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MASSACHUSETTS INSTITUTE OF TECHNOLOGY  
LINCOLN LABORATORY

ADVANCED ELECTRONIC TECHNOLOGY

QUARTERLY TECHNICAL SUMMARY REPORT  
TO THE  
AIR FORCE SYSTEMS COMMAND

1 NOVEMBER 1978 - 31 JANUARY 1979

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LEXINGTON

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## INTRODUCTION

This Quarterly Technical Summary covers the period 1 November 1978 through 31 January 1979. It consolidates the reports of Division 2 (Data Systems) and Division 8 (Solid State) on the Advanced Electronic Technology Program.

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DATA SYSTEMS  
DIVISION 2

INTRODUCTION

This section of the report reviews progress during the period 1 November 1978 through 31 January 1979 on Data Systems. Separate reports describing other work of Division 2 are issued for the following programs:

Seismic Discrimination	ARPA/NMRO
Distributed Sensor Networks	ARPA/IPTO
Education Technology	Bureau of Mines
Network Speech Systems Technology	OSD-DCA
Digital Voice Processing	AF/ESD
JTIDS Speech Processing	AF/ESD
Packet Speech Systems Technology	ARPA/IPTO
Radar Signal Processing Technology	ARMY/BMDATC
Nuclear Safety Designs	NRC

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DIGITAL INTEGRATED CIRCUITS  
GROUP 23

I. INTRODUCTION

A parallel/serial converter to complement the 1-GHz serial/parallel converter is being built. Signals were obtained from a 64K MNOS memory chip, and good progress was made in solving processing problems. Design of an improved 64K chip which will also be used to demonstrate techniques for larger capacity chips was completed.

II. HIGH-SPEED DIGITAL CIRCUITS

A. Parallel/Serial Converter

A parallel/serial converter has been designed as a modification to the previously reported 1-GHz serial/parallel circuit. Diffusion and via masks will be the same. New metal masks have been designed and are being made. Wafers already partially fabricated will be used for the first devices.

B. Poly-Ox Process Development

Introduction of a polysilicon layer to accept the heavy buried-collector arsenic implant has led to visually superior surfaces after processing and lower yield loss due to emitter-collector leakage. The use of a back-side gettering implant and a controlled-rate wafer puller during high-temperature processing has resulted in lower collector-substrate junction leakage.

Polysilicon emitter processing has been incorporated into the poly-ox process in the fabrication of test transistors and serial-to-parallel converter circuits. Transistor beta is high (90 to 110) and remains high at low collector current (0.1  $\mu$ A), indicating low recombination at the emitter-base junction. Dynamic testing will be performed.

The first two runs of a new test chip have been processed through first metal. Test transistors with emitter mask dimensions of  $1 \times 8 \mu\text{m}$  and  $3 \times 3 \mu\text{m}$  have excellent yield. Measurements on polysilicon-diode test structures on these chips indicate space-charge depletion widths of 400 to 800  $\text{\AA}$  in poly and a built-in voltage of 0.4 V. From forward I-V characteristics, recombination has been determined to be the primary forward-current mechanism below 0.5 V, and the minority carrier lifetime is about 60 psec.

III. MNOS MEMORY

A. 64K-Chip Fabrication

High digit-line impedance due to poor first-to-second-level contacts was fixed, in an experiment, by "burning in" the contacts on several 64K chips with bypassed decoder transistors. Successful storage and readout was obtained on these chips, with no signal attenuation observed along the digit line. Decoded  $3 \times 3$  arrays which do not need the metal digit line were also operated successfully. It was not possible to burn in contacts on the decoded 64K array. The first-to-second-level contact difficulty is being attacked as part of the between-layer insulation problem.

It was previously reported that incomplete coverage of the plasma-etched first-level metal by CVD oxide resulted in first-to-second-level metal shorts. At atmospheric pressure, the



mass transfer rate of the reactant species to the wafer surface is equal to the reaction rate at the surface. As a result, significant thickness differences occur due to variations in gas velocity across the metal pattern. At reduced pressures, however, the reaction is surface-rate controlled so that conformal coating is more likely. Successful coverage of the first-level-metal pattern was obtained by plasma-enhanced deposition of silicon nitride at low pressure. Test results on several wafers indicated that greater than 50 percent of the chips had no insulator shorts.

The use of a high-temperature polyimide plastic as a between-metal insulator has also been investigated, with promising results. The polyimide provides good corner/edge coverage, can have vias etched in it, and will withstand metal sinter temperatures ( $>400^{\circ}\text{C}$ ).

#### B. MNOS Memory Development

Masks have been ordered for the second generation of the 64K memory. The use of p-type word-resistor pulldowns and CMOS digit decoding is expected to give much better performance. The design incorporates several experiments to test ideas for higher-density chips.

Silicon nitride has been thermally grown in an ammonia atmosphere to a thickness of  $50 \text{ \AA}$ . Memory capacitors are being fabricated with thin thermal nitride as a replacement for the oxide layer in the usual MNOS storage structure. Some anticipated improvements with this structure are an elimination of the negative shift of the memory window which is often seen after many write erase cycles and, perhaps, improved storage characteristics.

A new sense amplifier with 10-MHz bandwidth and noise current of  $2.5 \times 10^{-13} \text{ A}/\sqrt{\text{Hz}}$  at 1 MHz has been used to sense signals from a  $1 \times 2.5 \text{ \mu m}$  storage capacitor in a  $30 \times 30$  array. It should be usable for storage sites as small as  $1 \text{ \mu m}^2$ .

#### C. Laser Selective Depopulation Studies

In order to understand the mechanism of charge storage and the fatigue phenomena in a MNOS device, a knowledge of the site symmetry and the energy levels of the charge trapping state in the insulating film is essential. Combinations of optical and electrical measurement techniques provide such information. Optical absorption and reflection of n-Si and silicon-on-sapphire wafers coated with  $\text{SiO}_2$  and  $\text{Si}_3\text{N}_4$  have been measured at room temperature from ultraviolet to infrared. Besides the characteristic bands of the substrate, broad bands associated with the Si-O and Si-N bonds have been observed. In order to obtain more information regarding site symmetry in the material, measurements at low temperature are planned. MNOS capacitors with indium-tin-oxide upper electrodes have been characterized with write "1" in the presence of He-Ne laser light. Further studies with write "0" and fatiguing of MNOS capacitors with and without a tunable laser light are planned next.

### IV. TESTING AND ANALYSIS

#### A. Testing

The TIC system capacitance-voltage tests have been revised to provide better data. Both standard and pulsed C-V tests may be performed. MOS parameters and impurity-concentration information are derived from the plots by the computer program. The hardware has been redesigned to provide more accurate voltage output, which should upgrade the test performance.

The TIC system is now being used to process data from the digital storage oscilloscope to obtain distributions of the "1" and "0" signals from MNOS memory chips.

## B. Mask Analysis

A mask artwork analysis program is being designed and implemented on the IBM 370 computer. The goal is to provide the user with a flexible set of mask manipulation primitives which will permit design rule checking and design verification. These primitives consist primarily of topological, Boolean, and input-output operations. Mask data are sorted so that the operations can be performed efficiently on large and complex masks. A limited version of the program was employed to calculate perimeter and area of intersection of first- and second-level metal of one of the gate array chips, LL608.2A. The total job CPU time, including sorts and data transfers, was 5 min.

COMPUTER SYSTEMS  
GROUP 28

As the quarter ended and the work load continued to grow, proposals for a more powerful replacement computer system have been received. These will be evaluated during the next quarter. Bids for a replacement of the obsolete Stromberg Datagraphix 4060 CRT plotter system have been received and evaluated. The result was a contract award to Information International for a FR80 system to be installed during the summer of 1979.

Users of APL can now obtain output from a line printer in the computer center. A special print train, made to Lincoln specifications, provides the full APL character set as well as upper- and lower-case alphabets, numerics, and common punctuation. Access to this capability, including the ability to switch modes from APL to alphabetic, is afforded by Lincoln-developed functions.

In response to a growing Laboratory interest in the programming language PASCAL, a number of compilers are being investigated and one will be installed and supported. PASCAL is of interest for a variety of reasons: it is the basis of the new DOD language which will be a mandatory standard for some systems in the near future, it is a higher-level language which can be used to develop mini- and micro-computer applications, and it embodies features which facilitate the writing of structured programs.

SOLID STATE  
DIVISION 8

INTRODUCTION

This section of the report summarizes progress during the period 1 November 1978 through 31 January 1979. The Solid State Research Report for the same period describes the work of Division 8 in more detail. Funding is primarily provided by the Air Force, with additional support provided by the Army, ARPA, NSF, and DOE.

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Head, Division 8

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DIVISION 8 REPORTS  
ON ADVANCED ELECTRONIC TECHNOLOGY

15 November 1978 through 15 February 1979

PUBLISHED REPORTS

Journal Articles

<u>JA No.</u>			
4816	Pressure and Intensity Dependence of Multiphoton Energy Deposition and Reaction Yield in Vinyl Chloride	F. M. Lussier* J. I. Steinfeld* T. F. Deutsch	Chem. Phys. Lett. <u>58</u> , 277 (1978)
4826	Thermal Conductivity and Specific Heat of $\text{NdP}_5\text{O}_{14}$	S. R. Chinn W. K. Zwicker*	J. Appl. Phys. <u>49</u> , 5892 (1978)
4838	Real-Time Spectral Analysis of Far-Infrared Laser Pulses Using a SAW Dispersive Delay Line	H. R. Fetterman P. E. Tannenwald C. D. Parker J. Melngailis R. C. Williamson P. Woskoboinkow* H. C. Praddaude* W. J. Mulligan*	Appl. Phys. Lett. <u>34</u> , 123 (1979)
4841	$\Lambda$ -Doubling in the $v = 2 \leftarrow 0$ Overtone Band in the Infrared Spectrum of NO	A. S. Pine J. W. C. Johns* A. G. Robiette*	J. Mol. Spectrosc. <u>74</u> , 52 (1979)
4847	Molecular-Beam Tunable-Diode-Laser Sub-Doppler Spectroscopy of $\Lambda$ -Doubling in Nitric Oxide	A. S. Pine K. W. Nill*	J. Mol. Spectrosc. <u>74</u> , 43 (1979)
4852	Transverse Modes in Gap-Coupled Surface-Wave Devices	S. A. Reible	Appl. Phys. Lett. <u>34</u> , 103 (1979)
4859	An Acoustic SAW/CCD Buffer Memory Device	D. L. Smythe R. W. Ralston B. E. Burke E. Stern	Appl. Phys. Lett. <u>33</u> , 1025 (1978)
4862	Efficient Thallium Photo-dissociation Laser	D. J. Ehrlich J. Maya* R. M. Osgood, Jr.	Appl. Phys. Lett. <u>33</u> , 931 (1978)
4875	Vibrational Kinetics of $\text{SF}_6$ Dissolved in Simple Cryogenic Liquids	S. R. J. Brueck T. F. Deutsch R. M. Osgood, Jr.	Chem. Phys. Lett. <u>60</u> , 242 (1979)

\* Author not at Lincoln Laboratory.



JA No.

- |      |                                                                                                          |                                                                       |                                           |
|------|----------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|-------------------------------------------|
| 4879 | Enhancement of Nonlinear Optical Processes with a Double-Pass Tight-Focusing Geometry                    | S. R. J. Brueck<br>H. Kildal                                          | Appl. Phys. Lett. <u>33</u> , 928 (1978)  |
| 4880 | Electrode Materials for the Photoelectrolysis of Water                                                   | J. G. Mavroides                                                       | Mater. Res. Bull. <u>13</u> , 1379 (1978) |
| 4883 | Effect of H <sub>2</sub> on Residual Impurities in GaAs MBE Layers                                       | A. R. Calawa                                                          | Appl. Phys. Lett. <u>33</u> , 1020 (1978) |
| 4884 | On the Possible Magnetic Field Dependence of the Nickel Carbonylation Rate                               | R. S. Mehta*<br>M. S. Dresselhaus*<br>G. Dresselhaus*<br>H. J. Zeiger | Surf. Sci. <u>78</u> , 681 (1978)         |
| 4887 | Beryllium-Ion Implantation in InP and In <sub>1-x</sub> Ga <sub>x</sub> As <sub>y</sub> P <sub>1-y</sub> | J. P. Donnelly<br>C. A. Armiento                                      | Appl. Phys. Lett. <u>34</u> , 96 (1979)   |
| 4893 | Efficient Frequency Tripling of CO <sub>2</sub> -Laser Radiation in Tandem CdGeAs <sub>2</sub> Crystals  | N. Menyuk<br>G. W. Iseler                                             | Opt. Lett. <u>4</u> , 55 (1979)           |
| 4904 | Optically Pumped LPE-Grown Hg <sub>1-x</sub> Cd <sub>x</sub> Te Lasers                                   | T. C. Harman                                                          | J. Electron. Mater. <u>8</u> , 191 (1979) |
| 4905 | Crystal Structure of K <sub>5</sub> NdLi <sub>2</sub> F <sub>10</sub>                                    | H. Y-P. Hong<br>B. C. McCollum*                                       | Mater. Res. Bull. <u>14</u> , 137 (1979)  |

Meeting SpeechesMS No.

- |      |                                                                                           |                              |                                                                                                                                                             |
|------|-------------------------------------------------------------------------------------------|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 4229 | Solar Energy Application of Natural Zeolites                                              | D. I. Tchernev               | In <u>Natural Zeolites: Occurrence, Properties, Use</u> , edited by L. B. Sand and Mumpton (Pergamon Press, Oxford and New York, 1978), pp. 479-485         |
| 4589 | High-Efficiency GaAs Shallow-Homojunction Solar Cells                                     | J. C. C. Fan<br>C. O. Bozler | In <u>Thirteenth IEEE Photovoltaic Specialists Conference - 1978</u> (IEEE, New York, 1978), pp. 953-955                                                    |
| 4590 | Selective-Black Absorbers Using Sputtered Cermet Films                                    | J. C. C. Fan                 | Thin Solid Films <u>54</u> , 139 (1978)                                                                                                                     |
| 4709 | Performance Requirements for Analog Signal Processors in Radar and Communications Systems | E. Stern                     | Proc. SPIE Vol. 154: <u>Real-Time Signal Processing</u> , T. F. Tao, Ed. (Society of Photo-Optical Instrumentation Engineers, San Diego, 1978), pp. 174-180 |

\* Author not at Lincoln Laboratory.

MS No.			
4757	An Acoustoelectric Schottky-Diode Memory-Correlator Subsystem	D. H. Hurlburt R. W. Ralston R. P. Baker E. Stern	1978 Ultrasonics Symposium Proceedings (IEEE, New York, 1978), pp. 33-37
4758	Acoustoelectric Signal-Processing Devices with Charge Storage	J. H. Cafarella	1978 Ultrasonics Symposium Proceedings (IEEE, New York, 1978), pp. 767-774
4759	Automated Pulsed Techniques for Measuring the Phase and Amplitude Response of SAW Devices	J. H. Holtham R. C. Williamson	1978 Ultrasonics Symposium Proceedings (IEEE, New York, 1978), pp. 607-610
4761	Interaction of Surface Waves and Bulk Waves in Gratings: Phase Shifts and a New Type of Resonance	J. Melngailis R. C. Williamson	1978 Ultrasonics Symposium Proceedings (IEEE, New York, 1978), pp. 623-629
4762	Transverse Modes in Acoustoelectric Convolvers	S. A. Reible K. L. Wang* V. S. Dolat	1978 Ultrasonics Symposium Proceedings (IEEE, New York, 1978), pp. 48-53
4763	High-Performance Hybrid SAW Chirp-Fourier-Transform System	V. S. Dolat M. B. Schulz L. A. Veilleux G. R. McCully R. C. Williamson	1978 Ultrasonics Symposium Proceedings (IEEE, New York, 1978), pp. 527-532
4766	Fast Synchronization in a Spread-Spectrum System Based on Acoustoelectric Convolvers	D. Brodtkorb J. E. Laynor	1978 Ultrasonics Symposium Proceedings (IEEE, New York, 1978), pp. 564-566
4780	mm-Wave Integrated Circuits for Strategic Sensors	R. W. Laton W. E. Courtney R. A. Murphy C. O. Bozler H. J. Stalzer G. B. Jones	Proc. Govt. Microcircuits Applications Conf., Monterey, California, 14-16 November 1978
4797	Surface-Oriented Schottky Barrier Diodes for Millimeter and Submillimeter Wave Applications	R. A. Murphy B. J. Clifton	Proc. IEEE Intl Electron Devices Mtg., Washington, D. C., 4-6 December 1978, pp. 124-128
4798	GaInAsP/InP Lasers and Detectors for Fiber Optics Communications at 1.1-1.3 $\mu$ m	J. J. Hsieh	Proc. IEEE Intl Electron Devices Mtg., Washington, D. C., 4-6 December 1978, pp. 628-629
4802	Vibrational Kinetics in Cryogenic Liquids and Applications to Nonlinear Optics	S. R. J. Brueck T. F. Deutsch H. Kildal R. M. Osgood, Jr.	Proc. SPIE Vol. 158: Laser Spectroscopy - Applications and Techniques, H. Schlossberg, Ed. (Society of Photo-Optical Instrumentation Engineers, San Diego, 1978), pp. 122-131

\* Author not at Lincoln Laboratory.

UNPUBLISHED REPORTS

Journal Articles

<u>JA No.</u>			
4829	$\nu_3$ Mode Absorption Behavior of Laser Excited SF <sub>6</sub>	T. F. Deutsch S. R. J. Brueck	Accepted by J. Chem. Phys.
4897	Linear Scan Control of Tunable Lasers Using a Scanning Fabry-Perot	M. J. Coulombe A. S. Pine	Accepted by Appl. Opt.
4899	Preparation of Sn-Doped In <sub>2</sub> O <sub>3</sub> (ITO) Films at Low Deposition Temperatures by Ion-Beam Sputtering	J. C. C. Fan	Accepted by Appl. Phys. Lett.
4906	Higher Order Nonlinear Processes in CdGeAs <sub>2</sub>	H. Kildal G. W. Iseler	Accepted by Phys. Rev. B
4907	Emission Cross Section and Flashlamp-Excited NdP <sub>5</sub> O <sub>14</sub> Laser at 1.32 $\mu$ m	M. M. Choy* W. K. Zwickler* S. R. Chinn	Accepted by Appl. Phys. Lett.

Meeting Speeches<sup>†</sup>

<u>MS No.</u>			
4295A	Liquid Phase Epitaxy of III-V Compounds	J. J. Hsieh	} American Association for Crystal Growth, Cambridge, Massachusetts, 23 January 1979
4883A	GaAs Solar Cells	J. C. C. Fan	
4753A	Flashlamp-Excited Low-Threshold Miniature NdP <sub>5</sub> O <sub>14</sub> Laser at 1.32 $\mu$ m	M. M. Choy* W. K. Zwickler* S. R. Chinn	} International Conference on Lasers '78, Orlando, Florida, 11-15 December 1978
4791A	Real-Time Spectral Analysis of Far Infrared Laser Pulses Using a SAW Dispersive Delay Line	H. R. Fetterman P. E. Tannenwald C. D. Parker J. Melngailis R. C. Williamson P. Woskoboinkow* H. C. Praddaude* W. J. Mulligan*	
4782	Efficient GaAs Shallow-Homojunction Solar Cells on Ge Substrates	C. O. Bozler J. C. C. Fan R. W. McClelland	
4793	Zn-Diffused, Stripe-Geometry, Double-Heterostructure GaInAsP/InP Diode Lasers	J. J. Hsieh	6th IEEE Intl Semiconductor Laser Conf., San Francisco, 30 October - 1 November 1978

\* Author not at Lincoln Laboratory.

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

<u>MS No.</u>			
4802B	Molecular Vibrations in Simple Liquids - Spectroscopy, Kinetics and Applications	S. R. J. Brueck	Harvard-MIT Joint Physical Chemistry Seminar, M.I.T., 16 November 1978
4844	Surface Acoustic Wave Devices: Principles and Applications	R. C. Williamson	MIT Industrial Liaison Symp., M.I.T., 7-8 December 1978
4878	Liquid Phase Epitaxy of $Hg_{1-x}Cd_xTe$	T. C. Harman	} Gordon Research Conference on Crystal Growth, Santa Barbara, California, 14-19 January 1979
4914	Crystallographic Orientation of Silicon on an Amorphous Substrate Using Artificial Surface Relief Grating and Laser Crystallization	M. W. Geis D. C. Flanders H. I. Smith	
4883	Solar Cells: Plugging into the Sun	J. C. C. Fan	Applied Physics Lectures, Harvard University, 5 December 1978
4905A	Alkali-Metal Resonance-Line Lasers	R. M. Osgood, Jr.	Seminar, National Bureau of Standards, Gaithersburg, Maryland, 29 January 1979



SOLID STATE  
DIVISION 8

I. SOLID STATE DEVICE RESEARCH

The sensitivity of shot-noise-limited semiconductor photodiodes has been calculated for the case where the high-frequency response is limited by the diffusion of photoexcited carriers to the junction. In this situation there is a marked decrease in high-frequency sensitivity, and the noise spectrum is not a true measure of the frequency response.

An optical isolator has been designed which utilizes the interband Faraday effect in GaAs, thus allowing incorporation of the device into integrated GaAs structures. Based upon new measurements of the Faraday coefficient, the design is shown to be feasible; but, even with an optimum configuration, lengths of the order of a centimeter or fields of many tens of kilogauss would be required for satisfactory performance.

Double-heterostructure GaInAsP/InP inverted mesa photodiodes have been fabricated which have an extremely fast response to optical pulses at 1.05  $\mu\text{m}$  from a  $\text{Nd}_{0.5}\text{La}_{0.5}\text{P}_5\text{O}_{14}$  mode-locked laser. The calculated response risetime of approximately 45 psec is in reasonable agreement with the measured value of  $\sim 50$  psec. Since all the light is absorbed in the depletion region, a high value of quantum efficiency ( $\sim 70$  percent) is observed which is limited primarily by reflection loss at the InP-air interface.

InP planar-guarded avalanche photodiodes have been fabricated from structures formed by Si- and Be-ion implantation into n-type epitaxial layers, which were grown by LPE on (100)-oriented  $\text{n}^+\text{-InP}$  substrates. The avalanche photodiodes exhibited breakdown voltages of approximately 18 V, and the avalanche gains were typically in the 6 to 8 range.

Deep Zn diffusion from a  $\text{ZnP}_2$  source has been found to provide a simple technique for fabricating high-quality, stripe-geometry GaInAsP/InP double-heterostructure diode lasers. Linear CW outputs up to 8 mW per facet have been observed for sufficiently narrow stripe widths, and initial life tests have not revealed any significant difference in reliability between diffused-stripe and conventional proton-defined-stripe lasers.

II. QUANTUM ELECTRONICS

Two distinct gas-recirculating systems have been designed and built for use with the mini-TEA laser. Pulse repetition frequencies in excess of 500 Hz, good mode quality, and average power outputs above 10 W were achieved. Frequency doubling at high repetition rates of the output of one of these units in  $\text{CdGeAs}_2$  has yielded an average-power conversion efficiency of over 28 percent.

A general theoretical analysis of a two-photon resonant third-harmonic generation system has been carried out for plane-wave geometry. The third-harmonic conversion efficiency saturates at 17 percent for a single pass under resonance conditions. This plane-wave result is believed to represent an upper bound on efficiency for any focusing condition, including the tight focusing geometry used to obtain the experimentally observed 4-percent conversion.

An FM mode-locked  $\text{Nd}_{0.5}\text{La}_{0.5}\text{P}_5\text{O}_{14}$  laser excited by a CW dye laser has been constructed. By using an intensity correlation technique, pulses as short as 14 psec have been measured, with a 480-MHz repetition rate.



Stimulated emission at 325 nm has been observed from the  $5d \rightarrow 4f$  transition in Ce:YLF by using a KrF excimer gas laser for optical excitation. The Ce:YLF laser, which is the shortest-wavelength optically pumped solid state laser obtained to date, is potentially a powerful source of tunable near-UV radiation.

A series of new lasers, involving transitions in Na, K, Rb, and Cs have been realized. Pulsed output powers of 1 to 10 kW have been obtained on the alkali-metal resonance lines. Details of the photodissociative excitation process have been studied in order to optimize these lasers.

The laser-initiated photodeposition of metal films is being investigated as a potential technique for microelectronics fabrication. An ArF excimer laser has been used to deposit cadmium films with microscopic features by photodissociating an organometallic carrier gas.

The tunable submillimeter spectrometer previously developed has been applied to a submillimeter-infrared double-resonance study of excited molecular states. The centrifugal distortion splittings of excited-state rotational transitions in  $\text{CH}_3\text{F}$  were measured. Generation and detection of tunable submillimeter radiation is accomplished using optically pumped lasers and Schottky-diode mixers.

### III. MATERIALS RESEARCH

The usefulness of laser heating for removing ion-implantation damage in InP has been demonstrated by annealing Se-doped samples with a CW Nd:YAG laser. For the best samples, the values of carrier concentration and mobility achieved by laser annealing are comparable to those typically observed for similarly implanted samples that have been thermally annealed.

The feasibility of using ion implantation followed by laser annealing in the fabrication of GaAs solar cells has been demonstrated by using this technique to prepare cells utilizing a shallow-homojunction  $n^+/p/p^+$  structure without a GaAlAs window. Conversion efficiencies up to 12 percent at AM1 have been obtained for these ion-implanted, laser-annealed (IIA) cells, in which the  $n^+$  layer was formed by implanting  $\text{Se}^+$  ions into the p-layer and then annealing, without encapsulation, by scanning with a CW Nd:YAG laser.

Conversion efficiencies up to 20 percent at AM1 have been obtained for single-crystal GaAs shallow-homojunction solar cells prepared by chemical vapor deposition on single-crystal Ge substrates. These devices, which are fabricated without  $\text{Ga}_{1-x}\text{Al}_x\text{As}$  layers, employ a thin  $n^+/p/p^+$  GaAs structure. The spectral response and efficiency show steady improvement as the  $n^+$  layer is thinned to 200 Å by means of an anodization-stripping technique.

The very large pressure dependence of the bandgap of Te, which makes this material an attractive candidate for optically pumped tunable lasers in the mid-infrared, has been precisely measured to 8 kbar in a study of the laser emission of an optically pumped sample at liquid-nitrogen temperatures. The bandgap at 63 K is given by the quadratic expression  $E_g(P) = E_g(0) + AP + BP^2$ , where  $P$  is the pressure in kilobars,  $E_g(0) = 333.5 \pm 0.5$  meV,  $A = -20.0 \pm 0.5$  meV/kbar, and  $B = 0.57 \pm 0.02$  meV/kbar<sup>2</sup>.

### IV. MICROELECTRONICS

A SAW/CCD accumulating correlator has been demonstrated which is capable of correlating two long-duration analog signals. The CCD samples, multiplies, accumulates, and reads out the cross-correlation function of two SAW input signals which counterpropagate on a delay line in close proximity to the CCD. A signal-processing gain of 30 dB at a bandwidth of 20 MHz has

been observed by correlating biphas-modulated pseudonoise waveforms of 100-msec duration in the presence of Gaussian noise.

Coplanar waveguide (CPW) has been compared theoretically with microstrip with the intent of determining which is better for incorporation in GaAs monolithic integrated circuits. Conductor and dielectric losses are lower in microstrip than in CPW when the substrate height is equal to the ground-plane spacing in CPW. However, when radiation loss is included and the ground spacing is allowed to increase in the CPW, the guides are comparable.

#### V. SURFACE-WAVE TECHNOLOGY

A high-speed (10-MHz) analog system for computing Fourier transforms by the chirp-transform technique has been developed. The critical elements are reflective-array-compressor (RAC) dispersive delay lines with large time-bandwidth products. When digital interfaces are added, the system functions as a fast hybrid computer.

Four-wave parametric interactions are being explored in acoustoelectric integrating correlators. Such interactions involve the differential delay, mixing, and integration of signal and reference SAWs propagating in the presence of a stationary pump applied to the silicon-diode array. The scheme significantly reduces spurious signals by permitting the degeneracy between signal and reference RF carriers to be lifted. In addition, a unique signal-processing function - triple-product correlation - may be implemented.

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