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Quarterly Technical Summary

General Research

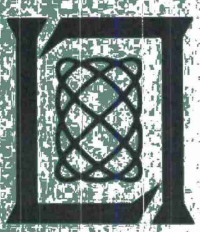
15 November 1969

Prepared under Electronic Systems Division Contract AF 19(628)-5167 by

Lincoln Laboratory

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Lexington, Massachusetts



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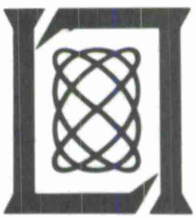

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INTRODUCTION

This Quarterly Technical Summary covers the period from 1 August through 31 October 1969. It consolidates the reports of Division 2 (Data Systems), Division 4 (Radar), Division 5 (Optics), 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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ENGINEERING – DIVISION 7

SOLID STATE – DIVISION 8

DATA SYSTEMS
DIVISION 2

INTRODUCTION

This section of the report reviews progress during the period 1 August through 31 October 1969 for the General Research Program of Division 2. Separate progress reports on Graphics and Seismic Discrimination describe other work in the Division.

F. C. Frick
Head, Division 2

M. A. Herlin
Associate Head

DIVISION 2 REPORTS ON GENERAL RESEARCH

15 August through 15 November 1969

PUBLISHED REPORTS

Journal Articles*

JA No.			
3376	A Radio Study of the H II Region Orion B	M.A. Gordon	Astrophys. J. 158, 479 (1969)
3465	Interstellar Hydroxyl Clouds	J.M. Moran	Science Journal 5A, 60 (1969)
3489	Venus: Mapping the Surface Reflectivity by Radar Interferometry	A.E.E. Rogers R.P. Ingalls	Science 165, 797 (1969)

UNPUBLISHED REPORTS

Journal Articles

JA No.			
3502	Seasonal Variation of the F 1 Region Ion Composition	J.V. Evans L. Cox	Accepted by J. Geophys. Res.
3519	Detection of Conjugate Photoelectrons at Millstone Hill	J.V. Evans I.J. Gastman	Accepted by J. Geophys. Res.
3560	Determination of F Region Vertical Drifts at Millstone Hill	J.V. Evans R.A. Brockelman R.F. Julian W.A. Reid L. Carpenter	Accepted by Radio Science
3595	OH Radio Emission Associated with Infrared Stars	J.M. Moran	Accepted by Astrophys. J.
3609	Remote Probing of the Moon by Infrared and Microwave Emissions and by Radar	T. Hagfors	Accepted by Radio Science

* Reprints available.

Division 2

Meeting Speeches*

MS No.			
2613	Radar Mapping of Venus with Interferometric Resolution of the Range-Doppler Ambiguity	A. E. E. Rogers R. P. Ingalls	IAU-URSI Symposium on Planetary Atmospheres and Surfaces, Woods Hole, 11-15 August 1969
2622	Theory and Practice of Ionosphere Study by Thomson Scatter Radar	J. V. Evans	URSI, General Assembly, Carleton University, Ottawa, 20 August 1969
2638	Pointing Calibration of Large Antennas with Cosmic Radio Sources	M. L. Meeks	IEEE Professional Group on Antennas and Propagation, Waltham, 24 September 1969

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

SURVEILLANCE TECHNIQUES
GROUP 21

I. SUMMARY

Group 21 is responsible for the operation and maintenance of the Millstone Radar and the Haystack Research facilities of Lincoln Laboratory's Millstone Hill Field Station. At Haystack the main emphasis of the operation is on planetary and lunar radar and on radiometric techniques, whereas at Millstone, ionospheric and radar propagation studies related to precision tracking techniques are carried out.

At Millstone the instrumentation phase of the ABMDA radar propagation program is nearing completion. The incoherent scatter program has now developed a capability of measuring temperatures and compositions with a height resolution about ten times better than before.

The data gathering and processing phase of the lunar radar mapping work at Haystack has been completed and the maps, both polarized and depolarized, are being prepared for a report to NASA due in January next year. Further observations have been made of the topography of both Venus and Mars.

The very long baseline interferometer (VLBI) observations made with the NRAO and Owens Valley facilities have been completed. Whereas the relativity results are not yet available, it has been shown by satellite observations that the interferometer configuration can measure velocity differentials of a few millimeters per minute. Five new sources of water vapor line emission near 22 GHz have been discovered.

II. SPACE SURVEILLANCE TECHNIQUES

Practically all the work in this area is now related to investigations of clutter and atmospheric refraction and scintillation effects on radar tracking. The incoherent scatter (Thomson scatter) work, previously covered in a separate section of this report, is now an appropriate part of the propagation study program sponsored by ABMDA and is fully covered in the semi-annual report to that agency.

The UHF beacon tracking feed system has been installed to augment the L-band radar on the 85-foot dish at Millstone and tests of the two-frequency system are beginning. A satisfactory solution to the voltage breakdown problem in the frequency-selective subreflector has been incorporated.

The receiving and data processing equipment is installed and has been checked out. Full scale acquisition of UHF beacon and L-band radar data should begin in December. Further analysis and observation programs for the auroral backscatter measurements are being developed.

Developmental work continues on sophisticated software to provide real-time orbit-determination, prediction, and subsequent computer steering for the Millstone tracker. Perturbations due to propagation effects during the steered portion of a satellite pass at low elevation angles (below 15°) will be apparent in the two-frequency monopulse system outputs. The program (MHESPOD) currently in use has provided encouraging results with polar-orbiting

navigational satellites even in the presence of fading target returns. This is particularly so after the inclusion of an adaptive data weighting procedure.

The incoherent (Thomson) scatter observational program has continued, with about two 24-hour UHF runs and two 12-hour L-band runs per month. In addition, brief runs have been made in conjunction with satellite passes in order to compare incoherent scatter data with corresponding data obtained by in situ measurements.

Considerable progress has been made on a two-pulse autocorrelation measuring scheme which will enable us to obtain frequency resolution as fine as in the present RETIAS all-range filter bank scheme, but which will provide for a tenfold increase in height resolution. A data-taking program is nearly completed but the analysis programs remain to be worked out.

Ground-clutter echoes at ranges of 90 and 150 km contaminate data taken near these altitudes and efforts to ameliorate this problem by modifications to the antenna feed and in the computer processing are in progress.

The computer programs necessary for complete machine reduction of the measurements made since mid-1968 are now essentially complete allowing immense savings in time and effort to analyze the results presently being obtained. The backlog of data that require hand analysis is slowly being reduced. Data for the year 1965 will shortly be published in a technical report.

Engineering studies are in progress to determine the most expeditious and economical scheme to permit rapid reconfiguration of the radar, data processing and computer facilities from the L-band radar mode to the UHF Thomson scatter mode. When these plans are implemented, it will be possible to change from one mode of operation to the other in a matter of minutes instead of the 1 to 2 hours presently required. Further, since electron density measurements with the existing equipment are impaired below about 200 km altitude owing to ground clutter echoes, we are considering a clutter fence erected around a 60° sector to the north of the antenna. These changes, which could be made at modest cost, should considerably enhance the refraction studies by permitting comparisons between observed refraction and ray-tracing calculations made using measured electron density profiles.

III. HAYSTACK PLANETARY RADAR

A. System Development

Liquid helium hold time in the radar dual maser receiver was extended from 12 to over 20 hours by modifications to the dewar header. This will result in a lower consumption of costly helium and in reduced time and effort requirements in operational preparations. Two night shift radiometric observations at X-band can be accomplished after one daytime cryogenic servicing.

A spare superconducting magnet for the receiver masers was constructed and tested with liquid helium cooling. This unit was used in tests of the closed-cycle refrigerator we hoped would replace the batch-filled dewars for maser cooling. The refrigerator itself cools to 4°K but failed to cool the superconducting magnet to a low enough temperature to allow superconduction. The problem appears to be an inadequate conduction path between the cold station and the mass of magnet structure. Lack of resources forced shelving of this project at the end of this quarter.

A new SCR stack modulator for the klystron transmitter was successfully tested. This grid modulator will allow pulse modulation of the beam current from μsec pulse widths up to CW.

Until this modulator was developed, the transmitter used a line pulser that produced 20-μsec beam current pulses to support RF pulses from 3 to 13 μsec duration.

The transmitter tube situation remains unsatisfactory. Operations during this period used VA-949AM klystrons Ser. No. 13 and aging Ser. No. 1 at a 300-kW limit. Serial No. 17 was installed in place of Ser. No. 1 and found to have an arcing problem which would cause operational difficulties. Serial No. 1 was then reinstalled, but has now developed excess body current in addition to having an aging cathode. We will have to operate with these problems at a 300-kW power limit until a new klystron is delivered. One new unit, Ser. No. 18, is under test at the vendor's plant.

A real-time decoder has been incorporated into the radar system. This device decodes the pseudorandom modulation of the planetary radar signal used in ranging experiments, a task formerly performed with the CDC 3300 processing software. Additional computer time will now be available for other real-time operations.

Modifications are under way to accommodate a planned bistatic Jet Propulsion Laboratory-Haystack Facility (GOLDSTACK) radar operation. They include additions to the system timing and pseudorandom code generation equipment to accommodate longer codes.

B. Planetary Studies

1. Mars

Measurements of the topography, radar reflectivity and surface roughness of the planet Mars which were started in May are now complete. The data from the 1967 and 1969 oppositions have been combined into maps of topography, reflectivity and roughness contours for a strip extending from the equator to 22°N.

Results show that the topography changes smoothly with longitude and latitude undergoing peak-to-peak deviations of 15 km. A large highland area is observed extending from 60° to 120° in longitude. The optically dark area known as Syrtis Major lies on the most steeply sloping area observed, rising to the West. In general, there is little variation in height with latitude over the relatively small range observed with the exception of a region near 215° in longitude which rises sharply to the North.

Radar measurements of the surface scattering law show average surface slopes to be predominantly less than 1° when averaged over 50 km. Average surface slopes are observed to increase with decreasing scale length but are still less than 6° when averaged on a scale of the 3.8-cm wavelength.

2. Venus and Mercury

Venus and Mercury ranging measurements were made routinely during the period from 1 August through 11 September. A considerable effort was made in analyzing Venus data acquired during the spring inferior conjunction period. In particular, these included an extensive coverage of radar cross section with planetary longitude and a determination of surface height variations on the planet. The surface height profile of Venus exhibits much less variation than that of either Mars or the earth.

C. Lunar Studies

All measurements have been completed for the two-polarization radar backscatter maps. The data have all been processed to yield 257 pairs of half-tone maps, representing the polarized and depolarized backscatter from most of the 267 ZAC* subareas. The remaining 10 ZAC areas, all of which are on the 10.0 (farside) ZAC ring, are not accessible to precise range-doppler mapping from the latitude of Haystack.

The maps are now being assembled into mosaics for publication in January in the Final Report to NASA.

The average scattering law for the moon has been calculated from the data and found to agree with the precise measurements made by J. V. Evans in 1967. Of even more interest is the tabulation of relative scattering coefficients (after the average scattering law has been removed) for the various types of surface feature on the moon. Contour maps will be prepared from this information for both polarized and depolarized backscatter.

Ephemeris discrepancies are in large part being tracked down to the effects of surface topography. A by-product of this investigation has been the production of height profiles of the lunar surface along selected cuts near the mean subearth point with a repeatability of ±250 m. This is at least twice as good as existing knowledge of the moon's topography. The observations that are analyzed to produce these profiles are the leading-edge calibration observations that were regularly interspersed with the map observations over the past 10 months. Work is continuing on both the ephemeris and the height measurements. It is planned to submit a proposal to NASA for further support to the topographic studies.

IV. RADIOMETRIC TECHNIQUES

A. Instrumentation

Throughout August and the first half of September, the Radiometer Box was prepared for its stay on the antenna during the following 6 weeks. Equipment for the VLBI (Very Long Baseline Interferometer) experiment was installed. The radiometers for the other two receiving terminals, assembled by students, were at Haystack to measure the relative phase stability of all three radiometer systems.

A 22.2-GHz degenerate parametric amplifier, on loan from MIT/RLE, was installed ahead of the mixer previously used at that frequency for water vapor studies. Single sideband system temperatures near 1500°K were measured, as compared to about 3500°K for the mixer alone.

All radiometer systems were used while the Radiometer Box was on the antenna. Occasional frequency changes of the 22.2-GHz paramp pump klystron caused the loss of some observing time during the first week, but this was the only reliability problem encountered.

The K-band mixer radiometer was used in the Planetary Radar Box for water vapor studies while the Box was on the antenna in September.

Construction of the new digital correlator continued. Its ability to frequency analyze a 20-MHz bandwidth in real time will be required early next year.

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* Zenith Azimuth Coordinate – a quasi range-doppler coordinate system used for planning purposes.

Design of a data recording terminal for VLBI experiments is proceeding. This unit, when completed, will allow digital recording of VLBI data using one of the CDC 3300 magnetic tape units without tying up the entire machine.

Work on the development of new computer-display techniques has continued. Although these techniques were intended for the display of 21-cm hydrogen data from the Milky Way, they appear to be generally useful. Newly developed display programs allow us to superimpose contour maps with variable-intensity maps. This technique resolves the ambiguity between peaks and depressions in conventional contour maps. We have also developed a means of expanding the dynamic range of our two-dimensional contour maps by the use of color. The computer produces three separate (black and white) negatives from which transparencies are prepared in three component colors. Superimposing these gives a presentation in full color.

B. Radio Astronomy

Throughout the present quarter we have continued to monitor time variations in 22-GHz water vapor emission from the new class of intense galactic sources discovered in January of this year. These sources are the brightest objects in the sky in the wavelength region approaching 1 cm. Their small angular size and narrow bandwidth require a maser-like amplification process in the source. In this sense, the H_2O sources resemble the anomalous OH sources, and in fact, eight of the nine water vapor sources are coincident with OH sources to within 30 seconds of arc. However, the time variability of the H_2O sources proceeds much more rapidly than that of the OH sources. In many cases, there are appreciable changes in H_2O emission in the interval of one week.

The purpose of the continued monitoring is to obtain sufficient data to characterize the patterns of variability and attempt to infer something about the source structure and emission mechanisms. One particular example of variability is provided by the water vapor source coinciding with the brightest thermal continuum source in the region designated W3. This source remained constant during July and the first two weeks of August. Then in an interval of three weeks it increased three-fold in intensity to a new plateau and narrowed in half-power bandwidth from 90 to 45 kHz. There has been no apparent change in frequency of the peak of this emission feature. Other sources have shown quantitatively similar behavior at other times.

During this quarter a search has also been made for H_2O emission from 140 known infrared sources as a part of an M.I.T. doctoral-research program. This program, as well as the time variation measurements during September and October, was greatly aided by the loan from M.I.T. of the 22-GHz parametric amplifier mentioned earlier. The IR source search uncovered five new water vapor sources, all relatively weak and difficult to detect without this (comparatively) low noise amplifier.

Another continuing time-variation study, conducted by Prof. W. A. Dent of the University of Massachusetts (Amherst), monitored flux changes of quasars and peculiar galaxies at 8 and 15.5 GHz. The observations are made at monthly intervals at each frequency, since this sampling period is appropriate to the slower changes in these extra-galactic sources.

A Very Long Baseline Interferometer experiment was performed in October using the Haystack 120-foot antenna, the 140-foot antenna of the National Radio Astronomy Observatory in West Virginia and the 90-foot antenna of Owens Valley Radio Observatory in California. The

main purpose of the experiment was to measure, to a higher precision than possible at optical wavelengths, the deflection of radio waves by the gravitational field of the sun, as predicted by General Relativity. Observations were made of the radio source 3C279 as it approached the limb of the sun, while other radio sources were observed as references. To eliminate ionospheric effects, observations were made at both L- and X-bands. Also, observations with the VLBI system were made of TACSAT to assess the ability of long baseline interferometry to refine satellite orbits.

While the relativity data are still being reduced, data from TACSAT observations have already shown that the differential velocity of the satellite with respect to the observing stations can be measured to better than a few millimeters per minute.

DIGITAL COMPUTERS
GROUP 23

I. CIRCUIT AND NEW MACHINE DEVELOPMENT

A. Semiconductor Processing

Fabrication of multi-level process chips (MLPC) has provided much useful information. These chips are essentially process evaluation devices to examine oxide pinhole density, via yield, and metal continuity and resistance for wiring with three levels of metalization. Examination disclosed a possible problem of stress cracking in the upper metal where it passed over underlying, second metal lines. The causes are being investigated.

Complete mask sets for the 80-gate array have been supplied to make load evaluation chips and prototype adder designs. No operating devices are available as yet.

A comparison of delay times for various standard and collector diffused isolation (CDI) ECL gate designs is given in Table I.

TABLE I
COMPARISON OF DELAY TIMES FOR STANDARD AND CDI ECL GATE DESIGNS

Power Dissipation (mW)	Resistor Sheet Resistivity		Propagation Delay	
	Standard (ohms/sheet)	CDI (ohms/sheet)	Standard (nsec)	CDI (nsec)
10	100		0.52	
5	100	400	0.60	1.20
5	200		0.83	
2.5	200	800	1.07	2.15

The CDI process is less complex than the standard, but pays for this in compromises in the transistor diffusions which tend to produce larger device capacitances and hence slower performance.

B. Computer-Controlled Wafer Probe

Many timing problems have been found and eliminated in the program controlling the motion of the Electroglas 900A probe. A "diamond-square" test program operates successfully. Accurate positioning to any point on a 2-inch wafer from any other point can now be performed by the computer. Various fixed probe configurations will be evaluated on 3-bit parity wafers. A 12-point probe has been received from Rucker and Kolls for initial experiments.

C. Interconnection of Integrated Circuits

The procedures for casting integrated-circuit chips in plastic have been defined. Registration of chip metalization to an interconnection wiring pattern has been excellent and is independent of chip geometry.

The selective crosslinking of a liquid layer of polyester resin and styrene monomer by exposure to short wavelength ultraviolet light has been demonstrated. Dielectric layers approximately 2 mils thick have been produced with 6-mil-square vias opened to the chip metallization below. Experiments indicate that smaller vias can be produced.

Current efforts are focused on applying conductive material in the vias and interconnecting the metallized vias by a photoetched covering layer of chemically deposited or evaporated metal.

D. LX-1 Microprocessor

Continued review and refinement of the design of the LX-1 Microprocessor has resulted in the following changes and additions:

(1) The Control Memory addressing has been rearranged to allow control memory read cycles to be overlapped with execute cycles when the next address depends on the current values of the special bits. Now, the only control memory read cycle which cannot be overlapped is one in which the next address is taken from the D-bus results of the present execute cycle.

(2) The Scratch Memory function box has been doubled in size to 256 16-bit words.

(3) The parity check network on the Control Memory has been eliminated since experience with memories with similar construction indicates an extremely low expected error rate. The former parity bit in the microinstruction will be used as a programmable breakpoint stop.

(4) The SHIFT and COMPLEMENT operations have been moved from inputs to the Adder-Logic function box to locations in series with the A-bus and B-bus, respectively. That is, the shift and complement operations are performed on the register contents which drive the buses and affect all function boxes equally. The output of the SHIFT operation drives the A-bus and the output of the COMPLEMENT operation drives the B-bus.

(5) A new Count function box and Count op code have been added to the machine. The Count function box makes a logical count of the left zeros of the 16-bit number on the B-bus and produces a 5-bit binary count result on the right end of the D-bus.

(6) The LX-1 hardware will fit into a set of three drawers named Control Memory, Register, and Function. The remainder of the back panel wiring consists of the Multiply function box (not in the function drawer), the input-output interfacing for the Registers and control circuitry for the overall machine.

E. Testing Computer

Test programs written in BCPL include routines for testing read-only memory circuits. Each read-only memory word is checked and the margins on the output lines measured automatically. The results confirmed those obtained manually. Register cards used in the test equipment interface buffer were also tested automatically. Thirty-two cards plus spares were tested in less than twenty minutes. Several selection problems were diagnosed that had been discovered during previous manual tests.

To date, the most noticeable problem in using a small computer to control test equipment has been the lack of a good output device; the teletype is slow and cumbersome. Since hardcopy is rarely needed, a storage scope display is being added to the system. It will be used for both text output and plotting data. Characters will be generated with software at speeds twenty times faster than they can be printed on a teletype.

II. MAGNETIC FILM ENGINEERING

A. Word Lines

A thorough study of scribing, resist and etching parameters has been completed. The results were used for dimensioning a new exposure master, currently being scribed, which is designed to eliminate all pad-to-line alignment problems.

B. Word Decoding Matrix

The problem of assembling 700 to 800 discrete diode chips into decoding arrays for LCM II word substrates has been approached in a variety of ways. Present efforts are directed toward a combination of potting the chips in a photosensitive plastic and making electromechanical connections with conductive epoxy. The plastic provides both the holding structure and the insulation for the diode sides to prevent shorting by the conductive epoxy.

C. Digit Lines

1. Materials

The first 52 inch long × 2.2 inch wide × 0.25 inch thick glass digit substrates were vacuum deposited with Cr, Ni Fe and Cu for keepered digit lines. The Ni Fe load on the tungsten filament of 15 percent by weight will have to be reduced to about 10 percent in the future because the Ni dissolves into the tungsten which opens the filament. Spattering is also a problem and may be cured by obtaining tungsten with fewer carbon impurities or using a longer outgassing time.

2. Scribing

The large scribing machine is mechanically complete, and the necessary control circuits remain to be built.

D. Substrate Testing

Some testing was done on two LCM-II substrates, but numerous shorts and opens made the number of testable lines rather small. Methods for improving the tester noise level have been found but not yet implemented.

E. Magnetic Film Plating

The use of intermediate layers of electroless Ni on copper word lines reduces the coercivity of the superimposed films to lower values than found on other substrates. The addition of Zn to Co and Co-Ni alloys has been found to raise their anisotropies to over 60 oersteds, an increase of over 20 percent, without significant effect on coercivity or squareness.

F. Optical Testing of Magnetic Films

The minimum diameter of permalloy film which can yield a B-H loop with a peak signal/rms noise ratio of 3 has been further reduced to 13 mils. The optical source is a GaAs diode whose radiation is focused on the film by an ellipsoidal reflector. The looper bandwidth is 10 kHz. Even though the use of the reflector greatly decreases the radiation reaching the detector from regions other than that being looped, the shot noise from this radiation is still the limiting factor in reducing the size of the minimum area for looping.

III. COMPUTER SYSTEMS

A. Display

1. Character Generator

Most of the symbols for the TX-2 character set have been designed. The design system takes characters drawn freehand on the tablet, using a grid on the CRT as a guide and produces the data required for the character strokes.

2. Box Generator

The box generator was installed in the TX-2 display system. Storage required for the mask data was reduced and flicker improved as anticipated.

B. Video Raster Printer

The input/output sequence switch has been designed, constructed and statically checked out. Plug in units for the sequence switch have been constructed and tested. The design of the in-out control box for the new sequence has been reviewed, and the resultant changes are being put into the design. The PDP-8/L to LDX interface box has been designed, drawings have been completed, and back panel wiring is in progress.

PSYCHOLOGY
GROUP 25

I. PROVISION FOR MAN-MACHINE INTERACTION ON THE IBM 360/67

A. Mediator/Reckoner System Improvements

The effort on the Mediator operating system and the initial library of user programs, the Reckoner, has been reduced during the current quarter. Documentation continues: two new documents have been completed, one of which is a comprehensive users manual for the Reckoner, and the other a guide to Fortran programming in the Reckoner/Mediator environment. These are being given some limited distribution at first to test their adequacy. Also, the program and hardware design has been completed for making use of an ARDS display unit as a high speed (1200 baud) editing and graph plotting terminal.

B. Field Test of the Reckoner/Mediator

There is a need for a rather extensive "field test" of this new facility. A few improvements in the Reckoner design itself have been made and need to be proven out in use. More important, though, is the hypothesis that the Mediator provides a more effective problem solving environment. In this environment problems are solved by running programs. Writing of new programs is at a minimum. A "self-augmenting" quality of the Reckoner should be apparent. That is, new programs should often serve the needs of the whole community of computer users – the ultimate goal of the application of the principles of coherent programming embodied in the Mediator operating system. An adequate test of these ideas requires a major scale operation of the system.

Currently the laboratory time-sharing environment – CP/CMS on the IBM 360/67 – is heavily loaded. This makes a reasonable field test of the utility of the system impossible. An important pre-condition for a test is ready access to the system – say, access for one hour within an hour. Also, the response of the machine should be immediate; that is, several user programs should run per minute of user time, as occurs currently when the competition for the machine is moderate. To meet these needs a plan has been devised to provide a separate time-sharing system for Reckoner users on the existing second processor of Lincoln's dual machine. Advent of this second system awaits delivery of a drum and other equipment.

II. PROVISION FOR MAN-MACHINE INTERACTION ON TX-2

A Master Copy file concept has been implemented in Apex. A file which is specially designated as a Master Copy is stored on the Apex drum area. Future requests for this file will cause the user to be given an ephemeral copy. This copy may be changed and experimented with as desired without endangering the Master. If the user does not subsequently name the copy it will automatically be dropped under the rules which govern ephemeral files.

Currently the drum is divided into two sections, a user-managed area and an Apex-managed area. A problem arises because Apex expects public programs to be non-self-modifying, and thus it normally provides only one copy in core for any number of users. Many older programs

modify themselves, however. It has been necessary for the writer of such programs to keep them in the user area of the drum and to manage them himself. (This was an adequate procedure because Apex gives a new copy for each request of a program loaded from the user area.) The same result can be achieved now by using the new feature, i.e., entering new programs in the Apex area, and by labelling self-modifying programs or parts of programs as Master Copy. The effect of this change is to allow effective management of the drum because most of it is now under control of a single agent, APEX.

A much reduced user managed drum area will be retained. It will continue to provide a scratch pad area for each console, and will also contain Apex itself and bootstrap and machine diagnostic programs needed to recover from serious hardware or software malfunctions.

III. HUMAN INFORMATION PROCESSING

The first experimental setup has been implemented on the PDP8-L. A system of programs has been written that provides a flexible basis for generating stimuli, controlling the sequence of events, and recording data. All subsequent analysis is done on one of the large Laboratory on-line facilities. Currently, communication of data is via paper tape to the TX-2 Reckoner.

The initial research is on the latency of response in the signal detection process. It has been inferred that latency of response is inversely related to the distance between the perceived magnitude of the stimulus and the detection criterion. It is known that latency depends on the amount of information gathered over time needed to make a decision. It has also been shown that response latency is affected by the probability of occurence of stimulus. A series of experiments is planned to sort out the effects of these variables, which appear to be confounded in many published experiments.

COMPUTER SYSTEMS
GROUP 28

I. COMPUTER CENTER DEVELOPMENT

Late in the quarter a new version of IBM's OS/360 batch monitor identified as OS/360, release 17/MFT 2/HASP 2.1, was put into regular operation. The principal feature of this system is that all input and output is done on line using the multiprogramming capability of the MFT 2 option without degrading the performance of the executing program. The system also allows the operator to exercise close control over the flow of work from the time it is submitted until it enters the queue for processing and finally returns to the user in the form of printed or punched output. Besides a noticeable improvement in turn-around time, the HASP system has substantially reduced the load on the 360 Model 40.

A new feature which will soon be added to the OS/360 batch monitor is the ability for two different central processing units to access the same disk drive. This capability will permit sharing a single copy of program libraries. It will now be possible to update commonly used programs on a daily basis rather than on the weekly schedule now required by the fact that each CPU uses its own separate copy of the library. The increase in effectiveness should permit users to greatly reduce the number of error-prone card decks which are carried to and from the Computer Center.

During the quarter, the CP/CMS Time Sharing System was modified to support the IBM 2260 Alphanumeric CRT display to function as an interactive terminal. This device has the advantage of being quiet and able to display data very quickly. It does not, of course, have the ability to produce a permanent record locally. However, it has been found to be very effective for applications involving editing and monitoring of dynamic information such as system status.

Since the 2260 terminals interface with the system through a separate control unit, the total number of interactive devices which can simultaneously access CP/CMS is now increased to 37. At this level of activity, the system does not provide satisfactory response time. For this reason, a considerable amount of attention will have to be focussed on improving the efficiency of dispatching and paging algorithms during this next quarter.

Among the several features which have been added recently or which are soon to be provided under CP/CMS is the facility for dynamically linking the file space of one user's account to the virtual machine of another user. This results in a dynamic file sharing capability in addition to the previous static capability. Also, it is now possible to issue console functions from a program in a virtual machine. This will permit a great deal of flexibility for the noninteractive use of the system and particularly for the batch monitor operation. Support of the PL/I Compiler, improvements to the machine language debug facility and the context EDIT command have also been completed.

II. LISTAR (Lincoln Information Storage and Associative Retrieval System)

Ascend links were made a standard part of LISTAR entries and the MOVE command was modified to permit a terminal user to move his place marker up the file as well as down. Two

new commands were added to the system: DELETE FROM and ADD ENTRY TO. DELETE removes an entry identified either by chief field name or marker name from a file. ADD ENTRY provides the user with a relatively easy means of adding a new entry to his file.

There are now 22 commands in the LISTAR system. The function programs supporting these commands cannot all reside in core simultaneously so an overlay scheme was implemented which automatically loads the program segment required by the current command.

A program called LSTBUG was written to provide LISTAR programmers with handy debugging aids.

RADAR
DIVISION 4

INTRODUCTION

The objective of the General Research program is to develop improved components and techniques which appear applicable for use in future systems. During the period 1 August through 31 October 1969 the primary emphasis has been on the development of microwave acoustic components and techniques, devices utilizing diodes, and precision timing technology. Separate reports are issued on the MTI radar program.

H. G. Weiss
Head, Division 4

DIVISION 4 REPORTS ON GENERAL RESEARCH

15 August through 15 November 1969

UNPUBLISHED REPORTS

Journal Article

JA No.			
3562	Status Report on Microsound Components, Circuits, and Applications	E. Stern	Accepted by IEEE Trans. Microwave Theory Tech., Special Issue on Microwave Acoustics, November 1969

Meeting Speeches*

MS No.			
2610	The Physics and Technology of Surface Elastic Waves	H. I. Smith	9th Annual Symposium on Physics and Nondestructive Testing, Chicago, Illinois, 23-25 September 1969
2699A	Acoustic Analogs of Microwave Components and Circuits	E. Stern	Seminar, Ohio State University, 21 October 1969

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

MICROWAVE COMPONENTS
GROUP 46

I. INTRODUCTION

Group 46 contributes to the Laboratory program through direct participation in specific projects and through a program of general research which is closely related to the microwave needs of the Laboratory. Continuing programs have been in the areas of microwave acoustics (microsound), diode-using devices, and timing technology. The microsound program is now under the sponsorship of ABMDA, and will in the future be reported under that program. The General Research effort of Division 4 is being redirected to the problems of Air Traffic Control. Reports on this activity will be made beginning with the next quarterly report.

II. MICROSOUND

A. Transducer Fabrication

A computer tape-controlled scanning electron microscope will be delivered in November 1969, and should permit the fabrication of transducers which operate in the S- and C-band frequency ranges. The microscope can also be used in a strobe mode to directly observe surface wave propagation and thus evaluate the behavior of wave focusing and guiding structures.

B. Materials

Piezoelectrically active thin films of ZnO have been prepared by rf sputtering of the compound in argon/oxygen atmospheres. Work is in progress to determine the conditions under which both C-axis normal and C-axis parallel preferred orientation can be obtained. An rf sputter-sputter etch system will become available this quarter and a start can be made on epitaxial growth studies.

C. Acoustic Amplifiers

Measurements are being continued on several acoustic amplifiers using n-type silicon wafers of resistivity values ranging from 50 to 250 ohm-cm. The surfaces of the amplifiers constructed until now have not been subjected to any final treatment, such as oxide passivation. Experimental results on these amplifiers have yielded a much weaker interaction than expected and indicate that the surfaces are depleted and possibly inverted. Amplifiers are now being tested which have a thin thermal oxide covering the surface. Measurements of the surface properties of the silicon with oxide have been made and show that there is an accumulation layer of electrons at the surface. In this case, we expect a much stronger interaction with a surface acoustic wave on an adjacent delay line.

D. Guided Elastic Waves

A perturbation theory for resonators and waveguides has been developed. Studies are being made of a waveguide consisting of an isotropic overlay of rectangular cross section on a substrate which is substantially more rigid than the overlay.

III. DIODE DEVICES

The theoretical work on IMPATT diodes has developed in seven areas for which papers or technical notes are being issued.

(a) The properties of recently discovered surface wave modes have been further investigated by numerical analysis. The results demonstrate the feasibility of a new method of active diode operation which uses dimensions and tolerances associated with much lower frequencies.

(b) An approximate theory of thermal effects from self-heating during long pulse or CW biases has been further developed. It reveals for sufficient self-heating that significant differences may arise not only in precise magnitudes, but in trends (i.e., shape of impedance vs frequency plots), negative-resistance threshold and peak frequencies, and multiplicity of negative resistance regimes, compared to "cool" diodes.

(c) The dynamics of self-resonant IMPATT diodes (in which oscillation frequency is determined by device geometry) has been explored and appears to parallel that of self-resonant LSA diodes despite the difference in basic physics.

(d) A discrepancy in the energy balance for active diodes has been uncovered which may have important consequences in the accuracy of the impedance descriptions of very long LSA diodes and acousto-electric diodes.

(e) The sensitivity of diode operation to geometry, such as non-cylindrical shapes and doughnut shapes, has been examined and used to delineate, in part, the range of validity of the usual one-dimensional quasi-static theory. Further work is required here.

(f) A new parameter σ (which has the properties associated with a negative conductivity) has been used to unify the description of diverse aspects of device behavior and has led to an approximate formula for impedance which greatly reduces and simplifies the numerical analysis.

(g) The dispersion relations for IMPATT have been re-examined and misleading statements in the literature have been clarified. A simple, tractable generalization has been advanced which takes extensive parameter asymmetry into account.

Experimental work was undertaken to investigate some of the effects disclosed by the above theoretical work, as well as pursue other areas not presently amenable to analysis.

(a) Subharmonic CW oscillation in a Sylvania silicon IMPATT diode has been observed. The fundamental (9 GHz) and a subharmonic (4.5 GHz) were detected in the vicinity of a diode mounted in a coaxial cavity. Tuning with multiple slugs constrained the fundamental to the vicinity of the diode while the subharmonic was permitted to transfer power externally. The power output and efficiency were not high. Further work is required in this area.

(b) Multi-resonant effects have been obtained in coaxial cavities so that single commercial IMPATT diodes have been run simultaneously at three or four nonharmonically related frequencies with a roughly equal power division among these frequencies.

OPTICS
DIVISION 5

INTRODUCTION

This section summarizes the General Research efforts of Division 5 for the period 1 August through 31 October 1969. A complete presentation of the Optics effort may be found in the quarterly Optics Research Report and in the Semiannual Technical Summary and Quarterly Letter Report to the Advanced Research Projects Agency.

R. H. Kingston
Head, Division 5

OPTICS AND INFRARED
GROUP 53

The average heterodyne detected signal attenuation along slant paths for several different H_2O partial pressures has been measured. A conically scanning local oscillator has been used to actively track a stationary target; improvements in the optical quality of the local oscillator beam, in the local oscillator stability, and in the frequency tracking receiver, which will increase the sensitivity of the active tracking mode, have been undertaken. The final amplifier has generated a nearly diffraction limited 1.4 kW beam and the power-handling capability of the transmitter optics is being increased to a compatible level.

A number of experiments have been carried out to measure the Lamb dip associated with CO_2 lasers. The accuracy and the range of results obtained in the preliminary experiments go far beyond those of previously published data. Experiments are currently under way to accurately determine shifts and assess stabilization capabilities.

The 10.6 μm beams from two $Pb_{0.88}Sn_{0.12}Te$ diode lasers were heterodyned in a Ge:Cu detector. The beat frequency could be changed by tuning either laser. Since $Pb_{1-x}Sn_xTe$ lasers can be chemically tailored to emit at any center wavelength from 6.5 to 32 μm, infrared heterodyne experiments are no longer restricted to the 10.6 μm range.

Coherent spectroscopic measurements of gas absorption lines near 10.6 μm have continued with the identification of several ammonia transitions and the measurement of the sulfur hexafluoride spectrum near several major P-transitions of the CO_2 laser.

ENGINEERING
DIVISION 7

INTRODUCTION

The Engineering Division's support of the General Research program has most recently involved the upgrading of receiver facilities at Haystack-Millstone, the design of high pressure apparatus for solid state research, and the development of components and research facilities for integrated circuitry.

During the August-October quarterly period, a hold time of 24 hours was achieved in the operation of the masers on the tracking antenna at Haystack. At Millstone, work continues on the installation of a new 10-foot diameter frequency-selective subreflector for the 84-foot tracker, and on the design of encoder couplings to improve antenna directional control in both elevation and azimuth.

The Integrated Circuit Facility has completed initial steps in the development of several types of semiconductors, including Impatt diodes, E-bird devices, and photodiode strips and arrays. Microwave circuits employing thin film resistors, capacitors and strip-line metalization have been fabricated and tested successfully during this period, and considerable research work is in progress on material properties for microwave structures.

J. F. Hutzenlaub
Head, Division 7

MECHANICAL ENGINEERING
GROUP 71

I. HAYSTACK CRYOGENICS

A superconducting magnet coil identical to the one used in masers Nos. 2 and 3 was completed as a spare and tested in liquid helium. The magnet operated satisfactorily after which the unit was installed in the closed cycle refrigerator. An attempt to have the magnet become superconducting failed, although the refrigerator attained a temperature of 3.8°K. It is believed that additional means of removing heat are required in order to enable the superconducting magnet to operate.

Tests were performed on masers Nos. 2 and 3 to try to improve the hold time on the antenna. By removing a series of thirteen baffles, we were able to increase the operating time of the masers to 24 hours. What effect, if any, this has on the system temperature is not known at this time. Helium liquid level sensors were installed in the maser head to allow more reliable monitoring of both filling and operating.

II. MILLSTONE

A. Frequency-Selective Subreflector (F. S. S.)

Fabrication and testing of a new 10-foot-diameter frequency-selective subreflector for the 84-foot-diameter Millstone Tracker have been completed by the Philco-Ford Corporation. Handling and alignment equipment are being assembled for a scheduled November installation. In addition, a 150-MHz twin-loop antenna has been tested and will be installed inside the subreflector housing. Special coaxial and signal cabling, including an azimuth cable wrap, has been installed from the transmitter building to the antenna apex enclosure for use with the new subreflector.

B. El-Az Encoders

Design has been completed for an on-axis encoder coupling for the elevation axis.

Equipment already existing on the azimuth axis prevents the installation of an on-axis encoder coupling. Mechanical design and dynamic analysis studies are being made for an off-axis, one-speed, cam-actuated coupling. Precision ground flat bars are attached to the inner bearing seat of the azimuth bearing to form a polygon cam. A cam follower, with as many flat sides as the cam (8-sided), is coupled to the encoder shaft. The encoder is mounted on a carriage which is allowed to slide radially on a rail frame. This entire rail frame and carriage are fixed to the pedestal base. When the antenna rotates, the cam rails rotate. As the cam follower slides along the cam rail, it also rotates through an angle, and turns the encoder shaft through a number of degrees depending upon the length of the rail. When the follower reaches an intersection of two rails, its adjacent side makes contact with a matching rail and the sliding action continues.

This process repeats until each cam follower side has moved along its matching rail. One revolution of the antenna results in one revolution of the cam follower and the encoder shaft.

A test program for this concept is planned in which a full-scale working model will be built and accurately measured using a rotating table.

III. SOLID STATE

A. X-ray Camera

A new high pressure x-ray diffraction apparatus using a boron-carbide (BoC) pressure vessel has been designed and built. The overall technique is based on a standard Debye-Scherrer Camera.

Pressure is generated at the sample by means of a gas intensifier up to 14 kilobars, thus avoiding uniaxial or frictional stress distortion of the sample.

The design of the pressure cell is such that x-ray diffraction patterns can be obtained by either powder or oscillating single crystal techniques.

X-ray absorption by boron-carbide is about 50 percent less than that of diamond, and both CuK and MoK radiation may be utilized. CuK radiation is especially useful in the back-reflection region.

MICROELECTRONICS
GROUP 77

The Integrated Circuit Facility has completed initial steps in the development of several semiconductor programs:

(1) Impatt diodes designed to operate at 5 GHz have been fabricated in mesa, planar, and passivated mesa form. Initial tests by the requesting group have indicated that the Impatt diodes oscillate at 4.5 GHz and are at least capable of current levels of 80 to 100 mA.

(2) E-bird devices (electron beam irradiated diodes) have been fabricated using special diffusion techniques to achieve junction depths of 0.3 μ with voltage breakdowns of 250 volts. Current gains of 800 have been observed during early testing, although the long range goal is to achieve current gains of 3,000, a power level of 1 kW and operating frequencies of 500 to 1,000 Mc.

(3) Semiconductor substrates with diffused regions and metalization have been fabricated as basic pieces of surface wave transducer amplifiers.

(4) Planar diodes and transistors have also been fabricated to support the hybrid integrated circuit activity and as forerunners of special monolithic circuits and arrays.

(5) The development of photodiode strips (60 to 120 diodes per strip) and photodiode arrays for special storage systems has been initiated. Masks and silicon wafers have been prepared for the development of millimeter wave Schottky Barrier devices with typical dimensions of a few microns.

(6) The metal oxide semiconductor capacitor development reported last time has been successfully completed, resulting in very useful storage elements.

Continued work on beam lead substrates employing rigid alumina material has advanced to systems accommodating 30 or more monolithic chips, and similar work employing flexible (Kapton) material is in progress.

Microwave circuits employing thin film resistors, capacitors and strip line metalization have been fabricated and tested successfully during this period and considerable research work is in progress on material properties for microwave structures.

Thick film materials research continues, particularly in dielectrics and fine line metalization, and numerous application-oriented networks such as gridded breadboard substrates have been fabricated.

A laser scanner for semiconductor device and circuit chip inspection and testing has been assembled and is currently being evaluated. Initial results indicate that three-dimensional-type representations are possible in addition to the expected presentation of metalization, diffusion regions, and other substrate features.

Computer programs are being written to allow fast layout digitizing, and work is continuing on the CIRCUS program to provide both a quick presentation of the static values of a circuit as well as a conversational mode of operation of the entire program.

SOLID STATE
DIVISION 8

INTRODUCTION

This section summarizes the work of Division 8 from 1 August through 31 October 1969. 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 August through 15 November 1969

PUBLISHED REPORTS

Journal Articles*

JA No.			
3301	Effective-Mass Theory for Polarons in External Fields	D.M. Larsen	Phys. Rev. 180, 919 (1969), DDC AD-694896
3380	Partial Pressures of Zn and Te_2 over ZnTe up to 917°C	R.F. Brebrick	J. Electrochem. Soc. 116, 1274 (1969)
3400	Magnetoreflection Studies in Arsenic	M. Maltz M.S. Dresselhaus	Phys. Rev. 182, 741 (1969)
3417	Space-Time Symmetry Restrictions on Transport Coefficients. III. Thermogalvanomagnetic Coefficients	W.H. Kleiner	Phys. Rev. 182, 705 (1969)
3441A	Magnetoreflection Studies on the Band Structure of Bismuth-Antimony Alloys	E.J. Tichovolsky J.G. Mavroides	Solid State Commun. 7, 927 (1969), DDC AD-693671
3442	Effects of Light on the Charge State of InSb-MOS Devices	W.E. Krag R.J. Phelan, Jr. J.O. Dimmock	J. Appl. Phys. 40, 3661 (1969)
3449	Magnetoemission Experiments in $Pb_{1-x}Sn_xTe$	J.F. Butler	Solid State Commun. 7, 909 (1969)
3467	Absolute Experimental X-Ray Form Factor of Aluminum	P.M. Raccah V.E. Henrich	Phys. Rev. 184, 607 (1969)
3468	Magnetospectroscopy of Shallow Donors in GaAs	G.E. Stillman C.M. Wolfe J.O. Dimmock	Solid State Commun. 7, 921 (1969), DDC AD-693903
3490	Hydroxyl and Water Masers in Protostars	M.M. Litvak	Science 165, 855 (1969)
3491	Perturbation of the Refractive Index of Absorbing Media by a Pulsed Laser Beam	P.R. Longaker M.M. Litvak	J. Appl. Phys. 40, 4033 (1969)

* Reprints available.

Division 8

JA No.

3503A	Millimetre Wave Emission by Interstellar Dust	M. M. Litvak	Nature 223, 1143 (1969)
3547	Polaron Cyclotron Resonance in CdTe	J. Waldman D. M. Larsen P. E. Tannenwald C. C. Bradley* D. R. Cohn* B. Lax*	Phys. Rev. Letters 23, 1033 (1969)
3583	Far Infrared Recombination Radiation from Impact Ionized Shallow Donors in GaAs	I. Melngailis G. E. Stillman J. O. Dimmock C. M. Wolfe	Phys. Rev. Letters 23, 1111 (1969)

MS No.

2024	The Raman Spectrum of Trigonal, α-Monoclinic and Amorphous Selenium	A. Mooradian G. B. Wright	The Physics of Selenium and Tellurium (Pergamon, New York, 1969), DDC AD-694135
2166A	Electronic Raman Scattering from Impurities in Semiconductors	G. B. Wright A. Mooradian	Proc. 9th International Conference on Physics of Semiconductors, Vol. 2 (Nauka, Moscow, 1968)
2194	The Two-Phonon Infrared and Raman Spectrum of CdTe	A. Mooradian G. B. Wright	
2236	Raman Scattering from Magnetoplasma Waves in Semiconductors	A. L. McWhorter P. N. Argyres	
2183	Interband Magnetoreflection of Gray Tin	S. H. Groves C. R. Pidgeon* A. W. Ewald* R. J. Wagner*	Proc. 9th International Conference on Physics of Semiconductors, Vol. 1 (Nauka, Moscow, 1968)
2188	Electroreflection Study of Inversion Asymmetry and Warping Induced Interband Magneto-Optical Transitions in InSb	C. R. Pidgeon* S. H. Groves	
2195	An Exciton in a High Magnetic Field – Germanium	E. J. Johnson	
2236A	Raman Scattering from Magnetoplasma Waves in Semiconductors	A. L. McWhorter P. N. Argyres	Light Scattering Spectra of Solids, G. B. Wright, ed. (Springer-Verlag, New York, 1969)
2331	Raman Scattering from Spin-Density Fluctuations in n-GaAs	D. C. Hamilton A. L. McWhorter	

* Author not at Lincoln Laboratory.

MS No.			
2332	Light Scattering from Single-Particle Electron and Hole Excitations in Semiconductors	A. Mooradian	Light Scattering Spectra of Solids, G.B. Wright, ed. (Springer-Verlag, New York, 1969)
2335	Light Scattering from Plasmons and Phonons in GaAs	A. Mooradian A.L. McWhorter	
2336	Light Scattering from Plasmons in Semiconductors	A.L. McWhorter	Electronic Structures in Solids (Plenum, New York, 1969), DDC AD-693902
2338	Meaning of an Anomaly in the X-Ray Scattering of ZnSe	P.M. Raccah	Electronic Structures in Solids (Plenum, New York, 1969), DDC AD-694134
2339	Band Approach to the Transition Metal Oxides	J. Feinleib	Electronic Structures in Solids (Plenum, New York, 1969), DDC AD-694133
2528	Light Scattering in Semiconductors	A. Mooradian	Festkörperprobleme IX (Pergamon, New York, 1969)

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UNPUBLISHED REPORTS

Journal Articles

JA No.			
3499	Infrared Cyclotron Resonance and Related Experiments in the Conduction Band of InSb	E.J. Johnson D.H. Dickey	Accepted by Phys. Rev.
3501	Evidence for a Native Donor in ZnSe from High Temperature Electrical Measurements	F.T.J. Smith	Accepted by Solid State Commun.
3517	Resonant Raman Scattering from LO Phonons in Polar Semiconductors	D.C. Hamilton	Accepted by Phys. Rev.
3520	An On-Line Data Recording System	W. Krag N. Daggett R.N. Davis F. Perkins*	Accepted by Rev. Sci. Instr.
3521	Ionized Impurity Density in n-Type GaAs	C.M. Wolfe G.E. Stillman J.O. Dimmock	Accepted by J. Appl. Phys.

* Author not at Lincoln Laboratory.

Division 8

JA No.			
3524	Inelastic Light Scattering from Semiconductor Plasmas in a Magnetic Field	F. A. Blum	Accepted by Phys. Rev.
3525	Magnetic Ordering Effects in the Ultraviolet Reflectance of EuS and EuSe	W. J. Scouler J. Feinleib J. O. Dimmock C. R. Pidgeon*	Accepted by Solid State Commun.
3528	Linear Wavevector Shifts in the Raman Spectrum of α-Quartz and Infrared Optical Activity	A. S. Pine G. F. Dresselhaus	Accepted by Phys. Rev.
3545	Cadmium Rhenium (V) Oxide, $Cd_2Re_2O_7$	J. M. Longo P. C. Donohue* D. A. Batson	Accepted by Inorg. Synth.
3546	Transport Equation for a Fermi System in Random-Scattering Centers. II. Independent Electrons in an Arbitrarily Varying Electric Field and Strong Single-Center Potentials	J. L. Sigel P. N. Argyres*	Accepted by Phys. Rev.
3553	MIS Electroluminescent Diodes in ZnTe	J. P. Donnelly A. G. Foyt W. T. Lindley G. W. Iseler	Accepted by Solid-State Electron.
3580	Electrically Active Point Defects in Cadmium Telluride	F. T. J. Smith	Accepted by Trans. Met. Soc. AIME
3582	Interpretation of $M_xV_2O_5$-β and $M_xV_{2-y}T_yO_5$-β Phases	J. B. Goodenough	Accepted by J. Solid State Chem.
3585	Residual Impurities in High-Purity Epitaxial GaAs	C. M. Wolfe G. E. Stillman E. B. Owens	Accepted by J. Electrochem. Soc.
3591	Comparison of Theoretical and Experimental Charge Densities for C, Si, Ge, and ZnSe	P. M. Raccah R. N. Euwema* D. J. Stukel* T. C. Collins*	Accepted by Phys. Rev.
3592	Structure and Magnetic Properties of $VOSO_4$	J. M. Longo R. J. Arnott	Accepted by J. Solid State Chem.
3597	The Hubbard Model: Insulator or Conductor for Narrow Band Regime?	R. A. Bari R. V. Lange*	Accepted by Phys. Letters

* Author not at Lincoln Laboratory.

JA No.			
3601	Structure of the $M_xV_2O_5$-β and $M_xV_{2-y}T_yO_5$-β Phases	J. Galy* J. Darriet* A. Casalot* J.B. Goodenough	Accepted by J. Solid State Chem.
MS-2666	Magnetic and Optical Properties of the High and Low Pressure Forms of $CsCoF_3$	J.M. Longo J.A. Kafalas J.R. O'Connor J.B. Goodenough	Accepted by J. Appl. Phys.

Meeting Speeches†

MS No.			
2545A	High Pressure Phases with Perovskite Related Structure in the System $Sr_{1+x}IrO_{3+x}$ ($x = 0, 1/3, 1/2, 1$)	J.M. Longo J.A. Kafalas	22nd International Congress on Pure and Applied Chemistry, Sydney, Australia, 20-27 August 1969
2548	Absolute Measurement of the Atomic Form-Factor of Ni	P.M. Raccah V.E. Henrich	8th International Congress on Crystallography, State University of New York, Stonybrook, 13-21 August 1969
2571A	Ion Implantation in Compound Semiconductors	A.G. Foyt	Seminar, Itek Corp., Lexington, Massachusetts, 24 September 1969
2586	Electrically Active Point Defects in Cadmium Telluride	F.T.J. Smith	Defects in Electronic Materials for Devices, Boston, 24-27 August 1969
2591	Photoluminescence Due to Isoelectronic Te Traps in $CdS_{1-x}Se_x$ and $Zn_{1-y}Cd_ySe$ Alloys	G.W. Iseler A.J. Strauss	International Conference on Luminescence, University of Delaware, 25-29 August 1969
2615	Magneto-Optics	J.G. Mavroides	Conference on High Magnetic Fields and Their Applications, University of Nottingham, England, 17-19 September 1969
2617A	One-Electron Theory of Interband Transitions	G. Dresselhaus	Seminar, General Electric Research and Development Center, Schenectady, 7 October 1969
2620	Thermodynamic Behavior and Deviations from Stoichiometry	R.F. Brebrick	136th National Meeting, Electrochemical Society, Inc., Detroit, 5-10 October 1969
2621	Variations of Infrared Cyclotron Resonance and the Density of States Near the Conduction Band Edge of InSb	E.J. Johnson D.H. Dickey	3rd Materials Research Symposium, Electron Density of States, Gaithersburg, Maryland, 3-6 November 1969

* Author not at Lincoln Laboratory.

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

Division 8

MS No.			
2628	On the Optical Properties and the Density of States in Arsenic	R.W. Brodersen* M.S. Dresselhaus	3rd Materials Research Symposium, Electron Density of States, Gaithersburg, Maryland, 3-6 November 1969
2630	Optical Properties of Aluminum	G. Dresselhaus M.S. Dresselhaus D. Beaglehole*	
2631	Localized States in Narrow Band and Amorphous Semiconductors	D. Adler J. Feinleib	
2623	Laser Beam Trapping and Non-Linear Interactions in Semiconductors	A. Mooradian	NEREM-69, Boston, 5-7 November 1969
2632	Explanation of Cyclotron Resonance in Finite Slab Galt Geometry	A.R. Wilson	Fundamental Problems in Metals Conference, Banff, Alberta, Canada, 11-22 August 1969
2644	Linear Wavevector Dispersion of the Shear Wave Phase Velocity in α-Quartz	A.S. Pine	Conference on Interaction of Light with Sound Waves, San Diego, 4-5 November 1969
2681	Optical Reflectance Study of the Magnetic Ordering Effects in EuO, EuS, EuSe and EuTe	C.R. Pidgeon* J. Feinleib W.J. Scouler	Symposium on Magnetic Semiconductors, Yorktown Heights, New York, 13-14 November 1969
2683	Temperature and Magnetic Field Dependence of the Conductivity of EuO	M.R. Oliver J.O. Dimmock T.B. Reed	
2708	Optical Properties of the Europium Chalcogenides	J.O. Dimmock	
2684	A Conceptual Phase Diagram for Outer Electrons in Solids	J.B. Goodenough	Seminar, 3-M Company, St. Paul, Minnesota, 17 October 1969
2691	Band Structure of Rare Earth Metals	J.O. Dimmock	The Metallurgical Society Fall Meeting, Philadelphia, 13-16 October 1969
2693	Comparison of Absolute X-Ray Form-Factors with the Predictions of Band Calculations	P.M. Raccah	Seminar, Purdue University, 9 October 1969
2694	Mass Spectrometry	E.B. Owens	Seminar, Instrumentation Laboratory, Lexington, Massachusetts, 13 November 1969
2696	Infrared Studies in Small Band-gap Pb-Sn Salt Materials	A.R. Calawa	Seminar, Case Institute of Technology, 7 October 1969

* Author not at Lincoln Laboratory.

MS No.			
2705	Interstellar Molecules and Non-Equilibrium Processes	M. M. Litvak	Physics Colloquium, University of Maryland, 29 October 1969
2706	The Effects of Light on the Charge State of InSb MOS Structures	W. E. Krag	Seminar, University of Rhode Island, 22 October 1969
2718	Inelastic Light Scattering from Semiconductor Plasmas in a Magnetic Field	F. A. Blum	Seminar, Yale University, 6 November 1969
2720	Spectroscopy of Shallow Donor Levels in GaAs Extrinsic Photodetectors	G. E. Stillman	Seminar, RCA Laboratories, Princeton, New Jersey, 6 November 1969
2726	Theory of Surface Plasmon Excitation in Low Energy Electron Diffraction and in Photoemission	K. L. Ngai	Seminar, University of Chicago, 29 October 1969
2727	Theory of Antiferromagnetism and Ferrimagnetism	J. B. Goodenough	Ceramics Research Meeting, University of Florida, 12 November 1969
2729	Two-Magnon Raman Scattering from Magnetic Insulators	S. R. Chinn	Seminar, M.I.T., 7 November 1969
2730	Non-Equilibrium Processes Related to Interstellar Molecules	M. M. Litvak	Course on Radio Spectral Lines, Harvard College Observatory, 4 November 1969

SOLID STATE
DIVISION 8

I. SOLID STATE DEVICE RESEARCH

Far infrared radiation corresponding to transitions of impact ionized electrons from excited-donor and conduction band states to the ground state of a shallow donor has been observed in high purity epitaxial layers of GaAs at 4.2°K. The emission has a main peak at 282 μ (4.4 meV) due to transitions from the lowest excited-donor state to the ground state and a broad continuum extending to higher photon energies. A total radiated power of 10^{-7} W has been observed, corresponding to an external efficiency of about 10^{-6}.

Proton bombardment has been used to produce n-type layers in p-type InSb and to fabricate high quality n-p junction photovoltaic detectors. The 20-mil diameter diodes produced in this manner have shown incremental resistances at zero bias in the range of several hundred thousand ohms. A peak detectivity of 7.7×10^{10} cm $Hz^{1/2}$/W has been observed at 5.3 μ, which is about half the background limited value for this wavelength. An array of 12 diodes has been fabricated on a single InSb wafer using this method; all diodes had 500°K black body detectivities in excess of 1×10^{10} cm $Hz^{1/2}$/W.

The temperature and magnetic field dependence of the Hall coefficient factor for polar optical mode scattering have been measured in high purity n-type epitaxial layers of GaAs between 77° and 300°K in magnetic fields up to 90 kG. The experimental variation is in fair agreement with theoretical calculations and provides the first test for the theory. This variation produces a change in the measured Hall constant in high purity GaAs which can give the appearance of a higher calculated carrier concentration at 77°K than at 300°K.

The conductivity of the ferromagnetic semiconductor EuO has been measured as a function of temperature from 30° to 300°K in magnetic fields up to 50 kG. The resistivity exhibits a sharp increase by as much as 10^8 between 50° and 70°K. Data are interpreted in terms of a transfer of electrons between a conduction band whose energy position is a strong function of temperature and magnetic field and a trap whose energy is roughly constant.

II. MATERIALS RESEARCH

An ideal equation for the relationship between liquidus and solidus compositions has been used to calculate solidus curves for a large number of homogeneous, monotonic alloy systems from liquidus and enthalpy of fusion data. The calculated curves are in good to excellent agreement with published solidus data, except for a few systems where reevaluation of the experimental data is indicated.

The solidus curve of the pseudobinary CdTe-ZnTe system has been determined by differential thermal analysis of heating curves obtained in experiments on homogenized alloys. Because of the relatively narrow liquidus-solidus gap, it has been possible to grow single crystals of the alloys by the Bridgman method from stoichiometric melts.

A large number of tellurates based on the alkali antimonates $NaSbO_3$ and $LiSbO_3$ have been prepared by sintering stoichiometric mixtures of oxides and carbonates. Most of these compounds have either the ilmenite structure of $NaSbO_3$ or the $LiSbO_3$ structure, but Na_2MnTeO_6, Na_2SnTeO_6, and the high temperature form of Na_2GeTeO_6 have a hexagonal structure which has not been identified.

Two spinels, Co_2RuO_4 and $ZnCoRuO_4$, have been prepared by reacting Co and Zn carbonates with Ru metal. These are the first reported spinels containing Ru^{4+}.

Quantitative treatment of x-ray powder diffraction data has shown that tetragonal α-$VOSO_4$ has the same structure as $NbOPO_4$. The magnetic properties of this tetragonal form differ markedly from those of the orthorhombic β-$VOSO_4$.

An earlier study of chemical analysis by EDTA titrations using color change end points showed that Zn can be determined to a precision of two parts per thousand by an automatic photometric method. It has been found that for many other metals comparable precision can be obtained by manual photometric titration, but not by the automatic method.

The published technique for making mass spectrographic analyses on frozen aqueous solutions has been modified by replacing the graphite sample cup and counterelectrode with a nickel sample cup and platinum counterelectrode. Initial results indicate that the modified method should make it possible to determine almost all elements in solution at the level of ten parts per million (atomic) or higher.

III. PHYSICS OF SOLIDS

The study of interband magnetoreflection from α-Sn has been completed. Possible explanations for the systematic deviation at high photon energies of the theory based on the inverted band structure model have been proposed.

Extension of the low temperature stress measurements on phosphorus-doped silicon to more homogeneous and higher stresses (up to 17.5×10^8 dynes/cm^2), about three times that of earlier experiments, has resulted in a significant improvement in the impurity optical spectra. This has allowed the observation of a nonlinear energy shift of the transition energies, which is explained theoretically by the downward shift of the ground state with stress.

A discrepancy exists between the observed deformation potential for donors in silicon obtained in photoexcitation spectra and hyperfine interaction measurements. The possibility of explaining the difference by considering a dipolar hyperfine interaction was explored and shown to be unlikely.

Shubnikov-de Haas measurements under hydrostatic pressure (up to 8 kbars) have been carried out in $Pb_{1-x}Sn_xTe$ alloys of composition $0.16 \leq x \leq 0.32$. The shape of the Fermi surface appears not to change with pressure although there is a decrease of the cyclotron effective masses.

Previous optical reflectance studies of magnetic ordering effects in the magnetic semiconductors EuS and EuSe, which have provided evidence that the conduction band is spin-polarized in the ferromagnetic state and that the low energy peak E_1 (at ~1.5 eV) is due to $4f^7 \rightarrow 4f^6 5d(t_{2g})$ transitions, have now been extended to the higher energy peak, E_2 (at ~4 eV). The results suggest that the E_2 peak is due at least in part to $4f^7 \rightarrow 4f^6 5d(e_g)$ transitions. Similar measurements have also been made on EuTe which is antiferromagnetic below 10°K. In

this case the reflectance is strongly field dependent at the lower fields. At high fields (above 60 koe) the E_1 structure has a form identical to that of ferromagnetic EuO, EuS and EuSe, and this is taken as evidence for field-induced spin alignment in EuTe.

Various aspects of neutron diffraction experiments yield conflicting results as to the order of the ferrimagnetic-antiferromagnetic transition in Cr_5S_6. In order to resolve this apparent contradiction, Cr_5S_6 is being examined theoretically by means of the Heisenberg Hamiltonian, and experimentally by investigating its magnetic properties as a function of pressure as well as magnetic field and temperature.

Accurate measurements of spin-wave resonance absorption peaks on two permalloy films from 5 to 70 GHz show that the deviation from a $1/p^2$ fall-off is a strong function of frequency. Consequently, any intensity model must incorporate such a frequency dependence. Furthermore, the spin-wave dispersion was quadratic in mode number from p = 9 to 21; also the mode number assignment for these films was unambiguous.

A new type of single determinant variational approach has been applied to a Hubbard model of localized and band magnetic semiconductors. Stability boundaries for different phases of the system, based on free energy, have been obtained.

A mathematical criterion for a phase transition, based on the asymptotic degeneracy of the largest eigenvalue of a certain linear operator, has been applied to the exactly soluble case of a linear chain of classical spins of arbitrary dimension interacting through an isotropic Heisenberg Hamiltonian.

The two-magon spectrum of $KNiF_3$ has been observed and compared with the Green's function calculation of the line shape for s = 1 spins. Agreement between the calculated and observed line shape is excellent.

The study of laser scattering from α-quartz has been continued. A linear wavevector dispersion, previously reported for the optical phonon, has now been observed in the transverse acoustic branches via backward Brillouin scattering.

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This Quarterly Technical Summary covers the period from 1 August through 31 October 1969. It consolidates the reports of Division 2 (Data Systems), Division 4 (Radar), Division 5 (Optics), Division 7 (Engineering), and Division 8 (Solid State) on the General Research Program at Lincoln Laboratory.

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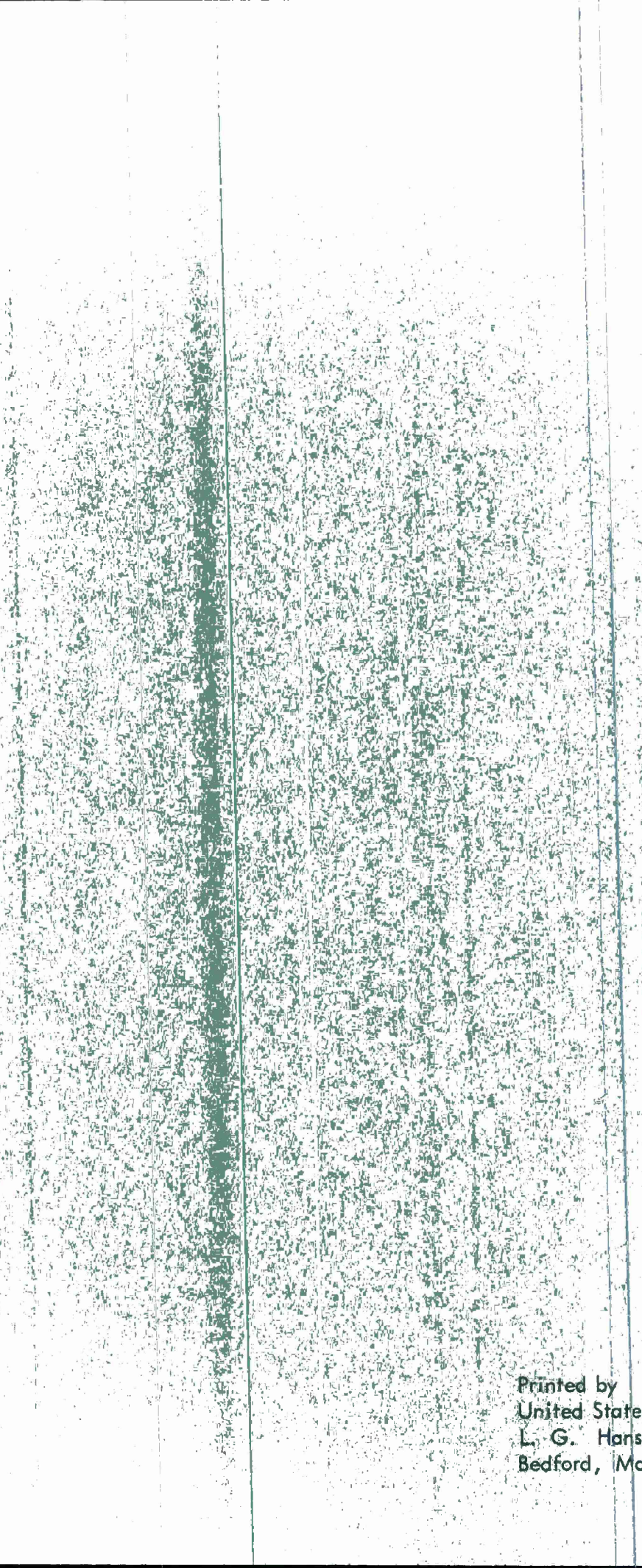

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