 653862.

† R. A. Wiesen, D. B. Yntema, J. W. Forgie, and A. N. Stowe. "Coherent programming in the Lincoln Reckoner." To be presented at ACM Symposium on Interactive Systems for Experimental Applied Mathematics, Washington, D. C., August 26-28, 1967.

Mod 1 differs from the full Character Stream Editor in two basic ways. It lacks the "locate" feature, which will be used to search for occurrences of a given string of characters; and the system parameters, such as the delimiters that divide the stream of characters into units, cannot be adjusted by the user. However, because the program works by building a "map" of the material to be edited, even this Mod 1 can move backward in the stream of characters as easily as it can move forward. Unlike many present editors, it does not have to run forward to the end of the stream, copying the whole file of information, whenever the user wants to back up.

Since the present arrangements for time-sharing the Model 67 are giving good service, Mod 1 is being assembled to work under the time-sharing monitor, rather than the batch processing monitor, OS 360. The various modules have been tested in isolation, and integration and overall checkout are proceeding.

B. Implementation of a Reckoner on the IBM 360/67

The implementation of a Reckoner facility, like the one currently operating on the TX-2 computer, is proceeding. Because of a change in the plans for time-sharing the 360, the original design had to be reworked in many respects. Currently, program logic diagrams are being completed preliminary to the writing of 360 code.

The first version will provide two basic services of the "Mediator," which is the substrate on which the Reckoner will run, and more generally, is the foundation for a library of coherent programs. These services include the program-running function and a Directory. The run function is based on a kind of push-down list called the Return List, and the Directory on a chain of definitions divided into levels; the definitions on one level supersede those on previous levels. To operate on these structures, the user, or his program, makes service calls to the Mediator. The calls invoke services including running programs, handling error returns, looking up inputs and making new entries in the Directory, and returning control to the keyboard.

Service routines that the programmer may insert in a Fortran program as subprograms will be provided. They will allow the program to issue the basic calls to the Mediator, report errors, and put results into one of the formats conventional in the library of coherent programs. Initially only two formats (i.e., two "file-types") will be required, an array of double-precision numbers and a file of characters. Fortran programs that do array arithmetic and matrix algebra will be provided in the initial package. Along with the type-in and type-out routines, and a few user "Commands" for Directory and Return List services, they will constitute the initial Reckoner.

It is expected that the initial version of the Mediator with a modest Reckoner facility will be operating at the end of the current quarter. Subsequently, improvements in keyboard and disk management, a process builder and runner, and other additions are planned. A display driver has been ordered that permits text and graphs to be transmitted at the rate of 2000 baud and shown on a direct-view, cathode-ray storage tube. This device is a copy of the ARDS-II device that is being developed at the M.I.T. Project MAC, and it will be integrated into the reckoning service when the computer's I/O hardware and time-sharing software permit.

III. HUMAN INFORMATION-PROCESSING

A. Recognition Aspects of Sensory Psychophysics

The following two facts are known from experiments on the detection of auditory signals in noise. (1) The observer's response is correlated with noise level as well as signal level. This is known from the responses given on no-signal trials (trials when noise is presented alone), both in the case where each sample of noise is presented to several observers, and in the case where each sample is presented repeatedly to one observer. (2) Under these conditions it is possible to infer how much of the response variance is related to the noise, and how much is random. The ratio typically remains constant at about one-to-one, even in experiments that differ by 20 db in the average level of the noise.

To generate a plausible explanation for these facts, a simulated signal-detection experiment was performed. A series of numbers in the range 100 to 200 was presented. The observer responded with one of six responses: HIGH or LOW, each with three levels of confidence rating. In one run the numbers were the sum of three components: (1) a fixed bias, (2) a fixed 'signal' increment added on randomly selected trials, and (3) a random 'noise,' which was the normal deviate of zero mean and fixed variance. The observer's response was highly correlated with both the signal and the noise, with little residual variance. Thus it is clear that the observer had fixed numerical criteria for his various categories of response.

In another case a fourth component, a sinusoidal variation of about one cycle per thirty trials, was also added to the numbers that served as stimuli. The response was correlated not only with signal and noise, but also with the sinusoidal component, and the residual variance was higher. It appears that the observer contrived to track the sinusoidal variation by making his responses depend on an average of about five of the most recent stimuli and fifteen of the most recent responses.

It seems likely that some such mechanism operates in the auditory detection task, where there is no direct way for the observer to compare the sensed magnitude of the stimuli to numerical criteria. Under those circumstances, letting the criteria for various categories of response depend on the magnitudes of recent stimuli, or of recent responses, or both, would be just the kind of mechanism that would achieve a correlation between the present signal and the present response.

The model implies that (1) there would be appreciable variance uncorrelated with the current noise on no-signal trials and (2) this fraction would remain relatively independent of the overall level – both of which agree with the facts observed in auditory experiments. Thus, the number experiment shows that the subject behaves in the context of unstable input levels in a way that would account for the auditory detection results.

B. Decay of Immediate Auditory Memory

It has often been assumed that auditory memory decays very rapidly in the first few seconds after presentation of a stimulus; however, the decay is very difficult to observe directly. If one simply presents a stimulus, waits a few seconds, and then administers a test of retention, usually no decay is observed – presumably because the subject rehearsed the stimulus during the interval of waiting. Two main techniques have been used to get around this difficulty. The

first is to present more material than the subject can possibly rehearse, and then at the end of the waiting interval indicate which part of the material he is to remember. The second is to fill the interval with a distracting task that makes rehearsal difficult. Both of these techniques have succeeded in showing a decline in retention as the waiting interval is increased, but they both complicate the interpretation of the results, especially in experiments on auditory memory.

An experiment has been performed in which a different strategy was used, i.e., to try to present stimuli that cannot be rehearsed. The subject was presented two nonsensical sounds 0.1 second long. (Actually, each sound was one of the digits zero through seven spoken backwards and very rapidly by a computer.) One of these sounds was presented in a wide-band masking noise, and the other in the clear. The onset of the clear sound varied from 10 seconds before to 10 seconds after the onset of the masked sound. The subject's task was to judge whether the two sounds were the same or different.

Because an earlier experiment had shown that the bias toward saying "same" or "different" can shift as the interval between the sounds changes, the subject was required to indicate his judgment on a four-point scale of sameness or difference. In that way a Receiver Operating Characteristic could be plotted, and the effects of response bias removed by the methods traditional in signal-detection experiments.

It was found that in general, retention does indeed decrease as the interval between the sounds is lengthened. With the exception of experiments in which the subject is required to compare the pitches of two tones, this appears to be the first demonstration of decay in immediate auditory memory without a distracting task and without a selective test of retention.

It was also found, as had been expected from previous experiments, that the subject's performance is generally better when the clear sound is presented before the masked sound, rather than afterward. This is consistent with the assumption that the masked sound is a more complex event, and is therefore more difficult to retain in immediate memory.

COMPUTER SYSTEMS
GROUP 28

I. COMPUTER CENTER DEVELOPMENT

As expected, the steady improvement in the performance of the time-sharing system has attracted an increasing number of users. During the quarter fourteen more terminals have been added to the system bringing the total to twenty. Of these, three are immediately adjacent to the computer for close coordination and systems programming work. The remaining seventeen terminals are located throughout the Laboratory serving a wide variety of programmers. A batch monitor capability for the time-sharing system to complement work sessions at the terminals is being designed. When it becomes operational, it is expected to take over many of the short daytime runs now done under Operating System 360.

In the meantime, OS/360 continues to bear the major part of the Laboratory's general purpose computing load. Besides the work of preparing the latest version of this system as distributed by IBM (Version 11), Lincoln programmers have succeeded in breaking a bottleneck which limited certain tape output. By programming around the input/output system, it is now possible to stack the output (i.e., plotting, punching) of several jobs directly on a single tape instead of mounting a new one for each run. Heretofore, this has been possible only by using valuable disk space and periodic dumps to tape.

The role of the 360/40 as a peripheral support system is already well established. During this quarter it has also become an important data collection system. Information gathered by such diverse devices as a telemetry receiver, a remote computer, and a digital voltmeter is already or will very soon be sent over communications lines to the 360/40. There the Lincoln written multi-programming supervisor collects the data onto assigned tape units for further processing. This kind of operation is continuous over periods of several hours during which the primary peripheral support role of the 360/40 goes on virtually uninterrupted.

II. LISTAR (Lincoln Information Storage and Retrieval System)

Descriptive information for LISTAR files are maintained in a special file called the Master File. The LISTAR service routines for processing user files require this information to carry out their functions. Over the past quarter, the Master File and a number of the basic service routines were coded and checked out. These include routines for allocating and managing free space and routines for locating items of information in the Master Files. The group is currently writing the routines which will permit a user to create and search a new file by issuing commands from a keyboard console. The programs are being written to operate under the time-sharing system in use at Lincoln Laboratory.

RADIO PHYSICS
DIVISION 3

INTRODUCTION

This section summarizes the General Research efforts of Division 3 for the period 1 May through 31 July 1967. A substantial portion of the Division's activities is devoted to the PRESS Program, reports for which appear in the Semiannual Technical Summary Report and the Quarterly Letter Report to ARPA.

S. H. Dodd
Head, Division 3

M. A. Herlin
Associate Head

DIVISION 3 REPORTS ON GENERAL RESEARCH

15 May through 15 August 1967

PUBLISHED REPORTS

Journal Articles*

JA No.			
2883	Electron Temperature and Ion Composition in the F_1 Region	J.V. Evans	J. Geophys. Res. 72, 3343 (1967)
3064	Observations of the 94α and 148δ Hydrogen and 94α Helium Emission Line in the Orion Nebula	M.A. Gordon M.L. Meeks	Astrophysical J. 149, L21 (1967)
3098	Spectral Line Interferometry with Independent Time Standards at Stations Separated by 845 Kilometers	J.M. Moran† P.P. Crowther† B.F. Burke† A.H. Barrett† A.E.E. Rogers J.A. Ball J.C. Carter C.C. Bare†	Science 157, 676 (1967)

* * *

UNPUBLISHED REPORTS

Meeting Speeches‡

MS No.			
1927	Radar Astronomy Aperture Synthesis with Application to Lunar Studies	T. Hagfors	Spring URSI, Ottawa, Ontario, Canada, 22 – 25 May 1967
1982	Photometry of [01] λ5577 and λ6300 on a Six-Minute Time Scale Within the Southern Auroral Zone	M.A. Gordon	Conjugate Point International Symposium, Boulder, Colorado, 13 – 16 June 1967
1991	Anomalous 18 cm Absorption and Emission of Interstellar OH	M.M. Litvak§ A.L. McWhorter§ M.L. Meeks H.J. Zeiger§	American Astronomical Society, Yerkes Observatory, Williams Bay, Wisconsin, 12 – 15 June 1967

* Reprints available.

† Author not at Lincoln Laboratory.

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

§ Division 8.

SURVEILLANCE TECHNIQUES
GROUP 31

Group 31 holds operational responsibility for Lincoln Laboratory's Millstone Hill Field Station (which incorporates both the Millstone and Haystack radio/radar facilities). It also holds primary responsibility for the research program which is centered around the Station. Currently, the Millstone facility is used both as a radar for ionospheric research, observations of satellites, and measurements of precipitation backscatter, and as a large collecting aperture in radio astronomy. The Haystack facility (currently the world's most sensitive radar) is involved in observations of Mercury, Venus and Mars by radar, as well as a considerable variety of short wavelength measurements in radio astronomy. In general Millstone is used for observations below about 3 GHz (10 cm wavelength) and Haystack for those above, to a current upper limit of 15 GHz (2 cm wavelength).

An X-band radar interferometer, which is planned for deriving the reflectivity distribution over the disk of Venus, has been established between Haystack and the 60-foot antenna of the Westford Communications Terminal. An interferometer experiment operating at 1.6 GHz (the OH spectral line) and using atomic frequency standards to provide a coherent reference was successfully performed between the 120-foot Haystack antenna and the 140-foot radio telescope of the National Radio Astronomy Observatory at Green Bank, West Virginia. These measurements for the first time established the angular diameter of one of the principal OH sources as less than 0.02 second of arc. Work is continuing on the installation of a coherent interferometric capability between the Millstone Radar antenna and the 84-foot telescope which is being installed at Harvard's Agassiz Observatory.

I. GENERAL ENGINEERING

A. Millstone Radar Facility

A 10-foot diameter rigid radome has been installed behind the prime focus of the 84-foot antenna. This radome enclosure will provide a weatherproof, controlled environment for radiometer receivers. Parametric amplifiers for observations of the hydrogen line (21-cm wavelength) and the OH line (18-cm wavelength) will be installed in the near future.

The L-band radar receivers have been improved by the installation of an A. D. Little helium compressor and refrigerator to cool the 4-channel parametric amplifiers in the tracking receivers. This closed-cycle system has reduced the system temperature from 170°K ± 10°K to 145°K ± 10°K. A new calibration system has also been added to the radar receiving system. Installation of solid state receivers for the L-band system has been terminated pending re-evaluation of the function of the Millstone antenna.

There have been no significant hardware additions to the SDS 9300 computer system in the last quarter. A Doppler tracking system permitting control of the local oscillator of the radar receiver by the SDS 9300 computer has been completed. This system is similar to one developed previously at Haystack.

B. Haystack Research Facility

1. Antenna System

The Haystack antenna system has supported 615.2 hours of operation with 1.7 hours of down time during the past three months. A total of 117 hours was used for preventive maintenance.

A digital monitoring system has been constructed and installed on the azimuth hydrostatic bearing in order to provide a higher level of protection against damage to the azimuth bearing system which would be particularly serious for the Haystack antenna. The system will detect momentary failures at any of the 24 pressure pads, identify the pad, and record the antenna position. A test simulator was built to verify the performance of the monitor system.

An aluminum platform was fabricated and installed on the right antenna yoke arm at the position of the elevation bearing. This platform provides safe access to the elevation calibration inclinometer as well as the digital sensor of angular position.

The elevation gears of the antenna have been modified so the antenna may be stowed at an elevation of 7.5° to minimize the transmitter radiation at ground level. An operator will no longer be required at the antenna controls during transmitter testing on the antenna.

In preparation for rerigging of the Haystack antenna during the fall of this year, the Optics Box has been modified to improve its instrumentation and operation based on inadequacies noted during its use in August 1966. Better communication, more uniform target illumination, safer access ladders, and better isolation from vibration have been provided.

2. Transmitter System

A number of modifications and additions were made to the transmitter system: Circulators were installed in the klystron output lines to provide for future dual polarization operation and to isolate the klystrons from reflected power. Complete cleaning and calibration of the cooling water manifold was performed, and the system used to balance klystron amplitude and phase was improved. Unfortunately, klystron serial No. 2 failed and was replaced by serial No. 7 on 17 June 1967. The failure occurred when the waveguide window seal opened, allowing water to enter the tube vacuum. This again left the transmitter with two usable klystrons but no spares.

3. Receiver System

Work on the receiver system during the current reporting period was largely confined to attempting to isolate and reduce a thermal leak in the maser dewar. At the end of the quarter, however, the problem had not been resolved. The closed-cycle refrigerator which is intended to replace the batch-filled dewars was assembled, and testing will take place during the next quarter. A second maser and control unit have been successfully tested and will serve as a spare for the operational system.

4. Computer System

In the last quarter, the only significant modification to the CDC 3300 computer was a change to the 3302 storage module, which has corrected faults that occurred on some real-time data-taking programs.

C. Station Time and Frequency System

The hydrogen maser was re-installed on 24 May after it was overhauled by the manufacturer. There has been no interruption in its operation or the phase-lock of the Station crystal oscillator since that time.

II. SPACE SURVEILLANCE

A. Computer-Aided Tracking

Millstone Hill's non-real-time orbit fitting program (NRTPOD) was brought into operational status on the SDS 9300 computer early this quarter. Coefficients for the zonal and tesseral gravitational harmonics have been modified to conform to the standard earth model used by SPACETRACK as of August 1966. Previously recorded satellite observations are being fitted to determine optimum parameter values for the currently operating version of MHESPOD, [Millstone's real-time orbit fitting program] to permit computer steering in angle and in Doppler. Only Millstone observations in range, azimuth, elevation, and range-rate have been used in this study, and when data are restricted to a segment of a single pass, the weighted least-squares criterion used by the program to minimize residuals has been found generally inadequate to assure fitting of the correct orbit, even though convergence has been obtained. The effect on the growth of residuals subsequent to the fitted portion of an orbit can be quite serious. Accordingly, attention has been focused on the acquisition and study of multi-pass data, where the consistency of a first-pass fit can be tested against subsequent observations using the more sophisticated force-model and convergence logic employed in NRTPOD. A similar approach using all of the data at hand is providing improved estimates of the appropriate bias corrections and standard deviations in the Millstone measurements.

B. Tracking Support

Tracking operations devoted to the MITRE/Millstone radar-interferometer development were conducted approximately one full day per week. Tracking on a regular basis of objects selected by the Space Defense Center was suspended this quarter so that a larger effort could be put into equipment upgrading and development. During April and May a number of tracks on the OGO 2 satellite were made to assist NASA in a precise orbit determination while satellite experiments were in progress. Several tracks were made on the Lincoln Calibration Sphere (LCS) for orbit updating at the request of the Arecibo Ionospheric Observatory.

III. LUNAR STUDIES

A. Polarization and Mapping Studies at 23 cm

The coherent analysis program that was developed for general lunar ("unambiguous") mapping at L-band has been used in the current period to map the depolarization of the echoes over the lunar surface. During these measurements the transmitter was circularly polarized and the returns were studied both in orthogonal circular and orthogonal linear polarizations.

B. High Resolution Radar Studies at 3.8 cm

No further observations at 3.8 cm were made during the current reporting period. Attention has been devoted to the reduction of those data taken in previous months. By the end of the current reporting period over 50 percent of the data were mapped in a form suitable for presentation in the final NASA report. The main difficulties involved interpretation of departures from the lunar ephemeris. When these departures are better understood, they will provide information that may improve the lunar ephemeris. The ephemeris difficulties, however, do not appear to compromise the data for the purposes required in fulfilling the NASA contract.

IV. PLANETARY STUDIES

A. Radar Observations at 3.8 cm

During this reporting period, the planets Mercury and Venus were observed approximately twice weekly (except while the radiometer box was on the Haystack antenna, 7 June – 7 July) for the determination of the precise round-trip echo delay. During the period surrounding the superior conjunction of Mercury, approximately 9 May, observations of this planet were made on an almost daily basis for 18 days in an attempt to improve further the so-called Fourth Test of General Relativity. Mars was observed at approximately one week intervals from 7 April to 2 June with an additional point in the latter part of July. These data appear to yield measurements of delay accurate to 5 μsec and will be extremely useful to upgrading the Martian orbit. From the individual runs made during the course of an evening, it has been possible to infer height variations on the surface of Mars to an accuracy approaching 1 kilometer. These results should be of considerable interest in planning for the Mariner and Voyager programs.

In this area the major improvement in techniques during the current reporting period lay in the programming of a much-shorter-baud-length configuration. This will enable the use of an equivalent pulse length of 24 μsec instead of the 60 μsec used previously. These data should permit greatly improved accuracy in the determination of round-trip echo delay to Mercury and Venus when the signals from these planets are sufficiently strong.

B. Preparations for Interferometric Studies of Venus at 3.8 cm

The Westford and Haystack antennas are currently being connected as an interferometer to enable the mapping of the radar reflectivity of Venus at 3.8 cm. Two different types of experiments are being attempted. In the first, a simple CW mode, the received signals are resolved into spectra with a 1-Hz filter width to provide a resolution of the planet into strips parallel to the rotation axis. The additional information derived from the interferometric observations will then be used to determine the power distribution along each strip. In the second, a phase-coded CW mode, delay-Doppler mapping will be carried out with a delay-resolution of 500 μsec (31 delays) and a Doppler resolution of 1 Hz (64 filters). The additional interferometric information will be used to resolve the ambiguities in the delay-Doppler maps otherwise present in this mode.

The interferometer requires local oscillator coherence between the two stations as well as an analogue signal return to Haystack where the data processing is carried out. The reference signals for this purpose are transmitted over a cable whose electrical length is maintained

constant by closed-loop servo control using a modulation-reflection method. The IF signals from both sites, after phase detection and digital conversion, are transferred in real time to the CDC 3300 computer. Here, in the simple CW mode, a digital phase correction is applied in real time, followed by spectral analysis. The complex spectra are stored on magnetic tape for non-real time analysis. In the phase-coded mode only the decoding operation takes place in real time. The phase correction and subsequent spectral analysis is planned for non-real time operation.

V. ATMOSPHERIC STUDIES

A. Thomson Scatter

The plans for the UHF two-pulse system formulated during the previous quarter are now being implemented. The components necessary for this system have been ordered and are mostly on hand, but much remains to be done. Debugging of the computer program which will obtain the power spectrum of the Thomson scatter signal by digital analysis is nearly complete as are modifications to the ionospheric data-gathering program to record data samples on magnetic tape for subsequent spectral analysis.

B. Auroral Studies

Additional spectral analysis of the auroral data have provided spectra at several ranges within a given cluster of echoes. While interpretation of the spectra continue to support the Farley-Bowles theory of an auroral electrojet, the frequent occurrence of both positive and negative Doppler shifts within the same echo indicates the need for further development of the theory.

VI. RADIO ASTRONOMY

A. Instrumentation

The principal effort in radiometric instrumentation during the present reporting period has been to design and construct local oscillator systems, video converters, and digital recording circuitry for the very-long-baseline interferometer experiment between Haystack and the 140-foot antenna of the National Radio Astronomy Observatory at Green Bank, West Virginia. The purpose of this interferometer experiment was to determine the angular size of the bright OH emission regions. The experiment used independent atomic frequency standards to generate the local oscillator signals at each antenna. The video output from each radio telescope was digitized and recorded; subsequently the signals from the two stations were correlated in a digital computer to search for fringes.

Additional hardware developments at Haystack involved the first use of the new multiple feed support for the Radiometer Box, installation of an improved parametric amplifier for OH observations, and development of a 35-GHz radiometer, which will be used to evaluate the rerigging of the Haystack antenna. Work on the phase-stable Millstone-Agassiz interferometer system was delayed because of the long-baseline experiment. However, the scientific importance of the short-baseline system is by no means diminished by the success of the long-baseline experiment.

The Radiometer Box was operated on the Haystack antenna from 7 June through 1 July. Because of difficulties with the maser dewar the Planetary Radar Box could not be used for radio astronomy during this quarter.

B. Spectral Line Observations

The interferometer observations between Haystack and NRAO were successful and set an upper limit of 0.02 second of arc on the angular size of the OH emission from the source W3. Subsequently on 24 and 26 July the terminal hardware for the spectral line interferometer was used for observations over an even longer baseline between Green Bank and the antenna at Hat Creek, California (operated at the Berkeley Campus of the University of California). Fringes were again seen, and some of the W3 emission features were resolved at about 0.004 second of arc. Other spectral line observations at Haystack were confined to observations of the OH source in NGC6334 which is continuing to show time variations.

C. Continuum Observations

The observational program to measure time variations in the radio emission from quasi-stellar sources at 3.7-cm and 2-cm wavelength was continued during this period.

VII. SPACE COMMUNICATIONS

A. Propagation Studies

1. Instrumentation Progress

The instrumentation for studies of the effects of precipitation on X-band propagation paths consists of:

(a) An FPS-18 radar which has been installed in the Millstone Warehouse. This is an S-band radar used for weather surveillance with remote display in the control rooms at Millstone and Westford.

(b) The Millstone L-band radar, modified to permit quantitative observations of echoes from precipitation.

(c) The existing 8-GHz radiometric system on the Haystack antenna and on the cornucopia horn antenna. These systems have been used without modification to measure emission from precipitation.

2. Observations

The equipment and data processing programs for the propagation studies were completed during the last quarter and observations have begun. The only remaining problem is to complete the overall calibration of the system. Investigation of ground-clutter effects reveals that the radar can be used to make quantitative measurements of rain intensity at ranges between 40 and 200 kilometers without problems resulting from masking by ground clutter.

Measurements of summer rain showers were made on eight days during the month of July. The data are now being analyzed, but preliminary results indicate that scale sizes of interest for the study of rain attenuation statistics are much smaller than the resolution of the radar system. The statistical uncertainty in the measurement of the backscatter cross section per unit volume of precipitation appears to be better than 1 db rms which is an improvement over most other weather radars. Measurements with the Haystack radiometer system were made on three of the eight days. These measurements have not been completely analyzed, but preliminary results show good agreement with predictions based on the weather radar data.

RADAR
DIVISION 4

INTRODUCTION

The Division 4 General Research activities in the period 1 May through 31 July 1967 are summarized in this section. The principal activities of the Radar Division are described in reports on RDT, PRESS, and BMRS. Other smaller programs are described in reports on Space Communications and Radar Studies of the Moon. The General Research activities in Division 4 are carried out by Group 46 and deal primarily with advanced instrumentation for high-performance microwave components.

J. Freedman
Head, Division 4

H. G. Weiss
Associate Head

MICROWAVE COMPONENTS
GROUP 46

I. INTRODUCTION

Group 46 contributes to the radar program through direct participation in specific projects, and through a program of general research which is closely related to the microwave requirements arising from radar projects. Contributions are made to the General Research Program through the support of Haystack Hill, operation of a high-power microwave laboratory, development of low-noise receiver techniques, studies of very-high-gain antennas and antenna feeds, and participation in a millimeter-wavelength program. The latter is reported separately under Radar Studies of the Moon.

II. HAYSTACK MICROWAVE COMPONENTS

A. Planetary Radar (PR) Box

The four high-power circulators have been installed and operated at power levels up to 300 kW CW. An improvement in the balance of the four high-power RF channels has resulted.

B. Model Study of an L-Band Feed

An appropriately scaled Clavin feed was tested in the 1/20 scale model of the Haystack antenna. The radiation patterns were quite good, but the overall gain was down 1.5 to 2.0 dB from a 55 percent aperture efficiency criterion. These results were generally in accord with those previously obtained at Haystack.

A good deal of effort was expended in investigating the causes of this gain loss. It became clear that the Clavin feed does not appear to have discrete and coincident phase centers in both E- and H-planes. Consequently, defocussing for operation in the near field is not straightforward, since it would tend to favor either the E-plane or the H-plane at the expense of the other plane. Unlike the horn-lens combination reported previously, the direction of defocussing was consistent with conventional near-field measurements, but the amount of defocussing was much smaller than expected.

Another difficulty with the Clavin feed arises from its lack of flexibility. The primary beamwidth cannot be adjusted over any meaningful range, and this results in substantial primary spillover with the present Haystack geometry.

For purposes of comparison, a simple focal point feed was substituted for the Clavin feed in the scaled version of the 90-inch paraboloid which illuminates the subreflector at Haystack. The radiation patterns were good, and the gain was equal to or even higher than that obtained with the Clavin feed. Since such a feed is very simple, very broadband, very flexible, and capable of polarization diversity, it will be investigated further and compared with the Clavin feed. However, aperture blockage (of the 90-inch dish) will undoubtedly reduce the efficiency of this feed compared to that attainable with a far-field Cassegrainian geometry.

C. Masers

The second maser has been operated at the Haystack facility. This unit will be used as a back-up for the maser prcsently employed in thc PR Box. Dewar problems have made it impossible to operate for periods longer than 4 hours on a fill of liquid helium.

The third maser has been integrated into the Air Products and Chemieals, Inc. closed-cyele helium refrigerator. The unit has been completely evaeuated and is ready for eool-down. Operation of this maser is expeeted during the next reporting period.

Plans are being made to broadband the waveguide-to-coaxial line transitions used in the maser located in the PR Box. With broadband transitions, operation should be possible over a 20 percent frequency band.

III. SOLID-STATE COMPONENTS

A. X-Band Parametric Amplifiers

A WR-112 waveguide-to-coaxial line transition has been designed whieh permits the appliea-tion of a bias voltage to the center conductor of the coaxial line. The transition was designed to permit the use of laboratory-designed X-band parametrie amplifiers with waveguide circulators. Two prototype units exhibited insertion losses of less than 0.1 dB and VSWR's of less than 1.08 over the frequency range from 7.0 to 8.5 GHz. Electroformed versions will be made in order to reduce both the size and the loss.

B. Diode Measurements

The design has been completed for a thirty-ineh diameter, radial transmission-line eavity, whieh will be used to measure the impedance of paekaged varactor diodes at frequeneies from about 6 to 40 GHz. When finished, this instrument should provide the information necessary to evaluate the equivalent eireuits of packaged diodes.

Diode test fixtures are being fabricated which will permit the mcasurement of varactor diode eutoff frequeneies at 35, 45, 55, 70, and 100 GHz.

C. Power Combiners

The eoaxial power eombiner whieh uses 18 puneh-through varaetors has been completed. It has been tested as a large signal doubler from 500 to 1000 Mlz with a 40-watt input, and found to have about the same effieieney as a single diode doubler operating with the same eireuitry and 1/18 the input power. When a new diplexer capable of higher power operation has been eonstrueted, the coaxial power eombiner will be tested with input power levels up to about 300 watts.

The design of the higher-frequency version power-eombiner mentioned in the preceding report* is being revised in the light of experience gained with the eoaxial power eombiner.

IV. MISCELLANEOUS

A. Test Sets for Measurement of Very Low Insertion Losses

Parts have bcen procured and assembly is proceeding on two insertion loss test sets, which have been described in previous reports. One of these will be used in the development of low noise receivers and the seeond will be available for general use within the Group.

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*General Research Quarterly Technical Summary, Lincoln Laboratory, M.I.T. (15 May 1967, DDC 653862).

ENGINEERING
DIVISION 7

INTRODUCTION

The Engineering Division presently supports the Laboratory's General Research Program by designing and fabricating mechanical components for the Haystack and Millstone Hill research facilities, and by its involvement in the design studies of the CAMROC radio telescope.

In the quarterly period ending 31 July, a new multifeed section was installed on the front end of the Haystack radiometer box, and work continued on the development of a closed cycle helium refrigerator for the maser system. At Millstone Hill, the installation of a hemispherical equipment shelter above the secondary reflector has continued, while major waveguide revisions were being made at the 220-foot zenith-pointing antenna.

Design effort in support of the CAMROC project to build a 440-foot diameter steerable radio/radar telescope in New England is concentrated on refining details of the parabolic antenna, its supporting structure, and its enclosing radome. The work is both analytical and experimental.

J. F. Hutzenlaub
Head, Division 7

MECHANICAL ENGINEERING
GROUP 71

I. HAYSTACK

A. Radiometer Box

The radiometer box was mounted at the center of the 120-foot antenna in mid-June with a new cylindrical multifeed front section. Five fixed reflectors were mounted on the front face of this section and, in addition, a 90-inch diameter L-band reflector was positioned on a track in front of the fixed reflectors. This L-band reflector can be stowed to one side mechanically when not in use.

B. Maser

The second maser has been assembled and is undergoing evaluation tests. The unit is to operate in a batch dewar. The dewar is on hand, but is plagued by a low temperature helium leak from the liquid helium container into the vacuum space. Steps are being taken to correct this condition.

The third maser has been integrated into the closed cycle refrigerator, and will be system tested during September 1967.

II. MILLSTONE

A. 84-Foot Diameter Antenna

1. Apex Equipment Enclosure

A 10-foot-diameter hemispherical equipment enclosure has been mounted on the apex platform above the secondary reflector. This insulated fiberglass radome, having a personnel door accessible from the spar ladder, will house equipment used in interferometer experiments. A 3-ton chiller, mounted on the front azimuth platform, will be used with strip heaters and controls to maintain a suitable operating temperature inside the enclosure.

2. Parametric Amplifiers

The four L-band parametric amplifiers which have been operated at near-liquid nitrogen temperatures have been retrofitted with a closed cycle refrigerator for 26 °F temperature operation.

B. 220-Foot Zenith Antenna

Installation is continuing on a WR-2100 waveguide receive-line from the antenna to the transmitter building. A second duplexer has been installed in a newly completed addition to the existing equipment enclosure located under the antenna. Completion of the installation is scheduled for September.

A 14-foot diameter by 6-foot high conical screen is being fabricated for installation around the horn to reduce expected ground clutter on the two-pulse UHF system. In addition, a 4-foot

wide nylon space net will be mounted on the inside of the three spars in an effort to absorb suspected ground clutter as a result of spar reflections. The net assembly will be hoisted into position by means of guide wires and a pulley arrangement whenever clutter interference is detected.

III. SOLID STATE

A. High Pressure X-Ray Camera

A camera has been developed with which studies of materials can be performed under controlled pressure and temperature conditions. Pressures are generated between two diamond anvils and the temperature of the material is controlled by radiation from a heater block. The maximum temperature obtained so far is 225 °C, although temperatures up to 500 °C are feasible.

B. Optical Cell

Microscope studies of the behavior of material under pressure are possible with this device. An arm and lever system transfers the load to the diamond anvil windows.

IV. CAMROC

A. Radome Studies

1. Structural

Studies of the capability of the membranes to provide support against buckling in a plane tangent to the surface of the radome have continued. Calculations have indicated that for some typical beam properties, the membrane provides considerable support. The use of fiberglass ropes to provide additional support for the beams has been found to be less attractive than the membrane alone because of the number and size of the ropes and the difficulty of attaching them to the beams.

Experiments are currently being planned to check the calculations and to provide a full scale evaluation of the structural capability of the beam-membrane combination.

2. Computer Program

Use of the STAIR computer program for structural analysis has continued. Data for a third radome geometry which has an average beam length of 28 feet (compared to the original design of 55 feet) have been prepared for use with the STAIR program. The resulting data will be used in the beam design program to obtain the optimum beam sizes. In addition, a supplementary program has been prepared which utilizes the equivalent shell technique to obtain the axial loads in each beam. This program has also been used to make approximate studies of the effect on beam sizes resulting from a change in the internal pressure in the radome. The preliminary results that have been obtained thus far indicate that some decrease in beam size is possible with an internal pressure.

3. Radome Configurations

Studies have continued to determine the optimum truncation for the sphere-cone combination. Preliminary calculations indicate that the use of a truncated cone between 15 ° and 30 ° below the

equator is attractive. Data have been prepared for a STAIR run for a space frame geometry which includes a conical base truncation. It is also planned that buckling calculations will be made on this configuration using the nonlinear buckling program prepared by Simpson, Gumpertz & Heger together with the M.I.T. Civil Engineering Department. When these data become available, it is expected that a final selection of the basic geometry will be made.

4. Instability

a. Analytical

The computer program for nonlinear buckling analysis of space frames has been used to compute the buckling load on the experimental radome model which has been tested recently at the M.I.T. Aeroelastic and Structures Research Laboratory. Preliminary evaluation of the results has indicated reasonable agreement with the experimental data. The documentation of the program and its results is presently being worked on. It is expected that further modification of the program will include the effects of distributed load along the beam and the effects of the restraining action of the membrane.

b. Experimental

A spherical, random geometry, space frame section 14 feet in diameter with a central angle of 104° has been designed, fabricated and instrumented at the M.I.T. Aeroelastic and Structures Research Laboratory. Buckling tests and preliminary data reduction have been carried out for comparison with analytical results as noted above. Documentation of the test is currently under way.

B. Antenna Studies

The Hammerhead 440-foot diameter antenna configuration now being studied includes important innovations when compared to the previous Hammerhead design. The most significant of these is the use of central elevation bearings placed inside the boom instead of the hydrostatic pads and large diameter tracks described previously. A more efficient structural system for the vertical trusses is made possible by the elimination of the large open ring that formerly encircled the Hammerhead, and this has produced a further reduction of weight and improvement of deflection control. Furthermore, it is possible to bring the reflector surface closer to the elevation axis and reduce the counterweights. All of these improvements have reduced the weight and estimated cost.

At each vertical truss location, the transverse members of the Hammerhead boom are made double and spaced approximately 18 inches apart to allow the vertical trusses to rotate between them. The chord members of the Hammerhead truss are connected through this 18-inch space by short, stiff members that carry the shear loads. The configuration of these chord members with the "spoke" members of the vertical trusses limits the elevation travel to 85°, and the buffer stops (which may be bypassed) impose another 2 1/2° limitation at each extreme of travel.

C. Surface Panels

In the Hammerhead antenna concept, the surface panels and purlin trusses are not deflection compensated and do not contribute structural stiffness via shell action. Their dead weight

is the major contributor to gravity deflections and stresses in the supporting structural components. Lightweight panels, therefore, are a prime requisite for an economic design of this type.

To reduce the number of different types of surface panels required for the reflector, a configuration was established having sides of equal length so that identical panels could be used in all of the quadrants of the reflector.

D. Purlin Trusses

The purlin trusses are triangular space frames approximately 14 feet on a side, spanning 56 feet horizontally between vertical trusses. They will be spaced 14 feet apart so that the surface panels will span between members of each purlin truss (14 feet) and between the purlin trusses themselves (14 feet). The deflections of a purlin truss, including effects of chord bending, were calculated for loadings corresponding to the orientations that occur in different parts of the structure and to different antenna elevations. The deflections at panel support points perpendicular to the reflector surface were computed and the largest was found to be approximately 0.05 inch; of this the contribution due to chord bending was computed as 0.01 inch.

E. Vertical Trusses

There are eight vertical trusses in the reflector backup structure. These planar trusses are spaced uniformly 56 feet apart along the Hammerhead truss and rotate about it in concert.

Each truss was analyzed by means of a computer program several times, incorporating variations of member areas and joint configuration. Gravity loads from surface panels, purlin trusses, and vertical truss members were applied at the joints of the vertical trusses, and deflections of the joints were computed for several elevation angles of the reflector. From this output of the computer, the changes in deflection as a function of elevation angle were computed.

All of the vertical trusses are now being optimized by a computer program that performs the following steps:

(1) Optimizes center sections of each truss with respect to rms error of surface.

(2) Determines the best fit paraboloid of all center sections.

(3) Optimizes tip sections to deflect into a shape fitting the paraboloid described in Step 2.

(4) Derives the optimum compensation as a function of elevation angle to provide the invariant paraboloid.

As the structural optimization program was applied to the vertical trusses, the rms of the displacements of the truss joints with respect to a best fit paraboloid was decreased substantially from 0.027 to 0.007 inch for face up and 0.030 to 0.004 inch for face side attitudes. The program will be employed to further optimize the trusses after some changes in their topology are made.

F. Torque Tube

The torque tube is a space frame, square in section, connecting the vertical trusses so that they rotate together in elevation. The size of the square cross section is such that it can rotate about the square Hammerhead truss.

The torsional stiffness of the torque tube was established so that elevation drives would be required only at the inboard trusses. When the elevation drives change speed, the acceleration forces will twist the torque tube, and this wrap-up will rotate the outboard trusses with respect to the antenna surface and produce a surface distortion at their tips.

Computer analysis indicates that the maximum truss displacement due to wrap-up of the torque tube with $0.02\,°/sec^2$ acceleration in elevation is 0.025 inch. The rms surface error resulting from this maximum 0.025 inch is well within allowable values.

The natural frequency of the vertical truss connected via the torque tube to an assumed infinitely stiff elevation drive is about 0.7 cps.

A technique for optimizing the distribution of torsional stiffness to maximize the lowest natural frequency of the torque tube has been devised. Preliminary calculations indicate that the preliminary design is near this optimum.

G. Hammerhead Truss

As for the case of the torque tube, the design is governed by the frequency requirements. A preliminary design of the Hammerhead truss has been made, and at present the sections where the vertical trusses are supported are being investigated.

CONTROL SYSTEMS
GROUP 76

I. HAYSTACK

Work has started on dividing the single pump hydraulic supply into a multiple pump system. The purposes are to eliminate hydraulic cross-talk between the hydraulic subsystems, to provide a firm limit of maximum antenna speed during control malfunction, to provide for more positive replenishing to protect motors during cavitation, and to reduce the volume of oil under compression in the servo valve-to-motor transmission lines. Planning is approximately 80 percent complete and the basic multiple pump packages are on order.

The first round of hydro-mechanical changes to the Laboratory-designed servo valve has been completed, and the first stage has been tested. First stage pressure versus current relations indicate a pressure discontinuity in the vicinity of the null operating region. This unexpected discontinuity is a function of oil viscosity and appears to be related to jet laminar-to-turbulent flow transition, effective jet cross section change and momentum transfer change as seen by the flapper.

Rerigging of the reflector has been scheduled for 7 weeks beginning the last week in September. Contracts for technical backup have been made with Simpson, Gumpertz & Heger, and North American Aviation. The actual rerigging will be performed by Laboratory personnel. Preliminary preparations of the optics box and related equipment are now in progress.

Scale testing of the photographic measurement system has been completed. The system is now ready for full scale implementation and testing.

II. MILLSTONE

Manufacture of an analog celestial-to-terrestrial coordinate converter for the Millstone Radar was completed. Preliminary tests indicate that the design goal of 0.01° (one sigma) accuracy has been achieved. This machine will be installed at Millstone early in August.

III. CAMROC

Analysis leading toward design of the CAMROC control system continues. Special attention is being given to such effects as that of air upon the apparent inertia of the antenna. This effect, small and masked by the torques required to overcome wind, windage, and mechanical inertia in smaller or outdoor reflectors, may prove significant in CAMROC because of the very light structure and the large volume of air displaced.

SOLID STATE
DIVISION 8

INTRODUCTION

This section summarizes the work of Division 8 from 1 May through 31 July 1967. A more detailed presentation is covered by the Solid State Research Report for the same period.

A. L. McWhorter
Head, Division 8

P. E. Tannenwald
Associate Head

DIVISION 8 REPORTS ON GENERAL RESEARCH

15 May through 15 August 1967

PUBLISHED REPORTS

Technical Notes

TN No.				DDC and Hayden Nos.
1967-15	A Theorem on Spin-Eigenfunctions	T. A. Kaplan W. H. Kleiner	24 May 1967	DDC 652840 H-849

Journal Articles*

JA No.			
2602	Introduction to the Theory of Exciton States in Semiconductors	J. O. Dimmock	Semiconductors and Semimetals, Vol. 3 (Academic Press, New York, 1967)
2811	Superconducting Transition Temperature and Electronic Structure in the Pseudo-binaries Nb_3Al-Nb_3Sn and Nb_3Sb-Nb_3Sb	F. J. Bachner† J. B. Goodenough H. C. Gatos†	J. Phys. Chem. Solids 28, 889 (1967)
2850	High-Temperature Expansions for the Classical Heisenberg Model. I. Spin Correlation Function	H. E. Stanley	Phys. Rev. 158, 537 (1967)
2891	New Phase Transformation in InSb at High Pressure and High Temperature	M. D. Banus M. C. Lavine	J. Appl. Phys. 38, 2042 (1967)
2900	Quantum Kinetic Equations for Electrons in Random Impurities	P. N. Argyres E. S. Kirkpatrick†	Ann. Phys. 42, 513 (1967)
2907	High-Temperature Expansions for the Classical Heisenberg Model. II. Zero-Field Susceptibility	H. E. Stanley	Phys. Rev. 158, 546 (1967)
2909	High-Pressure Study of the First-Order Phase Transition in MnAs	J. B. Goodenough J. A. Kafalas	Phys. Rev. 157, 389 (1967)
2941	Retrograde Solubility in n-Type PbS	A. J. Strauss	Trans. Met Soc. AIME 239, 794 (1967)
2955	Photo and Thermal Effects in Compensated Zinc-Doped Germanium	R. J. Keyes	J. Appl. Phys. 38, 2619 (1967)

* Reprints available.
† Author not at Lincoln Laboratory.

JA No.			
2962	GaAs-InSb Graded-Gap Heterojunction	E. D. Hinkley R. H. Rediker*	Solid-State Electron 10, 671 (1967)
2963A	Inversion of Conduction and Valence Bands in $Pb_{1-x}Sn_xSe$ Alloys	A. J. Strauss	Phys. Rev. 157, 608 (1967)
2967	Landau Damping of Magneto-plasma Waves for General Closed Fermi Surfaces	A. L. McWhorter J. N. Walpole*	Phys. Rev. 158, 719 (1967)
2968	Nonlocal Effects in Low-Field Helicon Propagation in PbTe	J. N. Walpole* A. L. McWhorter	Phys. Rev. 158, 708 (1967)
2975	Report on the Seventh International Conference on the Physics of Semiconductors	B. Lax* J. G. Mavroides	Phys. Today 20, 101 (1967)
2978	Magnetoplasma Cyclotron Absorption in PbSe	S. Bermon	Phys. Rev. 158, 723 (1967)
2993	Magnetic and Structural Study of the Spinel $MnYb_2S_4$	J. M. Longo P. M. Raccah	Materials Res. Bull. 2, 541 (1967)
2994A	Stability Measurements of CO_2-N_2-He Lasers at 10.6μm Wavelength	C. Freed	IEEE J. Quant. Electron. QE-3, 203 (1967)
3018	Growth of Single Ti_2O_3 Crystals from the Melt	T. B. Reed R. E. Fahey J. M. Honig	Materials Res. Bull. 2, 561 (1967)
3023	Laser Emission from Electron Beam Excited ZnTe	C. E. Hurwitz	IEEE J. Quant. Electron QE-3, 333 (1967)
3026	Stimulated Raman Scattering in an Infrared Active, Nontotally Symmetric Vibration of α-Quartz	P. E. Tannenwald D. L. Weinberg*	IEEE J. Quant. Electron QE-3, 334 (1967)
3052	Low-Energy Interband Transitions and Band Structure in Nickel	J. Hanus J. Feinleib W. J. Scouler	Phys. Rev. Letters 19, 16 (1967)
MS-1629A	Narrow Band Electrons in Transition-Metal Oxides	J. B. Goodenough	Czech. J. Phys. B17, 304 (1967)

UNPUBLISHED REPORTS

Journal Articles

JA No.			
3021	Localized vs Collective d Electrons and Néel Temperatures in Perovskite and Perovskite-Related Structures	J. B. Goodenough	Accepted by Phys. Rev.

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JA No.			
3025	InSb-GaAsP Infrared to Visible Light Converter	R. J. Phelan, Jr.	Accepted by Proc. IEEE
3066	Magnetic Interactions and Spiral Ground States in Spinels, with Application to $ZnCr_2Se_4$	K. Dwight N. Menyuk	Accepted by Phys. Rev.
3068	Theory of the Magnetic Properties of the Ilmenites $MTiO_3$	J. B. Goodenough J. J. Stickler	Accepted by Phys. Rev.
3069	Magnetic Resonance and Susceptibility of Several Ilmenite Powders	J. J. Stickler G. S. Heller* S. Kern* A. Wold*	Accepted by Phys. Rev.
3070	Tetrahedral-Site Copper in Chalcogenide Spinels	J. B. Goodenough	Accepted by Solid State Commun.
3074	A 10.6 Micron 4 Port Circulator Using Free Carrier Rotation in InSb	J. H. Dennis	Accepted by J. Quant. Electron.
3076	Spark Source Mass Spectroscopy	E. B. Owens	Accepted by 1968 McGraw-Hill Yearbook of Science and Technology
3080	Current Runaway and Avalanche Effects in n-CdTe	M. R. Oliver A. L. McWhorter A. G. Foyt	Accepted by Appl. Phys. Letters
3085	Observation of Exciton Fine Structure in the Interband Magneto-absorption of InSb and Germanium	E. J. Johnson	Accepted by Phys. Rev. Letters
3086	The Gunn Effect in n-CdTe	M. R. Oliver A. G. Foyt	Accepted by IEEE Trans. Electron Devices
3087	Inversion Asymmetry Effects on Oscillatory Magneto-resistance in HgSe	L. M. Roth* S. H. Groves P. W. Wyatt*	Accepted by Phys. Rev. Letters
3090	New Expansions for Classical Heisenberg Model and Similarity to S = 1/2 Ising Model	H. E. Stanley	Accepted by Phys. Rev.
3091	Electroreflectance Study of Interband Magneto-Optical Transitions in InAs and InSb at 1.5°K	C. R. Pidgeon* S. H. Groves J. Feinleib	Accepted by Solid State Commun.
3097	Perturbation Calculation of Band Structure Effects in Low-Field Helicon Propagation	A. L. McWhorter J. N. Walpole*	Accepted by Phys. Rev.

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Meeting Speeches*

MS No.			
1629D	Structure and Magnetism in Transition Metal Compounds	J. B. Goodenough	Seminar, Worcester Polytechnic Institute, 15 May 1967
1747A	On the Possible Phase Transitions for Two-Dimensional Heisenberg Models	H. E. Stanley	Seminar, Case Institute of Technology, 19 – 23 June 1967
1896	A Carbon Dioxide Laser Radar System	H. A. Bostick	Conference on Laser Engineering and Application, Washington, D. C., 6 – 9 June 1967
1913	Stability Measurements of CO_2-N_2-He Lasers at 10.6 μm Wavelength	C. Freed	
1916	Autotracking of Satellites from the Ground Through 8 – 12 μm Atmospheric Window	P. R. Longaker J. H. Dennis R. J. Keyes	National Infrared Information Symposium, San Francisco, 17 – 19 May 1967
1919A	Properties and Applications of Small-Bandgap $Pb_{1-x}Sn_xTe$ and $Pb_{1-x}Sn_xSe$	I. Melngailis	Seminar, NASA Electronic Research Center, Cambridge, Massachusetts, 31 May 1967
1950	Structural and Magnetic Consequences of Peculiar Chemical Bonding in $PbRuO_3$ and FeRh	J. B. Goodenough	International Symposium on Problems of Chemical Bonding in Semiconductor Crystals, Minsk, U.S.S.R., 28 May – 3 June 1967
1963A	Quantum Kinetic Equations for Electrons in Random Impurities	P. N. Argyres	U. S. Naval Ordnance Laboratory, Silver Spring, Maryland, 16 May 1967
1971	Mode Structure in a Resonant Raman Oscillator	P. E. Tannenwald	American Physical Society, Toronto, Canada, 21 – 23 June 1967
1972	Wide Range Continuously Tunable High Power Sum Frequency Generation	R. L. Carman	
2007	Dynamics of Intense Light Beams in Nonlinear Media	P. L. Kelley	
1976A	The Evolution of Intense Short Pulses in Nonlinear Optical Media	T. K. Gustafson† F. DeMartini† C. H. Townes† P. L. Kelley	Electron Devices Research Conference, McGill University, 21 – 23 June 1967
1999	Thermodynamics of Optical Pulse Interactions	H. A. Haus† P. L. Kelley T. K. Gustafson†	

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

† Author not at Lincoln Laboratory.

MS No.			
1980	Modern High Pressure Techniques	J. A. Kafalas	High Pressure Treatment of Materials, ManLabs, Incorporated, Cambridge, Massachusetts, 18 – 19 May 1967
2015	Survey of Equipment for High Pressure Studies	M. D. Banus	
2016	Retained High Pressure Phases and High Pressure Synthesis	M. D. Banus	
1986	$Pb_{1-x}Sn_xSe$ Diode Lasers	J. F. Butler T. C. Harman	Solid State Device Research Conference, University of California, 19 – 21 June 1967
1987	Photovoltaic Response of $Pb_{1-x}Sn_xSe$ Diodes	A. R. Calawa I. Melngailis T. C. Harman J. O. Dimmock	
1989	Epitaxial Gallium Arsenide for Gunn Effect Oscillators	C. M. Wolfe A. G. Foyt W. T. Lindley	
1991, 1991A	Anomalous 18 cm Absorption and Emission of Interstellar OH	M. M. Litvak	Seminar, M.I.T., 2 June 1967; American Astronomical Society, Yerkes Observatory, Williams Bay, Wisconsin, 12 – 15 June 1967
1996A	Electron-Beam-Pumped Lasers of of II-VI Compound Semiconductors	C. E. Hurwitz	Seminar, IBM Watson Research Laboratory, Yorktown Heights, New York, 16 June 1967
2023	Electron Band Structure Studies Using Differential Optical Techniques and High Magnetic Fields	J. G. Mavroides	Physics of Solids in Intense Magnetic Fields, Crete, Greece, 16 – 29 July 1967
2025	Magnetospectroscopy	J. G. Mavroides	Seminar, Demokritos Athens, Greece, 31 July 1967
2032	Plasmas for Material Preparation and Crystal Growth	T. B. Reed	Summer Course in Crystal Growth, M.I.T., 10 – 21 July 1967
2033	Vapor Growth of Crystals	T. B. Reed	
2039	High-Temperature Expansion of the Zero-Field Susceptibility for the Classical Heisenberg Model	H. E. Stanley	School of Physics, Santiago, Chile, 17 – 28 July 1967
2065	Conduction Processes in Oxides	J. B. Goodenough	Gordon Conference, Andover, New Hampshire, 17 – 21 July 1967
2067, 2067A	High Pressure Studies on Some Intermetallic Compounds and Defect-Structure Metallic Oxides	M. D. Banus	Batelle Memorial Institute, Richland, Washington, 1 August 1967; Lawrence Radiation Laboratory, University of California, 3 August 1967

* Author not at Lincoln Laboratory.

SOLID STATE
DIVISION 8

I. SOLID STATE DEVICE RESEARCH

The variation of detection efficiency with junction depth was determined for two $Pb_{0.933}Sn_{0.067}Se$ photovoltaic detectors. The minority carrier diffusion length was determined from this variation to be 3 and 4 μ for the two detectors. Response speeds ranging from less than 5 nsec to 100 nsec were determined for several $Pb_{1-x}Sn_xSe$ detectors. The diode capacitance was typically 2000 pf/mm^2 and the RC time constant ranged between 1 and 5 nsec indicating that the response speed of most detectors is not RC-limited. Photovoltaic response has been observed at temperatures as high as 195°K in several $Pb_{1-x}Sn_xSe$ detectors. The peak response decreased by about a factor of 20 below that determined at 12°K and 77°K.

$Pb_{1-x}Sn_xSe$ diode lasers have been fabricated with output powers as high as 80 mW and external quantum efficiencies of up to 5 percent. The output power of a $Pb_{0.945}Sn_{0.055}Se$ laser at 12°K was found to rise superlinearly, even at the highest power levels, indicating that its internal quantum efficiency has not attained its limiting value and that the output power of this diode is limited by some nonradiative recombination process.

Annealing experiments on $Pb_{1-x}Sn_xTe$ were carried out for the two compositions $x = 0.13$ and $x = 0.17$ at various temperatures and under both metal-saturated and Te-saturated conditions. The solidus lines for the Te-rich and metal-rich side of the phase diagrams have been determined.

Pulsed electron beam pumped lasers prepared from single crystal platelets of CdSe grown in an atmosphere of excess Cd have yielded 300 W of peak output power, an overall power efficiency of 28 percent, and an internal power efficiency of 38 percent at 4.2°K. With increasing temperature, the performance of the lasers fell off more rapidly than was the case in similar high power lasers of CdS. At 77°K, the maximum measured values of peak power, overall efficiency, and internal efficiency were 184 W, 19 percent and 25 percent, respectively. No lasing was observed at temperatures above approximately 100°K.

Epitaxial GaAs with good electrical properties has been grown on GaAs seeds by the $AsCl_3$-Ga-H_2 flow system. In order to obtain epitaxial layers which yield high efficiency Gunn effect oscillators, the use of a chelating agent in the preparation of the seed surface was required. Furthermore, large gradations in the impurity concentration of the epitaxial layer occurred whenever growth was initiated before the Ga boat was fully As-saturated. This variation is attributed to the effect of As pressure on out-diffusion of the seed dopant into the epitaxial layer. The impurity gradients can be eliminated and high efficiency Gunn effect devices can be obtained by initiating growth only after the Ga boat is saturated.

Gunn effect oscillations as well as current runaway caused by a bulk avalanche of electron-hole pairs in n-type CdTe have been studied. The current runaway occurs after several Gunn

oscillations and is accompanied by a drop in voltage below the Gunn threshold and the observation of light-emitting filaments extending from one contact to the other. The experimental results indicate that the avalanche is probably initiated by the traveling high-field Gunn domains. However, the mechanism which sustains the current runaway is not fully understood.

II. OPTICAL TECHNIQUES AND DEVICES

Recent measurements indicate marked improvements in the short-term frequency stability of stable CO_2 lasers. The width of the spurious frequency jitter was typically 6 to 10 kHz for observation times of several seconds, and less than 1 kHz for tens of milliseconds.

Improved efficiency and lifetime have been obtained in sealed-off CO_2 lasers. Continuous heating of the nickel cathode has yielded an operating lifetime greater than 800 hours, without interruption of the discharge.

Detectors of photovoltaic $Pb_{1-x}Sn_xSe$, operated at 77°K have achieved theoretically optimum operation for kHz and MHz heterodyne frequencies.

A 10.6-μ four-port circulator using free carrier rotation in InSb has been constructed. Isolation ratios of 1000:1 in power have been obtained with insertion losses of 10 percent. The power handling capability is under study.

III. MATERIALS RESEARCH

A simple method has been developed for measuring the concentration of available oxygen ($O_2 + H_2O$) in inert gases. The rate of increase in resistance of a coiled tungsten filament due to oxidation is measured by measuring the current through the filament at constant voltage.

Single crystals of $CrBr_3$ about 10 mm on a side have been grown from the vapor in the tapered tip of an evacuated silica ampoule, which is slowly raised out of a vertical resistance furnace heated to 900°C.

Differential thermal analysis has been used to determine the transition temperature between the low- and high-temperature forms of Ag_2Te as a function of hydrostatic pressure up to 14 kbars. X-ray diffraction data for the high-pressure phases Ag_2Te-II and Ag_2Te-III have been indexed on tetragonal cells with a = 8.92 Å and 8.68 Å, respectively, and c = 6.09 Å in both cases.

The crystal structure of $La_4Re_6O_{19}$ has been determined by computer analysis of integrated x-ray powder diffraction data. Rhenium-oxygen octahedra share edges and corners to form a three-dimensional network containing sizable voids within which there are La_4O tetrahedra.

Single crystals of $RbNiF_3$, a transparent ferrimagnetic material which may prove to be useful in Faraday rotation isolators for infrared radiation, have been grown from the melt by the Bridgman method. The absorption coefficient at 10.6 μm, the wavelength of the CO_2 laser, was found to be about 4 cm^{-1}.

Optical and magnetic measurements have shown that $CaF_2:U^{+3}$ crystals usually contain significant amounts of U^{+2} and U^{+4} ions. The laser threshold has been reduced by a factor of 4 in crystals prepared by a method which decreases the U^{+2} and U^{+4} concentrations.

An x-ray fluorescence method has been developed for the determination of rhenium and tungsten in $W_{1-x}Re_xO_3$ solid solutions. A method has also been developed for determining iron and yttrium in yttrium-iron garnets (YIG). The total of yttrium and iron is determined by an automatic EDTA titration, and the iron is determined separately by a spectrophotometric method.

IV. PHYSICS OF SOLIDS

The beat frequency observed in the Shubnikov-de Haas data on n-type HgSe is explained by inversion asymmetry splitting of the conduction band when magnetic field induced effects on the electron orbits are taken into account.

Extra transitions seen in electric field modulated magneto-reflection from InSb are attributed mainly to warping of the valence band energy surface and the resulting admixture of close-lying Landau level states.

Magneto-electroreflectivity measurements on the transition from the split-off valence band to conduction band in InAs and InSb at 1.5°K have yielded new values for several band parameters.

The oscillatory magnetoreflectivity in bismuth is satisfactorily described by a lineshape calculation which takes into account the nonparabolicity of the energy bands, the k-dependence of the velocity matrix elements, and the anisotropy of the energy surfaces near the L-point. The dependence of the Landau energy levels on the k-vector along the field was derived, with Baraff corrections included.

A reordering of the conduction band with respect to the d-band in nickel is in better agreement with de Haas-van Alphen data and infrared temperature-modulated reflectance data.

Symmetry properties of the cation d-bands for the nonmagnetic corundum structure are shown to place no restriction on whether Ti_2O_3 and V_2O_3, when structured like corundum, are semiconducting or metallic.

Measurements of the critical point exponents for the paramagnetic susceptibility and the magnetization of $La_{0.5}Sr_{0.5}CoO_3$ give values which are lower than predicted, respectively, by the high-temperature expansion method and the gas-ferromagnet analogy.

Polarization properties and relative intensities of the Raman laser scattering from mixed plasmon-phonon modes in GaAs crystals have been measured and compare favorably with cross-section calculations given in terms of the crystal Raman coefficients which couple the photons to transverse and longitudinal optic modes and to charge density fluctuations.

A reasonable estimate of the quartz Raman susceptibility and cross section has been made from the threshold power and gain for the quartz Raman oscillator pumped by a ruby laser.

The spectral power density of the broad frequency smearing which occurs when a high-power Nd:glass laser beam passes through a CS_2 liquid cell has been studied as a function of input power.

The beam pattern of the 337-μ wavelength oscillation of the far infrared cyanide laser has been mapped out. Also, coherent detection was obtained with a millimeter wave crystal diode detector.

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13. ABSTRACT

This Quarterly Technical Summary covers the period from 1 May through 31 July 1967. It consolidates the reports of Division 2 (Data Systems), Division 3 (Radio Physics), Division 4 (Radar), Division 7 (Engineering), and Division 8 (Solid State) on the General Research Program at Lincoln Laboratory.

14. KEY WORDS

data systems
digital computers
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