CIPS

Center for Integrated Plasma Studies

University of Colorado at Boulder

Annual Report 1997

Martin V. Goldman, Director
Carolyn M. James, Administrative Officer

September 1998

INTRODUCTION

Modern plasma physics is the study of collective, often nonlinear, electromagnetic processes in ionized gases called plasmas. Plasma physics related research at the University of Colorado is currently carried out primarily in the Physics Department, but also in the Astrophysical and Planetary Sciences Department, the Department of Applied Mathematics, and in the Departments of Mechanical Engineering, Aerospace, and Electrical and Computer Engineering. In the community at large, plasma research is conducted at NIST, at the High Altitude Observatory of NCAR, at the Space Environment Labs of NOAA, and at local companies such as Lodestar Corp. and Science Applications, Inc.

The purpose of CIPS is to provide a focal point and forum for the exchange of both educational and research ideas among scientists with these diverse affiliations. Research in plasma physics is extraordinarily broad, encompassing basic physics of plasmas, fusion sciences, space and astrophysics, beam and accelerator physics, laser-matter interactions, and industrial processing. CIPS possesses scientific expertise in all of these areas, and fosters unique new opportunities for sponsored research in interdisciplinary aspects of plasma physics. CIPS sets the guidelines for both undergraduate and graduate education in plasma physics at the University of Colorado, providing research opportunities and guidance for plasma physics Ph.D. candidates.

MISSION STATEMENT

Original mission statement developed at the time of the creation of CIPS:

- To centralize interdisciplinary plasma-related science and research in the Boulder community, and to bring plasma physics activities to the attention of the general public.

- To mobilize Boulder expertise in basic and applied plasma physics for the purpose of competing for new Federal grants.

- To coordinate a high-performance scientific computing and networking capability for the use of CIPS members and affiliates and students in pursuit of plasma physics research.

New addition to mission statement:

- To provide new tools for making plasma physics, general physics and astrophysics highly accessible to teachers, to non-scientists and to the general public through the creation of interactive "virtual experiments" on the World Wide Web, based on our extensive programming, networking and computer-visualization capabilities.

MESSAGE FROM THE DIRECTOR

The Center for Integrated Plasma Studies had an extraordinary year in 1997 in terms of research, education and outreach accomplishments. These accomplishments were funded by continually-expanding federal and state grant support totaling $4.7 million dollars for multi-year grants from agencies such as the National Science Foundation, the Department of Energy, NASA, and CCHE. Annual grant support within CIPS for 1997 exceeds that of a number of Departments in the Natural Sciences area of the College of Arts and Sciences. CIPS Fellows, Members and Research Support Staff for 1997 number 28, along with 21 graduate and undergraduate students and 18 off-campus CIPS Research Associates.

The research, education and outreach activities of CIPS accurately reflect our mission statement and that of the College of Arts and Sciences.

The interdisciplinary breadth of plasma physics is evident in the scope of our supported research areas and seminar series topics — which range from naturally-occurring space plasmas to laboratory plasma experiments to numerical simulations of controlled fusion energy research. Our research involves extensive use of advanced computer workstations, supercomputers, and networked input and output devices. Current and planned collaborative projects involve CIPS scientists working with each other and with scientists from other CU units and departments (LASP, Chemistry, APS, Communication, Applied Math), from other universities, both within Colorado (UNC, USC) and from other States (Texas, Cal Tech, UCLA, Wisconsin, Rutgers) and from institutions abroad (CNRS, France). We have internationally renowned research programs in dusty plasmas, plasma turbulence, beam physics, ionospheric modification, laboratory plasma diagnostics and in numerical simulations of plasma transport in fusion devices. A number of CIPS Fellows have assumed positions of national leadership in areas of computer simulation and in the development of electronic research journals (Parker is Leader of the DOE Cyclone team, Cary is Chair of the DOE National Transport Code Collaboration, Goldman is Chair of the American Physical Society's Publication Oversight Committee).

Our numerous research grants have enabled us to support 10 Ph.D. candidates and a number of Postdocs, as well as undergraduates. Our recent Ph.D.'s have easily found employment in their areas of expertise, and have been able to choose from among many job offers. One of our 1997 Postdoctoral Researchers (Meers Oppenheim) has just become a tenure-track Professor at Boston University. Carson Chow has just been appointed to a tenure track position at the University of Pittsburgh. A number of our Senior Research Associates are P.I.'s on their own research grants from federal agencies.

Our successes in the areas of technology-assisted outreach and education have been fostered by our expertise and experience with computers, scientific

visualization tools, and the Internet, as well as by our capital investments in technological infrastructure. The Physics-2000 Outreach Website Project and the Solar System Collaboratory for joint education across Colorado campuses have both received major support from CCHE ($750,000). These projects use Java applet technology to construct interactive learning environments on the Web. We have just been notified that both projects will be picked up by new sponsors beginning this year —by NSF and by the Department of Education. I have shared my experience in using the World Wide Web interactively in science education with Colorado High School teachers and with the ATLAS Steering Committee and a number of Subcommittees. I have also cooperated with the Chancellor's Office to give numerous presentations to Colorado educational institutional administrators. CIPS Senior Research Associate, Dr. I. Doxas has worked on the Solar System Collaboratory with representatives of other Colorado campuses. Professor J. Cary, as the FTEP program's Area Teaching Scholar, shares his knowledge about the use of computers and the Internet in education. All of these activities are consistent with our mission statement last item and with the mission of the College of Arts and Sciences — especially in the area of "Fostering educational exchange within the University, the Colorado community, and society as a whole."

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PERSONNEL

CIPS FELLOWS

Martin V. Goldman - Director and Professor of Physics
John R. Cary - Associate Director and Professor of Physics
James Meiss, Professor of Applied Mathematics
Scott Parker, Assistant Professor of Physics
Zoya Popovic, Associate Professor of ECEE
Scott Robertson, Associate Professor of Physics
Ted Speiser, Professor of APS
Raul Stern, Professor of Physics

CIPS MEMBERS

David Alexander, Research Associate
Fran Bagenal, Professor of APS
Dan Baker, Director of LASP
Isidoros Doxas, Senior Research Associate
Tim Fuller-Rowell, Senior Research Associate with CIRES
Alan Gallagher, Lecturer with Physics
Mihaly Horanyi, Research Associate with LASP
Jim Howard, Research Associate
Alan Kiplinger, Senior Research Associate with APS
David Newman, Research Associate
Meers Oppenheim, Research Associate
Sveta Shasharina, Senior Research Associate
Michael Spector, Research Associate
Weishi Wan, Research Associate

CIPS SCIENTIST ASSOCIATES

HAO/NCAR
Paul Charbonneau
Tom Holzer
Art Hundhausen
BC Low
Gang Lu
Art Richmond
Ray Roble

Lodestar Corp.
Dick Aamodt
Dan D'lppolito
Jim Myra
David Russell

Space Science Inst.
Paul Dusenbery

SEC/NOAA
Ernie Hildner
Terry Onsager
Vic Pizzo
Howard Singer
Ron Zwickel

NIST
John Bollinger

VISITING SCHOLARS

Chan Joshi, University of California, Los Angeles, California
Mikhail Medvedev, University of California, San Diego, California
Igor Manuilskiy, Princeton Plasma Physics Lab, New Jersey
Nathan Mattor, Lawrence Livermore National Laboratory, California
Neils Otani, University of Iowa

CIPS RESEARCH SUPPORT STAFF

John Adams, Professional Research Assistant
John Albers-Mead, Assistant
Krista Beck, Professional Research Assistant
Carolyn M. James, Professional Research Assistant
David Rea, Professional Research Assistant
David Underwood, Graphic Designer with ITS

GRADUATE STUDENTS

Jeff Biggus, Physics
Christopher Boozer, APS
Jonathan G. Fernsler, Physics
Brendan Field, Physics
Kathy Garvin-Doxas, Communication
Richard Ghrist, Physics
Samuel Jones, Physics
Charlson Kim, Physics
Jinhyung Lee, Physics
Kevin Sanbonmatsu, APS

UNDERGRADUATE STUDENTS

Lorraine Bell
Zachary Chandler
Aaron Forsyth
Michael Fuchs
Taunya Henriksen
Mark Masse
Niranjan Raj Sharma
Ronald Sudomo
Wenming Ye
Richard Younger
Margaret Wessling

RECENT PH.D.'S

Scott Hendrickson
Kevin Sanbonmatsu
Peter Stoltz

CIPS RESEARCH GRANTS ACTIVE DURING CALENDAR YEAR 1997, BY PRINCIPAL INVESTIGATOR

Cary, John R.	
DOE, 1994-97	$343,000
DOE, 1997-00	$504,000
DOE, 1995-98	$525,000
Doxas, Isidoros	
CCHE, 1996-97	$181,000
CCHE, 1997-98	$180,137
NASA, 1996-97	$57,367
NASA, 1997-99	$121,068
Goldman, Martin V.	
CCHE, 1996-97	$235,000
CCHE, 1997-98	$235,000
NASA, 1995-97	$151,533
NASA, 1997-99	$113,000
NSF, 1995-97	$22,800
NSF, 1993-97	$202,215
NSF, 1994-97	$412,806
Newman, David	
NSF,1997-99	$240,000
Oppenheim, Meers	
NASA, 1997-1998	$69,807
U. Iowa, 1996-97	$17,300
Parker, Scott	
DOE, 1997-2000	$259,000
DOE, 1997-99	$270,000
Robertson, Scott	
NSF, 1997	$5,000
Graduate School	$2,000
NSF/DOE, 1997-99	$273,000
NASA, 1996-98	$30,000
NASA, 1997-98	$30,000
NASA, 1996-97	$56,000
NASA, 1997-98	$56,000
NASA, 1994-97	$21,807
Stern, Raul	
NSF, 1993-97	$330,000
NSF, joint with CALTECH, 1995-98	$130,511

NSF, joint with UCLA, 1994-98 $214,319

WORKSHOPS

US-JAPAN JIFT WORKSHOP ON "LARGE SCALE SIMULATION STUDY AND VISUALIZATION MARCH 5-7, 1997 IN BOULDER, COLORADO

Participants from outside University of Colorado. Ritoku Horiuchi, National Institute of Fusion Science (Japan) (NIFS); Akira Kageyama, NIFS; Hideaki Miura, NIFS; Seiji Ishiguro, Tomohiko Watanabe, Sergey Bazdenkov, NIFS; Mitsuru Honda Osaka, Norman Zabusky Rutgers, David Grote, LLNL; Richard Sydora, UCLA; Julian Cummings, LANL; Zhihong Lin, PPPL; Andris Dimits, LLNL; Geoffrey Furnish, LLNL; Gary Kerbel, LLN;, Dave Nystrom, LANL; Wendell Horton, IFS; Allan Glasser, LANL; Charles Norton, JPL.

University of Colorado Participants. Svetlana Shasharina, John Cary, Marty Goldman, David Newman, Meers Oppenheim, Isidoros Doxas, Scott Parker, and several graduate students.

1998 CONFERENCE ON THE PHYSICS OF DUSTY PLASMAS.

CIPS is a sponsor of the 1998 Conference on the Physics of Dusty Plasmas to be held at the Boulderado Hotel in Boulder, April 6-9, 1998. CIPS personnel have established a web site for accepting registration and abstracts for this conference.

SEMINAR SERIES

1 January - 30 November 1997
Seminar Series Coordinator: Meers Oppenheim

Date	Speaker	Title
January 17	Travis Mitchell, NIST	Observation Of Spherical Focus In An Electron Penning Trap
January 24	Scott Parker, CIPS	Large-Scale Gyrokinetic Simulation Of Tokamak Plasma Turbulence
February 7	Hans De Sterck, HAO / Katholieke Universiteit Leuven (Belgium)	Dynamics Of Hot Filaments In A Tokamak Plasma
February 21	Dan Baker, LASP	Space Weather
February 24	Tetsuya Sato, Theory and Computer Simulation Center, NIFS	A Grand View Of Self-Organization In An Open System
February 28	Ellen Zweibel, JILA and CU APS Dept.	Magnetic Fields In Galaxies And Beyond
March 14	Frank Crary, CU APS Dept.	Io's Interaction With Jupiter's Magnetosphere
April 4	Nathan Mattor, Lawrence Livermore Nat'l. Laboratory	Scattering Of Spiral Density Waves To Lower Arm Number
April 11	Horanyi, LASP	Dusty Plasmas In Space
April 18	R. G. Roble, HAO/NCAR	Modeling Large-Scale Neutral Plasma Interactions In The Thermosphere And Ionosphere
April 25	Tuija Pulkkinen, LASP and Finnish Meteorological Institute, Helsinki, Finland	Polar Auroras - A Manifestation Of Instability Within A Thin Current Sheet In The Magnetotail
May 2	Scott Robertson, CIPS	Dusty Plasmas Experiments
May 9	Kevin Y. Sanbonmatsu, CIPS	New Kinetic Simulation Model For Wave-Wave And Wave-Particle Interactions In The Auroral Ionosphere

Date	Speaker	Title
September 22	Doyle Hall, LASP	On The Io Torus Electron Velocity Distribution
October 7	Mikhail Medvedev, UC San Diego	Nonlinear Dynamics Of Collisionless Dissipative Alfven Waves And Alfvenic Turbulence
October 13	Igor Manuilskiy, Princeton Plasma Physics Lab	General Properties Of Transport In Plasmas: An Overview Of Onsager Symmetry.
October 20	Hardi Peter, Max-Planck-Institute for Aeronomy, and HAO/NCAR	The Change Of The Elemental Abundances On The Sun From The Photosphere To The Solar Wind
November 3	Yuhong Fan, JILA	Buoyant, Interacting Magnetic Flux Tubes In The Solar Convection Zone
November 10	David Galloway, School of Mathematics and Statistics, University of Sydney, Australia and HAO	Slow Dynamos In Hexagons And Fast Dynamos In Cubes And Their Possible Astrophysical Relevance

RESEARCH INTERESTS

DAVID ALEXANDER

Professional activities include developing educational software for introductory physics and astronomy and education research.

JOHN CARY

Research activities include the areas of plasma physics, beam (or accelerator) physics, nonlinear dynamics, and computational physics. Plasma physics research includes the study of space plasma physics as well as fusion plasma physics of three-dimensional confinement systems (those with strong toroidal variation). Beam physics research is focused in understanding collective instabilities as well as in the nonlinear dynamics of two-degree-of-freedom symplectic maps. Computational physics research is focused in the developing area of scientific Object Oriented Programming.

ISIDOROS DOXAS

Research interests include plasma turbulence in laboratory and space plasmas, especially as analyzed by the methods of nonlinear dynamics and large-scale particle simulations. Other interests include magnetospheric physics, particularly on magnetic reconnection in the geomagnetic tail, and on global models of the dynamics of the coupled magnetosphere-ionosphere system. Educational interests include bringing advanced computational tools into the classroom at all levels of the science curriculum, and helping non-science majors see science as an exciting intellectual enterprise, rather than as an exercise in math skills

MARTIN V. GOLDMAN

Current research interests include: plasma physics, popularization of physics for the general public via the world wide web, nonlinear waves, electron-beam-plasma, radiation-plasma interactions, nonlinear optics, computer simulations of plasma turbulence and coherent processes, theory of modification of Earth's ionosphere by high-power radar, theory and simulation of laser-plasma interactions, and theory and simulation of auroral ionosphere wave-particle interactions

JAMES E. HOWARD

Research focuses on Hamiltonian systems, with applications to plasma physics, accelerator orbits, atomic physics, and celestial mechanics.

JAMES MEISS

Research interests focus on the area of dynamical systems, in particular the study of the onset and characterization of chaos.

DAVID NEWMAN

Research primarily focuses on the theoretical analysis and numerical simulation of turbulence in plasmas---especially in the near-Earth space environment. Of particular interest are artificially induced turbulence in Earth's ionosphere and naturally occurring turbulence in the magnetosphere and solar wind. This research also involves the comparison of turbulence in space vs. laboratory environments

MEERS OPPENHEIM

Research area is computational and theoretical space plasma physics.

SCOTT PARKER

Primary research is in the area of direct numerical simulation and basic theoretical understanding of plasma turbulence and transport. Research includes large-scale simulations of tokamak plasma turbulence. Other active research areas include theoretical and computational research on kinetic-fluid hybrid models, and renormalization procedures for collisionless kinetic systems to model nonlinear wave-particle interactions.

ZOYA POPOVIC

Projects in microwave and millimeter-wave quasi-optical systems, microwave high-efficiency amplifiers, antennas for wireless communications and fr photonics. Project with the Netherlands Foundation for Radioastronomy on a broad longterm (20-year) international project developing a new very large radiotelescope.

SCOTT ROBERTSON

Research interests include experimental plasma physics (the study of ionized gases) with emphasis on 1) space and laboratory plasmas containing dust, aerosols or large molecular clusters; 2) non-neutral plasmas; and 3) and particle beams as plasmas.

SVETLANA SHASHARINA

Nuclear Fusion Theory: confinement, transport; Computer Science: C++ modeling.

TED SPEISER

Magnetospheric substorms, the geomagnetic tail, current sheets and their stability, remote sensing of the topology of the geomagnetic tail current sheet using satellite observations of energetic ions along with our model, and theories of the onset of geomagnetic substorms.

RAUL STERN

Research focuses on experimental basic plasma physics, a variety of programs, one at CU and three additional projects in collaboration with major national and international research and educational institutions (Caltech, UCLA, University of Provence, France)

PUBLISHED PAPERS IN REFEREED JOURNALS, IN 1997

DAVID ALEXANDER

"Automated Langmuir Probe Data Acquisition and Analysis for a Double Plasma Machine," D. Alexander, J. Fernsler, and S. Robertson, November 1997, submitted to *IEEE Transactions on Plasma Science*.

"Electrostatic Charging Properties of Apollo-17 Lunar Dust", M. Horányi, B. Walch, S. Robertson, and D. Alexander, November 1997, submitted to *Journal of Geophysical Research*.

JOHN CARY

"Helical Plasma Confinement Devices with Good Confinement Properties," J. R. Cary and S. G. Shasharina, *Phys. Rev. Let.*, 78 (5), 674-677 (1997).

"Omnigenity and Quasihelicity in Helical Plasma Confinement Systems," J. R. Cary and S. G. Shasharina, *Phys. Plasma*, 4 (9), 3323-3333 (1997).

"Omnigenous Stellarators", J. R. Cary and S. G. Shasharina, *Stellarator News*, (49), 11-13 (Jan. 1997).

"Omnigenous Stellarators," J. R. Cary and S. G. Shasharina, *Plasma Phys. Reps*, 23 (6), 509-511 (1997).

"Comparison of C++ and Fortran 90 for Object-Oriented Scientific Programming," J. R. Cary, S. G. Shasharina, Julian C. Cummings, John V. W. Reynders, and Paul J. Hinker, *Comp. Phys. Comm*, 105, 20-36 (1997).

"Numerical observation of turbulence enhanced growth rates", I. Doxas and J. R. Cary, *Phys. Plasmas*, 4 (7), 2508-2518 (1997).

ISIDOROS DOXAS

"Numerical observation of turbulence enhanced growth rates", I. Doxas and J. R. Cary, *Phys. Plasmas*, 4 (7), 2508-2518 (1997).

"Non-Markovian electron diffusion in the auroral ionosphere at high Langmuir-wave intensities", K. Y. Sanbonmatsu, I. Doxas, M. V. Goldman, and D. L. Newman, *Geophysical Research Letters*, 24, 807-810, April 1, 1997.

JONATHAN FERNSLER

"Automated Langmuir Probe Data Acquisition and Analysis for a Double Plasma Machine," D. Alexander, J. Fernsler, and S. Robertson, November 1997, submitted to *IEEE Transactions on Plasma Science*.

MARTIN V. GOLDMAN

"Theory of convective saturation of Langmuir waves during ionospheric modification of a barium cloud", M. V. Goldman, D. L. Newman, R. P. Drake and B. B. Afeyan, *Journal of Atmospheric and Terrestrial Physics (JATP)*, 59/18, 2335-2350, Dec. 1997.

"Non-Markovian electron diffusion in the auroral ionosphere at high Langmuir-wave intensities", K. Y. Sanbonmatsu, I. Doxas, M. V. Goldman, and D. L. Newman, *Geophysical Research Letters*, 24, 807-810, April 1, 1997.

"Vlasov Simulations of Electron Heating By Langmuir Turbulence Near The Critical Altitude in the Radiation-Modified Ionosphere", J. G. Wang, D. L. Newman and M. V. Goldman, *Journal of Atmospheric and Terrestrial Physics (JATP)*, 59/18, 2461-2474, Dec. 1997.

JAMES E. HOWARD

Reply to "Comment on 'Saddle Point Ionization and The Runge-Lenz Invariant", J. E. Howard, *Phys. Rev. A*, 55, 1552.

JAMES MEISS

"Quadratic Volume Preserving Maps." Lomeli, H. E. and J. D. Meiss accepted for publication in *Nonlinearity*. (1997).

"Average Exit Time for Volume Preserving Maps", J. D. Meiss, *Chaos* 7, 139-147 (1997).

"Computing Periodic Orbits using the Anti-Integrable Limit", D. Sterling and J. D. Meiss, *Physics Letters A* accepted for publication (1997).

DAVID NEWMAN

"Theory of convective saturation of Langmuir waves during ionospheric modification of a barium cloud", M. V. Goldman, D. L. Newman, R. P. Drake and B. B. Afeyan, *Journal of Atmospheric and Terrestrial Physics (JATP)*, 59/18, 2335-2350, Dec. 1997.

"Non-Markovian electron diffusion in the auroral ionosphere at high Langmuir-wave intensities", K. Y. Sanbonmatsu, I. Doxas, M. V. Goldman, and D. L. Newman, *Geophysical Research Letters*, 24, 807-810, April 1, 1997.

"Vlasov Simulations of Electron Heating By Langmuir Turbulence Near The Critical Altitude in the Radiation-Modified Ionosphere", J. G. Wang, D. L. Newman and M. V. Goldman, *Journal of Atmospheric and Terrestrial Physics (JATP)*, 59/18, 2461-2474, Dec. 1997.

MEERS OPPENHEIM

"Evidence and effects of a wave-driven nonlinear current in the equatorial electrojet", M. Oppenheim, *Ann. Geophysicae*, 15, 899, 1997.

SCOTT PARKER

``Simulating Plasma Turbulence in Tokamaks", J. Kepner, S. Parker and V. Decyk *SIAM News* 30, 1 (1997).

``Nonlinear Kinetic-Fluid Equations", N. Mattor and S. E. Parker, *Phys. Rev. Lett*, 79, 3419 (1997).

"Stabilization of Ion-Temperature-Gradient-Driven Tokamak Modes by Magnetic-Field Gradient Reversal", M. Fivaz, T. M. Tran, K. Appert, J. Vaclavik, and S. E. Parker, *Phys. Rev. Let.* 78, 18 (1997).

ZOYA POPOVIC

``Quasi-optical antenna array amplifiers,'' Z. Popovic, R. York, E. Sovero, J. Schoenberg, Chapter 5 in "Active and Quasi-optical Arrays for Solid-State Power Combining," eds. R. A. York and Z. B. Popovic, John Wiley & Sons, 1997, pp. 187--244.

"A bi-directional quasi-optical lens amplifier," S. Hollung, A. Cox, Z. Popovic, *IEEE Trans. on Microwave Theory and Techniques*, 45, 12, 2352--2357, December 1997.

"Analysis and optimization of grid oscillators," W. A. Shiroma, Z. Popovic, *IEEE Trans. on Microwave Theory and Techniques*, 45, 12, 2380--2386, December 1997.

SCOTT ROBERTSON

"Automated Langmuir Probe Data Acquisition and Analysis for a Double Plasma Machine," D. Alexander, J. Fernsler, and S. Robertson, November 1997, submitted to *IEEE Transactions on Plasma Science*.

"Smith-Purcell radiation from a 50 MeV beam," J. H. Brownell, J. Walsh, H. G. Kirk, R. C. Fernow and S. H. Robertson, *Nuclear Instruments and Methods*, 393, 323-325 (1997).

"Electrostatic Charging Properties of Apollo-17 Lunar Dust", M. Horányi, B. Walch, S. Robertson, and D. Alexander, November 1997, submitted to *Journal of Geophysical Research*.

"Laboratory Measurements of Dust Charging in Plasmas", M. Horányi, S. Robertson and B. Walch, in The Physics of Dusty Plasmas, P. K. Shukla, D. A. Mendis and V. W. Chow, editors (World Scientific, Singapore, 1996), pp. 8-14. [The publication date is 1996, but the book was not distributed until 1997].

"Neoclassical Transport in an Annular Penning Trap", S. Robertson, *Physics of Plasmas*, 4, 2760-2762 (1997).

KEVIN SANBONMATSU

"Non-Markovian electron diffusion in the auroral ionosphere at high Langmuir-wave intensities", K. Y. Sanbonmatsu, I. Doxas, M. V. Goldman, and D. L. Newman, *Geophysical Research Letters*, 24, 807-810, April 1, 1997.

SVETLANA SHASHARINA

"Helical Plasma Confinement Devices with Good Confinement Properties," J. R. Cary and S. G. Shasharina, *Phys. Rev. Let.*, 78 (5), 674-677 (1997).

"Omnigenity and Quasihelicity in Helical Plasma Confinement Systems," J. R. Cary and S. G. Shasharina, *Phys. Plasma*, 4 (9), 3323-3333 (1997).

"Omnigenous Stellarators", J. R. Cary and S. G. Shasharina, *Stellarator News*, (49), 11-13 (Jan. 1997).

"Omnigenous Stellarators," J. R. Cary and S. G. Shasharina, *Plasma Phys. Reps*, 23 (6), 509-511 (1997).

"Comparison of C++ and Fortran 90 for Object-Oriented Scientific Programming," J. R. Cary, S. G. Shasharina, Julian C. Cummings, John V. W. Reynders, and Paul J. Hinker, *Comp. Phys. Comm*, 105, 20-36 (1997).

RAUL STERN

"Laser-Induced Fluorescence Observation of Self Organized Ion Structures Induced by Electrostatic Perturbations", G. Bachet, F. Skiff, M. Dindelegan, F.Doveil, and R. A. Stern, accepted by *Physical Review Letters*.

"Observations of Fast Anisotropic Ion Heating, Ion Cooling and Ion Recycling in Large-Amplitude Drift Waves", S. J. Sanders, P. M. Bellan, and R. A. Stern, accepted by *Physics of Plasmas*.

"Real -Time Phase-Selective Data Acquisition System for Measurement of Wave Phenomena in Pulsed Plasma Discharges", S. J. Sanders, R. A. Stern and P. M. Bellan, accepted by *Review of Scientific Instruments*.

INVITED PAPERS, IN 1997

JOHN CARY

"Controversies in Quasilinear Theory", J. R. Cary, Bull Am. Phys. Soc. 42, 2027 (1997).

"Enhanced velocity diffusion in slow-growing 1-D Langmuir turbulence", I. Doxas and J. R. Cary, Chaos Kinetics and Nonlinear Dynamics in Fluids and Plasmas, Marseilles, France, 1997.

"Adiabatic Free-Electron Lasers", Jefferson National Accelerator Lab, March, 1997

"Use of Computer Science Methods for Scientific Modeling Applications", Department of Energy, March, 1997

"Modifications to Quasilinear Diffusion", Princeton Plasma Physics Lab, March, 1997

"Object Oriented Accelerator Modeling", Brookhaven National Lab, March, 1997

"Reducing Chaos in Accelerator Lattices", U. Southern California, July, 1997.
"Client-Server Methods for Scientific Applications", Oak Ridge National Laboratory, October, 1997

"Client-Server Methods for Scientific Applications", Department of Energy, October, 1997

"Object Oriented Accelerator Modeling", Fermi National Accelerator Laboratory, October, 1997.

"Object Oriented Accelerator Modeling", Brookhaven National Laboratory, October, 1997.

ISIDOROS DOXAS

"The Solar System Collaboratory: Teaching Collaboratively through the Internet", I. Doxas and F. Bagenal, Meeting of the American Geophysical Union, Baltimore, MD, 1997.

"Enhanced velocity diffusion in slow-growing 1-D Langmuir turbulence", I. Doxas and J. R. Cary, Chaos Kinetics and Nonlinear Dynamics in Fluids and Plasmas, Marseilles, France, 1997.

MARTIN V. GOLDMAN

"Science Outreach Using Interactive Java Applets on the Internet: The Physics-2000 Project", M. V. Goldman and D. Rea, 1997 Spring Meeting of the American Geophysical Union, Baltimore MD, EOS Supplement, Paper SA 22B-6, Pg. S223, April 29, 1997.

" Langmuir Turbulence Generated During Ionospheric Modification", M. V. Goldman, RF Ionospheric Interactions Workshop (sponsored by NSF), Santa Fe, NM, April, 1997.

"New Insights into How Beam-Excited Instabilities Saturate , International Topical Conference on Plasma Physics: New Perspectives on Collective Effects", M. V. Goldman, D. L. Newman, and M. Oppenheim, International Centre for Theoretical Physics, Trieste, Italy, November 10, 1997.

"Beam-driven Langmuir turbulence in lab and space plasmas", M. Goldman, D. Newman, and M. Oppenheim, International Conference on the Interrelationship between Experiments in Laboratory and Space Plasmas, Maui, HI, June 23, 1997.

"Plasma Wave Turbulence in Earth's Foreshock", M.V. Goldman, Observatoire de Meudon, Paris, Nov., 1997

JAMES MEISS

"Chaotic Trajectories to the Moon," Colorado State University, Fort Collins, March 8, 1997.

DAVID L. NEWMAN

"New Insights into How Beam-Excited Instabilities Saturate", International Topical Conference on Plasma Physics: New Perspectives on Collective Effects, M. V. Goldman, D. L. Newman, and M. Oppenheim, International Centre for Theoretical Physics, Trieste, Italy, November 10, 1997.

"Beam-driven Langmuir turbulence in lab and space plasmas", M. Goldman, D. Newman, and M. Oppenheim, International Conference on the Interrelationship between Experiments in Laboratory and Space Plasmas, Maui, HI, June 23, 1997.

"Langmuir Turbulence Generated During Ionospheric Modification: Kinetic Simulation Techniques", D. L. Newman, RF Ionospheric Interactions Workshop, Santa Fe NM, April 1997.

MEERS OPPENHEIM

"New Insights into How Beam-Excited Instabilities Saturate", International Topical Conference on Plasma Physics: New Perspectives on Collective Effects, M. V. Goldman, D. L. Newman, and M. Oppenheim, International Centre for Theoretical Physics, Trieste, Italy, November 10, 1997.

"Beam-driven Langmuir turbulence in lab and space plasmas", M. Goldman, D. Newman, and M. Oppenheim, International Conference on the Interrelationship between Experiments in Laboratory and Space Plasmas, Maui, HI, June 23, 1997.

"Nonlinear physics of Small-Scale E-Region Waves: Simulations and Theory" M. Oppenheim, IAGA meeting, Uppsala, Sweden, August 1997.

"Two-stream waves in the E-region ionosphere nonlinearly drive large-scale D.C. currents", M. M. Oppenheim, URSI meeting, Montreal, Canada, July 1997.

SCOTT PARKER

"Large - Scale Plasma turbulence Simulation", S. Parker, Department of Applied Mathematics, University of Colorado, Boulder, September 26, 1997.

DAVID REA

"Science Outreach Using Interactive Java Applets on the Internet: The Physics-2000 Project", M. V. Goldman and D. Rea, 1997 Spring Meeting of the American Geophysical Union, Baltimore MD, EOS Supplement, Paper SA 22B-6, Pg. S223, April 29, 1997.

SCOTT ROBERTSON

"Rocket Instruments for Noctilucent Clouds," Institute of Meteorology, University of Stockholm, August 5, 1997.

"Dusty Plasma Experiments", Plasma Physics Group Seminar, University of Colorado, May 2, 1997.

"Plasma with Dust in the Lab and In Space", Department of Physics, University of Colorado, Boulder, September 17, 1997.

SVETLANA SHASHARINA

"Omnigenous, Nonquasihelical Systems", S. G. Shasharina and J. R. Cary, International Sherwood Fusion Theory Conference, Madison, Wisconsin, 1997.

RAUL A. STERN

"Laser-Induced Fluorescence Diagnostics in Plasmas", R. A. Stern, Annual Meeting, Division of Plasma Physics, American Physical Society, Pittsburgh, PA, November 1997.

CURRENT RESEARCH PROGRAMS

COMPUTATIONAL SPACE PLASMA PHYSICS (NSF, ONR, AFOSR, NASA)

Computation space plasma physics research is carried out with the participation of members of the University of Texas.

There are a variety of well-funded space plasma theory projects carried out in CIPS which involve intensive use of computers and supercomputers to carry out numerical simulations.

Ionospheric Modification. This is an international project in which high-power radio waves are used to heat and modify Earth's ionosphere. Experiments are carried out at Arecibo, Puerto Rico, in Alaska, and at various other sites around the world. Numerical simulations have been performed at CIPS on the effects of the high-power heater on plasma waves and particles, with the object of explaining experiments and providing new theoretical models.

Electron Beams. Numerical studies have been carried out on the plasma turbulence driven by naturally occuring electron beams in the solar wind and auroral ionosphere. Simulation results are carried out with in situ satellite measurements of waves and particles. A graduate student, Kevin Sanbonmatsu, completed his Ph.D. thesis in this area and graduated in the summer of 1997.

Electrojet. Theoretical conjectures concerning the existence and magnitude of wave-driven currents in the E-region of the ionosphere have been supported by a series of nonlinear 2-D simulations, including simulations of the Farley-Buneman instability, and by data collected by rocket instruments in the equatorial electrojet.

Magnetosphere. Development of global models for the magnetotail and the magnetospheric-ionospheric coupling. Non-linear dynamics techniques (embeding, dimensional analysis, Lyapunov exponents, etc) are being used to compare physics-based models with existing data-based models. A graduate student, Brent Goode, is working under the supervision of John Cary on both the plasma physics and nonlinear dynamics aspects of the project.

BEAM PHYSICS (DOE)

Beam physics is the study of the creation and evolution of intense directed beams, of either particle or light. The study of this physics has permitted the design of beams of higher energy, higher quality, greater intensity, and reduced size. Such beams are used for cancer therapy, the study of elementary particles, and processing of semiconductors. Hence, the study of how intense beams propagate has an impact on large areas of basic science and technology.

Several areas of beam physics are being pursued at CIPS. Our nonlinear dynamics studies, applied to beams, has shown how to make it easier to capture a larger beam by reducing the volume of chaotic orbits. Our work on beam instabilities has shown that there is a nonlinear mechanism for extracting beam energy by the interaction of the beam with weak cavity modes. Our work on free-electron laser dynamics has shown how one can create lasers of higher efficiency. Finally, we have shown how to develop software object models for accelerators. Such object models can be reused in many situations.

FUSION PLASMA THEORY AND COMPUTATION (DOE)

Recent developments in massively-parallel computing and object oriented programming are having an enormous impact plasma physics. Recent theoretical developments in nonlinear dynamics, kinetic-fluid closures and numerical methods such as delta-f and sympletic integration have had an enormous impact as well. CIPS is unique in its international leadership in all of these areas of theoretical and computational physics.

Fusion plasma theory and computation is being investigated by several researchers at CIPS. Topics include large-scale, massively parallel turbulence simulations; the use of modern computer science methods in modeling; and optimization of three-dimensional magnetic confinement systems to eliminate chaotic orbits. CIPS has played a leadership role in the DOE Cyclone project, whose purpose was to study the physics basis and reliability of the various transport models and turbulence simulations used an internationally funded fusion reaction project (ITER). Other current research areas include: development of new nonlinear gyro-Landau fluid closures, development of gyrokinetic-gyrofluid hybrid models and studies of the effects of profile variation.

Research in modern computer-science methods is directed towards developing models of highly complex systems that, due to the nature of research, change with time. One example is that of transport modeling in magnetic confinement systems. For such systems the classical calculations of particle loss fail, due to the existence of turbulence. Turbulence calculations like those just mentioned lead to new sets of equations describing the plasma evolution. To determine how well these new equations predict plasma evolution, one must have flexible modeling computer programs capable of rapidly accepting these new equations. Modern computer science methods, like Object Oriented Programming, permit the design of such programs.

With developments in nonlinear dynamics, we are now better able to predict the loss of particles in complex three-dimensional magnetically confined plasmas. Such systems, known as stellarators, have long been known to offer advantages of being steady state. However, early configurations had large particle losses due to chaos. Our recent research has shown how to reduce these large losses. These ideas are now being implemented in device design at our national laboratories.

PHYSICS-2000 OUTREACH EDUCATION PROJECT (CCHE)

Physics-2000 outreach education project is carried out with the participation of members of the Physics and Chemistry Departments.

Physics-2000 is a unique multidisciplinary educational-technology project which brings to students, educators and the general public a highly-accessible set of interactive *virtual experiments* embedded in a carefully-tailored authoritative popular exposition of the underlying 20th century science — all made widely and freely available on the Internet. Java applet technology enables the user to manipulate the computer mouse to perform the virtual experiments, which include both "thought" experiments and simplified "real" experiments illustrating basic physical principals. This project is directed by Professor Goldman. A staff of programmers, artists, formatters and other developers have worked with faculty and students to create the virtual experiments and accompanying narrative on the web site, www.colorado.edu/physics/2000. This project has been highly acclaimed throughout the nation and has received national press coverage. Content developed over the past year includes X-rays, CT scans, microwaves ovens, the Bose-Einstein condensate, quantum interference, and the physics of electromagnetic waves, including production of radiation at the atomic level. Professors Scott Robertson, Carl Wieman and Carl Lineberger have all contributed to the development of this educational project. This web site was used in a variety of undergraduate Physics department courses as a teaching supplement.

SOLAR SYSTEM COLLABORATORY (CCHE)

The solar system collaboratory is carried with the participation of members of the APS Department, the Communication Department, University of Colorado at Boulder (UCB), the University of Northern Colorado at Greeley (UNC), the University of Southern Colorado in Pueblo (USC), and Fort Lewis College in Durango (FLC).

The purpose of the collaboratory is to develop educational modules that can be incorporated into introductory science courses for non-majors, and then to assist participating schools in teaching the modules collaboratively across the state. The educational objective is to help schools introduce student-centered learning into their science classes, and to give their students the open-ended problem solving skills that the increasingly high-tech economy demands. The subject matter is general and introductory astronomy, with an emphasis on processes that are particularly relevant to Earth.

DUSTY PLASMA PHYSICS (NASA, DOE, NSF/DOE)

Dusty plasma physics research is carried out with the participation of members of LASP, the University of Northern Colorado, Rutgers University, and the University of Wisconsin.

Fundamentals of Dusty Plasmas. Theoretical and laboratory studies of dust charging, dusty plasma effects in noctilucent clouds and dust dynamics in photoelectric sheaths near surfaces in space (asteroids and satellites).

Dusty Plasma Dynamics Near Surfaces in Space Program to study, both experimentally and theoretically, the properties of dust-loaded photoelectron sheaths and to design and build laboratory analogues of microgravity experiments to be conducted on the space station.

Lunar Dust. Long term goal is to develop a laboratory lunar surface model, where time dependent illumination and plasma bombardment will closely emulate the conditions on the surface of the Moon.

Chondrule Forming Process. Investigation of short duration energetic events (`lightning') in the early solar system which may have lead to the creation of chondrules. This project is a collaboration between geochemists (at Rutgers U.), fusion plasma experimentalists (U. Wisconsin) and CIPS.

Rocket Instrument Development. To develop a charged dust/aerosol sensor for studies of polar mesospheric clouds and to fly our dust detecting instrument on the German/Norwegian/Swedish Midas rocket in the summer of 2000.

BASIC AND APPLIED EXPERIMENTAL PLASMA PHYSICS
(NSF, CNRS (FRANCE))

Basic and applied experimental plasma physics is carried out with the participation of members of Caltech, UCLA, and CNRS (the French national center for scientific research).

Stochastic Ion Heating. This research concerns processes whereby random but intense chaotic electric fields at low (ionic) frequencies in a plasma cause the plasma ions to acquire extremely large kinetic orbits. A collaborative program with Caltech has been continuous since 1984, and has led to notable advances in experimental plasma physics.

Wave-particle interactions in Ion-Acoustic Shocks. This is a program to study the major perturbations occurring in plasma ions in the presence of large-amplitude, driven plasma oscillations. This research was set up at the Plasma Turbulence group at CNRS/Universite de Provence.

Field-Particle interactions in Alfven Waves. This research is a novel attempt to study the effect of Alfven waves on ions, using the world's largest fundamental research plasma facility, the LAPD device at UCLA.

Lamb-shift Quench Diagnostics. This is a new diagnostic technique for measuring local electric and magnetic fields in plasmas with great sensitivity and resolution, based on fundamental atomic concepts. Preliminary data is being generated in both laboratories at Boulder and France (CNRS).

A number of experimental facilities at Boulder are used in support of the

ACTIVITY HIGHLIGHTS FOR 1997

JOHN CARY

- Chair, Publications Committee of the Division of Plasma Physics of the American Physical Society
- Area Teaching Scholar, Natural Sciences, A&S
- Member, National Stellarator Program Planning Committee
- Chair, computer committee, Center for Integrated Plasma Studies
- A&S Personnel Committee (S97)
- A&S Core Curriculum Task force (F97)
- A&S Curriculum Committee (F97)
- Member BFA Executive Committee (F97)
- Associate Director of Center for Integrated Plasma Studies

ISIDOROS DOXAS

- Completed Web Course in Introductory Astronomy as a part of the CCHE Collaboratory research project.

MARTIN GOLDMAN

- Chair of Publication Oversight Committee of American Physical Society.
- Associate Editor of Physics of Plasmas journal.
- Maxwell Prize Committee of Division of Plasma Physics (DPP) of American Physical Society.
- Publication Committee of Division of Plasma Physics of American Physical Society.
- Steering Committee of RF Ionospheric Interactions Group.
- Convenor of Educational Outreach Session for American Geophysical Union (AGU)
- Organized, hosted and made presentation at a Physics-2000 Conference/Workshop with Colorado-wide High School Physics Teachers.
- Organized, hosted and made presentation at a Physics-2000 Conference/Workshop with Colorado-wide Post-Secondary School Educators.
- Director of Center for Integrated Plasma Studies.

JAMES MEISS

- Editor for the journal Physica D.
- Organizing Committee, Nonlinear Dynamics in Astronomy Meeting and Southwest Dynamical Systems Meeting.
- Departmental Computer Liaison
- Representative for the Goldwater Scholarship.

SCOTT PARKER

- Appointed Leader of the Cyclone Team, a Department of Energy initiative to assess the physics basis and reliability of transport predictions for the International Thermonuclear Experimental Reactor.
- Elected to serve for three years on the Executive Committee of the American Physical Society Division of Plasma Physics.
- Served on the Executive committee of the Numerical Tokamak Turbulence Project, a Department of Energy Computing Grand Challenge Application.
- Host, organizer and Chair of the US-Japan Joint Institute for Fusion Theory (JIFT) Workshop on: Large-Scale Plasma Simulation and Visualization held March 5-7, 1997 at CU-Boulder.

ZOYA POPOVIC

- Member of Technical Program Committee, IEEE MTT International Microwave Symposium, reviewer for 40 papers
- Co-Chair of Technical Program Committee, IEEE MTT International Microwave Symposium, 8000 attendees in June 1997, Denver
- Associate Editor, IEEE Transactions on Antennas and Propagation

SCOTT ROBERTSON

- Organizer of professional meeting, 1997 Workshop on Nonneutral Plasmas, Boulder, July 29 - Aug 1, 1997: co-chairman (with John Bollinger of NIST).
- Organizer of professional meeting, 8th Scientific Assembly of IAGA, International Association of Geomagnetism and Aeronomy, Uppsala (Sweden), August 3 -16. 1997.

RAUL STERN

- External member, Institute of Plasma and Fusion Research, University of California.
- Member, Board of Visitors, U.S. Office of Naval Research.