Title
Center for Beam Physics

Author
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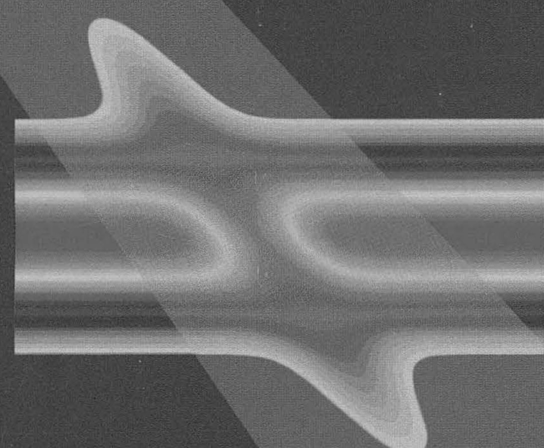

CENTER FOR BEAM PHYSICS

LBNL-43492

BERKELEY LAB

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Center for Beam Physics

1998-2000

Accelerator and Fusion Research Division
Lawrence Berkeley National Laboratory
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Berkeley, California 94720

February 2000

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WELCOME TO CBP

"Nothing happens unless first a dream"
— Carl Sandburg

As we draw close to the millemium and pause in self–introspection, we find ourselves in the midst of further diversification of our Center's activities. We have significantly expanded our experimental base and extended beam physics beyond traditional boundaries to such areas as laser-plasma interactions, optical manipulation of beams, probing ultrafast processes, power beaming to satellites and even quantum computing. And yet, we stay focused on our critical contributions to a few key activities of large scale national and international significance, e.g., the asymmetric B-Factory (PEP-II) at SLAC, the Next Linear Collider (NLC) design effort, research and development of very large Hadron Colliders, Muon Colliders and muon based Neutrino Sources, and the international Large Hadron Collider (LHC) at CERN. As we push the energy, luminosity and brightness frontiers of high energy colliders and synchrotron radiation sources, it is imperative that we actively maintain the culture of pursuing not only new concepts in colliders and accelerators in general, but also novel applications of beams and avenues of exploration opened up by them. It is important to renew and remind ourselves of our mission every so often.

The Center for Beam Physics is a multidisciplinary research and development unit in the General Sciences sector of Berkeley Lab, affiliated with the University of California. It is part of the Accelerator and Fusion Research Division and has strong interactive collaborations with the Physics, Nuclear Science, Material Science and Advanced Light Source Divisions. At the heart of the Center's mission is the fundamental quest for mechanisms of acceleration, radiation, transport, and focusing of energy and information. Dedicated to exploring the frontiers of particle and photon beam physics, its primary mission is to promote the science and technology of the production, manipulation, storage, and control of systems of charged particles and photons, often in the form of "beams" with directed energy and embedded information as applied to studies of the fundamental structure and processes of the natural world. The Center serves this mission via conceptual studies, theoretical and experimental research, design and development, institutional project involvement, external collaborations, association with industry, and technology transfer. These activities support exploring the next steps in the development of particle accelerators, further continuing the tradition of pioneering accelerator research at the Laboratory since its inception in 1932. The program of the Center is not limited to specific programmatic categories of the Department of Energy, but rather serves wide areas of research. The research program of the Center is directly linked to advances in high-energy and nuclear physics, condensed-matter research, the material and chemical sciences, physics of high energy density, the life sciences, and various industrial applications.

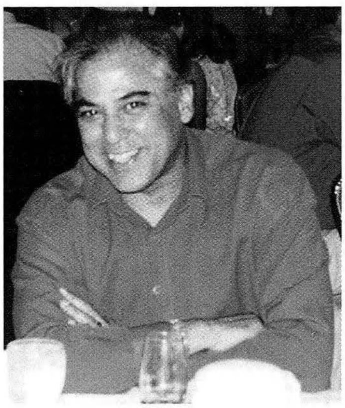
Yet another important mission of the Center is education of students, the scientific community, and society at large via graduate instruction, research supervision, pedagogical expositions, and public service.

Special features of the Center's program include addressing R&D issues needing long development time and providing a platform for conception, initiation, and support of institutional projects based on beams. The Center brings to bear a significant amount of diverse, complementary, and self-sufficient expertise in accelerator physics, synchrotron radiation, advanced microwave techniques, plasma physics, optics, and lasers on the forefront R&D issues in particle and photon beam research. In addition to functioning as a clearing-house for novel ideas and concepts and related R&D (e.g., various theoretical and experimental studies in beam physics such as nonlinear dynamics, phase-space control, laser-beam-plasma interaction, free electron lasers, optics, and instrumentation), the Center provides significant support to Laboratory facilities and initiatives.

The multidisciplinary programs of the Center are funded by various divisions within the DOE (largely by High Energy and Nuclear Physics). The Center also manages four in-house research facilities: the Lambertson Beam Electrodynamics Laboratory, l'OASIS Laboratory, the Beam Test Facility at the ALS and the RTA facility for two-beam accelerator research. Formal external collaborations include SLAC-LBNL-LLNL PEP-II and NLC studies, LBNL-CERN on two-beam accelerator research, CEBAF-LBNL on FEL studies, LBNL-Peking University on Photocathode/SCRF technology, LBNL-BNL on heavy-ion diagnostics and cooling for RHIC, LBNL-UC Davis on rf power technology, LBNL-SLAC-UC Davis on Advanced Thermionic Research initiative and LBNL-Kyoto University on general beam physics.

This roster and annual report provides a glimpse of the scientists, engineers, students, technical support, and administrative staff that make up the CBP's outstanding team and gives a flavor of our multifaceted activities during 1998 and 1999, going into the millennium year 2000. We welcome students, academia, industry, and the public at large to visit our Center (physically or on the web at http://www.lbl.gov/educational and http://www.lbl.gov/educational. sites/World of Beams) and participate in our programs to help us contribute to mutual flourishing.

Swapan Chattopadhyay
Head, Center for Beam Physics

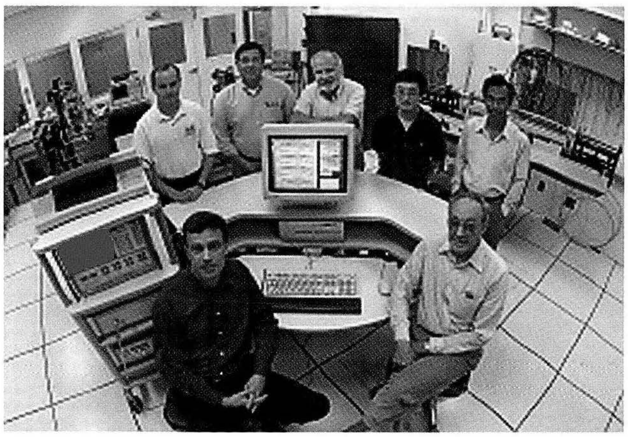


Swapan Chattopadhyay

FACILITIES

LAMBERTSON BEAM ELECTRODYNAMICS LABORATORY

Nurtured, promoted, and continually updated over the years by Glen Lambertson of LBNL, this laboratory houses, in an environment of controlled temperature, various instruments, equipment, and apparatus for low-power, high-precision rf measurements of beam-handling structures. Inventory includes a sophisticated bead-pulling apparatus, a time-domain reflectrometry setup, high-frequency network and spectrum analyzers, microwave parts and absorbing materials, etc. The lab also includes a small shop and facilities for performing sophisticated electrodynamic computations of properties of dynamic rf devices.

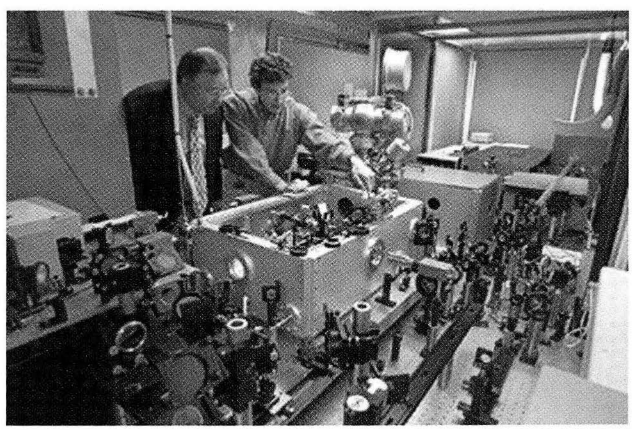


BEAM TEST FACILITY

This facility provides access to a 50 MeV electron beam from the ALS injector linac as well as a terawatt CPA laser system and a frequency quadupled ND:YAG ultraviolet laser. The electron beam is transferred via a magnetic transport line to a specially shielded experimental vault. At this facility, the world's shortest hard x-ray pulses have been generated through 90° Thomson scattering and a laser based microprobe for measurement of longitudinal and transverse phase space distributions of the electron bunch has been developed. Also, plasma lens focusing of the electron beam with laser produced plasmas has been demonstrated at this facility. The BTF has a fully computerized control and data acquisition system; diagnostics equipment available includes optical transition radiation-based electron beam diagnostics, fast beam position monitors, integrating current transformers, high resolution CCD cameras, a visible streak camera, Ge-detector system, etc.

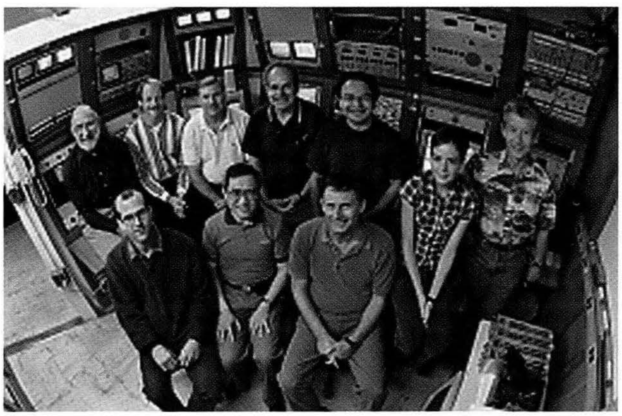
L'OASIS LABORATORY

The former Laser Optics Lab has been expanded in space and scope and is now called the l'OASIS lab (laser Optics and Acceleration Systems Integrated Studies). This laboratory houses solid state high power, ultra-short as well as long pulse laser systems for experiments on laser driven advanced accelerator concepts such as laser guiding and wakefield excitation in plasma channels. An EXCIMER laser is used for experiments on laser guided discharges. Its inventory includes various optical spectrometers, high resolution CCD cameras, visible and x-ray streak cameras, single short FROG system, optical interferometers, etc. Integrated with the lab is a mechanical development lab with CAD systems and a high precision mechanical shop.



RTA TEST FACILITY

We have established the RTA test facility at LBNL to verify the analysis used in the design of an rf power source based on the Relativistic Klystron Two-Beam Accelerator (RK-TBA) concept that could be used to upgrade the NLC to higher energy. The principal effort is in constructing a rf power source prototype where all major components of a larger machine can be tested. The injector for the prototype consists of two sections, a 1-MV, 1.2-kA induction electron source, referred to as the gun, followed by several induction accelerator cells to boost the energy to 2.8 MeV. At the time of writing, we have completed construction of the gun. Initial beam modulation will be accomplished with a transverse chopping technique. After this an adiabatic compressor section, a system of idler cavities and induction accelerator modules, will be used to bunch the beam and further accelerate it to an average energy of 4 MeV. After the adiabatic compressor, energy is periodically converted into rf energy (via extraction cavities) and restored to its initial value (via induction modules). RTA is designed to generate 180 MW per meter over the 8 meters of its extraction section. Most of FY'00 and '01 would be dedicated to the critical beam physics Betatron experiment on the Betatron Node Scheme to suppress transverse beam break-up instability.



CBP DEDICATED WORKSTATIONS

Hewlett-Packard 375

IBM RS/6000 (two)

VAXstation II

SPARC-2,4, 20

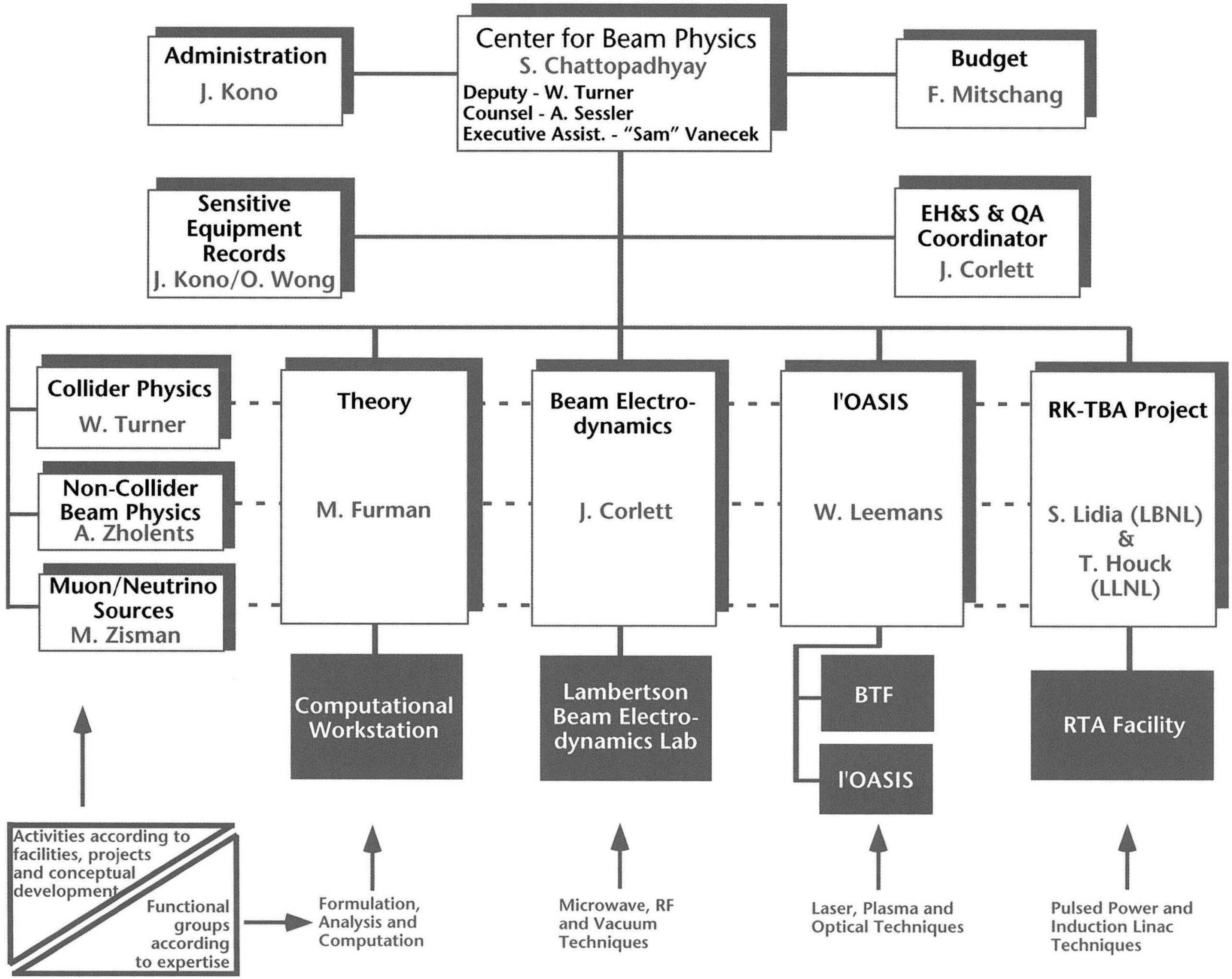
J. MICHAEL NITSCHKE MEMORIAL LIBRARY

This library contains selected reference and text books on beams, plasmas, lasers, accelerator physics, dynamics, etc., as well as a few technical journals, recent preprints, and conference proceedings. It is also used as a mini-conference room.

ALBERT GHIORSO CONFERENCE ROOM

This is a large conference room for seminars and meetings. It is equipped with the special feature of a video-conferencing facility, allowing joint conferences and meetings with the scientists and engineers from other national laboratories and universities, e.g., SLAC, Stanford University, LLNL, Fermilab, BNL, Los Alamos, etc. as well as international institutions like CERN in Geneva, Switzerland and KEK in Japan. At present, the room is routinely used for joint meetings on national and international projects (e.g., PEP-II, NLC, SNS, LHC, DARHT, etc.). It is also used regularly for the biweekly Center for Beam Physics seminars. There is also a video conference facility in the CBP Theory Group Conference Room in building 71B that is used for joint collaboration meetings.

ORGANIZATIONAL CHART



ROSTER

Scientific and Technical Staff

ARCHAMBAULT, Leon
BARRY, Walter
CHATTOPADHYAY, Swapan
CORLETT, John
DICKINSON, Michael
DIMAGGIO, Scott
DOUGHERTY, Jim
ESAREY, Eric
FURMAN, Miguel
KIM, Charles
LEEMANS, Wim
LI, Derun
LOZANO, David
RIMMER, Robert
SESSLER, Andrew
SHORT, Ron
TURNER, William
VOLFBEYN, Pavel
XIE, Ming
YU, Simon
ZHOLENTS, Alexander
ZISMAN, Michael
ZOLOTOREV, Max

UCB Faculty Associates

BIRDSALL, Charles
FALCONE, Roger
VAZIRANI, Umesh
WURTELE, Jonathan

Post Docs

BRUSSAARD, Seth
CATRAVAS, Palma
KIM, Eun San
OHGAKI, Tomomi
PENN, Gregory
SHADWICK, Bradley

Students

CHARMAN, Andrew
FRIEDBERG, David
GOVIL Richa
LEE, Peter
LEUNG, Michael
LIDIA, Steve
LIE, James
MOSHKOVICH, Emil
OSTROVSKY, Lauren
SALUR, Sevil
SCHROEDER, Carl

International and Domestic Visitors

FOREST, Etienne
GUO, Kang-Zhu
KRALL, Jonathan
KAR, Subal
KOSTA, Shakti
RAY, Ranjan
WATANABE, Y

Center Affiliates

BALDIS, Hector (LLNL)
BYRD, John (LBNL/ALS)
DELAHAYE, J. P. (CERN)
FAWLEY, William (LBNL/DARHT)
FOREST, Étienne (KEK)
GOUGH, Richard (LBNL/IBT)
HARTEMANN, Frédéric (LLNL)
HEIMAN, Phil (LBNL/ALS)
HOUCK, Tim (LLNL)
JOHNSON, Colin (CERN)
KIM, Kwang-Je (ANL)
LUHMANN, Neville (UC Davis)
PALMER, Robert (BNL)
ROBIN, David (LBNL/ALS)
SCHOENLEIN, Robert (LBNL/MSD)
SHANK, Charles (LBNL/MSD)
TAJIMA, Toshiki (LLNL)
VAN BIBBER, Karl (LLNL)
VANECEK, David (LLNL)
WESTENSKOW, Glen (LLNL)
VERBONCUER, John (UCB)

Administrative Support

KONO, Joy
FIKE, Cyndi
VANECEK, "Sam"
WONG, Olivia

Budget Administrator

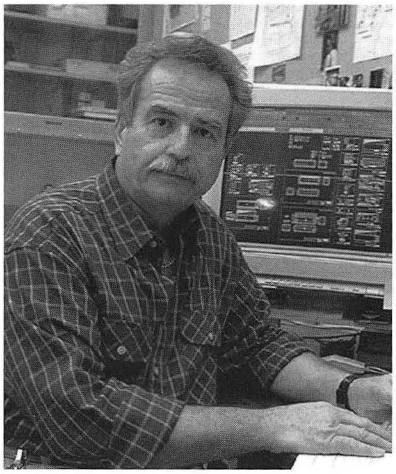
MITSCHANG, Faye

Participating Guests (Emeriti)

ELIOFF, Tom
GARREN, Alper
GHIORSO, Albert
GOLDBERG, David
LAMBERTSON, Glen
PETERSON, Jack
VOELKER, Ferdinand

SCIENTIFIC AND TECHNICAL STAFF

Leon Archambault



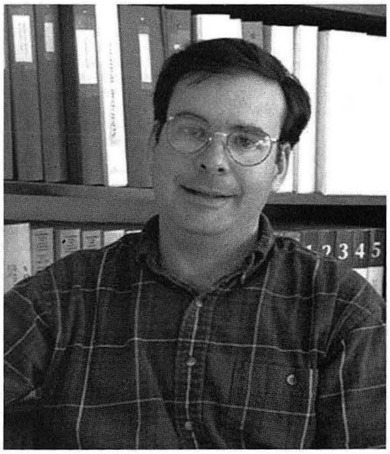
Senior Mechanical Engineering Associate
MS 71-259
(510) 486-7750
LFArchambault@lbl.gov
Joined LBNL in 1959

Research interests: Particle beam, vacuum, mechanical system design, engineering drawing, nuclear physics facilities, new acceleration methods.

Technical accomplishments: NSD team for studies of elements 104 and 106.
Nuclear physics research at LBNL's OASIS, IsoSpin Laboratory systems studies, target physics and engineering.
Plasma chamber for Beam Test Facility at the ALS.
Development of Laser Optics Lab with Terawatt Laser Systems and interaction chambers.

Selected publications: "Ultrashort Electron Bunches and Laser Channeled Wakefield Acceleration," (with W.P. Leemans, P. Catravas, S. Chattopadhyay, S. DiMaggio, E. Esarey, K.-Z. Guo, C.B. Schroeder, B.A. Shadwick, P. Volfbeyn and J.S. Wurtele), invited paper to the 1999 Particle Accelerator Conference, New York City, March 29 - April 2, 1999.

Walter C. Barry



Staff Scientist
MS 71-259
(510) 486-6705
Walter_Barry@lbl.gov
joined LBNL in 1992

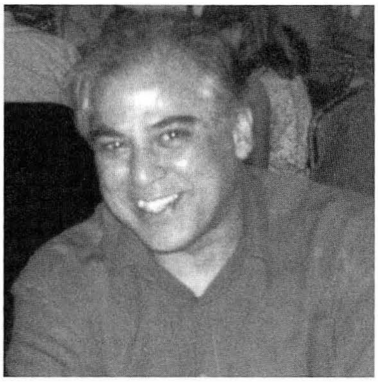
M.S., Electrical Engineering, Georgia Institute of Technology, 1982

Research interests: Accelerator instrumentation, theory and application of electromagnetic and microwave devices in accelerators, coherent transition and diffraction radiation, superconducting RF cavity studies, feedback systems for controlling coupled bunch instabilities in electron storage rings.

Selected publications: "An Autocorrelation Technique for Measuring Sub-Picosecond Bunch Length Using Coherent Transition Radiation," Proc. 1991 Advanced Beam Instrumentation Workshop, KEK National Laboratory for High Energy Physics, Tsukuba, Japan (April 1991).
A General Analysis of Thin Wire Pickups for High Frequency Beam Position Monitors," *Nucl. Instrum. Methods in Phys. Res.,* **A301** (3) (1991).
"Characteristic Impedance and Loss Data for Common Stripline Pickup Geometry," (with S.Y. R. Liu), *Nucl. Instrum. Methods in Phys. Res.,* **A288** (2,3) (1990).
"Perturbation Method for the Measurement of Longitudinal and Transverse Beam Impedance," (with G. Lambertson), *Proc. 1987 IEEE Particle Accelerator Conference* (March 1987).
"A Broadband Automated, Stripline Technique for the Simultaneous Measurement of Complex Permittivity and Permeability," *IEEE Trans. on Microwave Theory and Techniques, MTT-34* (1) (1986).

Senior Scientist and
Head, Center for Beam Physics
Visiting Professor, UC Berkeley,
College of Letters and Science

Swapan Chattopadhyay



MS 71-259
(510) 486-7217
chapon@lbl.gov
joined LBNL in 1984

Ph.D., Physics, UC Berkeley, 1982. Scientific Attaché, CERN, Geneva, Switzerland, 1982-84. Visiting Professor Univ. of Illinois at Urbana-Champaign, 1991. JAERI Distinguished Visiting Scientist, 1995.

Affiliations and honors: *Fellow*, American Physical Society (APS); *Halbach Prize*, 1996; ALS/LBNL (team award); *DOE Certificate of Distinction* for Mentorship in ERULF Program, 1998; *Certificate of Merit for Technology Transfer*, LBNL, 1991; *2000 Outstanding Scientists of the Twentieth Century Award* by the International Biographical Center, Cambridge, England for "Outstanding Contributions in Particle Physics, Beams and Femtoscience; *National Scholar* (1967) and *National Science Talent Scholar* (1967-69), Govt. of India; *Executive Board Member and Chair, Education Committee* of the APS Division of Physics of Beams; *Editor-in-chief*, Particle Accelerators (Western Hemisphere); *Series Editor*, "The Physics and Technology of Particle and Photon Beams" - Monograph Series by Harwood Academic Publishers; *Advisory Board Member* of PAC, EPAC and International Linac Conferences; *Member*, IEEE, AAAS, EPS and ICFA.

Research interests: Particle and photon beams, synchrotron radiation, free electron lasers, particle colliders, beam-plasma physics, nonlinear dynamics, ultrafast processes, quantum optics and quantum computers.

Selected publications: "Generation of Femtosecond Pulses of Synchrotron Radiation," (with R.W. Schoenlein, et.al.), *Science*, March 24, 2000, pp. 2237-2246.
"Alight a Beam and Beaming Light: A Theme with Variations," *Physics of Plasmas,* Volume 5, Number 5, p. 2081 (1998).

John Corlett

Staff Scientist
Group Leader, Beam Electrodynamics Group
Project Leader, NLC
MS 71-259
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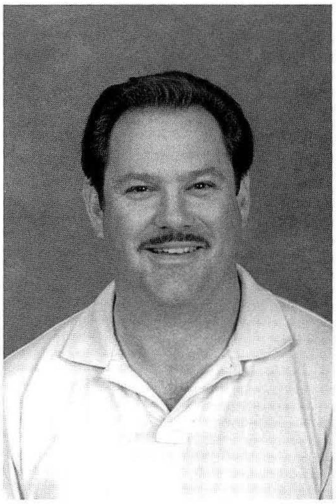
joined LBNL in 1991

B.S., Liverpool University, 1983; Microwave engineer EEV Co., Ltd, 1983-86; Accelerator physicist, Daresbury Laboratory, U.K., 1986-91

Research interests: Collective effects, feedback systems, beam impedance measurements and computation, RF and microwave structures and systems for particle accelerators.

Selected publications: "Impedance of Accelerator Components," Proceedings Beam Instrumentation Workshop, Chicago, May 1996.
"Observation and Calculation of Trapped Modes Near Cut-off in the ALS Bellows Shield," (with G.R. Lambertson, C. Kim), Proc. 5th. European Particle Accerlator Conference, Sitges, Spain, June 1996.
"Spectral Characteristics of Longitudinal Coupled-Bunch Instabilities at the Advanced Light Source," (with J.M. Byrd), *Particle Accelerators*, 1995, Vol. 51, pp. 29-42.
"Collective Effects in the PEP-II B-Factory," Proc. International Workshop on Impedance and Collective Effects in B-Factories, KEK, Tsukuba, Japan, June 1995.

Michael Dickinson



Mechanical Engineering Associate
MS 71-259
(510) 486-5706
MRDickinson@lbl.gov
joined LBNL in 1993

Research interests: Plasma and ion source development, mechanical system design and fabrication, CAD/CAM, vacuum system design and manufacture.

Technical accomplishments: Recipient of two R&D 100 awards for "technically advanced inventions", for plasma and ion source design.

Selected publications: Co-author of more than forty scientific papers (many in refereed journals).

Scott DiMaggio

Mechanical Engineering Tech I
MS 71-259
(510) 486-5895
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joined LBNL 1997

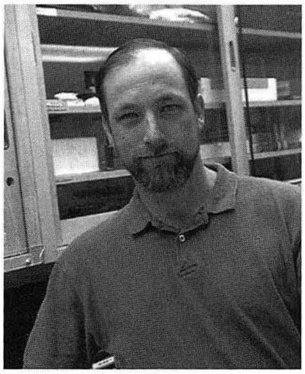
Research interests: CAD mechanical design, optical research, vacuum assembly, leak detection, and design/fabrication of electromechanical remote systems for vacuum and radioactive purposes.

Technical accomplishments: LBNL's l'OASIS labs channel guiding for laser wakefield accelerators. Assembly of one meter-long lithium plasma source, in collaboration with LBNL, SLAC, UCLA, and USC.

Assistance with research and development of possible patented high power termination device for safely ending high power laser beam transmission at a given point.

Selected publications: "Development of One Meter-Long Plasma Source and Excimer Mode Reduction for Plasma Wakefield Applications," (with L. Archambault, P. Catravas, P. Volfbeyn, and W.P. Leemans, LBNL; K. Marsh, P. Muggli, S. Wang, C Josh, UCLA), Los Angeles, CA. 90024.
"Ultrashort Electron Bunches and Laser Channeled Wakefield Acceleration," (with W.P. Leemans, P. Catravas, S. Chattopadhyay, E. Esarey, K.-Z. Guo, C.B. Shroeder, B.A. Shadwick, P. Volfbeyn, and J.S. Wurtele), invited paper to the 1999 Particle Accelerator Conference, New York City, March 29-April 2, 1999.

James R. Dougherty



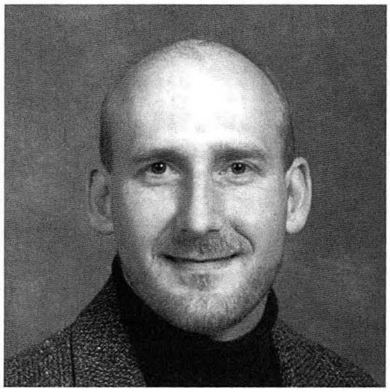
Mechanical Engineering Technologist II
MS 71-259
(510) 486-5967
JRDougherty@lbl.gov
joined LBNL in 1983

M.A., Industrial Arts, San Francisco State University, 1994

Research interests: Ultra-high vacuum, particle beam and laser beam systems.

Technical accomplishments: Technical support for Bio-Med Program, SuperHILAC, Earth Science Division, and Center for Beam Physics.

Eric Esarey



Staff Scientist
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EHEsarey@lbl.gov
joined LBNL in 1998

Ph.D., Plasma Physics, Massachusetts Institute of Technology, 1986

Affiliations and honors: Fellow of the American Physical Society; Alan Berman Research Publication Awards, 1992 and 1997, Naval Research Laboratory.

Research interests: Intense laser interactions with electron beams and plasmas, advanced acceleration concepts, advanced radiation sources, nonlinear optics.

Selected publications: "Trapping and Acceleration in Self-Modulated Laser Wakefields," (with B. Hafizi et al.), *Phys. Rev. Lett.* **80**, 5552 (1998).

"Electron Injection into Plasma Wakefields by Colliding Laser Pulses," (with R.F. Hubbard et al.), *Phys. Rev. Lett.*, **79**, 2682 (1997).

"Self-Focusing and Guiding of Short Laser Pulses in Ionizing Gases and Plasmas," (review article with P. Sprangle et al.), *IEEE J. Quantum Electron*, **33**, 1879 (1997).

"Overview of Plasma-Based Accelerator Concepts," (review article with P. Sprangle et al.), *IEEE Trans. Plasma Sci.*, **24**, 252 (1996).

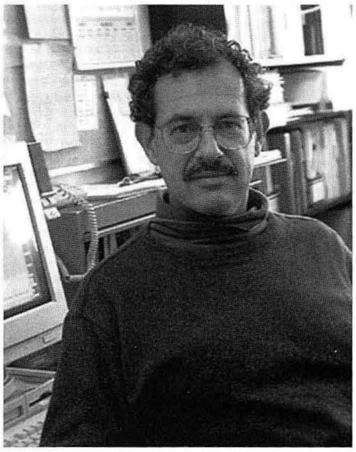
"Thomson Scattering of Intense Lasers from Electron Beams at Arbitrary Interaction Angles," (with S.K. Ride et al.), *Phys. Rev. E*, **52**, 5425 (1995).

"Laser Acceleration of Electrons in Vacuum," (with P. Sprangle et al.), *Phys. Rev.* E, **52**, 5443 (1995).

"Envelope Analysis of Intense Laser Pulse Self-Modulation in Plasmas," (with J. Krall et al.), *Phys. Rev. Lett.*, **72**, 2887 (1994).

"Generation of Stimulated Backscattered Harmonic Radiation from Intense Laser Interactions with Beams and Plasmas," (with P. Sprangle), *Phys. Rev. A*, **45**, 5872 (1992).

Miguel A. Furman



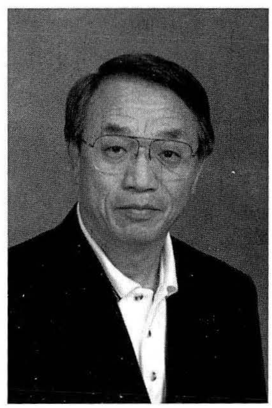
Staff Scientist
Theory Group Leader
MS 71-259
(510) 486-6443
MAFurman@lbl.gov
http://www.lbl.gov/~miguel
joined LBNL in 1984
Ph. D., Theoretical Particle Physics, University of California, Santa Cruz, 1977

Affiliations: Worked "on loan" for the SSC Central Design Group (1984–89) and for the SSC Laboratry, Texas (1989-90). Since 1990, worked for the PEP-II Project (1990-present),
the US-LHC Project (1997-present), and the muon collider (1996-present).

Research interests: Beam dynamics issues at high intensity, particularly the electron cloud effect; beam-beam interaction; large-scale simulations.

Selected publications: "The Electron-Cloud Instability in the Arcs of the PEP-II Positron Ring," (with G.R. Lambertson et al.), Proc. MBI-97 Workshop, KEK, Tsukuba (Japan), 15-18 July 1997, Y. H. Chin, ed., p. 170.
"Beam-Beam Issues for High-Luminosity e+e- Colliders," invited plenary talk, Proc. Advanced ICFA Workshop on "Beam Dynamics Issues for e+e- Factories," Frascati, 20-25 Oct. 1997, pp. 123-138.
"The Electron-Cloud Effect in the Arcs of the LHC," LBNL-41482/CBP Note 247/LHC Project Report 180, May 20, 1998.
"Beam-Beam Simulations with the Gaussian Code TRS," invited talk, to be published in the Proc. Intl. Computational Accelerator Physics Conf., Monterey, CA, USA, Sept. 14-18, 1998.
"Beam-Beam Effect and Dynamic Aperture of the Muon Collider," submitted to the PAC99, New York City, March 29-April 2, 1999.

Charles H. Kim



Staff Scientist (1943-2000)
MS 71-259
(510)486-7218
CHKim@lbl.gov
joined LBNL in 1978

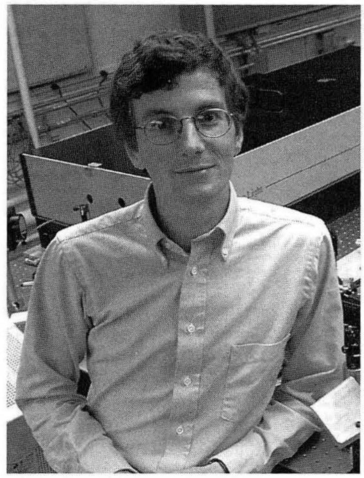
Ph.D., Physics, University of California, Los Angeles 1974

Affiliations and honors: Member of Professional Staff, TRW, 1974-1978; Member of American Physical Society, Hertz Foundation Fellow 1972-1974

Research interests: Muon collider, synchrotron radiation source, high intensity beams, computer simulation of particle beams, particle beam physics.

Selected publications: "A 3-D Touschek Scattering Theory," submitted for publication to *Particle Accelerator,* (1999).
"A Sensitivity Study for the K+ Gun of the 2 MeV Injector," *LBNL Fusion Energy Research Group Report*, HIFAN 976 (1999).
"Operational Principles and Its Implementation of the ALS Booster Synchrotron," *LBNL Advanced Light Source Report*, LSAP-264 (1999).
"Lifetime Studies at the Advanced Light Source," (with W. Decking, J. Byrd, and D. Robin), Proceedings of the European Particle Accelerator Conference, Stockholm (1998). http://www.cern.ch/accelconf/e98/PAPERS/THP18C.PDF
"Code for Calculating the Time Evolution of Beam Parameters in High Intensity Circular Accelerators," Proceedings of the 1997 Particle Accelerator Conference, Vancouver, BC, Canada, (1997).
"Modeling of the ALS LINAC," Proceedings of the XVIII International Linear Accelerator Conference, Geneva Switzerland, (1996).

Wim Leemans



Staff Scientist
l'OASIS Group Leader
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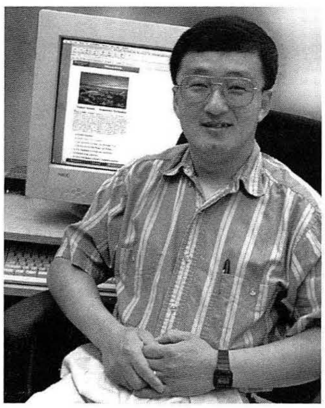
Ph. D., Electrical Engineering, University of California, Los Angeles, 1991

Major awards: Simon Ramo Award 1992, American Physical Society. ALS honors/LBNL Halbach Prize (Team Award). Chair, Advanced Concepts Section, ICFA, 2000-.

Research interests: Photon and particle beam-plasma interaction, advanced accelerator concepts, novel x-ray generation, ultra-high intensity pulse lasers, free electron lasers

Selected publications: "X-ray based Sub-Picosecond Electron Bunch Characterization Using 90° Thomson Scattering," (with R.W. Schoenlein, et al.), *Phys. Rev. Lett.*, **77**, 4182 (1996).
"Femtosecond X-ray Pulses at 0.4 Å Generated by 90° Thomson Scattering: A Tool for Probing the Structural Dynamics of Materials," (with R.W. Schoenlein et al.), *Science,* **274**, 236 (1996).
"Ultra-High Gradient Acceleration of Injected Electrons by Laser Excited Relativistic Electron Plasma Wave," (with C.E. Clayton et al.), *Phys. Rev., Lett.*, 70, 37 (1993).
"Non-linear Dynamics of Driven Relativistic Electron Plasma Waves," (with C. Joshi, W. B. Mori, C.E. Clayton, and T.W. Johnston), *Phys. Rev.* A, **46**, 14 (1992).

Derun Li



Staff Scientist
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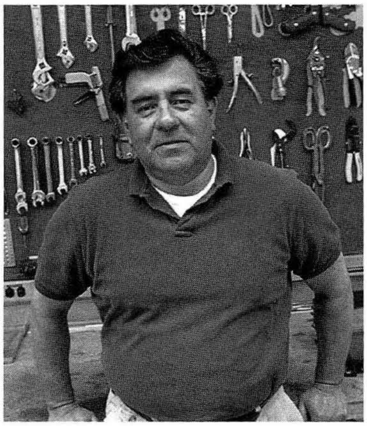
joined LBNL in 1997

Ph.D., Accelerator Physics, Indiana University, Bloomington, 1995

Research interests: RF structures for accelerators, microwave measurements, wake-field and beam impedance computations, coupled bunch feedback system, longitudinal and transverse nonlinear beam dynamics

Selected publications: "Wake-Field Studies on Phtonic Band Gap Accelerator Cavities," (with N. Kroll, D.R. Smith, S. Schultz), 7th Workshop on Advanced Accelerator Concepts Lake Tahoe, California (October 12-18, '96).
"Recent Progress on Photonic Band Gap Accelerator Cavities," (with D.R. Smith, D.C. Vier, N. Kroll, S.Schultz and H. Wang), 7th Workshop on Advanced Accelerator Concepts Lake Tahoe, California (October 12-18, 1996).
"Effect of Magnetized Electron Cooling on a Hopf Bifurcation," (with S.Y. Lee and et al), *Physical Review E,* Vol. 53, 1287 (1996).
"Effects of the RF Voltage Modulation on Particle Motion," (with M. Ball and et al.), *Nuclear Instruments and Methods in Physics Research,* A 364, 205-223, (1995).
"Analytic Solution of Particle Motion in a Double rf System," (with J.Y. Liu and et al), *Particle Accelerators,* 49, 221-251 (1995).
"Experimental Determination of the Hamiltonian for Synchrotron Motion with RF Phase Modulation," (with H. Huang, et al.), *Physical Review E,* Vol. 48, No.6, 5678 (1993).

David Lozano



Technical/Scientific Associate
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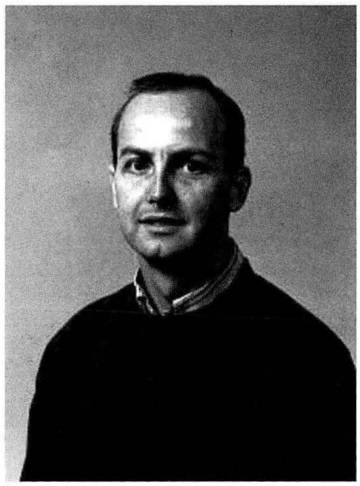
joined LBNL in 1970
A.S. degree, Machines & Metals Technology

Research interests: Technical and mechanical design, fabrication, installation and testing. Microwave systems mechanical and electrical design and fabrication.

Technical accomplishments: More than 25 years of service to the LBNL Bevatron/Bevalac; presently at the Center in the Beam Electrodynamics Group.

Robert A. Rimmer



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joined LBNL in 1988
Ph.D., Lancaster University, U.K., Engineering Department, 1988;
subject: High Power Microwave Window Failures
RF system physicist and deputy RF system manager for the PEP-II Collider Project

Research interests: High-power radio-frequency systems for accelerators, computer simulation of high-frequency electromagnetic problems, High-Order-Mode suppression in RF cavities and structures, microwave windows, beam impedance of accelerator components.

Selected publications: "High-Power Testing of the First PEP-II RF Cavity," (R.A. Rimmer et al.), Proc. EPAC 96, Sitges, Barcelona, 10-14 June, 1996, PEP-II AP Note 96.05, SLAC PUB 7210.
"Extraction and Absorption of High Order Modes in Room Temperature Accelerators," invited paper, Proc. Workshop on Microwave Absorbing Materials for Accelerators, MAMA (February 1993), CEBAF, Newport New, Virginia.
"RF Cavity Development for the PEP-II B Factory," Proc. International Workshop on B-Factories, BFWS92, KEK, Japan (November 1992).
"An RF Cavity for the B-Factory," (R. Rimmer, et al.), Proc. 1991 U. S. Particle Accelerator Conference, San Francisco, California (May 1991).
"Mode of Elliptical Waveguides: a Correction," (with D.A. Goldberg and L.J. Laslett), *IEEE Trans.*, MTT 38 (11), 1603-1608 (November 1990).

Andrew M. Sessler

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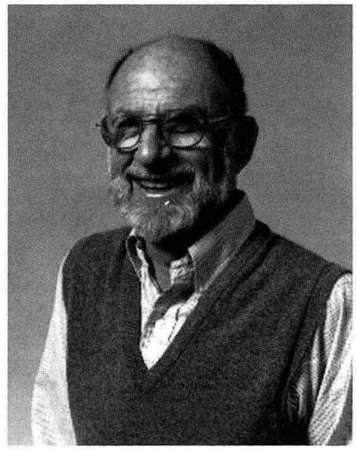
Ph.D., Theoretical Physics, Columbia University, 1953



Affiliations and honors: E.O. Lawrence Award by U.S. Atomic Energy Commission; U.S. Particle Accelerator School Prize; Dwight R. Nicholson Humanitarian Award; American Physical Society Wilson Award; Member, National Academy of Sciences, Past President of the American Physical Society.

Research interests: Beams in plasmas, conventional and novel high-energy accelerators, free electron lasers, beam physics.

Selected publications: "Status of Muon Collider Research and Development and Future Plans," (with C. Ankenbrandt et Genomics Home Mission Statement News, Events, and Jobs Research Thrusts Training Program Resources for Genomical.), accepted by *Phys. Rev. Special Topics: Accelerators and Beams*, (1999).
"Gamma-Ray Colliders and Muon Colliders," *Physics Today* 51, No.3, p. 48 (1998).
"Gamma-Gamma Colliders," (with K-J. Kim), SLAC Beam Line, Spring/Summer 1996, Vol. 26, No 1, 16-22 (1996).
"The Development of Colliders," (with Claudio Pellegrini), AIP Press (1995).
" Design of a Relativiatic Klystron Two-Beam Accelerator Prototype," (with G. Westenkow et al.), PAC 95 proceedings '95.
"Radio-Frequency Beam Conditioner for Fast-Wave Free-Electron Generators of Coherent Radiation," (with D.H. Whittum and L.-H Yu), *Phys. Rev. Lett.*, 64 (1992).
"A Plasma-Based Adiabatic Focuser," (with P. Chen, K. Oide and S.S. Yu), *Phys. Rev. Letts.*, 64, 1231 (1990).

William C. Turner

Senior Scientist and Deputy Head, CBP
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Ph.D., Experimental High Energy Physics, Yale University, 1972; Lawrence Livermore National Laboratory 1974-91; Superconducting Supercollider Laboratory 1991-94

Affiliations and honors: Fellow, American Physical Society; DPP; DPB Member; American Association for the Advancement of Science

Research interests: Physics and technology of accelerators for high energy physics.

Selected publications: "Luminosity Instrumentation for the Absorbers in the Low Beta Inserting of the LHC," LBNL-42180 (Aug. 98).
"Rf System Concepts for a Muon Cooling Experiment," Proc. of EPAC 98, Stockholm (1998).
"Absorbers for the High Luminosity Insertions of the LHC," Proc. of EPAC 98, Stockholm (1998).
"Beam Tube Vacuum in Low and High Field Very Large Hadron Colliders," Proc. of 1996 Snowmass Workshop on Future Direction in High Energy Physics, Snowmass, Colorado (1996).

Pavel Volfbeyn

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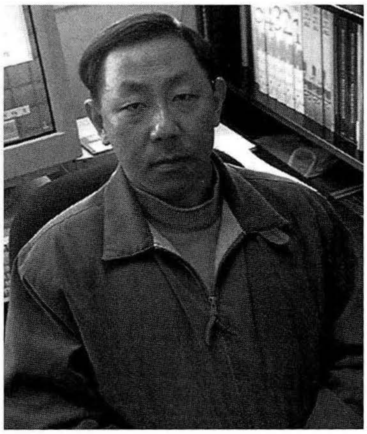
joined LBNL 1995

Ph.D., Physics, Massachusetts Institute of Technology, 1998
M.S., Physics, Massachusetts Institute of Technology, 1995

Research interests: Laser-plasma interactions, advanced accelerator concepts; laser, fiber optics, and X-ray based diagnostics and their industrial applications.

Selected publications: "Guiding of Laser Pulses in Realistic Plasma Channels," (with E. Esarey, W.P. Leemans), *Physics of Plasmas*, vol. 6, no. 6, p. 2269, May 1999.
"Laser Driven Plasma Based Accelerators: Wakefield Excitation, Channel Guiding, and Laser Triggered Particle Injection," (with W.P. Leemans, K.Z. Guo, S. Chattopadhyay, C.B. Schroeder, B.A. Shadwick, P.B. Lee, J.S. Wurtele, E. Esarey), *Physics of Plasmas*, v. 5, no. 5, p. 1615, May 1998.
"Driving Laser Pulse Evolution in a Hollow Channel Laser Wakefield Accelerator," (with P.B. Lee, J Wurtele, W.P. Leemans, G. Shvets), *Physics of Plasmas*, v. 4, no. 9, pp. 3403-3410, September 1997.
"X-ray Based Sub-picosecond Electron Bunch Characterization Using 90° Thomson Scattering," (with W.P. Leemans, R.W. Schoenlein, A.H. Chin, T.E. Glover, P. Balling, M. Zolotorev, K.J. Kim, S. Chattopadhyay, C.V. Shank), *Physical Review Letters*, v. 77, no. 20, pp. 4182-4185, (November 1996).

Ming Xie



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Ph.D., Physics, Stanford University, 1988
Visiting Professor of Peking University since 1998

Research interests: Laser accelerators, free electron lasers, fourth generation light sources, linear colliders, and laser optics.

Selected publications: "Laser Acceleration with Open Waveguides," *Proceedings of 1999 Particle Accelerator Conference*, FRA128 (1999).
"Capillary Waveguide for Laser Acceleration in Vacuum, Gases, and Plasmas," *Proceedings of 1998 European Particle Accelerator Conference*, 830 (1998).
"Laser Acceleration in Vacuum with an Open Iris-Loaded Waveguide," *Proceedings of 1997 Particle Accelerator Conference*, 660 (1997).
"Quantum Suppression of Beamstrahlung for Future e+e- Linear Colliders: An Evaluation of QED Backgrounds," *Proceedings of Workshop on Advanced Accelerator Concepts*, AIP Conf, 472 (1999).
"Design Optimization for an X-ray Free Electron Laser Driven by SLAC Linac," *Proceedings of 1995 Particle Accelerator Conference*, 183 (1996).
"Self-Amplified Spontaneous Emission for Short Wavelength Coherent Radiation," (with K-J. Kim), *Nucl. Instr. & Meth. in Phys. Res.*, A331, 359 (1993).

Simon Yu

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joined LBl in 1982

Ph.D., Physics, University of Washington, 1970

Affiliations and honors: Fellow American Physical Society.

Research interests: Induction accelerators, accelerator physics, linear colliders, heavy fusion, beams in plasmas, conventional and novel high-energy accelerators.

Selected publications: "High Current Injector for Heavy Ion Fusion," Research Trends in Physics, La Jolla International School of Physics, New York, New York p. 205, (1992).
"A Plasma-Based Adiabatic Focuser," (with A.M. Sessler), *Phys. Rev. Lett.*, 58, 2439 (1987).
"Waveguide Suppression of the Free Electron Laser Sideband Instability," (with S. Yu et al.), *Nucl. Instrum. Methods*, A259, 219-225 (1987).
"Intense Electron Beams," Lecture Notes in Physics, Proceedings of Frontiers of Particle Beams, South Padre Island, Texas p. 238 (1986).
"Phase Space Distortions of a Heavy Ion Beam Propagating through a Vacuum Reactor Vessel," (with E.P. Lee and W.A. Barletta), *Nucl. Fuson,* **21**, 961 (1981).

Alexander Zholents

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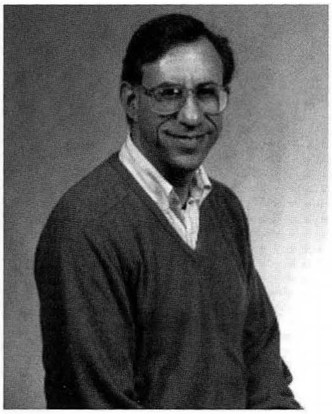
joined LBNL in 1992

Ph.D., Physics, Institute of Nuclear Physics, Novosibirsk, Russia, 1983

Research interests: Collider physics, synchrotron light sources, free electron lasers, instrumentation of charged particle beams, optical stochastic cooling.

Selected publications: "Generation of Subpicosecond X-ray Pulses Using RF Orbit Deflection," (with P. Heimann, M. Zolotorev, J. Byrd), *NIM section A.* (425), 1-2, pp. 385-389 (1999).
"FEL Options for Power Beaming," (with K.J. Kim and M. Zolotorev), *NIM section A* (407) 1-3, pp. 380-385 (1998).
"A Tau-Charm Factory with Longitudinal Polarized Beams and Monoenergetic Collisions at J/Psi Resonance," *Frascati Physics Series*, V.10, p. 447 (1998).
"Femtosecond X-Ray Pulses of Synchrotron Radiation," (with M. Zolotorev), *Phys. Rev. Lett.,* V76, p.912, (1996).
"Beam-Beam Effects," *AIP Conf. Proc.*, V344, p. 11, (1995).
"Transit-Time Method of Optical Stochastic Cooling," (with M. Zolotorev), *Phys. Rev. E,* V50, p. 3087, (1994).

Michael S. Zisman



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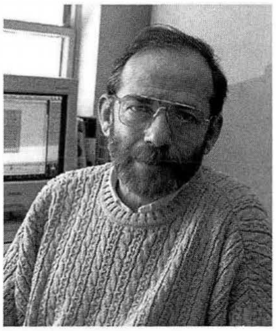
Ph.D., University of California, Berkeley, 1972

Research interests: Design of electron storate rings and high-luminosity electron--positron colldiers, beam instabilities, collective effects, design of PEP-II asymmetric B-factory, study of high-luminosity collider design.

Selected publications: "General B-Factory Design Considerations," *Lect. Notes in Phys.* 425-57, Springer-Verlag, Berlin, Germany (1994).
"Physics and Technology Challenges of BB Factories, " Proc. 1991 Particle Accelerator Conference, san Francisco, California, p.1. (May 1991). Also in *Lect. Notes in Phys.* 400, Springer-Verlag, Berlin), p. 600, (1992)
"PEP-II Asymmetric B-Factory: R&D Results," Proc. European Particle Accelerator Conference, Berlin, Germany, (March 1992).

Max Zolotorev



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joined LBNL 1996

Ph.D., Experimental High Energy Physics, Institute of Nuclear Physics, Novosibirsk (Russia), 1974: Doctor of Science, Institute of Nuclear Physics, Novosibirsk (Russia), 1979.

Research interests: Particle and photon beam physics, sources of polarized electorns, collider physics, nonlinear optics, P-and T-violation in atomic physics.

Selected publications: "Transit-Time Method of Optical Stochastic Cooling," *Phys. Rev. E*, v.50, 4, 3087 (1994).
"An Inverted-Geometry High voltage Polarized Gun with UHV Load Lock," *NIM*, A 350, 1-7 91994).
"Optical Stochastic Cooling," Phys. Rev. Lett., v.71, 25, p. 4146, (1993).
"Measurement of electron-beam bunch length and emittance using
shot-noise-driven fluctuations in incoherent radiation," Phys. Rev. Lett., v. 82, 25, p. 5261, (1999)
"Nonlinear magneto-optic effects with ultranarrow widths," Phys. Rev. Lett., v. 81, 26, p. 5788, (1998).
"Parity nonconservation in relativistic hydrogenic ions," Phys. Rev. Lett., v.78, 25, p.4717, (1997).
"Femtosecond X-ray Pulses of Synchrotron Radiation," Phys. Rev. Lett., v. 76, 6, p. 912, (1996).

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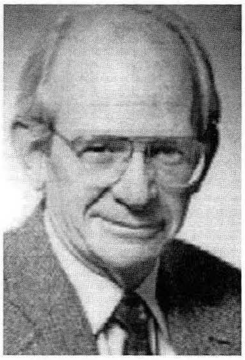
Charles K. Birdsall



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Joined UC Berkeley faculty in 1959

Ph. D., Electrical Engineering, Stanford University, CA 1951
8 years in microwave tube industry; Hughes Aircraft, 51-55, GE Palo Alto, 55-59

Major awards: Fellow of IEEE (1962), of APS (1972), of AAAS (1981); IEEE Plasma Science and Applications Award (1988). Visiting Prof./Lecturer Osaka Univ. 1966, Reading Univ. 1976, Nagoya Univ. 1981-82, Cal Tech, 1982, Garching and Innsbruck 1985, Nagoya Univ. 1988, Fulbright Univ. Innsbruck 1991.
Current research interests: Many-particle simulations of bounded plasmas (devices), RF and microwave discharges, resonant plasma surface waves, microwave tubes, from magnetron noise and instabilities to gigawatt generators, improvements in computation from algorithms to physical and numerical speed-ups.
Books: "Electron Dynamics of Diode Regions" (with W. B. Bridges) Academic Press 1966, "Plasma Physics via Computer Simulation" (with A. B. Langdon) McGraw-Hill 1985, Adam-Hilger, IOP 1991, "Bounded Plasmas" (with S. Kuhn), limited circulation, 1993.
Representative papers: "The resistive-wall amplifier" (with G.R. Brewer and A.V. Haeff) Proc. IRE Vol 41, pp 865-875 July 1953.

Roger W. Falcone

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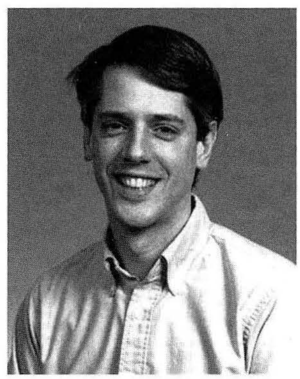

Ph.D., Electrical Engineering, Stanford University (1979)

Affiliations and honors: vin Chodorow Fellow, Applied Physics Department, Stanford University (1980-83); Fellow of the American Physical Society; Fellow of the Optical Society of America; Distinguished Traveling Lecturer, APS Laser Science Topical Group (1992-93); Presidential Young Investigator Award of the NSF (1984-89).

Research interests: Interactions of intense and ultrashort laser pulses with matter; applications of lasers in atomic, plasma, and condensed matter physics; time-resolved x-ray scattering from materials undergoing dynamical changes.

Selected publications: "Ultrafast Structural Changes Measured by Time-Resolved X-ray Diffraction," (with J. Larsson, et al.), Genomics Home Mission Statement News, Events, and Jobs Research Thrusts Training Program Resources for Genomic*Appl. Phys. A*, **66**, 587 (1998).
"Ultrafast X-ray Diffraction Using a Streak Camera Detector in Averaging Mode," (with J. Larsson, et al.), *Opt. Lett.*, **22**, 1012 (1997).
"High-Order Harmonic Generation in Atom Clusters," (with T. Donnelly, et al.), *Phys. Rev. Lett.*, **76**, 2472 (1996).
"Strong X-Ray Emission from High Temperature Plasmas Produced by Intense Irradiation of Clusters," (with T. Ditmire, et al.), *Phys. Rev. Lett.*, **75**, 3122 (1995).
"Measurement of Velocity Distributions and Recombination Kinetics in Tunnel-Ionized Helium Plasmas," (with T.E. Glover, et al.), *Phys. Rev. Lett.*, **75**, 445 (1995).
"Propagation of Intense, Ultrashort Laser Pulses in Plasmas," (with A. Sullivan, et al.), *Opt. Lett.* **19**, 1544 (1994).

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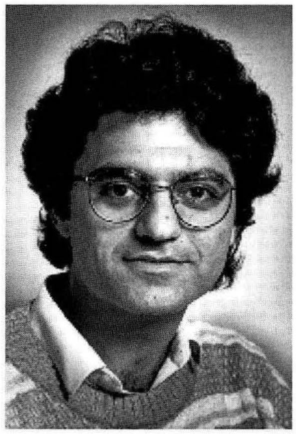

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Ph.D., Computer Science, UC B, 1986, B.S., Computer Science, Massachusetts Institute of Technology, 1981

Affiliations and honors: Friedman Mathematics Prize, 1985; Presidential Young Investigator Award, 1987; Young Faculty Development Award, University of California at Berkeley, 1988; Editor, Computational Complexity; Program Committee Member, FOCS 1986, STOC 1990, FOCS 1995; Organizer, Dagstuhl Workshop on "Randomized Algorithms", 1991; Berkeley Workshop on "Randomized Algorithms," 1995.

Research interests: quantum computation, computational foundations of randomness, computational complexity theory, and computational learning theory; in the area of computational learning theory. He is particularly interested in probabilistic models and in learning from Markov-chain distributions, which forms the theoretical basis for the analysis of reinforcement learning.

Selected publications: "An Introduction to Computational Learning Theory,"MIT Press, 1995.
"Quantum Complexity Theory," (with E. Bernstein), STOC, 1993, invited paper in special issue of *SIAM J. Computing* on quantum computing, 1997.

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Ph.D., Physics, University of California, Berkeley, 1985

Research interests: Generation of coherent radiation from charged particle beams, advanced accelerator concepts, intense laser-plasma interactions, nonneutral plasma physics.

Selected publications: "Damping of the Transverse Head-Tail Instability by a Periodic Modulation of the Chromaticity," (with W-H. Cheng and A.M. Sessler) (1996).
"Excitation of Accelerating Wakefields in Inhomogeneous Plasmas," (with G. Shvets, T.C. Chiou, and T.C. Katsouleas), *IEEE Plasma Science,* 24(2), 351 (1996).
"$\mu^+ \mu^-$ Collider: A Feasibility Study," (with the muon collider collaboration), Chap. 8.
"Free Electron Laser Simulation Techniques," (with T.M. Tran), *Phys. Reports,* 195, 1 (1990).
"Asymmetric Stable Equilibria in Nonlinear Plasmas," (with J. Notte, A.J. Peurring, J. Fajans, and R. Chu), *Phys. Rev. Lett.,* 69, 3065 (1992).
"Calculation of the Bunch Lengthening Threshold," (with X.T. Yu), *Proc. 1993 IEEE Particle Accelerator Conference* (1993), p. 3327.
"Advanced Accelerator Concepts," *Phys. Today,* (July 1994).
"Stability of Channel Guided Laser Pulses," (with G. Shvets), *Phys. Rev. Lett.* (1994).

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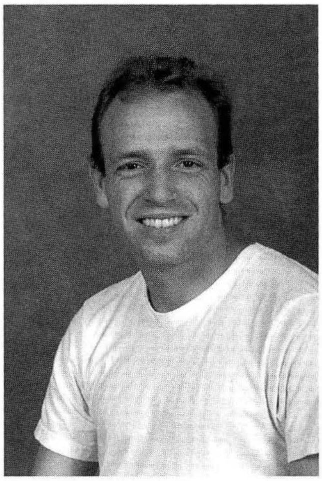

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Ph.D., Plasma Physics, Eindhoven University of Technology, 1999

Research interests: Experimental low-temperature plasma physics, plasma wakefield accelerators, laser-plasma interactions, ultrashort electron bunches.

Selected publications: "Drift Velocity and Diffusion in the Remote Arc Generated Argon Plasma," (with M.C.M. van de Sanden, D.C. Schram), submitted to *Plasma Sources Sci. Technol.* (1999).
"Stripping of Photoresist Using a Remote Therrmal Ar/O_2 and $Ar/N_2/O_2$ Plasma," (with K.G.Y. Letourneur, M. Schaepkens, M.C.M. van de Sanden, and D.C. Schram), submitted to *J. Vac. Sci. Technol. A* (1999).
"Evidence for Charge Exchange between N^+ and $N_2(A)$ in a Low Temperature Nitrogen Plasma," (with E. Aldea, M.C.M. van de Sanden, G. Dinescu, and D.C. Schram), *Chem. Phys. Lett.*, **290**, 379 (1998).
"Ion Densities in a High Intensity, Low Flow Nitrogen Plasma," (with M.C.M. van de Sanden, and D.C. Schram), *Phys. Plasmas* **4** (8), 3077 (1997).
"Langmuir Probe Measurements in an Expanding Magnetized Plasma," (with M. van der Steen, M. Carrère, M.C.M. van de Sanden, D.C. Schram), *Phys. Rev. E*, **54**, 1906 (1996).

Palmyra Catravas

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Ph.D., Electrical Engineering, Massachusetts Institute of Technology, 1998

Major award: E.O. Lawrence Post-doctoral Fellowship

Research interests: Laser-Plasma interactions, ultrafast systems, electron beam diagnosis

Selected publications: "Measurement of Electron-Beam Bunch Length and Emittance Using Shot-Noise-Driven Fluctuations in Incoherent Radiation," (with W.P. Leemans, J.S. Wurtele, M.S. Zolotorev, M Babzien, I. Ben-Zvi, Z. Segalov, X.J. Wang and V. Yakimenko), accepted by *Phys. Rev. Lett.*, expected in June 28, 1999 issue.
"Electron Bunchlength Measurement from Analysis of Fluctations in Spontaneous Emission," (with W.P. Leemans et al.), 1998 AAC Workshop Proceedings.
"Beam Profile Measurement at 30 GeV Using Optical Transition Radiation," (with W.P. Leemans et al.), 1999 Particle Accelerator Conference Proceedings.
"Development of One Meter-long Lithium Plasma Source and Excimer Mode Reduction of Plasma Wakefield Applications," (with S. DiMaggio et al.), 1999 Particle Accelerator Conference Proceedings.
"Growth and Saturation of Stimulated Beam Modulation in a Two-Stream Relativistic Klystrom Amplifier," (with C. Chen and G. Bekefi), *Appl. Phys. Lett.*, **62**, 14 (1993).

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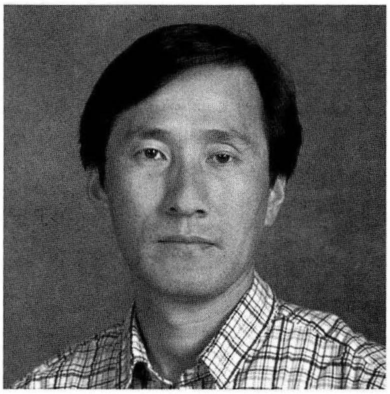


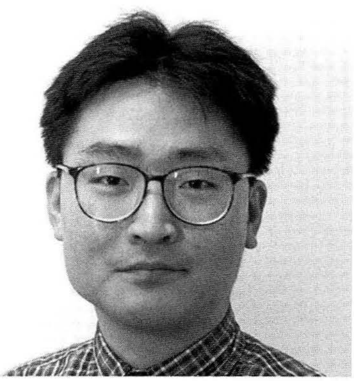
Ph.D., Accelerator Physics, the Graduate Univ. for Advanced Studies, 1997, jkJapan

Visiting scientist, KEK 1997

Research interests: Impedance and collective beam instabilities. beam-beam interaction, beam tail distributions, beam diagnostics, beam-beam interaction ionization muon cooling.

Selected publications: "Analysis of Longitudinal Collective Behavior in a 50GeV × 50GeV Muon Collider Ring," (with A.M. Sessler and J.S. Wurtele), *Physical Rev.*, Special Topic: Accelerator and Beams, Vol.2, 051001, 1999.
"Simulation of Transverse Instability in a 50GeV× 50GeV Muon Collider Ring," (with A.M. Sessler and J.S. Wurtele), LBNL-43044 (1999).
"Simulation of Beam-Tail Distributions for KEKB," *Particle Accelerators*, Vol. 63, p.1-19, (1999).
"Bunch lengthening in KEK-ATF Damping Ring," KEK-Preprint 98-21, 1998.
"Longitudinal Impedance in ATF Damping Ring," KEK-Report 98-6, 1998.

Tomomi Ohgaki



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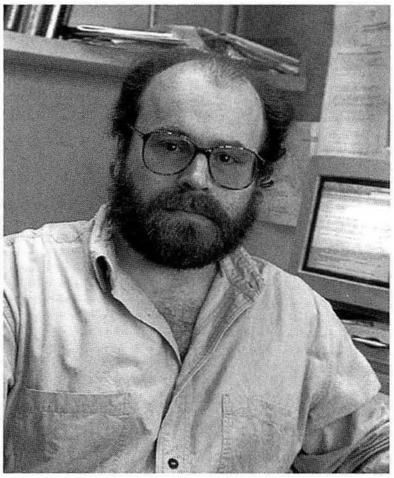
joined LBNL in 1998

Ph.D., Physics, Hiroshima University, 1998

Research interests: Particle and photon beam physics, collider physics, beam-beam interaction, Higgs physics, next linear colliders, photon-photon colliders, laser-driven accelerators.

Selected publications: "Hadronic Backgrounds through Gamma-Gamma Collisions in a 5 TeV e+e- Linear Collider," (with M. Xie), submitted to *Physical Review D*, May 1999.
"Evaluation of QED Backgrounds for an e+e- Linear Collider in Deep Quantum Beamstrahlung Regime," (with M. Xie), submitted to *Physical Review Special Topics - Accelerators and Beams*, May 1999.
"Simulations of the Interaction Region in a Photon-Photon Collider," (with P. Chen et al.), *Nucl. Instr. and Meth,* A397, 458 (1997).
"Measuring the Two-Photon Decay Width of Intermediate-Mass Higgs Bosons at a Photon-Photon Collider," (with T. Takahashi and I. Watanabe), *Phys. Rev. D,* 56, 1723 (1997).
"Influence of e+e- Pair Creation in Collision of Laser and High Energy Photons for Photon-Photon Colliders," (with T. Takahashi), *Nucl. Instr. and Meth,* A373, 185 (1996).

Bradley A. Shadwick



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Ph.D., Physics, The University of Texas at Austin, 1995

Research interests: Plasma wake field accelerators, intense laser-plasma interactions, advanced numerical methods for fluids and plasmas, and analytical and numerical methods for the continuous spectrum.

Selected publications: "Analysis and Simulation of Raman Backscatter in Underdense Plasmas," (with G. Shvets and J.S. Wurtele), *Physics of Plasmas,* accepted 1997.
"Wake Fields in Plasma Channels with Arbitrary Transverse Density Profiles," (with J.S. Wurtele and G. Shvets), *Bull. Am. Phys. Soc.,* **41**, 1601, (1996).
"Singular Eigenfunction Methods for the Vlasov–Poisson System," (with P.J. Morrision), *Bull. Am. Phys. Soc.,* **41**, 1492, (1996).
"Spectral Reduction for Two-Dimensional Turbulence," (with John C. Bowman and P.J. Morrison) in *Transport, Chaos, and Plasma Physics 2,* Marseille 1996.
"Exactly Conservative Integrators," (with John C. Bowman and P.J. Morrision), submitted to *SIAM Journal of Applied Mathematics,* 1996.
"Canonization and Diagonalization of an Infinite Dimensional Noncanonical Hamiltonian System: Linear Vlasov Theory," (with P.J. Morrison), *Acta Physica Polonica A,* **85**, 243, (1994).

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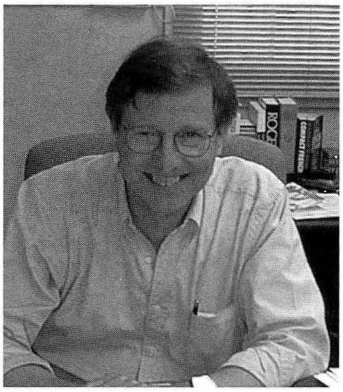

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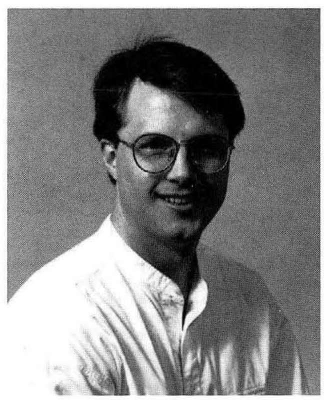
Ph.D. Plasma Physics, University of British Columbia 1971

Research interests: Plasma Physics and Inertial Confinement Fusion; x-ray laser physics and applications; photon-particle interaction physics; particle acceleration on laser fields; plasma diagnostics.Selected publications

Selected publications: "Spatial and Temporal Coeexistance of Stimulated Scattering Processes under Crossed-Laser Beam Irradiation", Phys. Rev. Lett., **82**, 3613 (1999).
"Non-linear modification of laser-plasma interaction processes under laser beams irradiation", Phys. Plasmas, **6**, 2048 (1999).
"Thomson scattering from kigh-Z laser-produced plasmas", Phys. Rev. Lett., **82**, 97 (1999).

John M. Byrd



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Ph.D., Physics, Cornell University, 1992

Research interests: Electron storage rings, synchrotron radiation, RF aspects of accelerators, single and coupled-bunch instabilities, feedback systems, beam diagnostics, nonlinear dynamics.

Selected publications: "Maximizing Integrated Brightness in Touschek-Dominated Synchrotron Light Sources," accepted for publication in *Nucl. Inst. and Meth. A.*
"Generation of Subpicosecond X-ray Pulses Using RF Orbit Deflection," (with A. Zholents, P. Heimann, M. Zolotorev), *Nucl. Inst. and Meth. A,* (425) 1-2), pp. 385-389 (1999).
"Beam-Based Characterization of Coupled-Bunch Instabilities," contribution to the *Handbook of Accelerator Physics and Engineering, World Scientific,* Singapore, 1999.
"Nonlinear Effects of Phase Modulation in an Electron Storage," (with W.-H. Cheng and F. Zimmermann), *Phys. Rev. E,* **48**, 4678, (1998).
"First Observations of a 'Fast Beam-Ion Instability," (with A. Chao, S. Heifets, M. Minty, T.O. Raubenheimer, J. Seeman, G. Stupakov, J. Thomson, F.Zimmermann), *Phys. Rev. Lett,* **79**, 79 (1997).

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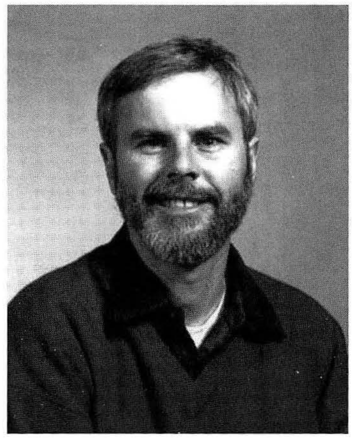
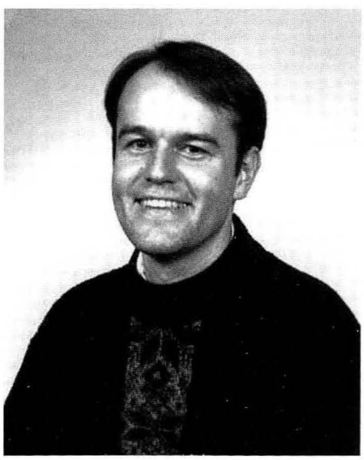


Ph.D., Astronomy, University of California, Berkeley, 1978
A.B., Astrophysical Sciences, Princeton University
Asst. Prof., Univ. of Pennsylvania, 1978-79
Physicist, Lawrence Livermore National Laboratory, 1979-1989.

Research interests: Intense charged-particle beam physics, free-electron lasers, heavy-ion fusion, novel accelerators, numerical simulation techniques.

Selected publications: "Coherence and Line-Width Studies of a 4-nm High Power Fel," (with A.M. Sessler and E.T. Scharlemann), *1993 Part. Accel. Conf.*, 93CH3279-7, 1530-1532 (1993).
"Simulation Studies of Space-Charge Dominated Beam Transport in Large Aperture Ratio Quadrupoles," (with L. J. Laslett *et al.*), *1993 Part. Accel. Conf.*, 93CH3279-7, 724-726 (1993).
"Beam Dynamics Studies with the MBE-4 Heavy-Ion Linear Induction Accelerator," (with T. Garvey *et al.*), *Physics of Plasmas*, 4, 800-894 (1997).
"Output Characteristics of SASE-Driven Short Wavelength FEL's," SPIE Proc. 2988, *Free-Electron Laser Challenges*, ed. P.G. OíShea and H.E. Bennett, 98-107 (1997).
"Beam Breakup Calculations for the Second Axis of DARHT," (with Y.J. Chen and T.L. Houck), *1999 Part. Accel. Conf.*, in press.

Étienne Forest



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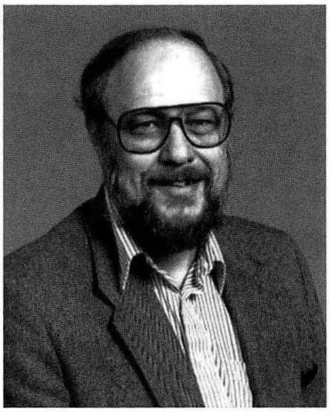
Ph.D., Physics, University of Maryland, 1984

Research interests: Nonlinear dynamics in accelerators, perturbation theory and other approximate methods for accelerator maps.

Selected publications: "Locally Accurate Dynamical Euclidean Group," *Phys. Rev. E*, March 1997.
"Beam Dynamics: A New Attitude and Framework," Gordon & Breach, published 1997.
"The Absolute Bare Minimum for Tracking in Small Rings," (with M. Reusch, D. Bruhwiler, and A. Amiry), *Particle Accelerators* (1994).
"Freedom in Minimal Normal Forms," (with D. Murray), accepted in *Physica D* (1994).
"Construction of Symplectic Maps for Non-linear Motion of Particles in Accelerators," (with S. Berg, R.L. Warnock, and R.D. Ruth), *Phys. Rev.* (1993).
"The Modern Approach to Single-Particle Dynamics for Circular Rings," (with L. Michelotti, A. J. Dragt, and J. S. Berg), with a foreword by J. Bentgsson, Proc. Workshop on Stability in Storage Rings, Upton, New York (1992), Series 54, AIP Conf. Proc. No. 292.

Richard A. Gough



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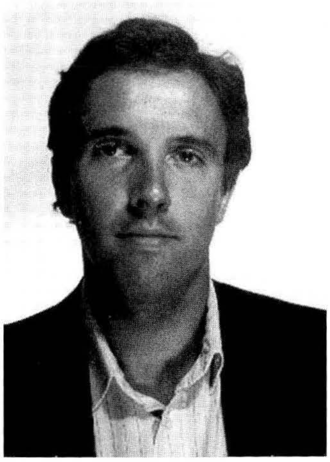
Ph. D., Nuclear Physics, McMaster University, 1970

Research interests: Design, construction, and management of accelerator facilities; conceptualization and development of accelerator systems with applications to the scientific community.

Selected publications: "Production of Low Energy Spread Ion Beams with Multicusp Sources," (with Y. Lee, L.T. Perkins, et al.), *Nucl. Instrum. Methods,* A374 (1995).
"Design of a Super-conducting Linear Accelerator for an Infrared Free Electron Laser of the Proposed Chemical Dynamics Research Laboratory at LBL," (with S. Chattopadhyay et al.), 16th International Linac Conference, Ottawa, Ontario, Canada (August 1992).
"Performance of the Oxygen Injector for the CERN Linac I," (with B. Wolf et al.), *Nucl. Instrum. Methds,* A258 (1987).
"Medical Heavy Ion Accelerator Proposals," *Proc. 1985 Particle Accelerator Conference,* Vancouver, B.C., Canada) , p. 3282 (May 1985).

Frederic V. Hartemann



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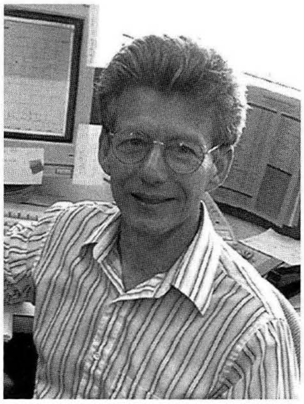
Ph.D., Physics, under Prof. G. Bekefi, MIT, 1986

Affiliations: Thomson Electron Tubes & Devices, 1986-92; Visiting scientist at Ecole Polytechnique, France, 1987; Visiting scientist at MIT, Plasma Fusion Center, 1988-91; Research scientist, UCLA, 1993; Associate research scientist, UC Davis/ LLNL, 1994-present.

Research interests: Nonlinear electrodynamics, ultrahigh intensity laser-electron interactions, free-electron lasers, high field QED, cavity QED, laboratory astrophysics

Selected publications: "Vacuum Electron Acceleration by Coherent Dipole Radiation," *Physical Review E* (1999).
"Coherence," *Wiley Encyclopedia of Electrical and Electronics Engineering,* Vol. 3, 540, (John Wiley & Sons, Inc., New York (1999).
"Three-Dimensional Relativistic Electron Scattering in an Ultrahigh Intensity Laser Focus," *Physical Review E,* 58, 5001 (1998).
"High-Intensity Scattering Processes of Relativistic Electrons in Vacuum," *Physics of Plasmas,* 5, 2037 (1998).

Timothy L. Houck



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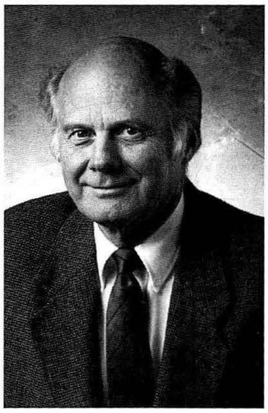
Ph.D., Physics, University of California, Davis, 1994

Affiliation: Member: American Physical Society, IEEE

Research interests: Induction accelerators; beam dynamics; high-power microwave generation; novel accelerators.

Selected publications: "Physics Design of the DARHT 2nd Axis Accelerator Cell," (T.L. Houck, et al.), Proc. 19th Int'l LINAC Conf. (UCRL-JC-130424) (1998).
"Prototype Microwave Source for a Relativistic Klystron Two-Beam Accelerator," (with F. Deadrick, et al.), *IEEE Trans. Plasma Science,* **24** (1996).
"Relativistic Klystron Two-Beam Accelerator," (with G. Westenskow), *IEEE Trans. Plasma Science*, Vol. 22 (Oct. 1994).
"Design Study of a Microwave Driver for a Relativistic Klystron Two-Beam Accelerator," *Proc. 1993 IEEE Particle Accelerator Conf.* (1993).
"BBU Code Development for High-Power Microwave Generators," (with G. Westenskow and S. Yu), *Proc. 16th Int'l LINAC Conf.* (1992).

John Irwin



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Ph. D., Theoretical physics, Cornell University, 1963

Major awards: Fellow, American Physical Society,1997

Research interests: Nonlinear dynamics, lattice design, beam-beam simulation, future linear colliders

Selected publications: "Model-independent beam dynamics analysis" (with C-x.Wang, et al.), *Phys. Rev. Lett.*, **82**, 1684 (1999).
"Double dynamic focusing for linear colliders," *Proc. XIX Int'l. Linac Conf. (Linac98)* (1998).
"High order horizontal resonances in the beam-beam interaction," (with T. Chen and R. Siemann), *Nucl. Instrum. Meth.*, A**402**, 21 (1998).
"Resonance basis maps and nPB tracking," (with Y.T. Yan et al.), *Part. Accel.*, 54, 263 (1996).
"The application of Lie Algebra techniques to beam transport design," *Nucl. Instrum. Meth.*, A**298**, 460 (1990).

Colin Johnson

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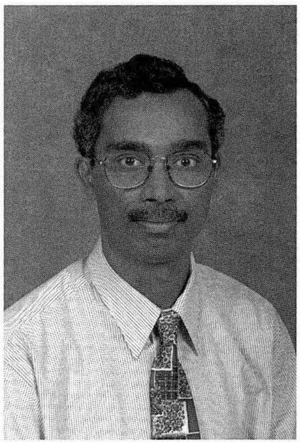
Ph.D. Biophysics, University of London, 1966
M.Sc. Nuclear Physics, University of London, 1960

Research interests: Accelerator physics - targetry, instrumentation, beam optics, high-current sources, particle colliders, numerical simulation of coherent and incoherent beam instabilities, muon colliders, neutrino factories.

Selected Publications: "Prospective Study of Muon Storage Rings at CERN - Radiological Hazard due to Neutrinos from a Muon Collider," with G. Rolandi and M. Silari, CERN 99-02, Ch. 6, 1999.
"Examination of the CLIC Drive Beam Pipe Design for Thermal Distortion Caused by Distributed Beam Loss," (with P. Kloeppel, TJNAF), AIP Topical Meeting, San Jose CA, 1996.
"CLIC - A Compact and Efficient High Energy Linear Collider," (with H. Braun et al.), PAC and HEPAC, Dallas, 1995.
"CLIC Drive Beam Generation by Induction Linac and FEL, Preliminary Experimental Studies," (with R. Corsini et al.), Nucl. Instr. Meth., A 341, 1994.
"CLIC Drive Beam Generation - A Feasibility Study," (with B. Autin et al.), EPAC, Oxford, 1994.

Subal Kar



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M. Tech (Radio Physics and Electronics). 1980, Ph.D. (Tech), 1989, Calcutta University, India. Reader [1994 -], Institute of Radio Physics and Electronics, Calcutta University, Fellow of the Institution of Electronics and Telecommunication Engineers, India.

Major awards: Recipient of the Young Scientist Award of the International Union of Radio Science, IEEE MTT, NRO and ARO of USA, 1995. Visiting scientist at Kyoto University, Japan, 1997. Listed in Marquis Who's Who In Science and Engineering (4th Ed. 1998-1999) published by Marquis Publication, USA.

Research interests: Microwave device-circuit interactions, modeling and simulation of microwave and optical devices and circuits, development of oscillators, amplifiers and power combiners at microwave and millimeter wave frequencies.

Selected publications: "A Modified Resonant-Cap Microwave IMPATT Oscillator," Indian Patent 157098.
"Computer Analytical Study of a Subcarrier Demultiplexing Scheme for SCM Optical Communication Systems," presented in the Microwave and Photonics Meeting, Tokyo, Japan, Oct. 1997.
"An Experimental Technique for the Design of Optimized Resonant-Cap Circuits for Microwave IMPATT Oscillators and Amplifiers," Microwave and Optical Technology Letters, vol. 19, pp. 81-84, Oct. 1998.

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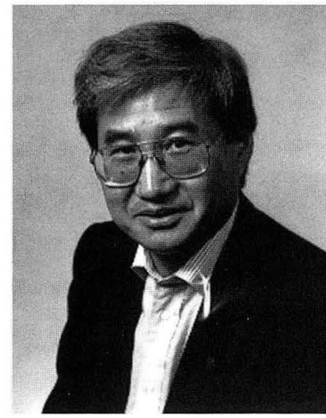

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Ph.D., Elementary Particle Physics, University of Maryland, 1970
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Affiliations and honors: Fellow of American Physical Society, International FEL Executive Committee (1993), International Advisory Committee for Pohang Light Source.

Research interests: Novel x-ray generation, free electron lasers, synchrotron radiation optics, high-brightness electron beams.

Selected publications: "Transition Undulator Radiation as Bright Infrared Sources," *Phys. Rev. Lett.*, **76**, 8, 1244 (1996).
"Radiative Cooling of Ion Beams in Storage Rings by Broad-Band Lasers," (with E.G. Bessonov), *Phys. Rev. Lett.*, **76**, 431 (1996).
"Generation of Sub-Picosecond X-rays by 90° Thomson Scattering," (with S. Chattopadhyay and C.V. Shank), *Nucl. Instr. Methods*, **A341**, 351 (1994).
"RF and Space Charge Effects in Laser-Driven RF Electron Guns," *Nucl. Instr. Methods,* **A275**, 201 (1989).
"Three-Dimensional Analysis of Coherent Amplification and Self-Amplified Spontaneous Emission in Free Electron Lasers," *Phys. Rev. Lett.,* **57**, 1871 (1986).

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Ph.D, Physics, Univ of Maryland, College Park, MD, 1972,
Professor, Electrical Engineering Department, UCLA, 1981

Affiliations and honors: Founder and Director of the UCLA Center for High Frequency Electronics, creator of the Microwave Integrated Circuits Laboratory, and Co-Director of the Joint Services Electronics Program; Fellow, American Physical Society (APS); Member: Tau Beta Pi and Sigma Xi.

Research interests: Millimeter wave solid state devices and systems, ultra short pulse electronics, gyrotrons, free electron lasers, plasma physics, tokamak diagnostics and far-infrared lasers, microwave/plasma interactions, vacuum microelectronics.

Selected publications: "250 MW X-Band TE 01 Ubitron Using a Coaxial PPM Wiggler," (with A.J. Balkcum, D.B. McDermott, R.M. Phillips, A.T. Lin*), IEEE Transactions on Plasma Science's Special Issue on High Power Microwave Generation,* November 1995.
"Nonlinear Ponderomotive Scattering of Relativistic Electrons by an Intense Laser Field at Focus," (with F.V. Hartemann, S. Fochs, G. Le Sage, J. Woodworth, M. Perry, Y.J. Chen, A.K.Kermen), *Physical Review E,* Vol. 51, No. 5, pg. 4833, May 1995.
"Classical Electrodynamical Derivation of the Radiation Damping Force," (with F.V. Hartemann), *Physical Review Letters,* Vol. 74, No. 7, pg.1107, February 1995.

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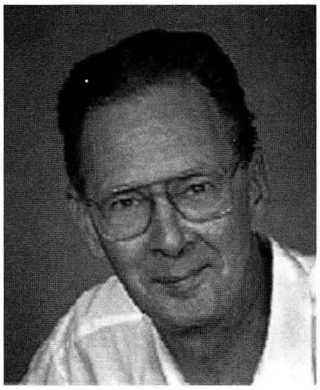

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Ph.D. High Energy Physics, Imperial College, London

Awards: 1993: Panofsky Prize (with Samios and Shutt) for the 1964 discovery of the omega particle, 1996: Brookhaven National Laboratory's Distinguished Research and Development Award., 1999: Wilson Prize for outstanding achievement in physics of particle accelerators.
Research interests: Primary interest at this time is in the design of a muon storage ring neutrino factory; secondary interest is in muon colliders.

Selected publications: Omega Minus: "Confirmation of the Existence of the W^{-} Hyperon" (with V.E. Barnes et al.), Phys. Letters 12, 134 (1964).
Inverse FEL: "The Interaction of Relativistic Particles and Free Electromagnetic Waves in the Presence of a Static Helical Magnet" Robert B. Palmer, J. Appl. Phys. 43, 3014-23 (1972).
Neutral Currents: "Observation of Neutrino-Like Interactions without Muon or Electron in the Gargamelle Neutrino Experiment" F. J. Hasert, et al., Physics Letters 46B, 138-40 (1973).
Lambda sub c: "Evidence for LS=-LQ Currents or Charmed-Baryon Production by Neutrinos" E. G. Cazzoli, et al., Phys. Rev. Lett. 34, 1125-8 (1975).
Laser Grating Acceleration: "A Laser Driven Grating Linac", R. B. Palmer, Particle Accelerators, Vol. 11, 275-284 (1980).

Rajan Ray

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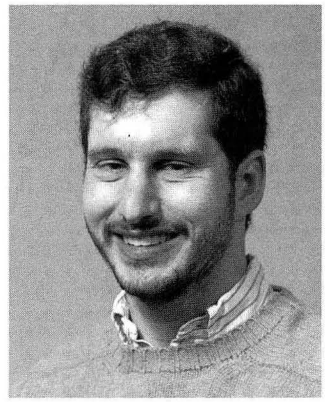
Ph. D., Theoretical Condensed Matter Physics, University of Oregon, Eugene, Oregon, USA, 1978. Lecturer and Professor of Physics at St. Xavier's College, Calcutta University, Calcutta, India, 1978 - present; Post-graduate lecturer at Presidency College, Calcutta University, Calcutta, India, 1990-present.Fulbright Fellow at the University of Michigan at East Lansing, Michigan, USA, June 1,1997 - March 30, 1998. Fulbright Fellow and Participating Visiting Guest Scientist at LBNL, April 1 - June 30, 1998.

Honors: US Fulbright Scholar, 1997-1998 and APS endowed visiting scientist at University of Michigan, East lansing, 1997-1998.

Research interests: Solid state and condensed matter physics; nonlinear dynamics, chaos and bifurcations; quantum Langevin systems; web-based computer architecture,network and software; physics education and pedagogy.

Publications: Many publications in professional, educational and amateur journals.

David Robin



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Ph.D. Accelerator Physics, University of California at Los Angeles, 1991

Research interests: Linear and nonlinear optics design of particle accelerators. Modeling single particle nonlinear dynamics in particle storate rings.

Selected publications: D. Robin, J. Safranek, and W. Decking , "Realizing the benefits of restored periodicity in the Advanced Light Source",i n Phys. Rev. ST Accel. Beams 1 044001 (1999)
D. Robin and R. Alvis, ``Low Alpha Experiments at the ALS", Micro Bunches Workshop, Upton NY (1995) 150 - 164
J. Laskar and D. Robin, ``Application of Frequency Map Analysis to the ALS", Particle Accelerators (1996)
D. Robin, C. Pellegrini, E. Forest and A. Amiry, ``Quasi-isochronous Storage Rings", Physical Review E, Vol. 48 No. 3 (1993) 2149 - 2156
C. Pellegrini and D. Robin,``Quasi-Isochronous Storage Ring", Nuclear Instruments and Methods, A301 (1991) 27-36.

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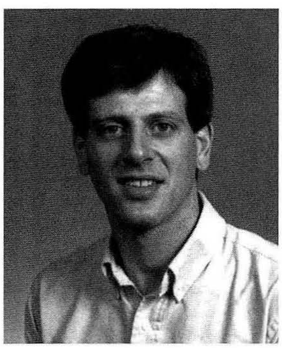

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Ph.D., Massachusetts Institute of Technology, 1989
Postdoctoral Fellow Lawrence Berkeley Laboratory, '89-'91.

Affiliations and honors: Sigma Xi, Eta Kappa Nu, Optical Society of America, Institute of Electrical and Electronics Engineers, American Physical Society, American Association for the Advancement of Science, Optical Society of America Adolph Lomb Medal - 1994

Research interests: Generation of femtosecond x-ray pulses via laser/electron beam interaction, investigation of ultrafast structural dynamics in condensed matter using femtosecond x-ray pulses, studies of laser-induced order/disorder phase transitions in semiconductors using time-resolved x-ray diffraction, studies of electron-hole dephasing and coherent vibrational dynamics in semiconductor nanocrystals.

Selected publications: "Generation of Dark Femtosecond Synchrotron Pulses from the Advanced Light Source," (with P. Balling, H.H.W. Chong, T.E. Glover, P.A. Heimann, C.V. Shank, A. Zholents, and M. Zolotorev), in *Springer-Verlag Series in Chemical Physics - Ultrafast Phenomena XI*, vol. 63, T. Elsaesser, J.G. Fujimoto, D.A. Wiersma, and W. Zinth, Eds. Berlin: Springer-Verlag, p. 390, 1998.

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joined LBNL in 1989

Ph.D., Electrical Engineering, University of California, Berkeley, 1969; AT&T Bell Laboratories: Member of Technical Staff (1969 – 1976); Head, Quantum Physics and Electronics Research Department (1976 – 1983); Director, Electronics Research Laboratory (1983 – 1989); Professor, University of California, Berkeley (1989 – present)

Affiliations and honors: The John Scott Award (1991), SPIE – The International Society for Optical Engineering 1990 Edgerton Award, Distinguished Engineering Alumnus Award (1990), IEEE David Sarnoff Award (1989), IEEE Morris E. Leeds Award (1983), Edward P. Longstreth Medal of the Franklin Society (1982), R.W. Wood Prize of the Optical Society of America (1981). Member: National Academy of Sciences (NAS), 1984; National Academy of Engineering (NAE), 1983; American Academy of Arts and Sciences; Fellow of the American Association for the Advancement of Science (AAAS); Fellow of the American Physical Society; Fellow of the Institute of Electrical and Electronics Engineers, Inc. (IEEE); Fellow of the Optical Society of America.

Research interests: Studies of ultrafast phenomena in condensed matter systems. Generation of femtosecond x-ray pulses for probing structural dynamics of materials.

Selected publications: "Vibrationally Coherent Photochemistry in the Femtosecond Primary Event in Vision," (with Q. Wang, R.W. Schoenlein, L.A. Peteanu, R.A. Mathies), *Science*, 226, 244-24 (1994, October 21).
"Generation of Femtosecond X-rays by 90° Thomson Scattering," (with K.-J. Kim, S. Chattopadhyay), in: *Nuclear Instruments and Methods in Physics Research*, A 341, Elsevier Science Publishers B.V. 351-354 (1994).
"Investigation of Ultrafast Phenomena in the Femtosecond Time Domain," **Science**, 233, 1276-1280 (September 1986).

Toshiki Tajima

Professor of Physics
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(512) 471-4574
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(sabbatical at LBNL first in 1989)
On leave of absence at LLNL since 1998.

Ph.D., Physics, Univ. of Califonia, Irvine, 1975; Staff Scientist at UCLA, 1976-80; Assistant, Associate and Full Professor at Univ. of Texas, Austin, 1980-present; Visiting Professor at Nagoya, 1972; Visiting scientist at Los Alamos National Laboratory, 1983-85; Univ. of Califonia, Berkeley, 1989; Institute of Nuclear Physics (Novosibirsk) 1990; Member of SSC Lab 1989-93.

Affiliations and honors: Fellow, Japan Society for Promotion of Science; Fellow, American Physical Society; Member, National Research Council of National Academy of Science; Leadership, Japan Atomic Energy Research Institute; Faculty Research Award, UT Austin (1995); R.W. Hamilton Award (1997).

Research interests: laser acceleration; beam-beam interaction; beam (and laser) cooling; solid state acceleration; x-ray and laser physics; plasma physics; computational techniques.

Selected publications: "Computational Plasma Physics," Addison-Wesley, Reading (1989).
"Laser Electron Accelerator," (with J.M. Dawson) *Phys. Rev. Lett.,* **43**, 267 (1979).
"Superluminous Laser Pulses in an Active Medium," *Phys. Rev. Lett.,* **71**, 4338 (1993).
"Particle Diffusion from the Beam-Beam Interaction in Synchrotron Colliders," (with J.K. Koga) *Phys. Rev. Lett.,* **72**, 2025 (1994).
"Plasma Astrophysics," (with K. Shibata), Addison-Wesley, Reading (1997).

Karl Van Bibber

Group Leader
High Energy Physics & Accelerator Technology, LLNL
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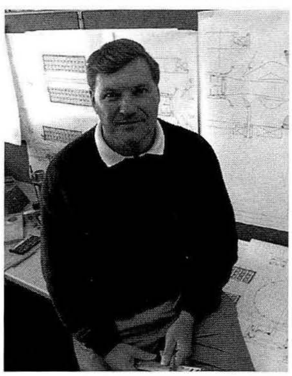
Ph.D., Physics, Massachusetts Institute of Technology, 1976

Affiliations and honors: Editorial board, SLAC Beam Line; Board of Directors, Wang NMR, Inc.; Physical Sciences Directorate LDRD Committee; Member, SLAC Users Organization Executive Committee; Vice-Chairman, LLNL Lab-Wide Institutional Research & Development Committee; Chairman, Exec. Comm, LSBL 88" Cyclotron Users Group; President, Stanford University, Phi Beta Kappa Executive Council; APS Division of Nuclear Physics Program Committee.

Research interests: Low energy nuclear physics, high energy physics, experimental particle astrophysics, and accelerator physics.

Selected publications: "Fabrication of DDS-3, an 11.4 GHz Damped-Detuned Structure," (with C. Adolphsen et al.), presented at the 1999 Particle Accelerator Conference, New York.
"An Energy - Loss Camera Based on Near-Threshold Crenkov Radiation," (with R. Bionata, H.S. Park, E. Ables, T.E. Cowan, F.S. Dietrich, E.P. Hartouni), invited talk at the Accelerator Applications '97 Conference (topical subgroup of the American Nuclear Society), 1997.
"Results from a High Sensitivity Search for Cosmic Axions," (with C. Hagmann et al.), accepted by *Physical Review Letters*, November 1997.

David Vanecek



Senior Designer
Engineering Division
MS 47-112
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joined LBNL in 1961

Selected publications: "Relativistic-Klystron Two-Beam Accelerator as a Power Source for a 1 TeV Next Linear Collider - A Systems Study," LBNL #36232, August 1994.
"A System Study of an RF Power Source for a 1 TeV Next Linear Collider Based upon the Relativistic-Klystron Two-Beam Accelerator," presented at the RF '94 Conf., Montack, NY, LBNL #36545, October 2, 1994.
"Heavy-Ion Fusion Driver Research at Berkeley and Livermore," presented at the Sixteenth IAEA Fusion Energy Conference, Montreal, Canada, October 7-11, 1996.

John P. Verboncoeur

Research Engineer
Plasma Theory and Simulation Group
Dept. Electrical Engineering and Computer Science
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510-642-3477

Ph. D. in Nuclear Engineering, University of California at Berkeley, 1992

Major Awards: Magnetic Fusion Energy Technology Fellowship (U.S. DoE 1986-1991), Memberships/Affiliations: American Physical Society, Institute of Electrical and Electronic Engineers

Reearch Interests: Computational plasma physics, electromagnetics, nonlinear and kintetic effects, stability, numerical methods, plasma waves and boundary phenomena, applications to microwave-beam devices, fusion,accelerators, and gaseous discharges for plasma sources, lighting and flat panel displays.

Selected publications: Y. Ikeda, J. P. Verboncoeur, P. J. Christenson and C. K. Birdsall,"Global Modeling of a Dielectric Barrier Discharge in Ne-Xe Mixtures for an AC Plasma Display Panel'', \textit{J. Appl. Phys.} (1999).T. M. Antonsen, Jr., A. A. Mondelli, B. Levush, J. P. Verboncoeur, and C.
K. Birdsall, "Advances in Modelling and Simulation of Vacuum Electronic Devices'', \textit{Proc. of the IEEE\textbf{\ 87}}, 804-839\textit{\ }%(1999), invited.

Glen Westenskow

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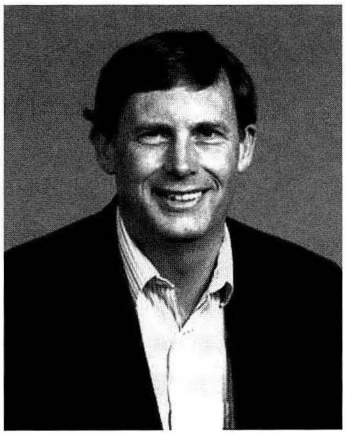
joined LLNL in 1986, worked on collaborative experiments with LBNL since 1996.



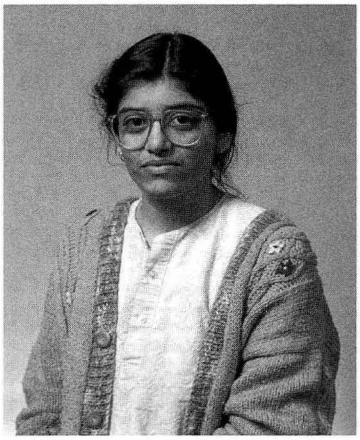
Ph.D., Physics, Stanford University, 1981

Research interests: High power rf sources; induction accelerators; electron sources; accelerator physics; conventional and novel high energy accelerators.

Selected publications: "Prototype Microwave Source for a Relativistic Klystron Two-Beam Accelerator," *IEEE Trans. on Plasma Sci.* (special issue on High Power Microwave Generation), **24** (3), 938-946 (1996).
"Transverse Instabilities in a Relativistic Klystron Two-Beam Klystron," *Proc. of the 1992 Linear Accelerator Conference*, pp. 263-267 (1992).
"High Gradient Electron Accelerator Powered by a Relativistic Klystron," *Phys. Rev. Lett.*, **63** (22), pp. 2472 (1989).
"The Stanford Mark III Infrared Free-Electron Laser," (7th Int. FEL Conf.) *Nucl. Instr. and Meth.*, **A250**, pp. 39-43 (1986).
"Microwave Electron Gun," *Laser and Particle Beams*, **2**, pp. 223-225 (1984).

STUDENTS

Richa Govil



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joined LBNL in 1991

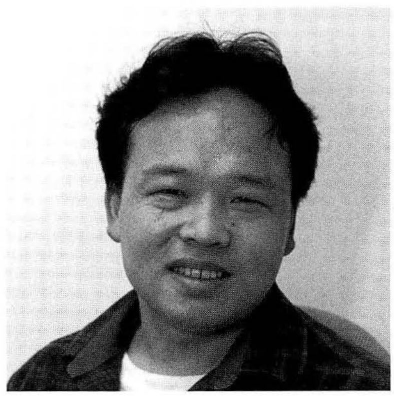
Ph.D., Physics, University of California, Berkeley, 1998, M.A., Physics, University of California, Berkeley, 1996, A.B., Physics, University of California, Berkeley, 1991

Major awards: Certificate of Distinction, University Medal, UC Berkeley, 1991

Research interests: Plasma-electron beam interactions, advanced accelerator concepts, free-electron lasers.

Selected publications: "UV Laser Ionization and Electron Beam Diagnostics for Plasma Lenses," (with P. Volfbeyn and W.P. Leemans), Proc. Particle Accelerator Conference, Dallas, Texas VW, 776 (1995).
"Time-Resolved Study of Sideband Generation and Transition to Chaos on an Infrared FEL," (with W.P. Leemans et al.), Proc. 16th Int'l FEL Conf., Stanford, CA, August 21-26, 1994.
"Design of RF Conditioner Cavities," (with R.A. Rimmer, A.M. Sessler and H.G. Kirk), Proc. 14th Int. FEL Conf., Kobe, Japan, August 23-28, 1992.
"Macroparticle Theory of a Standing-Wave-Free-Electron Laser Two-Beam Accelerator," (with K. Takayama and A.M. Sessler), *Nucl. Instr. And Meth. In Phys. Res.*, A230, 587 (1992).

Kang-Zhu Guo



Visiting Scholar
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Ph.D. student of IHEP (Institute of High Energy Physics), Chinese Academy of Sciences, since 1994
M.S., Technical Physics, Peking (Beijing) University, 1992

Research interests: Free electron laser, high energy nuclear interactions, plasma-electron beam interactions, beam diagnosis

Selected publications: "Beam Measurement System for BFEL (Beijing Free Electron Laser Facilities)," Proc. 3rd Academic Exchanges of Chinese Scientific Technology of Lasers for Young Scientists, Hangzhou, China, (1995).
"Phenomenological Model of Global Observable Energy and Multiplicity Distributions in Ultrarelativistic Nuclear Collisions," (with Zhengxing Wang), *Phys. Rev. C*, Vol. 48, No. 1, 379 (1993).

Undergraduate Student
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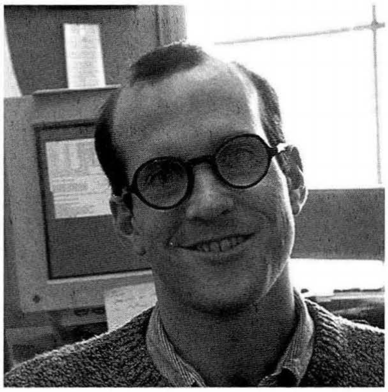
joined LBNL in 1996

Michael Leung

Pursing B.S. in Engineering Physics.
Researcg Interests; Particle physics, particle accelerators, cosmology.

Steven Lidia



Scientist
Group Leader: RK-TBA
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SMLidia@lbl.gov
joined LBL in 1995

Ph.D., Physics, University of California, Davis, 1999.
B.S., Engineering Physics, University of California, Berkeley, 1991

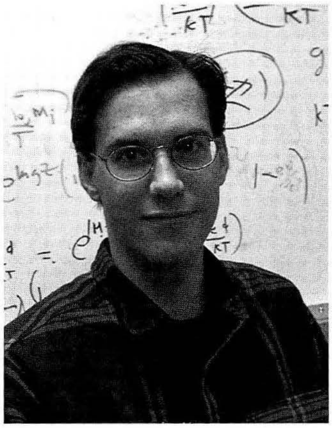
Affiliations: Member, American Physical Society

Research interests: Charged particle beam production of coherent radiation, beam dynamics and instabilities, free electron lasers, RF and induction linear accelerators, novel accelerators and colliders.

Selected publications: "RK-TBA Studies at the RTA Test Facility," 7th Advanced Accelerator Concepts Workshop, Lake Tahoe, California (October 1996).
"Relativistic Klystron Two-Beam Accelerator Approach to Multi-TeV e+e- Linear Colliders," APS New Directions in High Energy Physics Workshop, Snowmass, Colorado (July 1996).
"An Elliptically-Polarizing Undulator with Phase Adjustable Energy and Polarization," *Nucl. Instr. Methods in Phys.*, Res. A347, 77-82 (1994).

*Ph.D., Summer 1999, UC Davis
Scientist, LBNL, Fall, 1999
Group Leader, RK-TBA, January, 2000

Carl Schroeder



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M.A., Physics, University of California, Berkeley, 1995
B.S., Mathematics, University of Maryland at College Park, 1994
B.S., Physics, University of Maryland at College Park, 1994

Research interests: Laser-plasma interactions, plasma-based accelerators.

Selected publications: "Generation of Ultrashort Electron Bunches by Colliding Laser Pulses," (with P.B. Lee, J.S.Wurtele, E. Esarey, and W.P. Leemans), *Phys. Rev. E,* 59, 6037 (1999).
"Multimode Analysis of the Hollow Plasma Channel Wakefield Accelerator," (with J.S. Wurtele and D.H. Whittum), *Phys. Rev. Lett.*, 30, 1177 (1999).
"Laser-Included Electron Trapping in Plasma-Based Accelerators," (with E. Esarey, W.P. Leemans, and B. Hafizi), *Phys. Plasmas,* 5, 2262 (1999).

Peter (Byung) Lee

Undergraduate Student
University of California, Berkeley
MS 71-259
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B.S. Engineering Physics and Engineerimg Math/Stat, University of California at Berkeley, 1998; graduate school at Cal Tech majoring in Physics

Research Interests: Laser-plasma interactions, plasma-based accelerator, cosmology.

James Lie

Undergraduate Student
University of California, Berkeley
MS 71-259
(510) 486-6465
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B.A. Electrical Engineering, University of California at Berkeley, 1998

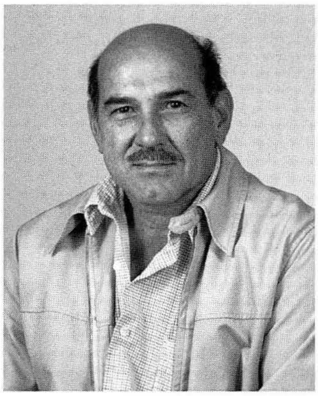
Research Interests: Microwaves, electromagnetics

CSEE Undergraduate Fellows

David Friedberg
Emil Moskovich
Lauren Ostrovsky

PARTICIPATING GUESTS (EMERITI)

Tom Elioff



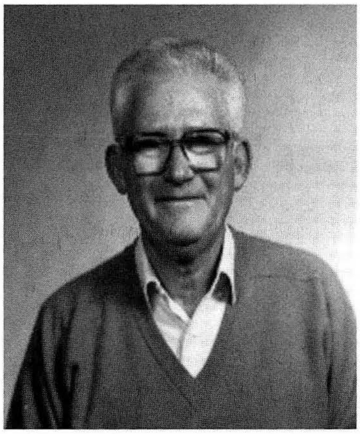
Senior Scientist Emeritus
telioff@SLAC.Stanford.EDU
(650)926-2149
Joined LBL in 1955

Ph.D. Physics, UC Berkeley 1959

Associate Director SSRL Division at SLAC and Director of SPEAR 3 Project

Selected Publications: Antiproton-proton Cross Sections from 534-1068 Mev (with O.Chamberlain et al),PR Letters 3, 285-8, Sept 15,59.
SSC Commissioning and Operations Plan, SSCL-SR-1210, March 92
SSC Conceptual Design Report, (with CDG group) March 86
Neutrino Mass Limits (with Clark et al) Phys Rev D:9:3:1, Feb 74.
PEP-I Conceptual Design Report (LBL-SLAC Staff) LBL-4288, Feb 96.
A Dedicated Medical Accelerator for Radiotheraphy, LBL-15043, Oct.82.
SPEAR 3- A Low Emittance Source for SSRL (SPEAR 3 Design Group), March l999 Particle Accelerator Conference.

Alper Garren



Senior Scientist Emeritus
(510) 486-6574
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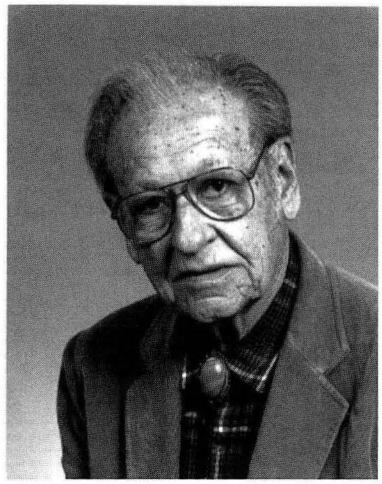
joined LBL in 1955

Ph.D., Physics, Carnegie Institute of Technology, 1955

Affiliations and honors: Accelerator theorist with contributions to design of many accelerators and their lattices, e.g., Bevatron, FNAL, PEP, BNL/CBA, ALS, PEP-II, SSC; author of the lattice program SYNCH; also contributed to heavy-ion fusion, magnetic fusion with mirror machines, spiral-ridge cyclotrons (e.g., 88 Inch Cyclotron at LBL), and to the Electron Ring Accelerator Study.

Selected publications: "SYNCH Users Guide," (with A.S. Kenney, E.D. Courant, A.D. Russell, and M. Syphers), SSCL-MAN-0002 (1993).
"APIARY B-Factory Separation Scheme," (with M. Sullivan), LBL PUB-30730 (May 1991).
"Apiary B-Factory Lattice Design," (with M.H.R. Donald), LBL PUB-30665 (May 1991).
"Low-Momentum Compaction Lattice Study for the SSC Low Energy Booster," (with E.D. Courant and U. Wienands), Proc. 1991 Particle Acclerator Conference (May 1991).
"Site-Specific Conceptual Design of Superconducting Supercollider," SSCL-SR-1056 (July 1990).
"An Asymmetric B-Meson Factory at PEP," (A.A. Garren et al.), Proc 1989 Particle Acclerator Conference, Chicago, Illinois (1989).

Albert Ghiorso



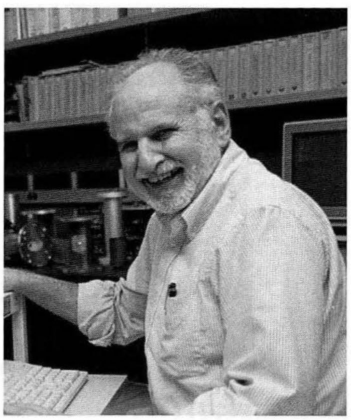
Senior Scientist Emeritus
MS/71-259
(510)486-7771
A_Ghiorso@lbl.gov
joined LBL in 1946

Honorary Doctor of Science degree, Gustavus Adolphus College, 1966
B.S. Electrical Engineering, University of California, Berkeley, 1937

Affiliations and honors: Presently a member of the Nuclear Science Division; Staff Member, University of Chicago Metallurgical Laboratory, 1942-46; Lawrence Berkeley Laboratory, 1946-82; Director of the HILAC and then the SuperHILAC from 1957-1971; Co-inventor of the Omnitron; Inventor of the BevaLac; member of American Physical Society, American Association for the Advancement of Science (AAAS), American Chemical Society Award: Nuclear Applications in Chemistry, 1973; Co-Discoverer of 13 elements, 95-106 and 110 (to be confirmed).

Selected publications: "Observation of Superheavy Nuclei Produced in the Reaction of ^{86}Kr with ^{208}Pb," (with V. Ninov et al.), submitted to *Phys. Rev. Letters,* March 26, 1999.
"Evidence for the Synthesis of Element 267110 Produced by the 59Co + 209Bi Reaction," (A. Ghiorso et al.), Proceedings of the Fifth International Conference on Nucleus-Nucleus Collisions, Taormina, Italy, May 30-June 4, 1994, *Nucl. Phys.* A 583, p. 861c (1995).
"A History of the Discovery of the Transplutonium Elements," in *Actinides in Perspective,* edited by N.M. Edelstein, Pergamon Press, (Oxford and New York), p. 23, 1982.
"The Omnitron: A Versatile Medium-Energy Synchrotron for the Acceleration of Light and Heavy Ions," (with R.M. Main, B.H. Smith), *IEEE Transactions on Nuclear Science,* NS-13, 280 (1966).

David Goldberg



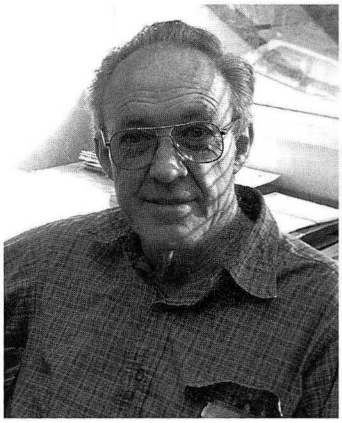
Staff Scientist Emeritus
MS 71-259
(510) 486-7222
DAGoldberg@lbl.gov
joined LBNL in 1980

Ph. D., Nuclear Physics, Johns Hopkins University, 1967

Research interests: Beam instrumentation and feedback, beam impedance measurements, stochastic cooling.

Selected publications: "Absolute Calibration and Beam Background of the Squid Polarimeter," (with M.M. Blaskiewicz et al.), contribution to XII Int'l Symposium on High-Energy Spin Physics (1996).
"Squids, Snakes, and Polarimeters: A New Technique for Measuring the Magnetic Moments of Polarized Beams," (with P.R. Cameron, et al.), contribution to Beam Instrumentation Workshop, Argonne Nat'l Lab. (1996).
"Measurement and Analysis of Higher-Order-Mode (HOM) Damping in B-Factory RF Cavities," (with M. Irwin and R.A. Rimmer), contribution to Particle Accelerator Conference (1995).
"Automated Bead-Positioning System for Measuring Impedances of RF Cavity Modes," (with R.A. Rimmer), contribution to Particle Accelerator Conference (1993).
"Dynamic Devices: A Primer on Pickups and Kickers," (with G.R. Lambertson), in *Physics of Particle Accelerators* (M. Month and M. Dienes, eds.) (1992).

Glen R. Lambertson



Senior Scientist Emeritus
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joined LBNL in 1951

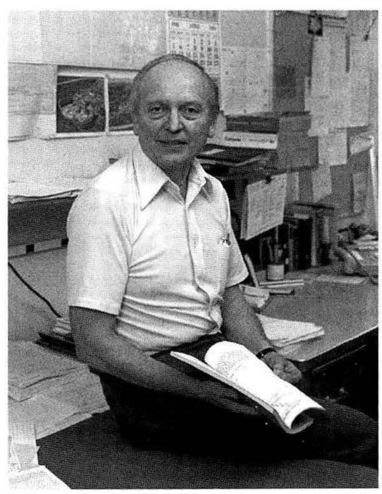
M. S., Physics, University of California, Berkeley, 1951
Visiting scientist, Brookhaven National Laboratory, 1995, Visiting scientist, CERN, Geneva, 1973

Award: U.S. Particle Accelerator School Prize for Achievement in Accelerator Physics and Technology, 1991.

Research interests: Electrodes and magnets for particle beams, feedback stabilization of beam instabilities, interaction between beam and enclosure.

Selected publications: "Beam-Bunch Fields in Layered Beam Enclosures," PEP II AP Note No. 96.31, Sept. 1996.
"Dynamic Devices, A Primer on Pickups and Kickers," (with D. Goldberg), *Proc. AIP Conference,* **249**, 537 (1992).
"Higher Order Mode Damping Studies on the PEP-II B-Factory RF Cavity," (with R.A. Rimmer et al.), *3rd European Particle Accelerator Conference* (1992).
"Transverse Feedback in a 100 TeV Storage Ring," *Proc. 19th Workshop on Maximizing Luminosity of Hadron Colliders at 130 TeV,* Erice, Italy (1991).
"Control of Coupled-Bunch Instabilities in High-Current Storage Rings," invited paper, 1991 IEEE Particle Accelerator Conference , **4**, 2537 (1991).

Jack Peterson



Senior Scientist Emeritus (1920-1999)
MS 71-259
joined LBNL in 1946, LLNL in 1952, and LBNL again in 1964

Ph.D., Physics, University of California, Berkeley, 1950
A.B., Physics, Harvard, 1942

Affiliations and honors: Fulbright Fellow, Bohr Institute, Copenhagen, 1960; Visiting Scientist, Max Planck Institute for Plasma Physics, Munich, 1973; Superconducting Super Collider Laboratory, 1985 - 1993.

Research interests: Methods of beam injection and extraction, beam emittance degradation due to various effects, storage-ring design, magnet design, effects of magnetic errors and their correction, collective beam effects, feedback systems, neutron cross-sections, neutron giant resonances.

Selected publications: "Correction of Random Multiple Errors with Lumped Correctors,"SSCL-N-383.
"Effects from Measured Ground Motions at the SSC," (with K-Y NG), SSCL-227-Rev, Fermilab Pub-9119 (1990).
"PEP Injections System," (with Karl Brown), Part. Accel. Conf., Wash., D.C., *IEEE Trans. Nucl. Sci.*, NS-22 3, p. 1423 (1975).
"Use of Collective Fields in the Acceleration of Particles," APS Mtg, San Francisco, LBL-704 (1972).
"Neutron Giant Resonances-A Nuclear Ramsauer Effect," *Phys. Rev.*, 125, p. 955 (1962).
"Photo-Production of Mesons by X-rays," (with E.M. McMillan and R.S. White), *Science*, 110, p.579 (1949).

Senior Engineer Emeritus
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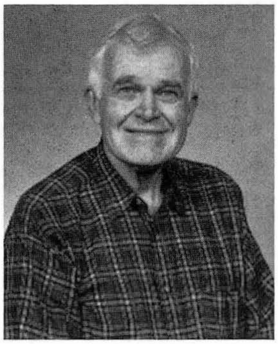
Ferd Voelker



M.S., Electrical Engineering, University of California, Berkeley

Research interests: Damping of HOM in RF cavities, study of multi-electrode kickers for particle beam, beam impedance measurements.

Selected publications: "ALS Longitudinal Kickers," presented at the 1992 Accelerator Instrumentation Workshop, LBL, Berkeley, California LBL-33088 (1992).
"Higher Order Model Damping Studies on the PEP-II B-Factory RF Cavity," (with R. Rimmer, D. Goldberg, G. Lambertson, et al.), presented at the 3rd European Particle Accelerator Conference, Technical University of Berlin, Germany, LBL-32549 (1992).
"Calculations of RF Cavity Feedback Using Simple Analytic Model," (with G. Lambertson) (1991).
"Technique for Beam Impedance Measurements above Cutoff," (wtih G.R. Lambertson, A.F. Jacob, and R.A. Rimmer), presented at the European Particle Accelerator Conference, Nice, France LBL-28190 (1990).

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PRINCIPAL COLLABORATORS

"I still say to myself when I am depressed and find myself forced to listen to pompous and tiresome people, 'Well, I have done one thing you could never have done, and that is to have collaborated with Littlewood and Ramanujan on something like equal terms.'"

— G.H. Hardy in
A Mathematician's Apology

Femtosecond X–ray Source Collaboration: R. Schoenlein, LBNL and C.V. Shank, LBNL

NLC Collaboration: D. Burke, SLAC

PEP–II B–Factory Collaboration: J. Dorfan, SLAC and D. Hitlin, Caltech

FEL Collaboration: M. Cornacchia, SLAC

Photocathode/SCRF Collaboration: Chia–Erh Chen, Peking University

Two–Beam Accelerator Collaboration: J.P. Delahaye, CERN, R. Ruth, SLAC, and T. Honck, LLNL

Heavy–Ion Beam Diagnostics and Cooling in RHIC: M. Harrison and S. Ozaki, BNL

Advanced RF Technology Collaboration: N. Luhman, UC Davis

General Beam Physics: Kunio Higashi, Institute for Advanced Energy, Kyoto University

SUMMARY OF ACTIVITIES 1998-2000
TABLE OF CONTENTS

Center for Beam Physics

Reported by Swapan Chattopadhyay, Center Director

In the years approaching the millenium, we have continued to expand—in breadth, depth and scope — our research and development activities. In this we stayed focused on our mission: to help meet the technical challenges of major facilities and initiatives (local, national and international) and to enhance Berkeley Lab's capabilities in particle and photon beam research.

In earlier years, our staff played pivotal roles in the design, construction and commissioning of the Advanced Light Source. Building on that base of experience, we were among the primary contributors to the genesis of PEP-II, the energy-asymmetric B-meson factory at the Stanford Linear Accelerator Center that has since evolved into a major collaborative construction project. The project, now complete, will greatly facilitate the study of CP violation and thus the advancement of the understanding of matter and energy. Our scientists and engineers have been heavily involved in the commissioning of the especially challenging low-energy ring of this high-luminosity collider, as well as in beam dynamics, rf and feedback systems. They also contributed in these areas to the ongoing enhancement and operational improvement of the ALS.

Meanwhile, with an eye toward the future of accelerators, we have spearheaded a collaboration on the preliminary design of the Next Linear Collider (NLC), now preparing for the transition from exploratory R&D to formal design. The NLC is a possible successor to the Stanford Linear Collider in high energy physics with lepton collisions. The NLC that we are envisioning would have a 500 to 1000 GeV center-of-mass collision energy. The Center's (and, indeed, AFRD's and LBNL's) responsibilities in this collaboration with SLAC include damping rings, the interaction-point collision physics, and scenarios and technologies for an eventual upgrade to 1.5 TeV and beyond. The energy upgrade studies are intimately tied to the various forms of two-beam accelerator studies in collaboration with LLNL, CERN, and SLAC.

Yet another major development has been the emergence of the Muon Collider and Neutrino Factory concepts. LBNL has been chosen by the national muon collider collaboration to coordinate work on the collider ring and the muon storage ring as a neutrino source; this work is predominantly done through the Center. In addition, Center scientists and engineers are involved in the simulation and radio-frequency hardware design for the muon cooling experiment being planned at Fermilab. Dr. Andy Sessler, the Center Counsel and a Distinguished Senior Scientist in the Center, has been chosen by the National Muon Collider and Neutrino Factory Collaboration to be its spokesperson.

We continued further expanding our experimental capabilities over the past years. Preparations are under way for research into all-optical particle injectors, laser acceleration, laser guiding and optical stochastic cooling. Short-pulse table-top lasers have been added to our l'OASIS Laboratory to embark on various laser-plasma-particle interaction studies involving novel acceleration, diagnostics and control techniques.

Aside from growth in these activities, we have also continued making progress in our traditional areas: accelerator theory; linear and nonlinear beam dynamics; free electron lasers, especially for applications in power beaming to satellites; radiation sources based on advanced femtosecond techniques; and high energy collider physics (including diagnostic and beam cooling for the Relativistic Heavy Ion Collider being built at Brookhaven). And our diverse research and educational activities have enjoyed enhanced participation by students and international visitors and collaborators, old and new, from various institutions around the world.

Advanced Collider Physics

Scientists and engineers from the Center are involved in supporting theoretical and conceptual developments for high energy colliders worldwide. Critical and limiting beam dynamics issues such as electron cloud effect, fast-ion instability etc. have been theoretically investigated for the LHC, PEP-II, etc. Various physics issues at high energy and high luminosity collision and interaction points at colliders has been investigated. And new regimes of acceleration and radiation in high energy colliders, e.g., beamstrahlung and GeV/m electric field gradients, are being explored.

PEP-II Commissioning

In the past year, the High-Luminosity Collider Group has focused on the commissioning of the PEP-II asymmetric *B* factory at SLAC. PEP-II comprises two rings: a High-Energy Ring (HER) that circulates 9 GeV electrons and a Low-Energy Ring (LER) that circulates 3.1 GeV positrons. Both rings are injected from the SLAC linac, the world's most powerful source of positrons. Our group has been involved in the PEP-II project since its inception and has been primarily responsible for the design, and now the commissioning, of the LER.

Main design parameters for PEP-II are summarized in Table 1. The most noteworthy LER parameters are the high beam current (2.16 A) and large number of bunches (1575).

Energy [GeV]	3.1
Circumference [m]	2200
Emittance, y/x [nm-rad]	1.5/49
Beta function at IP, y/x [cm]	1.5/50
Beam-beam tune shift	0.03
RF frequency [MHz]	476
RF voltage [MV]	3.2
Bunch length, rms [mm]	12

Table 1. PEP-II LER main parameters.

The LER, a newly constructed ring (as contrasted with the HER, which was to a large extent the old PEP ring) was completed in July 1998. Since then, three commissioning runs have taken place, the first in July 1998 (three weeks), the second in October–December 1998 (seven weeks), and the third in January–February 1999 (five weeks). All of these runs were made without the *BaBar* detector (with its powerful 1.5 T solenoid) in place, but with otherwise nominal low-beta collision optics. After the February run, the interaction region (IR) was disassembled so that the detector could be installed in the tunnel. The first commissioning run with the detector in place will begin in May and continue through the end of August. The commissioning team is made up mainly of accelerator physicists from LBNL and SLAC, with a few visitors from CERN and Saclay.

The LER (see Figure 1) is sixfold symmetric, with six FODO arcs (having 90° phase advance per cell in both planes) of 255 m connected by six straight sections of 110 m. Ring areas are designated according to the clock, with straight sections having even numbers (Regions 12, 2, 4, 6, 8, 10) and arcs odd numbers; beam direction is counter-clockwise. Optical elements are mirror symmetric about an axis between the centers of Region 8 and Region 2. Functional units of the ring are contained in the straight sections. Except in Region 2, the LER is 89 cm above the HER; in the interaction region the LER beam is transported downward to the plane of the HER and then restored to its normal elevation at the downstream end.

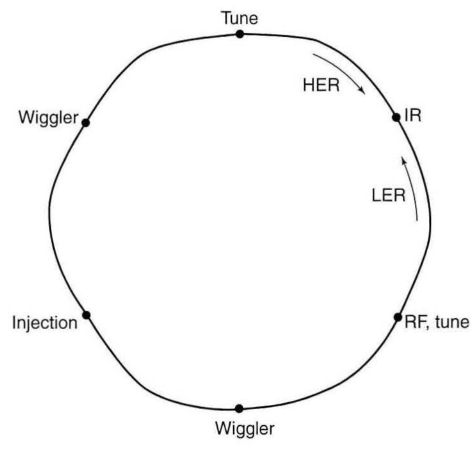


Figure 1. Functional layout of the LER.

To reach high currents with stable beam, bunch-by-bunch feedback systems operating in the time domain are employed to combat longitudinal and transverse instabilities. These systems are critical to the successful operation of the LER. Complementing the feedback systems is a very sophisticated low-level RF system that encorporates many feedback loops and digital filters to reduce the effective impedance of the RF system to a level that can be handled with the bunch-by-bunch feedback systems. Diagnostics devices use designs common to the HER.

July 1998 Commissioning Run

The LER was fully under vacuum (with a few significant leaks) on July 10, 1998; injection activities commenced immediately thereafter. Considerable time was spent beforehand to check out power supplies and polarities of more than 900 magnets, with the result that only one magnet wiring error was discovered with the beam. In view of the limited commissioning time available before detector installation, and the limited optics adjustment range available from the permanent magnet IR quadrupoles, the nominal collision lattice was used from the outset.

To minimize radiation dose to the "background" detectors at the interaction point (IP), a dipole string immediately upstream of the IP was initially turned off and the DC injection bump magnets were tuned for on-axis injection (incoming orbit 45 mm above the LER median plane). Two hours after the beam first arrived at the injection point it had reached the upstream side of Region 2, nearly 1.1 km downstream. Over the next few days the beam was tuned through the complicated IR and steered to get multiple turns. A 1 mA beam was stored on July 16, as observed with a beam position monitor (BPM) button attached to an oscilloscope and a DC current transformer (DCCT).

The main goals for this initial run were to store 50 mA of positrons, to begin characterizing the lattice and beam orbit, to commission the pulsed magnets (injection and abort kickers), and to commission key diagnostics devices, such as the BPM and beam loss monitor (BLM) systems and the DCCT. By the end of the run, the total beam current had reached 53 mA and the single-bunch current had reached 5 mA (the latter being about four times higher than the design value).

Agreement between the model and measured beta functions was reasonable; differences at the IR quadrupoles were about 50%. The measured natural chromaticity of the ring was about 10% higher than expected in both planes. We ascribe this to the orbit offset in the strong LER sextupoles. (In Region 2, orbit deviations at the sextupoles were initially 15 mm, though the rms orbit in the arcs was below 5 mm. This was ultimately traced to a 3.6% error in the polynomial for the "long bends" in Region 2.)

After storing the beam and correcting the orbit, it was observed that the orbit was not centered. Vertically, it was high by about 1 mm, and radially, it was offset toward ring center by about the same amount. The first offset was attributed to field from circulating currents in the cable tray above the ring (later verified by post-run measurements). The second offset was ascribed to an error of 4 mm in the 2200 m circumference.

The main difficulty during this run was poor lifetime—only 3 minutes—even at low beam current. The lifetime was insensitive to steering and tunes, and was shown to be unrelated to RF acceptance. Because of the high pressure in a few locations, vacuum was hard to eliminate as the cause of the poor lifetime. However, a few "suspicious" orbit bumps were found to be necessary in Arc 11, and the BLMs nearby had elevated count rates. After the run ended, a visual inspection of the Arc 11 chamber interior showed a folded-over rf gasket that occluded much of the beam aperture. Due to poor lifetime, scrubbing was minimal; only 0.5 A-hr was accumulated during the run.

October 1998 Commissioning Run

During the shutdown, considerable work was done to improve the ring vacuum. Major leaks were found and repaired, though a few small ones remained. For this run, the goals were to store a beam current of 250 mA and to reach a lifetime of 1 hour at 150 mA. Other important goals included correcting the rms orbit below 1 mm and commissioning the newly installed synchrotron light monitor along with the longitudinal and transverse feedback systems.

Comparison between HER and LER orbits showed that both rings were too large by about the same amount and a 1 kHz reduction in the RF system master oscillator frequency was made to center the orbit. (To keep the rings phase-locked to the SLAC linac, a corresponding –6 kHz adjustment was made to the linac frequency.) Subsequently, the LER rms orbit was corrected to less than 1 mm in both planes. (The vertical orbit was corrected, despite the cable tray current, with an algorithm that does not minimize corrector strengths.) Later, it became apparent that the LER (and HER) showed mm-scale orbit motion near the IP resulting from thermal motion of the magnet supports along with thermal flexing of various IR beam pipes, which causes slight magnet motion. (At high beam currents, various HER IR thermocouples show significant, though not extreme, temperature increases. This is due to two effects: synchrotron radiation fans from upstream HER dipoles striking uncooled stainless steel portions of the HER vacuum chamber, and strong LER synchrotron radiation fans from the B1 separation dipoles near the IP illuminating the upstream HER beam pipes.) The orbit change in each ring is correctable with a single corrector near the IP and we implemented orbit feedback loops to control the motion. This behavior should improve when *BaBar* comes on line due to changes in the vacuum chambers (bellows added to provide a "frangible link") and better thermal stabilization.

To improve the beam quality for collisions, we decoupled the ring with the global skew quadrupoles. Once the beam was well centered in the sextupoles, it was routinely possible to reach a closest tune approach of ≤0.001. Dispersion steering was also done, reducing the residual vertical dispersion in the arcs to about 10 mm.

Both the longitudinal and transverse feedback systems were made operational during this run. The beam was longitudinally stable up to about 300 mA but did show evidence for some "mode-0" oscillation amplitude, driven by the rf system. (The so-called woofer link between the longitudinal feedback and rf systems had not yet been implemented.) The transverse feedback system also showed no evidence for strong coupled-bunch motion aside from the resistive-wall instability. The newly installed LER synchrotron radiation monitor proved very useful in diagnosing beam instabilities as the current was increased, but its mirror is distorted.

During the run, the beam lifetime measured at low current (≈1 mA) reached 100 minutes; a beam lifetime of 63 minutes at 150 mA was also reached. By the end of the run in December, a beam of 415 mA was stored, and scrubbing of the vacuum chamber reached 20 A-hr.

January 1999 Commissioning Run

This would be the final commissioning period before *BaBar* was to come on line. The main goal was to reach a high beam current, 1100 mA, with beam stability sufficient for luminosity-producing collisions. (Maximum beam current was limited by the interim Q2 vacuum chambers; these are now being replaced to permit full-current operation.) In Figure 2, the

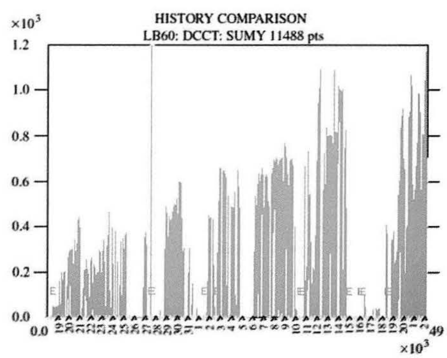


Figure 2. LER beam current vs. time during January 1999 commissioning run.

beam current increased steadily during the run; a stored positron beam current above 1 A was reached on February 12.

At the end of the run, 1160 mA was stored in the LER, making it presently the world's highest current positron ring. The integrated current has reached

153 A-hr. Unfortunately, there was an accidental vent in one arc (not beam related) one week prior to the end of the run. After resuming operation, the lifetime recovered to its earlier value (1 hour at 700 mA) but did not further improve. During collision tests, a 680 mA LER beam colliding with a 350 mA HER beam produced a measured luminosity of 5.2 x 10^{32} cm^{-2} s^{-1}.

The woofer link from the longitudinal feedback system to the rf system was commissioned and it reduced the mode-0 motion to below 0.01°. This was important in reaching the highest beam currents. Evidence was seen for true longitudinal coupled-bunch motion at high currents; the growing modes are mainly consistent with expectations based on measured rf cavity modes.

At high currents, we find that the pressure readings of the vacuum pumps increase markedly (Figure 3).

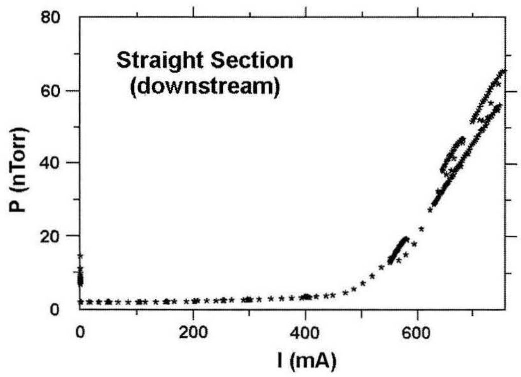


Figure 3. Pressure in straight section vs. beam current

The observed effect is sensitive to the fill pattern, with a larger number of bunches showing less increase. All pumps exhibit such behavior, with the straight sections being worse. The increase is clearly a real pressure rise, as the beam lifetime decreases and the background detectors in Region 2 show a corresponding increase and the same bunch pattern dependence. We believe the pressure rise is due to a pressure-bump phenomenon in which secondary electrons (or possibly ions) desorb gas locally from the chamber walls.

There is evidence that scrubbing alleviates the effect, since the arcs show less pressure rise than the straight sections, and the upstream part of a straight section (which is illuminated by synchrotron radiation) is better than the downstream part that has no scrubbing.

Summary, Schedule, and Plans

The next run will be May–August 1999. For the LER, the main goals will be to reduce detector backgrounds (with improved injected beam quality, with collimators, and possibly with a solenoidal field to suppress the anomalous pressure rise), and to continue optimizing the luminosity. For this run our goal is a luminosity of 1 x 10^{33} cm^{-2} s^{-1}.

LER commissioning is well under way, following the very successful HER program. After 15 weeks of commissioning, the LER has become the highest-current positron storage ring in the world. Thus far, there have been few surprises. We see no large instabilities, nor major misalignments or aperture restrictions, and component heating is modest. Scrubbing is going well, though we have a recurring problem with small leaks at the arc chamber flange joints.

Theory

Electron-Cloud Effect in PEP-II and the LHC

Any intense positively-charged bunched beam creates a cloud of electrons in the vacuum chamber that contains the beam, and this cloud can couple the transverse motion of the bunches, potentially leading to a multibunch instability. This effect is generic to all intense positively-charged beams, and is a distant cousin of the "beam-induced multipactoring" (BIM) effect first identified at the CERN Intersecting Storage Rings more than 20 years ago.[1]

[1] O. Gröbner, "Bunch-Induced Multipactoring," Proc. 10th Intl. Accel. Conf. (Serpukhov, Former USSR, 1977), pp. 277-282.
[2] M. Izawa, Y. Sato and T. Toyomasu, "The Vertical Instability in a Positron Bunched Beam," Phys. Rev. Lett. **74** , 25 (1995), pp. 5044-5047.
[3] K. Ohmi, "Beam Photo-Electron Interactions in Positron Storage Rings," Phys. Rev. Lett. **75**, 8 (1995), pp. 1526-1529.

Although it has been known for a long time that an electron cloud inevitably accompanies any positively-charged beam (the electrons arising mostly from ionization of residual gas), the possibility of a coupled-bunched instability induced by the electron cloud was only brought up in late 1994 by researchers at the KEK Photon Factory.[2,3] In this case, and in all other machines with closely-spaced bunches for which the ECE is being investigated, the electron cloud arises primarily from the photoelectric effect as the synchrotron radiation from the beam hits the walls of the vacuum chamber. In response to these observations, we have been studying this effect as it applies to the PEP-II positron beam and the LHC.

During the fall 1998-winter 1999 commissioning runs of the PEP-II collider, we carried out a few experiments whose aim was the study of multibunch instabilities in the positron ring in an attempt to correlate the results with our computer simulations of the ECE. We injected a train of some 40 bunches into the ring, separated by the nominal spacing of 1.26 m, and observed the instability of this train as a function of bunch charge. The observations had qualitative features in common with the simulations; for example, the bunches towards the tail of the bunch train were unstable but not those at the head.

We also briefly attempted to investigate the instability as a function of a small unevenness of the charge distribution along the train. Unfortunately, the results were inconclusive owing to other priorities of the commissioning program (the feedback system was capable of suppressing the instability, hence the ECE did not present an operational problem for PEP-II during these commissioning runs). However, towards the end of the commissioning run in February 1999, new observations at higher positron current, close to the achieved maximum of 1.2 A, showed that BIM may be present in certain regions of the vacuum chamber. We are investigating this effect by simulation, and we expect to correlate our results with further experiments during the next commissioning run.

We have also continued our simulation studies of the ECE for the LHC,[4] as part of the US-LHC project that is described further in Chapter 6. In the case of the LHC, the main consequence of the ECE is not a serious instability, but rather, a significant power deposition in the vacuum chamber walls from the electrons as they "rattle around" under the influence of successive proton bunches passing by. We have focused our attention on the dependence of the power deposition on certain parameters of the secondary emission spectrum, and also on the contribution of backscattered and rediffused electrons. We have found that these effects are significant, raising the estimate of the power deposition in the arc dipole magnets to as much as ~2.1 W/m, substantially higher than the ~0.75 W/m from our previous estimates that did not take these effects into account. As a result, we are evaluating proposed[5] mitigating mechanisms.

Beam-Beam Effect in a Muon Collider

The desire to have a muon collider with high luminosity, combined with the instability of the muon, places serious constraints on the lattice design of this machine. In particular, lattice nonlinearities are severe owing to the small ring size, and the beam-beam interaction has a strength comparable to that of a mature electron-positron collider.[6] Traditionally, the beam-beam interaction and lattice dynamics have been studied separately. For the muon collider, however, this separation might not provide a good approximation.

We have made an initial improvement[7] by carrying out multiparticle tracking simulations in which the lattice is represented by a nonlinear map obtained from the program COSY INFINITY[8] and the beam-beam interaction is represented by a thick lens. In this initial investigation there were several limitations:

[4] M. A. Furman, "The electron-cloud effect in the arcs of the LHC," LBNL-41482, May 20, 1998.
[5] O. S. Brüning et al., "Electron cloud and beam scrubbing in the LHC," *Proc.* 1999 IEEE Particle Accelerator Conf. (New York, New York, March 29-April 2, 1999).
[6] "Status of muon collider R&D and future plans," BNL-65-623, Fermilab-PUB-98/179, and LBNL-41935, Sept. 1998.
[7] "Beam-beam effect and dynamic aperture of the muon collider," *Proc.* 1999 IEEE Particle Accelerator Conf. (New York, New York, March 29-April 2, 1999); LBNL-42687, March 29, 1999.
[8] M. Berz, *COSY INFINITY v8 User's Guide and Reference Manual*, Nov. 7, 1997.

- The beam-beam interaction was represented only in weak-strong mode, assuming a tri-gaussian density distribution.

- The map did not incorporate rf cavities.

- Longitudinal beam-beam forces, radiation, quantum excitation, and the mutual interactions of the particles within the bunch were wholly neglected.

- We took the muon to be a stable particle, and assumed that there are no physical apertures anywhere in the ring.

The map was represented by a 9th-order polynomial in the six phase-space variables. For the particular lattice design we studied, the map has 5040 nonzero polynomial coefficients. We carried out single-particle studies (beam footprint and dynamic aperture calculation), and multiparticle tracking (evolution of the beam sizes in time).

Figure 4 shows the dynamic aperture boundary computed with and without the beam-beam interaction. It can be seen that there is little difference between the two cases. Therefore our results confirm the generally accepted rule that lattice nonlinearities do not affect the beam-beam dynamics significantly near the beam core. This result is confirmed by multiparticle tracking, which shows that beam size evolution is primarily determined by the beam-beam interaction. It is gratifying that this result is valid even in the case of this design, whose dynamic aperture is markedly smaller than in typical e^+e^- machines. We conclude that the luminosity performance will not be detrimentally affected by nonlinearities and, conversely, that the dynamic aperture will not be not significantly affected by the beam-beam interaction.

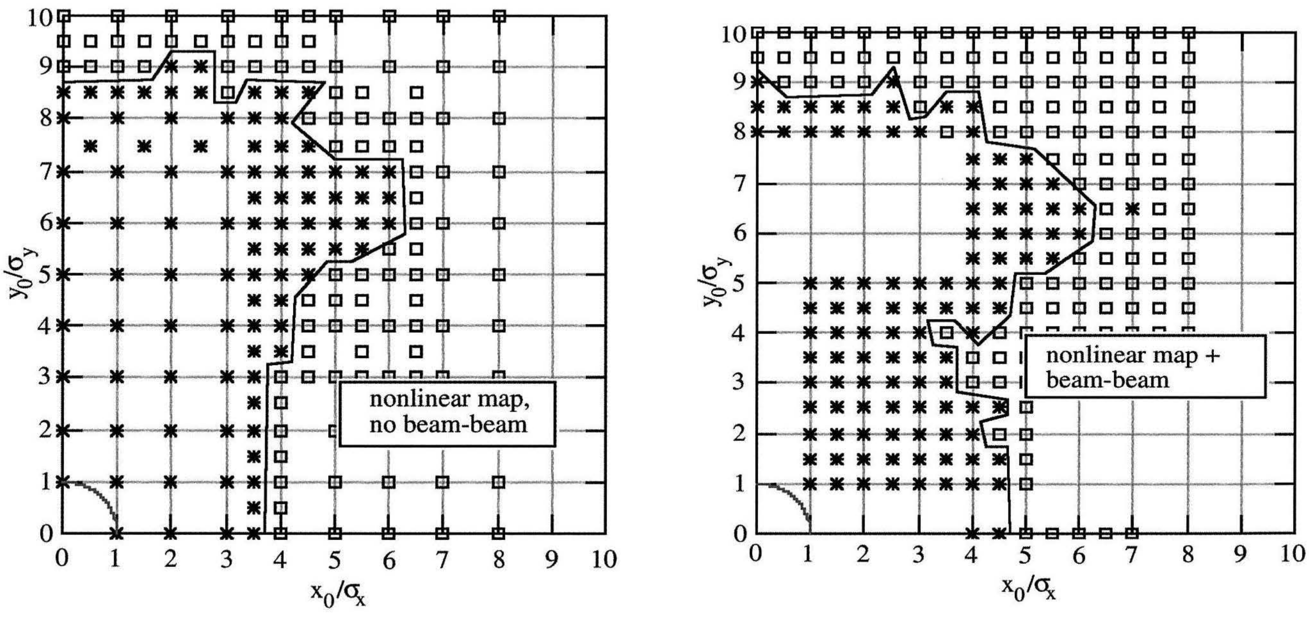


Figure 4. Left: dynamic aperture for the map without beam-beam. Right: map plus beam-beam. Crosses indicate particles that survived for 1000 turns, boxes those that did not. The hand-drawn polygon is meant to guide the eye along the dynamic aperture boundary. The quarter-circle at the lower left corner is the one-sigma beam profile.

Beam-Beam Effect for the Large Hadron Collider

The LHC will operate with two high-luminosity interaction points (IPs) in which the beam-beam parameter will be ~0.003, which is roughly a factor of 3 larger than in any hadron collider ever operated before.[9] We have carried out a first effort[10] to study the beam-beam interaction for the LHC by means of multiparticle tracking simulations in "strong-strong" mode with the code CBI.[11]

CBI (Collective Beam-beam Interactions) is a self-consistent code that models the transverse beam-beam dynamics of beams of arbitrary distribution and ellipticity. The two beams are dynamical in the sense that each affects the other during the collision (which is the definition of "strong-strong" mode). The code uses a particle-in-cell (PIC) calculation of the beam-beam force on a two-dimensional (transverse) Cartesian grid. The code is under development and presently has the following assumptions:

There is only one bunch per beam and only one collision point.

- The beams are ultrarelativistic.
- Longitudinal dynamics is not modeled.
- Arc transport is linear.
- Radiation damping and fluctuations are put in once a turn and at one point in the ring.
- The crossing angle is zero.
- Transverse dimensions and distributions of the beams can be completely arbitrary.

CBI is best suited for studying collective beam-beam effects in storage-ring e^+e^- colliders, particularly quadrupole effects (which affect the beam sizes). To our knowledge, quadrupole collective effects have never been studied for hadron colliders, and it seemed interesting and timely to undertake this study for the LHC. In particular, in light of a proposal for sweeping one beam around the other as a diagnostic for head-on collisions,[12] it seemed relevant to look at possible beam-size blow-up and distortion as a consequence of quadrupole collective effects.

We have tracked the beams for only 90,000 turns; although this is far longer than in typical e^+e^- simulations, it is a short time compared to the LHC damping time of 10^9 turns. In this sense our results are preliminary. We have found that, for nominal LHC parameters, and assuming only one bunch per beam, there are no collective (coherent) beam-beam instabilities. We have investigated the effect of sweeping one of the beams around the other and found that this operation does not cause any problems at the nominal current, though at higher currents there can be beam blow-up and collective beam motion. We are planning further studies in which the abovementioned limitations are removed in turn.

Novel Acceleration Concepts

The tremendous growth in accelerator energy during this century has been truly remarkable. However, the workhorse of this success, the microwave powered structure, has more or less reached its known limit in acceleration gradient. To continue its role well into next century as a primary instrument for exploration of fundamental physics at the high energy frontier, a microwave-powered accelerator will have to be powered by electromagnetic waves of much shorter length. Scaling down the dimensions of present-day technology is unattractive in the long run. The demand for high gradient acceleration has stimulated widespread interest in fundamentally different concepts and principles, such as laser acceleration.

[9] *The Large Hadron Collider: Conceptual Design*, CERN/AC/95-05 (LHC), 20 October 1995.
[10] S. Krishnagopal, M. A. Furman and W. C. Turner, "Studies of the Beam-Beam Interaction for the LHC," LBNL-43061, March 29, 1999; poster presentation, 1999 IEEE Part. Accel. Conf. (New York, New York, March 29-April 2, 1999).
[11] S. Krishnagopal, Phys. Rev. Lett. **76**, 235 (1996).
[12] W. C. Turner, "Luminosity instrumentation for the absorbers in the low beta insertions of the LHC," LBNL-42180 (August 1998), submitted for publication to Physical Review Special Topics—Accelerators and Beams.

Despite the impressive progress made in laser acceleration in recent years, high gradients have been demonstrated only over very short acceleration distances, up to a couple of centimeters. Standing between proof of principles and real-world applications are three major limitations. First, the distance of laser-particle interaction is limited by laser diffraction. Second, the distance over which a particle can continuously gain energy from a wave is limited by acceleration phase slippage due to the difference between particle speed and phase velocity of the wave. Finally, an acceleration structure, to be capable of both guiding laser field and harnessing energy transfer, has to withstand high laser power, and its effectiveness is limited by its laser damage threshold. Evidently, the key entry for a breakthrough is at the last point.

To overcome the three major limitations, we are developing a unified conceptual framework, based on solid-state open waveguide structures, for two classes of laser acceleration: direct acceleration with the longitudinal field and acceleration driven by the ponderomotive force of the transverse field of a laser. Through this study, innovative concepts and solutions are proposed that are crucial to all mainstream approaches of laser acceleration, whether in vacuum, gases or plasmas. In particular, two types of open waveguides are studied in detail: capillary waveguides and open iris-loaded waveguides. With these approaches, single-stage distance for high gradient acceleration can be increased to many meters.

Study of Interaction Point Physics for Future Linear Colliders

The interaction point (IP) of a linear collider is where intense beams from accelerators are brought into collision The collision products and processes place constraints upon the design of the collider as a whole. One of the most important constraints on the performance of an e^+e^- linear collider is that imposed by quantum-electrodynamic processes at the IP, in particular beamstrahlung. The approach to suppression of this process used in all current designs at 0.5 TeV scale will become more difficult technically, and less effective, at higher energy.

We have studied an effect known as quantum suppression of beamstrahlung (QSB) and examined the feasibility of utilizing the effect as an IP approach for future linear colliders. Unlike all other approaches that work on suppressing beamstrahlung by reducing or eliminating if possible the strong beam field, QSB is effective only when the beam field is sufficiently strong. In that regard, it is compatible with the ever-increasing beam density required of a linear collider at higher energy, so it deserves a careful investigation.

We have conducted an integrated case study of a linear collider designed to take advantage of quantum suppression. Monte Carlo simulations are carried out in steps from beam-beam interaction taking into account of all major QED processes, to generation of hadronic background events due to collisions of beamstrahlung photons, to simulation of detector environment, to analysis of background effect on a particular experiment of particle physics. As shown in Figure 5, our study indicates that QSB is indeed a promising IP approach for future linear colliders.

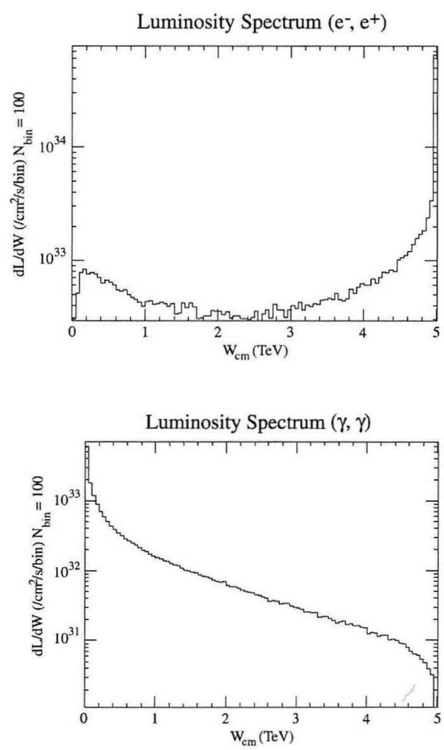


Figure 5. Some results of our simulation of Quantum Suppression of Beamstrahlung (QSB) for e^+e^- (*upper*) and gamma-gamma (*lower*).

Beam Electrodynamics

The increasing variety and difficulty of the radiofrequency manipulations needed by today's accelerators generates new opportunities for the Beam Electrodynamics Group (BEG). As specialists in microwave and radiofrequency manipulation, diagnostics, and instrumentation of charged particle beams, we have contributed to several projects. Our activities during the year have involved crucial work for the Next Linear Collider (NLC), the muon collider, the PEP-II B factory, the Advanced Light Source, the Relativistic Heavy Ion Collider (RHIC), and collaboration with industry.

Components for the Damping Rings of the Next Linear Collider

As part of the NLC pre-conceptual-design and R&D program, we have begun work on high-power rf systems, damping wigglers, and injection and extraction systems for the damping rings. A Memorandum of Understanding between SLAC and LBNL outlines the scope of work in which LBNL will be involved. We have targeted crucial components and systems for the damping rings as requiring immediate R&D in order to allow timely production for the rings, minimize technical risk, and improve cost estimates for the conceptual design stage. The R&D program will ensure that the damping rings reliably provide stable beams for injection into the linacs. Berkeley Lab is well suited to the task of design and R&D for the NLC damping rings, given our recent responsibilities for the design and construction of the 3 GeV Low Energy Ring for the PEP-II B-factory, as well as the 1.5 – 1.9 GeV Advanced Light Source here at Berkeley. Table 2 gives some significant parameters for the NLC damping rings.

Building on our experience with the successful higher-order-mode (HOM) damped accelerating cavities built for PEP-II B-factory, we are developing similar structures for the NLC damping rings. The requirement is to reduce HOM impedances by two to three orders of magnitude, such that coupled-bunch growth rates are below radiation damping thresholds, or in a regime where fast feedback systems may control residual oscillations of the beam. While damping the HOM's, it is important not to severely degrade the performance of the accelerating mode of the cavity.

	Pre-damping ring	Main damping rings
Energy (GeV)	1.9 – 2.1	1.9 – 2.1
Circumference (m)	214	297
Bunch spacing (ns)	2.8	2.8
Fill pattern	2 trains 95 bunches 2 gaps 100 ns	3 trains 95 bunches 3 gaps 68 ns
Damping time (ms)	< 5.21	< 5.21
N_{max} /bunch	1.9×10^{10}	1.6×10^{10}
Current (mA)	800	750
Injected emittance X/Y (m-rad)	$< 6 \times 10^{-2}$	$< 150 \times 10^{-6}$
Extracted emittance X/Y (m-rad)	$< 1 \times 10^{-4}$	$< 3 \times 10^{-6} / 0.03 \times 10^{-6}$
RF voltage (MV)	2	1.5
Momentum compaction	0.0051	0.00066
Bunch length (mm)	8.4	3.8
Straight length (m)	43	58
Wiggler length (m)	34	44
Wiggler period (m)	1	0.27
Wiggler field (T)	≈ 2	≈2
Maximum rep. rate (Hz)	120	120

Table 2. Important parameters of the envisioned NLC damping rings.

Figure 6 shows an exploded view of the 714 MHz cavity, with a section of the cavity body cut away. The beampipe can be seen on the lower end of the cavity, and the three damping waveguides with a "dogbone" cross section towards the top of the picture. Inside the cavity, the reentrant nosecone and circular coupling port with narrow ridge can be seen. The three waveguides will contain microwave absorptive materials, which absorb power deposited in the cavity HOM's, thereby reducing the impedance.

Figure 6. Cutaway of a 714-MHz cavity. The beampipe slants from top to bottom in this view.

Figure 7 shows results of a computation of longitudinal modes using the MAFIA code in time-domain for a similar cavity based on PEP-II cavity dimensions. The accelerating mode (in this example at 476 MHz) has an impedance of a few MΩ and is off-scale in this plot. A much lower impedance of 2 kΩ or less can be seen for the HOM's, demonstrating the effectiveness of the waveguide loaded cavity damping.

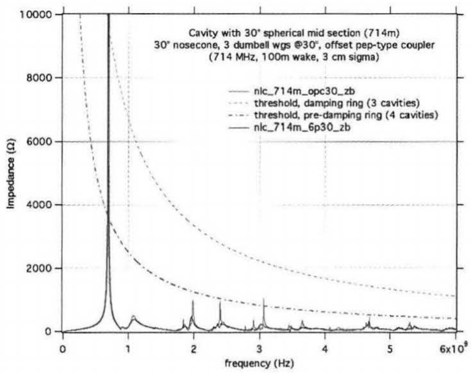


Figure 7. Calculated impedance of the NLC Damping Ring RF Cavity. The fundamental (accelerating) mode extends off scale at 714 MHz, and the higher-order-models are seen to be significantly reduced in impedance by the damping waveguides. Thresholds for the damping ring and pre-damping ring coupled-bunch instabilities are also shown.

Working with the ALS magnet group, we have begun design of a wiggler magnet for the damping rings. The damping provided by the wiggler is twice that of the bend magnets, and is an important factor in providing the NLC luminosity. The baseline design consists of an electromagnetic wiggler with steel pole pieces, and samarium cobalt permanent magnet attachments to avoid saturation of the field at the pole tip. A pure permanent magnet design is currently not favored due to the high-radiation environment in a storage ring operating at 120 Hz, with 60 kW beam power. A cross-section of the design is shown in Figure 8. Synchrotron radiation is absorbed on water-cooled sides of the vacuum chamber, in a similar design to that used in PEP-II LER wigglers. Distributed NEG pumps directly underneath the photon stop absorbs the vacuum load.

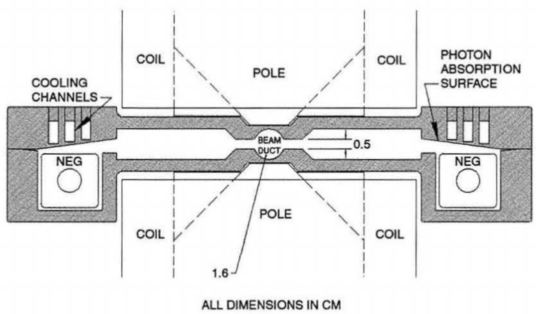


Figure 8. Cross section of a wiggler for the damping rings.

In addition to design of rf and wiggler components, we are performing R&D on the injection and extraction kickers, and developing the impedance budget for the damping rings. Measurements performed using the facilities developed in the Lambertson Beam Electrodynamics Laboratory are an important part of this work, and complement our expertise in performing state-of-the-art three-dimensional computer modeling of electromagnetic devices.

RF Systems for the Muon Collider

Beam Electrodynamics Group staff have been involved in the muon collider collaboration since its formation, and have made significant contributions to the design of rf structures for the experimental program, as well as other physics studies. Our staff are involved with the targetry experiment, to demonstrate the production and capture of high-flux pion beams, and the cooling experiment to demonstrate ionization cooling of a muon beam. Both experiments require advanced concepts in RF technologies.

In the ionization-cooling channel, the muons lose momentum by scattering in a "target," after which rapid re-acceleration in a linear accelerator restores the longitudinal momentum. Repeated application of this process, and transverse-to-longitudinal momentum exchange in bent solenoids, results in cooling of the muon beam six-dimensional phase space. Our responsibility has been in the design of the accelerating structures, and the study of wakefields in the linac section. Table 3 lists parameters for the cooling channel rf systems.

To maximize the shunt impedance, we make use of the muon's ability to pass through thin material without significant interaction, and we insert thin (125 μm) beryllium foils at each end of the accelerating cavity. These foils isolate each cell from its neighbors, and form a pillbox structure. The peak surface field is then equal to the peak accelerating field on the cell axis. To couple the cells in the linac structure, we connect alternate cells via coupling cells, and form two such chains with the accelerating cells interleaved. By appropriately phasing the drive in each chain, we obtain a large transit time factor, and a high shunt impedance for the structure. To gain another factor of two in shunt impedance, and to improve stresses from rf induced heating of the beryllium foil, we propose to cool the structure with liquid nitrogen. Figure 9 shows a schematic of this $\pi/2$ interleaved structure , as well as a photograph of the low-power test cavity with end cover removed, exposing the beryllium foil window.

Frequency (MHz)	805
Muon momentum (MeV/c)	180
Relativistic ß	0.87
Average accelerating gradient (MVm^{-1})	34
Beryllium window thickness (μm)	< 127
Transit time corrected shunt impedance ($M\Omega m^{-1}$)	37.8
Q_o	19600
Transit time T	0.9
Filling time (μs)	3.9
Cell length (cm)	8.1
Power for 34 MVm^{-1} ($MW\ m^{-1}$)	31

Table 3. Parameters of the cooling channel rf systems.

Figure 9. RF cavity (clockwise from top left): internals, schematic, and test preparations.

Our experiments with a low-power test cavity will help to understand the complications of operating a high-power rf system with thin metal foils, including the effects of cooling to liquid nitrogen temperatures, and rf power dissipation in the foil. Figure 9 also shows the test cavity undergoing rf measurements before being inserted into a vacuum tank for cooldown.

Harmonic Cavity Systems for the ALS

We are continuing to apply our group's capabilities to the improvement of the Advanced Light Source (ALS) here at LBNL. Our latest involvement has been in the design of a third harmonic RF system to induce bunch lengthening without an increase in energy spread, and thereby improve beam lifetime without other unwanted effects. Cavities tuned near to the third harmonic of the accelerating rf system, approximately 1.5 GHz, are inserted into the storage ring.

These cavities are excited by the passage of the beam, and resonate generating an rf voltage, which perturbs the total voltage, experienced by a bunch. By careful tuning of the cavities, the resulting rf potential is flattened over the length of the bunch, and as a result the bunch length increases. The longer bunch length reduces the volume of the bunch, and reduces the large-angle intra-beam scattering of electrons within a bunch, thereby increasing the Touschek lifetime. This improvement in lifetime is expected to be a significant benefit for users of the ALS facility.

Figure 10 shows a third-harmonic cavity before machining of the flange details. The cavity body is machined from two copper pieces, which are assembled and measured in the Lambertson Beam Electrodynamics Laboratory and tuned to the appropriate resonant frequency. After tuning, the cavity parts are electron beam welded together, and copper is plated over the cooling channels machined into the outside. (Machining, welding, and plating are performed by our collaborators at LLNL.) The resulting smooth surface, with water coolant pipes protruding, can be seen in the photograph. In the design and manufacture of this cavity, we have drawn on our experience with the PEP-II B factory cavities, and with our collaboration with LLNL in high-quality manufacturing techniques.

Schottky Signal Beam Diagnostics for RHIC

The Beam Electrodynamics Group has maintained its history of involvement in stochastic cooling by continued study of the beam diagnostics requirements for the Relativistic Heavy Ion Collider being built at Brookhaven National Laboratory.

The incoherent, or Schottky, signals from the beam can provide useful information on beam characteristics. These include momentum spread (from the frequency spread of longitudinal signals), synchrotron tune, transverse emittance (from the amplitude of transverse signals), and the fractional incoherent betatron tune. Detection of the incoherent signal of a bunched beam is complicated by the presence of the much stronger coherent signal. The latter is (usually) expected to appear most strongly at the rf frequency and its harmonics, but produces strong signals at all multiples of the revolution frequency, as well as at their betatron sidebands; its power scales with the number of particles per bunch N as N^2 whereas that of the incoherent signal scales as N. Since N typically is 10^9 or greater, the incoherent signal is many orders of magnitude weaker than the coherent signal. For a Gaussian bunch, in the

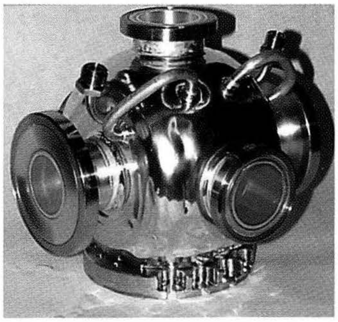


Figure 10. ALS third-harmonic cavity for flattening the rf potential over the length of a bunch, and thus reducing large-angle intrabeam scattering within the bunch.

absence of intra-bunch oscillations the coherent signal spectrum is limited in extent to maximum frequencies of the order of

$$f \text{ roll-off} \approx \frac{1}{2\pi\sigma}$$

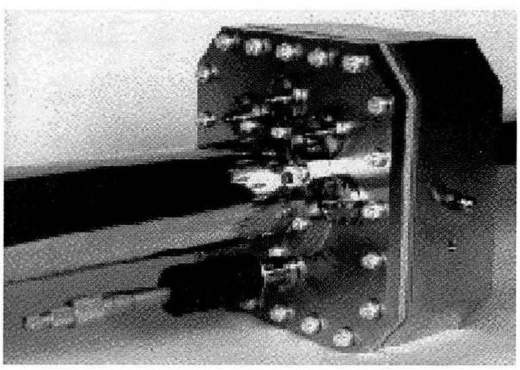
where s is the bunch length. The rate of fall-off of the coherent signal with frequency depends on the details of the bunch shape, but for most shapes it is usually tens of dB per octave for at least several octaves beyond *froll-off*. If the coherent signal can be reduced to within even 20 or so dB above the Schottky signal, the latter can usually be distinguished from the former on the basis of its greater frequency spread. For a typical bunch length of approximately 1 ns in RHIC, the roll-off frequency is about 160 MHz.

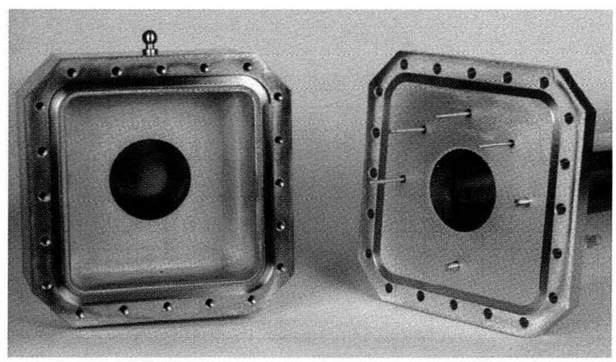
To maximize the signal-to noise ratio of the extremely weak Schottky signals, one wants a high-shunt-impedance detector such an a resonant cavity (Figure 11); to maximize the signal-to-coherent-background-signal ratio, one chooses a cavity resonant frequency as far above *froll-off* as possible, consistent with it not exceeding the cutoff frequency of the attached beam pipe.

(The RHIC beampipe cut-off frequencies are 3.3 GHz for TM modes, and 2.5 GHz for TE modes.) A further refinement is to operate the cavity at a frequency that is approximately a half-integer multiple of the rf frequency, in order to minimize the contamination from any residual coherent signals. The RHIC rf frequency of 197 MHz results in a multiple of 10.5 to arrive at an operating frequency of 2.07 GHz.

HMode		
TM_{120}	Frequency	2.071 GHz
	$Q_{unloaded}$	10,000
	$R_{\wedge}T^2/Q$	900 Ω
	$R_{\wedge}T^2$	9 MΩ/m
TM_{210}	Frequency	2.067 GHz
	$Q_{unloaded}$	10,000
	$R_{\wedge}T^2/Q$	900
	$R_{\wedge}T^2$	9 MΩ/m

Table 3-4. Key parameters of the Schottky cavity.





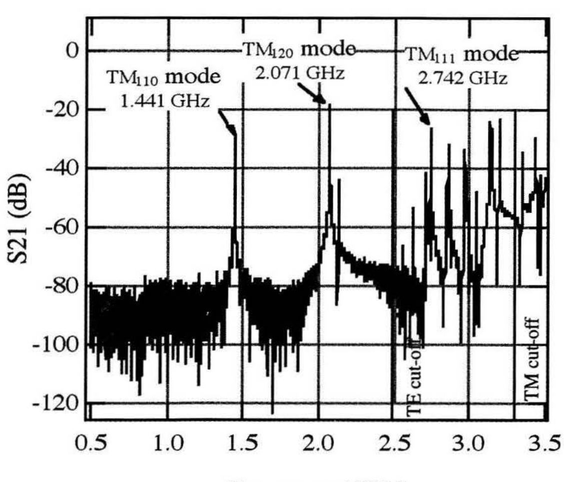


Figure 11. A cavity open for tuning (top left) and fully assembled for installation in the RHIC storage rings. The graph shows the spectrum measured from the vertical coupling probe to a 45° probe.

Industrial Collaborations in Technologies for Small Accelerators

Linear accelerators are manufactured commercially by several industrial concerns. Normally, the rfpower to these systems is provided by a klystron amplifier to achieve a beam power above approximately 10 kW. This klystron, and its associated modulator (dc power supply), are large and expensive components. Another potential rf power source, the magnetron, has in the past been limited to output powers of approximately 1 to 5 MW peak, and a few kW average power. The first stage of this project has been to develop the technology for production of a high-power magnetron to be used as the microwave power source instead of a klystron amplifier. An average power level of over 50 kW has been achieved. At the 50 kW level, the magnetron may be used to accelerate electron beams of 30 - 40 kW beam power. The magnetron has distinct advantages: the voltage required to operate the magnetron is lower than those required by a klystron, and the physical size and complexity of the device is reduced.

In the next stage of the project we propose to develop linear accelerator systems based on the magnetron as an rf power source. The magnetron technology is a development of magnetron design and manufacturing skills developed by the NIS partner State Research and Production Corporation (SRPC) or "Toriy," located in Moscow, Russia. Accelerator skills will be introduced by other NIS partner, the Moscow Engineering Physics Institute, and modulator expertise from NIS partner All-Russian Scientific Research Institute of Experimental Physics. The project will continue to involve Berkeley Lab's Beam Electrodynamics Group of the Center for Beam Physics, and also the U.S. industrial partner AS&E Corporation.

Relativistic-Klystron Two-Beam Accelerator

As a power source for linear colliders, the two-beam accelerator or TBA (see Figure 12), a concept developed by Andrew Sessler of the Center for Beam Physics, has the inherent advantage of very high efficiency for power conversion from the drive beam to rf power. In addition, TBAs based on induction linacs would scale quite favorably to high frequencies (≥11.4 GHz) and high accelerating gradients (≥100 MV/m). Recent reacceleration experiments at the LLNL Advanced Test Accelerator have demonstrated bunched beam transport through two reacceleration induction cells and three traveling-wave extraction cavities for a total rf output of over 200 MW. The phase and amplitude were shown to be stable over a significant portion of the beam pulse.

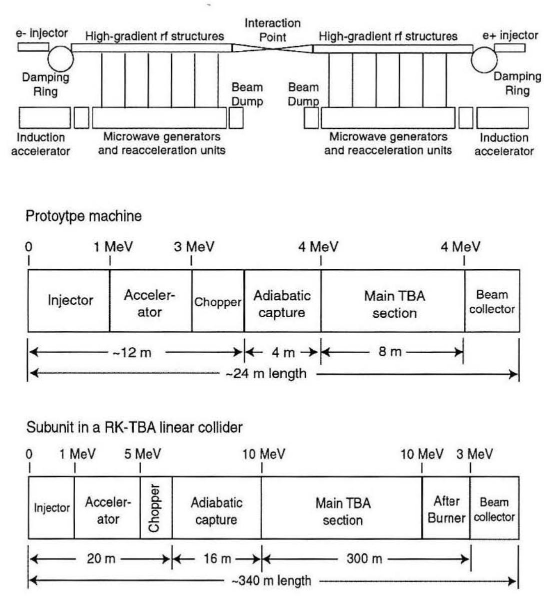


Figure 12. In the Two-Beam Accelerator, a high-current, low-energy drive beam is used for generating rf power that is applied to a high-gradient acceleration structure, where a low-current load beam is accelerated to high energy. Relativistic klystron would generate the rf power in the example we are studing for possible NLC applications, although we have also done research on wiggler-based TBAs. The point design for the RK-TBA of the NLC is also shown, as is the far shorter RK-TBA proof-of-concept prototype that we would like to build and operate at LBNL.

The technical challenges for making TBAs into real-world power sources lie in the dynamics of the drive beam, which is quite high in current (hundreds of amperes) and must propagate over long distances. In particular, the beam break-up (BBU) instability through the long multi-cavity relativistic klystron two-beam accelerator (RK-TBA) is known to be severe. While BBU suppression techniques have been successfully demonstrated for a few cavities, a scenario with acceptable BBU control over many traveling-wave cavities must be constructed. Similarly, the longitudinal stability of the rf bunches over a multi-cavity RK-TBA must be demonstrated. In addition to technical feasibility, a case for economic attractiveness is no less essential for the viability of the RK-TBA as a power source.

With these general considerations in mind, we performed a conceptual study, including physics and engineering designs and "bottom-up" cost analysis, for a new version of the RK-TBA that has acceptable longitudinal and transverse beam stability, as well as low cost and high efficiency. This RK-TBA is designed as a power source for a linear collider with ≥1.5 TeV center-of mass collision energy, representing the upgrade phase of the NLC.

RK-TBA Design, Specifications, and Progress

To generate an unloaded gradient of 100 MV/m in the NLC high-gradient structures, the RK-TBA must supply 360 MW of rf power at 11.4 GHz every 2 meters of the main linac's length. The output rf field is specified to have a 100-ns linear risetime followed by a 200-ns flat top. The repetition rate is 120 Hz. To power a 1.5-TeV 22.8-km-long collider (two 11.4-km arms), we propose 76 RK-TBA units, each 300 m long, operating at an average drive beam energy of 10 MeV, with an average current of 600 A over the duration of the pulse, and a reacceleration gradient of 300 kV/m.

The front end of each RK-TBA unit consists of a 1.5-kA injector, followed by an rf chopper at 2.5 MeV and then an "adiabatic capture" unit in which the chopped beam (average current 600 A) is accelerated to 10 MeV and further bunched with idler cavities in preparation for injection into the main RK-TBA. To enhance the efficiency of the RK-TBA system, an "afterburner" at the end of the main RK-TBA continues to extract rf power through 12 successive output cavities before depositing the spent beam (average beam energy below 3 MeV) at the beam dump. The overall conversion efficiency of drive-beam power to rf power of each RK-TBA unit is 90%.

The new RK-TBA design is based on the technology of the long-pulse (few microseconds) induction machines that have been studied over the last 18 years for heavy ion fusion applications and is also being applied to the Dual-Axis Radiographic Hydrodynamic Test facility, as described in Chapters 1 and 6 of the *1998 AFRD Research Highlights*, respectively. The magnetic material used in this design is Metglas, a metallic glass product that can accommodate a large magnetic flux swing—nearly 3 tesla—before saturation. The induction cores can therefore be made quite compact. Nonaccelerator applications of this material over the last few years have led to dramatic reductions in the cost of Metglas. The small Metglas cores, when combined with low-field (800 gauss) permanent magnets for quadrupole focusing, and small beam pipes (5-cm diameter), have led to a compact induction cell design whose transverse diameter is about 34 cm — much smaller than any of the previously known induction cell designs.

The pulse power for the induction cells comes from a low-voltage system. The induction cores consist of small 20-kV units, powered by pulse forming networks (PFNs) switched by thyratrons. Power is fed into the PFNs via dc power supplies and command-resonant charging (CRC) systems. The low-voltage design avoids step-up transformers, which have high losses. The main losses in the system are associated with core currents in the induction cells. Overall efficiency of the pulse power system (from wall plug to drive beam) is estimated at 40%.

The rf extraction cavities are located every 2 meters. Present designs center on traveling-wave structures with three inductively detuned rf cells, with an inner radius of 8 mm. Two iris waveguide structures in the last cell are matched for power extraction. Longitudinally, beams will debunch because of space-charge-and rf-induced energy spread. To counter these debunching effects, the rf output cavities are inductively detuned. This is accomplished by making the phase velocity of the three-cell traveling-wave structure faster that the velocity of the particles. The particle bunch lags behind the deaccelerating crest of the wave, and the energy loss becomes phase dependent, with the particles at the bunch tail losing the least energy. Kinematics cause the tail to catch up with the head of the bunch, which is followed by synchrotron oscillation in stable rf buckets. PIC simulations with a coupled cavity circuit model show stable propagation through 150 cavities. For comparison, cavities with no inductive detuning are shown to result in particle debunching after a few cavities.

A key design feature of this particular RK-TBA is that the betatron period is exactly equal to the spacing between adjacent output cavities. This "betatron-node" scheme leads to minimal beam offset at the rf cavities. Excitation of the HEM_{11} mode at 14 GHz is drastically reduced as a result. Transverse dynamics have been modeled with a beam-breakup code that includes both cumulative and regenerative effects: it shows BBU growth is acceptable, less than 4 e-folds. The cavity parameters for these simulations were obtained from the codes URMEL and MAFIA. For a 8-mm radius cell, a natural de-Qing of the dipole mode occurs because of the coupling to the TE_{11} mode in the beampipe. The betatron-node scheme imposes constraints on the accuracy of the focusing fields and beam energy. Sensitivity studies to this point indicate that without feedback, the field errors must be less than $\pm 1\%$ and energy variation from head to tail must have comparable accuracy.

There is another low-frequency BBU mode, associated with the induction gaps, that must be controlled. The relatively low current of 600 A, combined with the Landau damping that occurs naturally because of the energy spread in the rf buckets, again kept the simulated BBU growth below 4 e-folds in a 300-m long RK-TBA subunit. To achieve this low growth, the induction gaps were designed for maximal dipole de-Qing, using the induction-cavity design code AMOS.

A preliminary design report for our systems study has been completed. On the basis of this design, a joint proposal between LBNL and LLNL was submitted to DOE for a seven-year RK-TBA project that will build and test a 28-m prototype. The prototype is at LBNL, in the RTA Test Facility. To date, the electron gun has been built, and an electron beam has been extracted from a hot dispenser cathode and transported to the exit of the anode stalk and into a beam dump. By design, the beam has a very low emittance (300 mm-mrad normalized edge emittance). This is the lowest-emittance beam anyone has attempted to generate at such high currents. Characterization of the extracted beam is underway.

The facility (Figure 13) will test many of the critical issues of cost, efficiency, and beam dynamics of an RK-TBA system. Should the power extraction test prove successful, the RTA could be mated to the NLC Test Accelerator at SLAC to power the NLCTA high-gradient structures to 100 MV/m. The proposed RTA work is a component of the collaborative effort by SLAC, LBNL, and LLNL, is incorporated in the NLC ZDR and was reported at the 1996 American Physical Society Division of Particles and Fields Snowmass Workshop and Study.

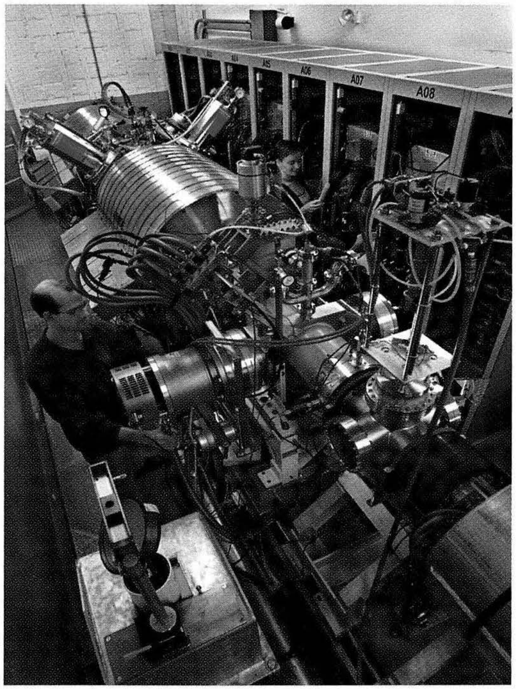


Figure 13. Students working on the RTA injector

Free Electron Lasers and Advanced Radiation Sources

FEL Design and Power Beaming to Satellites

Electrical power has always been a limiting factor for satellites, restricting the services that they can perform. The need for additional transponders to satisfy the demand for satellite-supplied television, e-mail, worldwide web, long distance telephone, rapid computer data transfer, and many other types of telecommunication is increasing. The number of transponders has risen from about 24 active transponders per satellite in the late 1980s to 94 active transponders on a Hughes satellite launched in late 1997. The demand for additional power for transponders over the last few years grows exponentially and the end is nowhere in sight.

The only practical limitation for generation of the additional power for transponders is the availability of electricity from the solar panels on the satellite. At present the size of satellite solar panels is effectively at a maximum. Additional satellites in the same "space slot" can be deployed to increase the total solar panel area, and this is where many satellite companies are going. A major drawback of this approach is that the output signals of the various satellites are out of phase, so interference between satellite transmissions can be a problem. The biggest drawback, however, is that it is very expensive to launch so many satellites.

One way to add more power to satellites is to beam concentrated light into their "solar" panels from the Earth. The problem is that the atmosphere causes distortions to the light beam. However, if the light beam has a distortion-free initial wave front, then adaptive optics can be used to avoid atmospherically introduced imperfections. In this case the light beam will propagate through the atmosphere to great distances. The wavelength 840 mm is within one of the transmission windows of the atmosphere, and, conveniently, also near the peak of the photovoltaic conversion efficiency of Si and GaAr solar panels. A beam of 200 kW average power beamed from Earth at this wavelength can increase the power level on the satellite an order of magnitude above that available from the sun.

Free electron lasers (FELs) offer excellent potential to generate high power at optical wavelengths with a distortion-free transverse coherent wave front. This is due to the simplicity (in comparison with conventional lasers) of the working medium — the electron beam. The average power in an electron beam may be about 100 MW, and corresponding power density is of the order of 1 $GW/mm.^2$ Such high power is simply the consequence of the high electron velocity; the corresponding volume energy density is only 3 $mJ/mm.^3$ Unlike conventional lasers, which all use changes of electronic energy levels in a material, the light in the FEL is generated in vacuum and has a distortion-free wavefront. However, the current state of the art for FELs generating visible light is at an average power level of 300 W. Before FELs can produce hundreds of kilowatts of visible light, a high peak current *and* high average current electron beam of about 100 MeV must be achieved. This poses a challenge to the designer.

A free electron laser called the Ignition Feedback Regenerative Amplifier (IFRA) has been designed for satellite power beaming. The main requirement of this application is that the FEL generate ~ 200 kW of coherent radiation at 840 nm. The functional scheme of the laser and some principal parameters are shown in Figure 14 below.

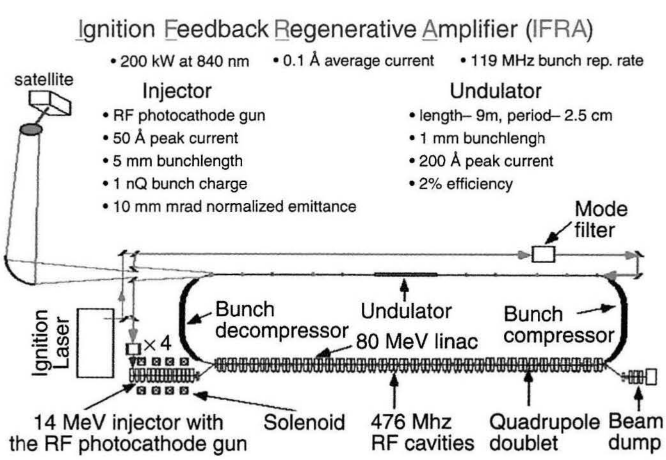


Figure 14. A schematic view of the Ignition Feedback Regenerative Amplifier.

The IFRA consists of an rf photocathode gun, an rf initial accelerator, a main linear accelerator, a bunch compressor, a bunch decompressor, a regenerative FEL amplifier, and a beam dump. A feed-back loop from the FEL undulator output to the rf photocathode gun provides the photon flux necessary to produce a high average electron beam current. Another loop in the light beam provides the input power for the regenerative FEL amplifier. A mode filter controls the power levels, which are fed back, thus preventing positive feedback loops and the electron beam instabilities associated with them.

A conventional laser is used to start up the operation of the rf photocathode gun and the regenerative FEL amplifier. The main linear accelerator (linac) is used for acceleration of electrons before radiation and deceleration of spent electrons after the radiation. If the path length from the linac through the FEL to the linac is chosen properly, the spent electrons will decelerate instead of accelerating. Their energy returns to the accelerating rf field, thus reducing demand for the rf power to the level needed to compensate for cavity-wall dissipation.

It is, therefore, tempting to save on cavity-wall dissipation by using a superconducting linac. However, it is much more difficult to deal with a high average beam current in superconducting linacs than in normal conducting linacs. For this reason, and also because of the higher cost for a superconducting linac, we choose a "room temperature" (normal conducting) linac as the main accelerator.

Deceleration of the electrons also reduces the radiation hazards in the beam dump.

Ultrafast X-Ray Pulses

The dynamic properties of materials are governed by atomic motions that occur on the fundamental time scale of a vibrational period, ~ 100 fs. This is the time scale of interest for ultrafast chemical reactions, non-equilibrium phase transitions, vibrational energy transfer, surface desorption and reconstruction, and coherent phonon dynamics. To date, our understanding of these processes has been limited by lack of appropriate tools for probing atomic structure on an ultrafast time scale. The time resolution of even the third-generation high-brightness synchrotron light sources is more than two orders of magnitude too slow for these studies. However, the desired x-ray pulses may be achieved at these sources by selecting radiation that originates from a thin ~ 100 fs temporal slice of an electron bunch. Here we describe two techniques of doing this that are being developed at the Center for Beam Physics, complementing our previous work on the Thomson source.

Laser Beam Interaction

The ~ 100 fs temporal slice of an electron bunch can be created through the interaction of a femtosecond laser pulse co-propagating with an electron bunch in a wiggler magnet. The high electric field in the femtosecond laser pulse produces an energy modulation in the electrons as they traverse the wiggler (some electrons are accelerated and some are decelerated, depending on the optical phase).

The optimal interaction occurs when the laser wavelength satisfies the well-known FEL resonance condition. In addition, the far-field laser radiation must overlap with the far-field spontaneous radiation from the electron passing through the wiggler, and the laser spectral bandwidth must match the spectrum of the fundamental wiggler radiation.

We estimate that a 35 fs laser pulse with a photon energy 1.55 eV, and pulse energy 100 μJ will produce an energy modulation ΔE @ 10 MeV, using a wiggler with 19 periods and 16 cm wavelength and a deflection parameter of 13 at an electron beam energy of 1.5 GeV.

Only electrons that temporally overlap with the laser pulse experience this modulation. The laser-induced energy modulation is several times larger than the rms beam energy spread in the typical 1.5 GeV electron storage ring. The accelerated and decelerated electrons are then spatially separated from the rest of the electron in the bend magnets of the storage ring by a transverse distance that is several times larger than the rms transverse size of the electron beam. Finally, by imaging the displaced beam slice to the experimental area, and by placing an aperture radially offset from the focus of the beam core, we will be able to separate out the radiation from the offset electrons. Figure 15 schematically shows all three phases of preparing the femtosecond x-ray pulses, and Figure 16 shows the layout.

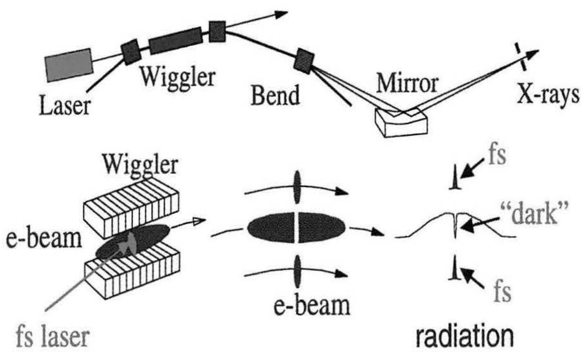


Figure 15. Preparation of the femtosecond slices of synchrotron radiation.

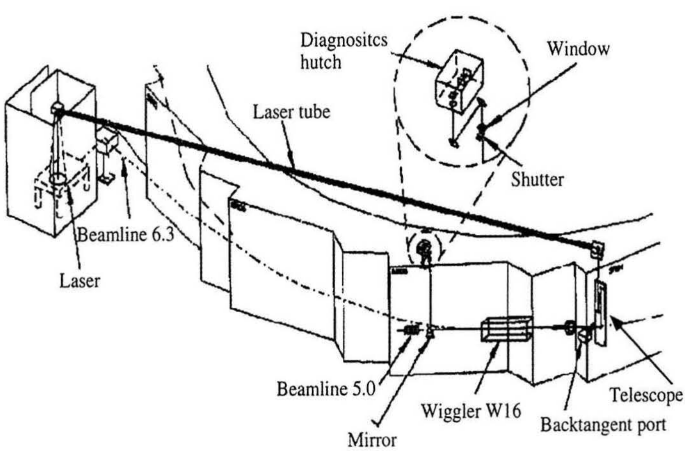


Figure 16. The layout of the experiment.

Since the spatially offset electrons result from interaction with the laser pulse, the duration of the synchrotron radiation produced by these electrons will be approximately the same as the duration of the laser pulse, and will be absolutely synchronized with it. The extraction of an ultrashort slice of electrons also leaves behind an ultrashort hole or dark pulse in the core of the electron bunch. This time structure will be reflected in the generated x-rays by beam core electrons, and can also be used for time-resolved spectroscopy. We estimate a femtosecond x-ray flux of 3 x 10^5 photons/sec/0.1% BW at 2 keV (5 x 10^4 photons/sec/0.1% BW at 10 keV) from a bend-magnet beamline at the ALS with a 3 mrad x 0.4 mrad collection optic.

Synchrotron radiation damping provides for recovery of the electron beam between interactions. Furthermore, the bunch slice is only a small fraction of the total bunch. Thus the storage ring damping time is more than sufficient to allow recovery of the electron beam between laser interactions (even for laser repetition rates as high as 100 kHz).

A proof of principle experiment has been conducted at the ALS storage ring here at Berkeley Lab. A femtosecond Ti:sapphire laser synchronized to the storage ring is located near beamline 6.3.2, and the laser beam is projected across the storage ring roof blocks to sector 5, where it enters the main vacuum chamber through a back-tangent optical port. Amplified femtosecond laser pulses co-propagate with the electron beam through wiggler W16 in sector 5. A mirror following the wiggler reflects the laser light and the visible wiggler emission out of the vacuum chamber for diagnostic purposes. Images of the near field and far field wiggler radiation are observed on a CCD camera, and the near and far field modes of the laser propagating through the wiggler are matched using a remotely adjustable telescope at the back tangent port. The spectrum of the laser is also matched to the fundamental wiggler emission spectrum.

The efficiency of the laser/e-beam interaction is tested by measuring the gain in the intensity experienced by the laser beam passing with the electron beam through the wiggler. This gain is a direct indication of the magnitude of the energy exchange between the laser and the electrons. Femtosecond duration synchrotron pulses are directly measured by cross-correlating the visible light from bend-magnet beamline 6.3.2 with the synchronized laser pulses. Figure 17 shows a laser pulse and a synchrotron radiation pulse cross-correlation measurement on a 100 ps time scale. The measured synchrotron pulse duration, σ = 16 ps, corresponds to the overall electron bunch duration. Measurement with 100 times higher time resolution (Figure 3-17b) shows the femtosecond "dark" pulse s = 112 fs), which appears as a narrow ~ 25% deep hole in the main pulse, and originates from the central core of the sliced electron bunch. Both the width and the height of the hole appear to be close to the expected values. The pulse duration

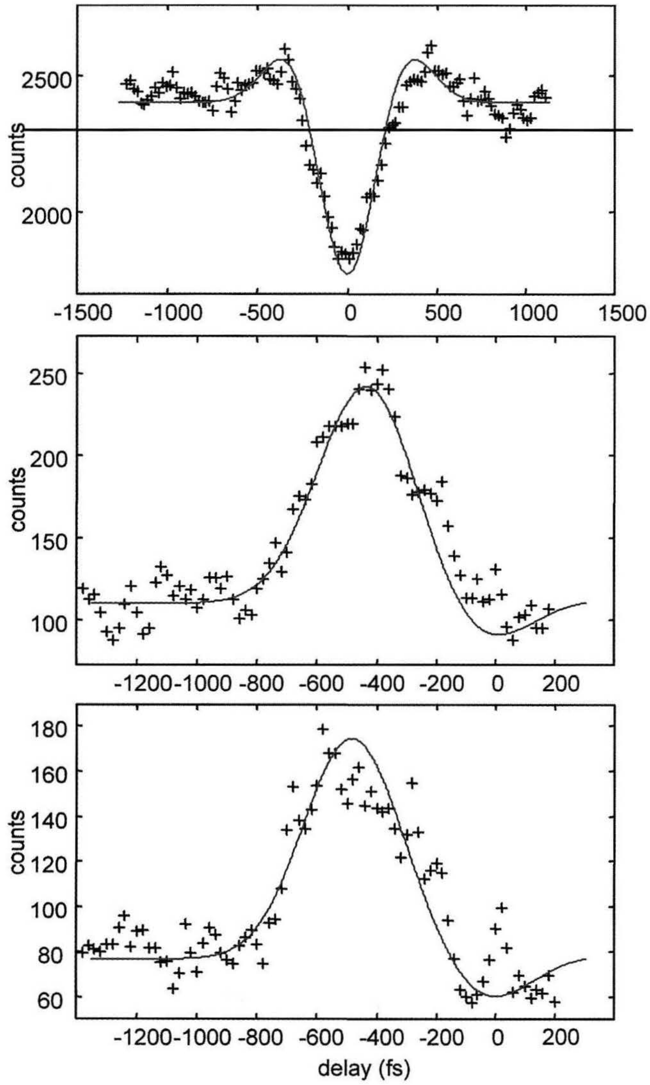


Figure 17. The measured synchrotron radiation pulse duration.

is mainly defined by a spread of the pathlengths of the electron trajectories between the wiggler and the 6.3.2 bend-magnet.

Figure 17c shows a measurement of the femto second pulse (σ = 161 fs) originating from the spatial wings of the sliced electron bunch. Note that the femtosecond time structure is invariant over the entire spectral range of bend-magnet emission from the near infrared to x-rays. An important point is that in the far infrared region (λ =100–300 mm) the narrow hole in the electron bunch radiates coherently such that the intensity of the radiation is proportional to the square of the number of missing electrons in the hole. We estimate that this radiation carries ~ 1 nJ per pulse.

RF Orbit Deflection

Another way to create femtosecond slices of electrons is rf orbit deflection. The femtosecond slices of the electron bunch are made by creating a correlation between the longitudinal coordinates of the electrons within the electron bunch and their vertical angles. While passing the accelerating structure, electrons are deflected by the rf magnetic field.

This deflection couples the longitudinal and transverse motions of the electrons. To confine this coupling in a section of a storage ring, a second accelerating structure is placed an integer number of betatron wavelengths downstream of the first accelerating structure.

Figure 18 schematically shows two accelerating structures, trajectories of the head and tail parts of the electron bunch and side views of the bunch profile in several locations as it propagates from left to right. Two types of locations along the orbit are convenient source points of synchrotron radiation for our purpose. At the A locations, the coordinate displacements of the electrons have reached their maxima. At the B locations, the variation in angle of the electron trajectories has its maximum value.

For zero beam emittance, the radiation of each femtosecond slice would be separated from the radiation of the neighboring slices if the difference in

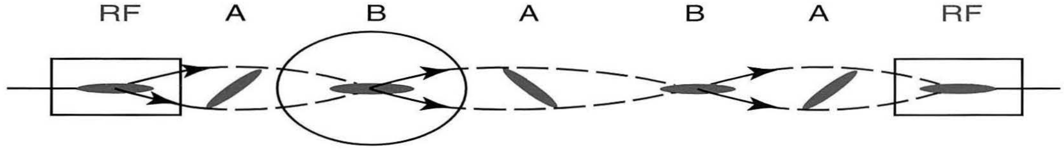


Figure 18. A schematic of the beam coupling produced by the rf cavities in the E_{110} mode.

angle or coordinate between the neighboring slices is larger than the opening angle of the radiation, in the case of the angular separation or the diffraction-limited size of the radiation. For non-zero beam emittance we need to account for the broadening of the radiation field due to the coordinate and angular spread of electrons.

The compression of the radiation of all beam slices into a single femtosecond x-ray pulse takes place in the x-ray beamline. Asymmetrically cut crystals may be used as optical elements for x-ray pulse compression. Because of the different incident and diffractive angles, they produce a variable path length across the x-ray beam.

The advantage of the rf orbit deflection technique is that femtosecond x-ray pulses are generated by every electron bunch on every orbit turn and all electrons contribute to the radiation. Therefore, the resulting flux of the x-rays is many orders of magnitude higher than in the first technique (~ 10^{13} photons/sec/0.1% BW at 5 keV for undulator radiation). However, the flux that currently can be utilized in pump-probe measurement is approximately three orders of magnitude less; it is limited by the flux available from today's femtosecond lasers.

l'OASIS

The activities within the l'OASIS Group (Laser Optics and Accelerator Systems Integrated Studies) for 1997-1999 continued to be centered around experiments involving the interaction of high intensity lasers with particle beams and plasmas. The aim is development of laser based acceleration techniques, novel ultrashort radiation sources, ultrafast beam diagnostics, and new accelerating and focusing mechanisms involving the use of electron beams in plasmas. The Group has developed two experimental facilities: the Beam Test Facility (BTF), which uses the 50 MeV ALS linac, and the l'OASIS Laboratory, which houses a multi-terawatt Ti:sapphire laser and a shielded cave.

The following experiments have been done or are in progress:

- Ultrafast x-ray spectroscopy.
- Plasma lens focusing.
- Laser guiding and wakefield excitation in plasma channels.
- Laser triggered electron injection and wakefield acceleration.
- Participation in the E-157 plasma wakefield acceleration experiment at SLAC

Below, a brief summary is presented of those various activities.

Ultrafast X-ray Spectroscopy

Following up on the successful 1995-1996 demonstration of the generation of femtosecond x-rays through 90° Thomson scattering of a terawatt laser pulse off a relativistic electron beam,[1] as well as the possibility of using laser beams to probe transverse and longitudinal phase space of an electron beam,[2] the laser scattering experiments have concentrated on evaluating the user potential of the Thomson scattering source. Beam time was provided to the Femtosecond Spectroscopy Group of the Material Science Division for a study of ultrafast dynamics of laser induced lattice changes in solid state materials. This effort led to a Ph.D. dissertation for Alan Chin from UC Berkeley.[3]

Plasma Lens Focusing

The second experiment that was done at the BTF was a study of return current effects in overdense plasma lenses.[4] In this regime, the plasma skin depth is comparable to the electron beam size. The plasma not only neutralizes the beam's space charge but also neutralizes its current, as a substantial fraction of the plasma current flows inside the beam evelope.

A code based on an envelope model for the electron beam propagation and a fluid model for the plasma response was developed to model the experiment (Figure 19). In addition, particle-in-cell simulations were performed using the XOOPIC code[5] developed by Prof. C. K. Birdsall and Dr. J. Verboncoeur at UC Berkeley. Good agreement is obtained between experiment, envelope model and simulation: return current cancellation is seen to lower the plasma lens strength. This experiment resulted in a Ph.D. dissertation for Richa Govil from UC Berkeley.

The l'OASIS Laboratory: Laser Driven Acceleration Experiments

The Group has been expanding the Laser Optics Laboratory. This lab, started in 1992, is now called the l'Oasis Laboratory. It houses an excimer laser, which is used for experiments on laser guided current channels through a collaboration with the Fusion Energy Research Program, and a multi-terawatt ultra-short pulse laser system for research on laser driven acceleration.

The multi-terawatt $Ti{:}Al_2O_3$ laser system,[6] built starting in 1996, has been used at the 1- 2 TW level for experiments on laser guiding. These experiments have resulted in a Ph.D. dissertation for Paul Volfbeyn from MIT. Recently, the laser was upgraded to deliver more than 10 TW peak power at 10 Hz repetition rate through the addition of a second parallel amplifier arm. This additional laser power will be used for experiments on electron acceleration using laser wakefield excitation in plasmas. Part of the laser system is shown in Figure 3-20.

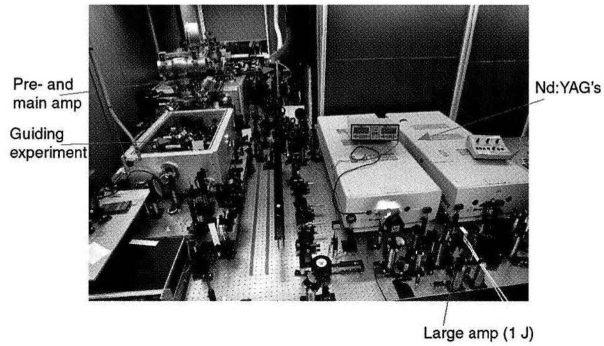


Figure 20. Part of the multi-terawatt $Ti{:}Al_2O_3$ laser system built by the l'OASIS Group of the Center for Beam Physics. The laser is in Building 71, Room 253.

The experimental program consists of three parts: comprehensive study of guiding of high intensity laser beams (10^{18} W/cm^2) over macroscopic distances (a centimeter or more) in a plasma channel; probing of plasma wakefields excited in the channels by the laser pulse using optical techniques; and study of laser triggered injection of electrons into a plasma structure.

Channel Guiding for Laser Wakefield Accelerators

To overcome the laser diffraction length limit, a novel method of plasma channel production for laser guiding, the Ignitor-Heater technique, was proposed and tested experimentally.[7] With this technique,

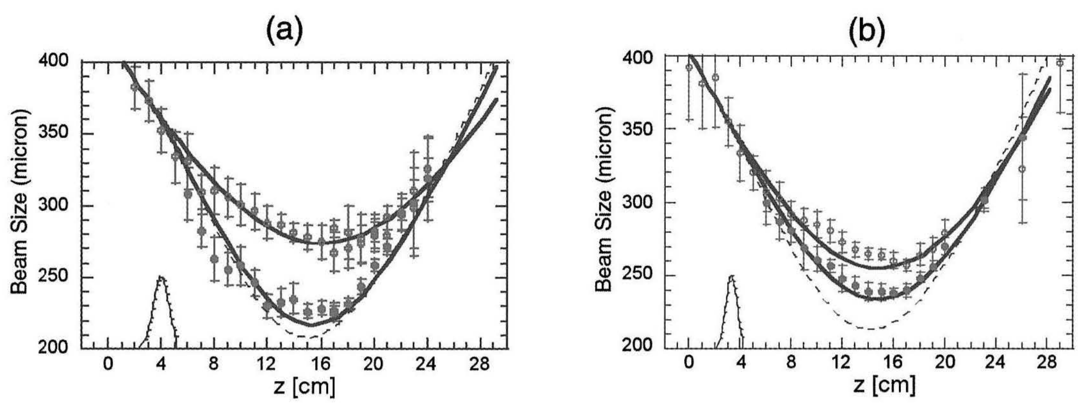


Figure 19. Measured beam size as a function of propagation distance in a) an overdense and b) a very overdense plasma. The laser produced plasma is located around z = 4 cm. The solid line is a fit through the data using the envelope model including return currents; the dashed line is a fit excluding return currents.

plasma channels can be created in hydrogen and deeply ionized nitrogen without high atomic number additives, thereby allowing high intensity laser pulse guiding. To avoid ionization induced refraction of the guided laser pulse, channels were formed in the plume of a pulsed gas jet. It should also be noted that the Ignitor-Heater scheme employs cylindrical optics that are out of the path of the accelerator beam (for plasma-based accelerator applications) and, potentially, may allow the recycling of the laser beams. The channel formation process was fully characterized with time resolved 2D longitudinal interferometry diagnostic using a sub-ps probe pulse. The shape of the initial spark was proven to affect the shape of the plasma channel. By using in-plane or orthogonal beam combining configurations, elongated, or slab channels, with 1D guiding properties and cylindrically symmetric, round, channels with guiding in both transverse dimensions were created in both nitrogen and hydrogen. See Figure 21.

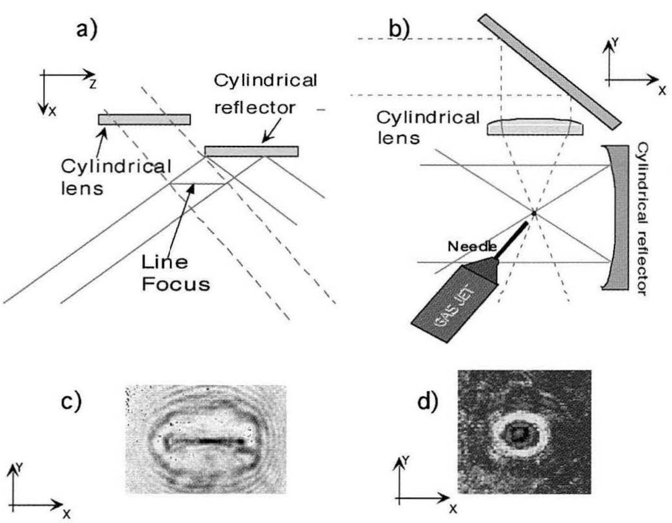


Figure 21. Ignitor-heater plasma channel production geometries: (a) In-plane laser beam combining and b) 90° beam configurations; with c) and d) the corresponding channel shadowgrams in the x, y plane.

Laser pulses at high intensity (2–5 x 10^{17} W/cm^2) were injected in nitrogen slab channels and in hydrogen cylindrical channels and observed to be guided over about 5-10 Rayleigh lengths, limited by the gasjet length. Leakage and transmission measurements for the slab channels were found to agree well with the theoretical predictions.[19] Similar measurements in cylindrical channels are underway.

Beam images of laser pulses (20 mJ in 60 fs) in vacuum and injected in round channels, produced in an H_2 gas jet, are shown in Figure 22 (a) and (b) respectively. Line profiles are shown in 21(c).[8]

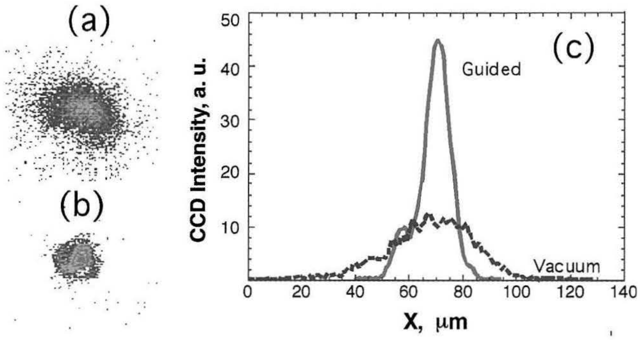


Figure 22. Transverse laser beam images for the beam propagating (a) in vacuum, (b) in a cylindrical hydrogen plasma channel, and (c) the corresponding lineprofiles. The plane imaged onto the CCD camera was located at the channel exit. The gas jet backing pressure was 1000 psi.

Single mode and multimode laser propagation in round channels was observed as a function of time delay of the probe pulse injection after the spark heating. The modal content is found to be in good qualitative agreement with predictions from a 2D leakage theory.[19] An optical diagnostic is currently being designed to diagnose the spatial density profile of the channel, and to measure the laser excited wakefields in the channel.[9] Efforts are also directed towards the development of long-scale-length, high-pressure gas jets (1-2 cm), resulting in a substantial increase in guiding distance.

Optical Injection

In the second phase of the work, optical techniques for particle injection will be studied. The generation of electron bunches with stable energy and low momentum spread, using plasma structures with characteristic scale length on the order of a few tens of mm, requires femtosecond electron bunches that have femtosecond synchronization with respect to the plasma wake. All-optical methods have been proposed for injection into a standard LWFA using a first laser pulse to generate the wake field (i.e., plasma oscillation) and a second to locally dephase electrons, which then can get trapped in the plasma wake.[10] In collaboration with researchers from the Naval Research Laboratory, we have recently proposed a colliding pulse technique for laser induced trapping of plasma electrons in a laser excited wake.[11] This novel technique is a promising avenue for the development of an all-optical particle accelerator.

In the colliding pulse scheme, three collinear laser pulses are used: an intense laser pulse (denoted by subscript 0) that generates a large wakefield (> 20 GV/m), and two counterpropagating injection pulses (denoted by subscript 1 and 2 for forward and backward, respectively). The frequency, wave number and normalized intensity of the three pulses are denoted by, ω_i, k_i, and a_i (i = 0, 1, 2) respectively. Figure 23 shows the profiles of the pump laser a_0, the wake potential f, and the forward a_1 injection pulse, all of which are stationary in the $\Psi=kp(z-vp_0t)$ frame, and the backward injection pulse a_2 which moves to the left, where $v_{p0} \approx$ is the phase velocity of the wake. Furthermore, $\omega_1 = \omega_0 - \Delta\omega$, $\omega_2 = \omega_0$, and $\omega_0 >> \Delta\omega >> \omega_p$ are assumed such that $k_2 = -k_0$ and $k_1 \approx k_0$.

When the injection pulses collide (some distance behind the pump) in the plasma wake of the pump laser, they generate a slow phase velocity ponderomotive beat wave. This beat wave can cause electrons, undergoing a plasma oscillation caused by a_0, to acquire a momentum and phase change sufficient for trapping. Figures 24a-d show the electron energy vs. phase in the wake (dots), before, during and after the laser pulses collide, with the separatrix which distinguishes the trapped and untrapped regions superimposed (dashed line).

Particle tracking simulations in 1-D[22] and 3-D[12] indicate that production of high current electron bunches as short as 1 fs, with a mean energy on the order of 40 MeV and a normalized energy spread of 0.3 % are possible after an acceleration distance of 1 mm, using injection laser pulse intensities on the order of 10^{17} W/cm^2 . The number of trapped electrons in a plasma with a density of 7×10^{17} cm^{-3} is on the order of 4 x 10^6, with a normalized emittance on the order of 1 mm-mrad. Generation of an all-optical injector will have a significant impact on the development of laser driven accelerators. Because such a source would intrinsically produce ultrashort bunches of electrons with perfect synchronization to the ultrashort laser pulse, it could be an alternative for generating ultrashort x-ray radiation pulses.

Detailed parametric studies of the beam dynamics in one and three dimensions have been done to characterize the longitudinal and transverse phase space properties of the trapped electron bunches.[23] The theoretical work is part of a Ph.D. dissertation for Carl Schroeder and led to an undergraduate thesis for Peter Lee.

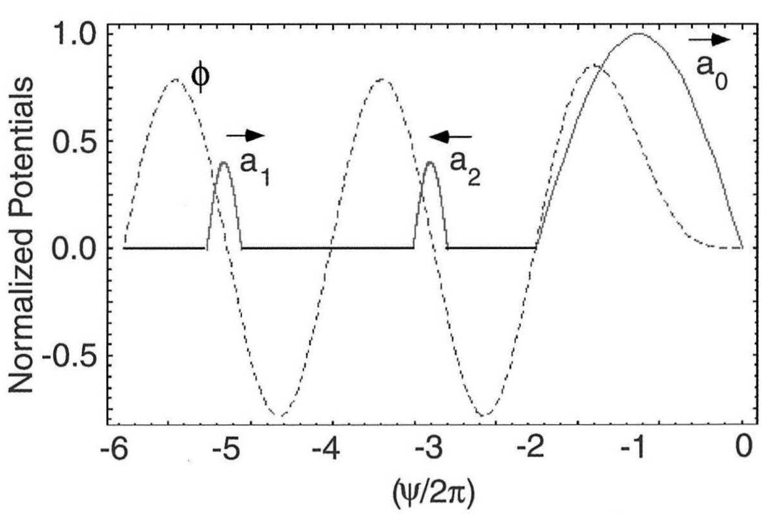


Figure 23. Profiles of the pump laser a_0, the wake f, and the forward a_1 injection pulse, all of which are stationary in the $\Psi=kp(z-vp_0t)$ frame, and the backward injection pulse a_2, which moves to the left at ≈0 2 c.

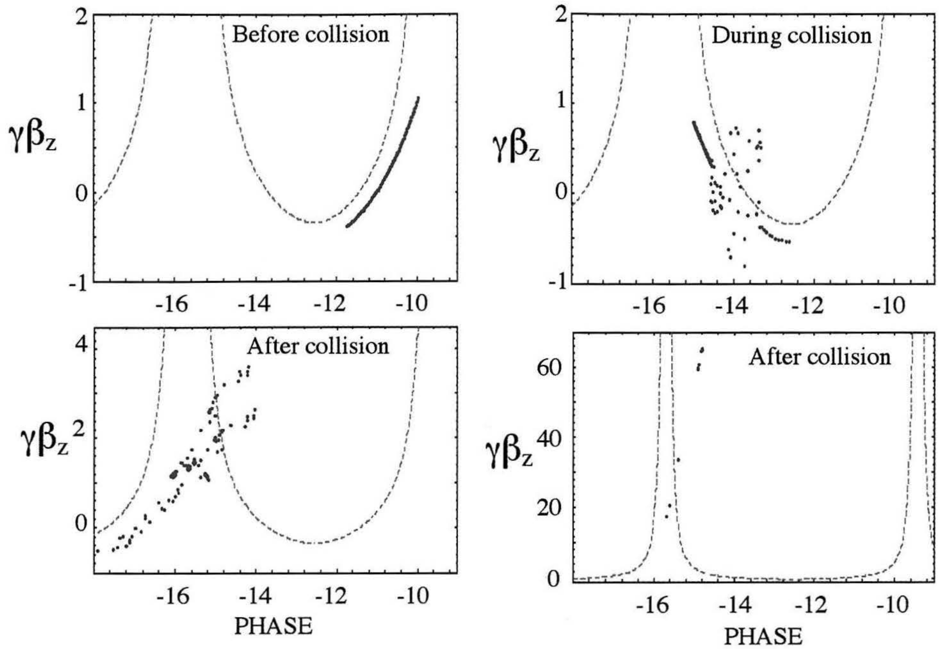


Figure 24. Snapshot in time of the particle energy before (top left), during (top right) and after (bottom) the overlap of the laser pulses. Superimposed (dashed line) is the separatrix from the plasma wake. Particles inside the separatrix are trapped and accelerated.

Experimental implementation of the optical injection scheme is being designed and constructed. A second high power amplifier arm has been added which produces peak power per pulse in excess of 10 TW at 10 Hz repetition rate. The laser beams are propagated under vacuum into the downstairs shielded cave area into a total of three vacuum compressors followed by a target chamber. A double focusing spectrometer is being designed to analyze the electron beam properties, and ultrafast electron beam diagnostics are being developed. A photograph of the current setup is shown in Figure 25.

Plasma Wakefield Acceleration Experiment E-157 at SLAC

The l'OASIS group is one of the collaborators (with SLAC, the University of California, Los Angeles, and the University of Southern California) on a plasma wakefield experiment using the 30 GeV electron beam at the SLAC Final Focus Test Beam facility (FFTB).[13] In this experiment, a 30 GeV electron bunch is used to both excite and witness a large amplitude wake in a meter long plasma cell.

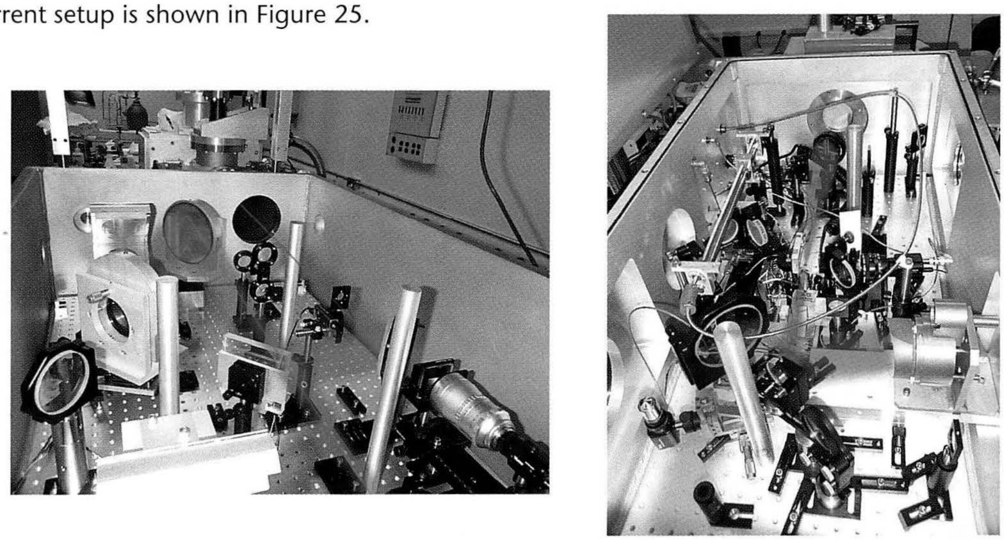


Figure 25. Photograph of the laser compressor chamber and target chamber in Building 71, Room 146.

The three main components of this experiment are: the 30 GeV electron beam, a plasma source and electron beam diagnostics. The LBNL group, in collaboration with UCLA, has developed a 1m long Li-plasma source,[14] and has delivered an ionization laser and focusing telescope, as well as beam line components for laser beam transport and electron beam diagnostics. Figure 26 shows the plasma source.

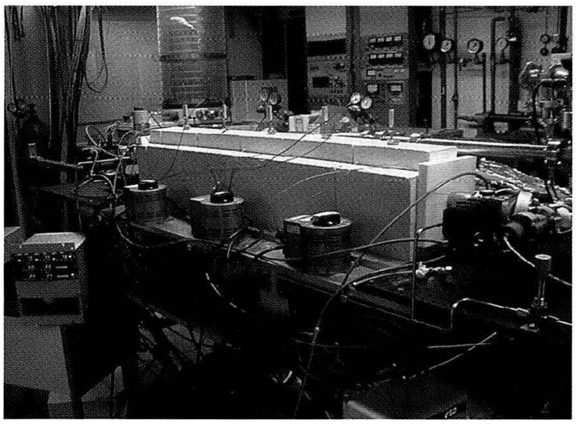


Figure 26. One meter long lithium heat pipe oven constructed for the plasma wakefield acceleration experiment E-157 at SLAC.

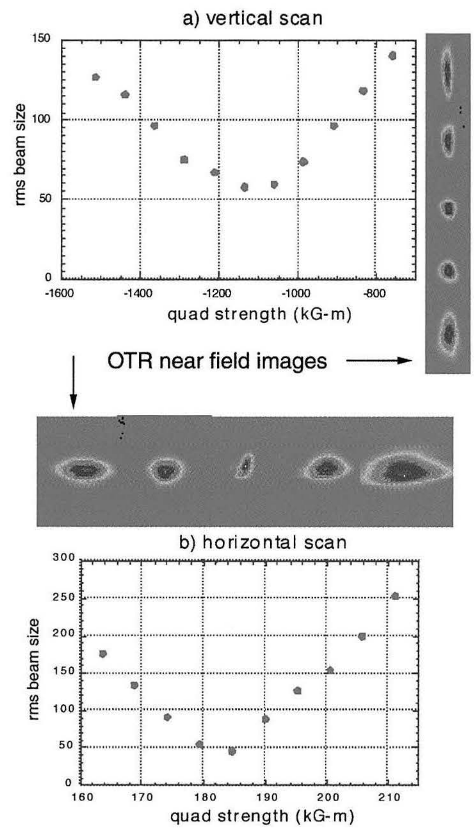


Figure 27. Spot size vs. quadrupole strength measured with OTR and near field images for vertical and horizontal quadrupole scans.

Li was chosen for its low ionization potential (5.4 eV), which allows the use of a low power excimer laser (193 nm) for ionization. A neutral density of Li on the order of 10^{15} atoms/cm^3 is obtained by heating the vapor to about 750 °C. The laser beam is reflected onto the path of the electron beam using 150 mm thin quartz substrates, coated on one side with a high reflectance coating for 193 nm laser radiation, and Aluminum on the other side.

The aluminum coating allows optical transition radiation (OTR) to be generated and reflected onto a high sensitivity CCD camera and allows for instantaneous monitoring of the electron beam profile.[15] One camera is used to image the electron beam spot on the substrate, a second camera is focused at infinity and provides a measurement for beam divergence. A spot size and divergence scan using OTR are shown in Figures 27 and 28, respectively.

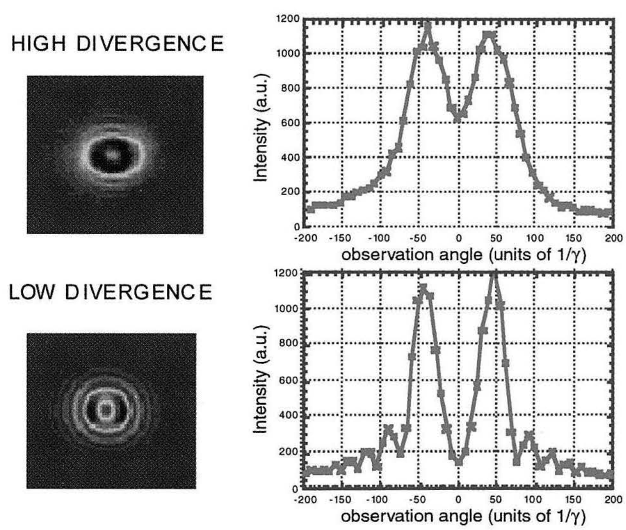


Figure 28. Two foil interference image and corresponding horizontal line profile for the case where the beam size on the OTR radiator was close to its waist (high divergence) and far from it (low divergence). The interference pattern evolves from low to full modulation, consistent with the divergence change.

Education in Beam Physics

Members of the Center have been contributing to the education in physics, beam physics and physics of radiation sources at the following schools: the University of California at Berkeley; the U.S. Particle Accelerator School; the United Nation-KEK School of Synchrotron Radiation, the Winter School on Beam Physics at CAT, Indore, India; and the Telecourse on Beam Physics from the University of Michigan, East Lansing.

Drs. Chattopadhyay and Wurtele have presented thorough semester-long and year-long advanced graduate courses on Equilibrium and Non-Equilibrium Statistical Physics, as well as Advanced Seminar courses on Beams and Plasmas and Collider Physics Basics for High Energy Physicists, at the UC Berkeley Department of Physics and here at Berkeley Lab.

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AND THE OTHER SIDE OF CBP

(from LBNL Currents, Vol. 28, No. 11, June 4, 1999)

"Piano with a Soul Brings Heart And Music to Physics Group,"

By Monica Friedlander

"If I were not a physicist, I would probably be a musician. I often think in music. I live my daydreams in music. I see my life in terms of music. I get most joy in life out of music."

— *Albert Einstein, 1929*

The back wall of the conference room at the Center for Beam Physics is adorned by an old, yellowed isotope chart that once used to hang in Glenn Seaborg's office long before he and other scientists added the last 11 elements to it. To its left stands a device used in the discovery of element 106 (seaborgium). And next to it is an unusual addition to this artifact-rich room: a piano.

The baby grand, however, is not just any piano, the people there will tell you. It's an instrument with a soul. And over the last few months it has brought immeasurable joy and life to the Center for Beam Physics.

"Science is not an isolated thing in our world," says veteran nuclear physicist Al Ghiorso, who in recent years has turned much of Bldg. 71 into an art museum. "Music and art are as important as science. They go together."

From Albert Einstein to former Lab Director and flute-player Andy Sessler, great minds in science have often had an unusual aptitude for music. Experts have long suspected that the connection between the two is more than coincidental. And here at the Lab, and very notably in Bldg. 71, one can sense a keen awareness of the power of music to open minds and hearts.

It all started with the dream of a young physicist, and was made possible by the persistence of a man who has made a habit out of turning dreams into reality.

Palma Catravas, a postdoctoral student at the Center, was once an accomplished pianist who performed solo with the Baltimore Symphony Orchestra when she was only 12. Her interest in physics, however, had put piano playing on the back burner. Without a piano, in fact, she had stopped playing altogether.

During a retirement party held for a fellow physicist last fall, she found herself with an opportunity to play and with an audience to appreciate her talent, recalls Olivia Wong, the administrative assistant for the Center. "I heard her play and was transported somewhere else," Wong says.

Perhaps inspired by that event, or simply by the artistic atmosphere in Bldg. 71, Catravas approached Ghiorso and asked him to allow her to put a piano in the conference room so that she and others could play after hours. Ghiorso was thrilled. One little problem still remained: someone had to come up with an awful lot of money to buy it.

Undaunted by the task, Joy Kono, program administrator at the Center, started a candy fund last October hoping to raise at least part of the money that way. People donated, but, Ghiorso says, "After a couple of weeks I saw [the candy selling] was going nowhere fast and I suggested trying to buy a piano out of foundation money."

Funding projects is something Ghiorso knows a lot about. Since the death of Lab physicist Mike Nitschke in 1995, Ghiorso, who was named executor of his estate, has set up the J. Michael Nitschke Fund, administered by the East Bay Community Foundation. Through this fund he has financed a wide range of programs, both scientific and educational.

Among them is the National Historical Chemical Landmark, a project started by Ghiorso and Glenn Seaborg a little over a year ago to commemorate the discovery of 11 transuranium elements on the Hill. Ghiorso picked the lower area of Bldg. 71 for the Landmark and started to rework it as a museum, incorporating scientific artifacts as well as art, most of which he and his wife have personally purchased and donated. Could a piano now fit in with the project as well?

"I called up the Foundation," Ghiorso says, "and two days later the answer came back. They bought the idea."

Ghiorso personally took Catravas to the shop of the person who has taken care of his family's piano for decades. While she sat down to play at an upright piano, Ghiorso eyed another piano next to it — a baby grand from the 1920s. With its ornate wood carvings and aged look, the piano has rare and obvious character. Catravas wouldn't have dreamt of even trying it, but Ghiorso knows a winner when he sees one. Despite the $5,000 price tag, Ghiorso's mind was made up.

"It was a complete surprise when he bought it," a delighted Catravas says. "Al couldn't have picked a better piano for the Landmark. It conveys a sense of history that goes with the work done here over the years. The piano has seen other times and has a special sound quality. It has a soul."

Picking the piano and getting the foundation to pay for it were only the beginning. A donation of this kind had never been made to the Lab before, and no channels were in place to see it through.

Swapan Chattopadhyay, head of the Center for Beam Physics and a music lover himself who plays Indian instruments, found a way. He turned the donated piano into a science project, with himself as the principal investigator. As a piece of Lab equipment, the instrument was assigned a project number and was donated as a gift to the University of California. The Center for Beam Physics simply has custody of the instrument with Chattopadhyay as its custodian. The problem was finally solved.

"Scientists need to have music," Chattopadhyay says. "They are used to looking for patterns, to make sense out of chaos. And music is pattern. Those who have an innate ability for math can play Bach. If you have a kinship with one, you look for symmetry and harmony in the other."

By early this year, the music project Catravas started had attracted a number of musicians who formed a chamber music group. In addition to Catravas, the group includes Jon Arons, chair of the Astronomy Department at UC Berkeley; violinist Richard Laden who directs a consulting firm started by UC Berkeley faculty members; violinist Louise Kaufman and cello player Joan Glassey, both wives of Lab and UC scientists, respectively; and violist Ellen Ruth Rose.

On March 1 the group gave a successful recital in the Bldg. 71 conference room, which included selections from Haydn and Brahms. Catravas and Ghiorso hope this is only the beginning, and that the group will attract many more musicians from the Lab. Further recitals are tentatively planned for this summer.

Since the acquisition of the piano, says Chattopadhyay, he already sees a major difference in the atmosphere of his group. "I notice a calmness that was not here before," he says. "People are more relaxed. Scientists are so focused on what they do and who gets the credit. Art goes beyond all that. It's bigger, universal."

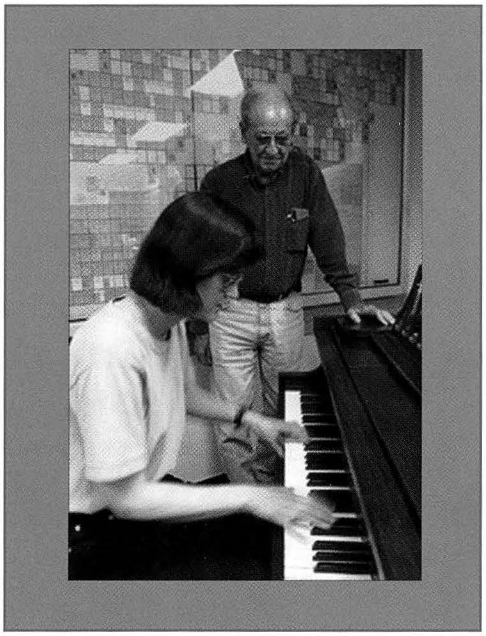
Joy Kono, who along with Olivia Wong has done much of the legwork to see the project through, couldn't agree more. "The recital has been the highlight of the year," Kono says. "We work together as a team, and events such as these help foster a sense of teamwork."

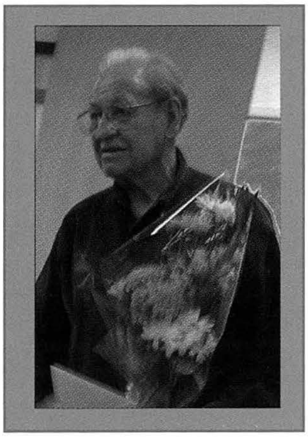
For her part, Catravas is especially thankful to her supervisor, Wim Leemans, without whose support, she says, she would have never dared bring music to the Center — or piano playing back into her life. "He told me he did not want me to lose that side of me," she says. "I wish the same thing for other people. It makes such a big difference. It gives people an outlet. And it makes you dream a little."

And dreams are a big part of the group in Bldg. 71, particularly for Al Ghiorso. Although formally retired, the 84-year-old continues to do research, organize community projects, write an autobiography, and is actively involved with the Landmark project. Within a year he hopes to move the piano downstairs, where the acoustics will be far better.

Moreover, he has already discussed with Director Charles Shank his plans to also use the Center for lectures, educational events, and the promotion of science in general. "I would like to bring people from other disciplines and educate them about the good sides of science."

As for the music project, he says, "We've had no opposition so far. And if we did, it wouldn't make any difference, because we know that in the end we'd win. Music is the king of everything."





Piano Recital

The Stroud baby grand piano is a gift from the J. Michael Nitschke Fund of the East Bay Community Foundation to the University of California, and is in custody of the Center for Beam Physics at Berkeley Lab.

Mike was a Senior Scientist in the Nuclear Science Division, as well as a close associate of the Center for Beam Physics. He provided the principal leadership to the national study on isospin and radioactive beam facilities until his early death in 1995.

First Chamber Music Recital at the *CENTER FOR BEAM PHYSICS*

Lawrence Berkeley National Laboratory

Saturday, May first
1999

Building 71, Conference Room 264,

Four p.m.

Program

Welcome ....Dr. Swapan Chattopadhyay

Trio in D major, Hob. XV:16 ....Haydn

short intermission

Violin Sonata in G major, 1st movement......Brahms

Piano Quintet in F minor, 1st movement......Brahms

PERFORMED BY

Richard Laden, violin

Louise Kaufman, violin

Ellen Rose, viola

Joan Glassey, cello

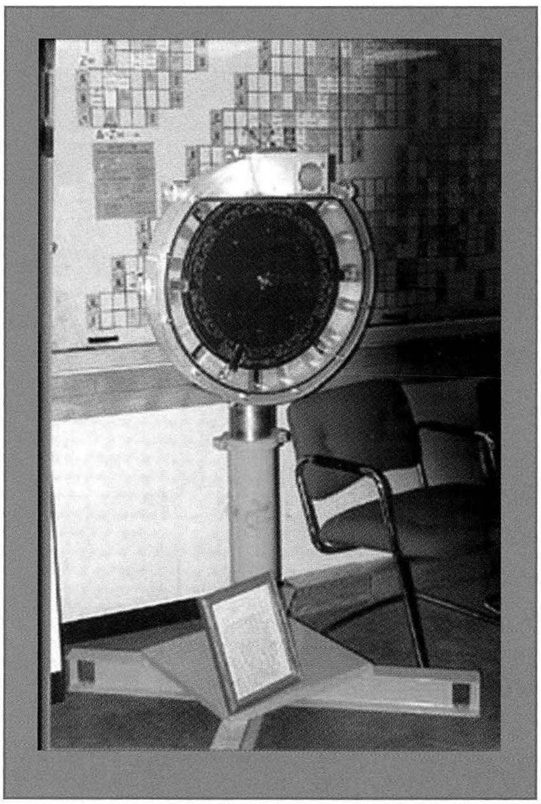
Jon Arons, cello

Palma Catravas, piano

SPECIAL ACKNOWLOGEMENTS

"With heart-felt appreciation
from his friends and
colleagues the
Center for Beam Physics,
we especially want to thank
Dr. Albert Ghiorso,
who was instrumental in
securing the funding for the piano."

Kwang-Je Kim's Farewell
1/1998



Vertical Wheel
(used to discover element 106, Seaborgium)

Landmark Project

In Memory of Charles Kim
1943 - 2000

March 2, 2000

We have gathered here today to remember our dear friend Charles Kim. I am here to speak not only for myself, but on behalf of all his friends and colleagues at the Lawrence Berkeley Laboratory of the University of California — scientists, engineers, administrative staff, students,...folks from all walks of life, but first and foremost "FRIENDS". We have known Charles for the past twenty two years in various ways — as a scientist; as a team player at work and in sports; as a responsible and loving family man — husband and father; as a man with utmost humility who bowed in reverence to God and in respect to his fellow human beings; and as one with resolute character and moral strength.

Early in his career, when he was a doctoral student at UCLA as a Hertz Fellow in Physics, he made his mark in plasma physics with a pioneering article on Cavitons in Plasmas — a singular article that still continues to enrich our field. Ever since he joined our laboratory on the hill in 1978, Charles has made progressive contributions to the fields of heavy ion fusion, synchrotron radiation sources and most recently in the exciting new field of muon colliders. Charles was a pleasure to have at our Center picnics where he often brought his own Bulkogi assortments with a personal flair and played volleyball spiritedly. I know he loved his family as I often discussed with him such matters as his daughters and son, their studies and music, etc. Charles had nothing derogative to say about anyone even on the face of hostility from colleagues on occasions of stressful work situations — others had "lost " it as we say, but never Charles, who was as polite, humble and blameless to others as ever. I know he gave a lot to his church and we often discussed his Sunday school affairs at relaxed times. His devotion could not have been better expressed than when he sang, at my request, at our annual Christmas party at my home this last December — that deep, rich, melodic, base voice singing Christmas carols could not have been anything but in praise and love of the supreme. He must be special to have been endowed with such voice to sing the song of praise for all of us to hear!! He was entertaining us, but he was SINGING for the ONE that matters!!

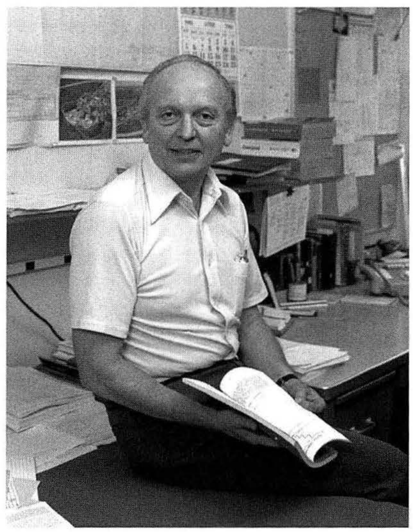
Our community is diminished significantly today by one outstanding individual. During Charles' struggle in the last few days, many of us really felt that there must be a warmer and brighter place for him to be at than where he was. Today, we can rest assured that he is there without question.

On behalf of all friends of Charles Kim at the Berkeley Lab, I offer our love, admiration, respect and support to his dear wife Cynthia, daughters Jean and Vicky, son Christopher and the rest of his family and friends.

Thank you. *Swapan Chattopadhyay*

Remembering ....

Jack Peterson



1920-1999

Albert Ghiorso Conference Room

Center for Beam Physics
Ernest Orlando Lawrence
Berkeley National Laboratory
October 15, 1999
11:00 AM

Remembering Jack Peterson
October 15, 1999

Palma Catravas

A selection of Mozart and Bach

Swapan Chattopadhyay	Remembering Jack
Andy Sessler	All about Jack
Edward Lofgren	Old Times
Glen Lambertson	Electron Ring Accelerator Days
Tom Elioff	PEP
Alex Chao	SSC Days
Phil Morton	PEP, SSC and all that
Olivia Wong	As I remember Jack

Words from family and friends

Palma Catravas

"2nd Movement Concerto in E Minor", Chopin
"Waltz in A^b Major", Brahms

Lunch

A few members of the

CENTER FOR BEAM PHYSICS

gathered on September 2, 1999
between the "Theory Ghetto" (Bldg. 71B)
and the "Experimental Slum" (Bldg. 71 proper)