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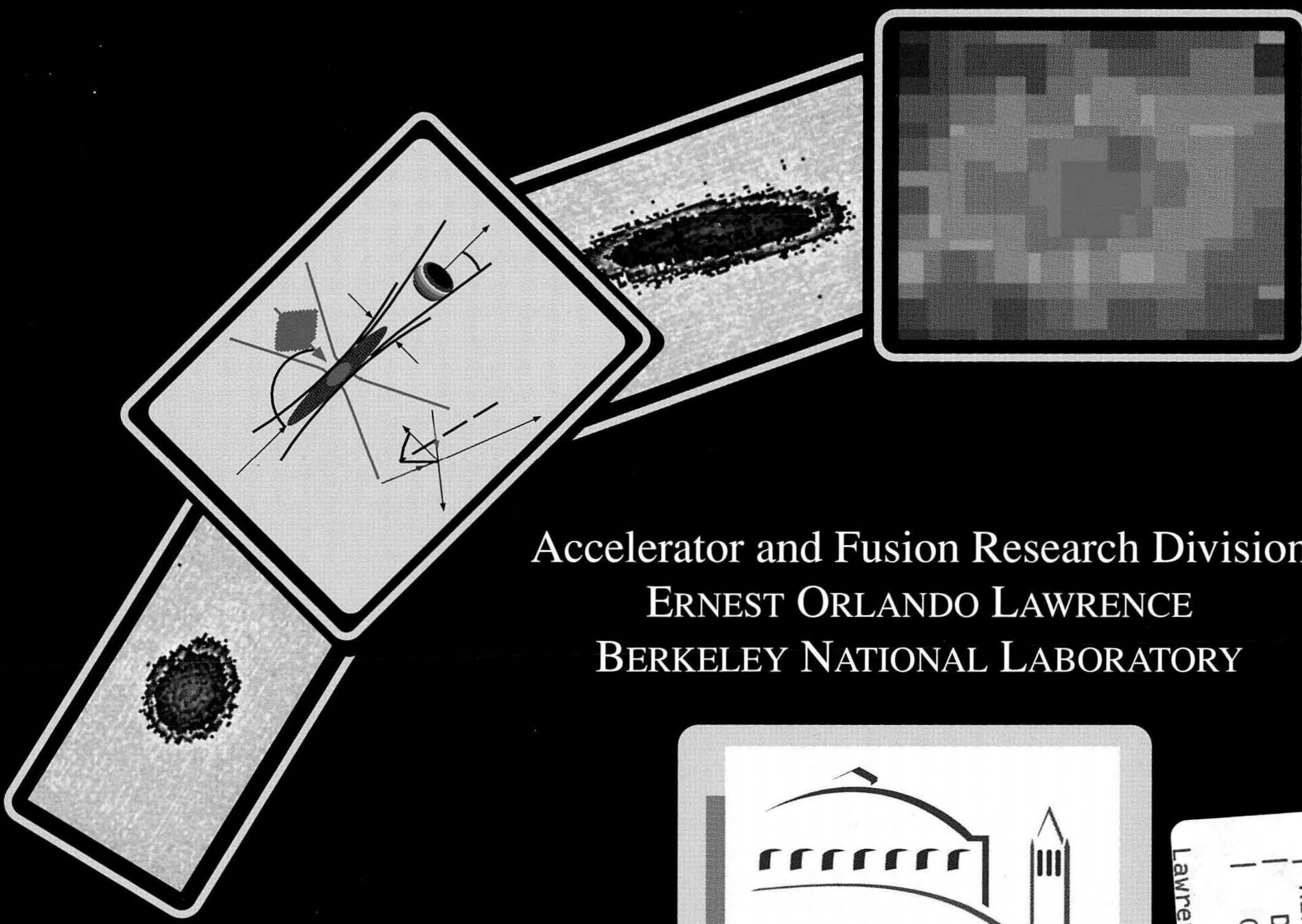
CENTER FOR BEAM PHYSICS



Accelerator and Fusion Research Division
ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

1996-97
FEBRUARY 1997

DISCLAIMER

LBNL-39980
UC-411

CENTER FOR BEAM PHYSICS

1996-97

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

February 1997

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WELCOME TO CBP

"Nothing happens unless first a dream" — Carl Sandburg

As we pause to ponder in mid-FY'97, we find ourselves in the midst of tremendous 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 and even quantum computing. And yet, we stay focused on our critical contribution 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, the Relativistic Heavy Ion Collider (RHIC), and the international Large Hadron Collider (LHC) at CERN. As we push 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 acceleration in general, but also new novel applications of beams and new avenues of exploration opened up by them. It is important to renew and remind ourselves of our mission every so often.

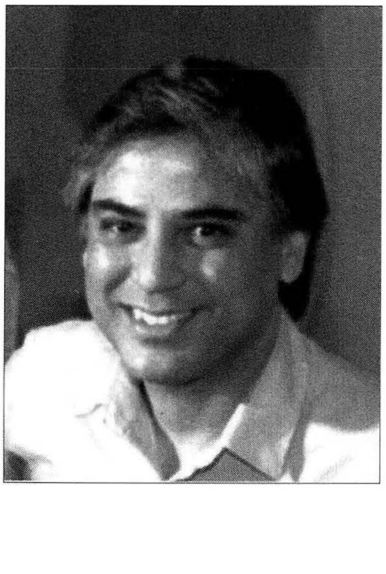
The Center for Beam Physics is a multidisciplinary research and development unit in the Accelerator and Fusion Research Division at the Ernest Orlando Lawrence Berkeley National Laboratory of the University of California. At the heart of the Center's mission is the fundamental quest for mechanisms of 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 in 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 clearinghouse 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 and Basic Energy Sciences), as well as by Laboratory-directed R&D funds. 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 IRFEL studies, LBNL-Peking University on Photocathode/SCRF technology, LBNL-BNL on heavy-ion cooling for RHIC, LBNL-LLNL on Advanced Laser-Acceleration methods, LBNL-UC Davis on photocathode source 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, technical support, students, and administrative staff that make up the CBP's outstanding team and gives a flavor of our multifaceted activities during 1996 and 1997. We welcome students, academia, industry, and the public at large to visit our Center (physically or on the web at http://bc1.lbl.gov/CBP_pages/CBP-Homepage.html) and participate in our programs to help us contribute to mutual flourishing.



Swapan Chattopadhyay

Swapan Chattopadhyay
Head, Center for Beam Physics

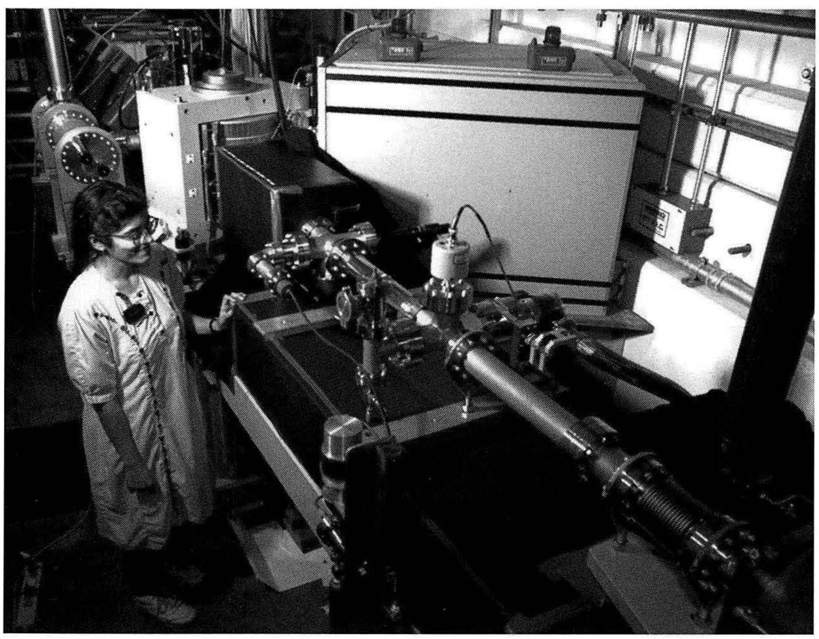
FACILITIES

Lambertson Beam Electrodynamics Laboratory

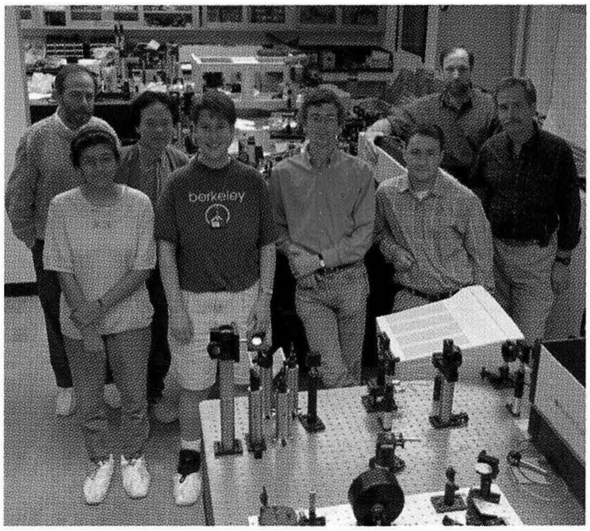
Nurtured, promoted, and continually updated over the years by Glen Lambertson of LBNL, this laboratory houses, in an environment of controlled temperature, various instruments, equipment, and apparatus for low-power, high-precision rf measurements of beam-handling structures. Inventory includes a sophisticated bead-pulling apparatus, a time-domain reflectometry 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 quadrupled 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.

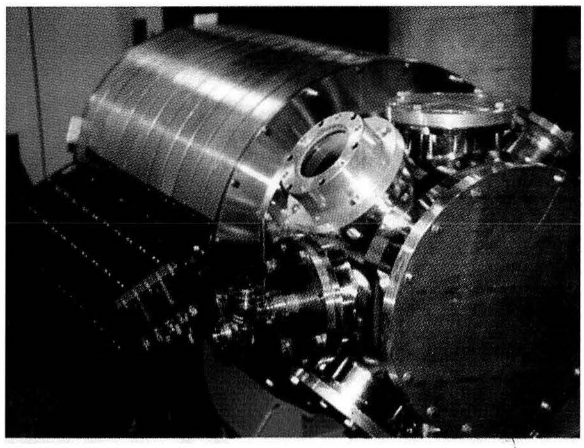


l'OASIS Laboratory



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 shot 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 constructed one-half 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 it's extraction section.

CBP Dedicated Workstations

Hewlett-Packard 375
IBM RS/6000 (two)
VAXstation II
SPARC-2, 4, 20

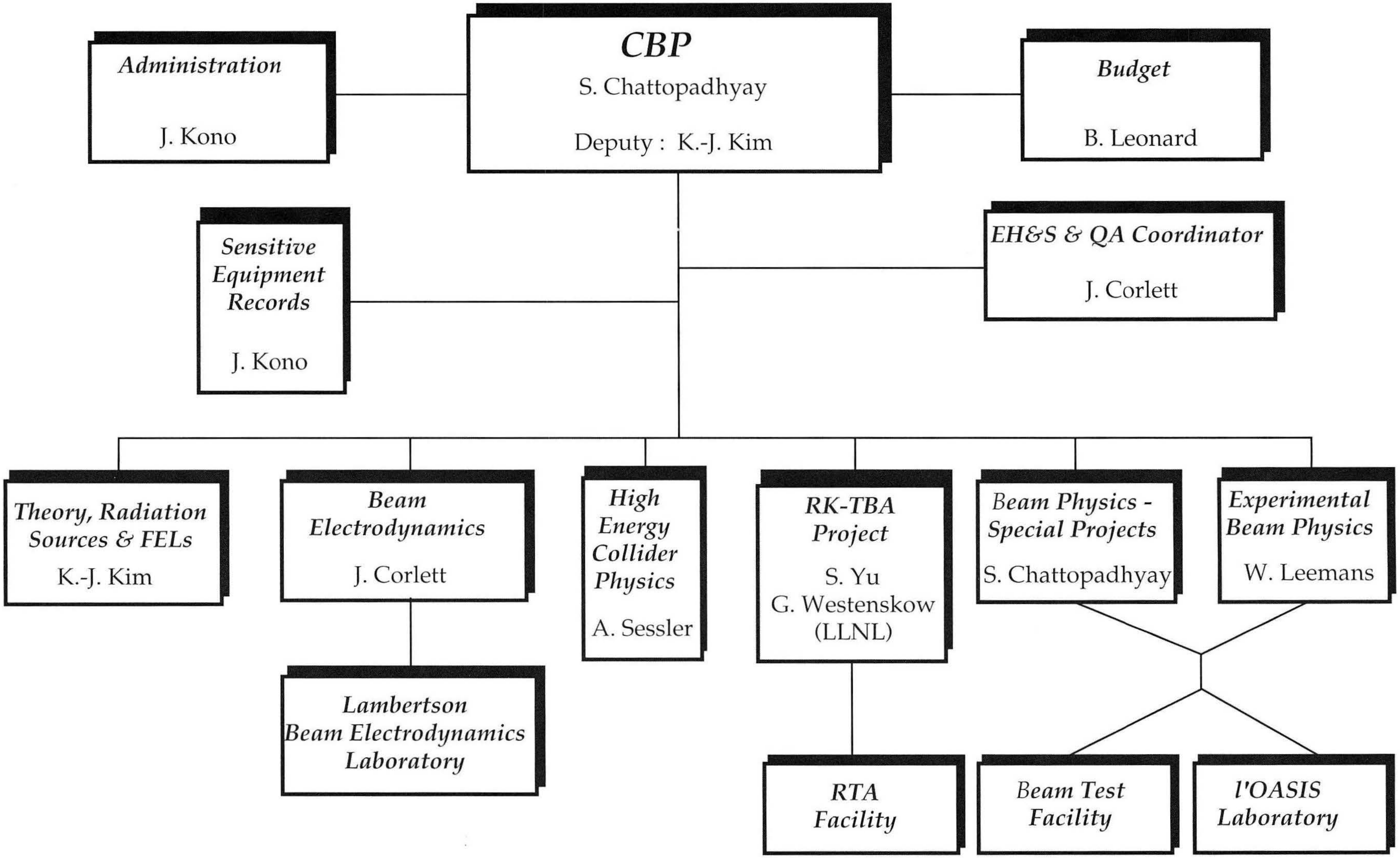
CBP Mini-Library

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

APIARY Conference Room and Video Link

This is a large conference room for seminars and meeting. It is equipped with the special feature of a video-conferencing facility, allowing joint conferences and meeting with the scientists and engineers from other national laboratories and universities, e.g., SLAC, Stanford University, Livermore, 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 LBNL-SLAC-LLNL meetings on the PEP-II asymmetric B-factory (elegantly acronymed APIARY (Asymmetric Particle Interaction Accelerator Research Yard) by LBNL physicist A.A. Garren before the present project title was adopted). It is also used regularly for the biweekly Center for Beam Physics seminars.

CENTER FOR BEAM PHYSICS



ROSTER

Scientific and Technical Staff
ARCHAMBAULT, Leon
BARRY, Walter
*BYRD, John
CHATTOPADHYAY, Swapan
CORLETT, John
DOUGHERTY, James
FURMAN, Miguel
GOLDBERG, David
KIM, Kwang-Je
LEEMANS, Wim
LEONARD, Bud
LOZANO, David
RIMMER, Robert
SESSLER, Andrew
TURNER, Bill
XIE, Ming
YU, Simon
ZHOLENTS, Alexander
ZOLOTOREV, Max
HOUCK, Tim
JOHNSON, Colin
LUHMANN, Neville
PALMER, Robert
SCHACHINGER, Lindsay
SCHOENLEIN, Robert
SHANK, Charles
TAJIMA, Toshiki
van BIBBER, Karl
VANECEK, David
WESTENSKOW, Glen
ZISMAN, Michael

UCB Faculty Associates
FALCONE, Roger
VAZIRANI, Umesh
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International Visitors
KISHIMOTO, Y.
KOGA, J.

Post Docs
CHENG, Wen-Hao
SHADWICK, Bradley

Center Affiliates
DELAHAYE, J. P.
EDIGHOFFER, John
FAWLEY, William
FOREST, Etienne
FREEMAN, Richard
GOUGH, Richard
HARTEMANN, Fred

Administrative Support
CONDON, Martha
KONO, Joy
NOEL, Linda
PITTMAN, Illona
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WONG, Olivia

Students
CHIN, Alan
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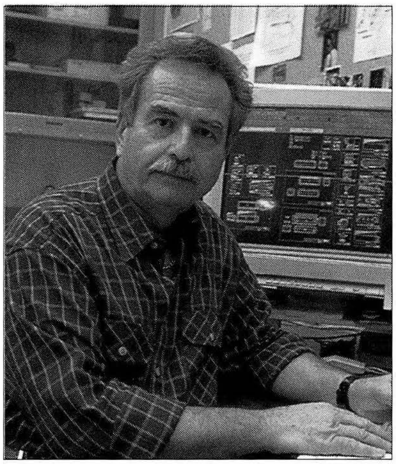
GOVIL, Richa
GUO, Kang-Zhu
IRWIN, Michael
LEE, Peter
LIDIA, Steve
LIE, James
PONCE, David M.
SCHROEDER, Carl
VOLFBEYN, Pavel
WHEELER, Susan

Participating Guests (Emeriti)
GARREN, Alper
GHIORSO, Albert
LAMBERTSON, Glen
PETERSON, Jack
SELPH, Frank
VOELKER, Ferdinand

(* at ALS starting FY'97)

SCIENTIFIC AND TECHNICAL STAFF

Leon Archambault



Senior Mechanical Engineering Associate
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joined LBNL in 1959

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

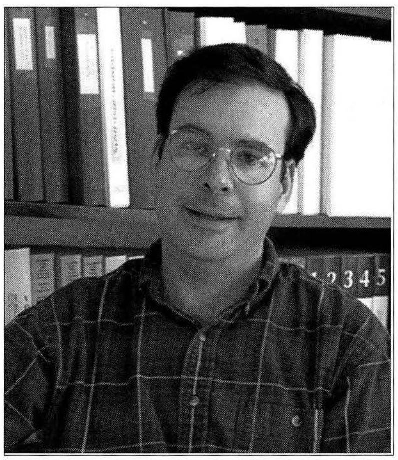
Technical accomplishments: NSD team for studies of elements 104 and 106.

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.

Walter C. Barry



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Walter_Barry@macmail.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).

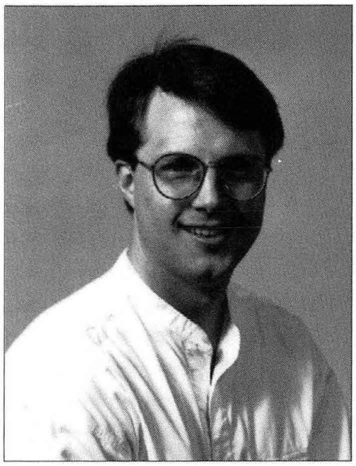
"A General Analysis of Thin Wire Pickups for High Frequency Beam Position Monitors," *Nucl. Instrum. Methods in Phys. Res.* **A301** (3) (1991).

"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).

John M. Byrd



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Joined LBL in 1991

Ph.D., Physics, Cornell University, 1992.

Research interests: RF aspects of accelerators, single and coupled-bunch instabilities and feedback systems.

Selected publications: "Beam Instabilities," in *Synchrotron Radiation Sources—A Primer* (H. Winick, ed.), World Scientific Publishing Company (July 1994), Chapter 12, p. 306.

"Spectral Characterization of Longitudinal Coupled-Bunch Instabilities at the Advanced Light Source" (with J. N. Corlett), to be published in *Particle Accelerators.*

"Measurements of Collective Effects at the Advanced Light Source," Proceedings of the European Particle Accelerator Conference (June 1994).

"Coupled-Bunch Stability at the ALS" (with J. N. Corlett), *Proc. 1993 IEEE Particle Accelerator Conference* (May 1993).

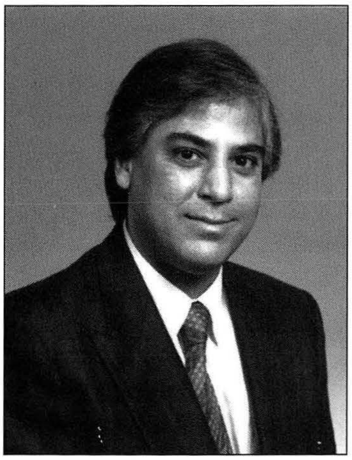
"Simulation of the ALS Longitudinal Feedback System," *Proc. 1993 IEEE Particle Accelerator Conference* (May 1993).

"ALS Transverse Multibunch Feedback System" (with W. Barry, J. N. Corlett, J. Hinkson, and G. R. Lambertson), *Proc. 1993 IEEE Particle Accelerator Conference* (May 1993).

"Coupled-Bunch Stability at the PEP-II B-Factory," *Proc. 1993 IEEE Particle Accelerator Conference* (May 1993).

"A Collection of Complex Permittivity and Permeability Measurements" (with W. Barry, J. Johnson, and J. Smithwick), *Proc. Workshop on Microwave-Absorbing Materials for Accelerators* (February 1993).

Swapan Chattopadhyay



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Ph.D., Physics, University of California, Berkeley, 1982. Scientific Attaché, CERN, Geneva, Switzerland, 1982-84. Visiting Professor, UC Berkeley, 1987 and University of Illinois at Urbana-Champaign, 1991. JAERI (Japan Atomic Energy Research Institute) Distinguished Visiting Scientist, 1995.

Affiliations: Fellow, American Physical Society (APS); Editor-in-Chief, *Particle Accelerators* (Western Hemisphere); Series Editor, *"The Physics and Technology of Particle and Photon Beams"* — Monograph Series by Harwood Academic Publishers; Member: European Physical Society (EPS), American Association for the Advancement of Science (AAAS), Optical Society of America (OSA), Executive Committee of Division of Physics of Beams of APS, International Committee on Future Accelerators (ICFA), Advisory Board of International Linac and Particle Accelerator Conferences, Advisory Committee of PEP-II Project. National Scholar (1967) and National Science Talent Scholar (1967-72), Govt. of India.

Research interests: Particle and photon beam physics, synchrotron radiation, free electron lasers, beam-plasma physics, nonlinear dynamics, collider physics, novel accelerators and radiation sources, ultrafast processes, quantum optics and computation.

Selected publications: "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**, 11 October 1996, p. 236.

"Generation of Femtosecond X-rays by 90° Thomson Scattering" (with K.-J. Kim and C. Shank), *Nucl. Instrum. Methods in Phys. Res.* **A341**, 351-354 (1994).

"Accelerator Issues and Challenges at the IsoSpin Laboratory," *Particle Accelerators*, 1994, **47**, No. 3 - 4, pp. 119 - 126.

"Physics and Design Issues of Asymmetric Storage Ring Colliders at B-Factories," *Particle Accelerators* **30** (1990).

John Corlett

Staff Scientist
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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. Joined CBP in 1991.

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", J. N. Corlett, to be published in the Proc. Beam Instrumentation Workshop, Chicago, May 1996

"Observation and Calculation of Trapped Modes Near Cut-off in the ALS Bellows-Shield", J.N. Corlett, G.R. Lambertson, C. Kim, Proc. 5th. European Particle Accelerator Conference, Sitges, Spain, June 1996.

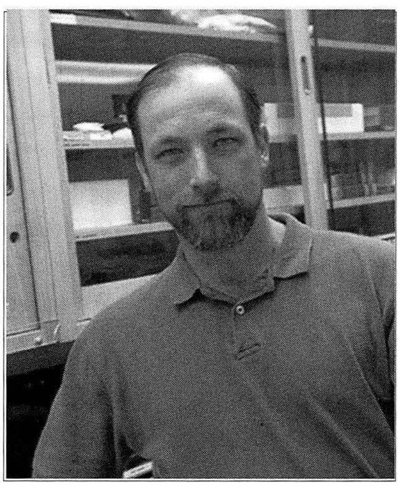
"Spectral Characteristics of Longitudinal Coupled-bunch Instabilities at the Advanced Light Source", J. M. Byrd and J. Corlett, Particle Accelerators, 1995, Vol. 51, pp. 29-42.

"Collective Effects in the PEP-II B-Factory", J. N. Corlett, Proc. International Workshop on Impedance and Collective Effects in B-Factories, KEK, Tsukuba, Japan, June 1995. LBL-37780.

"Transverse Feedback Systems for the PEP-II B-Factory", J. N. Corlett, W. Barry, J. M. Byrd, G. Lambertson, J. Johnson, M. Fahmie, Proc. International Workshop on Impedance and Collective Effects in B-Factories, KEK, Tsukuba, Japan, June 1995. LBL-37781.

"Experience with Cavity Design Programs," J. Corlett, Proc. CERN Accelerator School rf Engineering for Particle Accelerators, CERN 92-03, Geneva, June 1992.

James R. Dougherty



Mechanical Engineering Technologist II
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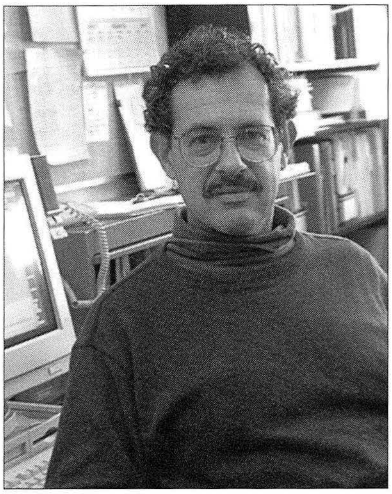
joined LBNL in 1983

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.

Miguel A. Furman



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joined LBNL in 1984

Ph. D., University of California, Santa Cruz, 1977 (theoretical particle physics). Joined LBL in August, 1984. Worked "on loan" for the SSC Central Design Group (1984–1990). Since 1990, working full-time at the CBP on the PEP-II project.

Research interests: beam dynamics issues at high-luminosity (*e.g.*, e^+e^- "factories" and muon collider); impedances and beam instabilities, particularly the electron cloud instability; beam-beam interaction; space-charge effects; large-scale simulations.

Selected publications: "The Electron-Cloud Instability in PEP-II" (with G. R. Lambertson), LBNL-38220/PEP-II AP 96-03/CBP Note-173, June 1996. Submitted to the EPAC96, Barcelona, Spain, June 10–14, 1996.

"The Classical Beam-Beam Interaction for the Muon Collider: A First Look," LBL-38563/BF-19/CBP Note-169, April 25, 1996, published as section 8.6 of: "m^+m^- Collider: A Feasibility Study," BNL-52503/Fermi Lab-Conf-96-092/LBNL-38946, July 1996, and to be published in the Proc. 1996 Snowmass Workshop "New Directions for High-Energy Physics."

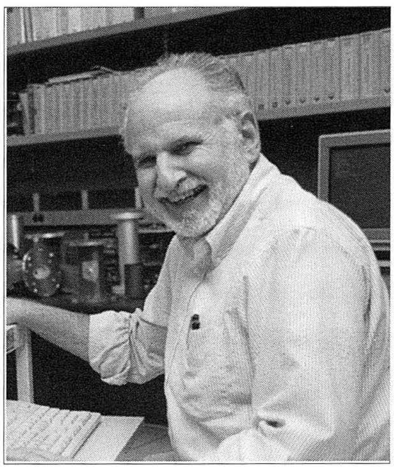
"Compact Complex Expressions for the Electric Field of 2-D Elliptical Charge Distributions," Am. J. Phys. **62** (12), Dec. 1994, pp. 1134–1140.

"Beam-Beam Tune Shift and Dynamical Beta Function in PEP-II," Proc. European Particle Accelerator Conference, London, England, June 27 - July 1, 1994, p. 1145.

"Closed Orbit Distortion from Parasitic Collisions in PEP-II," Proc. European Particle Accelerator Conference, London, England, June 27 - July 1, 1994, p. 1147.

"Beam Instabilities" (with J. Byrd and S. Chattopadhyay), in "Synchrotron Radiation Sources: A Primer," H. Winick, ed., World Scientific, 1994, Chapter 12 (p. 306).

David A. Goldberg



Staff Scientist
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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).

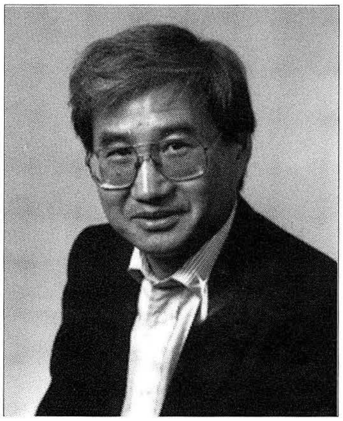
"Automated Bead-Positioning System for Measuring Impedances of rf Cavity Modes," (with R. A. Rimmer), contribution to Particle Accelerator Conference (1993).

"Dynamic Devices: A Primer on Pickups and Kickers," (with G. R. Lambertson), in *Physics of Particle Accelerators* (M. Month and M. Dienes, eds.) (1992).

"Modes of Elliptical Waveguides: A Correction," (with L. J. Laslett and R. A. Rimmer), *IEEE Trans. on Microwave Theory and Techniques* **38** (1990).

"Successful Observation of Schottky Signals at the Tevatron Collider," (with G. R. Lambertson), *Particle Accelerators* **30** (1990).

Kwang-Je Kim



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Joined LBL in 1978

Ph.D., Elementary Particle Physics, University of Maryland, 1970. Visiting Scientist, SLAC 1970-73; Max Planck Inst. für Phys. and Astrophys., 1973-75; University of Mainz, 1975-78.

Affiliations: 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).

"Brightness, Coherence, and Propagation Characteristics of Synchrotron Radiation," *Nucl. Instr. Methods* **A246**, 71 (1986).

"A Synchrotron Radiation Source with Arbitrarily Adjustable Elliptical Polarization," *Nucl. Instr. Methods* **219**, 425 (1984).

Wim Leemans

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joined LBNL in 1991

Ph. D., Electrical Engineering, University of California, Los Angeles, 1991.

Major awards: Simon Ramo Award 1992, American Physical Society.

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).

"Experiments and Simulations of Tunnel-Ionized Plasmas" (with C. E. Clayton et al.), *Phys. Rev.* A **46**, 1091-1105 (1992).

"Plasma Physical Aspects of Tunnel-Ionized Gases" (with C. E. Clayton et al.), *Phys. Rev. Lett.* **68**, 321-324 (1992).

"Stimulated Compton Scattering from Pre-formed Underdense Plasmas" (with C. E. Clayton, K. A. Marsh, and C. Joshi), *Phys. Rev. Lett.* 67, 1434-1437 (1991).

"Detection of Trapped Magnetic Fields in a q-Pinch Plasma Using a Relativistic Electron Beam" (with C. Joshi and C. E. Clayton), *Rev. Sci. Instrum.* **59**, 1641 (1988).

Bud Leonard

Budget Analyst for CBP, IBT and Supercon groups
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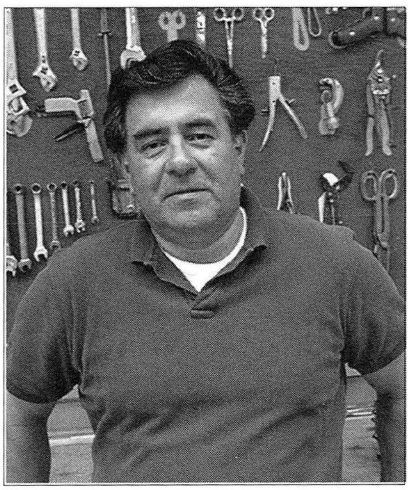
BWLeonard@lbl.gov
joined LBL in 1976

B.S. Business Administration with minor in Economics, California State University, Hayward 1991; M.B.A. Finance option, California State University, Hayward 1992; Electronics Technician 1976 to 1988, Electronics Coordinator 1988 to 1991, Budget analyst 1991 to present.

David Lozano



Senior Assistant Tech Coordinator
MS 71-259
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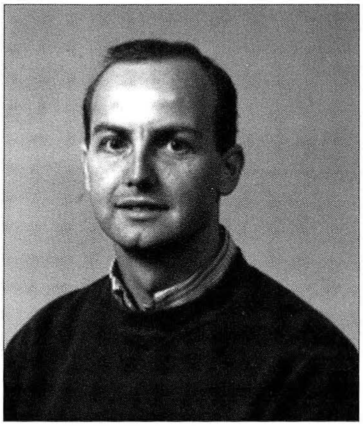
joined LBNL in 1970

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



Staff Scientist
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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, LBNL 38147, 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).

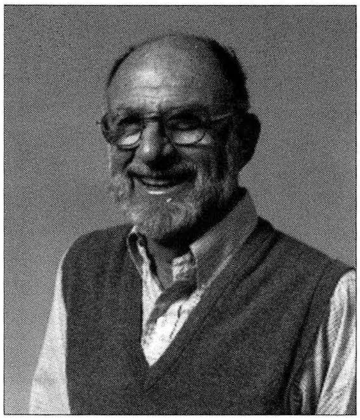
"An rf Cavity for the B-Factory," (R. Rimmer, et al.), Proc. 1991 U. S. Particle Accelerator Conference, San Francisco, California (May 1991).

"Mode of Elliptical Waveguides: a Correction," (with D. A. Goldberg and L. J. Laslett), IEEE Trans. MTT 38 (11), 1603-1608 (November 1990).

"Beam Impedance Measurements on the ALS Curved Sector Tank," (R. A. Rimmer et al.), Proc. 1990 European Particle Accelerator Conference, Nice, France (June 1990); LBL-28192.

"Determination of Failure Mechanisms of rf Cavity Aperture Windows," Proc. 1989 IEEE Particle Accelerator Conference, Chicago, Illinois (March 1989).

Andrew M. Sessler



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Joined LBNL 1961
Director 1973-1980

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

Major awards and affiliations: E.O. Lawrence Award by U.S. Atomic Energy Commission; U.S. Particle Accelerator School Prize; Leland J. Haworth Distinguished Scientist, Brookhaven National Laboratory; Dwight R. Nicholson Humanitarian Award; American Physical Society Wilson Award; Member, National Academy of Sciences, President-Elect of the American Physical Society.

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

Selected Publications: "A Plasma-Based Adiabatic Focuser", (with P. Chen, K. Oide and S.S. Yu) Phys. Rev. Letts. 64, 1231 (1990).

"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).

"Progress on the Design of a High Luminosity Muon-Muon Collider" (with R. Palmer, A. Tollestrup) EPAC'96, Barcelona Spain, Vol 1, 861 (1996).

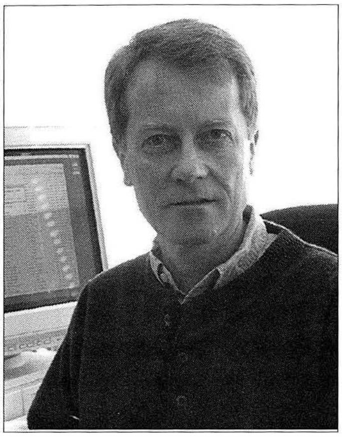
" Design of a Relativiatic Klystron Two-Beam Accelerator Prototype" (with G. Westenkow, et.al.) PAC 95 proceedings (1995).

"Gamma-Gamma Colliders" (with Kwang Je kim) SLAC Beam Line, Spring/Summer 1996, Vol. 26, No 1, 16-22. (1996).

" The Cooling of Particle Beams" Tamura Symposium on Accelerator Physics (1994).

"The Development of Colliders" (with Claudio Pelligrini) AIP Press (1995).

William C. Turner



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Joined LBNL in May 1994

PhD, Experimental High Energy Physics, Yale University, 1972, Lawrence Livermore National Laboratory 1974-91, Superconducting Supercollider Laboratory 1991-94.

Affiliations: Fellow, American Physical Society, DPP, DPB

Member, American Association for the Advancement of Science

Current research interest: Physics and technology of accelerators for high energy physics.

Selected publications: "Beam tube vacuum in low and high field very large hadron colliders", *Proc. of 1996 Snowmass workshop on future directions in high energy physics*, to be published.

"An induction linac approach to phase rotation of a muon bunch in the production region of a μ^+-μ^- collider", *9th ICFA Advanced Beam Dynamics Workshop, AIP Conf. Proc. 372* (1996).

"Ion desorption stability in superconducting high energy physics proton colliders", *J. Vac. Sci. Tech., A14*, 2026 (1996).

"Beam tube vacuum in future superconducting proton colliders", *Accelerator Physics at the Superconducting Super Collider*, AIP Conf. Proc. 326 (1995).

Ming Xie

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Joined LBNL in 1988
Ph.D., Physics, Stanford University, 1988.

Research interests: Free electron lasers, fourth generation light sources, photon colliders, laser-driven accelerators, and laser optics.

Selected publications: "Design Optimization for an X-ray Free Electron Laser Driven by SLAC Linac", *IEEE Proceedings of 1995 Particle Accelerator Conference,* No. 95CH3584, 183(1996).

"Self-Amplified Spontaneous Emission for Short Wavelength Coherent Radiation", (with K-J. Kim), *Nucl. Instr. & Meth. in Phys. Res.* A331, 359(1993).

"Three-Dimensional Theory of the Small-Signal High-Gain Free Electron Laser Including Betatron Oscillations" (with Y. Chin and K-J. Kim), *Phys. Rev.* A46(10), 6662(1992).

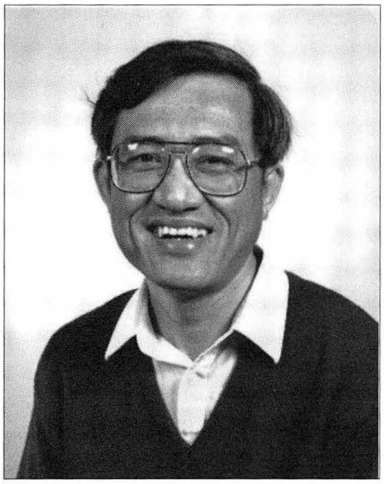
"Performance of Hole Coupling Resonator in the Presence of Asymmetric Modes and FEL Gain" (with K-J. Kim), *Nucl. Instr. & Meth. in Phys. Res.* A318, 877(1992).

"Stability and Performance of CDRL-FEL", (with K-J. Kim), *Nucl. Instr. & Meth. in Phys. Res.* A304, 146(1991).

"Eigenmode Analysis of Optical Guiding in Free Electron Lasers" (with D.A.G. Deacon and J.M.J. Madey), *Phys. Rev.* A41(3), 1662(1990).

"Theoretical Study of FEL Active Guiding in the Small Signal Regime" (with D.A.G. Deacon) *Nucl. Instr. & Meth. in Phys. Res.* A250, 426(1986).

Simon Yu



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Joined LBL in 1992

Ph.D., University of Washington, 1970.

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

Affiliations and honors: Fellow of American Physical Society.

Selected publications: "High Current Injector for Heavy Ion Fusion" (with S. Yu et al.), *Proc. International Symposium on Heavy Ion Inertial Fusion,* Frascati, Italy (1993).

"Study of Recirculating Induction Accelerator as Drivers for Heavy Ion Fusion," *Research Trends in Physics,* La Jolla International School of Physics, New York, New York (1992), p. 205.

"A Plasma-Based Adiabatic Focuser" (with P. Chen, K. Oide, and A. M. Sessler), *Phys. Rev. Lett.* **64**, 1231 (1990).

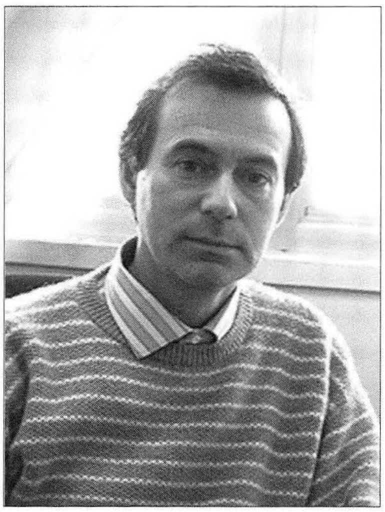
"Relativistic Klystron Version of the Two-Beam Accelerator" (with A. M. Sessler), *Phys. Rev. Lett.* **58**, 2439 (1987).

"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 (1986), p. 238.

"Phase Space Distortions of a Heavy Ion Beam Propagating Through a Vacuum Reactor Vessel" (with E. P. Lee and W. A. Barletta), *Nucl. Fusion* **21**, 961 (1981).

Alexander Zholents



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Joined LBNL in 1992

Ph.D., 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.

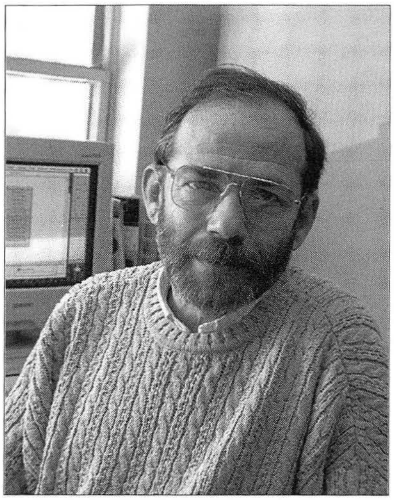
Selected publications: "Femtosecond X-Ray Pulses of Synchrotron Radiation" (with M.Zolotorev), *Phys. Rev. Lett.,* V76, p.912, (1996).

"Transit-time Method of Optical Stochastic Cooling" (with M.Zolotorev), *Phys. Rev. E,* V50, p.3087, (1994).

"The Tau-Charm Factory" (with J.M.Jowett, M.Munoz, J.-M.Quesada, C.Willmott), *Proc. of 16th Inter. Conf. on Charged Part. Acc.,* p.439, (1993).

"Beam-Beam Effects in Electron Storage Rings", *Lect. Notes in Phys.,* v.400, p.321 (1992).

Max Zolotorev



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Ph.D. experimental high energy physics, Institute of Nuclear Physics, Novosibirsk (Russia), 1974. Doctor of Science, Institute of Nuclear Physics, Novosibirsk (Russia), 1979; Leading Physicist, Novosibirsk, Russia, 1979 - 1985; Professor of Novosibirsk State University, Russia, 1985 - 1989; Staff Scientist, Lawrence Berkeley Laboratory USA, 1989 -1990.

Affiliations and honors: Special Award of the Academy of Sciences of the USSR for the best experimental work of the year (1979). Member: American Physical Society (APS).

Research interests: particle and photon beam physics; sources of polarized electrons; 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. (with A. Zholents).

"An inverted-geometry high voltage polarized gun with UHV load lock," NIM, A 350, 1-7, 1994. (M. Breidenbach, et al.,).

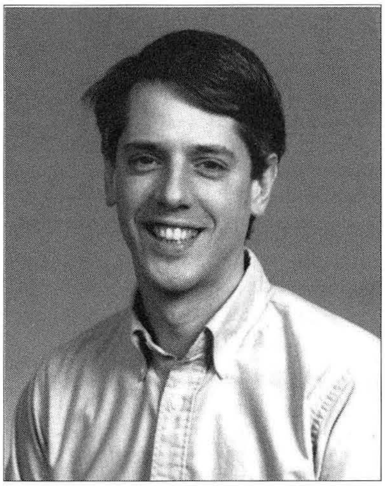
"Optical Stochastic Cooling," Phys. Rev. Lett., v. 71, 25, p. 4146, 1993." (with A. Mikhalichenko)

"Investigation of Nearly Degenerate Opposite Parity States in Atomic Dysprosium, " Phys. Rev. Lett., v. 70, 20, 3019, 1993. (with D.Budker, E. Commins, and D. DeMille).

"Observation of Parity Nonconservation in Atomic Transition," Sov. JETP Pis`ma 28, 379, 1978. (with L. Barkov).

UCB FACULTY ASSOCIATES

Roger W. Falcone



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Joined LBNL/UCB in 1983

Ph. D. (Electrical Engineering) Stanford University (1979); Marvin Chodorow Fellow, Applied Physics Department, Stanford University (1980-83).

Major awards: 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 light with matter; applications of lasers in atomic, plasma, and condensed matter physics; ultrashort pulse lasers; time-resolved x-ray scattering.

Selected publications: T. Donnelly, T. Ditmire, M.D. Perry, R.W. Falcone, "High-order Harmonic Generation in Atom Clusters," Phys. Rev. Lett. **76**, 2472 (1996).

T. Ditmire, T. Donnelly, R.W. Falcone, M.D. Perry, "Strong X-Ray Emission from High-Temperature Plasmas Produced by Intense Irradiation of Clusters," Phys. Rev. Lett. **75**, 3122 (1995).

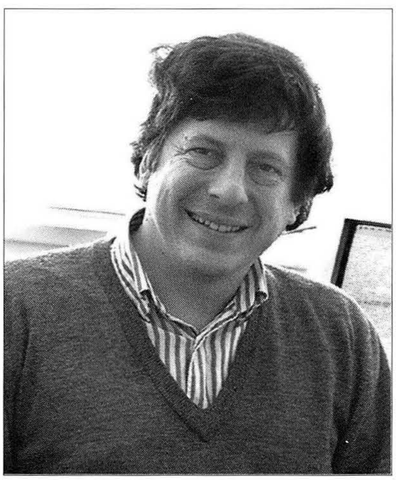
T.E. Glover, J.K. Crane, M.D. Perry, R.W. Lee, R.W. Falcone, "Measurement of Velocity Distributions and Recombination Kinetics in Tunnel-Ionized Helium Plasmas." Phys. Rev. Lett. **75**, 445 (1995).

A. Sullivan, H. Hamster, S.P. Gordon, H. Nathel, R.W. Falcone, "Propagation of Intense, Ultrashort Laser Pulses in Plasmas," Opt. Lett. **19**, 1544 (1994).

S.P. Gordon, T. Donnelly, A. Sullivan, H. Hamster, R.W. Falcone, "X-Rays from Microstructured Targets Heated by Femtosecond Lasers," Opt. Lett. 19, 484 (1994).

H. Hamster, A. Sullivan, S. Gordon, R.W. Falcone, "Short-Pulse Terahertz Radiation from High-Intensity Laser-Produced Plasmas," Phys. Rev. E 49, 671 (1994).

Jonathan S. Wurtele



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Joined LBNL in 1995

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," W-H. Cheng, A. M. Sessler, and J. S. Wurtele, LBL-39642 (1996).

"Excitation of Accelerating Wakefields in Inhomogeneous Plasmas," G. Shvets, J.S. Wurtele, 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, LBNL-38946

"Free Electron Laser Simulation Techniques," (with T. M. Tran), *Phys. Reports* 195, 1 (1990).

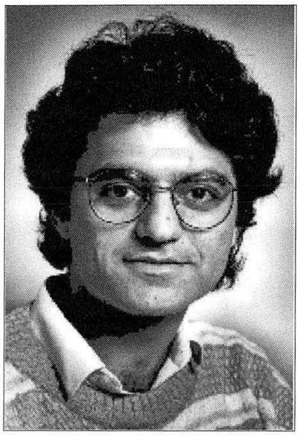
"Asymmetric Stable Equilibria in Nonlinear Plasmas," (with J. Notte, A. J. Peurring, J. Fajans, and R. Chu), *Phys. Rev. Lett.* 69, 3065 (1992).

"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).

Umesh V. Vazirani



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B.S., Computer Science, Massachusetts Institute of Technology, 1981

Ph.D., Computer Science, University of California at Berkeley, 1986

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.

Awards and Affiliations: 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.

Selected Publications: "An Introduction to Computational Learning Theory," (with Michael Kearns), MIT Press, 1995.

"Quantum Complexity Theory" (with E. Bernstein), STOC, 1993. Invited paper in special issue of *SIAM J. Computing* on quantum computing, 1997.

"Strengths and Weaknesses of Quantum Computers," Siam Journal of Computing, (with C. Bennett, E. Bernstein, G. Brassard), invited paper special issue of *SIAM J. Computing* on quantum computing, 1997.

"Matching is as Easy as Matrix Inversion," (with K. Mulmuley and V. V. Vazirani), invited paper in *Combinatorica*, Vol. 7, No. 1, 1987.

"Random Polynomial Time is Equal to Semi-Random Polynomial Time," (with V.V.~Vazirani), FOCS, 1985.

"An Introduction to Computational Learning Theory," (with Michael Kearns), MIT Press, 1994.

POST DOCS

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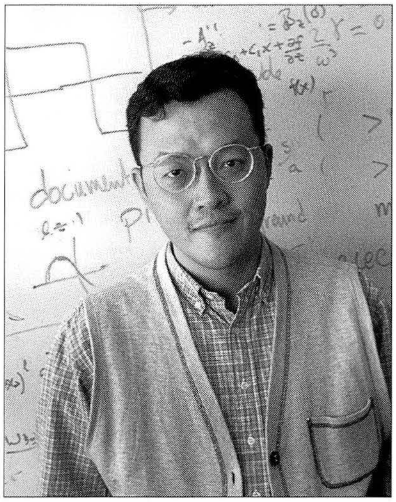

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Ph.D., Physics, University of Maryland at College Park, 1995

Research Interest: Collective effects in a high luminosity muon collider, space charge dominated beam, damping schemes for beam instabilities and nonlinear dynamics in accelerators.

Selected publications: "Damping of the Transverse Head-Tail Instability by a Periodic Modulated Chromaticity" (with A.M. Sessler and J.S. Wurtele), Lawrence Berkeley Laboratory Report, LBNL-39642 (1996).

"Single Bunch Collective Effects in Muon Colliders" (with A.M. Sessler, J.S. Wurtele and K.Y. Ng), Proceedings of 5^{th} European Particle Accelerator Conference, Barcelona, Vol. 2, p. 1081, June, 1996.

"Stability and Halo Formation of a Breathing Axisymmetric Uniform-Density Beam" (with R.L. Gluckstern, S.S. Kurennoy and H. Ye), Physical Review E, **54**, No. 6, 6788 (1996).

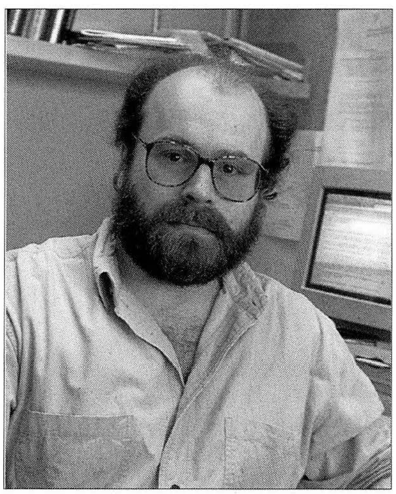
"Studies of Collective Instabilities in Muon Collider Rings" (with A.M. Sessler and J.S. Wurtele), Proceedings of the 9^{th} Advanced ICFA Beam Dynamics Workshop: Beam Dynamics and Technology Issues for $\mu^+\mu^-$ Colliders, Montauk, pp. 206-217, Oct. 1995.

"Stability of a Uniform-Density Breathing Beam with Circular Cross Section" (with R.L. Gluckstern and H. Ye), Physical Review Letters **75**, No. 15, 2835 (1995).

"Frequency Dependence of the Penetration of Electromagnetic Fields through a Small Coupling Hole in a Thick Wall" (with A. Fedotov and R.L. Gluckstern), Physical Review E **52**, No. 3, 3127 (1995).

"Synchrobetatron-coupling Effects in Alternating Phase Focusing Linacs" (with R.L. Gluckstern, and H. Okamoto), Physical Review E **48**, No.6, 4689 (1993).

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 theVlasov–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.

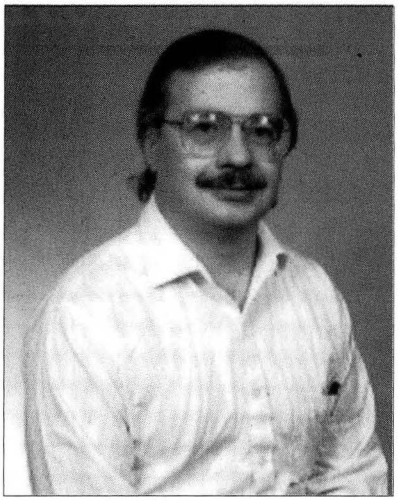
"Canonization and Diagonalization of an Infinite Dimensional Noncanonical Hamiltonian System: Linear Vlasov Theory" (with P. J. Morrison), *Acta Physica Polonica A*, **85**, 243, (1994).

CENTER AFFILIATES

"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

John A. Edighoffer



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Ph.D., Applied Physics, Stanford University, 1981. Ten years at TRW doing FEL research.

Research interests: Free electron lasers, optical diagnostics, photocathodes, superconducting RF, accelerator physics and modeling, accelerator diagnostics; CDRL FEL conceptual design, Stanford/LBL/BNL superconducting RF collaboration; Stanford/LBL FEL diagnostics collaboration; LBL/CEBAF FEL/RF photocathode collaboration; hole out-coupling scaled FEL benchtop experiments.

Selected publications: "Energy Measurement of the Electron Beam Beyond the PALADIN Wiggler" (with T. J. Orzechowski et al.), Proc. 11th FEL Conf. (September 1989).

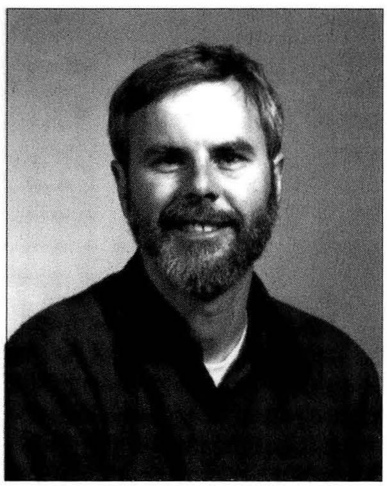
"Visible Free-Electron Laser Oscillator (Constant and Tapered Wiggler)" (with G. R. Neil et al.), *J. Appl. Phys.* (June 1987).

"First Operation of a Tapered Wiggler Free Electron Laser Oscillator" (with S. W. Fornaca et al.), J. Appl. Phys. (1983).

"Free Electron Laser Small Signal Gain Measurement at 10.6 mm," *Appl. Phys. Lett.* (1982).

"Observation of Inverse Cerenkov Interaction Between Free Electrons and Laser Light" (with W. D. Kimura, R. H. Pantell, M. A. Piestrup, and D. Y. Wang), *Phys. Rev. A* **23** (4) (April 1981).

William M. Fawley



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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.*), *Nuovo Cimento* (in press) (1993).

"Multidimensional Simulation Studies of the SELENE FEL Oscillator/Buncher Followed by a Radiator/Amplifier Output Scheme" (with S. J. Hahn), LBL-36749, to appear in Laser Power Beaming II, SPIE Tech. Conf. 2376 (San Jose, February 1995).

"Beam Dynamics Studies with the MBE-4 Heavy-Ion Linear Induction Accelerator" (with T. Garvey et al.), to be published in *Physics of Plasmas*, March 1997.

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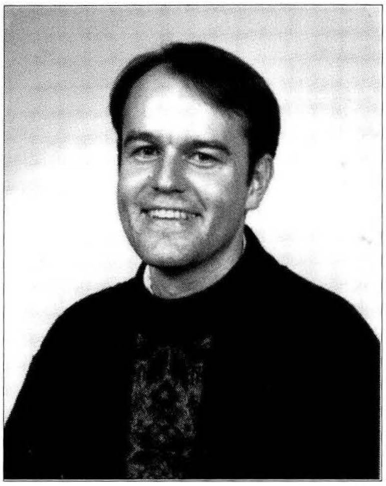

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Ph.D., University of Maryland, 1984.

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

Selected publications: "Locally Accurate Dynamical Euclidean Group," *Phys. Rev. E*, March 1997.

"Beam Dynamics: A New Attitude and Framework", Gordon & Breach, to be 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.

"Sixth Order Lie Group Integrator," *J. Comp. Phys.* (1992).

"A Contemporary Guide to Beam Dynamics" (with K. Hirata), KEK Report 92-12 (1992).

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Background: Faculty of MIT 1973-76; Member of Technical Staff, Bell Labs 1976-81; Department Head, Research, Bell Labs 1981-1995; LLNL 1976-present; Professor, UCD 1997-present; Fellow, American Physical Society, Optical Society of America

Research Interests: High Intensity Lasers, Interaction of High Intensity Lasers with matter, especially atoms, electrons and plasmas, Interactions of High Intensity Lasers, with relativistic electron Beams, Free electron laser physics

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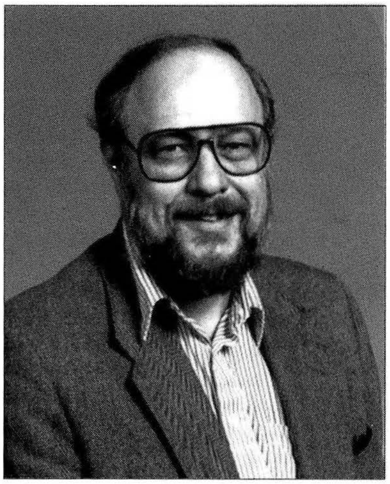

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Ph. D., Nuclear Physics, McMaster University, 1970.

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 (May 1985), p. 3282.

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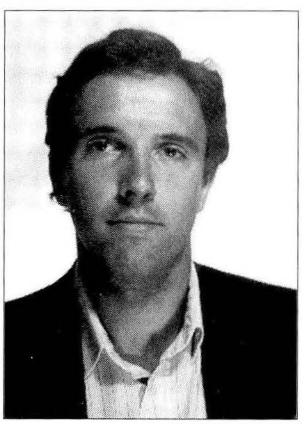

Ph.D., Physics, under Prof. G. Bekefi, MIT, 1986. Thomson Electron Tubes & Devices, 1986-92. Visiting scientist at Ecole Polytechnique, France, 1987. Visiting scientist at MIT, Plasma Fusion Center, 1988-91. Research scientist, UCLA, 1993. Research scientist, UC Davis/LLNL, 1994-present.

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

Selected publications: "Classical theory of nonlinear Compton scattering", *Phys. Rev. Lett.* 76, 624, (1996)

"Classical electrodynamical derivation of the radiation damping force", *Phys. Rev. Lett.* 74, 1107 (1995)

"Time and frequency domain analysis of superradiant coherent synchrotron radiation in a waveguide free-electron laser", *Phys. Rev. Lett.* 72, 1192 (1994)

"Single-mode operation of a Bragg free-electron maser oscillator", *Phys. Rev. Lett.* 72, 2391 (1994)

"Nonlinear ponderomotive scattering of relativistic electrons by an intense laser field at focus, *Phys. Rev. E*51, 4833 (1995)

"Spectral analysis of the nonlinear Doppler shift in ultrahigh intensity Compton scattering", *Phys. Rev. E*54, 2956 (1996)

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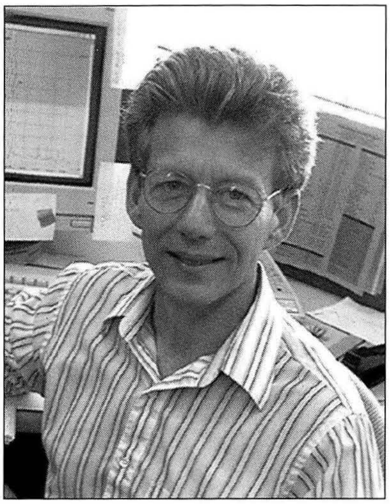

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Research interests: induction accelerators; beam dynamics; high-power microwave generation; novel accelerators.

Selected publications: "Prototype Microwave Source for a Relativistic Klystron Two-Beam Accelerator" (with F. Deadrick, et al.), *IEEE Trans. Plasma Sci.*ence 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).

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

Selected publications: "Beam Tests of a 2 cm Diameter Lithium Lens" (with G. Dugan [FNAL] et al.), PAC Vancouver, 1985.

"Possibilities of $\bar{p}$ Production at CERN", Hyperfine Interactions 44, 1988.

"On the Feasibility of Antideuteron Production and Storage at CERN" (with T.R. Sherwood), Ibid.

"A Linac-on-Ring Collider B-Factory Study" (with P. Grosse Wiesmann et al.), AIP Conference Proceedings 214, Beam Dynamics Issues of High-Luminosity Asymmetric Collider Rings, Ed. A, Sessler, 1990.

"Incoherent Beam-Beam Effect - The Relationship Between Tune-Shift, Bunch Length and Dynamic Aperture" (with L. Wood), Ibid.

"The Consequence of Beam-Beam Effect and Beam Fluctuations in Linear-on-Ring Colliders", AIP Conference Proceedings 261, Rare and Exclusive B & K Decays and Novel Flavor Factories, Ed. D.B. Cline, 1992.

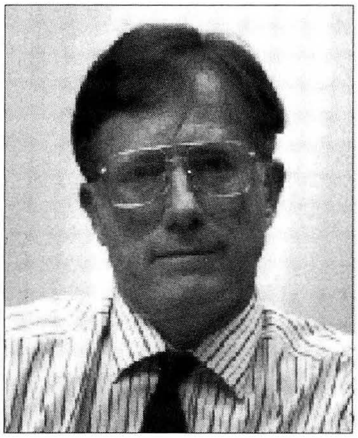
"CLIC Drive Beam Generation by Induction Linac and FEL" (with R. Corsini et al.), PAC, Washington, 1993.

"CLIC Drive Beam Generation - A Feasibility Study" (with B. Autin et al.), EPAC, Oxford, 1994.

"CLIC Drive Beam Generation by Induction Linac and FEL, Preliminary Experimental Studies" (with R. Corsini et al.), Nucl. Instr. Meth. A 341, 1994.

"CLIC - A Compact and Efficient High Energy Linear Collider" (with H. Braun et al.), PAC and HEPAC, Dallas, 1995

"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 (to be published).



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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: A.J. Balkcum, D.B. McDermott, K.C. Leou, F.V. Hartemann, N.C. Luhmann, Jr. "Theory and Design of a High-Harmonic Gyrofrequency Multiplier," *IEEE Trans. on Plasma Science*, Vol. 22, No. 5, pg. 913, October 1994.

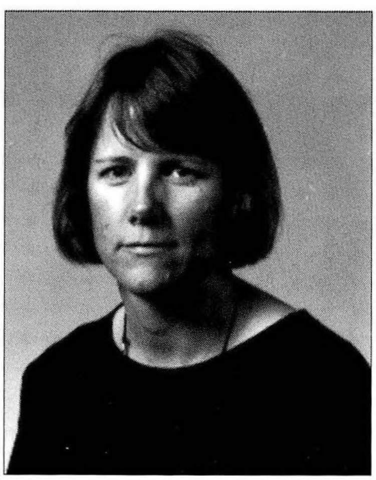
F.V. Hartemann, G.P. Le Sage, D.B. McDermott, N.C. Luhmann, Jr., "Coherent Radiation in an Cylindrical Waveguide with a Helical Wiggler," *Physics of Fluids B*, Vol. 1, No. 1, pg. 1, May 1994.

F.V. Hartemann, N.C. Luhmann, Jr., "Classical Electrodynamical Derivation of the Radiation Damping Force," *Physical Review Letters,* Vol. 74, No. 7, pg.1107, February 1995.

F.V. Hartemann, S. Fochs, G. Le Sage, N.C. Luhmann, Jr., J. Woodworth, M. Perry, Y.J. Chen, A.K.Kermen, "Nonlinear Ponderomotive Scattering of Relativistic Electrons by an Intense Laser Field at Focus," *Physical Review E,* Vol. 51, No. 5, pg. 4833, May 1995.

A.J. Balkcum, D.B. McDermott, R.M. Phillips, A.T. Lin, N.C. Luhmann, Jr., "250 MW X-Band TE 01 Ubitron Using a Coaxial PPM Wiggler, "IEEE Transactions on Plasma Science's Special Issue on High Power Microwave Generation,November 1995.

H. Shi, W-M. Zhang, C.W. Domier, N.C. Luhmann, Jr., L.B. Sjogren, H-X.L. Liiu, "Novel Concepts for Improved Nonlinear Transmission Line Performance," IEEE Transactions on Microwave Theory and Techniques, Vol.43, No. 4, pg. 780, April 1995.



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Ph.D., Physics, Rutgers University, 1978.

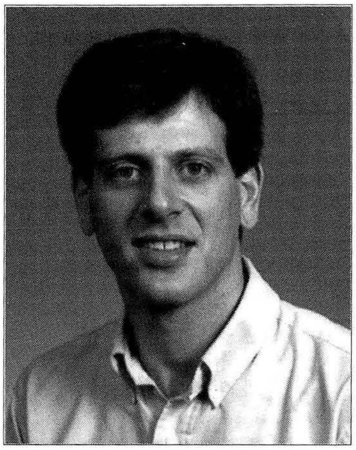
Research interests: Accelerator simulation and modeling both for design and controls, nonlinear dynamics, controls and modeling for accelerator physics studies in circular accelerators.

Selected publications: "Summary of the Working Group on Modeling and Simulation," *Proc. Advanced Beam Dynamics Workshop on Effects of Errors in Accelerators, Their Diagnosis and Corrections,* AIP Conference Proceedings No. 255, Particles and Fields Series, 48, Corpus Christi, Texas (1991).

"Experimental Investigation of Nonlinear Dynamics in the Fermilab Tevatron" (with A. Chao et al.), *Phys. Rev. Lett.* **61**, 2752 (1988).

"Teapot: A Thin-Element Accelerator Program for Optics and Tracking" (with R. Talman), *Part. Accel.*, **22**, 35 (1987).

Robert W. Schoenlein



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Affiliations: 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, Newport Research Award - 1988

Research Interests: Generation of femtosecond x-ray pulses via Thomson scattering, femtosecond structural dynamics of materials using x-ray pulses, studies of electron-hole dephasing and coherent vibrational dynamics in semiconductor nanocrystals, ultrafast carrier scattering and dephasing dynamics in metal films, femtosecond photochemical isomerization and non-stationary states in rhodopsin pigments.

Selected Publications: .W. Schoenlein, W.P. Leemans, A.H. Chin, P. Volfbeyn, T.E. Glover, P. Balling, M. Zolotorev, K.-J. Kim, S. Chattopadhyay, and C.V. Shank, "Femtosecond x-ray pulses at 0.4 Å by 90° Thomson Scattering: A new tool for probing structural dynamics of materials," *Science*, **274**, 236, 1996.

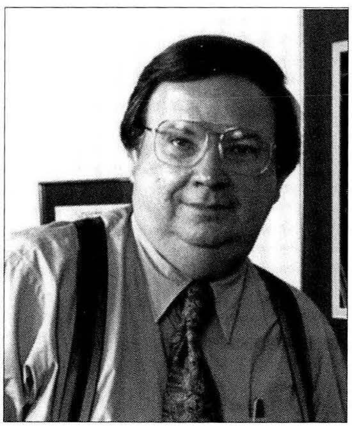
W.P. Leemans, R.W. Schoenlein, P. Volfbeyn, A.H. Chin, T.E. Glover, P. Balling, M. Zolotorev, K.-J. Kim, S. Chattopadhyay, and C.V. Shank, "X-ray based sub-picosecond electron bunch characterization using 90 degrees Thomson scattering," *Phys. Rev. Lett.*, **77**, 4128, 1996.

T. E. Glover, R. W. Schoenlein, A. H. Chin, and C.V. Shank, "Observation of laser assisted photoelectric effect and femtosecond high-order harmonic radioation," *Phys. Rev. Lett.*, **76**, 2468, 1996.

R.W. Schoenlein, D. M. Mittleman, J. J. Shiang, A. P. Alivisatos, and C. V. Shank, "Investigation of femtosecond electronic dephasing in CdSe nanocrystals using quantum-beat-suppressed photon echoes," *Phys. Rev. Lett.*, **70**, 1014, February 1993.

R. W. Schoenlein, L. A. Peteanu, R. A. Mathies, and C. V. Shank, "The first step in vision: Femtosecond isomerization of rhodopsin,"*Science,* **254**, 412, October 1991.

Charles V. Shank



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Ph.D. (1969): Electrical Engineering, University of California, Berkeley. 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).

Major awards and affiliations: 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 (OSA).

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

Selected publications: C.V. Shank. (1986, September 19). "Investigation of Ultrafast Phenomena in the Femtosecond Time Domain." Science, 233, 1276-1280.

K.-J. Kim, S. Chattopadhyay, and C.V. Shank. (1994). "Generation of femtosecond X-rays by 90° Thomson Scattering." In: Nuclear Instruments and Methods in Physics Research. A 341, Elsevier Science Publishers B.V. 351-354.

Q. Wang, R.W. Schoenlein, L.A. Peteanu, R.A. Mathies, and C.V. Shank. (1994, October 21). "Vibrationally Coherent Photochemistry in the Femtosecond Primary Event in Vision." Science, 226, 244-24.

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Major awards and affiliations: 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).

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).

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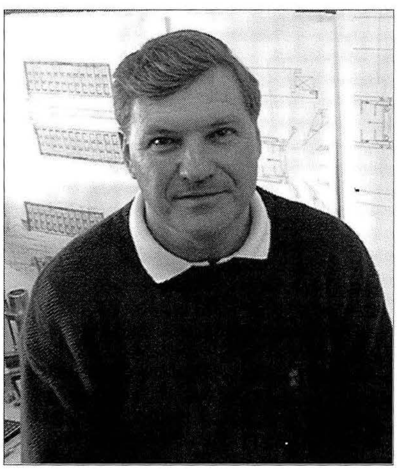

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Selected publications: "Relativistic-Klystron Two-Beam Accelerator as a Power Source for a 1 TeV Next Linear Collider - A Systems Study", LBNL #36232, August 1994.

"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, 10/2/94, LBNL # 36545.

"Heavy-Ion Fusion Driver Research at Berkeley and Livermore", presented at the Sixteenth IAEA Fusion Energy Conference, Montreal, Canada, October 7-11, 1996.

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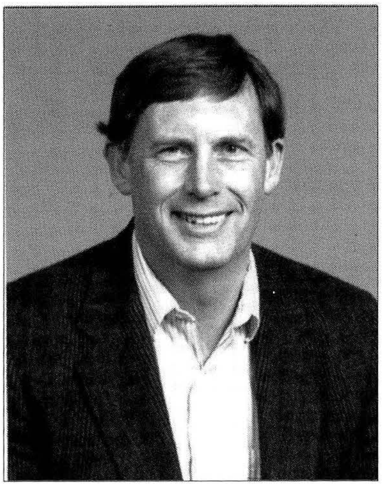

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Ph.D., Stanford University, Physics, 1981.

Research interest: 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).

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Affiliations: Fellow, American Physical Society; Alfred P. Sloan Research Fellow, 1982 - 85.

Research Interests: High energy physics. accelerator physics, experimental astrophysics, esp. dark-matter searches, and instrumentation for science-based stockpile stewardship, esp. radiography.

Selected Publications: "Zeroeth-order Design Report for the Next Linear Collider," C. Adolphsen et al., UCRL-ID-124161, May 1996

"Test Results of a Combined Distributed Ion Pump/Non-Evaporable Getter Pump Design Developed as a Proposed Alternative Pumping System for the PEP-II Asymmetric B-Factory Collider," F. Holdener et al., (UCRL-JC-119407), Proc. of the 1995 Particle Accelerator Conference and International Conference on High-Energy Accelerators (Dallas, TX, May 1-5, 1995)

"Test Results of Pre-Production Prototype Distributed Ion Pump Design for the PEP-II Asymmetric B-Factory Collider," F.R. Holdener *et al.*, presented at the 1995 Particle Accelerator Conference and International Conference on High-Energy Accelerators (Dallas, TX, May 1-5, 1995)

"The PEP-II Asymmetric B Factory: Design Details and R&D Results," E. Bloom et al., SLAC-PUB-6564, presented at the Fourth European Particle Accelerator Conference (EPAC '94), London, England, June 27-July 1, 1994

"A Warm Gas Jet Target for the PEP Storage Ring," J.D. Molitoris, K. van Bibber, Proc. of the Workshop on Electronuclear Physics with Internal Targets, SLAC, January 5-8, 1987, SLAC-Report-316, p. 180

"A Precise Calibration of the SLAC 8 GeV Spectrometer Using the Floating Wire Technique," L. Andivahis et al, SLAC-PUB-5753, February, 1992, Submitted to *Nucl. Instr. and Meth.*

"PEGASYS — An Internal Target - Spectrometer System for the PEP Storage Ring," K. van Bibber, *Nucl. Instr. and Meth.* B40/41, 436 (1989)

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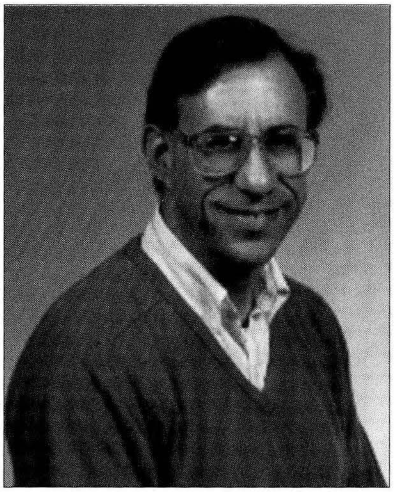

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Research interests: Design of electron storage rings and high-luminosity electron-positron colliders, beam instabilities, collective effects, design of PEP-II asymmetric B-factory, study of high-luminosity collider design.

Selected publications: "General B-Factory Design Considerations," *Lect. Notes in Phys.* 425, 57 (H. Dienes, M. Month, B. Strasser, S. Turner, eds.) Springer-Verlag, Berlin, Germany (1994).

"Physics and Technology Challenges of $B\bar{B}$ Factories," *Proc. 1991 Particle Accelerator Conference*, San Francisco, California, (May 1991), p. 1. Also in *Lect. Notes in Phys.* 400 (M. Dienes, M. Month, S. Turner, eds.), Springer-Verlag, Berlin (1992), p. 600.

"PEP-II Asymmetric B-Factory: R&D Results" (with J. Dorfan, A. Hutton, and W. Barletta for the PEP-II Design Group), *Proc. European Particle Accelerator Conference*, Berlin, Germany (March 1992).

"B Factory RF System Design Issues," *Proc. International Conference on B Factories: The State of the Art in Accelerators, Detectors and Physics*, Stanford, California (April 1992).

"PEP-II: An Asymmetric B Factory Based on PEP" (with A. Hutton, for the SLAC/LBL/LLNL B Factory Design Group), *Proc. 1991 Particle Accelerator Conference*, San Francisco, California (May 1991), p. 84.

"ZAP and Its Application to the Optimization of Synchrotron Light Source Parameters," *Part. Accel.* **23**, 289 (1988).

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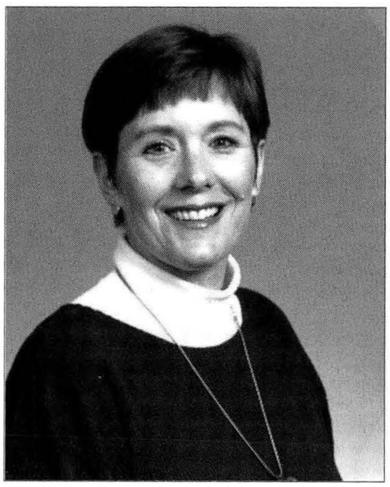

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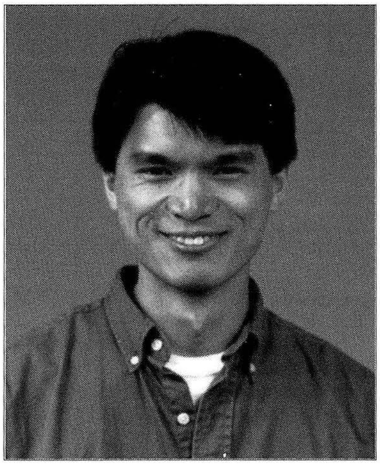

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B.S., Physics, Electrical Engineering, Oregon State University, 1990.

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Susana Fernandez

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University of California at Berkeley
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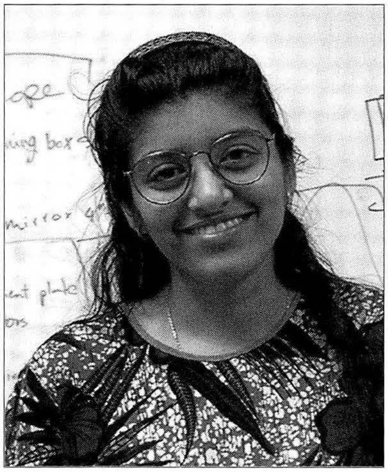
LBNL MS 71-259
susana@physics.berkeley.edu
joined CBP's Laser Optics Group in 1996

B.S., Engineering Physics, University of California at Berkeley, Dec. 1997

Research Interests: laser-plasma interactions, ultra-high intensity lasers, 3D Laser Imaging

Plans after graduation: enter graduate program in applied physics, fall 1998.

Richa Govil



Graduate Student
UC Berkeley
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joined LBNL 1991

M. A., Physics, University of California, Berkeley, 1996.

A. B., Physics, University of California at 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. A320 (1992) 587.

Kangzhu Guo

Visiting Scholar
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Joined LBNL in 1996

M.S., Technical Physics, Peking(Beijing) University,1992.

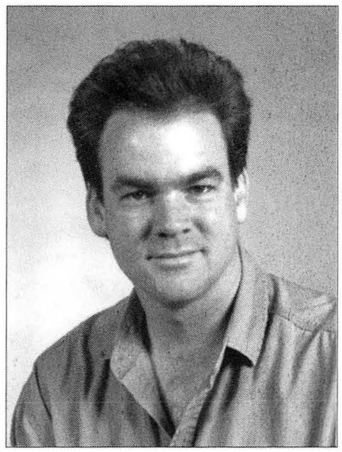
Ph.D. student of IHEP (Institute of High Energy Physics), Chinese Academy of Sciences, since 1994.

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

Selected publications: "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).

"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)

Michael Irwin



Undergraduate Student
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Joined LBL in 1994

Research interests: Engineering physics.

Peter (Byung) H. Lee

Undergraduate Student
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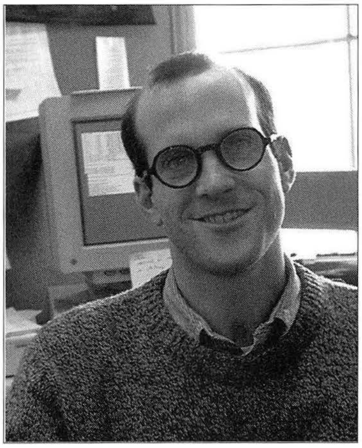
Pursuing B.S. in Engineering Physics and B.S. in Engineering Math/Stat at the University of California at Berkeley.

Research Interests : Laser-plasma interactions, plasma-based accelerators,cosmology

Steven M. Lidia



Graduate Student
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Joined LBL in 1995

B.S., Engineering Physics, University of California, Berkeley, 1991

Doctoral Candidate, Physics, University of California, Davis, 1995

Affiliations: Member, American Physical Society

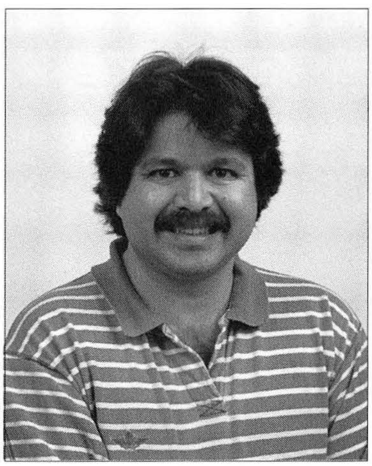
Research Interests: Charged particle beam production of coherent radiation, beam dynamics and instabilities, free electron lasers, RF and induction linear accelerators, novel accelerators and colliders

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).

David M. Ponce



Graduate Student
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joined LBL 1991

B.S., University of California at Berkeley, Engineering Physics, 1994

Major Awards: Honorable mention, National Science Foundation Graduate Research Fellowship, 1996.

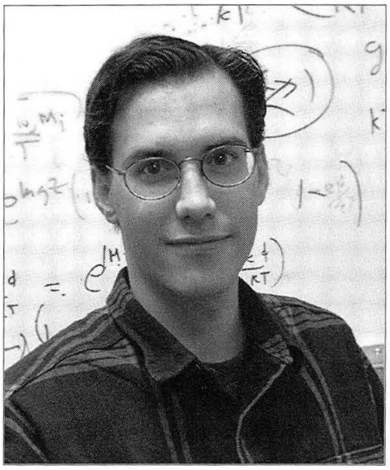
Research Interests: Laser Wakefield particle acceleration, Laser plasma interactions, particle beam transport.

Selected Publications:
"Photoemission Starting of RF Driven Multicusp Ion Sources," (with D.S. Pickard, K.N. Leung et. al) Rev. Sc. Instrum., 66, N10, 1995.

"Laser and Spectroscopic Diagnostics of H^- Ion Source Plasma," (with A.T. Young, K.N. Leung et. al) Rev. Sc. Instrum., 65, N4, 1994.

"Laser , Spestroscopic, and Langmuir Probe diagnostics of an Inductively Coupled RF Discharge H^- Ion Source," (with A.T. Young, D.A. Bachman et. al), Lawrence Berkeley Laboratory report LBL 33118R1, 1993.

Carl B. Schroeder



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

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

Pavel Volfbeyn

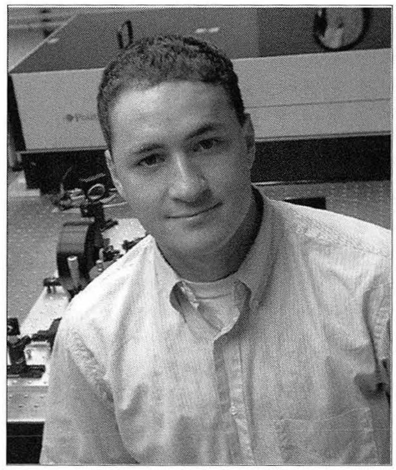
Graduate Student
Massachusetts Institute of Technology
MS 71-259
(510) 486-5107
pavel@lbl.gov
joined LBNL 1995

M.S., Physics, Massachusetts Institute of Technology, 1995

Research Interests: laser-plasma interactions, advanced accelerator concepts, ultra-high intensity lasers, x-ray generation, free electron lasers.

Selected Publications: "X-ray based sub-picosecond electron bunch characterization using 90° Thomson scattering", Physical Review Letters, v. 77, no. 20, November 11, p. 4182, 1996.

"Observations of frequency chirping and phase of a free electron laser amplifier", Nuclear Instruments and Methods of Research, Section A, vol. 341, no. 1-3, p.119-23, 1994



Susan Wheeler

Laboratory Technician
MS 71-259
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wheeler@csa1.lbl.gov
joined LBL 1996

B.S., University of Michigan, Physics, 1996

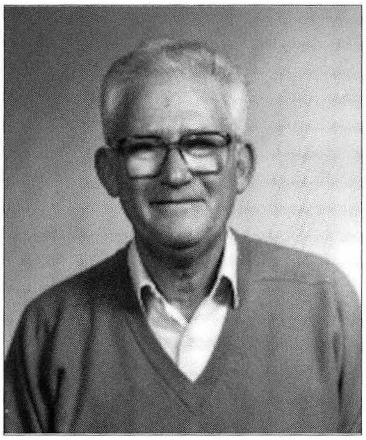
Major Awards: National Science Scholar Scholarship, 1991.

Research Interests: Plasma lenses for relativistic electron beams, advanced accelerator concepts.

Selected Publications: "Plasma Lenses for Relativistic Electron Beams at LBNL" (with R. Govil and W. P. Leemans), presented at APS Division of Plasma Physics, Denver, Colorado, 1996.

PARTICIPATING GUESTS (Emeriti)

Alper Garren



Senior Scientist
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Joined LBL in 1955

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

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 Accelerator Conference* (May 1991).

"Site-Specific Conceptual Design of the Superconducting Supercollider," SSCL-SR-1056 (July 1990).

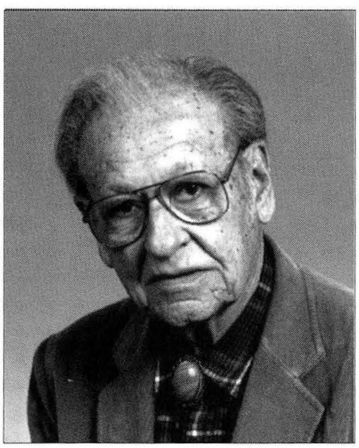
"An Asymmetric B-Meson Factory at PEP" (A. A. Garren et al.), *Proc. 1989 Particle Accelerator Conference,* Chicago, Illinois (1989).

"Thin Lens Optics with Space Charge," *Proc. 7th International Conference on High Energy Accelerators,* Yerevan, USSR, UCRL-19313 (1969).

"Lattice of the NAL Proton Synchrotron," *Proc. 1969 Particle Accelerator Conference* (1969).

"Orbit Dynamics in the Spiral-Ridged Cyclotron" (with Lloyd Smith), UCRL-8598 (1959)

Albert Ghiorso



MS/71-259
(510)486-7771
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Joined LBL in

Presently a member of the Nuclear Science Division.

Staff Member, University of Chicago Metallurgical Laboratory, 1942-46. Senior Scientist, Lawrence Berkeley Laboratory, 1946-82.

Senior Scientist Emeritus, ditto 1982-present.

Education: B.S. Electrical Engineering, University of California, Berkeley, 1937; honorary Doctor of Science degree, Gustavus Adolphus College, 1966; American Chemical Society Award: Nuclear Applications in Chemistry, 1973

Co-Discoverer of 13 elements, 95-106 and 110 (to be confirmed).

Some selected papers:

Systematics of Alpha-Radioactivity; I. Perlman, A. Ghiorso and G.T. Seaborg; Phys. Rev. 77, 26 (1950)

Evidence for Subshell at N = 152;. Ghiorso, S. G. Thompson, G. H. Higgins, B. G. Harvey and G. T. Seaborg; Phys. Rev. 95, 293 (1954)

New Elements Einsteinium and Fermium, Atomic Numbers 99 and 100; Ghiorso et al; Phys. Rev. 99, 1048 (1955)

The Omnitron: A Versatile Medium-Energy Synchrotron for the Acceleration of Light and Heavy Ions; A. Ghiorso, R. M. Main and B. H. Smith

IEEE Transactions on Nuclear Science NS-13, 280 (1966)

A History of The Discovery of The Transplutonium Elements; Albert Ghiorso; In Actinides in Perspective, edited by N.M. Edelstein (Pergamon Press, Oxford and New York, 1982), p. 23

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).

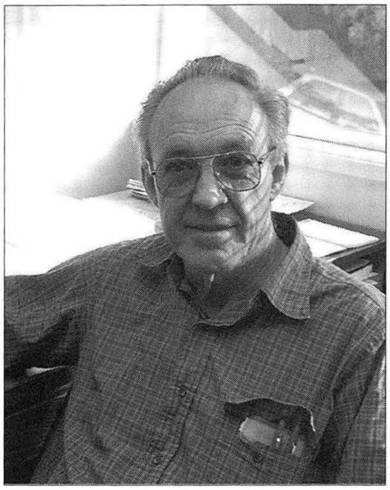
Director of the HILAC and then the SuperHILAC from 1957-1971.

Co-inventor of the Omnitron.

Inventor of the BevaLac.

Affiliations: American Physical Society; American Association for the Advancement of Science (AAAS).

Glen R. Lambertson



Senior Scientist
MS 71-259
(510)486-7205
lambertson@lbl.gov
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).

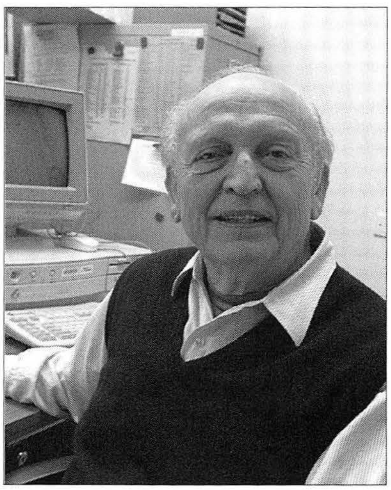
"Higher Order Mode Damping Studies on the PEP-II B-Factory RF Cavity," (with R. A. Rimmer et al.), *3rd European Particle Accelerator Conference* (1992).

"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).

"Techniques for Beam Impedance Measurements Above Cutoff" (with A. F. Jacob, R. A. Rimmer, and F. Voelker), 2nd European Particle Accelerator Conference, Nice, France (June 1990), p. 1049; LBL-28190.

Jack M. Peterson



Senior Scientist
MS 71-259
(510)486-6570
Joined LBNL in 1946, LLNL in 1952, and LBNL again in 1964

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

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: "Photo-production of Mesons by X-rays" (with E.M. McMillan and R.S. White), Science, 110, p.579 (1949)

"Neutron Giant Resonances—A Nuclear Ramsauer Effect", *Phys. Rev.*, 125, p. 955, (1962)

"Use of Collective Fields in the Acceleration of Particles", APS Mtg, San Francisco, LBL-704, (1972)

"PEP Injection System", (with Karl Brown), Part. Accel. Conf., Wash., D.C. IEEE Trans. Nucl. Sci. NS-22 3, p.1423, (1975)

"Effects from Measured Ground Motions at the SSC", (with K-Y Ng), SSCL-277-Rev, Fermilab Pub-9119, (1990)

"Correction of Random Multipole Errors with Lumped Correctors", (with E. Forest), SSCL-N-383

Frank Selph

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Joined LBL in 1962

M.S., Physics, University of California, Berkeley, 1963. Joined LBL in 1962, retired 1991. Continues to work on accelerator projects.

Current research: ALS linac improvement, design of a storage ring for improved ion stripping.

Selected publications: "A Ring to Test Stripping Enforcement," LBL-35289 (1993).

"Magnetic Ring for Stripping Enhancement," LBL 82940 (1992).

"Operating Experience with the ALS Linac" (with D. Massoletti), *Proc. 1991 Particle Accelerator Conference,* IEEE 91CH3038-7, Z (1991), pp. 2978–80.

"Compensation of Beam Loading in the ALS Injector Linac," *Proc. 1988 Linear Accelerator Conference,* CEBAF Report 89-001 (1988), pp. 580–82.

"Wakefield Effects in the Two-Beam Accelerator" (with A. Sessler), *Nucl. Instrum. Methods* **A244,** 323–29 (1986).

"Acceleration of Uranium at the Bevalac" (with J. Alonso et al.), *Science* **217,** 1135–37 (1982).

"The Next Generation of Relativistic Heavy Ion Accelerators" (with H. Grunder and C. Leeman), *Proc. Symposium on Heavy Ion Research,* G.S.I. Darmstadt, Germany (1978).

"A Method for Obtaining Linac Beams of Continuously Variable Energy," *Proc. 1970 Proton Linac Accelerator Conference,* National Accelerator Laboratory, Batavia, New York (1970), pp. 868–79.

Ferdinand Voelker

Senior Scientist
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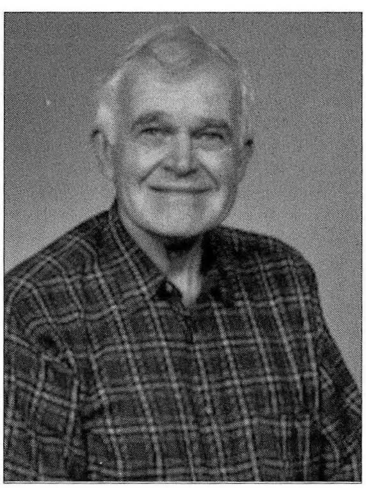
Joined LBL in 1952



M.S., 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 (1992); LBL-33088.

"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 (1992); LBL-32549.

"Calculations on RF Cavity Feedback Using Simple Analytic Model" (with G. Lambertson) (1991).

"Technique for Beam Impedance Measurements Above Cutoff" (with G. R. Lambertson, A. F. Jacob, and R. A. Rimmer), presented at the European Particle Accelerator Conference, Nice, France (1990); LBL-28190.

"A High-Frequency Schottky Detector for Use in the Tevatron" (with D. A. Goldberg, W. Barry, and G. R. Lambertson), presented at the Particle Accelerator Conference, Washington, D.C. (1987); LBL-22273.

"An Array of 1 to 2 GHz Electrodes for Stochastic Cooling" (with T. Henderson and J. Johnson), presented at the 1983 Particle Accelerator Conference, Santa Fe, New Mexico (1983).

PRINCIPAL COLLABORATORS

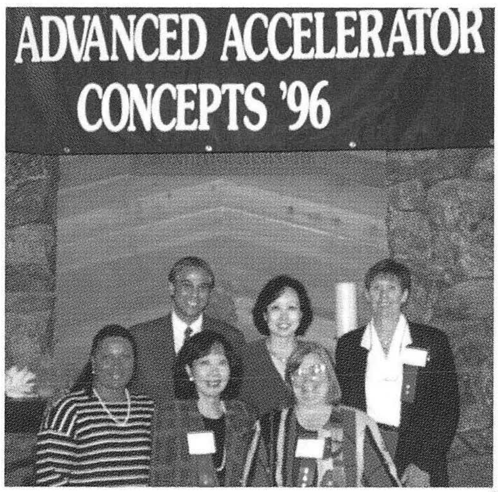
"I still say to myself when I am depressed and find myself forced to listen to pompous and tiresome people, 'Well, I have done one thing you could never have done, and this is to have collaborated with Littlewood and Ramanujan on something like equal terms.'"

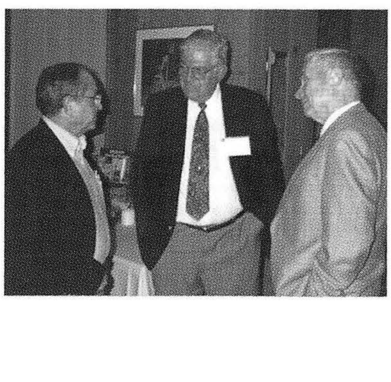
— *G.H. Hardy in*
A Mathematician's Apology

CENTER FOR BEAM PHYSICS — Principal Collaborators

Femtosecond X-ray Source Collaboration:	R. Schoenlein, LBNL C.V. Shank, LBNL
NLC Collaboration:	D. Burke, SLAC
PEP-II B-Factory Collaboration:	J. Dorfan, SLAC D. Hitlin, Caltech
FEL Collaboration:	F. Dylla, CEBAF
Photocathode/SCRF Collaboration:	Chia-Erh Chen, Peking University
Two-Beam Accelerator Collaboration:	J.P. Delahaye, CERN J. Haimson, Haimson Research G. Westenskow, LLNL
Heavy-Ion Beam Cooling in RHIC:	M. Harrison, BNL S. Ozaki, BNL
Advanced Accelerator Concepts:	M. Campbell, LLNL R. Freeman, LLNL K. van Bibber, LLNL M. Iizumi, JAERI, Japan Y. Kishimoto, JAERI, Japan A. Sergeev, Nizni Novogorod, Russia T. Tajima, UT, Austin
X-band Photocathode Source Technology Collaboration:	N. Luhman, UC Davis

SUMMARY OF ACTIVITIES





SUMMARY OF ACTIVITIES

In nineteen ninety-six and ninety-seven, we are witnessing significant expansion in breadth, depth and scope — of the Center's research and development activities. Originally chartered as the Exploratory Studies Group in 1985, we were soon recognized and organized as a Center, in accordance with our mission: to help meet the technical challenges of major facilities and initiatives (local, national and international) and to generally enhance LBNL's capabilities in particle and photon beam research.

Our staff played a pivotal role in the design, construction, and commissioning of the Advanced Light Source. We were also one of the primary factors in 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, when completed, will greatly facilitate the study of CP violation. Our scientists and engineers remain involved with the ALS and PEP-II, especially in beam dynamics studies and in rf and feedback systems. (The technical problems are similar; PEP-II benefits from ALS experience and, with care to avoid disrupting user operations, we can use the ALS as a testbed.) Meanwhile, with an eye toward the future of accelerators, we have spearheaded a collaboration on the preliminary design of the Next Linear Collider (NLC), 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-GeV center-of-mass collision energy. The Center's responsibilities in this collaboration with the Stanford Linear Accelerator Center include damping rings, an interaction point for gamma-gamma collision physics to leverage the investment, and scenarios and technologies for an eventual upgrade to 1 TeV. The energy-upgrade studies are intimately tied to the Two-Beam Accelerator (TBA) concept that we have been exploring for some years in collaboration with Lawrence Livermore National Laboratory. The collaboration is now constructing a testbed at LBNL for a relativistic-klystron TBA where we would prototype the technology that could serve as the source of rf power for the NLC upgrade.

Yet another major development has been the emergence of the Muon Collider Concept. LBNL has been chosen by the national muon collider collaboration to coordinate work on the collider ring and this work is predominantly done through the Center.

We continued expanding our experimental capabilities over the past year. The Beam Test Facility, which will increase the benefits of the ALS between ALS injection cycles, was fully commissioned. Besides the first two experiments under current study — plasma focusing of beams and generation, detection, and use of femtosecond x-ray pulses — preparations are under way for research into laser acceleration, laser guiding, optical stochastic cooling, and the entropy of particle and photon beams. And short-pulse tabletop terawatt lasers are being added to our Laser Optics Laboratory (now named l'OASIS lab) to embark on various laser-plasma-particle interaction studies for novel acceleration, diagnostics and control techniques.

Aside from the growth in these activities, we have also continued making progress in our traditional focus areas: accelerator theory, linear and nonlinear beam dynamics, the fundamental physics of free-electron lasers, and high-energy collider physics (including diagnostics and beam cooling for large facilities such as the Large Hadron Collider at CERN and the Relativistic Heavy Ion Collider at Brookhaven). We have joined the LCLS (Linac Coherent Light Source) collaboration with Stanford and major collaborative initiations with LLNL and JAERI (Japan Atomic Energy Research Institute) are under way for studies of laser manipulation of beams. And our diverse research and educational activities have enjoyed enhanced participation by students and international visitors, and collaborations, old and new, from various institutions around the world.

ADVANCED COLLIDER PHYSICS

During the past years we have pursued intense research in advanced collider physics. The year 1996 culminated in the Snowmass workshop, under the joint auspices of the Division Physics of Beams (DPB) and the Division of Particle and Fields (DPF) of the American Physical Society, with the Center scientists responsible for one of the five accelerator working groups. Our task was to set the direction of these groups, writing the charges to them, organizing the invited presentations, etc. A significant result of the Snowmass workshop, strongly promoted by the Advanced Accelerator Concepts working group leaders—S. Chattopadhyay, and D. Whittum together with Jonathan Wurtele—was a consensus that the beamstrahlung constraint in collider design must be circumvented—by improvements in detectors, by compensated collisions, or by some similar concept. Such a procedure would modify collider scalings so as to help meet the challenges faced by short wavelength accelerator designs (e.g., THz, plasma-based, laser, etc.). In addition to conventional e^+e^- collisions, the complementary collisions of photons on photons via a gamma-gamma collision arm was singularly spear-headed by LBNL with Kwang-Je Kim as its leader, in collaboration now with SLAC and LLNL.

LBNL was chosen by the muon collider collaboration to coordinate work on the collider ring and to give an invited presentation at Snowmass, thereby becoming responsible for the chapter on the collider ring in the muon collider feasibility study ("$\mu^+\mu^-$ Collider: A Feasibility Study", LBNL-38946, Chapter 8, pp. 313-360). The feasibility problem was studied and much discussed at the workshop, but the larger problem faced by the US high-energy community was not. Without a new development, we face the possibility that the United States will have no high energy facility beyond the Tevatron and B-factory. The muon collider could be that "new development." But only continued intensive collaboration, supported by a vigorous and well-conceived R&D program, can bring this to fruition. As a part of that effort, LBNL continues to coordinate the ring design and has led, together with FNAL, a week-long workshop on the collider ring and detector at LBNL in February, 1997. LBNL, via CBP, is also leading the Worskshop on Muon Colliders to be held at Orcas Island in May, 1997.

Gamma-Gamma Collider

An e^+-e^- collider can be made into an e^--γ or γ-γ collider by converting the electrons into gamma rays via Compton backscattering with terawatt laser beams, as shown schematically in Figure 1. This is desirable because γ-γ collisions could provide unique access to some areas of fundamental physics, for example, direct measurement of the partial decay width of a Higgs boson into two γ quanta. The data from γ-γ collisions also supply desirable redundancy to the data from e^+-e^- collisions. In March 1994, the Center organized The Workshop on Gamma-Gamma Colliders to examine these issues. It was concluded during the workshop that a future linear collider should incorporate e^--γ and γ-γ collisions in addition to the e^+-e^- collision as it will have a relatively small incremental cost, and that the technology is sufficiently advanced today to seriously consider a gamma-gamma collider.

In early 1995, an international collaboration was organized to complete a gamma-gamma IR design for the ZDR (Zero-order Design Report) of NLC. Under the coordination of the Center, a weekly video conference has been established, and extensive work has been carried out by scientists from LBNL, LLNL, SLAC, Rochester University, University of Tennessee, Hiroshima University, KEK, and BINP. This work culminated in the ZDR and in the special session of presentations on gamma-gamma collider design at SNOWMASS'96.

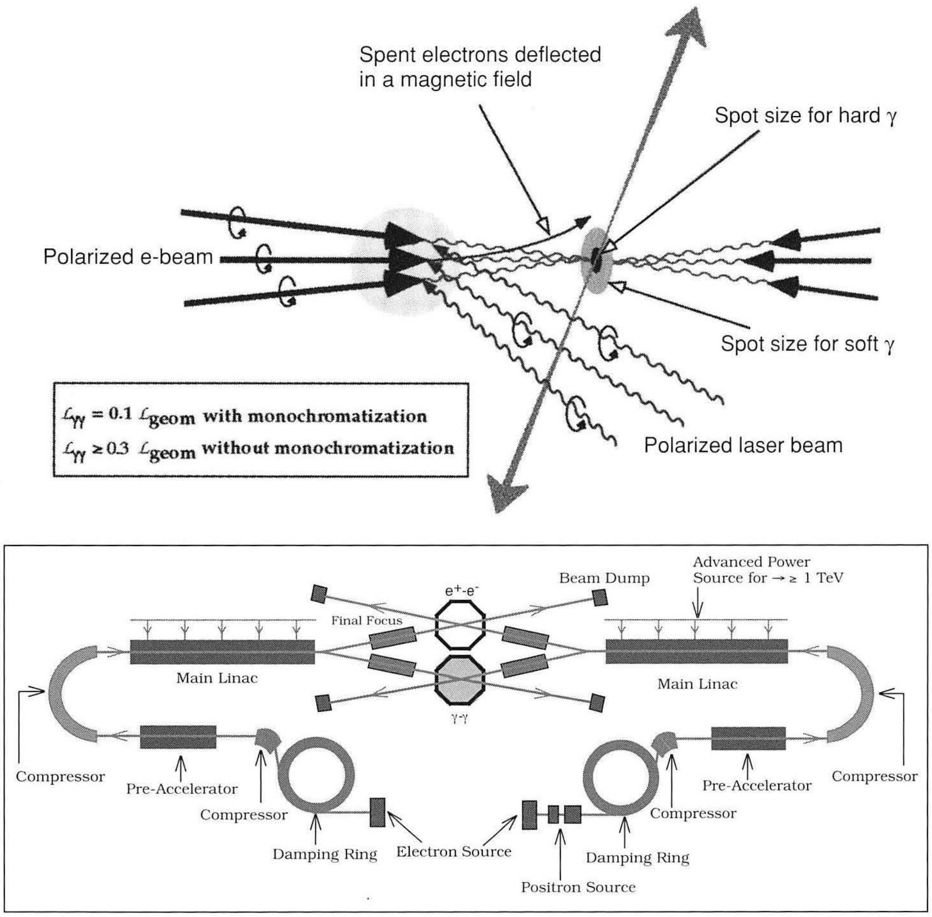


Figure 1. (a) Compton conversion into hard gamma rays by scattering laser photons of a relativistic electron beam.
(b) A schematic of a TeV-scale linear collider with a second IP for gamma-gamma collision.

The physical processes in the γ-γ interaction region are more complicated than in the case of e^+-e^- collision. One of the most important achievements through the collaboration is the development and benchmarking of a comprehensive Monte-Carlo simulation code (CAIN). The code, developed by K. Yokoya at KEK simulates both Compton conversion and gamma collision. It includes all electromagnetic processes: linear/nonlinear Compton scattering and pair creation at the Conversion Point (CP), beamstrahlung, disruption and coherent pair creation at the Interaction Point (IP).

There are many challenging technical issues for realizing the gamma-gamma collider. The high power optical beam has to be transported into the tight space limited by the vertex chamber, the mask, and quadrupoles, and later disposed of. A baseline optical design was provided by D. Klem of LLNL. To remove the spent electron beam after Compton conversion, it is desirable to introduce a magnet, called the "sweeping magnet," between the CP and the IP. A preliminary design of the sweeping magnet based on pulsed coil technology by G. Silvestrov and V. Telnov, of BINP, Novosibirsk, was proposed. Background due to synchrotron radiation from upstream may damage mirrors, and the secondary photons and particles generated in the mirrors may present further problem to the detector. A. Weidemann from SLAC studied these and other background issues and found that with a reasonable model for the synchrotron radiation, the problem appears to be manageable. To optimize luminosity for gamma collision, the final focus system is modified.

The requirements for the laser are extremely challenging: a pulse energy of about 1 Joule, a pulse length of a few picoseconds, an average power of 10 to 20 kW, and variable polarization. M. Perry from LLNL has worked out an approach based on the solid state laser. High power diode lasers for pumping and lasing materials that can handle high thermal loading are two major issues. Fortunately there has been an active development effort in these areas linked to other major military and civilian projects. Based on these developments, the laser needed for a gamma-gamma collider can in principle be built out of 1 kW unit cells.

We have proposed and studied an alternative choice for the laser system, a free electron laser. The FEL uses a pulse stretching, FEL amplifying, and pulse compression technique to produce laser beam of the required characteristics. The requirements for the electron beam are consistent with the induction linac technology. Preliminary study shows that possible degradation of the pulse compression performance due to the phase/frequency fluctuation of the optical beam (caused by the electron beam fluctuation from the induction linac) is small.

Study of Linear Collider Beyond NLC

It is believed that a linear collider at around 1 TeV center of mass energy can be built with existing technology. But it is practically impossible to go much beyond that energy without new, largely unknown accelerator technology. However, apart from knowing the details of the future technology, certain collider constraints are considered quite general and have to be satisfied, such as site power and the constraints imposed by the collision: beamstrahlung, disruption, pair creation, etc. Therefore it would be appropriate to explore the preferred regime of operation, to chart out a region in parameter space based on these constraints, and with that hopefully to offer some guidelines for the current development of advanced accelerator technology.

Taking such a point of view, we have examined the IP performance of e+-e- collider in a large parameter space at 5TeV, in collaboration with T. Tajima from UT. Austin and K. Yokoya from KEK. We found that a major change of paradigam in collider design is necessary as we go to higher and higher energies. One of the traditional design guidelines for NLC type of collider is to stay away from the high Upsilon regime, where Upsilon is a parameter that characterizes the strength of beamstrahlung. However, it becomes increasingly difficult to do so at higher energies. But actually beamstrahlung could be suppressed by a previously known quantum effect, if Upsilon becomes extremely large - under some conditions of the order of a thousand. It also appears by examining general scalings, that laser wakefield accelerator can be projected, more appropriately than other known acceleration mechanisms, to take advantage of this effect and satisfy the collider constraints reasonably well. Our simulation of collision at very large Upsilon has confirmed the effect that beamstrahlung induced energy spread can indeed be suppressed to an acceptable level.

Collective Effects in a High Luminosity Muon Collider

Yet another important activity is the research and development for a high luminosity muon collider. Muons have important properties compared to electrons and protons when considering a possible next step for a high energy physics facility. Since radiation by muons is much suppressed compared to electrons, it is feasible to consider a relatively compacty circular collider in the TeV energy range. However the muon, like the electron, is a point particle and therefore can explore the same physics regime as protons with approximately tentimes higher energy. Accordingly the muon collider has attracted increasing interest over the past couple of years and a collaboration led by scientists at BNL, FNAL and LBNL has been formed. Since the muon is an unstable particle there are many new facets of accelerator physics and technology that need to be examined before one can say with confidence that such a device will work. A feasibility study submitted to the Snowmass 96 conference last summer was a first step. Our specific work includes designs of the entire muon collider complex, theoretical studies of beam impedance and stability in the main collider ring. Optimization of muon collider luminosity taking account of their decay and relatively large phase space leads to a choice of beam parameters markedly different from electron and proton devices. In particular all of the muons in each of the circulating beams are stored in one or two very short bunches with peak current two orders of magnitude higher than any existing proton or electron device. Controlling single bunch coherent instabilites will be crucial for successful operation and we would continue the investigations that have just started. A relatively newly discovered type of instability that can be a problem at very high beam intensities is the so called fast ion instability. It arises from the interaction between the ionization products at the head of a bunch or bunch train with the trailing particles to produce unstable coherent oscillations which increase the beam cross section and reduce luminosity. The growth rate of the instability depends on the vacuum pressure in the beam tube. The analysis of the head-tail interaction is similar to analysis of the wake field electromagnetic interaction between beam and its surrounding vacuum chamber which lead to the beam break up instability. The first observations of the multi bunch version of this instability were recently made at the ALS. Analysis of this instability for a muon collider and means to control it if necessary would be important milestones in muon collider research.

Theoretical examination is made of single bunch collective effects in the collider ring of a 2 TeV x 2 TeV Mu-Mu Collider complex, shown schematically in Fig. 2. The situation involves an intense bunch, a short bunch, a small momentum compaction, and luminosity life time limited by muon decay to a thousand turns.

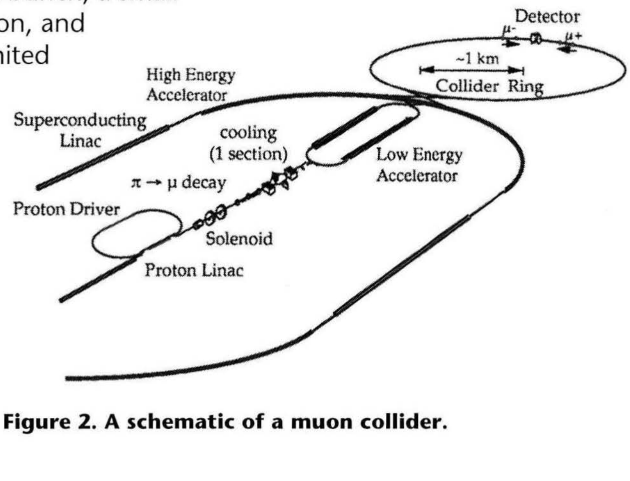


Figure 2. A schematic of a muon collider.

Longitudinal Behaviors

The quasi-isochronicity of the muon collider ring makes both the potential-well distortion — a static effect, and the coherent instability — a dynamical effect, important to the preservation of the beam's luminosity. In attempting to explore a possible operating point in the parameter space, we examined the beam's longitudinal behavior in the collider ring by multi-particle simulations, in which the static effect, the coherent effect, the incoherent effect, the nonlinear synchrotron oscillation, and muon decay are all included. Our study shows that, by choosing the parameters properly, the longitudinal behavior of a muon beam in the collider ring is controllable. (Fig. 3)

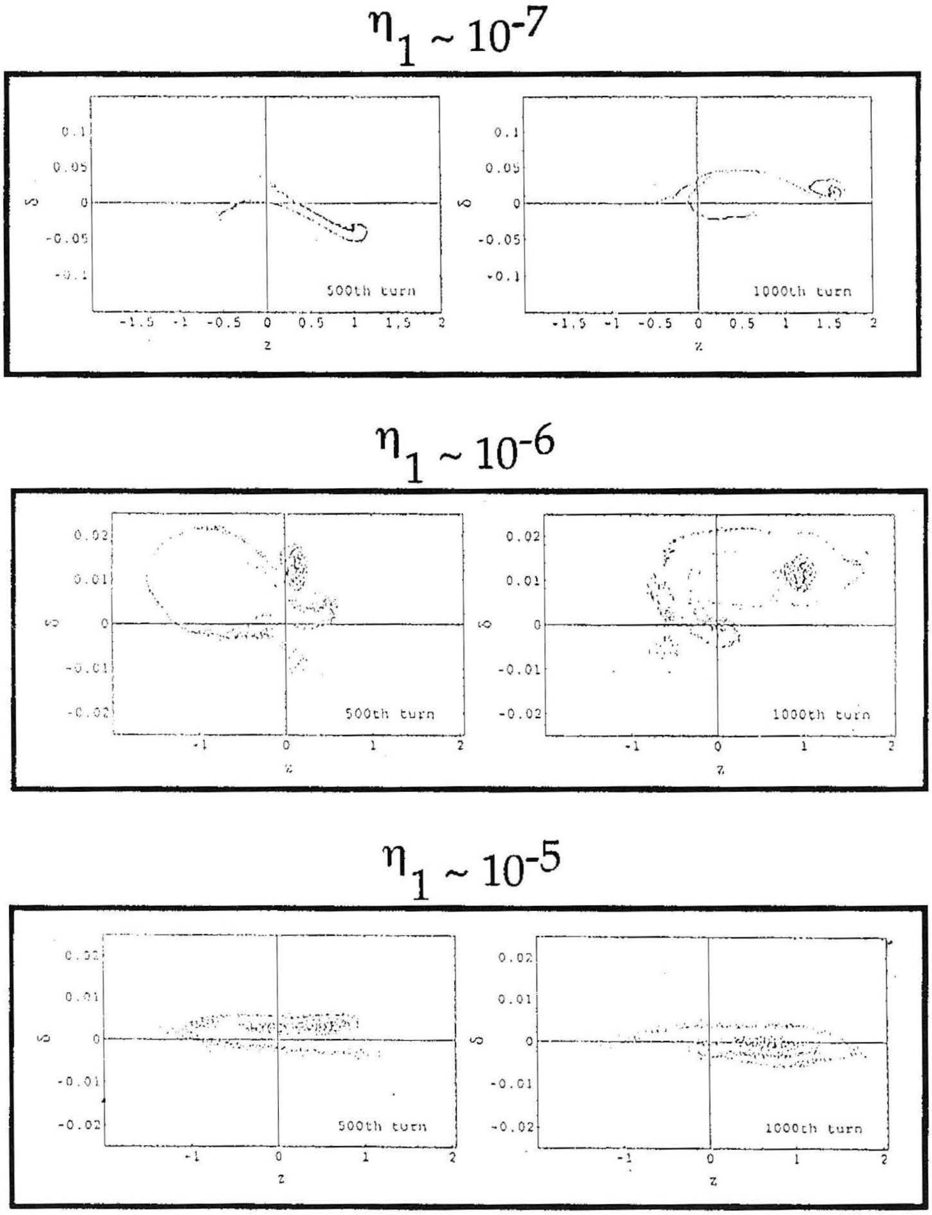


Figure 3. Muon Beam Evolution in longitudinal phase space for various values of the phase slip factor.

Transverse Behaviors

The quasi-isochronicity of the muon collider ring also makes the transverse dynamics similar to that of a linac. The use in rings of techniques such as BNS damping, developed for linear colliders, to study the beam-break-up behavior, is investigated. The effects of combination of the chromatic tune spread, beam-beam tune shift, BNS tune shift and coherent tune shift due to the ring and rf impedances, are under examination.

An assessment of the impedance budget is underway to achieve a better study of the collective effects in the muon collider ring. Furthemore, possibilities of other technologies, such as bunch rotation and rf-gymnastics or temporal modulation of accelerator parameters are being examined.

Temporal Variation of Accelerator Parameters

Varying Chromaticity

Analytical and numerical study of the suppression of the transverse head-tail instability by modulating the chromaticity over a synchrotron period are studied. We find that a threshold can be developed, and it can be increased to a value larger than the strong head-tail instability threshold. The stability criterion derived agrees very well with the simulations. The underlying physical mechanisms of the damping scheme are the rotation of the head-tail phase (such that the instability does not occur), and the Landau damping due to the incoherent betatron tune spread generated by the varying chromaticity.

In the previous work, via both theoretical analysis and multi-particle simulations, we have successfully demonstrated that by periodic modulation of the chromaticity, the head-tail instability is damped due to an enhanced Landau damping. We found that a threshold can be developed, and it can be increased to a value larger than the strong head-tail instability threshold. This implies that the limitations of peak current in a storage ring can be increased by the varying chromaticity scheme. Studies of practical operational issue, such as rapidly modulated sextupole magnets, and theoretical issues, such as the reduction of dynamic aperture, and exact calculations of the azimuthal mode-coupling, are in progress.

Longitudinal Beam Dynamics of Alternating Slippage Factor in Circular Accelerators

The success of the varying chromaticity scheme in damping of the transverse head-tail instability implies that, the temporal variation of accelerator parameters could be a generic scheme to improve the performance of accelerators. We apply this new approach to the longitudinal dynamics of coasting beam and bunched beam. Specifically, explorations for the possibility of suppression of the negative-mass instability and/or the microwave instability by a varying slippage factor, are underway.

Experimental & Theoretical Studies of the Nonlinear Beam Dynamics in Advanced Light Source

In collaboration with the Advanced Light Source Center in LBNL, study of nonlinear beam dynamics in an electron storage ring is currently in progress. Specifically, through a periodic modulation of the rf phase and/or rf voltage, particle tracking as well as the amplitude and phase of the beam transfer function are measured. Experimental data are compared with the numerical and analytical results. Effects of radiation damping, quantum fluctuation, noise, and bifurcation are taken into account.

Physics of Laser Channeling and Laser Wakefield Acceleration

We have been examining the wake fields produced by an intense, short laser pulse propagating in a plasma channel which has an arbitrary (continuous) density profile. Previous theoretical studies of plasma wakes in channels have considered either step-function density profiles, for which there is an exact expression for the wake, or, alternatively, parabolic profiles for which the wake is only computed approximately. We approach this problem by solving for the exact wake eigenmode taking into full account the channel profile. A consequence of a general channel profile is a spatially dependent plasma frequency; thus in a temporal Fourier decomposition, there exists the possibility of a resonance between the mode frequency and the plasma frequency. This resonance is manifest in the presence of (typically regular) singular points in the differential equation for the wake field amplitude. To obtain an accurate solution for wake eigenmode, such singular points must be handled with care. We have analysed the transverse structure of the wake for a wide range of experimentally accessible channel profiles. In addition to solving the Fourier domain equations for the wake field, we are currently working on solving the cold fluid equations in the time domain to corroborate our Fourier space analysis. The study of intense pulse propagation in plasma channels is important not only for the laser accelerator but also for other applications, such as the fast-ignitor concept for the proposed National Ignition Facility.

We have examined analytically and numerically particle beam injection into a hollow channel Laser Wake Field Accelerator. The code we employ follows full six dimensional particle motion and loads a beam using the TDA code loading algorithm. The optimal wake phase for beam injection was computed to provide maximum acceptance given beam energy and wake field parameters. We are also investigating the use of high brightness lasers to accelerate particle beams (vacuum acceleration). The growth of beam emittance and energy spread during acceleration over distances of a Rayleigh range is currently being studied. The goal of this work is to study the performance of laser/plasma and vacuum laser accelerator schemes using realistic beams. Among the topics we plan to study are an analysis of sensitivities to: a) jitter in the laser and plasma parameters, b) plasma instabilities, and c) channel deformation.

BeamDynamics for the PEP-II B-Factory

Electron-cloud effect for the PEP-II LEB

Any intense positively-charged bunched beam creates a cloud of electrons in the vacuum chamber, and this cloud couples the transverse motions of the bunches, potentially leading to an instability. We are actively studying this electron cloud effect of the low-energy (positron) beam of the PEP-II collider. This effect is generic to all intense positively-charged beams, and was first tentatively identified some 20 years ago. The issue laid dormant until late 1994, when Japanese researchers at KEK pointed out that this effect can have significant detrimental consequences for intense positron beams of closely-spaced bunches. In response to this observation, we have been studying this effect as it applies to PEP-II. In the future we consider exploring the consequences for other machines, including proton storage rings.

We are developing a substantial simulation code to study this effect. Current results indicate that there is a possible multibunch instability with a growth time of 1-2 ms. Although an instability with such a growth time is well within the range controllable by the feedback system contemplated for PEP-II, the simulation needs further developments for a more definitive answer. The figure below, (Fig. 4) obtained from the simulation code, show the contour levels of the electron cloud in a pumping straight section and in a dipole bending magnet.

Beam-beam interaction.

We are also studying, by means of simulation, several aspects of the beam-beam effect. We have carried out a fairly detailed study of the luminosity performance with the code TRS, which is optimized to study the core of the beam, and we have thereby identified the areas in the tune plane where the machine would not perform optimally. In collaboration with S. Krishnagopal of CAT, Indore, India, we are also developing a PIC code, called CBI, to carry out more accurate calculations than TRS. This code is much slower to run on the computer, but it has the advantage over TRS that it can identify single-bunch coherent resonance effects. These resonances are undesirable, and it is therefore of practical interest to learn the conditions under which they appear in order to avoid them. This instability is generic to all colliders whose beams are composed of bunches sufficiently closely spaced that parasitic collisions occur in the neighborhood of the interaction point. It is generally believed to be the mildest of the beam-beam effects and thus the least likely to adversely affect machine performance. Nevertheless, it is important to understand it in order to have a smooth commissioning of the machine. A code that was developed to study the same problem in the SSC is available but needs to be augmented to accommodate the asymmetric nature of PEP-II and the more complicated IR optics; this development will be carried out during this year here at the CBP.

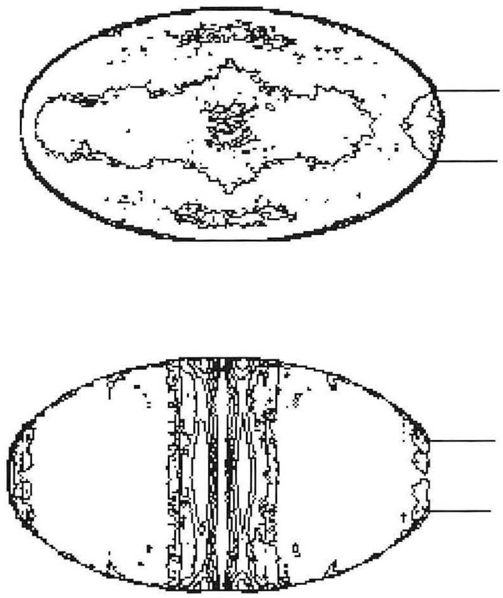


Figure 4. Contour level plots of the electron cloud. Top: pumping straight section. Bottom: dipole bending magnet. The beam orbit is at the center of the ellipse. The antichamber slot is shown at the right-side of the chamber. The ratio between successive levels is 2, and the top level is at 99% of the peak.

Optical Stochastic Cooling

During this past year, several of the Center's staff have been involved in a study of Optical Stochastic Cooling (OSC) — a new technique that has the potential to make the cooling of relativistic protons and heavy ions in storage rings quicker by several orders of magnitude, compared to what has been achieved in microwave stochastic cooling.

A detailed theoretical analysis of the optical stochastic cooling (OSC) is being developed. Considering the stochastic cooling in the optical wavelength regime, we were able to clarify the role of the phase space volume in general stochastic cooling. The concept of the sample is seen to be the coherent neighborhood in 6-D phase space, and the optimum cooling could be achieved by maximally mismatching the radiation and the particle phase space distributions. This way of thinking leads to a new way of stochastic cooling, such as the energy sampling rather than the time sampling. For explicit analysis, the field of a particle as a function of the kinematic variable at the pick-up is determined by solving Maxwell equation, and is approximated by a simple Gaussian function. At the kicker an amplified superposition of fields from all particles of the beam is applied to a particle. The change of rms spreads of the beam is evaluated using distribution function of kinematic variables. We find that a sample in OSC is delineated not only by its length, as it is in microwave stochastic cooling, but by its 6-D phase space volume of the optical signal. Therefore the sample corresponding to a particle should be defined as the coherent 6-D phase space neighborhood.

We have also identified two problems that have to be resolved experimentally to verify the feasibility of OSC. The first is isochronicity of the lattice in the presence of a cooling insertion, along with preservation of fluctuations in the beam when it passes the insertion. The second is transport and amplification of the pulse of undulator light while preserving fluctuations in the initial signal. Looking for an opportunity to do the experimental work at LBNL, we settled on the electron beam from the ALS booster synchrotron at 150 MeV (which is far lower than the normal injection energy for the ALS storage ring, but is attainable). After extraction, the electrons would be directed to a special beamline that will include two undulators connected by a highly isochronous lattice, a setup that resembles a cooling insertion for a storage ring. Several variants of this beamline that would fit in the available space in the extraction area of the booster have been designed, as shown in Figure 5. The first experiment would consist of observation of the interference pattern of the radiation extraction from the two undulators.

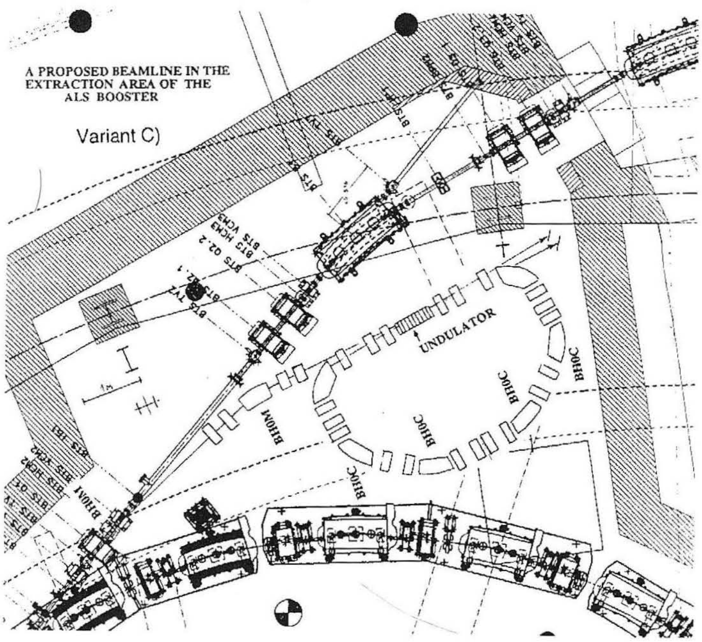


Figure 5. A schematic of the Optical Stochastic Cooling testbed that could make use of the beam from the Advanced Light Source booster synchrotron.

BEAM ELECTRODYNAMICS

The increasing variety and difficulty of the radiofrequency manipulations needed by today's accelerators has opened new opportunities for what began as our beam-cooling activity some years ago. Now called the Beam Electrodynamics Group (BEG), its activities during the years involved crucial work for the PEP-II B-factory, the ALS, the Next Linear Collider (NLC) design effort and the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory. Particular attention has been focused on radiofrequency (rf) and microwave components and systems for PEP-II.

Feedback systems for PEP-II

Control of the longitudinal and transverse coupled-bunch oscillations of the electron and positron beams in PEP-II is crucial to the success of the project. Feedback systems, together with impedance minimization, are required to achieve this goal. Beam Electrodynamics Group members are responsible both for the design and fabrication of the transverse coupled-bunch feedback systems, and, in collaboration with SLAC, the longitudinal feedback system. Previous work on beam impedance calculations and measurements of a test cavity in the Lambertson Beam Electrodynamics Laboratory have determined the dominant driving impedances for the coupled-bunch instabilities.

The coupled-bunch instabilities encountered at ALS have characteristics similar to those expected for the PEP-II rings. In particular, the growth times of the coupled-bunch modes are of the order of milliseconds or less in both cases. The ALS feedback systems are fully operational, as described below, and the systems at the ALS are being used as prototypes for PEP-II. Our experience in building and commissioning the ALS feedback systems has been of great value for PEP-II feedback systems design.

The transverse feedback system receivers, which use signals from pickups in the accelerator vacuum chamber to determine the beam position, have been constructed and are under test in the Lambertson Beam Electrodynamics Laboratory. Tests of the receivers using the ALS beam to simulate B-factory conditions are planned. The orbit offset suppression chassis, which operates a feedback loop within the system to suppress signals generated by an off-axis beam (closed-orbit error), or imbalance in receiver rf components, is being tested in the laboratory. This system gives an average of 20 dB suppression of these unwanted signals, which could otherwise cause saturation of the 500 MHz analog-to-digital converter used elsewhere in the system. Figure 6 shows a completed receiver ready for laboratory tests.

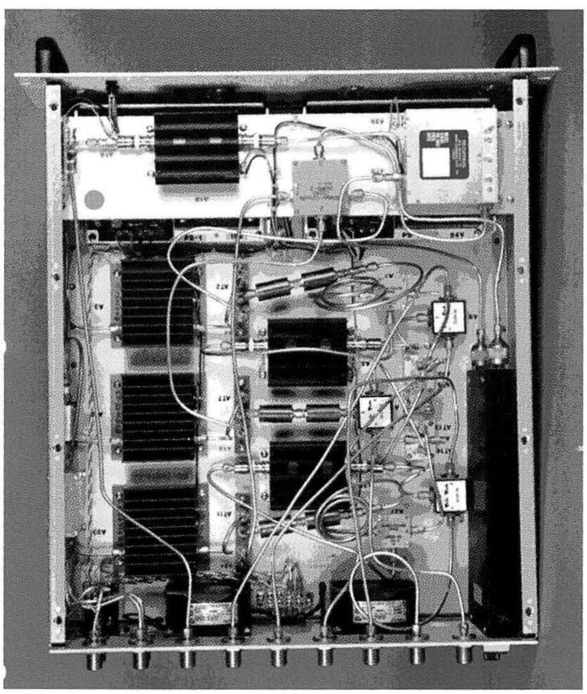


Figure 6. A completed receiver for the PEP-II transverse feedback system. Each receiver takes signals induced by passing bunches in a set of four pickups. The microwave devices in the receiver generate a signal representing the position of each bunch as it passes through the pickups. Deviations of the beam position due to coupled-bunch motion are corrected by calculating a compensatory kick signal from position measurements at two points in the storage ring.

Pickups for both feedback systems have been installed in the high energy ring (HER). The stripline kickers, which create electromagnetic fields and provide the transverse kick to the beam, have also been installed in the HER after being measured in the laboratory. During the prototype stage, damping of parasitic modes was developed to minimize the beam impedance and heating of the kickers. These kickers, as with the longitudinal feedback kickers, have been blackened using an ion implantation technique to improve radiative cooling of the electrodes in the vacuum environment of the accelerator. Figure 7 shows the measured shunt impedance of the transverse kickers.

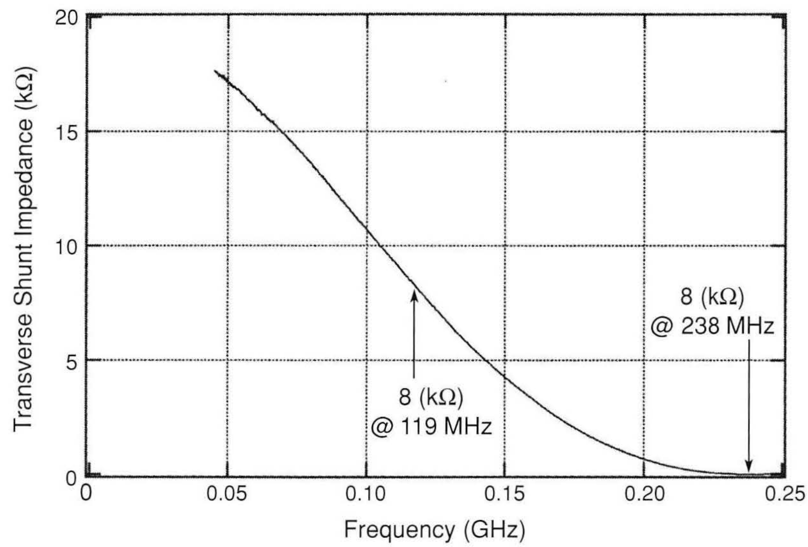


Figure 7. The measured transverse shunt impedance of the transverse coupled-bunch feedback system kicker. The system operates from 10 kHz to 119 MHz. Frequencies below 45 MHz are outside the range of the precision network analyzer used for these measurements, however the response of the kicker is well predicted at these low frequencies. The kickers impart corrective momentum changes to individual bunches, at relatively low frequencies, where the efficiency of these devices is best.

Digital electronics to provide a suitable delay between pickup signal and corrective kick, and also to allow particular bunches in the beam to be driven to large amplitude to scrape off some of the charge, are at an advanced design stage. Memory boards have been produced, and the motherboard design is in detailed checking. High-power radio-frequency amplifiers that generate the deflecting kick to correct the beam oscillations have been delivered, tested at LBNL, and shipped to SLAC.

In addition to the transverse feedback systems, a multi-element longitudinal kicker has been designed for the longitudinal feedback system. This traveling-wave device consists of two coaxial electrodes connected by delay lines that provide voltages of opposite sign at the ends of the electrodes, increasing the efficiency of the structure. Such high-impedance kickers are necessary to provide the voltage kick of several kilovolts needed in the PEP-II rings, at a reasonable cost in high-power rf amplifiers. The design of the longitudinal feedback kickers is complete for the HER, and the kickers are now installed in the storage ring. For the low energy ring (LER), the electrodes of the longitudinal feedback kickers are cooled by conduction through beryllia supports, which have little effect on the electrical characteristics of the kicker, but allow good thermal transport. The heating arises from beam-induced currents on the surface of the electrodes, and is approximately 10 W for the longitudinal kickers at high current. The LER design is at an advanced stage, with thermal tests to begin soon. In order to reduce the heating of the electrodes, a two-element kicker has been used instead of the three-element kicker originally proposed. Figure 8 shows a 3-D drawing of the kicker electrodes.

The power generated at the upstream terminals of the longitudinal kicker is appreciable, and the vacuum feedthroughs, commissioned from industry, have been designed to transmit up to 5.5 kW of rf power at frequencies up to 7 GHz.

As with the transverse feedback kickers, damping of parasitic modes was developed to minimize the beam impedance and heating of the electrodes. Measurements using the state-of-the-art equipment in the Lambertson Beam Electrodynamics Laboratory, and computations using 3-D electromagnetic design codes, have been made to confirm the characteristics of these essential rf structures.

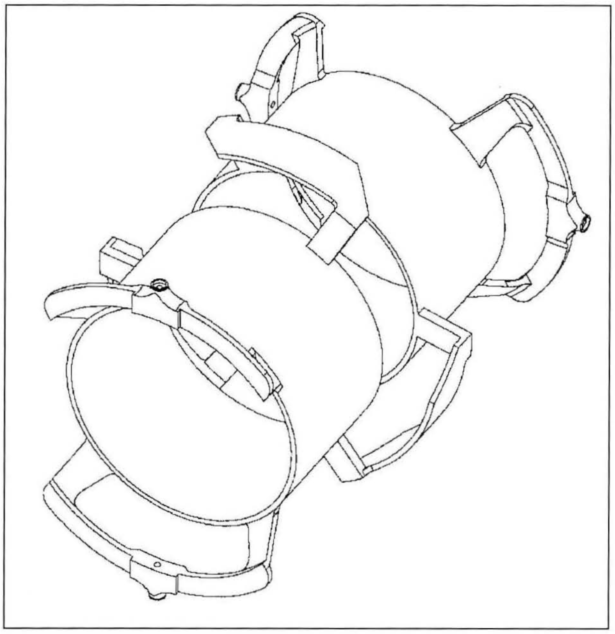


Figure 8. 3-D rendition of the longitudinal feedback kicker electrode. Note the two cylindrical drift-tubes, connected by delay lines 180° long at the operating frequency. These delay lines ensure opposing voltages on the facing ends of the drift tubes, thereby doubling the voltage seen by the beam passing along the axis of the device. The structures connected to the outside ends of the drift-tubes are to allow power to be fed into the kicker, and power induced by the beam to travel out of the kicker.

Impedance measurements of PEP-II components

Cataloging the impedance of components in the vacuum chamber is another ongoing task of the Beam Electrodynamics Group. These impedances give rise to beam instabilities, as the wall currents induced by the beam excite electromagnetic fields that influence the trajectory of following particles. Impedance computations of components have been made with state-of-the-art two- and three-dimensional electromagnetic design codes, and careful measurements are made in the laboratory of prototype components to assure a low impedance of the machine.

Particular attention has been paid to the design of the rf shielding structures for the bellows required to allow thermal expansion and installation of machine components.Without an rf shield, the impedance of the corrugated bellows is known to be unacceptably large. Spring-loaded sliding fingers have been designed, which allow smooth passage of the beam-induced currents in the accelerator wall, and also movement of the vacuum chamber. Since such components have intricate structure, careful measurements and computations have been made to provide a high degree of confidence in their successful operation at the large beam currents in the PEP-II storage rings.

Feedback systems and collective effects measurements for ALS

We are continuing to apply our group's capabilities to the improvement of the Advanced Light Source (ALS) here at LBL. Besides the obvious benefit of enhancing this important user facility, the opportunity to use a state-of-the-art storage ring like the ALS in developing systems for PEP-II is not missed. Bunch-by-bunch coupled-bunch feedback systems control all rigid-body coupled-bunch modes of oscillation in the ALS electron beam, and control of similar oscillations is essential in maintaining beam current and luminosity in PEP-II.

Feedback systems are essential to provide the ALS advertised source properties, and commissioning of the feedback systems is proceeding. The design, fabrication, and commissioning of the ALS transverse feedback systems was the responsibility of the Beam Electrodynamics Group, and the responsibility for the longitudinal feedback systems was held jointly with SLAC.

Installation of the coupled-bunch feedback systems at the ALS is complete, and the systems operate routinely during user shifts. Spontaneous betatron and synchrotron oscillations are successfully damped at the nominal ALS user conditions - 400 mA in 320 bunches (this includes a short gap for ion-clearing and feedback system re-synchronization).

Commissioning of the feedback systems involved some optimization of the accelerating RF cavity conditions, in particular the temperature of the two RF cavities. Coupled-bunch motion of the beam is sensitive to cavity temperatures since the frequencies of the higher-order-modes (HOM's) that drive the beam motion are a strong function of the cavity conditions. Changes in cavity cooling water temperature cause small dimensional changes in the cavity which in turn cause frequency changes in cavity modes. The fastest-growing longitudinal coupled-bunch modes are mode numbers 96 and 125, which are driven by the dominant cavity HOM's at 808 MHz and 2849 MHz. These cavity HOM's are high-Q (i.e. narrow-bandwidth) and are not damped by the filters located in the power feed waveguide. Transverse coupled-bunch motion is less sensitive to cavity conditions.

Traveling-wave-tube amplifiers have been used as power amplifiers in the longitudinal feedback system, however we have experienced some unreliable operation with these devices and we are currently considering the purchase of solid-state power amplifiers. A 500 W solid-state amplifier has been on test for the B-factory project and has worked exceptionally well in the ALS longitudinal feedback system. Measurements of the beam characteristics at the ALS have led to a greater understanding of the storage ring beam impedance. Bunch length measurements, tune shift with beam current measurements, and transverse beam dimensions measurements have been made, and instability thresholds measured. The broadband impedance derived from these measurements is estimated to be 0.2 Ω. This is consistent with the small impedances found in ALS components measured in the laboratory and computed by BEG members.

Simulations of beam behavior for PEP-II

Computations of instability thresholds and collective effects—including simulations of the operation of the feedback systems with realistic machine impedances and under realistic conditions of injection transients—have been updated for the latest impedance estimates and measurements for PEP-II. For rigid-bunch motion the feedback systems are shown to control the beam motion. Estimates of the broad-band beam impedance, which drives effects experienced by a single bunch, have been refined. Figure 9 shows the reactive impedance for the LER. Single-bunch instabilities are not expected to occur under normal operating conditions.

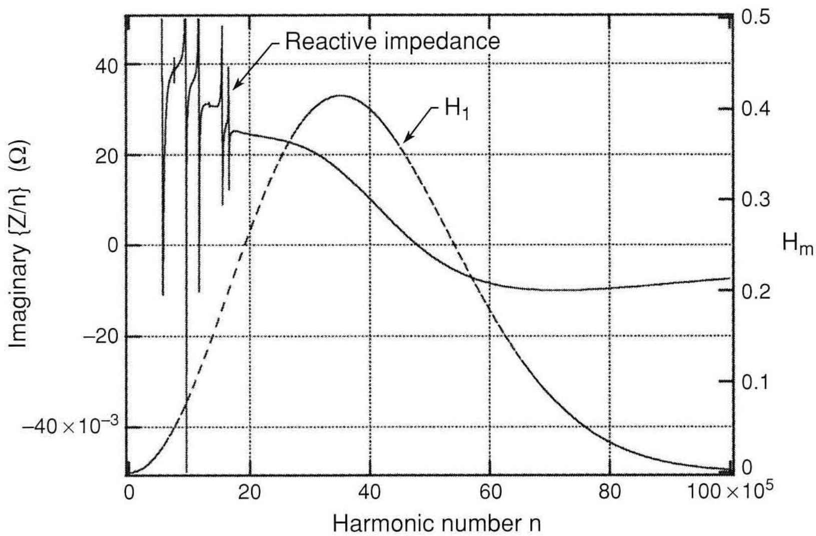


Figure 9. The reactive impedance of the PEP-II LER, normalized to the orbit frequency (n is the ratio of frequency to orbit frequency). Also shown is the power spectrum h_1 for the first mode of oscillation within the bunch. The effective impedance is the impedance weighted by the appropriate power spectrum.

High power RF systems for PEP-II

CBP has been actively involved in the development of the rf systems for PEP-II, initially as an offshoot of LER development and now directly as a top-level project subsystem. BEG physicists have helped to determine the operating requirements of the system and have been involved in the ongoing R&D of the major components, particularly the high-power cavity, vacuum window, and higher-order-mode (HOM) absorbers.

The high-power rf system incorporates a distinctive arrangement of three special HOM damping waveguide loads that open into the body of the cavity and damp the beam-driven higher-order modes of the cavity. Their design has been optimized to make best use of the absorbing material and to fit into the limited space available in the tunnel. The damping waveguides are folded so that the loads are "tucked in" parallel to the beam pipe. The cavity, coupler, and load assembly are pre-aligned and tested on a raft before installation in the tunnel (Figure 10). This damping scheme, designed and developed by BEG group members, was proved to be very effective by a series of measurements on a cold-test model in the Lambertson Beam Electrodynamics Laboratory. With the success of this model, the RF group, drawing upon resources from SLAC and LLNL as well as LBNL, designed a full-power version with only minor changes to the geometry. The major challenges in the design of the high-power cavity were in the area of thermal management; i.e., to efficiently dispose of the power from wall losses and to minimize stresses in the cavity body. The cooling scheme was optimized with sophisticated three-dimensional finite-element, rf, thermal, and stress analyses.

The high-power cavities are now in production, and tests have verified the designs developed over the past few years. Production cavities have been tested up to LER power, i.e. 105 kW, developing an accelerating voltage of 850 kV. The high-power test cavity was run up to 120 kW with a few excursions to higher power for short periods. All critical components of the design

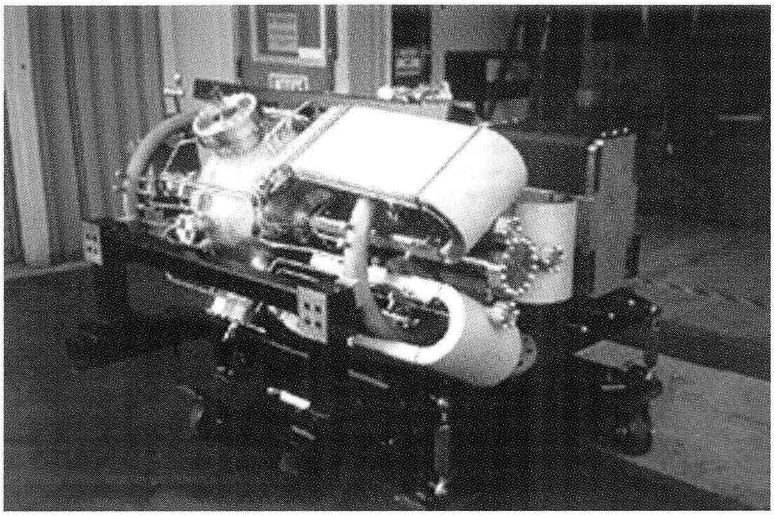


Figure 10. A PEP-II accelerating rf cavity ready for installation. The cavity, damping waveguides, power feed waveguide, tuner, and water cooling distribution system are mounted on a raft for high-power conditioning followed by installation in the storage ring.

have performed well, and eight cavities will be installed in the HER for the initial commissioning starting in spring 1997. A further 12 will be installed in the late summer, to provide the full compliment of cavities for the HER. Installation of LER cavities will follow.

Measurements of a production cavity have been made in order to accurately determine the impedance presented by the RF cavity HOM's. This information is necessary in determining the minimum power and gain requirements for the coupled-bunch feedback systems, and has been incorporated in the latest calculations of beam instabilities.

Stochastic cooling and beam diagnostics

The group has maintained it's history of involvement in stochastic cooling by continued study of the beam cooling and diagnostics requirements for the Relativistic Heavy Ion Collider being built at Brookhaven national laboratory. Stochastic cooling is the process by which the deviations from nominal energy or position of particles in a beam are measured and corrected. The control of gold ions in this machine is a particular problem, and microwave frequency stochastic cooling systems are likely to be required to provide sufficient integrated luminosity to effectively study the collisions of these heavy ions. Cooling in both transverse directions and longitudinally is under consideration.

Diagnostics are necessary to determine the behavior of the beam and make necessary corrections, and BEG members are developing a cavity based detectors for the purpose of measuring the Schottky noise signals of the beam - an important quantity in hadron and heavy ion colliders. A prototype cavity has been designed, and the associated electronics is in the conceptual design stage. Measurements of the prototype cavity are expected to allow fine-tuning of the cavity parameters for optimum performance.

An exciting new venture for the group has been in the area of spin measurement techniques. A novel system utilizing superconducting quantum interference devices (SQUID's) has been developed by BNL with the assistance of BEG members. It is hoped that the concept may be tested in an experiment at Brookhaven national laboratory AGS machine, before a detailed design for RHIC is developed.

A new venture for us in the past years has been the collaboration with SLAC on the NLC, which involves several groups within the Center for Beam Physics. In particular, our group is involved in the rf systems design and studies of collective effects and feedback systems for the damping rings. The large beam current (1A), divided into four trains of bunches, results in transient loading of the rf system, which must be compensated to maintain beam quality. Beam instabilities must be avoided by impedance minimization and feedback systems. We contributed an anlysis of the damping rings' coupled-bunch instabilities and an outline of the rf system design to the preliminary design. These were incorporated in the NLC ZDR (Zero-Order Design Report) and reported at the 1996 DPF Snowmass Workshop and study.

THE RK-TBA AS A POWER SOURCE FOR THE NLC

As a power source for linear colliders, the two-beam accelerator or TBA (see Figure 11), 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 have successfully 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.

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 particular RK-TBA is

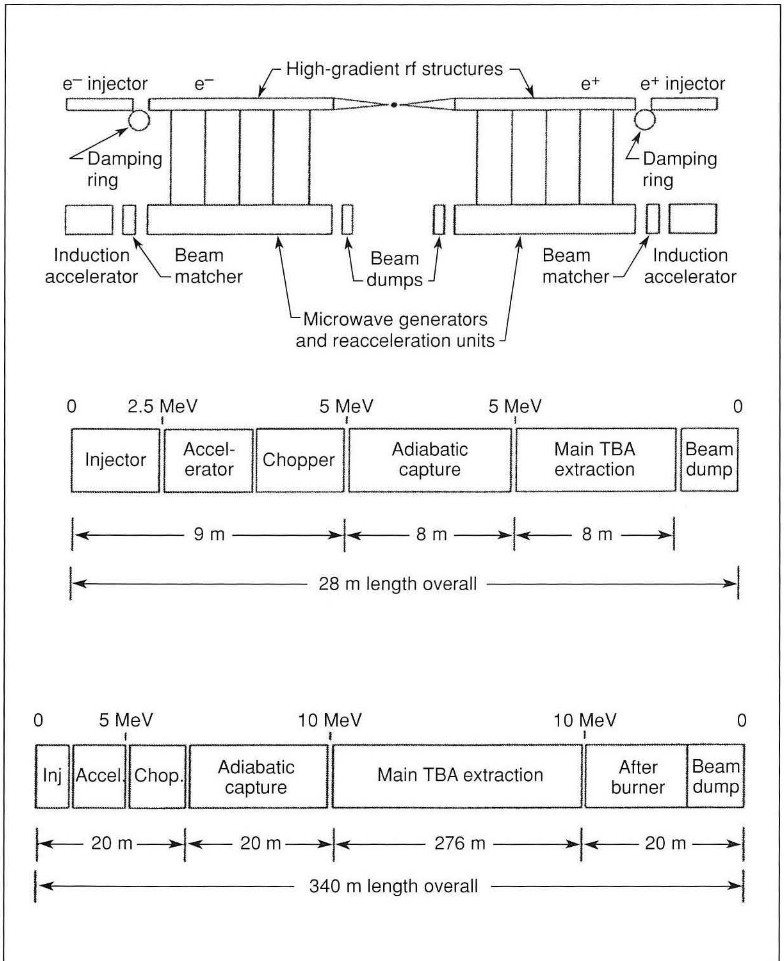


Figure 11. In the Two-Beam Accelerator, a high-current, low-energy drive beam is used for generating rf power that is applied to a high-gradient acceleration structure, where a low-current load beam is accelerated to high energy. Relativistic kylstrons would generate the rf power in the example we are studing for possible NLS 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.

designed as a power source for a linear collider with ≥1.5 TeV center-of mass collision energy, representing the upgrade phase of SLAC's proposed Next Linear Collider (NLC).

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 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. 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 the use of step-up transformers, which have high losses. The main losses in the system are associated with core currents in the induction cells. The overall efficiency of the pulse power system (from wall plug to drive beam) is estimated to be 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 first engineering and costing exercise for the full RK-TBA system has been performed. The electrical design includes all components starting from the ac power distribution system, through the dc power supplies, the CRC system, the pulse forming networks, and the induction cores. Racks and installation, as well as instrumentation and control, were included in this exercise. Costs were estimated with a "bottom-up" approach (that is, starting from individual components and adding them up to arrive at the entire system), assuming mass production procedures for fabrication and assembly. Our preliminary cost estimate for the TBA-based power source for a 1-TeV center-of-mass linear collider is less that $1 billion. This estimate does not include conventional facilities, or any institutional overhead. The overall efficiency of the system (wall plug to rf) is estimated to be 36%.

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 will be sited at LBNL in the RTA Test Facility. To date, half of the electron gun has been prepared and is currently being tested. The facility 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 DPF Snowmass Workshop and Study.

FREE-ELECTRON LASERS AND RADIATION SOURCES

The Free-Electron Laser and Radiation Source Group carries on the Center's long-standing interests in sources of radiation via relativistic beams. This largely theoretical group studies subjects of characterization and manipulation of photon and particle beams, and generation of intense photon beams from infrared to gamma rays for wide-range of applications. In particular, the following topics are under investigation: 3D high gain Free-Electron Laser (FEL) theory, initiation, growth, saturation, transverse and longitudinal coherence of Self-Amplified Spontaneous Emission (SASE), characterizing the qualities of particle and photon beams via Wigner function and entropy, radiative laser cooling of relativistic heavy ions beams, radiative laser cooling of electron beam via Compton scattering, transition undulator radiation, generation of high average power FEL for research and industrial applications, and of intense X-ray FEL as "fourth generation light sources". We have been providing main theoretical/numerical leadership to the SLAC Linac Coherent Light Source (LCLS) project. A major new activity of the Group is to bring about a high power FEL project at LBNL for future satellite power beaming application.

Free Electron Laser R&D

We have been steadily expanding our analytical and numerical capabilities for reliable predictions of the high gain FEL operation in the short wavelength region. We have developed so far the most complete and accurate solutions of 3D FEL theory. These solutions take into account energy spread, emittance and betatron oscillation of the electron beam, and diffraction and guiding of the photon beam. Powerful interpolating formulas based on these solutions are obtained and being used world-wide for the study, design and optimization of high gain FELs, in particular, those based on the SASE principle. Furthermore, the unique solutions of the higher order FEL eigenmodes provide the tool for a quantitative analysis of transverse coherence of SASE. It is found from this study that the well-known criteria for diffraction-limited or transversely coherent undulator radiation, which requires the beam emittance to be less than the wavelength divided by 4π, can be violated by a large factor for SASE without significant reduction in transverse coherence. These results have significantly advanced our understanding of SASE, the backbone of the fourth generation light souces, and their implications are important for the recent development of linac-based X-ray FELs. In addition to the development of 3D FEL theory, a theoretical framework for handling the startup and exponential gain behavior, taking into account the slippage and the effect of finite pulse duration has been formulated.

Over the years we have accumulated various simulation codes to study different aspects of the FEL behavior. In particular, the simulation code GINGER has been refined and upgraded to permit calculation of the harmonic generation, startup from noise, undulator interruptions, oscillator FELs, etc. These capabilities have enabled us to play a leading role in the LCLS collaboration in the theory/simulation area. The prominence of the Group as an international center in short wavelength FEL research is recognized through the representation of its members in the executive and program committee of international FEL conferences, and through its presence via numerous invited talks, various FEL panels and project review committees.

Experimental FEL Studies

Jonathan Wurtele of the CBP is a collaborator in the BNL FEL experiment at the ATF. The experiment uses a tunable microwiggler. The MIT Microwiggler provides a 0.45 Tesla on-axis field over 70 periods of 8.8 mm each and is notable for its extensive tunability and a novel tuning regimen through which rms spreads in peak amplitudes has been reduced as low as 0.08%. Preparations are currently underway for runs at 34 MeV (1.064 um) and 48 MeV (532 nm) at ATF. In support of the efforts to commision an FEL at these wavelengths, we have calculated the gain for small pass number and shown how the radiation frequency shifts from the spontaneous emission peak to the peak gain frequency with increasing pass number. This theory indicated that the previous beam used at the ATF had too few pulses to lase.

In the past year, we have developed a novel technique for characterizing the properties of a 50 MeV electron beam directly from the microwiggler spontaneous emission. Experimental work in this area is typically limited by poor resolution and the difficulty of distinguishing between numerous inherent spontaneous emission broadening mechanisms such as energy spread, beam divergence, off-axis electron propagation, beam trajectory errors and collection angle effects. In particular, energy spread and electron beam divergence are difficult to separate because two-parameter fits to the data do not always produce a unique solution and resolution is diminished when the contribution of natural linewidth is large. The MIT Microwiggler offers unique opportunities for such an application through its compact size, extensive profile tunability, adjustable field strength, long length and period, which makes the emissions particularly sensitive to beam parameters, and sets the wavelength of emission in the visible (532 nm at approximately 50 MeV), where a wide variety of optical diagnostics are available. The response of the spontaneous emission-based technique to beam parameters was demonstrated with a systematic series of experiments at the Accelerator Test Facility.

The setup for spontaneous emission studies of the electron beam is simple and efficient. The spatial profile of spontaneous emission into a Cerenkov Cone is recorded using a narrow bandwidth interference filter and a CCD camera. The radius of the cone depends on the interference filter central wavelength and electorn beam energy, while the cone width is determined by energy spread and divergence broadening, and the number of periods in the wigggler. Systematic measurements of the cone width over a range in beam energy, energy spread, tuning parameters and wiggler field strength have been performed. Simple analytic expressions for the contribution of natural linewidth, energy spread and divergence were derived, and it was found that by looking at large angles, a figure for beam divergence could be extracted directly from a single shot measurement.

The technique developed in non-perturbative beam characterization is useful for estimating beam emittance and for matching the beam into the wiggler and provides direct, instantaneous feedback during beam tuning and optimization. It can therefore be applied to Free Electron Laser research, as well as far more general applications.

Linac Coherent Light Source

We have done significant analysis and numerical modeling for several different conceptual FELs proposed both at LBNL and at other institutions. Our most extensive effort has been in support of the LCLS which is being studied by a consortium of institutions including SLAC, UCLA, LBNL, LLNL, and University of Milan. The LCLS proposes to use part of the SLAC linac up to 15-GeV with high peak current (5 kA), low emittance (1-2 π mm-mrad normalized) in a long (50-100 m) undulator to produce very high brightness, coherent X-ray emission in the 1.5-15 Å wavelength range. We have developed a powerful system optimization tool, and carried out a comprehensive multi-dimensional parameter optimization necessary for making a proper choice of undulator and electron beam parameters, and for developing a strategy for a phased approach from a longer wavelength operation toward the ultimate goal at the short wavelength.

We used the time-dependent, 2D (r-z) FEL simulation code GINGER to examine the start up of the LCLS FEL from shot noise (i.e. random bunching) naturally present in the input electron beam and the development of longitudinal coherence as the radiation exponentially grows with distance down the undulator. We have also investigated the usefulness of various modifications such as making the first part of the undulator resonant with the 3rd sub-harmonic (e.g. 4.5 Å compared with the desired output at 1.5 Å) whose exponential gain length is shorter. The second half of the undulator, which would remain resonant at 1.5 Å, uses the third-harmonic bunching produced by the first undulator as an enhanced "seed" for continued exponential growth. We have also investigated the advantages and disadvantages of inserting various drift spaces in between undulator sections; explored the possibilities of using electron beam in the FEL as an effective X-ray lens to control the angular divergence of the X-ray beam it is generating; and found that the inclusion of time-dependent effects significantly reduces the gain from what would be found in a monochromatic signal case.

High Power FEL for Satellite Power Beaming

In the past we have been actively working on designs of user optimized FELs, in an effort to bring an FEL user facility at LBNL. This effort was best summarized in a comprehensive conceptual design report of an infrared FEL we produced several years ago for the proposed chemical dynamics research laboratory. Although the project has not been materialized for the lack of funding, having recognized the possible unique applications of high average power FEL for research communities and industries, we have been continuously pursuing various schemes of FELs based on highly efficient, multi-turn, recirculating linacs.

More recently we have studied such a high power FEL for beaming power from ground to solar cells on orbiting satellites. A multi-institution collaboration is established to further clarify the R&D issues leading to a preliminary design report. The works that have been done so far in this group include the following. A numerical simulation code was developed to study the energy loss instability of the accelerator system, which is crucial for the multi-turn, recirculating accelerators. Following extensive modifications to GINGER to model oscillator FELs, we have used it and a 1D time-dependent code to model the so-called "electron output coupling scheme" which was proposed as a path to a high average power FEL. The scheme involves a relatively standard oscillator FEL whose major purpose is to bunch the electron micropulses followed by a single-pass amplifier undulator (the "radiator") in which the bunched beam would radiate copious amounts of coherent power without limitations due to mirror damage. In a series of papers, we investigated the requirements for stable mode operation of the oscillator, especially in an optical klystron configuration, and the expected extraction efficiency of the output radiator, with and without tapering of the undulator. Depending upon the exact beam parameters chosen, we found that relatively high cavity losses and careful detuning will probably be necessary to produce output bunching parameter at a level of 0.3 to 0.5. Furthermore, extraction efficiencies much above a few percent will require relatively long (> 5 m) radiator undulators.

Generation of Femtosecond Bursts of X-rays in a Storage Ring

Ultrashort pulses (less than 100 femtoseconds in duration) of X-rays (1 Angstrom and shorter in wavelength), if produced, will be a valuable research tool in probing ultrafast processes in condensed matter physics, chemistry and life sciences. One scheme of producing such a source of radiation, originally conceived at the Center, is Thomson scattering a short visible laser pulse off a low energy but relativistic electron beam in an orthogonal geometry. In fact experiments have already been carried out in the Center's Beam Test Facility and the results are reported in the section on Experimental Beam Physics. The success of this experiment in achieving the expected flux in a micropulse is encouraging and we await the successful use of these generated x-rays in a first experiment on time-resolved studies of phase transition on the surface of silicon. In anticipation of the future needs for such a source, we have focussed on how to improve upon the average flux (photons/second) of such a source to the level of 10^9 x-rays per second.

Such an extrapolation seems plausible in a scheme that utilizes a bunch of electrons stored in a storage ring and periodically interacting with a short pulse (100 femtoseconds) of visible laser photons stored in an optical cavity with a regenerative amplifier inside , as shown in Fig. 12. Although a typical electron bunch in a storage ring is tens of picosecond long, only a short portion of it
(100 femtoseconds long) retains the memory of having interacted with a short visible laser pulse for a brief period. This interaction 'tickles' the beam, so to speak, and induces a systematic energy modulation on the beam over a 100 femtoseconds only out of its full length. For a 2 GeV beam as in the ALS, interacting with a Terawatt peak power 0.8 micron wavelength laser, this modulation could be as high as 10 MeV and higher. The dispersive magnetic lattice of the storage ring can then be used to discriminate spatially, in the direction transverse to beam motion, the 100 femtosecond slice against the rest of the beam (Fig. 13 a). This beam then is allowed to radiate through a special radiator where the 'discriminated' slice will radiate differently from the rest of the beam. A specially designed beam line (with choppers, etc. to chop out and synchronize the multiple interactions of the electron and laser pulses suitably) will then deliver femtosecond bursts of x-rays to users (Fig. 13b). The average flux of femtosecond x-ray bursts expected would be 10^9 per second with a spectral brightness close to usual synchrotron radiation sources. The scheme looks prmising enough that we have actually designed, on the Computer Aided Design system, an actual set-up of the laser path along the ring and the vacuum chamber as shown in Fig. 14. The modification to the back-port of a specially selected undulator straight section has already started.

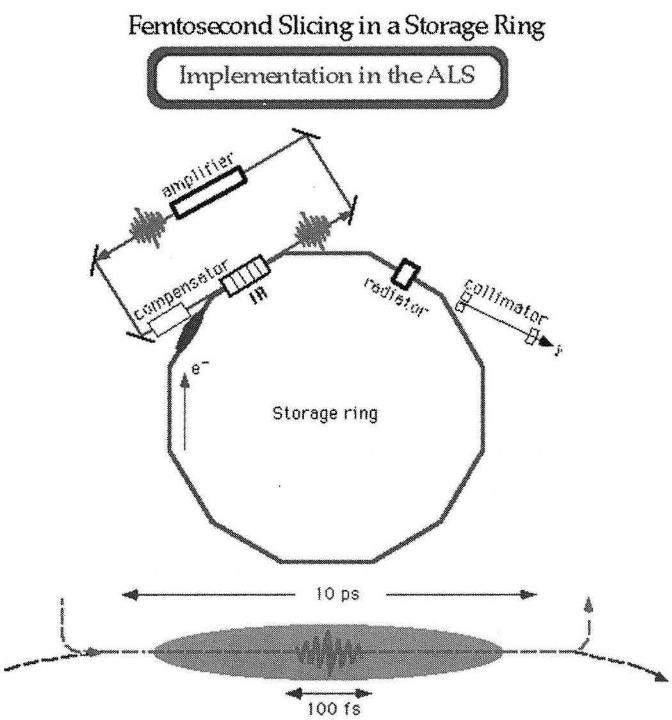


Figure 12: The scheme of an electron storage ring in conjunction with a regenerative laser ring resonator in a configuration that allows generation of femtosecond x-ray bursts.

Figure 13a: **Magnetic discrimination of the energy-modulated femtosecond longitudinal slice in the transverse plane.**

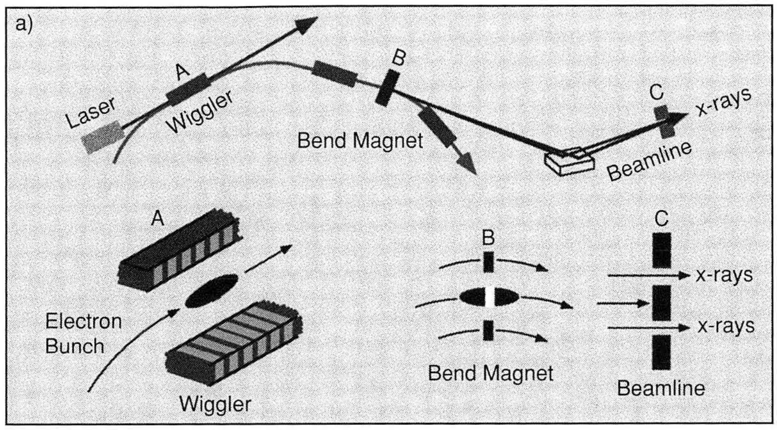
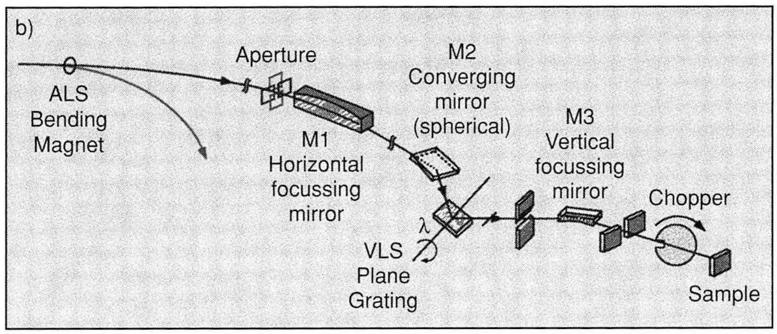


Figure 13b: A special beamline for the femtosecond x-rays from the ring.



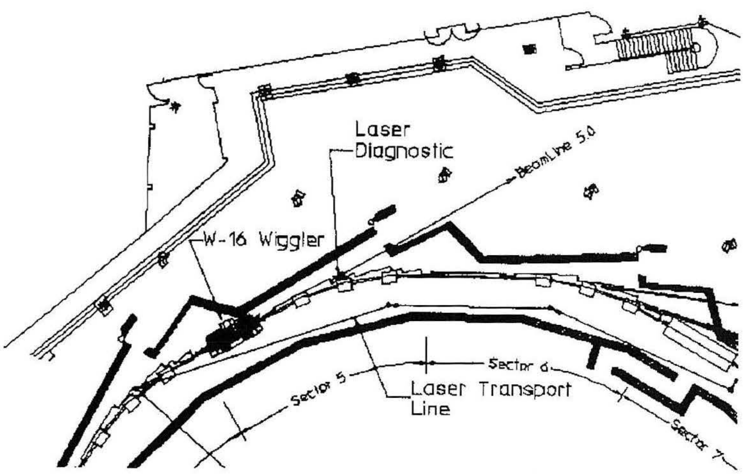


Figure 14: A CAD drawing of the laser path around the ALS ring and its vacuum chamber.

Entropy of Particle and Photon Beams

We have investigated the entropy of a particle beam, relating it to the more familiar concept of emittance as a measure of its disorder. These concepts can be generalized to the case of photon beams, the entropy in this case being related to the density operator. We study in detail the case where the photon beam is a stochastic superposition of coherent Gaussian beams. The goal of the study is to understand the qualities of the particle and photon beams from a fundamental point of view.

During the past two years, the group has continued to work on experiments involving the interaction of high intensity lasers with particle beams and plasmas with an aim towards the development of novel radiation sources, high performance laser based beam diagnostics, as well as new accelerating and focusing mechanisms involving the use of plasmas. The group has designed, constructed and operated the Center for Beam Physics' Beam Test Facility (BTF) at the Advanced Light Source. The BTF was designed in 1993 and commissioned in 1995 by the Center for Beam Physics. A transfer line from the linac carries the electron beam into an adjacent, shielded cave equipped with diagnostic instrumentation for electron and photon beams and with a femtosecond, terawatt laser system built by the Materials Sciences Division on the top of the shielding. Because the linac does not need to operate for synchrotron radiation users except to fill the storage ring, it is conveniently available most of the time for BTF use.

Femtosecond X-rays

A first experiment succesfully completed at the BTF during the 1995-1996 period, was on the scattering of a high intensity photon beam off relativistic electrons. In collaboration with the Femtosecond Spectroscopy group of the Material Science Division, the group successfully generated the world's shortest hard x-ray pulses using 90° Thomson scattering of a terawatt laser pulse off a relativistic electron beam as shown in Fig. 15. This novel geometry allows production of femtosecond x-ray pulses using a tightly focused but temporally long electron bunch. The transit time of the light through the beam determines the length of the scattered light pulses and this time can be matched to the laser pulse length in the femtosecond range by focusing the electron beam to a narrow waist in the interaction region.

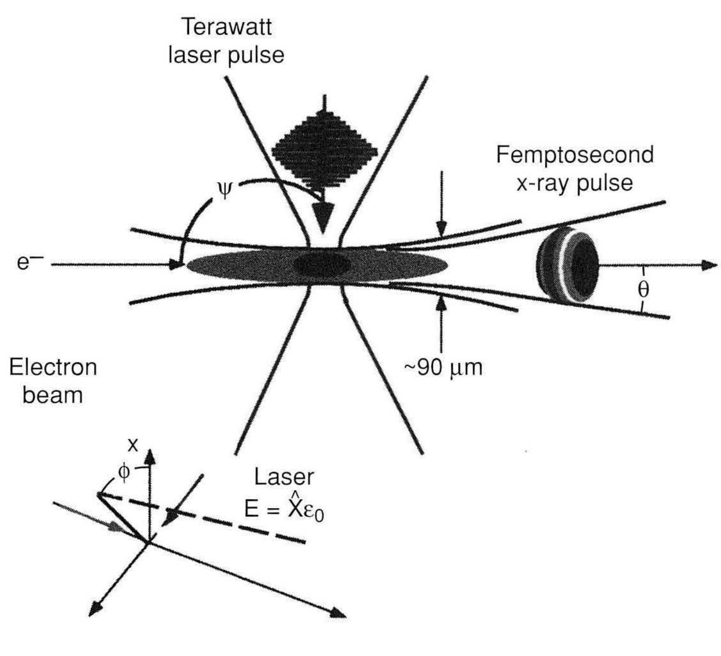


Figure 15. Orthogonal Thomson scattering configuration for producing femtosecond x-rays.

Another aspect of the 90° geometry is that transverse and longitudinal phase space distribution measurements of the electron bunch become possible. The laser acts as a microprobe for the electron beam and the x-rays carry the signature of the beam properties. Such a technique will become increasingly important for measurement of detailed electron bunch properties in high quality accelerators.

For the experiment, the group used the 50-MeV electron beam from the ALS linac consisting of electron bunches of 1.3 nC charge and with a 20-ps FWHM duration. The femtosecond laser system comprised a Ti:Al_2O_3 laser followed by a chirped pulse amplification system (pulse stretcher, preamplifier and amplifier powered by a Q-switched YAG laser, and pulse compressor) Fig. 16. The laser output consisted of 60-mJ pulses lasting 100-fs (FWHM) at a wavelength of 800 nm. The measured interaction area was 90 μm in diameter.

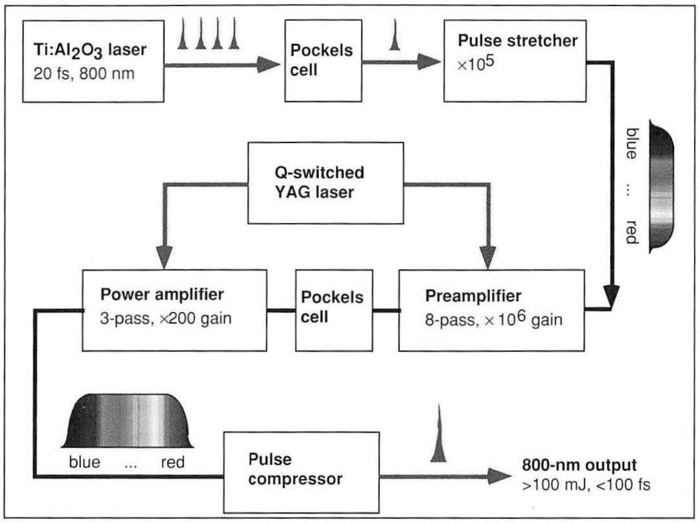
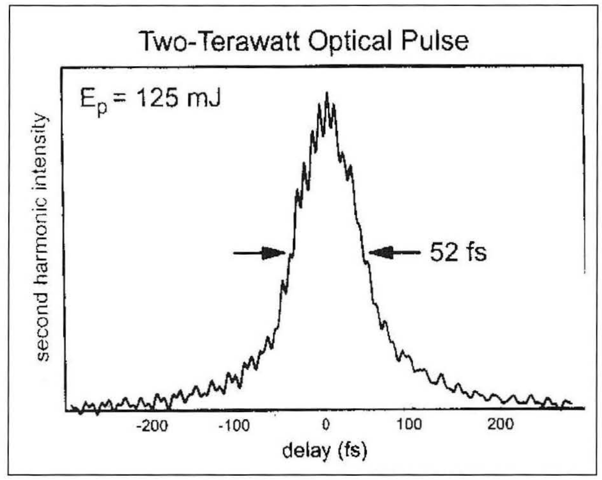


Figure 16. The femtosecond terawatt laser system that will be used in this experiment was developed by LBNL's Material Sciences Division (Femtosecond Laser Spectroscopy Group)



These parameters result in an x-ray flux close to the measured value of about 5×10^4 photons/second at a wavelength of 0.4 Å. Measurements of the x-ray beam profile as imaged on a phosphor screen with a CCD camera yielded a beam size consistent with the expected beam divergence of $1/\gamma$ (Fig. 17). Analysis of the obtained far-field image provided a single shot measure for the electron beam divergence of essentially a 200-300 fs slice of the 25-30 ps long bunch. Transverse and longitudinal scanning of the laser beam across the electron beam yielded the spatial and temporal structure of the electron bunch. Subtle chromatic aberrations in the transport line, which were not picked up by an optical transition based diagnostics due to resolution limits, were observed with the laser probe and corrected by adjusting the magnetic transport lattice. Spectral measurements with a germanium detector at various observation angles agreed closely with theoretical calculations, indicating that the theory can be used as a guide for predicting performance under various experimental conditions.

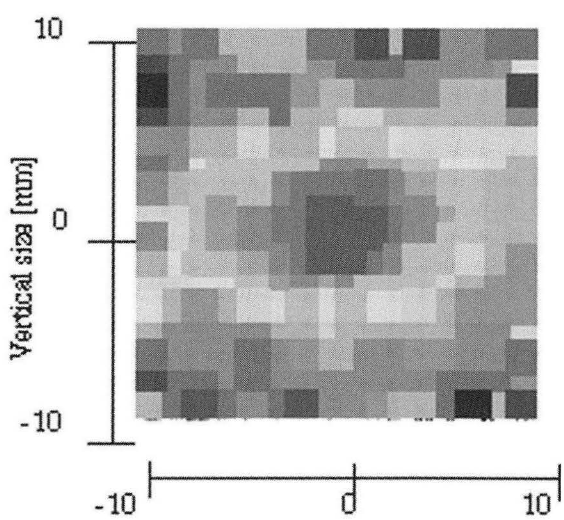


Figure 17. False color CCD image of the spatial profile of a 30 keV x-ray pulse on the phosphor screen, which is located 80 cm from the IP.

The brightness achieved in the first experiments, about 2 x 10^5 photons/ sec · mm^{-2} · $mrad^{-2}$ in a 15% BW, is sufficient for static x-ray diffraction from strong scatterers (a few minutes to obtain a rocking curve). But the long-term goal is to carry out time-resolved EXAFS and other studies of structural dynamics on the femtosecond time scale of the atomic motions that underlie such phenomena as phase changes, chemical reactions, and surface processes. Substantial but realizable improvements primarily in linac technology, such as higher repetition rate, reduced bunch length, and lower beam emittance, together with a boost in laser pulse energy could increase the x-ray brightness to nearly 10^{11} photons/sec · mm^{-2} · $mrad^{-2}$ in a 3% BW, enough for experiments of this type.

In future experiments, the group will attempt to shorten the x-ray pulses to as little as 50 fs by focusing the electron beam more strongly. Also on the agenda is to attempt pump-probe experiments with laser excited samples to observe the time evolution of Bragg-diffraction peaks and hence changes in long-range order.

Plasma Lens

The second experiment which has become operational at the BTF is a parametric study of plasma lens focusing. In this experiment, the 50 MeV electron beam is focused into a plasma column which is typically about 1 mm high and 1- 2cm long and has a density of 5 x 10^{12} - 2 x 10^{14} cm^{-3}. The plasma is produced through two-photon ionization in tripropylamine (TPA) using a frequency quadrupled Nd:YAG laser beam(266 nm radiation) which is focused to a line using cylindrical optics. The advantage of this technique is the fact that the plasma density can be controlled either through the chamber fill pressure (linear dependence) or through the laser intensity profile (quadratic dependence). For example, by tailoring the laser beam profile at the focus, plasmas with longitudinally (direction of the electron beam) varying density profiles can be created. Detailed interferometric measurements of the plasma density have been carried out using 94.3 GHz in-quadrature microwave interferometry, which gives both phase and amplitude of the microwave beam simultaneously. A schematic of the diagnostic is shown in Fig. 18 as well as results from a scan of plasma density versus TPA fill density for a fixed incident laser intensity of 91.8 MW/cm^2 This technique not only makes it possible to probe sub-critical

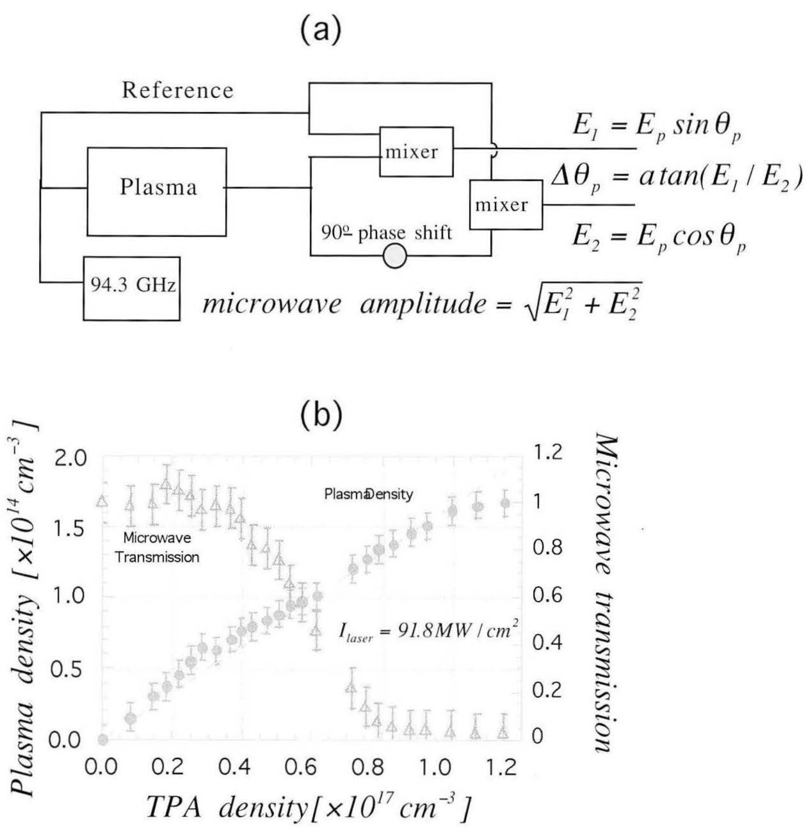


Figure 18. a) Schematic of the 94.3 GHz microwave interferometer. b) Plasma density and microwave transmission as a function of TPA density.

plasma densities but also super-critical. Plasmas were produced with thickness less than the collisionless skindepth, allowing the evanescent microwave fields to tunnel through the plasma.

The electron beam profile is measured using optical transition radiation produced when the electron beam passes through a thin aluminized mirror. The beam spot is imaged with about 12 micron resolution onto a 16 bit CCD camera or a picosecond streak camera system, which are mounted about 8.5 m away from the interaction chamber. The beam current is monitored using an integrating current transformer mounted together with the mirror on a movable carriage inide the vacuum chamber. This system allows, through time integrated measurements of the electron beam size versus longitudinal position, a direct calculation of the beam's Twiss parameters as shown in Fig 19.

First observation of the electron beam focusing after propagation through the plasma was made in June 1996, only 20 minutes after turning all systems on. Figure 20 shows a typical scan of beam size versus longitudinal position with laser off and on. In addition to laser induced ionization, measurements have indicated electron beam impact ionization to be an important effect when using TPA. Since the initial results, detailed studies are ongoing on various regimes of operation of the plasma lens (i.e. overdense, current cancellation, and underdense regime) to evaluate the ultimate focusing strength, temporal lens dynamics, beam matching into the plasma, beam induced ionization etc.. The expertise gained in this experiment is also being applied to a proposed plasma wakefield

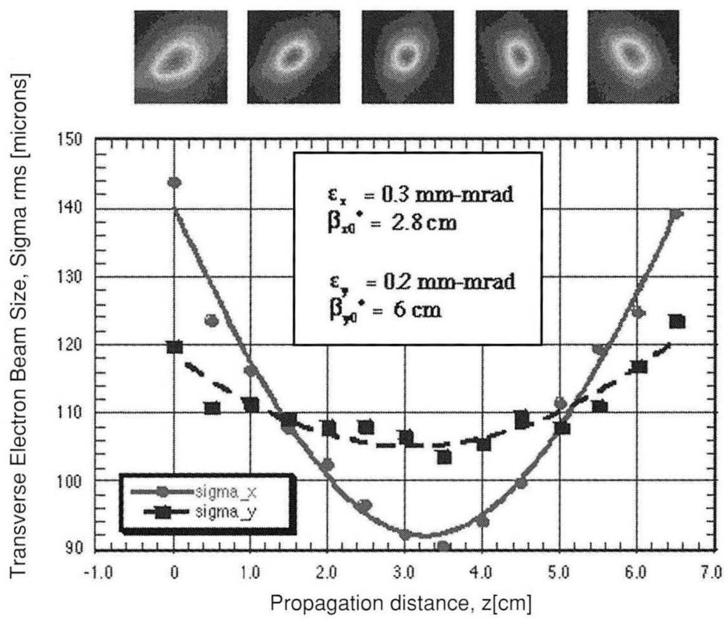


Figure 19. Electron beam size (horizontal and vertical) measured using OTR as a function of propagation distance. The solid lines are quadratic fit, which give the beam beta-function and emittance.

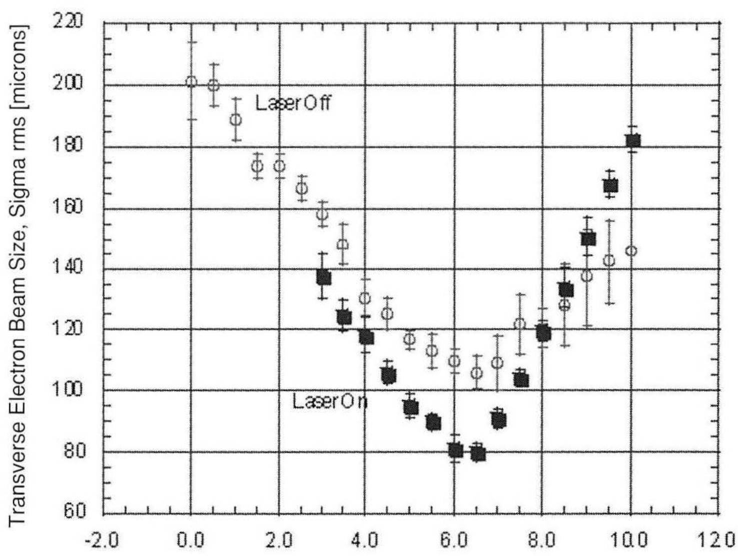


Figure 20. Vertical electron beam size as a function of propagation distance with (solid squares) and without (open circles) plasma.

l'OASIS Lab: a testbed of laser-plasma-particle beam interactions

In addition to the BTF experimental activities, the Group has been expanding the Laser Optics Laboratory. This lab, which was started in 1992, is now called the l'Oasis laboratory. In addition to the EXCIMER laser, which is used for experiments on laser guided current channels by the Fusion Energy Research Program, a multi-terawatt ultra-short pulse laser system will be available. The new laboratory will serve as experimental test bed for concepts on the interaction of high intensity ultra-high frequency electromagnetic fields with particle beams, plasmas and accelerating structures, towards the development of novel acceleration techniques and associated diagnostics; production of plasma based devices compatible with particle accelerators; development of laser components for optical stochastic cooling experiments; and novel radiation sources.

Construction of the new laboratory was started in January 1996 and completed in April 1996. Lab space in four separate rooms was consolidated; water cooling, electrical power, and laser interlock system were installed. A large laser system is presently under construction for experiments on laser guiding and wakefield excitation in a plasma fiber, as well as laser induced particle trapping for injection into the high gradient wakefields. The aim of the first phase of the experiment is to demonstrate guiding of intense (> 10^{18} W/cm^2), ultra-short pulses (50 fs) in a plasma channel, and excitation of high gradient longitudinal accelerating fields in the channel. The plasma channels will be produced with a by a long laser pulse which has been focused to a line focus with an axicon lens. With this technique, pioneered by H. Milchberg et al. from the University of Maryland, 100 ps long pulses with intensities on the order of 10^{14} - 10^{15} W/cm^2 have been guided over distances of up to 70 Rayleigh lengths. In our experiment guiding of laser pulses with intensities relevant for laser wakefield excitation over a distance of 1 - 2 cm will be attempted. In addition plasma density modulations excited by the guided laser pulse in the channel will be measured optically. In the second phase, optical techniques for particle injection will be studied. In collaboration with researchers from the Naval Research Lab, we have recently proposed a colliding pulse technique for laser induced trapping of plasma electrons in a laser excited wake. This novel technique, a variant on the LILAC concept, is a promising avenue for the development of an all-optical particle accelerator as it requires about two orders of magnitude lower laser intensity than the LILAC scheme. Implementation of the technique will be readily possible with the laser under construction.

The laser system under development operates at 800 nm wavelength and utilizes Ti:Al_2O_3 as the amplifying medium. Ultra-short pulses (typically 25 - 30 fs long) produced by a Kerr lens modelocked oscillator, which operates at 81 MHz and is pumped by an Ar-ion laser, are injected at a 1 kHz repetition rate into a commercially built regenerative amplifier (Spitfire-regen). The Spitfire is pumped by a 1 kHz intra-cavity doubled Nd:YLF laser and has a built in optical stretcher and compressor. The oscillator pulses are stretched about a factor 10^4 and subsequently amplified after about 20 passes from the nJ level to 1.4 - 1.6 mJ. A 95 % reflective mirror sends the laser pulses to a two-pass pre-amplifier followed by a three pass main amplifier. The remaining 5 % is compressed inside the Spitfire and frequency doubled.

The pre-amplifier and main amplifier, presently under construction, are pumped by a frequency doubled Nd:YAG laser system, which delivers about 2 J at 532 nm. The expected final energy after amplification will be about 600 mJ. Half of the energy will be utilized for plasma production and heating. The other half of the energy will be pulse compressed in a scaled-up version of the Spitfire compressor, which has been built and tested to compress the long pulses (300 ps) down to about 40-50 fs long pulses, and then injected into the plasma channel. The frequency doubled weak pulse from the Spitfire will be utilized for a radial plasma density profile measurements using Mach-Zender interferometry.

Based on a theoretical model for wakefield excitation in the plasma channel, we have designed and built a single shot frequency resolved optical gate (FROG) to time resolve, with femtosecond resolution, how the laser pulse shape and phase are changed through the interaction with the plasma guide.

Experiments are slated to commence during summer 1997.

EDUCATION IN BEAM PHYSICS

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

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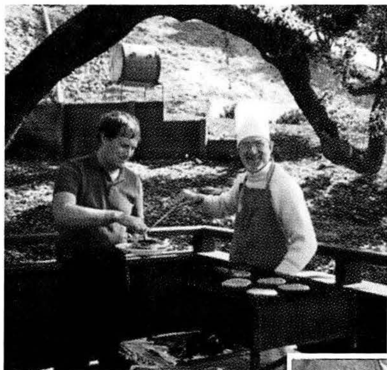

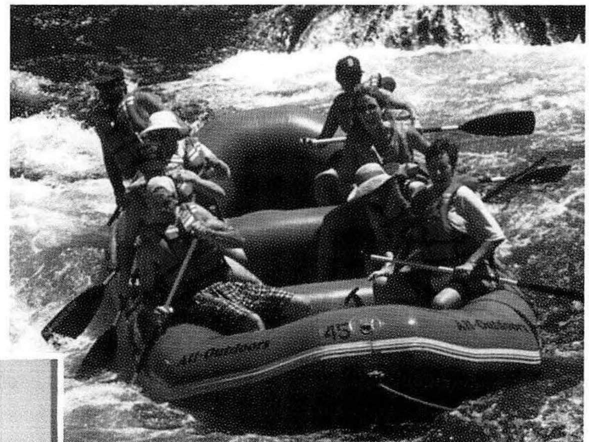

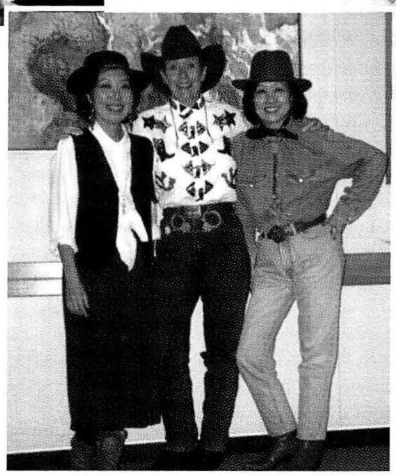

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