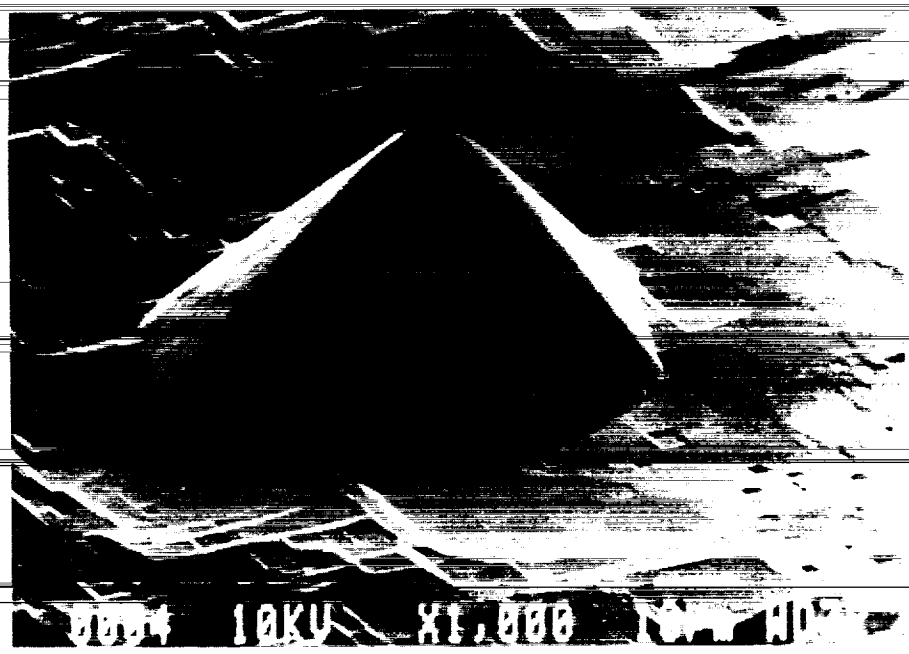
JPL Publication 91-18

Center for Space Microelectronics Technology

1990 Technical Report



July 15, 1991

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

C S M T

This scanning electron microscope (SEM) photograph shows a "tunneling tip" used in a prototype micromachined silicon electron tunneling accelerometer that was built by the JPL Microdevices Laboratory (MDL) in 1990. As designed, it is several orders of magnitude smaller than existing accelerometers with the same sensitivity. It is hoped that other sensors based on tunneling will be able to detect vibration, pressure, infrared radiation, force, magnetic fields, and microscopic dust particles.

The tip, which is the source for the tunneling electrons, is formed by undercutting a small oxide mask with an anisotropic silicon etchant. The geometrical facets on the tip and cantilever surface surrounding it result from the anisotropic nature of the etchant. The tip is coated with 3000 Å of gold. When the tip is positioned 10 Å above a second flat gold electrode, individual electrons can "tunnel through" the empty space between the electrodes.

In general, the probability for tunneling depends exponentially on electrodes' separation, and it changes by an order of magnitude for each 1 Å change in the separation. Therefore, transducers are very sensitive to changes in electrode separation and are benefited by closely spaced features.

A working miniature high-sensitivity accelerometer and a miniature Golay-cell infrared detector were constructed recently at the MDL with tunneling transducers like the prototype's.

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The research described in this publication was carried out by the Jet Propulsion Laboratory, California Institute of Technology, and was sponsored by the National Aeronautics and Space Administration, Strategic Defense Initiative Organization/Innovative Science and Technology Office, Defense Advanced Research Projects Agency, U. S. Army, U. S. Navy, U. S. Air Force, and U. S. Department of Energy.

Abstract

The 1990 Technical Report of the Jet Propulsion Laboratory Center for Space Microelectronics Technology summarizes the technical accomplishments, publications, presentations, and patents of the center during the past year. The report lists 130 publications, 226 presentations, and 87 new technology reports and patents.

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Director's Report

The Center for Space Microelectronics Technology (CSMT) was established in 1987 at the Jet Propulsion Laboratory (JPL) of the California Institute of Technology (Caltech). The CSMT's mission is to perform research and advanced development in the area of microelectronics to support new space missions for the National Aeronautics and Space Administration (NASA) and the U.S. Department of Defense (DOD).

Among the CSMT's activities are the development and evaluation of new electronic and optical concepts for improved sensors, high-data-rate information processing and storage, and real-time signal processing. The Center explores novel concepts in advanced, solid-state devices for application in space, and develops the technological base to advance space computing concepts and architectures. Four major research areas are encompassed: solid-state devices, photonics, custom microcircuits, and advanced computing.

The Director's Report focuses on recent CSMT achievements on the technical, programmatic, and institutional fronts.

Technical Highlights

On the technical front for 1990, the CSMT has a number of achievements to report. CSMT scientists and engineers accomplished the following:

- Development of a submicron size superconductor–insulator–superconductor ($Nb/Al_2O_3/Nb$) tunnel junction mixer element that yielded the lowest noise temperature ever seen in a 205-gigahertz receiver.

- Invention and demonstration of a silicon-based (Si_xGe_{1-x}/Si) heterojunction infrared detector with 6-percent quantum efficiency at 8 microns, 3-percent quantum efficiency at 12 microns, and photoresponse at up to 17 microns.

- Demonstration of a gallium arsenide multiple-quantum-well infrared detector with peak response at 12 microns (at AT&T Bell Laboratories).

- Demonstration of InGaAs/GaAs/AlGaAs lasers with the highest power ever achieved from a cleaved, single-stripe structure. These 980 nm lasers also exhibit record reliabilities, making them ideal for pumping Er-doped fiber amplifiers for long-distance optical communications applications.

- Development of a high-temperature superconducting coplanar waveguide filter with cutoff at 10 gigahertz; demonstration of performance superior to copper at 77 kelvins. Five filters were space qualified and delivered to the Naval Research Laboratory for the planned Strategic Defense Initiative Organization (SDIO) space experiment.

- Demonstration of an electron tunnel-sensor-based accelerometer micromachined from single-crystal silicon. Achievement of noise-limited sensitivity of 10^{-8} g/$\sqrt{\text{Hz}}$ in a device the size of a penny.

- Implementation of neural network learning algorithms using analog very large scale integration (VLSI) chips interfacing with digital computers. Demonstration of learning using a robotic arm.

- Invention of a new analog VLSI architecture for solving the resource allocation problem. Demonstration of a weapon-target assignment problem in hardware. Circuit simulations suggest that 60 resources would be assigned to 20 consumers in less than 30 microseconds.

- Demonstration of an Acousto-Optical Tunable Filter (AOTF) coupled to a charge-coupled device imager to form a compact tunable spectral analysis system.

Programmatic Highlights

The CSMT hosted or cohosted a number of technical workshops and conferences over the past year. Four are listed below.

- The First International Workshop on Ballistic Electron Emission Microscopy, held at the Laboratory on March 9, 1990.

- The Terahertz Technology Symposium, organized with the NASA Center for Space Terahertz Technology and held at the University of Michigan in Ann Arbor from March 5 to 6, 1990.

- The Innovative Long-Wavelength Infrared Detector Workshop, held at the Laboratory from April 24 to 26, 1990.

- The Image Recognition Workshop, held at the Laboratory from May 17 to 18, 1990, and sponsored by the Strategic Defense Initiative Organization/Innovative Science and Technology Office.

Also during the past year, the CSMT Director served on a visiting technical review committee for the Office of Naval Research, cochaired two of the above workshops, participated in Joint Services Electronics Program reviews at Stanford and the University of Southern California, served on the Technical Review Committee for the University of Michigan Center for Space Terahertz Technology, served on the NASA Sensor Working Group, participated in NASA/Office of Aeronautics, Exploration and Technology long-range planning meetings, made a presentation to the NASA Space Systems Technology Advisory Committee (SSTAC) on infrared detectors, and participated in the SDIO/Innovative Science and Technology Office technical interchanges with the SDIO National Test Bed in Colorado Springs, Colorado.

CSMT personnel worked closely with program managers at NASA, SDIO, the Defense Advanced Research Projects Agency and the U.S. Army to define and plan technical programs that met each sponsor's needs and achieved maximum synergism for the overall CSMT effort. This involved extensive discussions with space technology users at NASA and the Department of Defense. Discussions on specific technologies were held with the NASA Office of Space Science and Applications and Office of the Space Station; the U.S. Air Force Space Division, Electronic Systems Division, and Rome Air Development Center; the U.S. Army Space and Strategic Systems and Space Technology and Research Offices; the Naval Air Development Center, Surface Warfare Center, and Weapons Center; and the SDIO National Test Bed.

The CSMT again hosted several Distinguished Visiting Scientists in 1990. Participating were Steven Lyon of Princeton University, Leo Schowalter of Rensselaer Polytechnic Institute, David Casasent of Carnegie–Mellon University, Craig Davis of the Ford Motor Company, Ravi Athale of George Mason University, James Mayer of Cornell University, and Michael Spencer, Howard University.

Institutional Highlights

The Microdevices Laboratory (MDL) has been completed and occupied since December, 1989. The MDL became fully operational in early 1990, and today represents one of the finest microelectronics research and development facilities in the world. In addition to JPL researchers, the MDL serves several Caltech faculty who are active in the CSMT program.

During 1990, the CSMT technical thrust formerly named "Computer Architecture and Subsystems," was renamed "Advanced Computing" to reflect the broad range of activities in advanced space-based and high-performance, ground-based computing being pursued in the program.

On November 13, 1990, a new consortium of 14 research institutions was formed to procure and utilize the Intel Delta parallel supercomputer. The Delta, based on technology invented at Caltech, will have 528 nodes with a peak performance of 32 gigaflops, which makes it the world's most powerful computer. The Delta is housed at the Caltech Campus and is available to JPL users over the network. Consortium partners include Caltech and JPL, NASA, DARPA, the National Science Foundation, several U.S. Department of Energy laboratories, and other institutions. The Delta will be used by the CSMT to address large, computationally intensive problems in space science, design of spacecraft systems, and the analysis and visualization of space data.

Carl A. Kukkonen, Director

I. Solid State Devices

Overview

The Solid State Device Research Program is directed toward developing innovative devices for space remote and in-situ sensing, and for data processing. Innovative devices can result from the "standard" structures in innovative materials such as low and high temperature superconductors, strained-layer superlattices, or diamond films. Innovative devices can also result from "innovative" structures achieved using electron tunneling or nanolithography in standard materials. A final step is to use both innovative structures and innovative materials. A new area of emphasis is the miniaturization of sensors and instruments molded by using the techniques of electronic device fabrication to micromachine silicon into micromechanical and electromechanical sensors and actuators.

1990 Major Technical Achievements

Electron Tunneling

- **Hosted** the first workshop on Ballistic Electron Emission Microscopy (BEEM), developed at JPL, on March 9, 1990. About 70 scientific representatives from the U. S., Europe, and the Far East attended. Ten invited speakers presented talks on new BEEM results and theory. Many groups worldwide are now active in BEEM research on technologically important material systems.

- **Advanced** the understanding of carrier transport in $CoSi^2$/Si infrared sensor structures using the technique of BEEM. These studies show that there is a large defect density which results in a large lateral variation in the efficiency of carrier transport through the interface. These types of studies can be used to help optimize the efficiency of sensor structures.

- **Advanced** the understanding of carrier scattering processes in device structures. A Monte Carlo simulation of carrier scattering processes in metals was developed for application to BEEM theory.

Superconductivity

- **Experimental**: Both the dc and ac (10 - 10^5 Hz) transport properties of high-temperature superconducting epi-films and single crystals have been studied in the presence of moderate magnetic fields (up to 7 kG). The ac conductivity experiments in the described frequency range are the first direct transport measurements of the magneto-impedance of high-temperature superconductors. These electrical transport measurements provide useful information on the nature on the "true" superconducting state (the so-called "vortex-solid" state).

- **Theoretical:** The finite size effect on the vortex-solid/vortex-liquid melting transition of high-temperature superconductors has been investigated. (See **Publications.**) The microwave magneto-impedance of high-temperature superconductors in the presence of high magnetic fields has also been studied based on a "thermally activated flux flow" model. (See **Publications.**) Both theoretical investigations are the first of this kind of quantitative studies in high-temperature superconductivity.

- **Fabricated** high-Q superconducting oxide, X-band, microwave cavities using unique melt deposition process. Observed Q-values in excess of 10^5, significantly higher than any previously reported for superconducting oxides. Process produces high quality $Bi_2Sr_2CaCu_2O_8$ oriented films on curved MgO ceramic substrates. Hermetically sealed cavities are compact with good mechanical and thermal stability. We believe this could lead to near term applications.

- **Prepared** melt deposited films of $Bi_2Sr_2CaCu_2O_8$ on MgO with clean, oriented crystals, with diameters up to about one millimeter, for etching studies and surface analyses. Learned that Br-ethanol etch produces good superconducting surfaces, and that as little as one minute exposure to air produces significant surface alteration. Also learned that clean surfaces in the normal state have a sharp Fermi edge.

- **Established** a laser ablation process for the deposition of high quality thin films of the high temperature superconductor YBaCuO. The deposition system includes a load-lock for rapid sample turn-around and a main growth chamber with three electron-beam guns and four sputter guns. This growth chamber design enables the deposition of multiple materials during a single run, which is an essential feature for practical device fabrication.

- **Fabricated** low-pass microwave filters with a 9.5 GHz cutoff frequency from thin films of YBaCuO. These filters were delivered to the Naval Research Laboratory for the High Temperature Superconductor Space Experiment (HTSSE) sponsored by SDI/IST. The objective of this satellite-based experiment, scheduled to launch in 1992, is to demonstrate and evaluate the technology required for the practical application of high-temperature superconductor devices in the space environment.

- **Fabricated** both edge-geometry and planar-geometry YBaCuO/Au/Nb microbridges. From a device viewpoint, the planar-geometry structures probe the short-coherence-length c-axis, but have the advantage of being fabricated entirely in situ. The edge-geometry device, in contrast, probes the longer coherence length a-b surface. These studies will lead to the fabrication of high-quality microbridges for a variety of applications, including low loss, high speed interconnects and SQUIDS.

- **Elucidated** the chemical nature of the tunnel barrier in YBaCuO/Pb tunnel junctions using X-ray photoemission spectroscopy. These studies determined that the barrier consists of a combination of $BaCO_3$ formed from air exposure and a reaction between the YBaCuO and Pb counterelectrode. Further study of these barriers and others may lead to the fabrication of high quality, low leakage high temperature superconductor tunnel junctions.

- **Extended** our previously developed chemical techniques for the preparation of superconducting surfaces on YBaCuO to other high temperature superconductors. It was demonstrated with X-ray photoemission spectroscopy that wet chemical cleaning techniques can be successfully applied to superconducting thin films of BiSrCaCuO, TlBaCaCuO, and NdCeCuO.

- **Developed** a surface passivation technology for YBaCuO using chemical techniques to form nonreactive compounds on the film surface. Using X-ray photoemission spectroscopy, it was demonstrated that $H_3C_2O_4$ or H_2SO_4 treatment can be used to prevent reaction with water, while leaving the bulk of the superconducting film intact.

Submillimeter (Terahertz) Receiver Technology

- **Developed** materials and device technology for the fabrication of state-of-the-art all-refractory superconductor-insulator-superconductor (SIS) tunnel junctions. Planar geometry Nb/AlO_x/Nb, and both edge and planar geometry NbN/MgO/NbN tunnel junctions with areas down to 0.1 μm^2 have been fabricated. The fabrication of submicron planar geometry tunnel junctions has required several innovations including the development of anisotropic reactive ion etches and electron-beam lithographic pattern transfer techniques. Nb/AlO_x/Nb tunnel junctions with areas of 0.25 μm^2 have been tested in heterodyne receiver systems in the 200 GHz regime at several laboratories. Mixer performances which equal or surpass those of the more mature Pb-alloy based SIS mixers have been achieved. As a result Nb tunnel junctions fabricated at JPL will be used at the Owens Valley Radio Observatory for observing at 115 and 230 GHz. Current efforts are directed toward the extension of this technology to higher frequencies and to quasioptical coupling configurations. Nb/AlO_x/Nb and NbN/MgO/NbN SIS mixers for operation at 626 and 500 GHz have been fabricated and will be tested in the near future.

- **Integrated** microstrip tuning elements were **designed and tested** with NbN mesa junctions. These tuning elements were critical in supplying, for the first time, the appropriate rf-embedding impedance for these junctions. Measurements of mixer conversion, G_m, and mixer noise temperature, T_m, were made using our waveguide SIS mixer at 200-210 GHz. We obtained G_m = -11.2 dB, and T_m = 134 $\pm$10 K using a 1 μm^2 junction at a physical temperature of 1.5 K. Mixer performance improved on cooling from 4.2 K to 1.5 K, suggesting the presence of a temperature-dependent loss mechanism. The importance of the long magnetic penetration depth (3000-4000 Å) in NbN on the microstrip design was determined. In addition, very high current density, submicron NbN edge junctions without integrated tuning elements were tested. These junctions gave comparable performance with G_m = -10.7 dB, and T_m = 145 $\pm$10 K at 4.2 K. These are the best results ever achieved for SIS mixers using NbN junctions.

- **Investigated** mixer performance using submicron Nb-AlO_x-Nb junctions. We obtained G_m = -2.1 dB, and T_m = 60 $\pm$10 K at 4.2 K. These are single sideband results (sideband ratio 19 dB). This is the best result ever reported for an SIS mixer near 200 GHz.

- In another effort, a method was **developed** for actively varying the rf electrical length of a planar transmission line using a mechanical tuner. This tuner consists of a thin metallic plate with holes in it which provide a periodic variation of the transmission line impedance to enhance the rf reflection coefficient. The plate is insulated from the line by a thin mylar insulator. It can be easily slid along the line to vary the electrical length. Thus, planar rf transmission lines can be actively tuned after fabrication. This will allow for more rapid optimization of high-frequency planar-integrated circuits for receiver applications. This is the first demonstration of such a mechanical tuner.

- Quasi-optical SIS mixer devices of a new design were **successfully fabricated**. These mixers employ a twin-slot antenna and a superconducting microstrip transmission line to couple the signal radiation into a 1-2 μm^2 Nb/Al-Oxide/Nb tunnel junction. Receiver tests are now under way at 500 GHz.

- **Developed** new optics for quasi optical receiver system for the THz frequency range. The coupling efficiency is a factor of 3 higher than previous designs and achieves efficiencies as good as waveguide horn antennas. Successful tests at 345 GHz and 492 GHz were carried out at the Caltech Submillimeter Observatory in June and October of 1990.

- **Fabricated** planar SIS mixer array and test cryostat. This is the first time a true heterodyne planar SIS array receiver has been built for the submillimeter wave band. Extensive performance evaluation will begin in FY91.

- **Designed, fabricated, and analyzed** a new broadband submillimeter wave dichroic plate for use at high-incidence angles. For the first time an electrically thick dichroic plate was fabricated at 1 THz with a bandwidth in excess of 25% at a 45° incidence angle.

- Successfully **designed and fabricated** diodes on thick GaAs wafers which were subsequently "lifted off" and transferred to quartz in a process which will prove invaluable for the fabrication of ultra thin planar devices to be used in high frequency mixers, multipliers and direct detectors.

Semiconducting Materials: Growth and Characterization

- **Developed** an MBE-based technique for fabricating stoichiometric silicide columns embedded in single-crystal silicon epitaxial layers. This technology has applications in infrared detectors and high-voltage electronics.

- **Invented** method based on embedded columnar growth of silicides to fabricate tailorable three-dimensional composite materials. Demonstrated fabrication of nanometer-scale particles with well-defined aspect ratios using TEM and optical probes.

- **Demonstrated** the fabrication of high-quality InAs/GaAs quantum well structures, using novel polarization-dependent optical absorption technique. These are the highest strain pseudomorphic structures grown to date.

- **Made operational** an atomic layer epitaxy (ALE) growth capability based on existing MOCVD system. Demonstrated atomic layer control in the growth of InAs epitaxial layers. This capability will enable the fabrication of new superlattice structures for infrared detectors.

- **Demonstrated** the growth of high-quality GaSb-based alloys by LPE and GaInP by MOCVD for special-wavelength laser applications.

Infrared Detectors

- **Invented and demonstrated** the feasibility of a novel silicon compatible LWIR detector based on Si/SiGe heterojunction structure. This Heterojunction Internal Photoemission (HIP) detector has shown response up to 15 μm with internal quantum efficiencies of 5%. Efforts are under way to optimize the structure to enhance the internal quantum efficiency.

- **Invented and demonstrated** the feasibility of GaAs/AlGaAs heterojunction LWIR detector. The absorbtion measurements indicate that this Heterojunction Internal Photoemission (HIP) detector will respond in the entire 8μm-17μm range.

- **Demonstrated** PtSi/Si columnar Schottky diode detectors and layered internal photoemission detectors which outperform Schottky detectors fabricated by conventional design. These detectors are based on the development of new three-dimensionally structured silicide-in-silicon growth techniques.

- **Fabricated** p-type Si homojunction detectors by MBE with quantum efficiencies of ~ 5% in the 8-12 μm range. This is orders of magnitude higher sensitivity than previously reported in Japan for n-type homojunction devices, and indicates that this approach offers promise as a viable LWIR technology.

Charge-Coupled Devices

- **Developed and demonstrated** a design/processing technique to reduce dark current generation in CCDs to the lowest possible level. Dark current generation rates of less than 6 pico-amps/cm^2 have been achieved by several CCD manufacturers using the technique developed by JPL.

- **Developed and demonstrated** predictive model of proton damage to CCDs and utilized it to design NASA flight imaging cameras working in high energy radiation environments (e.g. NASA's CRAF/Cassini imaging and star tracking cameras).

- **Developed and demonstrated** a CCD technology to achieve sub-electron read noise floors. Noise levels less than 0.5 electrons rms have been measured.

- **Developed and demonstrated** a CCD technology to improve low-level charge transfer efficiency in high energy radiation environments. A factor of ten improvement has been realized. NASA's CRAF/Cassini and potentially the Hubble Space Telescope missions will be the first users of notch CCDs.

- **Developed** a clocking technique to allow mapping of single electron traps in CCDs. The technique has been mainly used to screen for good silicon wafers to achieve the highest charge transfer efficiency possible for the CCD. Pocket pumping is also employed to characterize radiation damage effects in CCDs and other semiconductor components.

- **Developed and demonstrated** a CCD clocking technique which eliminates image blooming in CCDs due to overexposure of isolated details. This enables CCD exposures for faint objects in the presence of much brighter targets.

- **Designed and developed** a new 512 x 512 CCD technology to combine the best attributes of multi-phase and virtual-phase CCD technologies. The main feature of this technology is to achieve high QE in the blue and UV without requiring backside thinning or organic phosphor coatings.

- **Designed, developed and demonstrated** a high performance 1024 x 1024 pixel CCD for NASA's CRAF/Cassini project. Several hundred cosmetically free CCDs have been fabricated and several are now being used at institutions worldwide.

- **Designed and developed** two new state-of-the-art CCDs as backup for the Wide Field/Planetary Camera II flight CCDs for the Space Telescope Project. The first CCD is an 800 x 800 15-micron pixel detector and the second is an 800 x 800 7.5-micron pixel detector for enhanced resolution.

- **Organized** a working group to address high energy radiation effects on CCD detectors. Approximately 150 participants attended two, two-day JPL meetings this year.

- Images from the Galileo Solid State Imager from the Wide Field/Planetary Camera on the Space Telescope have been **analyzed** to access CCD radiation effects in space. For example the Galileo CCD has shown significant radiation-induced damage since launch last year.

Diamond Film Technology

- **Deposited** polycrystalline diamond films on Si substrates in the electron cyclotron resonance (ECR) system at 10 torr and 590 to 750 degrees C. This brings JPL to the state of the art in this field. This is an essential lead-in to deposition at further reduced pressures and temperatures, which is unique to the ECR system and would enable deposition on thermally sensitive substrates, over relatively large areas and on curved surfaces.

- **Deposited** diamond-like carbon films as physically and chemically resistant antireflection coatings for crystalline Si solar cells. High quality films are deposited at temperatures as low as ambient.

- **Demonstrated** the critical effect of RF bias for producing diamondlike films.

- **Identified** SiC or SiO as interfacial materials between diamond films and underlying Si substrates. This is important for enhancing nucleation, one of the most important issues in diamond film development.

Silicon Micromachining

- **Initiated** the development of silicon micromachined neural probes in collaboration with Professor Pines at Caltech. Ultimately neurons will be cultured on these probes with the goal of establishing functional synaptic connections with a host central nervous system.

- **Fabricated** a wind sensor using micromachined silicon sensors as a prototype for microweather stations for in situ measurements on Mars.

- **Invented and fabricated** a prototype of a micromachined single-crystal silicon accelerometer with an electron tunneling transducer controlled by electrostatic deflection. Initial tests indicate operation within a factor of 10 on the Shot noise limit. This work opens the door to the development of monolithic silicon sensors which will combine high-performance with low-cost, low-power consumption, compact volume, and array compatibility.

- **Invented and initiated** the fabrication of a micromachined silicon micro-Golay cell for infrared detection based on an electron tunneling transducer.

Device Fabrication Technology

- E-beam lithography system was **made fully operational** in the Microdevices Laboratory thus enabling the:

  - **Fabrication** of submicron SIS tunnel junction for submillimeter wave mixers;

  - **Fabrication** of 40 nm gate length, dual-gate HEMTs for lateral tunneling/ 2 DEG ballistic transport studies;

  - **Fabrication** of a test Ronchi ruling for measuring distances between two closely spaced celestial objects such as stars and satellites which orbit them.

Electron Tunneling

Publications

"Ballistic Electron Emission Microscopy"
M. H. Hecht, L. D. Bell, and W. J. Kaiser
Proceedings of the XIIth International Congress for Electron Microscopy (San Francisco Press, Inc., San Francisco, p. 613, 1990)

"Direct Spectroscopy of Electron and Hole Scattering"
L. D. Bell, M. H. Hecht, W. J. Kaiser, and L. C. Davis
Phys. Rev. Lett., 64, 2679 (1990)

"Ballistic-Hole Spectroscopy of Interfaces"
M. H. Hecht, L. D. Bell, W. J. Kaiser, and L. C. Davis
Phys. Rev. B, 42 (1990) 7663

Presentations

"A New Scanning Tunneling Microscopy Probe of Inelastic Scattering in Metal/Semiconductor Systems"
M. H. Hecht, L. D. Bell, and W. J. Kaiser
American Physical Society Meeting, Anaheim, CA, March 12-16, 1990

"A New Spectroscopy of Electron and Hole Scattering"
L. D. Bell, M. H. Hecht, W. J. Kaiser, and L. C. Davis (Ford)
STM '90, Baltimore, Maryland, July 23, 1990

"Ballistic Hole Spectroscopy of Metal-Semiconductor Interfaces"
W. J. Kaiser, M. H. Hecht, L. D. Bell, and L. C. Davis (Ford)
STM '90, Baltimore, Maryland, July 23, 1990

"Ballistic-Electron-Emission Microscopy: An Electron and Hole Probe of Interfaces"
M. H. Hecht
Solid State Seminar, Stanford University, Feb. 21, 1990, Stanford, CA

"Ballistic-Electron-Emission Microscopy: New Opportunities for Investigation of Materials, Interfaces, and Carrier Transport"
W. J. Kaiser
University of California, Los Angeles, CA, April 23, 1990

"Semiconductor Interface Electronic Structure Probing with Ballistic Electrons and Holes"
L. D. Bell, M. H. Hecht, F. J. Grunthaner, and William J. Kaiser
Physics and Chemistry of Semiconductor Interfaces (PCSI), Jan. 31 - Feb. 2, 1990, Tampa, FL

"Semiconductor Interfacial Microstructure Imaging by Ballistic-Electron-Emission Microscopy"
L. D. Bell, M. H. Hecht, W. J. Kaiser, and F. J. Grunthaner
Society of Photo-Optical Instrumentation Engineers (SPIE), March 18, 1990, San Diego, CA

"Ballistic Electron Emission Microscopy"
M. H. Hecht
Invited presentation, XIIth International Congress on Electron Microscopy, Seattle, WA, August 12-19, 1990

"Ballistic Electron Emission Microscopy at 77°K"
M. H. Hecht
Ballistic Electron Emission Microscopy Workshop, Pasadena, CA, March 9, 1990

"Ballistic Electron Emission Microscopy: New Results in Interface Research"
M. H. Hecht
Northern California American Vacuum Society Meeting, Menlo Park, CA, June 19, 1990

"Interface Analysis with Ballistic Electron Emission Microscopy"
M. H. Hecht
Invited presentation, 37th National Symposium of the American Vacuum Society, Toronto, Canada, October 8-12, 1990

"Ballistic Electron Emission Microscopy: New Insights into Electron Tunneling and Transport"
M. H. Hecht
Condensed Matter Seminar, University of California at Berkeley, October 31, 1990

"Ballistic Electron Emission Microscopy"
M. H. Hecht
Xerox Palo Alto Research Center, Palo Alto, CA, October 30, 1990

"Ballistic Electron Emission Microscopy"
W. J. Kaiser
Invited presentation, Gordon Research Conference, Ventura, CA, February 26-March 2, 1990

"Ballistic Electron Emission Microscopy: New Opportunities for Investigation of Materials, Interfaces, and Carrier Transport"
W. J. Kaiser
Ballistic Electron Emission Microscopy Workshop, Pasadena, CA, March 9, 1990

"Ballistic Electron Emission Microscopy: New Opportunities for Investigation of Materials Interfaces, and Carrier Transport"
W. J. Kaiser
American Physical Society, Tutorial Lecture Series on Condensed Matter Physics, March 11, 1990

"Ballistic Electron Emission Microscopy: Imaging and Spectroscopy of Subsurface Interface Structure and Carrier Transport"
W. J. Kaiser
Invited presentation, NATO Solid State Science and Technology Conference, Biarritz, France, September 16-21, 1990

"A New Scanning Tunneling Microscope Probe of Inelastic Scattering in Metal/Semiconductor Systems"
M. H. Hecht, L. D. Bell, W. J. Kaiser
American Physical Society Meeting, Anaheim, CA, March 13-16, 1990

Patents and New Technology Reports

"Carrier Scattering Spectroscopy Using a Ballistic Emission Microscope"
M. H. Hecht, L. D. Bell, and W. J. Kaiser
JPL New Technology Report 18411/7943

Superconductivity

Publications

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N.-C. Yeh
Phys. Rev. B 42, 4850 (1990)

"Continuous Two-Dimensional Melting of the Vortex-Solid in High-Temperature Superconductors" in "High-Temperature Superconductors: Fundamental Properties and Novel Materials Processing"
N.-C. Yeh
Edited by D. Christen, J. Narayan, and L. Schneemeyer
Materials Research Society Symposium Proceedings, Vol. 169, 23-26 (1990)

"Microwave Applications and Characterization of the Microwave Properties of High Temperature Superconducting Films"
D. M. Strayer, J. J. Bautista, A. L. Riley, G. J. Dick, R. M. Housley
Proc. SPIE 1292 Superconductivity Applications for Infrared and Microwave Devices, 54-70 (1990)

"Chemical Removal of Contaminants from Thin Film $Bi_4Sr_3Ca_3Cu_4O_{16}$ Surfaces"
R. P. Vasquez, R. M. Housley
J. Appl. Phys. 67, 7141 (1990)

"Electrical Characterization of Chemically Modified YBaCuO Surfaces"
B. D. Hunt, M. C. Foote, and R. P. Vasquez
Appl. Phys. Lett., 56 (1990) 2678

"Electrical Contact Studies of Chemically Treated $YBa_2Cu_3O_7$ Surfaces"
B. D. Hunt, M. C. Foote, and R. P. Vasquez
High Tc Superconducting Thin Films: Processing, Characterization, & Applications, Proceedings # 200, R. L. Stockbauer, S. V. Krishnaswamy, R. Kurtz, Editors (American Institute of Physics, New York, 1990) p. 212

"Wet Chemical Passivation of $YBa_2Cu_3O_{7-x}$"
R. P. Vasquez, B. D. Hunt, and M. C. Foote
J. Electrochem. Soc., 137 (1990) 2344

"Wet Chemical Techniques for Passivation of $YBa_2Cu_3O_7$"
R. P. Vasquez, B. D. Hunt, and M. C. Foote
High Tc Superconducting Thin Films: Processing, Characterization, & Applications, Proceedings # 200, R. L. Stockbauer, S. V. Krishnaswamy, R. Kurtz, Editors (American Institute of Physics, New York, 1990), p. 189

"XPS Core Level Spectra of Some Y Compounds"
R. P. Vasquez
J. Electron Spectroscop. Relat. Phenom., 50, (1990) 167

Presentations

"Phenomenology of Flux Line Melting and Depinning in High-Temperature Superconductors"
N.-C. Yeh
American Physical Society 1990 March Conference, Anaheim, CA

"High-Frequency Vortex Dynamics and Dissipation in High-Temperature Superconductors"
N.-C. Yeh
Materials Research Society 1990 Fall Conference, Boston, MA

"Effect of Oxygen Stoichiometry and Oxygen Diffusion on the Electronic Properties of High-Temperature Superconducting Oxides"
N.-C. Yeh
Invited presentation, Materials Science Colloquium, UCLA, Jan. 26 (1990)

"A New Era of Superconductivity"
N.-C. Yeh
Invited presentation, Earnest C. Watson Lecture, Caltech, Nov. 14 (1990)

"RF Characterization of HTS Material, NRL Space Experiments"
D.M. Strayer, R.M. Housley
NASA High Temperature Superconductors Program Review
Invited presentation, Catholic University, Washington, D.C., August 1, 1990

"X-Ray Photoelectron Spectroscopy Study of Chemically Etched Nd-Ce-Cu-O Surfaces"
R. P. Vasquez, A. Gupta (IBM)
Materials Research Society Meeting, Boston, MA, November 26-30, 1990

"Planar and Edge Geometry SNS Devices for Electrical Surface Characterization of Epitaxial TBaCuO Films"
B. D. Hunt, M. C. Foote, L. J. Bajuk
Materials Research Society Meeting, Boston, MA, November 26-30, 1990

"YBaCuO/Au/Nb Device Structures"
B. D. Hunt, M. C. Foote, L. Bajuk, R. P. Vasquez
Invited presentation, SPIE Symposium on High Temperature Superconducting Transistors and Other Devices, Santa Clara, CA, October 4, 1990

"Chemical Nature of the Barrier in Pb/YBaCuO Tunneling Structures"
R. P. Vasquez, M. C. Foote, B. D. Hunt, L. J. Bajuk
American Vacuum Society Meeting, Toronto, Canada, October 8-12, 1990

"Chemical Nature of the Barrier in Pb/YBaCuO Tunneling Structures"
R. P. Vasquez, M. C. Foote, B. D. Hunt, L. J. Bajuk
DARPA 2nd Annual High Temperature Superconductor Workshop, Danvers, MA, October 3-5, 1990

"YBaCuO/Au/Nb Sandwich Geometry SNS Weak Links on C-Axis Oriented YBaCuO"
M. C. Foote, B. D. Hunt, L. J. Bajuk
Applied Superconductivity Conference, Aspen, CO, September 24-28, 1990

"YBaCuO/Au/Nb SNS Device Structures"
B. D. Hunt, M. C. Foote, R. P. Vasquez
American Physical Society Meeting, Anaheim, CA, March 12-16, 1990

"Surface Chemical Etching of BiSrCaCuO Thin Films"
R. P. Vasquez, R. M. Housely
American Physical Society Meeting, Anaheim, CA, March 12-16, 1990

"Edge Geometry YBaCuO/Au/Nb SNS Devices"
B. D. Hunt, M. C. Foote, L. J. Bajuk
Applied Superconductivity Conference, Aspen, CO, September 24-28, 1990

"A Low-Pass Coplanar Waveguide Filter for High Temperature Superconductivity Space Experiment"
A. L. Riley, B. D. Hunt, W. Chew, L. Bajuk, M. C. Foote, D. Roscoe, T. Cooley
2nd World Congress on Superconductivity, Houston, TX, September 11, 1990

"Planar and Edge Geometry YBaCuO/Au/Nb Device Structures"
M. C. Foote, B. D. Hunt, L. J. Bajuk
DARPA 2nd Annual High Temperature Superconductor Workshop, Boston, MA, October 3-5, 1990

"High Temperature Superconductor SNS Devices"
B. D. Hunt, M. C. Foote, L. J. Bajuk, R. P. Vasquez
Invited presentation, Rensselaer Polytechnic Institute, Troy, NY, December 3, 1990

"YBaCuO/Au/Nb SNS Devices"
B. D. Hunt, M. C. Foote, L. J. Bajuk, R. P. Vasquez
General Electric Research and Development Center, Schenectady, NY, December 3, 1990

"Planar and Edge Geometry YBaCuO SNS Devices"
B. D. Hunt, M. C. Foote, L. J. Bajuk
DARPA Workshop on Flux Quantum Logic, NIST, Boulder, CO, December 13, 1990

"Low Pass Coplanar Waveguide Filter for NRL HTSSE"
A. L. Riley, B. D. Hunt, W. Chew, L. J. Bajuk, M. C. Foote, D. Rascoe, T. Cooley
NRL HTSSE Review, Washington D.C., December 18, 1990

"High Temperature Superconductor Thin Film Devices"
B. D. Hunt, M. C. Foote, R. P. Vasquez, L. Bajuk
NASA Lewis Research Center, Cleveland, OH, March 26, 1990

Patents and New Technology Reports

"Superconductor/normal-metal/superconductor Device Structure Utilizing an Edge-Defined Weak Link"
B. D. Hunt and M. C. Foote
NASA New Technology Report, submitted 6/15/90 (case #18303/7822)

"Passivation of High Temperature Superconductors"
R. P. Vasquez
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Submillimeter (Terahertz) Receiver Technology

Publications

"Performance of All-NbN Superconductive Tunnel Junctions as Mixers at 205 GHz"
W.R. McGrath, J.A. Stern, and H.G. LeDuc
Physica B 165 & 166, 75 (1990)

"Adjustable RF Tuning Elements for Planar Millimeter Wave and Submillimeter Wave Circuits"
W.R. McGrath, V. Lubecke, D.B. Rutledge
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"Performance of SIS Mixers at 205 GHz Employing Submicron Nb and NbN Tunnel Junctions"
H.H.S. Javadi, W.R. McGrath, S.R. Cypher, B. Bumble, B.D. Hunt, H.G. LeDuc
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"Development of a 600-700 GHz SIS Receiver"
W.R. McGrath, K. Jacobs, J. Stern, H. LeDuc, M. Frerking, R.E. Miller
Proceedings of the First International Symposium on Space Terahertz Technology, University of Michigan, Ann Arbor, MI, p. 409 (March 1990)

"The Dielectric-Filled Parabola: A New Millimeter/Submillimeter Wavelength Receiver/Transmitter Front End"
P.H. Siegel and R.J. Dengler
IEEE Trans. Ant. and Prop., 38, no. 12 (Dec. 1990)

"Measured and Computed Performance of a Microstrip Filter Composed of Semi-Insulating GaAs on a Fused Quartz Substrate"
P.H. Siegel, J. Oswald, R.J. Dengler, D.M. Sheen, and S.M. Ali
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"Performance of All-NbN Superconductive Tunnel Junctions as Mixers at 205 GHz"
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"Performance of NbN Superconductive Tunnel Junctions as SIS Mixers at 205 GHz"
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"A Submillimeter-Wave Heterodyne Array Receiver Using a Dielectric-Filled Parabola: Concept and Design"
P.H. Siegel
Int'l. Sym. on Space THz Tech. (Mar. 5-6, 1990)

"A Technique for Fabricating Free-Standing Electrically-Thick Metallic Mesh and Parallel Wire Grids for Use as Submillimeter Wavelength Filters and Polarizers"
P.H. Siegel and J.A. Lichtenberger
1990 IEEE MTT-S Int'l. Mic. Sym. Digest (June 1990)

"A Planar Heterodyne Array Receiver Using a Dielectric-Filled Parabola"
P.H. Siegel
Invited presentation, Caltech EE Dept. Seminar Series (April 1990)

"Submillimeter-Wave Mixers for Ozone Depletion Monitoring"
P.H. Siegel
Invited presentation, National Radio Astronomy Observatory Seminar (Feb. 1990)

"Development of Components for Submillimeter-Wave Heterodyne Radiometers at JPL"
M.A. Frerking, B.D. Hunt, H.G. LeDuc, W.R. McGrath, P.H. Siegel, and T. Tolmunen
Invited presentation, 29th Liege Astrophysical Colloquium Proceedings (July 1990)

"Characterization of NbN Films and Tunnel Junctions"
J. A. Stern and H. G. LeDuc
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"Watt Level Quasi-Optical Monolithic Frequency Multiplier Development"
J. Maserjian, R.J. Hwu, N.C. Luhmann, Jr., L. Sjogren, X.H. Tin, W. Wu, D.B. Rutledge, B. Hancock, and U. Lieneweg
First NASA International Symposium on Terahertz Technology, University of Michigan, March 5-6, 1990

"Submicron Area NbN/MgO/NbN Tunnel Junctions for SIS Mixer Applications"
H. G. LeDuc, A. Judas, S. R. Cypher, B. Bumble, B. D. Hunt, and J. A. Stern,
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"Adjustable RF Tuning Elements for Microwave, Millimeter Wave, and Submillimeter Wave Integrated Circuits"
W.R. McGrath, V. Lubecke
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R.J. Dengler and P.H. Siegel
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"A Photolithographically Producible All Metallic Parallel Wire Grid Polarizer for Millimeter and Submillimeter Wavelengths"
P.H. Siegel and R.J. Dengler
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"Tunable Submillimeter Wave Generator"
J. Maserjian and A.C. Gossard
JPL I.R. 30-17754/7256

"Millimeter Wave Monolithic Diode-Grid Frequency Multiplier"
J. Maserjian
JPL I.R. 30-17258/6763

Semiconducting Materials: Growth and Characterization

Publications

"Confirmation of Temperature-Dependent Photovoltaic Effect on Fermi Level Measurements of Photoemission Spectroscopy"
S. Chang, I. M. Vitomorov, L. J. Brillson (Xerox), P. D. Kirchner, G. D. Pettit, J. M. Woodall (IBM), and M. H. Hecht
Phys. Rev. B, 41 (1990)

"Ion Channeling Studies of Single-Crystal Columns of $CoSi_2$ Embedded in Epitaxial Si on Si(111) Grown by MBE"
Shin Hashimoto, Q.F. Xiao, W.M. Gibson, C.W. Nieh, and R.W. Fathauer
Nuclear Inst. Meth. in Phys. Res. B 45, 434 (1990)

"Unambiguous Identification of Heavy and Light Hole States in the Photoreflectance of InGaAs/GaAs Heterostructures"
A. Ksendzov, H. Shen, and F. Pollak
Solid State Communications 73, 11 (1990)

"Resonance Raman Scattering Study of Narrow Gap HgCdTe"
A. Ksendzov, F.H. Pollak, P.M. Amittharaj and J.A. Wilson
Semiconductor Science and Technology 5, S78 (1990)

"Determination of Protein Orientation on Surfaces with X-Ray Photoelectron Spectroscopy"
R. Margalit and R. P. Vasquez
J. Protein Chem., 9 (1990) 105

"Evaluation of Device Quality Germanium-Germanium Oxynitride Interfaces by High-Resolution Transmission Electron Microscopy"
D. C. Paine, James J. Rosenberg, Suzanne C. Martin, and D. Luo
Appl. Phys. Lett. 57 (14) p. 443, 1 October 1990

"Photovoltaic Effects in Photoemission Studies of Schottky Barrier Formation"
M. H. Hecht
J. Vac. Sci. Technol., B8 (1990) 1018

"Intersubband Infrared Absorption in Ge_xSi_{1-x}/Si Superlattice by Photocurrent Measurement"
R.P.G. Karunasiri, J.S. Park, K. L. Wang, L.J. Cheng
Appl. Phys. Lett. 56, 1342 (1990)

"Columnar Growth of $CoSi_2$ on Si(111), Si(100), and Si(110) by Molecular Beam Epitaxy"
R.W. Fathauer, C.W. Nieh, Q.F. Xiao, and Shin Hashimoto
Thin Solid Films 184, 335 (1990)

"Columnar Epitaxy of PtSi on Si(111)"
R.W. Fathauer, Q.F. Xiao, Shin Hashimoto, and C.W. Nieh
Applied Physics Letters, 57, 686 (1990)

"Role of Photocurrent in Low-Temperature Photoemission Studies of Schottky-Barrier Formation"
M. H. Hecht
Phys. Rev. B, 41, 7918 (1990)

"Growth of $IrSi_3$ by Molecular Beam Epitaxy"
T. L. Lin, C. W. Nieh, Shin Hashimoto, and Q. F. Xiao
Thin Solid Films 184, 343 (1990).

"Maximum Boron Doping Concentration without Oxygen Incorporation for Si Molecular Beam Epitaxy Using HBO_2 and B_2O_3 as Dopant Sources"
T. L. Lin, R. W. Fathauer, and P. J. Grunthaner
Thin Solid Films 184, 31 (1990).

"Fabrication of $IrSi_3$/p-Si Schottky Diodes by a Molecular Beam Epitaxy Technique"
T.L. Lin and J.M. Iannelli
Appl. Phys. Lett., 56, 2013, 1990

"Use of X-Ray Photoelectron Spectroscopy in the Measurement of Protein Orientation on Surfaces"
R. P. Vasquez and R. Margalit
Thin Solid Films, 192 (1990) 173

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"Photovoltaic Effects in Photoemission Studies of Schottky Barrier Formation"
M. H. Hecht
Physics and Chemistry of Semiconductor Interfaces (PCSI), Jan. 31 - Feb. 2, 1990, Tampa, FL

"Fabrication of Three-Dimensional Epitaxial Silicon/Silicide Structures Using Columnar Epitaxy and Electron-Beam Lithography"
R. W. Fathauer, P. D. Maker, R. E. Muller, and R. P. Ruiz
6th International Conference on Molecular Beam Epitaxy, San Diego, CA August 27-30, 1990

"Unambiguous Identification of Heavy-Hole and Light-Hole States in the Photoreflectance of InGaAs/GaAs Heterostructures"
A. Ksendzov, H. Shen and F.H. Pollak
APS Meeting, March 10-14, Anaheim, CA, March, 1990

"Study of Band Offset in $In_xGa_{1-x}As$/GaAs System Using Photoreflectance of Single Quantum Wells"
A. Ksendzov, H. Shen and Fred H. Pollak
SPIE Meeting, San Diego, CA, March 17-21, 1990

"Carrier Dynamics in Staggered-Alignment GaAs/AlAs Heterostructures"
B. A. Wilson
Invited presentation, NSF-sponsored U.S.-Japan Workshop on Excited State Dynamics, U. HI, Manoa, November 6-10, 1990

"Chemical and Electronic Structure of Pseudomorphic GaAs/InAs/GaAs Quantum Wells and InAs/GaAs Interfaces"
F. J. Grunthaner, J.K. Liu, B. Hancock, and K. Delgadillo
Physics and Chemistry of Semiconductor Interfaces, Clearwater Beach, Fla., 1990

"HF Acid Cleaning for Silicon Molecular Beam Epitaxy"
P. J. Grunthaner
Invited presentation, American Physical Society Meeting, Anaheim, CA, March 12-16, 1990

"Columnar Epitaxy of Hexagonal and Orthorhombic Metal Silicides on Silicon Substrates"
R. W. Fathauer
Proceedings of MRS Spring Meeting, San Francisco, CA, April 16-21, 1990

"Fabrication of Three-Dimensional Epitaxial Silicon/Silicide Structures Using Columnar Epitaxy and Electron-Beam Lithography"
R.W. Fathauer
Sixth International Conference on MBE, San Diego, CA, Aug. 30, 1990

"Fabrication of Structured Silicon-Silicide Layers"
R.W. Fathauer
Invited presentation, Texas Instruments Central Research Laboratory, October 5, 1990

Patents and New Technology Reports

"Method for Producing Three-Dimensional Nanometer-Scale Epitaxial Metallic Structures on a Silicon Substrate"
Robert Fathauer
NPO 17835

Electronic Device Technology

Publications

"An $In_{.15}Ga_{.85}As$/GaAs Pseudomorphic Single Quantum Well HEMT"
J. J. Rosenberg, M. Benlamri, P. D. Kirchner, J. M. Woodall, and G. D. Pettit
IEEE Elec. Dev. Lett. in October 1985 (has been selected for republication in an IEEE book entitled *MODFETs: Principles, Design, and Technology)*

"Analytical Solution for the Current-Voltage Characteristic of Two Mesoscopic Tunnel Junctions Coupled in Series"
M. Amman, R. Wilkins, E. Ben Jacob, P. D. Maker, and R. C. Jaklevic
Physics Rev. B, Brief Report, June, 1990

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"AlAs Diffusion Barrier on GaAs"
W. J. Kaiser, F. J. Grunthaner, L. D. Bell, and M. H. Hecht
NASA Tech. Brief, July, 1990, p. 30

"Improved Semiconductor Manufacturing Techniques and Semiconductor Devices Fabricated Thereby"
W. J. Kaiser, L. D. Bell, M. H. Hecht, and F. J. Grunthaner
JPL Case No. C17795 w/17796 (patent applied for)

"Hydrogen Stabilized Semiconductor Devices"
J. Maserjian and A.W. Overhauser
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Infrared Detectors

Publications

"LWIR Detector Arrays Based on nipi Superlattices"
J. Maserjian, F. J. Grunthaner, C.T. Elliot
Infrared Physics 30, 27 (1990)

"A Tunable Quantum Well Infrared Detector Based on Photon-Assisted Resonant Tunneling"
K. L. Doughty, R. J. Simes, A. C. Gossard, J. Maserjian, J. L. Merz
Semiconductor Science Technology 5, 494 (1990)

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R.W. Fathauer, J.M. Ianelli, C.W. Nieh, and Shin Hashimoto
Appl. Phys. Lett. 57, 1419 (1990)

"Novel p^+-Si_xGe_{1-x}/p-Si Heterojunction Detectors Fabricated by Molecular Beam Epitaxy"
T.L. Lin and J. Maserjian
Appl. Phys. Lett. 57, 1442 (1990)

"Issues and Directions in IR Readout Electronics"
E.R. Fossum
Workshop on Innovative LWIR Detectors, NASA/JPL, April, 1990

"Novel $Si_{1-x}Ge_x$/Si Heterojunction Internal Photoemission Long Wavelength Infrared Detectors"
T.L. Lin
Innovative Long Wavelength Infrared Detector Workshop, JPL Publication 90-22, Pasadena, CA, April 24-26, 1990

"A Novel Electron Tunneling Infrared Detector"
T. W. Kenny, S. B. Waltman, J. K. Reynolds, and W. J. Kaiser
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"New Heterojunction LWIR Detector Options"
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Innovative Long Wavelength Infrared Detector Workshop, JPL Publication 90-22, Pasadena, CA, April 24-26, 1990

"InAs/GaAs and InAs Doping Superlattices"
F. Grunthaner
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"New Heterojunction LWIR Detector Options"
J. Maserjian
Invited presentation, Innovative Long Wavelength Infrared Detector Workshop, JPL, April 24-26, 1990

"Physics of New IR Detectors"
J. Maserjian
Invited presentation, IEEE Workshop on Advanced Solid-State Imagers, Harriman, NY, May 18-20, 1990

"Optoelectronic Studies of an Electronically Tunable Infrared Detector"
K.L. Doughty, K.-K. Law, A.C. Gossard, J. Maserjian and J.L. Merz
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"SiGe/Si Heterojunction Internal Photoemission (HIP) Detectors"
T. L. Lin, J. Maserjian, T. N. Krabach, S. Dejewski, A. Ksendzov, M. L. Huberman, and R. Terhune
48th Annual Device Research Conference, 1990, at University of California, Santa Barbara, CA, June 25-27, 1990

"SiGe/Si Heterojunction Internal Photoemission Long-Wavelength Infrared Detectors"
R.W. Fathauer (for T.-L. Lin)
1990 Fall Materials Research Society Meeting, Boston, November 26-30, 1990

"InAs/GaAs and InAs Doping Superlattices"
F. Grunthaner
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"Novel Infrared Detectors Based on Three-Dimensional Schottky Barrier Structures"
R.W. Fathauer
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"Novel Si-Based Detector Technologies"
R.W. Fathauer
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R.W. Fathauer
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"Novel SiGe/Si Infrared Detector Grown by Molecular Beam Epitaxy"
T.-L. Lin
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"Issues and Directions in IR Readout Electronics"
E.R. Fossum
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"Imager Architecture Using Lift-Off and Laminated Process for Hybridization of Detector Array and Multiplexer"
E.R. Fossum and F.J. Grunthaner
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Charge-Coupled Devices

Publications

"Predicting the Effects of Proton Damage on Charge-Coupled Devices Using the Radiation Transfer Technique"
James Janesick, George Soli, Tom Elliott
IEEE Nuclear and Space Radiation Effects Conference, Reno, NV, July 20, 1990

"Large Bandwidth (13kHz - 1GHz) Planar-Doped 2DEG-CCD with High Transfer Efficiency at Room Temperature"
J.-I. Song, D.V. Rossi, S. Xin, W. Wong and E.R. Fossum
1990 Device Research Conference, Santa Barbara, CA, June, 1990

"Scientific CCD Technology at JPL"
J. Janesick, A. Collins, and E.R. Fossum
NASA Technology 2000 Conference, Washington D.C., November, 1990

"A Resistive-Gate Two-Phase 2DEG-CCD for III-V IR Detectors"
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James Janesick, George Soli, Tom Elliot
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"Sub-Electron Noise Charge-Coupled Devices"
C. Chandler, J. Janesick
SPIE, Charge-Coupled Devices and Solid State Optical Sensors, Santa Clara, Feb. 23-26, 1990

Patents and New Technology Reports

"Charge-Coupled Device with Delta-Doped Channel"
E. R. Fossum
JPL New Technology Report NPO-18372

"Charge Packet Steering Structure"
E. R. Fossum
JPL New Technology Report NPO-18387

"Iridium Film for Charge-Coupled Device"
M. H. Hecht
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"Nitric Oxide Enhances Charge-Coupled Device"
M. H. Hecht and E. H. Poindexter (U.S. Army ETDL)
NASA Tech. Brief, June, 1990, p. 26

"Silicide Schottky Barrier for Back-Surface-Illuminated CCD"
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Diamond Film Technology

Publications

"Electron Cyclotron Resonance Deposition of Diamond-Like Films"
Y. H. Shing and F. S. Pool
Vacuum, 41, 1368 (1990)

"Deposition of Diamondlike Films by Electron Cyclotron Resonance Microwave Plasmas"
F. S. Pool and Y. H. Shing
J. Appl. Phys., 68, 62 (1990)

Presentations

"Diamond Film Technology"
Y. H. Shing and F. S. Pool
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"Deposition of Diamond-like Films by ECR Microwave Plasma"
Y. H. Shing and F. S. Pool
New Technology Report No. 18094 - NASA NPO-18094-1-CU-7604 (patent application being filed by NASA)

Silicon Micromachining

Presentations

"A Micromachined Silicon Electron Tunneling Sensor"
T. W. Kenny, S. B. Waltman, J. K. Reynolds, and W. J. Kaiser
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JPL New Technology Report

"Electronically Tunable Elastic Suspension for Sensors"
W. J. Kaiser, T. W. Kenny, S. B. Waltman, and J. K. Reynolds
JPL New Technology Report

II. Photonics

Overview

This section concentrates on optoelectronic materials and devices. Optical processing is included in the section on Advanced Computing. Optoelectronic devices, which generate, detect, modulate, or switch electromagnetic radiation are being developed for a variety of space applications. The program includes spatial light modulators, solid state lasers, optoelectronic integrated circuits, nonlinear optical materials and devices, fiber optics, and optical networking photovoltaic technology and optical processing.

1990 Major Technical Achievements

Spatial Light Modulators

- **Achieved** strong modulation of the exciton absorption in an optically addressed SLM device based on a periodically δ-doped InGaAs/GaAs multiple quantum well structure embedded in a Fabry-Perot cavity. Test results indicate useful modulation levels for excitation levels compatible with low-power semiconductor lasers for OEIC applications, and promise record contrast ratios at higher excitation intensities.

Lasers

- **Fabricated** InGaAs/GaAs/AlGaAs lasers with a single-ended output power as high as 240 mW. This is the highest power ever achieved from a single-stripe structure without nonabsorbing facets. These lasers emitting at 980 nm have also demonstrated record reliabilities, making them ideal for pumping Er-doped fiber amplifiers for long-distance optical communications applications.

- **Demonstrated** the first GaAs/AlGaAs and pseudomorphic InGaAs/GaAs/AlGaAs high-power surface-emitting lasers with integrated 45° beam deflectors. This innovation offers a simple approach for integrating surface-emitting lasers with a wide range of electronic devices for OEIC applications.

- **Demonstrated** for the first time a surface-emitting laser with both first- and second-order grating mirrors, providing independent optimization of laser-cavity feedback and output coupling.

- **Demonstrated** for the first time a semiconductor laser with nonresonant output coupler. This device establishes the ability to steer the output beam for interchip optical connections.

Optoelectronic Integrated Circuits

- **Demonstrated** the first operational optical neuron consisting of an LED, a phototransistor and a double heterostructure bipolar transistor. A 10x10 array of these neurons has also been fabricated.

- **Demonstrated** monolithic integration of a double heterostructure phototransistor (DHPT) with a self-aligned gate (SAG), a MESFET, and a SAG-MESFET/double diffused LED on MOCVD-grown material. This combination offers a low-power second-generation optical neuron which can be implemented in 100x100 arrays with reasonable total power consumption.

Nonlinear Optical Materials and Devices

- **Fabricated** low cost, low power thin-film electro-optic polymer Fabry-Perot modulator. Test results show performance comparable to similar $LiNbO_3$ modulators with 2% modulation achieved using 20 V drive voltage.

- **Developed** new approach for second-order nonlinear optical molecules which has resulted in the development of compounds with nonlinearity per unit length 3 times greater than any material ever reported.

- **Grew** device quality crystals of JPL developed second order NLO material with very large optical nonlinearity, dimethyl amino-stilbazolium tosylate (DAST). Previously projected large electro-optic coefficient was measured and confirmed in collaboration with General Electric Central Research and Development to be 410 pm/V.

- **Fabricated** low cost bulk electro-optic polymer based voltage sensor which can measure potentials from 1 to 30KV linearly. This is the first time such a device has been made utilizing the bulk polymer architecture which reduces cost of electro-optic component from \$1000 to < \$1.

Fiber Optics and Optical Networking

- A fiber-optic exposure experiment **was recovered** in January after 5 1/2 years in low earth orbit aboard the Long Duration exposure Facility Shuttle payload. Examination of 10 fiber optic cable samples was begun. All 10 samples were functional.

- A new basic research task **was begun** in June 1990 to investigate the concept of implementing network protocols in the optical domain, eventually evolving toward an integrated all-photonic architecture where light packets self-route from source to destination without any repeated electronic/optical conversion. Developments this year include a CRAY supercomputer program to evaluate the modal group velocity dispersion in single mode fiber, and the initial construction of a 200-fs mode locked Erbium fiber ring laser for generating test pulse trains in the 100GHz-1THz region.

- A new applied research task **was begun** in September 1990 to develop a distributed concurrent computing application for the CASA Gigabit Supercomputer Network Testbed - a heterogeneous collection of supercomputers at JPL, Caltech, the San Diego Supercomputer Center, and Los Alamos National Laboratory, interconnected by a gigabit fiber optic network. The objective of the JPL task is to develop and model a multi-data set earth science rendering problem (seismic, LANDSAT, and digital elevation data) using functional decomposition methods. An adjunct to this effort will include the installation of a small gigabit fiber network in '91-'92 between JPL's CRAY supercomputer, Caltech's INTEL Delta supercomputer, a few graphics workstations, and an interface to the CASA wide-area network.

- A new applied research task **was begun** in October 1990 to study using the ACTS gigabit communication facilities to remotely control the Keck Telescope in Hawaii from a Caltech control room in Pasadena. JPL will conduct a preliminary high-level design of an 800-Mbit/x HIPPI interface between the Keck Observatory, the ACTS satellite ground station, and the Caltech control room.

Photovoltaic Technology

- **Achieved** highly photosensitive amorphous Si (a-Si:H) films using the electron cyclotron resonance (ECR) system, with an excellent light-to-dark conductivity ratio, up to 10^6, and an optical bandgap in the desired range of 1.75 to 1.85 eV. This material is being integrated into the first a-Si:H solar cells containing ECR-deposited material.

- **Demonstrated** the capability of the ECR system to deposit device quality amorphous (a-SiC:H) and microcrystalline (μc-SiC:H) silicon carbide, which are used as window layers in a-Si:H solar cells. Microcrystalline materials are expected to exhibit reduced photodegradation relative to their amorphous counterparts.

- **Deposited** a new form of conductive a-Si:H with low hydrogen content by the ECR process. The material contains a microcrystalline phase, which is expected to exhibit reduced photodegradation.

Optical Processing

- **Invented** a new class of optical correlators which exhibit "self-amplification."
  - capable of recognizing weak patterns in cluttered background
  - expandable to multiple-channel pattern recognition
- **Demonstrated** three-dimensional acousto-optic spectrum analysis.
- **Obtained** a superfine resolution of 0.1 Hz.
- **Built** an analyzer with a volume of less than 1 cubic foot.

- **Demonstrated successfully**, for the first time, imaging by phase conjugation and image edge enhancement using photorefractive Fe-doped InP. This demonstration opened the door to use photorefractive compound semiconductors, other than GaAs, for innovative optical processing applications.

- **Made significant progress** in computer simulation of morphological filters using various combinations of dilation and erosion processes. Results have established a base for development of hardware preprocessors which will be capable of reducing the influence of the clutter in the image and enhancing the probability of correct object recognition. In addition, a preliminary design of a test chip for "smart" spatial light modulators using a combination of VLSI and liquid crystal technologies has been initiated.

- **Assembled** a spatial light modulator based optical associative memory and demonstrated successfully high capability of target discrimination.

- **Modified successfully** the existing visible AOTF imaging spectrometer breadboard by inserting a three-foot long bundle of approximately 800x1000 optic fibers between the foreoptics and the AOTF. Good images were obtained. To our knowledge, this is the first demonstration of AOTF imaging spectrometer using optic fibers as image transfer vehicle. This demonstration has shown the feasibility that the foreoptics of an AOTF imaging spectrometer can be mounted on a flexible arm apart from the robotic vehicle rover body in which the spectrometer is mounted, critically important for future Mars and Lunar rover applications.

- **Conceived, designed and fabricated**, for the first time, a special VLSI chip capable of detecting light intensity peaks and their locations only. Preliminary evaluation results of devices from the first run are encouraging. If developed, the device will make a breakthrough in image correlation technology by reducing drastically the time for extracting the needed information, namely, location and intensity of the correlation peak. (This work has been done in collaboration between the Optical Processing group and Neural Network and Analog Computing Device group.)

- **Made excellent progress** in image correlation experiment using photorefractive GaAs with two modified electrically addressed liquid crystal spatial light modulators. The results have shown advantages of the correlator including: high-quality operation (due to true matched filter operation); high-speed (1200 frame/second demonstrated); no preprocessing need for edge enhancement; use of real reference image (no preprocess of Fourier transform on the reference objects); and easy alignment. These advantages make the GaAs image correlator a serious candidate for a practical real-time image correlator.

- **Completed** a short-wave infrared (SWIR) AOTF (2.2-2.4 microns) imaging spectrometer breadboard system for the first time. A number of experiments were successfully performed to investigate the characteristics of the system. They included multispectral images and spectral scan of a cell containing toluene as well as plant leaves. The results show the system is functional, however, more improvements will be done to make the system more effective.

- **Demonstrated successfully** that the visible AOTF imaging spectrometer, after some improvement, can take outdoor pictures at the video rate, an important step toward the realization of the AOTF imaging spectrometer as a remote sensor instrument on a moving platform.

- **Conducted**, for the first time, an experiment on imaging by phase conjugation in photorefractive GaAs crystal using the beam from a single-mode diffraction-feedback GaInAsP/InP semiconductor injection laser. This has demonstrated the feasibility of integrating photorefractive GaAs crystals with semiconductor lasers to form compact optical processors. (Collaborated with Norman Hwang of ORTEC, Alhambra, who provided the lasers used.)

- **Made significant progress** in the simulation on the recognition of range Doppler radar signatures of spaceborne objects.

- **Made significant progress** in the understanding of photorefractive mechanism in InP, specifically related to the requirement of high beam intensity for optical processing due to high dark conductivity, and demonstrated that low temperature operations can reduce the intensity requirement.

Spatial Light Modulators

Patents and New Technology Reports

"Improved Photovoltaic-Driven Quantum Light Modulator"
J. Maserjian
(NPO-17357/6866)

"Photovoltaic-Driven Quantum Well Modulator"
J. Maserjian
JPL I.R. 30-16914/6432

"Multiple Quantum Well Optical Modulator"
J. Maserjian
U.S. patent #4,818,079

Lasers

Publications

"A 980 nm Pseudomorphic Single Quantum Well Laser for Pumping Erbium-Doped Fiber Amplifiers"
A. Larsson
IEEE Photonics Technology Letters 2, 540 (1990)

"Highly Efficient Pseudomorphic InGaAs/GaAs/AlGaAs Single Quantum Well Lasers for Monolithic Integration"
A. Larsson, J. Cody, S. Forouhar, and R. Lang
Applied Physics Letters 56, 1731 (1990)

"High-Power Operation of Highly Reliable Narrow Stripe Pseudomorphic Single Quantum Well Lasers Emitting at 980 nm"
A. Larsson, S. Forouhar, J. Cody, and R.J. Lang
IEEE Photonics Technology Letters, 2, 307, 1990

Presentations

"A 980 nm Pseudomorphic Single Quantum Well Laser for Pumping Erbium-Doped Optical Fiber Amplifiers"
A. Larsson
Topical Meeting on Optical Amplifiers and Their Applications, Monterey, CA, Aug. 6-8, 1990

"Highly Efficient High-Power Pseudomorphic InGaAs/GaAs/AlGaAs Single Quantum Well Lasers"
A. Larsson, S. Forouhar, J. Cody, and R.J. Lang
CLEO'90, Anaheim, CA, May 21-25, 1990

"High-Power Operation of Highly Reliable Narrow Stripe Pseudomorphic Single Quantum Well Lasers Emitting at 980 nm"
A. Larsson, S. Forouhar, J. Cody, and R.J. Lang
Conference on Optical Fiber Communication, San Francisco, Jan. 22-26, 1990

Patents and New Technology Reports

"Unstable Resonator Distributed Bragg Reflector Laser"
R. J. Lang
NPO-17906

"Surface-Emitting Laser with Multilayer Dielectric Reflector"
R.J. Lang
NPO-17763

"High-Power AlGaAs/GaAs Single Quantum Well Surface-Emitting Lasers with Integrated 45 degree-beam-deflectors"
J. Kim
NPO-18281, 1990

"Pseudomorphic InGaAs/GaAs/AlGaAs Single Quantum Well Surface-Emitting Lasers with Integrated 45° Beam Deflectors"
J.H. Kim
NPO-18243, 1990

"Multiperiod Grating Surface-Emitting Laser"
R.J. Lang
NPO-18054

"High-Power AlGaAs/GaAs Single Quantum Well Lasers on Migration-Enhanced Molecular Beam Epitaxial GaAs-Coated Si Substrates"
J.H. Kim, R.J. Lang, G. Radhakrishnan, and J. Katz
NPO-17988

"Wavelength Tunable Semiconductor Laser"
R.J. Lang and A. Mozer

"Surface-emitting Laser with Integrated Multilayer Reflector"
R.J. Lang
NPO-17912

"Annular Bragg Reflector Surface-emitting Laser"
R.J. Lang
NPO-17763

"Multiple-period Grating Distributed Bragg Reflector"
R.J. Lang

Optoelectronic Integrated Circuits

Publications

"High-Power AlGaAs/GaAs Single Quantum Well Surface Emitting Lasers with Integrated 45°-Beam-Deflectors"
J. Kim, R. Lang, and A. Larsson (with TRW and Hughes)
Appl. Phys. Lett. 57, 2048 (1990)

Presentations

"Integrated Two-Dimensional Array of Optoelectronic Neurons for Neural Networks"
J. H. Kim
Invited presentation, 11th Korea Int'l Conference, Seoul, Korea, June 25-July 7, 1990

"Surface-Emitting Single Quantum Well Lasers with Integrated Beam Deflectors"
J. Kim
IEEE LEOS'90 Annual Meeting, Boston, November 4-9, 1990

Patents and New Technology Reports

"Monolithic Two-Dimensional Arrays of Optoelectronic Threshold Devices for Neural Networks"
D. Psaltis, J. Katz, J.H. Kim, and S.H. Lin
NASA Tech. Briefs 14, 28 (1990)

"High Gain Zinc-Diffused Base Double Heterojunction Bipolar Transistors for Optoelectronic Integrated Circuits"
J. H. Kim and S. Lin
NPO-18177, 1990

Nonlinear Optical Materials and Devices

Publications

"Molecular and Macroscopic Second-Order Optical Nonlinearities of Substituted Dinitrostilbenes and Related Compounds"
B. Tiemann, S.R. Marder, J.W. Perry, L.T. Cheng
Chemistry of Materials, 2, 690 (1990)

"Second-Order Optical Nonlinearities and Photostabilities of 2-N-Methylstilbazolium Salts"
S.R. Marder, J.W. Perry, B. Tiemann, R.E. Marsh, W.E. Schaefer
Chemistry of Materials, 2, 685 (1990)

"Solvent-Tuned Intramolecular Charge-Recombination Rates in a Conjugated Donor-Acceptor Molecule"
L.R. Khundkar, A.E. Stiegmann, J.W. Perry
J. Phys. Chem., 94, 1224 (1990)

"Unusual Structural Distortions Induced by Charge-Transfer Interactions through Conjugated Molecules: Crystal Structures of $NH_2C_6C_4(CC)_nC_6H_4NO_2(n=0\text{-}3)$"
E.M. Graham, V.M. Miskowski, J.W. Perry, D.R. Coulter, A.E. Stiegman, W.E. Schaefer, R.E. Marsh
J. Am. Chem. Soc., 111, 8771 (1990)

"Soluble Highly Conjugated Polyacetylenes via the Ring Opening Metathesis Polymerization of Cyclooctatetraenes"
C.B. Gorman, E.J. Ginsburg, S.R. Marder, R.H. Grubbs
Polymer Preprints, 31, 386 (1990)

"Quadratic Hyperpolarizabilities of Some Organometallic Compounds"
L.T. Cheng, W. Tam, G.R. Meredith, S. R. Marder
Mol. Cryst. and Liq. Cryst. 189, 137 (1990)

"Organic, Organometallic and Polymeric Materials with Nonlinear Optical Properties"
S.R. Marder, J.W. Perry, W.P. Schaefer, E.J. Ginsburg, C.B. Gorman, R.H. Grubbs
Multifunctional Materials: Materials Research Society Symposium Proceedings, Vol. 175, A. Buckley, G. Galleger-Daggitt, F.E. Karasz, D.R. Ulrich, eds., Materials Research Society, Pittsburgh, 1990, 101

"Synthesis, Characterization, and Applications of Substituted Polyacetylenes Derived From Ring-Opening Metathesis Polymerization of Substituted Cyclooctatetraenes"
E.J. Ginsburg, C.B. Gorman, R.H. Grubbs, F.L. Klavetter, N.L. Lewis, S.R. Marder, J.W. Perry, M.J. Sailor
Proceedings of 1989 NATO Workshop of Olefin Metathesis, Kluwer Academic Publishers, New York, 1990

"Excited State Absorption and Optical Nonlinearities of Metallophthalocyanines and Naphthalocyanines in Solution"
J. W. Perry, L. R. Khundkar, D. R. Coulter, T. H. Wei, E. W. Van Stryland, and D. J. Hagan
IEEE Digest, "Nonlinear Optics: Materials, Phenomena and Devices," 1990

"Hybrid optical Limiters Utilizing Metallophthalocyanine Based Dyes and II-VI Semiconductors"
T. H. Wei, E. W. Van Stryland, D. J. Hagan, J. W. Perry, L. R. Khundkar, D. R. Coulter and M. E. Kenney
CLEO '90, Technical Digest Series, Vol. 7, 316 (1990)

Presentations

"Second Order Molecular and Macroscopic Optical Nonlinearities of Organic and Organometallic Compounds"
S.R. Marder, B.G. Tiemann, J.W. Perry, L.T. Cheng, W. Tam, W.P. Schaefer, R.E. Marsh
Symposium on New Materials for Nonlinear Optics, American Chemical Society National Meeting, Boston, MA, April, 1990

"Excited State Absorption and Optical Nonlinearities of Metallophthalocyanines and Naphthalocyanines in Solution"
J. W. Perry, L. R. Khundkar, D. R. Coulter, T. H. Wei, E. W. Van Stryland, and D. J. Hagan
IEEE/LEOS International Conference, "Nonlinear Optics: Materials, Phenomena and Devices," Kauai, July, 1990

"Second-Order Nonlinear Optical Properties of Donor-Acceptor Acetylene Compounds"
A.E. Stiegman, J.W. Perry, L.T. Cheng
Symposium on Organic Materials for Nonlinear Optics II, Meeting of the Royal Society of Chemistry, Oxford, England, September, 1990

"Second Order Nonlinear Optical Properties of 4-N-methylstilbazolium tosylate Salts"
C. Yakymyshyn, S.R. Marder, K.R. Stewart, E. Boden, J.W. Perry, W. P. Schaefer
Symposium on Organic Materials for Nonlinear Optics II, Meeting of the Royal Society of Chemistry, Oxford, England, September, 1990

"New Polymeric Materials with Cubic Nonlinearities Derived from Ring-Opening Metathesis Polymerization"
R.H. Grubbs, C.B. Gorman, J.W. Perry, S.R. Marder
Invited presentation, Symposium on New Materials for Nonlinear Optics, American Chemical Society National Meeting, Boston, MA, April, 1990

"Studies of the Nonlinear Optical Properties of Molecules and Materials"
J.W. Perry
Invited presentation, Symposium on New Materials for Nonlinear Optics, American Chemical Society National Meeting, Boston, MA, April, 1990

"Structure/Property Relationships for Organic and Organometallic Materials with Second Order Optical Nonlinearities"
S. R. Marder, D.N. Beratan, B.G. Tiemann, L.T. Cheng, W. Tam
Invited presentation, Symposium on Organic Materials for Nonlinear Optics II, Meeting of the Royal Society of Chemistry, Oxford, England, September, 1990

"Electronic Hyperpolarizability and Chemical Structure: A Tutorial"
D.N. Beratan
Invited presentation, Symposium on New Materials for Nonlinear Optics, American Chemical Society National Meeting, Boston, MA, April, 1990

"Optical Nonlinearities of Conjugated Macrocyclic Dyes and Processable Polyacetylenes"
J.W. Perry
Invited presentation, NATO Advanced Research Workshop on Organic Molecules for Nonlinear Optics and Photonics, La Rochelle, France, August, 1990

Patents and New Technology Reports

"Method for Fabrication of Bulk Samples of Electro-optic Polymer"
A. Gottsche, J.W. Perry
New Technology Report # 18207/7719

"Fiber Optic High Voltage Sensor Based on an Electro-optic Polymer"
A. Gottsche, J.W. Perry, A. Johnston
New Technology Report #18311/7706

Fiber Optics and Optical Networking

Presentations

"NASA Fiber Optic Experiment in the Long Duration Exposure Facility (LDEF)"
A. R. Johnston
Proceedings AFCEA Fiber Optics Conference '90, McLean, VA, March 20-23, 1990

"Overview of Fiber Optics in the Natural Space Environment"
C. Barnes, L. Dorsky, A. Johnston, L. Bergman, E. Stassinopoulos
Proceedings SPIE, San Jose, CA, September 19, 1990

Photovoltaic Technology

Publications

"Silicon Carbon Alloy Thin Film Deposition Using Electron Cyclotron Resonance Plasmas"
Y. H. Shing, F. S. Pool and C. E. Allevato
Proc. 21st IEEE Photovoltaic Specialists Conf., Orlando, FL, 1574-1578 (1990)

"Electron Cyclotron Resonance Microwave Plasma Deposition of a-Si:H and a-SiC:H Films"
Y. H. Shing and F. S. Pool
Proc. SERI/DOE 10th Photovoltaic Advanced Research and Development Review Meeting, Lakewood, CO, Solar Cells (in press)

"Amorphous Silicon Deposition Research with In-Situ Diagnostics"
Y. H. Shing, F. S. Pool and J. M. Essick
SERI Photovoltaic Branch 1990 Annual Report (accepted for publication)

Presentations

"Silicon Carbon Alloy Thin Film Deposition Using Electron Cyclotron Resonance Plasmas"
Y. H. Shing, F. S. Pool and C. E. Allevato
21st IEEE Photovoltaic Specialists Conference, Orlando, FL, 05/21/90 to 05/25/90

"Electron Cyclotron Resonance Microwave Plasma Deposition of a-Si:H and a-SiC:H Films"
Y. H. Shing and F. S. Pool
SERI/DOE 10th Photovoltaic Advanced Research and Development Review Meeting, Lakewood, CO, 10/23/90 to 10/25/90

Optical Processing

Publications

"Self-Pumped and Double Phase Conjugation in GaAs"
Peter Chua, Duncan T.H. Liu, and Li-Jen Cheng
Applied Physics Letters, 57, 858 (1990)

"Three-Dimensional Acousto-Optic Spectrum Analysis"
H. Ansari, B. D. Metscher, J. R. Lesh
Optics Letters 15, 1245 (November 1, 1990)

"Experimental Considerations for Two-Dimensional Acousto-Optic Spectrum Analysis"
H. Ansari, B. D. Metscher, J. R. Lesh
Applied Optics 29 (December 20, 1990)

Presentations

"Real-Time Image Correlator Using Photorefractive GaAs"
Duncan Liu, L.J. Cheng, T.H. Chao, Jeffrey Yu, and Don Gregory
SPIE's 1990 International Symposium on Optical and Optoelectronic Applied Science and Engineering, San Diego, CA, July 8-13, 1990

"High-Resolution Optical Novelty Filter Using Photorefractive GaAs and High-Speed Nematic Liquid Crystal Phase Modulator"
Duncan T.H. Liu, Li-Jen Cheng, and Shing-Tson Wu
Technical Digest of the Topical Meeting on Photorefractive Materials, Effects, and Devices II, Aussois, France, January 17-19, 1990, page 352

"Dynamic Range Compression Via Noise-Induced Scattering in Photorefractive Crystals"
H. K. Liu
Conference Record of 1990 International Topical Meeting on Optical Computing, 182-184, (1990)

"Neural Network Principles and Optical Implementations"
H. K. Liu
Short Course, SPIE International Symposium on Optoelectronic Applied Science and Engineering (1990)

"Photorefractive Dynamic Range Compression"
H. K. Liu
1990 Technical Digest Series, Optical Society of America, 7, 216-218 (1990)

"AOTF Imaging Spectrometer-System Issues"
Jeffrey Yu, T.H. Chao, and L.J. Cheng
Processing on Optical Engineering and Photonics in Aerospace Sensing, SPIE, Orlando, Florida, April 16-20, 1990

"Optical Computing and Image Processing Using Photorefractive Gallium Arsenide"
Li-Jen Cheng and Duncan T.H. Liu
Conference Record of 1990 International Topical Meeting on Optical Computing, April 8-12, 1990, Kobe, Japan, p. 404

"Self-Pumped and Double Phase Conjugation in GaAs with applied DC Electric Field"
Peter L. Chua, Duncan T.H. Liu and Li-Jen Cheng
1990 Technical Digest Series, Conference on Lasers and Electro-Optics, Vol. 7 (Optical Society of America, Washington, DC, 1990), p. 76

"AOTF Imaging Spectrometer-Breadboard Demonstration"
T.H. Chao, J. Yu, L.J. Cheng, and J. Lambert
Processing on Optical Engineering and Photonics in Aerospace Sensing, SPIE, Orlando, Florida, April 16-20, 1990

"A SLM Based Optoelectronic Associative Memory"
Tien-Hsin Chao
OSA Topical Meeting on Spatial Light Modulators and Applications, OSA Technical Digest Series Vol. 14, p. 28-32, 1990

"Real-Time Optical Correlator Using Computer Generated Holographic Filter on a Liquid Crystal Light Valve"
Tien-Hsin Chao and Jeffrey Yu
SPIE's 1990 International Symposium on Optical and Optoelectronic Applied Science and Engineering, San Diego, CA, July 8-13, 1990

"Characterization of a New CdSe Liquid Crystal Light Valve"
Tien-Hsin Chao
OSA Topical Meeting on Spatial Light Modulators and Applications. OSA Technical Digest Series, Vol. 14, p. 132-135, 1990

"Predetection Dynamic Range Compression Using $BaTiO_3$ Photorefractors"
H. K. Liu
Invited presentation, 20th Winter Colloquium on Quantum Electronics, Snowbird, UT, Jan. 1990

"The Optical Implementation of Inner Product Neural Associative Memory"
H. K. Liu
Invited presentation, SPIE Annual Meeting, San Diego, CA, July 1990

"Optical Neural Network Activities"
Jeffrey Yu
Optical Neural Network Workshop at Jackson,Wyoming, February 7-8, 1990

"AOTF Imaging Spectrometers"
Li-Jen Cheng, Tien-Hsin Chao, Jeffrey Yu, and George Reyes
In-Situ Science and Engineering Technology Workshop of the SAAP project, June 26-27, 1990, Pasadena, CA.

"Self-Pumped and Double Phase Conjugation in GaAs with Applied DC Electric Field"
Peter Chua, Duncan Liu and Li-Jen Cheng
CLEO'90, Anaheim, CA, May 21-25, 1990

Patents and New Technology Reports

"A Method and Apparatus for Generating Tensor Components"
H. K. Liu
NASA Tech. Briefs, March, 1990

"Liquid-Crystal Light Valve Enhances Edges in Images"
T.H. Chao and H. K. Liu
NASA Tech. Briefs, June, 1990

"Net Photorefractive Gain in Gallium Arsenide"
Tsuen-Hsi Liu and Li-Jen Cheng
NASA Tech. Briefs, April, 1990

"Optical Modulation via the Photorefractive Effect"
Li-Jen Cheng, A. Partovi, and E. Garmire
NASA Tech. Briefs, May, 1990

"Auto- and Hetero-Associative Memory Using a 2-D Optical Logic Gate"
Tien-Hsin Chao
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"Matrix-Vector Multiplication in Thin Photorefractive Crystal"
Li-Jen Cheng and Gregory O. Gheen
NASA Tech. Briefs, June, 1990

"Liquid-Crystal Light Valve Enhances Edges in Images"
T.H. Chao and H.K. Chao
NASA Tech. Briefs, June, 1990

"Active Limiters for Photodetectors"
J. Katz and L.J. Cheng
NASA Tech. Briefs, September, 1990

"Real Time Optical Edge Enhancement Using a Hughes Liquid Crystal Light Valve"
Tien-Hsin Chao
NASA Tech. Briefs, in press

"Modular Multilayer Perceptron"
Li-Jen Cheng and Duncan Liu
NASA Tech. Briefs, in press

"Two-Dimensional Acousto-Optic Spectrum Analysis"
H. Ansari, B. D. Metscher, J. R. Lesh
Accepted NASA Tech. Brief

"Superfine Resolution and Three-Dimensional Acousto-Optic Spectrum Analysis"
H. Ansari, J. R. Lesh
Accepted NASA Tech. Brief

III. Advanced Computing

Overview

Advanced concepts in hardware, software and algorithms are being pursued for application in next generation space computers and for ground-based analysis of space data. The research program focuses on massively parallel computation and neural networks, as well as optical processing and optical networking which are discussed in the Photonics Section. Also included are theoretical programs in neural and nonlinear science, and device development for magnetic and ferroelectric memories.

1990 Major Technical Achievements

Parallel Computation

- Thirteen research institutions and federal agencies that are active in computational science **formed** the Concurrent Supercomputing Consortium (CSC) for massively parallel computing. JPL, NASA, Caltech, DARPA, NSF and several other U.S. DOE laboratories are part of the CSC membership with Caltech as the lead institution.

- CSC **selected** the Intel Touchstone Delta System as its first parallel supercomputer which will be acquired by and operated at Caltech on behalf of the Consortium. The Intel Delta, based on technology developed at Caltech, will have 528 nodes with a peak speed of 32 gigaflops and 8 gigabytes of memory making it the most powerful computer in the world.

- **Developed** 2D and 3D vector finite elements software to run on a parallel processor for the electromagnetic analysis of arbitrarily-shaped scatterers consisting of dielectric and conducting materials with possibly inhomogeneous dielectric properties. Can analyze objects with up to 935,000 4-node tetrahedral elements on the 64-node JPL/Caltech Mark IIIfp Hypercube.

- **Developed** 2D coupled approach electromagnetic analysis software which combines finite element and integral equation methods.

- **Implemented** two-dimensional electromagnetic plasma particle-in-cell (PIC) code on the Mark IIIfp Hypercube. All aspects of the simulation, including particle push, field solve, load balancing, diagnostics, and graphical output execute in parallel. This will be used to study plasma waves and turbulence in the solar wind.

- **Completed** studies of electron dynamics in low mach number magnetosonic shock waves using a one-dimensional electromagnetic plasma PIC code on the Mark IIIfp Hypercube.

- Two 32-node Mark III hypercubes were **delivered** to U.S. Air Force in Colorado Springs and are fully functional. Parallel processing technology is being applied to evolve network computing solutions for air defense problems.

- A 128-node Mark IIIfp was **delivered** to the Caltech Concurrent Supercomputing Facility (CCSF) and is operational.

- Hyperswitch technology was **transferred** to Unisys as a key component for a high-end transactions processing network.

- **Organized and conducted** workshop at Sandia National Laboratory to teach techniques of concurrent PIC simulations of Plasma.

- **Developed** version 1.0 of analysis code for the retrieval of atmospheric parameters from Fourier transform Infrared Spectrometer data. This code is being developed to run on both sequential and parallel processing platforms.

- **Completed** construction of 10 MAX (prototype spacecraft fault tolerant multicomputer) modules and evaluation of existing user software development tools. Shipped four MAX modules to Ames Research Center for evaluation.

- **Implemented** two and three-way voting fault tolerant capability in MAX.

- **Demonstrated** conversion of Planetary Rover subsystem data to MAX dataflow.

- **Demonstrated** ability to reliably and seamlessly patch code during program execution.

- **Developed** a distributed memory implementation of a computer code which uses a variational principle to study the collisions of low-energy electrons with industrially important gases such as SiH_4, NF_3 and AsH_3. These cross sections play an important role in modelling plasmas used in materials processing since such collisions produce the reactive species that are responsible for etching and deposition in these plasmas. The high-speed and cost-effective computing provided by these distributed-memory machines considerably enhances our ability to study these cross sections. These calculations are probably the first of their kind to be implemented on such machines. We also believe that the critical steps of this parallel implementation of our computational methodology will be directly useful in applications of variational approaches to other physical problems on these machines.

Advanced Networking

- (See Fiber Optics and Optical Networking in the Photonics section.)

Neural and Analog Computing

- Several new, fully parallel, programmable, neural and synaptic "building block" chips have been **developed, designed, and fabricated** in analog VLSI. This has substantially increased our building block library of the cascadable chips, allowing us to implement and demonstrate various new architectures in hardware. Two examples are given below:

  - A synapse-neuron hybrid building block chip has been **designed and fabricated** in 2-micron CMOS. This 32 x 32 component chip has 7-bit resolution per synapse in its synaptic array and 32 neurons along its diagonal. An order of magnitude reduction in the footprint of the nonlinear neurons has allowed us to accomplish the integration of neurons and synapses on the same chip, and yet retain its cascadability.

- A 32x32 optical sensor array chip (based on phototransistors) for thresholding and a possible winner take all function has been **designed and fabricated** in 2-micron CMOS. This is a building block chip for a fully parallel optoelectronic implementation of a neural network.

- **Demonstrated** "supervised learning" in a fully parallel, reconfigurable neural network hardware based on our VLSI building blocks. This system utilizes programmable analog (capacitor refresh) synapses and variable gain VLSI neurons. While learning with a gradient descent algorithm, the system brings the RMS error between target and actual output below .0001 in less than 200 passes.

- **Demonstrated** supervised learning in analog hardware neuroprocessor as applied to a robotics inverse kinematics problem. The system shows excellent learning capability in spite of the static and dynamic system noise.

- **Applied** the conjugate gradient approach to the learning problem in inverse kinematics of a 3-link robotic arm. This has resulted in a major speedup in the learning time by a feed forward network, compared to the earlier error-back-propagation algorithm.

- **Applied** the neural net hardware learning system to the problem of ground feature recognition/classification (water, plants, rocks, etc.) from the multispectral LANDSAT imagery. The system learns from selected examples and performs very well on untrained areas.

- A fully connected, feedback neural network hardware system with 64 neurons and 4096 (7-bit) synapses, has been **applied** to a 7x7 resource allocation problem. This is a first ever demonstration of such a problem in analog hardware. Indeed, with JPL's novel "analog prompt" scheme, the hardware provides a "very good" solution (one of the top few solutions out of the total of over 5000 possibilities) in a few neuron time constants (microseconds).

- **Demonstrated** for the first time "many-to-many" assignments using an expanded resource allocation circuit simulator, a prerequisite to the hardware fabrication. A 60x20 assignment problem with over 10^{66} possible assignments is solved in about 25 (simulated) microseconds, orders of magnitude improvement over a typical digital algorithm. The solution speed and accuracy were compared with a digital benchmark algorithm (Munkre's) obtained from Dr. T. Gottschalk of Caltech.

- **Further expanded** the resource allocation circuit simulation to include the performance on the assignment problem with dynamically changing association costs. Demonstrated the potential enabling power of the allocation neuroprocessor in dynamic, many-to-one "target to weapon" assignments, even when the targets are in motion, a very important but computation-intensive application scenario.

- **Designed and fabricated** the first fully parallel, 8x8, analog VLSI test chip for resource allocation (based on a capacitor refresh nonlinear neuron design). When implemented as a 64x64 dedicated analog neuroprocessor, it has potential to solve such a one-to-one assignment problem with over 10^{89} (64!) possibilities, in a few milliseconds, over 4 orders of magnitude faster than a fast digital computer.

- **Applied** the "superneuron" concept (local excitation/inhibition), developed for the resource allocation function, to the travelling salesman problem (TSP) in a circuit simulation. This has allowed us to expand the scope of the TSP solution from ~ 8 cities to over 20 cities, in a hardware implementable architecture.

- **Designed and successfully simulated** a circuit for the "cluster buster" function in our analog implementation scheme. Such a circuit incorporation forces the desired single-loop solution of the travelling salesman problem rather than the lower cost multi-salesman solution. An application-specific, integrated chip is under development.

- **Developed, designed, and submitted** (for fabrication by MOSIS) a test chip for the signal propagation algorithm that provides a "minimum path - tactical movement analysis function" for DoD applications, and a "path planning" function for planetary rover applications.

- **Observed, for the first time,** a non-destructive photogenerated current from ferroelectric (lead zirconate titanate, PZT) thin films (sandwich geometry with platinum contacts), dependent on and proportional to their remanent polarization and incident radiation (UV) intensity. This property is being exploited as a possible Non-Destructive Read-Out (NDRO) mechanism for digital as well as analog, non-volatile memories based on ferroelectric thin films.

Neural and Nonlinear Theory

- **Discovered** new method for **global optimization** of multiextremal functions based on "Terminal Repeller Unconstrained Subenergy Tunneling" (TRUST).
  - over 100 times faster than competing state-of-the-art approaches on standard SIAM benchmarks
  - TRUST algorithms designed for easy implementation on massively parallel optoelectronic hardware
  - major benefit expected for many defense, space, energy, etc. applications

- **Developed** new methodology for multitarget tracking in a dense threat environment based upon hydrodynamical techniques coupled with neural network algorithms.
  - demonstrated tracking errors of under one percent for threat configurations involving several thousand elements
  - method selected for priority classified dissemination by SDIO/IDA's Advanced Concepts Panel

- **Developed** the novel theory of Non-Lipschitzian Neural Dynamics.
  - the ability of our networks to change spontaneously their structural behavior as a result of parametrical periodic excitations lead to a performance which phenomenologically resembles brain activity

- work importance emphasized by biologists in recent issues of Journal of Neuroscience
- work also leads to design of unpredictable systems having important defense applications in information processing

- **Formulated** neural learning theory in terms of adjoint operators.
  - enables highly efficient spatio-temporal pattern processing (speedup greater than factor N^2, for an N-neuron network)
  - designed for real time applications
- **Developed** a new methodology enabling rapid tactical situation assessment under battlefield conditions.
  - capable of identifying enemy force structures using as little as twenty percent of detected nodes and arbitrary template warping
  - capable of predicting location of undetected nodes

Data Storage

- **Discovered** destabilization of Vertical Bloch Line (VBL) stripe domains induced by bit-stabilization made from thin film, permanent magnet strips.
- **Demonstrated** stabilization of VBL stripe domains in the absence of VBL bit-stabilization.
- **Demonstrated** major line operation in VBL memory.
- **Conceived** a technique with the aid of supercomputer simulations to stabilize magnetic bubble domains in the major line at the same broadly-applied bias field at which stripe domains are stable in the minor loops. This technique is being tested in the VBL chips now being processed.
- **Discovered and explained** stripe-domain-head repulsion by dams between minor loops and read/write gates in a partially grooved garnet surface.
- **Discovered** a sharp variation in ion-implantation depth as a function of ion implantation energy from one garnet composition to another.

Vector Supercomputing for Solar Physics

- **Completed** quasilinear studies of the saturation of forced current sheet tearing modes in the solar corona.

Parallel Computation

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R.D. Ferraro
Invited presentation, Atlanta, GA, July 17, 1990

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L. Sparks, J. E. Patterson, J. L. Fanselow
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Neural and Analog Computing

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S. Gulati, J. Barhen and S. Iyengar
The Computer Journal, 33 (3), 204-214 (1990)

"Neurocomputing Formalisms for Learning and Machine Intelligence"
S. Gulati, J. Barhen, and S. Iyengar
Advances in Computing 1990, M.C. Yovits ed., Academic Press, New York (in press, 1990)

"Computational Neural Learning Formalisms for Manipulator Inverse Kinematics"
S. Gulati, J. Barhen, S. Iyengar
IEEE Trans. S.M.C. (in press, 1990)

"Creative Dynamical Approach to Neural Intelligence"
M. Zak
Biological Cybernetics, 64 (1), 15-23 (1990)

"Photorefractive Dynamic Range Compression"
H. K. Liu
1990 Technical Digest Series, Optical Society of America, 7, 216-218 (1990)

Presentations

"Serial and Parallel Computation of Kane's Equations for Multibody Dynamics"
A. Fijany
Proc. 4th Workshop on Computational Control of Flexible Aerospace Systems (in press, 1990)

"Adjoint Operator Algorithms for Learning in Neural Networks"
J. Barhen, N. Toomarian and S. Gulati
IJCNN, 1 (W), 512-516 (1990)

"Creative Dynamics Approach to Neural Intelligence"
M. Zak
Proceedings of 4th Annual Parallel Processing Symp. (1990)

"Unpredictable Neurodynamics for Robot Intelligence Simulations"
M. Zak, J. Barhen and N. Toomarian
INNC-Paris, pp. 205-208, Kluwer-Academic Press, Dordrecht, Holland (1990)

"Creative Dynamics Approach to Optimization Problems"
M. Zak, N. Toomarian and J. Barhen
IJCNN, 3 (SD), 765-772 (1990)

"Pattern Recognition by Hierarchy of Attracting Sets"
M. Zak
Int. Symp. Expert Systems and Neural Networks, Honduly (in press, 1990)

"Robot-Assisted Extravehicular Activity: Part I - Perceptual Manipulation Architecture"
S. Gulati and S. T. Venkataraman
Proceedings, SPIE Conference on Cooperative Intelligent Robots in Space, Philadelphia, PA (in press, 1990)

"Robot-Assisted Extravehicular Activity: Part II - Sensorimotor Control"
S. T. Venkataraman and S. Gulati
Proceedings, SPIE Conference on Cooperative Intelligent Robots in Space, Philadelphia, PA (in press, 1990)

"Fast Neural Learning Algorithms for Neurocontrol"
J. Barhen, S. Gulati and N. Toomarian
Invited presentation, Fourth Annual Parallel Processing Symposium, Fullerton, CA, April 4-6, 1990

"Control Issues Related to Robot-Assisted Extravehicular Activity"
S. Gulati and S. T. Venkataraman
Invited presentation, Fifth IEEE International Symposium on Intelligent Control, Philadelphia, PA, Sept. 5-7, 1990

"Computational Chaos in Massively Parallel Neural Systems"
S. Gulati and J. Barhen
Invited presentation, Fourth Annual Parallel Processing Symposium, Fullerton, CA, April 4-6, 1990

"Perceptual Robotics: A Vehicle for Synergistic Man-Machine Systems"
S. Gulati and S. T. Venkataraman
Invited presentation, IEEE Conference on Biomedical Engineering, Philadelphia, PA, Nov. 1990

"Perceptual Manipulation Systems in Manufacturing"
S. Gulati
Invited presentation, SME Workshop on Neural Networks: Opportunities and Applications in Manufacturing, Detroit, MI, April 3-4, 1990

"Adaptive Sensorimotor Control for Robot-Assisted Extravehicular Activity"
S. Gulati, S. T. Venkataraman and C. R. Weisbin
Invited presentation, Fourth Annual Parallel Processing Symposium, Fullerton, CA, April 4-6, 1990

"Precise-Compliant Adaptive Sensorimotor Control"
S. T. Venkataraman and S. Gulati
Invited presentation, Fifth IEEE International Symposium on Intelligent Control, Philadelphia, PA, Sept. 5-7, 1990

"Predetection Dynamic Range Compression Using $BaTiO_3$ Photorefractors"
H. K. Liu
Invited talk, 20th Winter Colloquium on Quantum Electronics, Snowbird, UT, Jan. 1990

"The Optical Implementation of Inner Product Neural Associative Memory"
H. K. Liu
Invited talk, SPIE Annual Meeting, San Diego, CA, July 1990

"Neural Network Principles and Optical Implementations"
H. K. Liu
Short Course, SPIE International Symposium on Optoelectronic Applied Science and Engineering (1990)

"Dynamic Range Compression Via Noise-Induced Scattering in Photorefractive Crystals"
H. K. Liu
Conference Record of 1990 International Topical Meeting on Optical Computing, 182-184 (1990)

Patents and New Technology Reports

"Algorithmically-Specialized Parallel Architecture for Robotics Applications"
A. Fijany and A. K. Bejczy
NASA Journal of Tech. Briefs (in press, 1990)

"Efficient Computation of Manipulator Inertia Matrix"
A. Fijany and A. K. Bejczy
NASA Journal of Tech. Briefs (in press, 1990)

"Fast Parallel Computation of Manipulator Inverse Dynamics"
A. Fijany and A. K. Bejczy
NASA Journal of Tech. Briefs (in press, 1990)

"Parallel Algorithms for computation of Manipulator Inertia Matrix"
A. Fijany and A. K. Bejczy
NASA Journal of Tech. Briefs (in press, 1990)

"Parallel Architecture for Robotics Computation"
A. Fijany and A. K. Bejczy
NASA Journal of Tech. Briefs, June 1990, pp. 36-38

"Fast Conjugate Gradient Algorithms for Manipulator dynamic Simulation"
A. Fijany and R. E. Scheid
NASA Journal of Tech. Briefs (in press, 1990)

"Chaotic Motion of a Two-Link Planar Mechanism"
M. Zak
NASA Tech. Briefs, NPO-17387/6898, Vol. 13, No. 8, 1990

"Characteristic Wave Approach as a Complement to Modal Analysis"
M. Zak
NASA Tech. Briefs, Vol. 14, No. 5, 1990

"Non-Lipschitzian Dynamics for Modelling Neural Networks"
M. Zak
NASA Tech. Briefs, NPO-17814, 1990

"Propagation of Pulse Vibrations in Large Structures"
M. Zak
NASA Tech. Briefs, NPO-17559, 1990

"Vibrational Responses of Structures to Impulses"
M. Zak
NASA Tech. Briefs, 1990

"Vibrational Responses of Structures to Impulses"
M. Zak
NASA Tech. Briefs, Vol. 14, No. 3, 1990

"A Highly Parallel Computer Architecture for Robotics Computation"
A. Fijany and A. K. Bejczy
Patent Pending, NASA & JPL Case No. NPO-17632

Data Storage

Publications

"Data Storage Technology Comparisons"
R. R. Katti, H. L. Stadler and J. C. Wu
Proceedings of the Second Annual NASA VLSI Design Symposium, University of Idaho NASA Spaceflight Engineering Research Center, November 1990, pp. 7.1.1-7.1.18

"Integrated Vertical Bloch Line Memory"
R. R. Katti, J. C. Wu, and H. L. Stadler
Proceedings of the NASA Technology 2000 Conference, November 1990

"Vertical Bloch Line Memory"
R. R. Katti, J. C. Wu, and H. L. Stadler
Proceedings of the Second Annual NASA VLSI Design Symposium, University of Idaho NASA Spaceflight Engineering Research Center, November 1990, pp. 8.3.1-8.3.20

"Thickness and Roughness Dependence of DC Modulation Noise in Thin Film Magnetic Recording Media"
R. R. Katti and D. A. Saunders
IEEE Transactions on Magnetics, Vol. 26, No. 5, pp. 2712-2714, September 1990

Presentations

"Data Storage Technologies for a Planetary Rover"
R. R. Katti
National Space Development Agency of Japan (NASDA) Meeting, October 1990, Tsukuba Space Flight Center, Tokyo, Japan

"Data Storage Technology Comparisons"
R. R. Katti, H. L. Stadler and J. C. Wu
Accepted for Presentation, Second Annual NASA Symposium on VLSI Design, Univ. of Idaho NASA Spaceflight Engineering Research Center, November 1990, Moscow, ID

"The Effect of Random Coercivity on Domain Growth Processes in Rare Earth-Transition Metal Alloys"
R. S. Weng, J. C. Wu, and M. H. Kryder
Magnetism and Magnetic Materials Conference, November 1990, San Diego, CA

"Solid State Magnetic Memory"
J. C. Wu
Invited presentation, Caltech Course on Magnetic Recording (EE 150), May 1990, Pasadena, CA

"Spaceflight Data Storage and Vertical Bloch Line Memory"
R. R. Katti
Invited presentation, 3M-National Media Laboratory Meeting, October 1990, St. Paul, MN

"Major Line Operation in Vertical Bloch Line Memory"
J. C. Wu, R. R. Katti, and H. L. Stadler
Magnetism and Magnetic Materials Conference, November 1990, San Diego, CA

"Minor Loop Operation in Vertical Bloch Line Memory"
J. C. Wu, R. R. Katti, and H. L. Stadler
Magnetism and Magnetic Materials Conference, November 1990, San Diego, CA

"Integrated Vertical Bloch Line Memory"
R. R. Katti, J. C. Wu, and H. L. Stadler
NASA Technology 2000 Conference, November 1990, Washington, DC

"Vertical Bloch Line Memory"
R. R. Katti, J. C. Wu, and H. L. Stadler
Accepted for Presentation, Second Annual NASA Symposium on VLSI Design, Univ. of Idaho NASA Spaceflight Engineering Research Center, November 1990, Moscow, ID

"The Vertical Bloch Line Memory"
H. L. Stadler
Invited presentation, Department Colloquium, Electrical Engineering Department, University of Victoria, May 1990, Victoria, British Columbia, Canada

"Vertical Bloch Line Memory Concepts"
H. L. Stadler
Invited presentation, 3M-National Media Laboratory Meeting, October 1990, St. Paul, MN

"Current Results on Vertical Bloch Line Memory Development"
J. C. Wu
Invited presentation, NEC Corporation Meeting, October 1990, Tokyo, Japan

Patents and New Technology Reports

"Magnet-Hall Effect Random Access Memory"
J. C. Wu, H. L. Stadler, and R. R. Katti
Patent Application Submitted, Based on NTR-17999

"Magnetoresistive Random Access Memory"
J. C. Wu, H. L. Stadler, and R. R. Katti
Patent Application Submitted, Based on NTR-17954

"Analog Random Access Memory"
R. R. Katti, J. C. Wu, and H. L. Stadler
Patent Application Submitted

"Compact Memory Using Hybrid Magnetic Recording Technology for Gigabit-level Storage"
R. R. Katti
NTR-18218, February 21, 1990

"Three-Dimensional Magnetic Bubble Memory System"
R. R. Katti, J. C. Wu, and H. L. Stadler
NTR Submitted

Vector Supercomputing for Solar Physics

Publications

"Linear Tearing Modes of a Forced Current Sheet Equilibrium"
P. C. Liewer and D. G. Payne
Astrophysical Journal, 353, 1990, p. 658.

"Quasilinear Saturation of Forced Current Sheet Tearing Modes"
P. C. Liewer and D. G. Payne
Geophysical Research Letters, 17 (1990) p. 2047

Presentations

"Quasilinear Saturation of Forced Current Sheet Tearing Modes"
P. C. Liewer and D. G. Payne
1990 Conference on Transition Regions in Solar System Plasmas, Yosemite, February, 1990

"Magnetic Reconnection in a Nearly Singular Current Sheet"
P. Liewer and D. Payne
AAS Solar Physics Division Meeting, Albuquerque, NM, June 1990

"Quasilinear Saturation of Tearing Modes in a Forced Current Sheet Equilibrium"
D. G. Payne and P. C. Liewer
AGU, December 1990, San Francisco, CA

Vector Supercomputing Applications for Astrophysics

Presentations

"Numerical Simulations of Magnetized Jets"
K.R. Lind, D.G. Payne & D.L. Meier
Meeting of the American Astronomical Society, Washington DC, January, 1990

"Numerical Simulations of Magnetized Jets"
K.R. Lind, D.G. Payne & D.L. Meier
Meeting of the American Astronomical Society, Albuquerque, NM, June, 1990

"Numerical Simulations of MHD Jets"
D.G. Payne
Invited presentation, Workshop on Quasars and Active Galactic Nuclei, Pasadena, CA, December, 1990

"Numerical Simulations of Magnetized Jets"
T. Elvins, T. McLeod, D.G. Payne, D.L. Meier & K.R. Lind
SIGGRAPH, Dallas, TX, (video presentation) June, 1990

"Numerical Simulations of Magnetized Jets"
T. Elvins, T. McLeod, D.G. Payne, D.L. Meier & K.R. Lind
Supercomputing '90, New York, NY (video presentation) November, 1990

IV. Custom Microcircuits

Overview

The goals of this program are to develop custom microcircuit technology, also known as Application Specific Integrated Circuit (ASIC) technology, for use in flight and ground programs. Supporting this effort are activities to investigate the effects of the space environment, and particularly ionizing radiation, on microcircuits and to develop a space qualification methodology. Another aspect of the program emphasizes innovative applications of custom microcircuit technology to image and signal processing and communications.

1990 Major Technical Achievements

Application Specific Integrated Circuits

- **Fabricated** and successfully tested VLSI design of a Universal Noiseless Coder Chip.
- **Developed** VLSI design of GPS digital receiver chip using LSI Logic gate array.
- **Developed** the data path for the layout of a Floating Point Unit chip for Sandia National Laboratory.
- **Designed** Fault Management Unit chip and Control Unit chip as part of the SPACE 16/Common Flight Computer development. The chips were designed using JPL standard cell library.
- **Designed, fabricated, tested, and demonstrated** a Data Compression chip which performs high-speed lossless data compression for the Eos HIRIS instrument.
- **Designed** systolic Binary Tree-Searched Vector Quantizer (BTSVQ) chip for the Eos onboard SAR processor and Alaska SAR Facility. The BTSVQ performs high-speed VLSI lossy image compression.
- **Developed** an adaptive VLSI neuroprocessor for high performance data compression.
- **Developed** a hardware-annealed VLSI neuroprocessor for real-time optical flow computing.
- **Co-designed and performed** layout of two versions of PO32, a "Smart Camera" chip. Both chips contain 1024 pixels and are capable of determining if they have a parallel optical input, and each has real time image analysis applications.
- **Designed** test chips with various photosensitive elements for use in "Smart Cameras."
- **Received and tested** a standard cell version and a gate array version of a custom chip for the Big Viterbi Decoder (BVD). Production runs (600 chips) of each version were obtained. The chips are installed and under test in the BVD board.

Quality Assurance and Space Qualification Methodology

- **Designed** and fabricated Total Ionizing Dose (TID) test chips in MOSIS 2.0μ (n-well and p-well), 1.6μ (n-well) and 1.2μ (n-well) CMOS processes.
- **Characterized** Single-Event Upset (SEU) test chip with a Polonium alpha particle source. Permits economical bench-level SEU characterization of a CMOS process. Results presented at Nuclear and Space Radiation Effects Conference in July 1990.
- **Designed** and delivered JPL/SEMATECH test chip for the SEMATECH 0.5μ CMOS process. Fabrication of a test chip set initiated at SEMATECH.

Application Specific Integrated Circuits

Publications

"Real-Time Computing of Optical Flow Using Adaptive VLSI Neuroprocessors"
W.C. Fang, B.J. Sheu
IEEE Proceedings of International Conference of Computer Design, Cambridge, MA, Oct. 1990, pp. 122-125

"Systolic Tree-Searched Vector Quantizer for Real-time Image Compression"
W.C. Fang, C.-Y. Chang, B.J. Sheu
IEEE Proceedings of 1990 Workshop on VLSI Signal Processing, San Diego, CA, Nov. 7-9, 1990, pp. 352-361

Presentations

"Real-Time Computing of Optical Flow Using Adaptive VLSI Neuroprocessors"
W.C. Fang, B.J. Sheu
IEEE International Conference of Computer Design, Cambridge, MA, Oct. 1990

"Systolic Tree-Searched Vector Quantizer for Real-time Image Compression"
W.C. Fang, C.-Y. Chang, B.J. Sheu
1990 IEEE Workshop on VLSI Signal Processing, San Diego, CA, Nov. 7-9, 1990

Quality Assurance and Space Qualification Methodology

Publications

"Using Advanced Microelectronic Test Chips to Qualify ASICs for Space"
M.G. Buehler, B.R. Blaes and Y-S. Lin
NASA SERC 1990 Symp. on VLSI Design, pp. 105-116 (1990)

"Fault Chip Defect Characterization for Wafer Scale Integration"
D.J. Hannaman, H.R. Sayah, R.A. Allen, M.G. Buehler, M. Yung
IEEE Proceedings 1990 Int. Conf. Microelectronic Test Structures, Vol. 3,
pp. 67-71 (1990)

"Linewidth and Step Resistance Distribution Measurements Using an Addressable Array"
H.R. Sayah, M.G. Buehler
IEEE Proceedings 1990 Int. Conf. Microelectronic Test Structures, Vol. 3,
pp. 87-92 (1990)

"Error Analysis for Optimal Design of Accelerated Tests"
D.J. Hannaman, N. Zamani, J. Dhiman, M.G. Buehler
Proc. Int. Rel. Phys. Symp., pp. 55-60, March 1990

"Test SRAMs for Characterizing Alpha-Particle Tracks in CMOS/Bulk Circuits"
M.G. Buehler, B.R. Blaes
IEEE Transactions on Nuclear Science, December 1990

Presentations

"ASIC Quality Assurance for Space Qualified Application-Specific Integrated Circuits (QASIC)"
M.G. Buehler
IEEE Parts Steering Committee Meeting (February 14, 1990)

"A Vernier Technique for Mapping Alpha-Particle Sensitive Area in Special Static Memories"
M.G. Buehler, B.R. Blaes, U. Lieneweg, G.A. Soli
Seventh Symposium on Single-Event Effects, Los Angeles, CA, April 24-25, 1990

"Modelling Radiation Induced Timing Delays Measured from the Timing Sampler Test Structure"
Y.S. Lin, B.R. Blaes, M.G. Buehler
DNA/HDC Workshop on Test Structure Device Radiation Hardening and Hardness Assurance, Los Angeles, CA, April 26, 1990

"Alpha Particle Sensitive Test SRAMs"
M.G. Buehler, B.R. Blaes, G.A. Soli, K.A. Hicks, U. Lieneweg
Nuclear Space Radiation Effects Conference, Reno, NV, July 17, 1990

"Space Qualified Application Specific Integrated Circuits (QASIC): Design and Fabrication Verification Procedures"
M.G. Buehler, S.A. Peak
Advanced Microelectronics Technology-Qualification and Logistics Workshop, San Diego, CA, August 29, 1990

Patents and New Technology Reports

"Asymmetric Memory Circuit Would Resist Soft Errors"
M.G. Buehler, M. Perlman
NASA Tech. Brief, Vol. 14, No. 1, January 1990

"Thermal-Interaction Matrix for Resistive Test Structure"
M.G. Buehler, J.K. Dhiman, N. Zamani
NASA Tech. Brief, Vol. 14, No. 4, April 1990

"Exact Chord-Length Distributions for SEU Calculations"
M.G. Buehler, K.L. Luke
NASA Tech. Brief, Vol. 14, No. 4, April 1990

V. Appendix

CSMT-Caltech Campus Collaboration
(Cumulative List)

T. Phillips	Submillimeter Detectors
J. Zmuidzinas	Submillimeter Detectors
D. Rutledge	Submillimeter Antennas
V. Lubecke	Submillimeter Receiver Technology
G. Fox	Hypercube Concurrent Computing
P. Messina	Hypercube Concurrent Computing
H. Keller	Concurrent Plasma Simulations
T. Krucken	Concurrent Plasma Simulations
J. Hopfield	Neural Networks, Molecular Computation
C. Koch	Neural Networks
C. Mead	Neural Networks
T. Gottschalk	Neural Networks
D. Psaltis	Optical Processing
J. D. Baldeschweiler	Scanning Tunneling Microscopy
F. Culick	Robotic Computing
K. Vahala	E-Beam Lithography
D. Goodstein	High Tc Superconductivity
R. Housely	High Tc Superconductivity
M. Cross	High Tc Superconductivity
T. Tombrello	High Tc Superconductivity
D. Dougherty	Optical Switching Materials
A. Yariv	Infrared Detectors
H. Gray	Molecular Electronics
A. Zewail	Optical Characterization
R. Grubbs	Nonlinear Optical Materials

N. Yeh	High Tc Superconductivity
J. Pine	Micromachined Silicon Biological Probes
L. Hood	Custom VLSI for Genome Sequencing
V. McKoy	Diamond Film Technology

Distinguished Visiting Scientists
(Cumulative List)

- Professor Albert W. Overhauser, Department of Physics, Purdue University

  - Chaired Professor
  - Member NAS
  - Buckley Prize Winner (1975)

- Professor Hadis Morkoc, Department of Electrical Engineering and Material Research Laboratory, University of Illinois

  - MBE semiconductor devices

- Dr. Robert Jaklevic, Principal Research Scientist, Ford Motor Co., Research Staff

  - Inventor of Superconducting Quantum Interference Devices (SQUID)
  - Inventor of Inelastic Electron Tunneling Spectroscopy

- Dr. C. Thomas Elliot, Royal Signals and Radar Establishment, United Kingdom

  - Leading international expert on IR technology
  - Inventor of the Sprite (Signal Processing in Element) detector

- Professor Lester Eastman, Electrical Engineering, Cornell University

  - Fellow of the IEEE
  - Member of the U.S. Government Advisory Committee on Electron Devices
  - Member National Academy of Engineering

- Professor Max Schultz, Department of Applied Physics, University of Erlangen, West Germany

  - Infrared imaging
  - Semiconductor interface characterization and silicon MBE
  - MOS physics

- Professor John Wilkins, Department of Physics, Cornell University

  - Solid state theory of metals, superconductors and semiconductors

- Professor O. Engstrom, Department of Solid State Electronics, Chalmers University of Technology, Gothenburg, Sweden

  - Energy properties of solid memory cells

- Professor Pieter Balk, Delft Institute of Technology, Delft, The Netherlands

- Director of the Delft Institute of Microelectronics and Submicron Technology
- MBE of III-V materials and SiGe
- MOS physics

- Professor Floyd Humphrey, Department of Electrical Engineering, Boston University, Massachusetts

  - Magnetic mass random access memory
  - Microsecond optical studies of magnetic switching
  - 1988 IEEE Magnetics Society Achievement Award

- Professor C.D.W. Wilkinson, Department of Electronics and Electrical Engineering, University of Glasgow, United Kingdom

  - Nanometer electron beam lithography

- Dr. T. Andersson, Department of Physics, Chalmers University, Sweden

  - MBE of III-V materials
  - Interface formation in thin films

- Professor N. Farhat, Department of Electrical Engineering, University of Pennsylvania

  - Optical neural networks
  - Photonics

- Professor James Mayer, Department of Materials Science and Engineering, Cornell University

  - Francis Norwood Bard Professor of Materials Science and Engineering
  - RBS/channeling and ion beam modification of materials
  - Interdiffusion and reactions in thin films

- Professor L. Eric Cross, Department of Electrical Engineering, Cornell University

  - Chaired Professor
  - Former Director of Materials Research Laboratory
  - Member of National Academy of Engineering
  - Piezoelectric and Ferroelectric Materials

- Dr. John Lambe, Ford Motor Co. (retired)

  - Superconductivity
  - Neural networks

- Professor James Rosenberg, Department of Electrical Engineering, Brown University

  - Germanium IR detectors
  - High speed devices

- Dr. L. Craig Davis, Ford Motor Co.

  - Theory of ballistic electron devices
  - Electronic structure devices of semiconductors

- Professor Eric Fossum, Department of Electrical Engineering, Columbia University

  - Charge-coupled device design and physics
  - MOS physics

- Professor Leo Schowalter, Department of Physics, Rensselaer Polytechnic Institute

  - Silicon molecular beam epitaxy
  - Ballistic electron emission microscopy

- Professor James Lukens, Department of Physics, State University of New York, Stony Brook

  - Superconducting terahertz local oscillator

- Professor Steven Lyon, Department of Electrical Engineering, Princeton University

  - Optical Properties of Semiconductors
  - Infrared Detectors

- Professor David Casasent, Department of Electrical Engineering, Carnegie-Mellon University

  - Optical signal and image processing

- Professor Ravi Athale, Department of Electrical Engineering, George Mason University

  - Optical neural networks and optical computing

- Professor Michael Spencer, Department of Physics, Howard University

  - Director of Materials Science Research Center of Excellence
  - III-V Compound Semiconductor growth and characterization

Conferences and Workshops Sponsored and/or Hosted by CSMT
(Cumulative List)

- Polymers in Non-linear Integrated Optics (July 24, 1986)
- Neural Network Devices and Applications (February 18-19, 1987)
- OSA Topical Conference on Machine Vision (March, 1987)
- Submillimeter (Terahertz) Receiver Technology (April 7-8, 1987)
- CLEO (April 27-May 1, 1987)
- Highly Parallel Fault-Tolerant Computers for Space Applications (June 9-10, 1987)
- International Conference on Scanning Tunneling Microscopy '87 (July 20-24, 1987)
- Congress of the International Commission for Optics (August 24-28, 1987)
- Neural Information Processing Systems - Real and Synthetic (November 8-12, 1987)
- Hypercube Concurrent Computers and Applications (January 19-21, 1988)
- Spatial Light Modulator and Applications (June, 1988)
- Microspacecraft for Space Science (July 6-7, 1988)
- Solid-State Terahertz Sources Workshop (August, 1988)
- American Vacuum Society, Southern California Section (January 1989)
- Hypercube Concurrent Computers and Applications (March 1989)
- 1989 Space Cryogenics Workshop (July 1989)
- Technology Information Meeting - Microelectronics (November 1989)
- First International Workshop on Ballistic Electron Emission Microscopy (March 1990)
- Terahertz Technology Symposium (March 1990)
- First International Symposium on Space THz Tech. (March 1990)
- Image Recognition Workshop (May 1990)

- Innovative Long Wavelength Infrared Detector Workshop (April 1990)
- Symposium on New Materials for Nonlinear Optics, Boston, MA (April 1990)
- Distributed Memory Computing (April 1990)
- Neural Networks (October 1990)

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15. Supplementary Notes

16. Abstract

The 1990 Technical Report of the Jet Propulsion Laboratory for Space Microelectronics Technology summarizes the technical accomplishments, publications, presentations, and patents of the center during the past year. The report lists 130 publications, 226 presentations, and 87 new technology reports and patents.

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