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Center for Beam Physics 1993

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1 of 1

CENTER FOR BEAM PHYSICS

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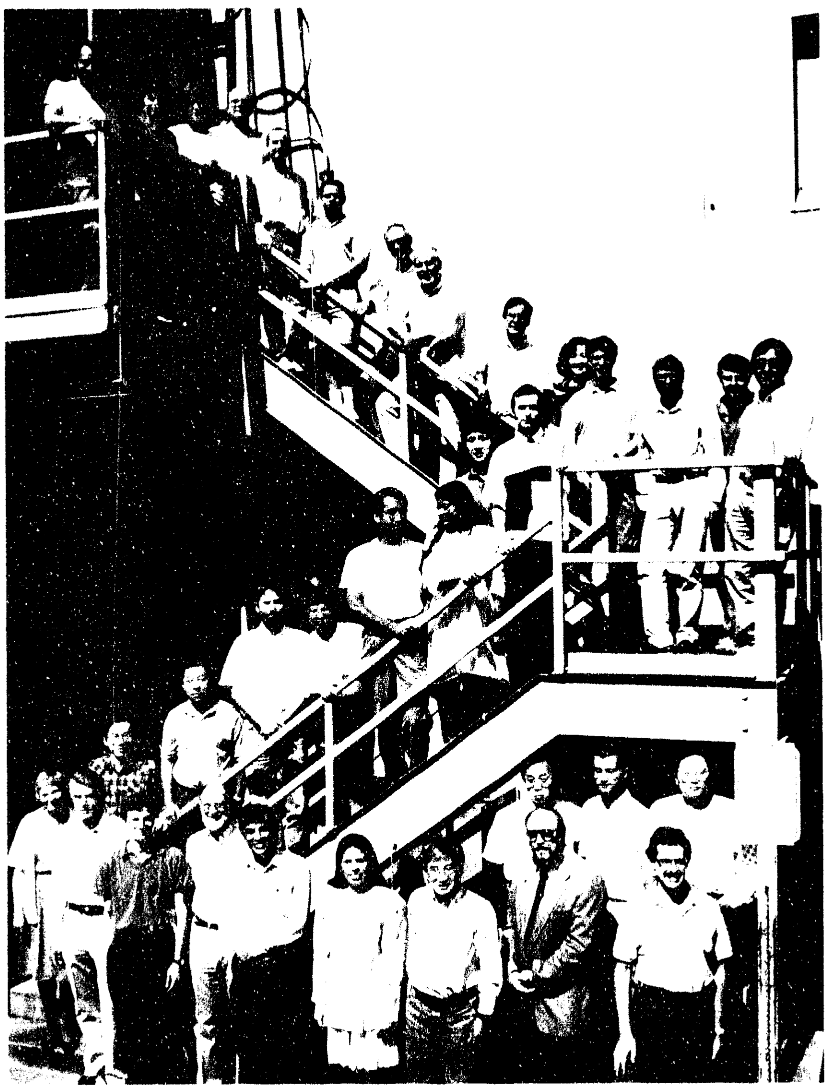
Contents

Welcome to CBP

"Nothing happens unless first a dream" — Carl Sandburg

The Center for Beam Physics is a multi-disciplinary research and development unit in the Accelerator and Fusion Research Division of the Lawrence Berkeley Laboratory. At the heart of the Center's mission is the fundamental quest for mechanisms of acceleration, radiation and focusing of energy. Dedicated to exploring the frontiers of the physics of (and with) particle and photon beams, 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 — as applied to studies of the fundamental structure and processes of the natural world. The Center serves this mission via conceptual studies, theoretical and experimental research, design and development, institutional project involvement, external collaborations, association with industry, and technology transfer. These activities support exploring the next steps in the development of particle accelerators, further continuing the tradition of pioneering accelerator research at the laboratory since its inception in 1932. The program of the Center is not limited to specific programmatic categories of the Department of Energy, but rather serves wide areas of research. The research program of the Center is directly linked with advances in high energy and nuclear physics, condensed matter, material and chemical sciences, the life sciences and various industrial applications.



Yet another important mission of the Center is education of students and the scientific, as well as outside, community via graduate instruction, research supervision and pedagogical expositions.

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 a significant amount of diverse, complementary and self-sufficient expertise in accelerator physics, synchrotron radiation, advanced microwave techniques, plasma physics, optics, and free electron lasers to bear on the forefront R&D issues in particle and photon beam research. In addition to functioning as a clearing house for ideas and concepts and the necessary related R&D (e.g., various theoretical and experimental studies in beam physics, nonlinear dynamics, optics, and instrumentation), the Center provides significant support to laboratory facilities and initiatives (e.g., the Advanced Light Source (ALS), the PEP-II asymmetric B-factory, and the LBL proposed Chemical Dynamics Research Laboratory (CDRL) initiative, etc.).

The multi-disciplinary 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 laboratory directed R&D funds. The Center also manages three in-house research facilities: the Lambertson Beam Electrodynamics Laboratory, the CBP Laser-Optics Laboratory and the Beam Test Facility at the ALS. Formal external collaborations include: SLAC-LBL-LLNL PEP-II studies, Stanford-LBL-BNL-TRW on FEL SCRF technology, LBL-Stanford on FEL diagnostics, CEBAF-LBL on IRFEL studies, and LBL-Peking University on Photocathode/SCRF technology.

This roster provides a glimpse at the scientists, engineers, technical support, students, and administrative staff that make up this outstanding team and a flavor of our multifaceted activities during 1993. We welcome students, academia, industry, and the public at large to participate in our programs to help us contribute to mutual flourishing.

Swapan Chattopadhyay

Swapan Chattopadhyay
Head, Center for Beam Physics

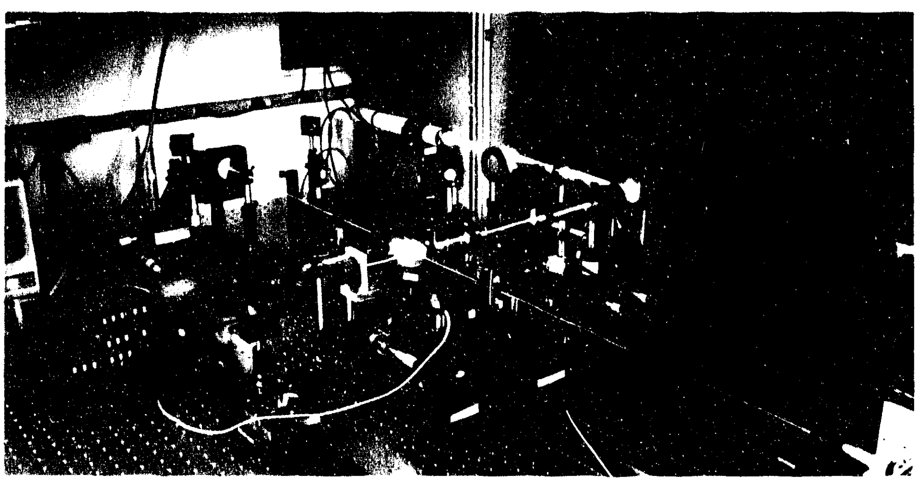
Facilities

Lambertson Beam Electrodynamics Laboratory

Nurtured, promoted and continually updated over the years by Glen Lambertson of LBL, the laboratory houses, in an environment of controlled temperature, various instruments, equipments and apparatus for low level (power-wise), high precision RF measurements of beam handling structures. Inventory includes sophisticated bead pulling apparatus, time domain reflectrometry set up, high frequency network and spectrum analyzers, microwave parts and absorbing materials, etc. Also includes a small shop and facilities to perform sophisticated electrodynamic computation of properties of dynamic RF devices.

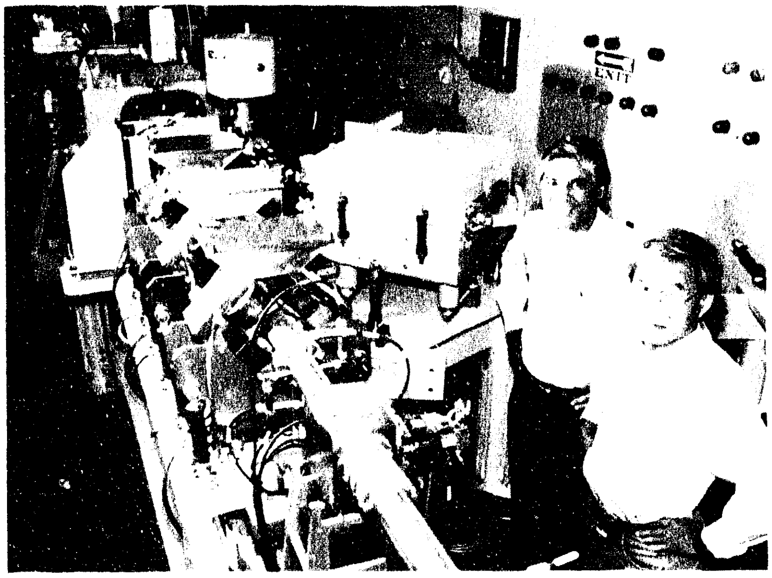
CBP Laser-Optics Laboratory

The Laboratory houses lasers, optical components, plasma devices and computers for data acquisition and control for experimental study of optical cavities, optical spectrometers, scaled FEL optics configurations, plasmas, etc.



Beam Test Facility

The facility, presently under construction, will provide access to a 50 MeV electron beam from the ALS injector linac, transferred via a magnetic transport line to a specially shielded experimental vault for various beam-plasma, laser-electron beam scattering and beam-RF structure interaction studies.



CBP Dedicated Workstations

Solbourne 502
Hewlett Packard 375
IBM RS/6000 (two)
VAXstation II

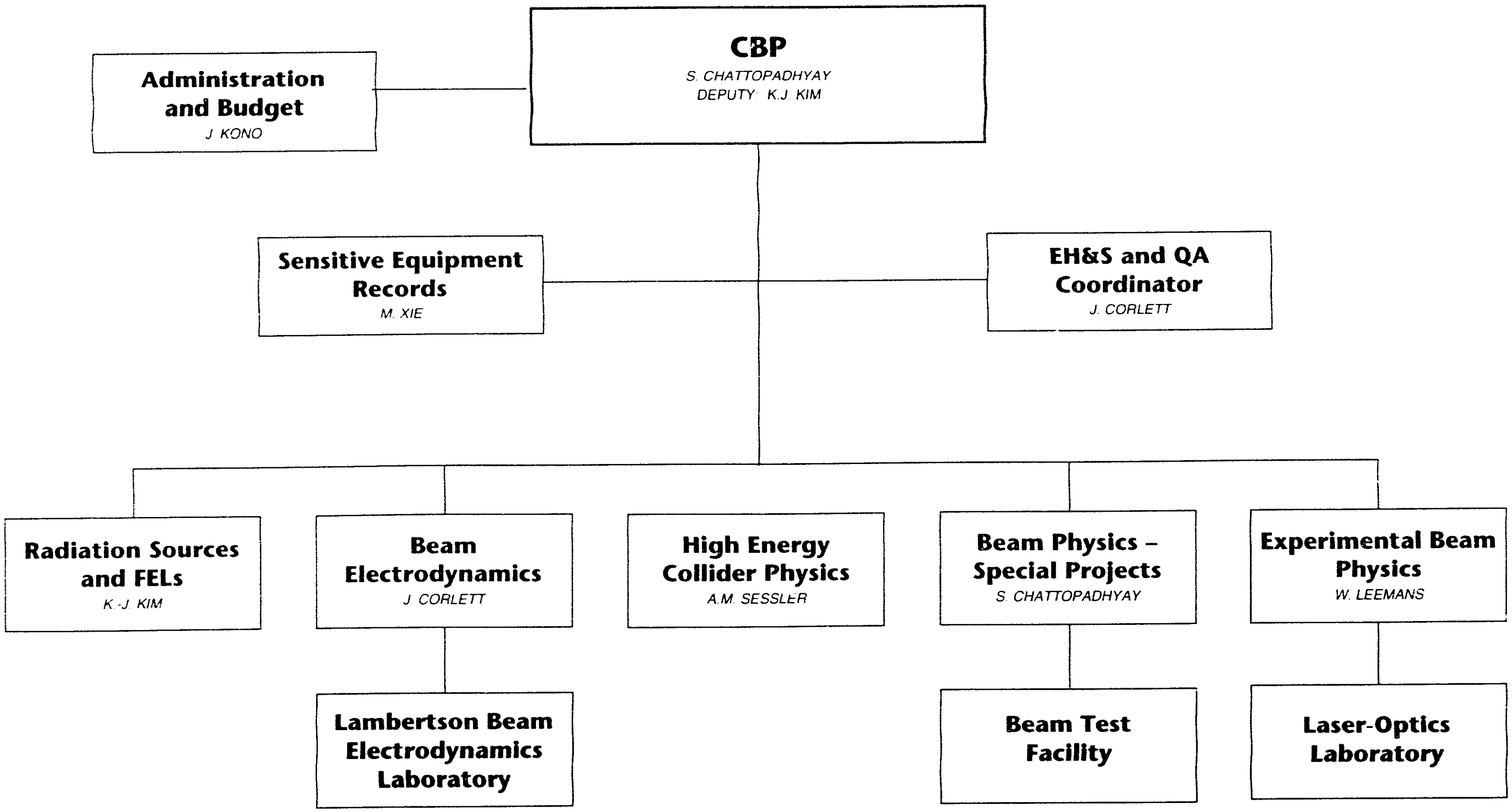
CBP Mini-Library

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

APIARY Conference Room and Microwave Link

This is a large conference room for seminars and meetings with the special feature of being connected via a microwave link to SLAC, allowing joint conferences and meetings with the scientists and engineers from SLAC and Stanford University. At present, the room is routinely used for joint LBL-SLAC-LLNL meetings on the PEP-II asymmetric B-factory, elegantly acronymed as APIARY by LBL physicist A.A. Garren previous to the present project title. It is also used regularly for biweekly Center for Beam Physics seminars.

Center for Beam Physics
Organization



Roster

Scientists and Engineers

BARLETTA, William
BARRY, Walter
BENGTSSON, Johan
BYRD, John
CHATTOPADHYAY, Swapan
CHIN, Yong Ho
CONDE, Manoel
CORLETT, John
EDIGHOFFER, John
FAWLEY, William
FOREST, Etienne
FURMAN, Miguel
GARREN, Alper
GOLDBERG, David
GOUGH, Richard
HAHN, Sang June
JACKSON, Alan
JOHNSON, Jimmie
KELLER, Roderich
KIM, Charles
KIM, Kwang-Je
KRISHAN, Vinod
KWON, Soo-Il
LAMBERTSON, Glen
LEEMANS, Wim
LI, Hai
MEDDAHI, Malika
NISHIMURA, Hiroshi
OKAMOTO, Hiromi
RIMMER, Robert
ROBIN, David
SCHACHINGER, Lindsay
SELPH, Frank
SESSLER, Andrew
VOELKER, Ferdinand
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Students

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VAN DER GEER, Bas
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Scientific Staff

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Joined LBL in March 1993

Ph.D., experimental high energy physics, Univ. of Chicago (1972). 1989-92: Visiting Professor, Dept. of Physics, UCLA. 1990-93: Assist. Lab. Assoc. Director for Programs at Lawrence Livermore National Laboratory.

Affiliations and honors: Sigma Xi (Yale), Woodrow Wilson Fellow (Univ. of Chicago), member of American Physical Society.

Selected publications: "Luminosity Limitations in Hadron Supercolliders", to be published in *Supercolliders and Superdetectors,* W. Barletta and H. Leutz ed. World Scientific, (1993).

"Characteristics of a High Energy $\mu^+\mu^-$ Collider Based on Electro-production of Muons" (with A.M. Sessler), LBL-33613, for submission to *Nucl. Instrum. Methods,* (Jan. 1993).

"Physically Transparent Formulation of the Free Electron Laser in the Linear Gain Regime" (with A. M. Sessler and L. H. Yu), *Nucl. Instrum. Methods,* and *Proceedings of the 14th International Free Electron Laser Conference,* Kobe, Japan (Aug. 1992).

"Measurements of Photo-desorption from Copper Alloys" (W.A. Barletta et al.), *Proc. of the 15th International High Energy Accelerator Conference,* Hamburg, Germany (July 1992).

"Critical Vacuum Issues for B-factories," *Proc. of Internation Symposium on B-factories: State of the Art,* Stanford (April 1992).

Walter C. Barry

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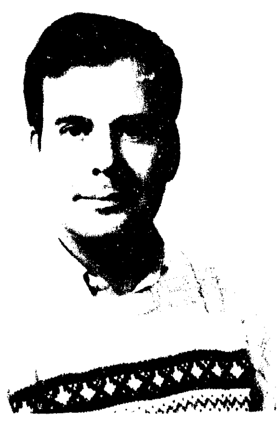

M.S., Georgia Institute of Technology, electrical engineering, 1982.

Research interests: Accelerator instrumenation, theory and applications 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. of the 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*, Vol. A301 (Mar. 1991).

"Characteristic Impedance and Loss Data for a Common Stripline Pickup Geometry" (with S. Y. R. Liu), *Nucl. Instrum. Methods,* Vol. A288 (Mar. 1990).

"Perturbation Method for the Measurement of Longitudinal and Transverse Beam Impedance" (with G. Lambertson), *Proc. of the 1987 IEEE Particle Accelerator Conference,* (Mar. 1987).

"A Broadband Automated, Stripline Technique for the Simultaneous Measurement of Complex Permittivity and Permeability," *IEEE Transactions on Microwave Theory and Techniques,* Vol. MTT-34, No. 1 (Jan. 1986).

Johan A. Bengtsson

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Joined LBL in 1989

Ph.D., Physics, MAX-lab, University of Lund, Sweden, 1988.

Research interests: computer modeling, nonlinear dynamics, control theory, circular accelerators, beam measurements, signal processing, computer science.

Selected publications: "A Closed-Loop Photon Beam Control Study for the Advanced Light Source" (with G. Portmann), IEEE 1993 Particle Accelerator Conference, Washington D.C. (May 1993).

"Study of Possible Energy Upgrade for the ALS and Modeling of the 'Real Lattice' for the Diagnosis of Lattice Problems" (with M. Meddahi), IEEE 1993 Particle Accelerator Conference, Washington D.C. (May 1993).

"Study of Transverse Coupled Bunch Instabilities by Using Non-Linear Taylor Maps for the Advanced Light Source (ALS)" (with M. Meddahi), IEEE 1993 Particle Accelerator Conference, Washington D.C. (May 1993).

"Achromatic and Isochronous Electron Beam Transport for Tunable Free Electron Lasers" (with K.-J. Kim), *Nucl. Instrum. Methods*, Vol. A318 (1992).

"Application of the Yoshida-Ruth Techniques to Implicit Integration and Multi-Map Explicit Integration" (with E. Forest and M. F. Reusch), *Phys. Lett. A,* Vol.158 (1991).

"Global Matching of the Normalized Ring" (with E. Forest), Advanced Beam Dynamics Workshop on Effects of Errors in Accelerators, their Diagnosis and Corrections, Corpus Christi, Texas (Oct. 1991).

John M. Byrd

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Joined LBL in 1991

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

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

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

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

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

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

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

"Progress on PEP-II Multibunch Feedback Kickers" (with J. Johnson, G. Lambertson, F. Voelker), *Proc. SLAC B Factory Workshop*, (June 1992).

"Longitudinal Beam Response Measurements at CESR," *Proc. of the 1991 IEEE Particle Accelerator Conference* (May 1991).

"Measurement of Octupole-induced Decoher-ence at CESR" (with D. Sagan), *Proc. of the 1991 IEEE Particle Accelerator Conference* (May 1991).

Swapan Chattopadhyay

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Joined LBL in 1984

Ph.D. (Physics), University of California, Berkeley, 1982. Attaché Scientific, CERN, Geneva, Switzerland, 1982-84. Guest lecturer, UC Berkeley, 1987. Visiting Prof., Univ. of Illinois at Urbana-Champaign, 1991.

Affiliations: Editor-in-chief, *Particle Accelerators* (Western Hemisphere); Member: American Physical Society (APS), American Associaton for the Advancement of Science (AAAS), International Committee on Future Accelerators (ICFA), Advisory Board to International Linac Conferences, Advisory Committee to 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.

Selected publications: "Generation of Sub-Picosecond X-rays" (with K.-J. Kim and C. Shank), LBL-31968, submitted to *Phys. Rev. Lett.*, (Feb. 1992).

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

"Feasibility Study of a Storage Ring for a High-Power XUV Free Electron Laser" (with J.J. Bisognano et al.), *Particle Accelerators,* Vol. 18, p. 223 (1986).

"Some Fundamental Aspects of Fluctuation and Coherence in Charged Particle Beams in Storage Rings," *AIP Conf. Proc. Series,* No. 127, p. 467 (1985).

Yong Ho Chin

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Joined LBL in 1988

Ph.D., The University of Tokyo, 1984.

Major awards: Japan Accelerators Society Annual Award.

Research interests: free electron laser, calculation of wake fields.

Selected publications: "User's Guide for ABCI,Version 8.7 (Azimuthal Beam Cavity Interaction)," CERN Report SL/94-02 (AP) (1994).

"Three-Dimensional Theory of Small-Signal, High-Gain Free Electron Laser Including Betatron Oscillations" (with K.-J. Kim and M. Xie), *Phys. Rev. A,* Vol 46, p. 6662 (1992).

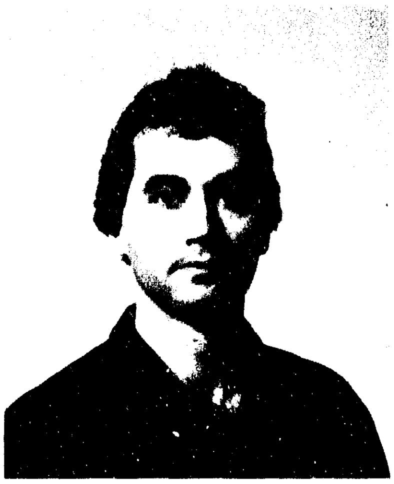
"Renormalized Theory of Beam-Beam Interac-tion in Electron-Positron Colliders," in *Proc. of the 3rd Advanced ICFA Beam Dynamics Workshop on Beam-Beam Effects in Circular Colliders*, edited by I. Koop, and G. Tumaikin Akademgorodok, Novosibirsk, USSR, pp. 69-75 (May 1989).

"User's Guide for New MOSES Version 2.0 (Mode-coupling Single Bunch Instability in an Electron Storage Ring)," CERN Report CERN/LEP-TH/88-05 (1988).

"Nonlinear Perturbation Approach to Bunch Lengthening and Blow-up of Energy Spread" (with K. Yokoya), *Nucl. Instrum. Methods,* Vol. 226, p. 223 (1984).

"Analytical Approach to the Overshoot Phe-nomenon for a Coasting Beam in Particle Accelera-tors" (with K. Yokoya), *Phys. Rev. D,* Vol. 28, p. 2141 (1983).

Manoel E. Conde



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Joined LBL in 1992

Ph.D. in Physics, Massachusetts Institute of Technology, 1992.

Research interests: free-electron lasers, particle accelerators and plasma physics, photocathode rf guns and plasma lenses.

Selected publications: "Observations of frequency upshift in a pulsed free-electron laser amplifier" (with C.J. Taylor and G. Bekefi), *Phys. Fluids B*, Vol 5, p. 1934 (1993).

"Electron Quantum Yields from a Barium Photocathode Illuminated with Polarized Light" (with S. Chattopadhyay et al.), LBL-33303 (May 1993).

"Amplification and Superradiant Emission from a 33.3 GHz Free Electron Laser with a Reversed Axial Guide Magnetic Field" (with G. Bekefi), *IEEE Trans. Plasma Sci.*, Vol 20, p. 240 (1992).

"Experimental Study of a 33.3 GHz Free Electron Laser Amplifier with a Reversed Axial Guide Magnetic Field" (with G. Bekefi), *Phys. Rev. Lett.*, Vol. 67, p. 3082 (1991).

"Shape of the Plasma Boundary in TBR" (with R. M. O. Galvao et al.), *Rev. Bras. Fis.*, Vol. 17, p. 109 (1987).

John N. Corlett

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Joined LBL in Dec. 1991

BSc Liverpool University, 1983. Microwave engineer, EEV Co. Ltd, 1983-1986. Accelerator physicist, Daresbury Laboratory, U.K., 1986-1991. Joined CBP in 1991.

Research interests: monochromatic rf structures, beam coupling impedance, feedback systems, bunched beam instabilities.

Selected publications: "Measurements of the Higher Order Modes of the ALS 500 MHz Accelerating Cavities" (with J. Byrd), presented at the Particle Accelerator Conference, Washington, D.C. (May 1993).

"Impedance Measurements of Components for the ALS" (with R. Rimmer), presented at the Particle Accelerator Conference, Washington, D.C. (May 1993).

"New Injection Kicker Magnets for the Daresbury SRS" (with J.A. Clarke), *Proc. 3rd European Particle Accelerator Conference*, Berlin, Ger. (March 1992).

"Higher Order Modes in the SRS 500 MHz Accelerating Cavities," Particle Accelerator Conference, Chicago, IL (March 1989).

"SRS-2 Performance and Achievements" (with V.P. Suller et al.), Particle Accelerator Conference, Chicago, IL (March 1989).

"Beam Instability Characteristics of the Daresbury SRS" (with M.W. Poole, V.P. Suller and J.S. MacKay), European Particle Accelerator Conference, Rome, Italy (June 1988).

John A. Edighoffer

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Joined LBL in Aug. 1991

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 bench top experiments.

Selected publications: "Energy Measurement of the Electron Beam Beyond the PALADIN Wiggler" (with T.J. Orzechowski, P. Lee, T.E. Smith, Y.P. Chong, A.C. Paul and J.T. Weir), *Proc. of the 11th FEL Conf.* (Sept. 1989).

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

"First Operation of a Tapered Wiggler Free Electron Laser Oscillator" (with S.W. Fornaca, G.R. Neal, C. Hess, H.A. Schwettman and T.I. Smith), J. Appl. Phys. (1983).

"Free Electron Laser Small Signal Gain Measurement at 10.6 mm," *Appl. Phy. Let.* (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), *Phy. Rev. A,* Vol. 23, No. 4 (April 1981).

William M. Fawley

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Joined LBL in 1990

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

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

Selected publications: "Coherence and Line-width Studies of a 4-nm High Power FEL" (with A.M. Sessler and E.T. Scharlemann), *1993 Part. Accel. Conf.*, 93CH3279-7, 1530-1532 (1993).

"Simulation Studies of Space-charge Dominated Beam Transport in Large Aperture Ratio Quadrupoles" (with L. J. Laslett et al.), *Nuovo Cimento* (in press) (1993).

"Lead Pulse Stability Issues" (with R. F. Hubbard), *J. Defense Res.*, Vol. 21, p. 311-336 (1992).

"Sideband Control in a Millimeter-Wave Free Electron Laser" (with J. Masud et al.), *Phys. Rev. Lett,* Vol. 58, 763-766 (1987).

Etienne Forest

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Joined LBL in 1985

Ph.D., Univ. of Maryland, 1984.

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

Selected publications: "The Absolute Bare Minimum for Tracking in Small Rings" (with M. Reusch, D. Bruhwiler and A. Amiry), *Part. Accel.* (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 J.S. Berg, R.L. Warnock and R.D. Ruth), *Phys. Rev.* (1993).

"Symplectic Methods in Circular Accelerators", Workshop on Integration Algorithms for Classical Mechanics, The Fields Institute, Waterloo, Ontario, Canada (Oct. 1993).

"The Modern Approach to Single-Particle Dynamics for Circular Rings" (with L. Michelotti, A.J. Dragt and J.S. Berg), with a foreward by J. Bentgsson, P*roc. of the Workshop on Stability in Storage Rings*, Upton, NY (1992). Series 54, AIP Conf. Proc. No. 292.

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

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

"Dynamic Aperture Study for the Duke FEL Storage Ring" (with Y. Wu, V.N. Litvinenko and J. Madey), *Nucl. Instrum. Methods, A,* (1992).

Miguel A. Furman

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Joined LBL in 1984

Ph. D., University of California, Santa Cruz, theoretical particle physics, 1977. Joined LBL/CBP in August, 1984. Worked "on loan" for the SSC Central Design Group (1984–1989), and then for the SSC Laboratory (1989–1990). Since 1990, he has been working full-time at CBP on the PEP-II project.

Research interests: beam-beam interaction; longiudinal phase space management and matching in chains of accelerators; space-charge effects.

Selected publications: "Beam-Beam Diagnostics from Closed-Orbit Distortion" (with Y-H Chin, J. Eden, W. Kozanecki, J. Tennyson and W. Ziemann), to be published in the *Proc. of the 15th Intl. Conf. on High-Energy Accelerators,* Hamburg, Ger. (July 1992).

"Beam-Beam Issues in Asymmetric Colliders," invited talk, *Proc. B Factories: State of the Art in Accelerators, Detectors and Physics*, SLAC (Apr. 1992).

"RAMPRF: a Program for Synchronous Acceleration," *Proc. 1991 Particle Accelerator Conference*, San Francisco, CA (May 1991).

"Hourglass Effects for Asymmetric colliders," *Proc. 1991 Particle Accelerator Conference,* San Francisco, CA (May 1991).

"Beam-Beam Studies for the Proposed SLAC/LBL/LLNL B Factory," *Proc. 7th ICFA Workshop on Beam Dynamics*, UCLA (May 1991).

"A Possible Symplectic Coherent Beam-Beam Model" (with A. W. Chao and K.Y. Ng), *Proc. European Particle Accelerator Conference*, Rome, Italy (June 1988).

Alper Garren

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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, etc. Author of the lattice program SYNCH. Also contributed to heavy ion fusion, magnetic fusion with mirror machines, spiral-ridge cyclotrons (e.g. 88" 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, M. Syphers), SSCL-MAN-0002 (1993).

"APIARY B-Factory Separation Scheme" (with M. Sullivan), LBL-30730 (May 1991).

"APIARY B-Factory Lattice Design" (with M.H.R. Donald), LBL-30665 (May 1991).

"Low Momentum Compaction Lattice Study for the SSC Low Energy Booster" (with E.D. Courant and U. Wienands), *Proc. of 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. of 1989 Particle Accelerator Conference*, Chicago, IL (1989).

"Thin Lens Optics With Space Charge," *Proc. of 7th Int. Conf. on High Energy Accelerators*, Yerevan, USSR, UCRL-19313, (1969).

"Lattice Of The Nal Proton Synchrotron," *Proc. of 1969 Particle Accel. Conference.* (1969).

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

David A. Goldberg

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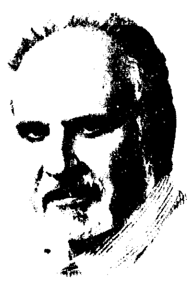

Ph.D., Johns Hopkins University, nuclear physics, 1967.

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

Selected publications: "Automated Bead-Positioning System for Measuring Impedances of R.F. Cavity Modes" (with R.A. Rimmer), Particle Accelerator Conference (1993).

"Measurements of Higher-Order Mode Damping in the PEP-II Low-Power Test Cavity" (with R.A. Rimmer), Particle Accelerator Conference (1993).

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

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

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

"Improving the Performance of Power-Limited Stochastic Cooling Systems" (with G.R. Lambertson), *Particle Accelerators*, Vol. 30 (1990).

"Beam Impedance Measurements on the ALS Curved Sector Tank" (with R.A. Rimmer et al.), 1990 European Particle Accelerator Conference.

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Program Head Ion Beam Technologies, AFRD

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

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

Selected publications: "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 (Aug. 1992).

"Design Overview of Highly Stable Infrared Free Electron Laser at LBL" (with K.-J. Kim et al.), Proc. of Twelfth International Free Electron Laser Conference, Paris, France (Sept. 1990).

"Performance of the Oxygen Injector for the CERN Linac I" (with B. Wolf et al.), *Nucl. Instrum. Methods*, Vol. A258 (1987).

"Medical Heavy Ion Accelerator Proposals," *Proc. of 1985 Particle Accelerator Conference*, Vancouver, B.C., Canada (May 1985).

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Joined LBL in Nov. 1993

Ph.D. (Physics), Pohang Institute of Science & Technology(POSTECH), Pohang, Korea, 1993. Research Scientist, Pohang Light Source(PLS), Pohang, Korea, 1988-1989. Research Associate, POSTECH, Pohang, Korea, 1993.

Research interests: Coherent radiation sources; Free-electron lasers; Nonlinear dynamics and chaos; beam-plasma physics.

Selected publications: "Chaotic Transitions in a Short-Pulse FEL Oscillator", submitted to *Nucl. Instrum. Methods A*, (Aug. 1993).

"Nonlinear Short-Pulse Propagation in a Free-electron Laser", *Phys. Rev. E*, Vol. 48, p. 2162, (1993).

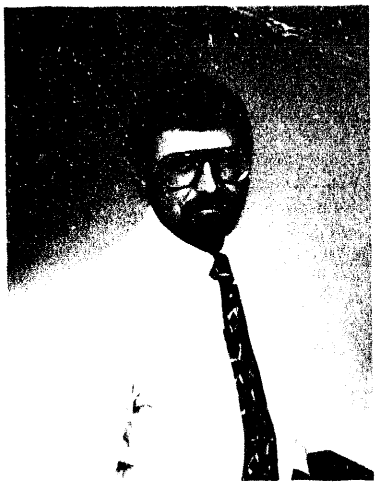
"Optical Spikes and Superradiant Pulse Propagation in a Free-electron Laser", *Nucl. Instrum. Methods*, Vol. A331, p. 390 (1993).

"Bifurcations in a Short-Pulse Free-electron Laser Oscillator", *Phys. Letters A*, Vol. 176, p. 339, (1993).

"Kinetic Simulation for the Transient Sheath in the Plasma Ion Implantation", *Jpn. J. Appl. Phys.*, Vol. 31, p. 2570 (1992).

"Off-Peak Saturation Effects of Beam-Plasma Instability", *IEEE Trans. Plasma Science*, Vol. 19, p. 52 (1991).

Alan Jackson



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Joined LBL in 1984

BA (Hons) Physics, Lancaster University, 1968. 1968-84: Scientific Officer at Daresbury Nuclear Physics Laboratory, U.K. 1984-present: At LBL, member of the team that designed and commissioned the third generation Advanced Light Source.

Affiliations: Member APS and AAAS.

Research intrests: design, construction and operation of synchrotron radiation sources; fourth generation synchrotron radiation source.

Selected publications: "Ideas for Future Synchroton Light Sources," presented at the Third European Accelerator Conference, Berlin, Germany, March 1992, and to be published in the proceedings.

"The Challenges of Third Generation Synchrotron Light Sources," *Synchrotron Radiation News*, Vol. 3, No. 3, pp. 13-20 (May-June 1990).

"The Effect of Insertion Devices on the Behavior of the ALS," (A. Jackson et al.), *IEEE Trans. Nuc. Sci.*, IEEE 89CH2669-0 (1989).

"A Comparison of the Chasman-Green and Triple Bend Achromat Lattices," *Particle Accelerators*, Vol. 22, No. 2 (1987).

"Feasibility Study of a Storage Ring for a High Power XUV Free Electron Laser" (with J. Bisognano et al.), *Particle Accelerators*, Vol. 18 (1986).

"The NINA Polarised Photon Beam," *Nucl. Instrum. Methods*, Vol. 129 (1975).

Jimmie K. Johnson

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Joined LBL in 1981

B.S., Electronics Engineering, University of California, Davis, 1981.

Research interests: accelerator technology, microwave devices, computer-aided modeling, multi-bunch feedback systems.

Selected publications: "Novel Electrode Design for a 4-8 GHz Stochastic Cooling System" (with D. Goldberg, G. Lambertson, F. Voelker), *Bull. Am. Phys. Soc.*, Vol. 33, p. 1025 (1988).

"Power Combiners/Dividers for Loop Pickup and Kicker Arrays for FNAL Stochastic Cooling Rings (with R. Nemetz), 1985 Particle Accelerator Conference, Vancouver, B.C., Canada, (May 1985), *IEEE Trans. Nucl. Sci.*, NS-32, p. 2171 (October 1985).

"An Array of 1 to 2 GHz Electrodes for Stochastic Cooling (with F. Voelker and T. Henderson), 1983 Particle Accelerator Conference, Santa Fe, NM (Mar. 1983).

Roderich Keller

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Joined LBL in 1988

Dr. rer. nat., University of Kiel, Germany, experimental physics, 1973.

Awards: Three patents on ion sources and components.

Research interests: particle accelerators; ion sources for accelerators and industrial applications.

Current activities: Characterization of the Advanced Light Source electron storage ring and its development for operation with multiple insertion devices.

Selected publications: "Final Analy· s of the ALS Lattice Magnet Data," *IEEE #93 CH32977*, p. 2811 (1993).

"Survey and Alignment of the Advanced Light Source in Berkeley," *Nucl. Instrum. Methods*, Vol. B56/57, p. 422 (1991).

"Study of a 'Relaxed' ALS Storage Ring Lattice," Second European Particle Accelerator Conf., Nice, France (1990).

"Ion Extraction Systems: Optics and Design," *Nucl. Instrum. Methods* Vol. A298, pp. 247-254 (1990).

"High Current Gaseous Ion Sources" in: I.G. Brown, ed., *The Physics and Technology of Ion Sources*, p. 151, John Wiley, NY (1989).

"Spectroscopic Measurements on an H- Ion Source Discharge," *IEEE Trans. Nucl. Sci.* NS-32, p. 1736 (1985).

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Joined LBL in 1978

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

Awards: Fannie and John Hertz Foundation Fellow.

Research interests: Accelerators, rf linac, synchrotron, storage ring, accelerator diagnostics instrumentation, linac simulations.

Selected publications: "Performance of the ALS Injector," *Proc. of the IEEE Particle Accelerator Conference*, p. 2036 (1993).

"Advanced Light Source Instrumentation Overview," *Proc. of the 1992 Accelerator Instrumentation Workshop.* (1992).

"Commissioning Experiences of the ALS Booster Synchrotron", *Proc. of the IEEE Particle Accelerator Conference*, p. 2691 (1991).

"Dynamic Aperture of the ALS Booster Synchrotron," *Proc. of the IEEE Particle Accelerator Conference*, p. 1328 (1989).

"Simulation of Emittance Growth in the ALS Pre-Injector, " *Linear Accelerator Conference Proceedings*, p. 427 (1988).

"Design of a Bunching System for a High-Intensity Electron Linac," *Proc. of the European Particle Conference*, p. 863 (1988).

"Development of Heavy Ion Induction Linear Accelerators as Drivers for Intertial Confinement Fusion," *Proc. of the European Particle Conference*, p. 1521 (1988).

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

Affiliations: American Physical Society, Int'l FEL Program Committee (1993), Int'l Advisory Committee for Pohang Light Source.

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

Selected publications: "Generation of Sub-Pico Second X-rays by 90° Thomson Scattering" (with S. Chattopadhyay and C.V. Shank), To be published in *Nucl. Instrum. Methods. Phys. Res. A* 341 (1994) 351-354.

"Spectral Bandwidth in FEL Oscillators," *Phys. Rev. Lett.*, Vol. 66, p. 2746 (1991).

"Free Electron Lasers: Present Status and Future Prospect" (with A.M. Sessler), *Sciences*, Vol. 250, p. 88 (Oct. 1990).

"RF and Space Charge Effects in Laser-Driven RF Electron Guns," *Nucl. Instrum. Methods*, Vol. A275, p. 201 (1989).

"Three-Dimensional Analysis of Coherent Amplification and Self-Amplified Spontaneous Emission in Free Electron Lasers," *Physical Review Letters*, Vol. 57, p. 1871 (1986).

"Brightness, Coherence and Propogation Characteristics of Synchrotron Radiation," *Nucl. Instrum. Methods*, Vol. A246, p.71 (1986).

"A Synchrotron Radiation Source With Arbitrarily Adjustable Elliptical Polarization," *Nucl. Instrum. Methods*, Vol. 222, p.11 (1984).

Vinod Krishan

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LBL visitor from Oct. 93-Jan. 94.

Ph.D. (Physics), University of Tennessee, 1971. Post doc, University of Alberta, Edmonton, Canada 1971-73. Research Associate, Indian Institute of Science, Bangalore, India 1973-78. Indian Institute of Astrophysics, Bangalore, India since 1978.

Affiliations: Member, Scientific Committee International Astronomical Union, Commission 49, Associate member International Center for Theoretical Physics, Trieste, Italy, Secretary Plasma Science Society of India, member, Astronomical Society of India, Dr. Vikram Sarabhai Awardee, 1991.

Research interests: Magnetohydrodynamics of Solar Plasmas, Nonthermal Radiation Processes in Solar and Quasar Atmospheres, Solar Granulation, Large Scale Structure of the Universe.

Selected publications: "Rapid Variability of Polarization in Intense Sources" (with R.T. Gangadhara), *Astrophysical Journal*, (1994).

"The Extra-Terrestrial Raman Scattering," *Current Science*, Vol. 64, p. 301 (1993) (Review article).

"Clustering of Galaxies by the a-effect," *Mon. Not. Roy. Astron. Soc.* Vol. 264, p. 257 (1993).

"An Inverse Cascade Model of Solar Granulation," *Mon. Not. Roy. Astron. Soc.*, Vol. 250, p. 50 (1991).

Soo-Il Kwon

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Ph.D., Nuclear Physics, Sung Kyun Kwan University, Korea, 1988.

Research interests: radiation detection and measurement, radiation damage, free electron lasers, laser-driven photocathode electron source.

Selected publications: "Electron Spin Resonance of Gamma-irradiated Single Crystal of L-Alanine," *Kor. Appl. Phys.*, Vol. 6, No. 3 (1993).

"ESR Study of the Proton-Deuteron Exchange P ıction in Irradiated L-Alanine," *Kor. Appl. Phys.*, Vol. 6, No. 3 (1993).

"A Study on the Fabrication of the BGO Scintillation Detector and Its Gamma-Ray Spectroscopic Characteristics," *Kor. Appl. Phys.*, Vol. 4, No. 1 (1991).

"The Effects of Scintillator Shape and Surface Treatment on the Light Output of BGO Detector," *Kor. Appl. Phys.*, Vol. 3, No. 4 (1990).]\

"Characteristics of BGO Scintillation Detector Using Silicon Photodiodes," *J. Kyonggi Univ.*, Vol. 21 (1989).

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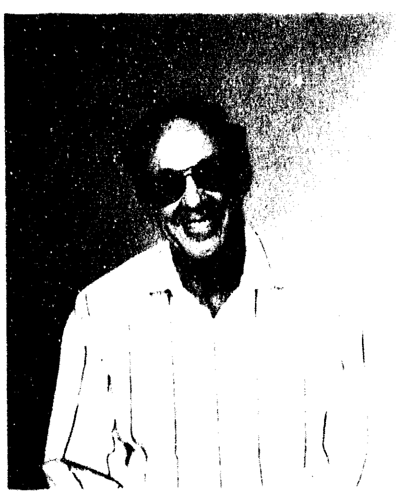
Joined LBL in 1951



M.S. University of California, Berkeley, Physics, 1951.

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

Current research: particle beam electrodes, stochastic beam cooling, feedback stabilization of beam instabilities.

Selected publications: "Dynamic Devices, A Primer on Pickups and Kickers" (with Goldberg), *AIP Conf. Proc.*, Vol. 249, p. 537 (1992).

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

"Transverse Feedback in a 100 TeV Storage Ring," Proc. of 19th Workshop on Maximizing Luminosity of Hadron *Colliders at 180 TeV*, Erice, Italy (1991).

"Control of Coupled-Bunch Instabilities in High-Current Storage Rings," invited paper, *Proc. of the 1991 IEEE Particle Accelerator Conference*, Vol. 4, p. 2537 (1991).

"Higher Order Mode Damping in a Pill Box Cavity" (with Rimmer and Voelker), *Proc. of the 1991 IEEE Particle Accel. Conf.*, Vol. 2, p. 687 (1991).

"Techniques for Beam Impedance Measurements Above Cutoff" (with Jacob, Rimmer and Voelker), *2nd European Particle Accel. Conf.*, p. 1049 (June 1990).

Wim Leemans

Staff Scientist
Group Leader Experimental Beam Physics
MS 71-259
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Joined LBL in 1991

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

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

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

Selected publications: "Ultra-high Gradient Acceleration of Injected Electrons by Laser Excited Relativistic Electron Plasma Wave" (with C.E. Clayton et al.), Phys. Rev. Lett., Vol. 70, p. 37 (1993).

"Non-linear Dynamics of Driven Relativistic Electron Plasma Waves" (with C. Joshi et al.), Phys. Rev. A, Vol. 46, p. 15 (Sept. 1992).

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

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

"Stimulated Compton Scattering from Pre-formed Underdense Plasmas" (with C. E. Clayton, K. A. Marsh and C. Joshi), *Phys. Rev. Lett.*, Vol. 67, pp. 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.*, Vol. 59, p. 1641 (August 1988).

Hai Li

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Joined LBL in 1993

Ph.D., Physics, University of Maryland at College Park, 1993.

Research interests: analytical and numerical studies of beam and microwave physics which are related to the conceptual design of rf linear colliders, especially the two beam accelerators of both the standing wave free electron laser version and the relativistic klystron version.

Selected publications: "Design Consideration of Relativistic Klystron Two-Beam Accelerator for Suppression of Beam-Break-Up" (with T. L. Houck, S. Yu and N. Goffeney), presented at the SPIE International Symposium, Los Angeles, CA, (Jan. 1994), to be published in the Proceedings.

"Suppression of Beam-Break-Up in a Standing Wave Free Electron Laser Two-Beam Accelerator" (with J. S. Kim), presented at the SPIE International Symposium, Los Angeles, CA, (Jan. 1994), to be published in the Proceedings.

"Space Charge Instabilities in Gyrotron Beams" (with T. M. Antonsen, Jr.), accepted for publication in Phys. *Fluids B*, (1993).

"Theory of Gyro-traveling-wave Tubes at Cyclotron Harmonics" (with G. S. Nusinovich), *Int. J. Electron.* Vol. 72 (5-6), pg. 895 (1992).

"Theory of Relativistic Gyro-twistron" (with G. S. Nusinovich), *Phys. Fluids B*, Vol. 4(4), pg. 1058 (1992).

"Large-signal Theory of Gyro-traveling-wave Tubes at Cyclotron Harmonics" (with G. S. Nusinovich), *IEEE Tran. Plasma Sci.*, Vol. 20(3), p. 170 (1992).

Malika M. Meddahi

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Joined LBL in 1991

Ph.D., University of Paris 7, 1991.

Awards: Daniel Guignier Prize, 1991.

Research interests: nonlinear dynamics; accel-erator studies; beam-beam effects; ALS transverse damping scheme.

Selected publications: "Influence of a Wiggler Magnet in a Circular Machine" (with R. Schmidt), CERN-SL (July 1992).

"Ideas for Future Synchrotron Light Sources" (with A. Jackson and W. Hassenzahl), EPAC 1992, Berlin, Ger. (Mar. 1992).

"Proton-Antiproton Collisions at a Finite Crossing Angle in the SPS" (with K. Cornelis and W. Herr), LHC Note 150 (1991).

"Measurement of the Beam-Beam Effect as a Function of the Separation in LEP" (with K. Cornelis et al.), EPAC 1990, Nice, France (Jun. 1990).

"Calculations of the Tune Spreads Induced Beam-Beam Effects in the Case of Partially Separated Beams" (with R. Schmidt), CERN-SL/90-15 (1990).

"Tracking Studies on the Beam-Beam Effect in the CERN-SPS p-pbar Collider" (with W. Herr and R. Schmidt), CERN-SL/91-5(AP).

"Beam-Beam Effects in the Strong-Strong Regime at the CERN SPS" (with L. Evans, J. Gareyte and R. Schmidt), 1989 Part. Acc. Conf, Chicago, IL (Mar. 1989).

"Experimental Study of a Beam Excitation in the Presence of the Beam-Beam Interaction" (with K. Cornelis, R. Schmidt and D. Vandeplassche), SPS/AMS/Note 89-04.

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Joined LBL in 1985

Ph.D., University of Tokyo, Physics, 1982.

Research interests: accelerator physics for ALS; modeling and simulation code construction for real accelerator control using the novel programming methodologies like OOP.

Selected publications: "Dynamic Accelerator Modeling Uses Objects in Eiffel," *Computers in Physics,* Vol. 6, p. 456 (1992).

"Framework for Control System Development" (with C.W. Cork), to appear in the *Proc. of the International Conference on Accelerator and Large Physics Control Systems,* Tsukuba, Japan (1991).

"Vertically Integrated Simulation Tools for Self-Consistent Tracking and Analysis" (with E. Forest), *Proc. Part. Accel. Conf.*, CH2669, p. 1304 (1989).

"Dynamic Aperture of the ALS Booster Synchrotron" (with C. Kim), *Proc. Part. Accel. Conf.*, CH2669, p. 132 (1989).

"The Effects of Insertion Devices on the Behavior in the ALS" (with A. Jackson, E. Forest and M.S. Zisman), *Proc. Part. Accel. Conf.*, CH2669, p. 1752 (1989).

"TRACY, A Tool for Accelerator Design and Analysis," *Proc of the European Part. Accel. Conf.*, p. 803 (1988).

"Particle Simulation Code for Non-Relativistic Electron Bunch in LASERTRON," *Proc. Linear Accel. Conf.*, GSI-84-11, p. 165 (1984).

"LASERTRON: Laser Triggered RF Source for Linacs in the TeV Region" (with M.Yoshioka et al.), *Proc. Linear Accel. Conf.*, GSI-84-11, p. 469 (1984).

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Ph.D., Physics, Kyoto University, 1989.

Research interests: beam-plasma dynamics; linear accelerating structures; free electron lasers; collider physics; coupling impedance analysis.

Selected publications: "Longitudinal and Transverse Impedance of an Iris in a Beam Pipe" (with S. Jiang and R. L. Gluckstern), submitted to *Phys. Rev. E* (1994).

"Three Dimensional Laser Cooling of Stored and Circulating Ion Beams by Means of a Coupling Cavity" (with A. M. Sessler and D. Möhl), submitted to *Phys. Rev. Lett.* (1994).

"Synchrobetatron-Coupling Effects in Alternating-Phase-Focusing Linacs" (with W-H. Cheng and R. L. Gluckstern), *Phys. Rev. E*, Vol. 48, No. 6, p. 4689 (1993).

"One-dimensional Beam Stability Analysis Based on the Waterbag Model", *Nucl. Instrum. Methods*, Vol. A332, p. 1 (1993).

"Analysis of the Saturation of a High Gain FEL" (with R. L. Gluckstern and S. Krinsky), *Phys. Rev. E*, Vol.47, No. 6, p. 4412 (1993).

"Beam Dynamics of Alternating Phase Focused Linacs", *Nucl. Instrum. Methods*, Vol. A284, p. 233 (1989).

"Simple Measurement Systems for Permanent Magnet Quadrupole Lenses" (with Y. Iwashita and H. Takekoshi), *Rev. Sci. Instr.*, Vol. 60 (9), p. 2975 (1989).

Robert A. Rimmer

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Joined LBL in 1988

Ph.D., Lancaster University, UK, Engineering Dept., 1988, subject: High Power Microwave Window Failures.

Research interests: computer simulation of high frequency electromagnetic problems, Higher-Order-Mode suppression in rf cavities and structures, microwave windows, beam impedance of accelerator components.

Selected publications: "Extraction and Absorption of Higher Order Modes in Room Temperature Accelerators," R.A. Rimmer, invited paper, *Proc. Workshop on Microwave Absorbing Materials for Accelerators*, MAMA, (Feb. 1993), CEBAF, Newport News, VA.

"RF Cavity Development for the PEP-II *B* Factory," *Proc. Int. Workshop on B-Factories*, BFWS92, KEK, Japan, (Nov. 1992).

"An RF Cavity for the B-Factory" (R. Rimmer et al.), *Proc. 1991 U.S. Part. Accel. Conf.*, San Francisco, CA (May 1991).

"Modes of Elliptical Waveguides; a Correction" (with D.A. Goldberg and L.J. Laslett), *IEEE Trans. MTT*, Vol. 38, No. 11, pp. 1603-1608 (Nov. 1990).

"Beam Impedance Measurements on the ALS Curved Sector Tank" (R.A. Rimmer et al.), *Proc. 1990 Europ. Part. Accel. Conf.*, LBL-28192, Nice, France (June 1990).

"Determination of Failure Mechanisms of RF Cavity Aperture Windows," *Proc. 1989 IEEE Part. Accel. Conf.*, Chicago, IL (March 1989).

David S. Robin

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Joined LBL in 1991

Ph.D., University of California at Los Angeles, physics, 1991.

Research interests: studies of the linear and non linear dynamics of lepton storage ring colliders.

Selected publications: "Quasi-isochronous storage rings" (D. Robin, et al.), *Physical Review E*, Vol. 48, No. 3, 2149-2156 (1993).

"Study of a Magnetic Lattice for a Quasi-Isochronous Ring" (A. Amiry, et al.), LBL-34065 (to be published in*Particle Accelerators*) (1993).

"Status of the Variable Momentum Compaction Storage Ring Experiment in Spear" (P. Tran et al.), to be published in P*roceedings of the 1993 IEEE Particle Accelerator Conference*, (1993).

"Localized Chromaticity Correction of Low-Beta Insertions in Storage Rings" (M. Donald et al.), to be published in P*roceedings of the 1993 IEEE Particle Accelerator Conference*, (1993).

"Local Chromatic Correction Scheme for LER of PEP-II" (E. Forest et al.), Proc. *International Workshop on B Factories: Accelerators and Experiments*, KEK, Tsukuba, Japan (Nov. 1992).

"Quasi-Iso-chronous Ring Flavor Factories" (with C. Pellegrini), *Rare and Exclusive B and K Decays and Novel Flavor Factories* (1992).

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Joined LBL in 1990

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

Research interests: accelerator simulation and modeling both for design and controls, non-linear dynamics, controls and modeling for accelerator physics studies in circular accelerators.

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

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

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

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Joined LBL in 1962

M.S., Univ. of California, Berkeley, Physics, 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 (Sept. 1993).

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

"Operating Experience with the ALS Linac" (with D. Massoletti), *Proc. of the 1991 Part. Accel. Conf.*, IEEE 91CH3038-7, p. 2978-80.

"Compensation of Beam Loading in the ALS Injector Linac," *Proc. of the 1988 Linear Accel. Conf.*, CEBAF Report 89-001, p. 580-82.

"Wakefield Effects in the Two-Beam Accelerator" (with A. Sessler), *NIM,* Vol. A244, p. 323-29 (1986).

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

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

"A Method for Obtaining Linac Beams of Continuously Variable Energy," *Proc. of the 1970 Proton Linac Accel. Conf.*, p. 868-879, Natl. Accel Lab., Batavia (1970).

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Joined LBL 1961

Director 1973-1980

Ph.D., Columbia University, theoretical physics, 1953.

Major awards: E.O. Lawrence Award by U.S. Atomic Energy Commission; U.S. Particle Accelerator School Prize; Leland J. Haworth Distinguished Scientist, Brookhaven National Laboratory; member, National Academy of Sciences.

Research interests: beams in plasmas; conventional and novel high energy accelerators; free-electron lasers.

Selected publications: "Radio-Frequency Beam Conditioner for Fast-Wave Free-Electron Generators of Coherent Radiation" (with D.H. Whittum and L.-H. Yu), *Phys. Rev. Lett.*, Vol. 64 (1992).

"Photon Storage Cavities" (with K.-J. Kim), *Nucl. Instrum. Methods*, Vol. A318 (1992).

"Free Electron Laser Generation of VUV and X-Ray Radiation Using a Conditioned Beam and Ion-Channel Focusing" (with L.-H. Yu and D.H. Whittum), *Nucl. Instrum. Methods*, Vol. A318 (1992).

Transverse Resistive Wall Instability in the Two-Beam Accelerator" (with D.H. Whittum and V.K. Neil), *Phys. Rev. A*, Vol. 43 (1991).

"Relativistic Klystrons for High-Gradient Accelerators" (with G.W. Westenskow et al.), *Proc. of 1990 Linear Accel. Conf.* (1991).

"Standing-Wave Free-Electron Laser Two-Beam Accelerator" (with D.H. Whittum, et al.), *Nucl. Instrum. Methods*, Vol. A306 (1991).

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M.S., University of California, Berkeley.

Research interests: damping of HOM in RF cavities; study of multi-electrodes kickers for particle beam; beam impedance measurements

Selected publications: "ALS Longitudinal Kickers," presented at the 1992 Accelerator Instrumentation Workshop, LBL, Berkeley, CA, LBL-33088 (Oct. 1992).

"Higher Order Model Damping Studies on the PEP-II B-Factory RF Cavity" (with R. Rimmer, D. Goldberg, G.R. Lambertson, et al.), presented at the 3rd European Particle Accelerator Conference, Technical University of Berlin, Germany, LBL-32549 (Mar. 1992).

"Calculations on RF Cavity Feedback Using Simple Analytic Model" (with G.R. 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, LBL-28190 (Jun. 1990).

"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., LBL-22273 (Mar. 1987).

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

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Research interests: electron cyclotron resonance maser; free-electron lasers; electron beam conditioner; relativistic klystron simulation.

Selected publications: "Stability of the Equili-brium Helical Orbits in Free-Electron Lasers", Submitted for publication in *Phys. Lett. A*, (1993).

"Simulation analysis of the effect of beam pipes and multi-mode competition in the standing-wave Free-Electron Laser Two-Beam Accelerator", Submitted for publication in *Nucl. Instrum. Methods A*, (1993).

"Three-Dimensional Simulation Analysis of a 3-cm Wavelength Free-Electron Laser Afterburner", Submitted for publication in *IEEE Transaction on Plasma Science,* 1993.

"An Efficient Microwave Power Source: Free-Electron Laser Afterburner" (with Andrew M. Sessler), *J. Appl. Phys.*, Vol. 74, p. 4840 (1993).

"Three-Dimensional Simulation Analysis of the Standing-wave Free-electron Laser Two Beam Accelerator" (with Andrew M. Sessler) in Intense Microwave Pulses, *Proc. SPIE*, 1872, p. 130, SPIE, Los Angeles, CA (1993).

"Conditioner for a Helically Transported Electron Beam", in *Advanced Accelerator Concepts*, AIP Conf. Proc. Vol. 279, p.126 (1992).

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Ph.D., Stanford University, Physics, 1988.

Research interests: generation of intense short wavelength radiation, free electron laser, laser optics.

Selected publications: "Self-Amplified Spontaneous Emission for Short Wavelength Coherent Radiation" (with K.-J. Kim), *Nucl. Instrum. Methods, Vol. A331,* p.359 (1993).

"Three-Dimensional Theory of the Small-Signal High-Gain Free Electron Laser Including Betatron Oscillations" (with Y. Chin and K.-J. Kim), *Physical Review A,* Vol. 46, No.10, p. 6662 (1992).

"Performance of Hole Coupling Resonator in the Presence of Asymmetric Modes and FEL Gain" (with K.-J. Kim), *Nucl. Instrum. Methods,* Vol. A318, p. 877 (1992).

"Hole Coupling Resonator for Free Electron Lasers" (with K.-J. Kim), *Nucl. Instrum. Methods,* Vol. A304, p. 792 (1991).

"Stability and Performance of CDRL-FEL" (with K.-J. Kim), *Nucl. Instrum. Methods,* Vol. A304, p. 146 (1991).

"Eigenmode Analysis of Optical Guiding in Free Electron Lasers" (with D.A.G. Deacon and J.M.J. Madey), *Physical Review A,* , Vol. 41, No.3, p. 1662 (1990)

"Theoretical Study of FEL Active Guiding in the Small Signal Regime" (with D.A.G. Deacon), *Nucl. Instrum. Methods,* Vol. 250, p.426 (1986).

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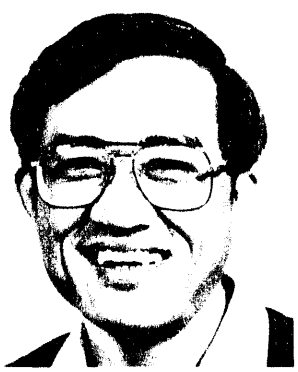

Ph.D., University of Washington, 1970.

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" (S. Yu et al.), *Proceedings of the 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,* p. 205, La Jolla International School of Physics, New York, NY (1992).

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

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

"Waveguide Suppression of the Free Electron Laser Sideband Instability: (S. Yu et al.), *Nucl. Instrum. Methods,* Vol. A259, pp. 219-225 (1987).

"Intense Electron Beams," Lecture Notes in Physics, *Proceedings of Frontiers of Particle Beams,* p. 238, South Padre Island, TX (1986).

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

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Research interests: dynamics of charged particle beams, high-luminosity electron-positron colliders, optical stochastic cooling.

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

"Beam-Beam Effects in Electron Storage Rings," *Lecture Notes in Physics*, Vol. 400, p. 321 (1992).

"A Combined Symetrical and Asymmetrical B-Factory with Monochromatization" with (A. Dubrovin), *IEEE*, Vol. 5, p. 2835 (1991).

"Beam-Beam Effects with Large Dispersion at the Interaction Point" (with A. Gerasimov, D. Shatilov), *NIM*, Vol. A305, p. 25 (1991).

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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," *Lecture Notes in Physics*, Vol. 425 p. 57 (1994).

"Physics and Technology Challenges of BO(B,SUP9(_)) Factories," *Proc. of 1991 Particle Accelerator Conference*, p. 1, San Francisco, CA (May 1991) Also in *Lecture Notes in Physics*, Vol. 400 p. 600 (1992).

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

"B Factory RF System Design Issues," *Proc. of Intl. Conf. on B Factories: The State of the Art in Accelerators, Detectors and Physics*, Stanford, CA (Apr. 1992).

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

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

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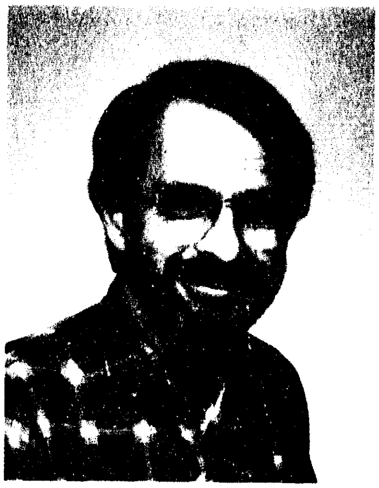

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Selected publication: "Status of the 50 MeV Plasma Lens experiment at LBL" (with W.P. Leemans, B. van der Geer, A.M. Sessler and S. Chattopadhyay), presented at APS (November 1993).

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Selected publication: "Design of a Reaccel-eration Experiment Using the Choppertron," presented at SPIE Symposium (January 1993).

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Research Interests: relativistic klystron two-beam accelerators, beam-break-up instabili-ties, astrophysical plasmas, parametric plasma instabilities, numerical simulations.

Selected Publications: "Design of Output Structures for a Traveling Wave Relativistic Klystron Two-Beam Accelerator: Suppression of Multi-Bunch Beam-Break-Up" (with H. Li, T. Houck, and S. Yu), *Proceedings of the 1994 SPIE Symposium on Intense Microwave Pulses OE/LASE-94*, Vol. 2154-10,

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Selected publications: "Macroparticle Theory of a Standing-Wave Free-Electron Laser Two-Beam Accelerator" (with K. Takayama and A.M. Sessler), *Nucl. Instrum Methods,* Vol A320 p. 587 (1992).

"Design of RF Conditioner Cavities" (with R.A. Rimmer, A.M. Sessler and H.G. Kirk), *Proc. 14th Int. FEL Conf.*, Kobe, Japan, (Aug. 1992).

"A Proposed Experiment for Beam Conditioning" (with I. Ben-Zvi, L-H Yu and A.M. Sessler), *Proc. 14th Int. FEL Conf.*, Kobe, Japan, (Aug. 1992).

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Selected publications: "Removal of Singu-larities from Taylor Series," LBL-27689, ESG Note-77 (Aug. 1989).

"Lie Series in an Extended Region of Phase Space," *J. Phys. A*, Vol. 23, p. 3875 (1990).

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Selected publication: "Status of the 50 MeV Plasma Lens experiment at LBL" (with W.P. Leemans, M. de Loos, A.M. Sessler and S. Chattopadhyay), presented at APS (Nov. 1993).

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Selected publications: "Experimental Test of Hole-Coupled FEL Resonator Designs Using a CW-HeNe Laser" (with W.P. Leemans, M. Xie, K-J. Kim), presented at the SPIE International Symposia on Laser Engineering, Los Angeles, CA, LBL-33603 (Jan. 1993).

"Experimental and Simulation of Hole-Coupled Resonator Modes with a CW HeNe Laser" (with W.P. Leemans, M. Xie, J.A. Edighoffer, K-J. Kim, and S. Chattopadhyay), presented at the 14th International FEL Conference, Kobe, Japan, LBL-32285 (Aug. 1992).

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Selected publications: "Advantages of the 'kinetic' amplification regime in a free electron laser with optical undulator" NIM, A304, p.520 (1991).

"X-ray free electron laser in a crystal as distributed feedback resonator" (with V.G.Barushevsky and I.Ya. Dubovskaya), NIM, A304, p.421 (1991).

"The influence of absorption on the generation threshold in an X-ray laser by channeling radiation in the presence of distributed feedback," *Phys. Lett. A*, Vol. 149, p.30 (1990).

"X-ray laser by channeling radiation in the presence of a distributed feedback" (with V.G.Barushevsky and I.Ya. Dubovskaya), NIM, B51, p.368 (1990).

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APPENDIX 3. Center for Beam Physics

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IN 1993, AFTER NEARLY FIVE YEARS OF RESEARCH and planning, construction of PEP-II was approved by the U.S. Department of Energy. This B-meson "factory," based on the Positron-Electron Project storage ring at the Stanford Linear Accelerator Center, is scheduled for completion in 1998. The Center for Beam Physics has played a key role in it since the beginning, working closely with SLAC and Lawrence Livermore National Laboratory. The year's achievements in the LBL portion of the program centered on design refinement of the rf system, multibunch feedback system, and magnetic lattice, as well as a better understanding of beam-beam interaction.

To meet the technical challenges of this and other initiatives and to generally enhance LBL's capabilities in particle- and photon-beam research, the Center continued adding to its experimental capability in 1993. The highlight of these achievements was the construction of the Beam Test Facility, which is now being commissioned. This facility will increase the benefits of the investment in the Advanced Light Source injector linac by using it for beam physics experiments during the several hours of otherwise idle time between ALS injection cycles. Many experiments are possible; immediate plans include generation and detection of x-ray pulses as short as tens of femtoseconds and focusing of a beam by using plasma lenses.

Among the Center's other diverse activities, research continues in accelerator theory, nonlinear dynamics, and fundamental FEL physics. The High-Energy Collider Physics group continued its long-range Two-Beam Accelerator research. The Beam Electrodynamics Group contributed to and supervised the ALS and PEP-II rf and feedback design efforts. It also began exploring beam-cooling techniques for a challenging new application: the Relativistic Heavy Ion Collider (RHIC) that is being built at Brookhaven National Laboratory.

PEP-II: Refining The Design and Preparing for Construction

The worldwide high-energy physics community has become intensely interested in B factories, which are electron-positron colliders that produce copious $B\bar{B}$ pairs. They enable fundamental studies of charge-parity (CP) violation and other phenomena measurable through rare B-meson decays, the ultimate goal being an explanation of why the universe as we know it is dominated by matter rather than antimatter (sidebar). A collaboration of the Center, the Stanford Linear Accelerator Center (SLAC), Lawrence Livermore National Laboratory (LLNL), and Caltech has designed a B factory called PEP-II with one high-energy and one low-energy storage ring. This "energy-asymmetric" collider, an idea pioneered at LBL, will be built in the tunnel of the old Positron-Electron Project (PEP) collider at SLAC and will reuse many PEP components, resulting in a design that is both scientifically and economically attractive.*

An international review panel, set up jointly by the Department of Energy and the National Science Foundation, examined both the PEP-II proposal and the other U.S. B-factory initiative, CESR-B at Cornell University. The panel found that the PEP-II design was sound and conservative and that the schedule and budget were well-founded. In October 1993, President Clinton announced Secretary of Energy O'Leary's selection of SLAC as the preferred site, and Congress followed through with $34 million for a PEP-II construction start in fiscal year 1994.

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* A B meson and its antimatter equivalent produced together. Pronounced "bee bee-bar."

B Decays and CPT Symmetry

The universe appears to be made almost entirely of matter. Why not almost entirely antimatter? Why not equal proportions of matter and antimatter, annihilating each other whenever they came in contact? For that matter, why not just energy? PEP-II may help provide the answer.

Judging particle interactions by the standards of the familiar macroscopic world, one would think that if the objects participating in some process were replaced either by their antimatter equivalents or by versions of themselves as seen in a mirror, the rate of the process would remain the same. It seems equally intuitive that reversing the process would yield the original participants, much as though one were running a movie in reverse and watching the actors run backward in their own footprints.

But on the scale of subatomic particles and the quarks that make them up—a scale where the weak interaction becomes the strongest of forces—the first two rules, called "conservation of parity" and "charge conjugation," are not necessarily obeyed. Not even CP symmetry, which combines both rules, necessarily holds true. The remaining variable is time; we are left with CPT symmetry—a scheme in which C, P, and CP symmetry violations can occur, but only if the arrow of time is allowed to take a different course when reversed, going back to a different beginning.

Thus far, CP violation has been observed through asymmetries in the decay modes of the neutral K meson and its antiparticle. The K^0 and $\bar{K}^0$ contain a "strange" quark that is not part of the group of quarks that make up ordinary matter. In a few of the K's wide variety of possible decay modes, the K^0 decays a few tenths of a percent differently than the $\bar{K}^0$, a sign of CP violation. But studies of the K system have left many questions unanswered about the mechanisms and magnitude of CP violation.

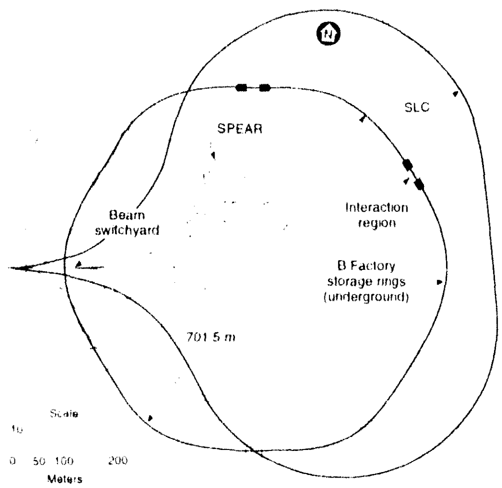
The B meson, which contains a different unusual quark ("bottom" as opposed to "strange"), is predicted by the Standard Model of Particles and Interactions to have asymmetries as great as 30% in some rare decay modes. This makes it a very promising candidate for CP-violation studies. However, the branching fraction—the proportion of $B\bar{B}$ pairs that will not only decay through the unusual modes but also violate CP symmetry in doing so—is only about 10^{-4} to 10^{-5}. Therefore, about 10^7 to 10^8 $B\bar{B}$ pairs will have to be produced to get good CP-violation statistics. This requirement, implying the need for many e^+e^- collisions, brings us to the luminosity frontier of accelerator physics, the source of most of the physics and engineering challenges in PEP-II.

The ultimate goal of this research is to test the validity of the Standard Model—today's partial theory of the building blocks of nature and how they interact—or replace it with a new, more satisfactory theory. In either case, CP violation will have to be better quantified, and its origins will have to be explained. The present Standard Model does not disallow CP violation but does not explain it either. These studies also have ramifications beyond particle physics.

In 1967, not long after the discovery of CP violation, Andrei Sakharov pointed out that it might explain one of the long-standing riddles of cosmology: why the universe did not originate with equal, evenly distributed quantities of matter and antimatter. For some reason, the laws of nature appear to prefer matter over antimatter—a phenomenon that makes possible the physical universe we see every day.

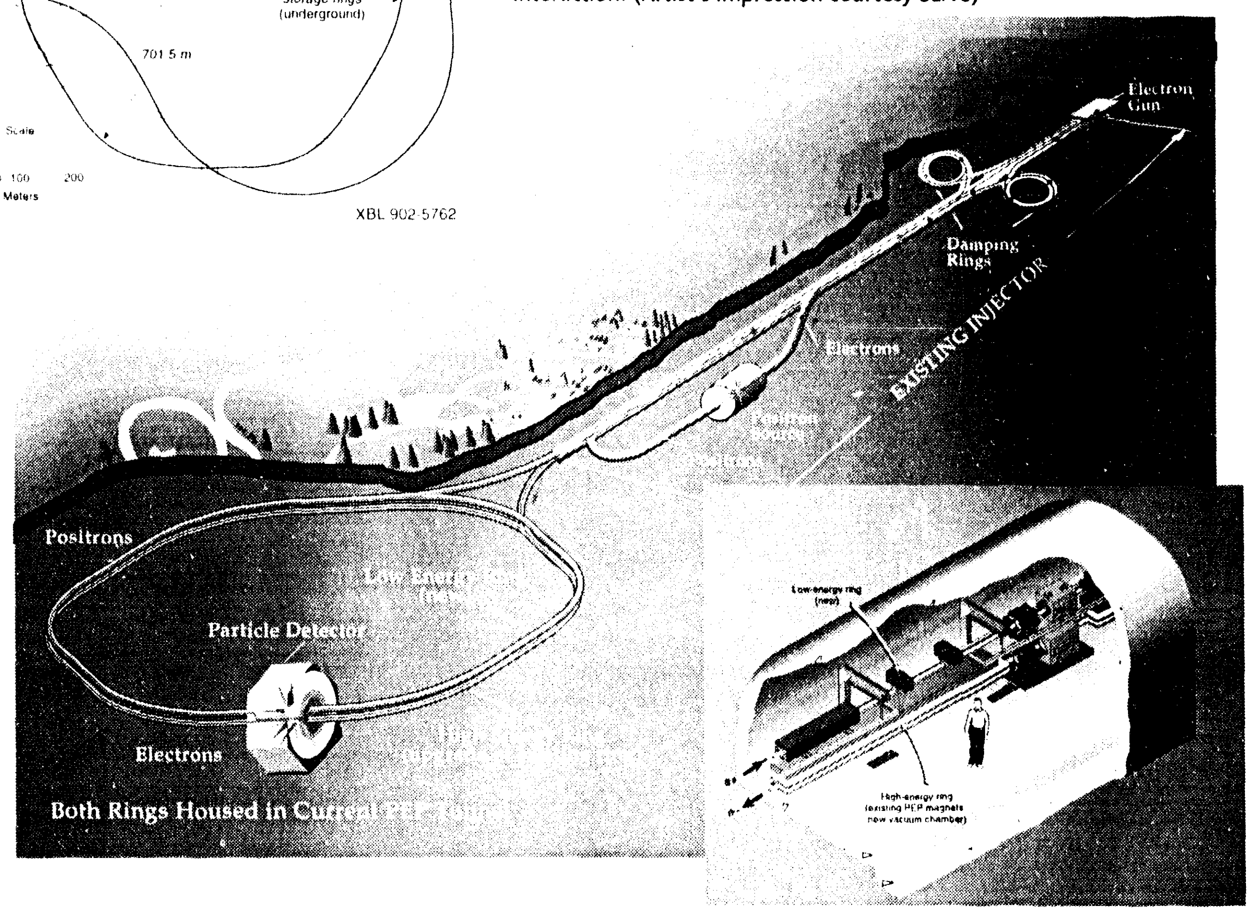
Conceptual Design Overview

During 1993, the PEP-II collaboration continued refining the design of a B factory in which a 9-GeV electron beam in PEP collides with a 3.1-GeV positron beam circulating in a new storage ring. The new low-energy ring will be of the same circumference as PEP and will be mounted above it in the existing tunnel, as shown in Figure 3-1. The chosen energy combination reaches the Upsilon (4S) resonance, at which $B\bar{B}$ pairs are produced in the abundance required for the study of CP violation (*sidebar*). The challenge in the design of a B factory is to reach an initial luminosity of 3×10^{33} cm^{-2} s^{-1}, which is more than an order of magnitude beyond the luminosities achieved to date in electron-positron colliders.



XBL 902-5762

Figure 3-1. The asymmetric B factory PEP-II is being built in the Positron-Electron Project tunnel at the Stanford Linear Accelerator Center, using a substantial amount of the existing hardware for the PEP collider. The year's achievements in the LBL portion of the program centered on design refinement of the rf system, multibunch feedback system, and magnetic lattice, as well as a better understanding of beam-beam interaction. (Artist's impression courtesy SLAC)



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An Overview of PEP

In PEP-II, the electrons, at 9 GeV, are supplied by a modified version of the Positron-Electron Project ring built by SLAC and LBL in the mid-1970s. It uses all the original PEP magnets. The rf system is new, as are the beam pipe and the vacuum systems. The low-energy ring, a new accelerator in the same tunnel, supplies 3.1-GeV positrons.

PEP-II is designed to produce a luminosity of 3×10^{33} cm^{-2} s^{-1}, an increase by a factor of 15 over the current record, achieved at the Cornell Electron Storage Ring. Table 3-1 summarizes the main parameters.

Compared with present-day colliders, PEP-II has unextraordinary single-bunch parameters (bunch current, emittance, rms bunch length, and beam-beam tune shift), along with a vertical beta function of only a few cm at the interaction point. The extreme luminosity comes primarily from a far greater number of bunches. This means higher beam current, implying that the vacuum system and rf system must be considerably improved because of synchrotron radiation, and also that feedback systems to combat coupled-bunch instabilities are needed.

The key enabling circumstances of the PEP-II project include not only the existing PEP ring and tunnel, but also the availability of the "two-mile linac" that feeds the Stanford Linear Collider. The linac can produce 120 pulses per second at about 3×10^{10} electrons or positrons per pulse, giving at least a 300% safety factor above the injection requirements for PEP-II. This uniquely powerful linac should be able to fill both rings from zero current in about 6 minutes, then top them off within 3 minutes when necessary.

Table 3-1. Main PEP-II Collider Parameters.

	Low-Energy Ring	High-Energy Ring
Energy, E [GeV]	3.1	9
Circumference, C [m]	2199.32	2199.32
$\varepsilon_y/\varepsilon_x$ [nm·rad]	2.6/64	1.9/48
β_y^*/β_x^* [cm]	1.5/37.5	2.0/50.0
$\xi_{0x,0y}$	0.03	0.03
f_{RF} [MHz]	476	476
V_{RF} [MV]	5.9	18.5
Bunch length, σ [cm]	1	1
Number of bunches, k_B	1658†	1658†
Bunch separation, s_B	1.26	1.26
Damping time, τ_L/τ_x [ms]	19.8/40.3	18.4/37.2
Total current, I [A]	2.14	0.99
U_0 [MeV/turn]	1.14	3.58
Luminosity, $\mathscr{L}$ [$cm^{-2}s^{-1}$]	3×10^{33}	

†allows for gap of ≈5% for ion clearing

Lattice Design Progress

The basic lattice designs of both rings were completed in earlier years; the primary effort during 1993 was optimization of the lattices of the low-energy ring. Earlier, using single-particle-tracking simulation codes, we had identified a need to increase the dynamic aperture of the low-energy ring.* Enlarging the dynamic aperture increases injection efficiency and reduces the degradation of beam lifetime caused by beam-beam and quantum effects. Good dynamic behavior requires a stable aperture of at least 10 times the natural beam size. The simulation tools that we used accounted fully for nonlinearities, magnetic-field imperfections, and magnet-position errors. In 1993, we also began considering beam-beam interaction.

Increasing the dynamic aperture of the low-energy ring presents special difficulties. We knew that, to compensate for linear chromaticity, sextupole magnets would be needed in the ring arcs; this is a standard approach. However, PEP-II presents an additional challenge in the form of strong quadrupoles that focus the beams near the interaction point. Arc sextupoles strong enough to correct for the resulting linear chromaticity would introduce their own nonlinear chromaticity. We decided that the low-energy ring also needed "local" compensation in both planes near the interaction point, which is the source of the linear chromaticity.

Such a scheme requires sextupole magnets in the interaction-region straight section. Although straightforward in principle, it will be nontrivial to build, especially within the geometrical constraints imposed by the existing tunnel and by the relative position of the two rings. The detailed design of this system, in the larger context of interaction-region design, will be one of the ongoing challenges of building PEP-II.

We also discovered that the dynamic aperture of the low-energy ring is very sensitive to higher-order multipole magnetic fields in the first quadrupoles near the interaction point. Careful attention will have to be paid to their design in order to minimize higher-order fields.

Meanwhile we improved the lattice design of the high-energy ring by decreasing its vertical beta function from 3 cm to 2 cm. This reduced the beam current, formerly 1.5 A, to 1.0 A (proportionately reducing the synchrotron-radiation heat load, among other benefits); the change also relaxed the beam-emittance requirement. The expense was an increase in chromaticity and thus a decrease in dynamic aperture. However, because an electron beam can be made with lower intrinsic emittance and energy spread than a positron beam, the high-energy ring's dynamic aperture was already higher, and is now comparable to that of the improved low-energy ring.

Studying the high-energy ring's dynamic aperture showed that one of the limiting factors is coupling between synchrotron and betatron oscillations, arising from the energy dependence of the beta functions at the rf cavity. We are examining a chromaticity correction scheme, similar to the one devised for the low-energy ring, in the hope of alleviating this limitation. We also found that placing beam position monitors at additional quadrupoles would improve orbit correction.

We are continuing to optimize the design of both rings. However, designs that appear both dynamically and physically acceptable are in hand.

* The dynamic aperture is the area within which the particles exhibit stable betatron and synchrotron oscillations. The beam can be contained magnetically within this area. Particles that go beyond the dynamic aperture are lost to various nonlinear, dynamic processes.

Beam-Beam Interaction Studies

While working on the lattice design, we continued our studies of beam-beam effects. (These beam-beam studies are based on multiparticle tracking simulations, so they require much more computation than the single-particle dynamic-aperture studies. Progress toward combining the two approaches into one consistent whole was itself a significant achievement of 1993.) Closed-orbit effects resulting from parasitic collisions came under particular scrutiny. We also simulated various injection schemes, continued scanning for the most desirable operating point in parameter space, and began studying beam lifetime.

Because of their relatively close spacing, as the bunches enter and leave the interaction point where they are supposed to collide head-on, they experience "parasitic" glancing collisions in the horizontal plane. Although each beam experiences several of these collisions, the one closest to the interaction point is the most disruptive. The parasitic collisions distort the horizontal closed orbit, skewing the beam displacement and turning the intended head-on collisions into glancing or off-center collisions. With a first-order analytic calculation, we showed that these effects are small if the fractional horizontal tune is kept above a certain minimum value.

If the beams were injected in the horizontal plane, a special and severe case of parasitic collision could occur. At injection, the bunches are "bumped," or displaced transversely from their nominal orbits, by a distance of approximately eight times their diameter, so the parasitic collisions could be almost head-on rather than glancing. Vertical injection avoids this problem, since parasitic collision in PEP-II can occur only in the horizontal plane. However, vertical injection can also increase beam blowup. Nonetheless, simulations showed that the beam would still be easily accommodated within the dynamic aperture and that its emittance would still be acceptable, so the design continues to call for vertical injection.

Another of the ongoing detailed-design efforts has been the search for an adequate "working point" in the multivariate parameter space. A working point above the half-integer, with fractional tunes $(\nu_x, \nu_y) = (0.64, 0.57)$ for both beams, had been shown to give adequate luminosity in previous beam-beam simulations, but the dynamic-aperture studies, using single-particle tracking, showed a preference for (0.57, 0.64). So we carried out an extensive tune scan above the diagonal on the tune diagram, centering on (0.57, 0.64). The tentative conclusion is that it is harder (but possible) to find a good working point in this area than below the diagonal. However, with the horizontal tune closer to the half-integer, a dynamic beta-function effect shrinks the beam horizontally, so even if the beam is larger vertically than it would be at (0.64, 0.57), the net effect might be enhancement of luminosity.

In collaboration with SLAC (and also separately as a means of cross checking the results), we are beginning to simulate the effect that beam-beam interaction has on beam lifetime. This is much more difficult than studying most other beam-beam effects because the region of interest is primarily the tail of the particle distribution, where the particle density is much more sparse and the dynamic effects take longer to act. Although initial work has been promising, the nonlinearities and imperfections of a real accelerator are expected to be important, and they have been incorporated into the simulations only in a rudimentary way thus far.

In summary, most of the challenges of the PEP-II design have been addressed satisfactorily, and technical solutions are in hand. As the construction project gets under way, the collaboration is continuing to finish and then optimize the detailed engineering design, and further suggestions for improvements continue to be put forth as the accelerator physics and other technical issues become better understood.

Beam Test Facility: Commissioning Progress and Experimental Plans

The ALS injection complex includes a valuable resource for other investigations: a traveling-wave linac that produces a 50-MeV electron beam. After the storage ring has been filled, the injection complex sits idle during the several hours of useful lifetime of the stored beam. A variety of interesting experiments can be conducted in the meantime with the linac beam, including plasma focusing of beams, tests of accelerator structures, and generation of short and "chirped" photon pulses. Accordingly the Center has built the Test Beam Facility (BTF), a DOE-funded initiative. The facility (Figure 3-2), which is now being commissioned, will use the linac between injection cycles to provide a highly productive and cost-effective program in beam physics with minimal disruption to ALS operations.

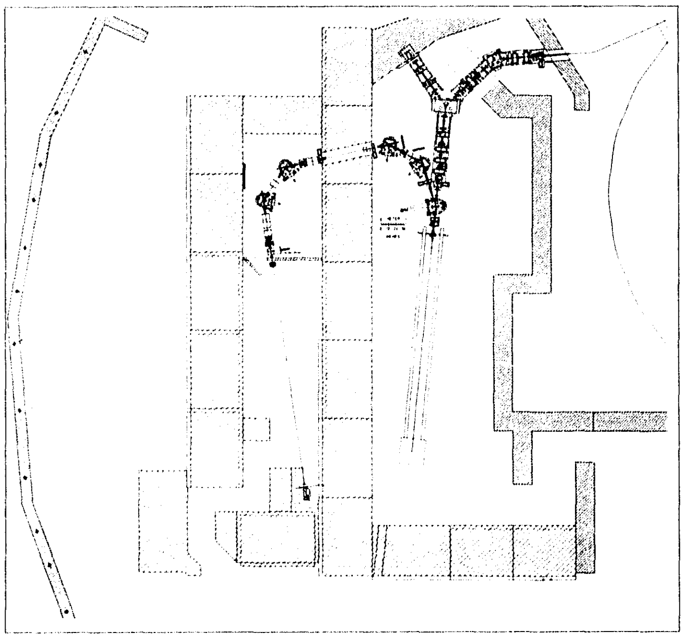

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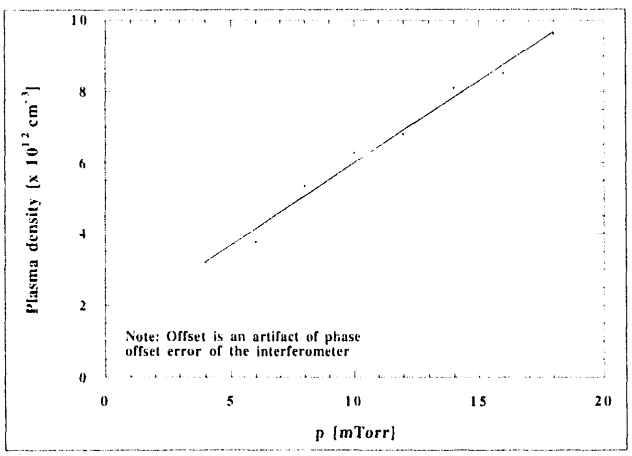
Figure 3-2. Because the ALS is based on a storage ring, the injector linac is idle much of the time. This affords a highly cost-effective opportunity to develop a facility for beam-physics research. This diagram shows the layout of the Beam Test Facility, which is now being commissioned. The facility will support a variety of experiments, such as plasma focusing of an electron beam. Tests of laser-produced plasmas suitable for the plasma focus experiment have been promising. Among other things, we have found that the density scales linearly with filling gas pressure and quadratically with laser intensity, as expected in a two-photon ionization process.



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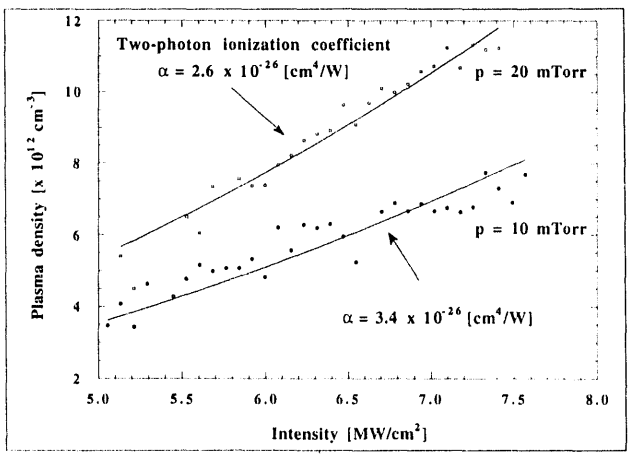

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Plasma-Focus Experiments

When a relativistic electron beam passes through a plasma, electromagnetic interactions focus the beam. To date, most work with the plasma-focus concept has involved thin "lenses." Continuous plasma focusing with thick lenses holds the promise of overcoming the so-called Oide limit—a fundamental limit of focusability arising from statistical emission of high-energy photons in a sharp focusing bend. Our plans include a proof-of-principle test and systematic exploration of plasma-focus ideas generated at our Center.

One of the ideas is a long, continuous plasma focus in which the plasma density is tapered by either diaphragms and differential pumping or a focused laser beam. The density will be tapered from about 1×10^{10} to 5×10^{12} cm^{-3} over a length of 0.5 m. We hypothesize that, at 50 MeV, such a device could focus a beam with a 3-mm cross section into a 400-μm spot. Our scaled proof-of-principle work will involve plasma lengths ranging from 10 to 50 cm, with density tapering from about 1×10^{11} to 5×10^{13} cm^{-3} over that distance.

Two requirements must be satisfied for an effective plasma focus: the plasma response time must be short compared to the pulse length, and the plasma return currents within the beam must be small. We have calculated parameters for a number of experiments that can be performed using the 50-MeV injector; they will allow careful study of these requirements in both underdense and overdense plasmas.* Furthermore, a study of how plasma return currents change the effectiveness of the focusing can provide insight into the usefulness of plasmas in reducing beam-beam interaction.

While BTF commissioning proceeds, we are using the Center for Beam Physics optics laboratory to generate and characterize plasmas whose densities and scale lengths are suitable for the BTF plasma focus. In these experiments, we use UV light from a class-IV excimer laser to ionize tripropylamine. By tailoring the cross section of the laser beam, we have produced plasmas as long as 50 cm with a 1-cm2 cross section. The plasmas were characterized with microwave interferometry equipment from Lawrence Livermore National Laboratory. Within the density range accessible to this equipment—from 1×10^{12} to 1.2×10^{13} cm^{-3}—we have found that the density scales linearly with filling gas pressure and quadratically with laser intensity, as expected in a two-photon ionization process.

The next step will be to generate plasmas with longitudinally varying density, which is necessary for studying adiabatic and tapered lenses. We are currently designing an optical interferometer with high spatial resolution to measure the radial density profile. To measure the temporal dynamics, we will use a visible-light streak camera to measure the light produced by an optical-transition radiation system and scanned along the path of the beam.

Sub-Picosecond X-ray Pulses

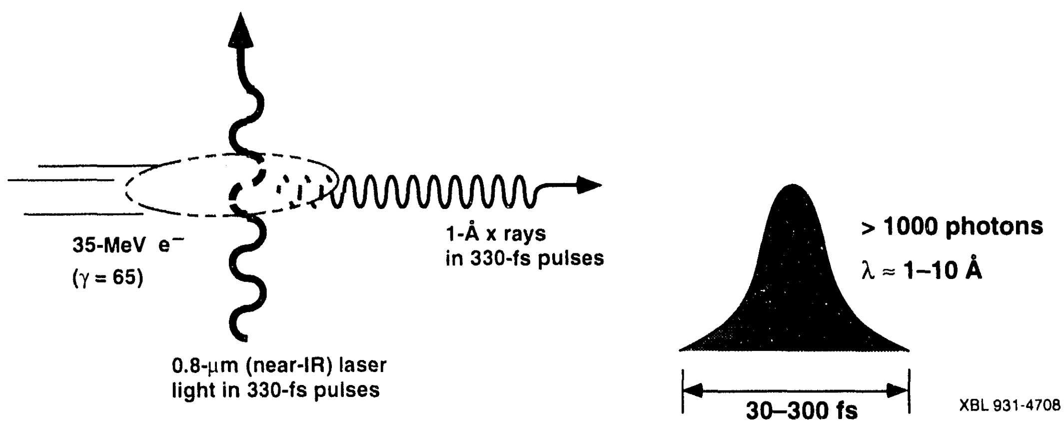
Another experiment at the BTF will produce ultrashort x-ray pulses. Today, the shortness of photon pulses that are produced by either interaction with a magnetic field (synchrotron radiation) or interaction with visible photons (Thomson scattering) is limited by, and comparable with, the length of the electron beam bunch. For the ALS linac beam, the shortest photon pulses

* The terms "overdense" and "underdense" indicate whether the plasma is denser than the particle beam or vice versa.

obtainable from a direct collinear interaction would be a few tens of picoseconds long. We have recently hypothesized that a third approach could break through this limit, producing sub-picosecond x-ray pulses.

The new approach, being supported with Laboratory-Directed Research and Development funds, is based upon 90° Thomson scattering with a visible laser (Figure 3-3). In this configuration, the shortness of the x-ray pulse is limited not by the length of the electron pulse, but rather by the length of the laser pulse or the transit time of the laser pulse across the waist of the focused electron pulse. Therefore it is crucial to focus the electron beam to a narrow waist matching the laser pulse length. The output pulse is much higher in energy than the laser pulse: the upshift is given by $4\gamma^2$, where γ is the Lorentz factor of the electron beam.

A short-pulse, solid-state laser (τ_L = 200 fs, E = 100–200 mJ) is nearing completion in the femtosecond laser laboratory of LBL's Materials Sciences Division. In cooperation with that division's Center for X-ray Optics, we are examining ways to direct the beam onto detectors and experimental apparatus. To detect the x-ray beam with femtosecond resolution, itself a



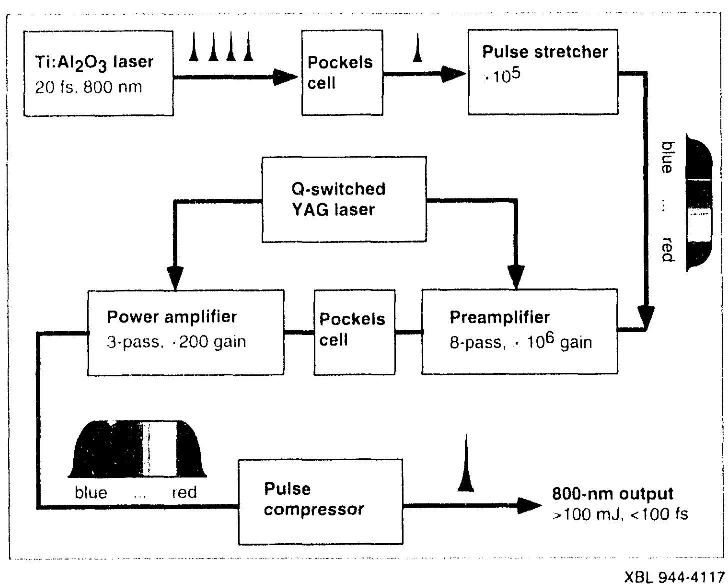


Figure 3-3. One of the most intriguing experiments for the Beam Test Facility is production of sub-picosecond x-ray pulses through 90° Thomson scattering of a visible laser beam against a relativistic (<50-MeV) electron beam. The femtosecond terawatt laser system that will be used in this experiment is being developed by LBL's Chemical Sciences Division.

challenging problem, this collaboration is developing an x-ray detector that uses part of the laser beam to melt a silicon wafer and then measures the change in diffraction pattern as a function of the known delay time before the arrival of the x-ray beam. (We are also exploring autocorrelation of the laser pulse with the visible pulse given off by a gas column that was photoionized by the x-ray pulse.) We are also designing the beamline components required to focus the electron beam to a 70–100 μm spot and then separate it from the x-rays after the interaction point. With the current design parameters, we should be able to produce a 100–300 fs x-ray pulse, containing about 10^5–10^6 photons, with a wavelength that can be varied in the range of 1–10 Å by changing the electron-beam energy.

A variety of other experiments will also be made possible by the facility, including beam-structure interaction studies, investigations of beam-conditioning cavities for free-electron lasers, and the "chirping"* of conveniently long (10-ps) electron-beam bunches to produce photon pulses much shorter than that.

Laser-Optics Laboratory

The Center for Beam Physics has a laser-optics laboratory that serves many efforts, including development of optical components and techniques for the Beam Test Facility. The highlight of the laboratory's 1993 work was continued development, together with Stanford University, of advanced optical diagnostics for infrared free-electron lasers (IRFELs).

Advanced Optical Diagnostics for FELs

Working with colleagues from Stanford University, we had earlier designed a novel diagnostic system to measure the spectrum and pulse width of an IRFEL's output. By using an image dissector and a high-speed single-element detector with integrating sphere, the system provides spectral and temporal information for each micropulse within the pulse train. The system is shown schematically in Figure 3-4.

Key elements for the spectral diagnostics are the mode-matching telescope, high-resolution spectrometer, imaging telescope, and image dissector. The imaging telescope, located between the spectrograph and the image dissector, varies the magnification of the image that arrives at the dissector, thus allowing the desired spectral resolution to be selected. For pulse-width measurement, the system uses single-pulse autocorrelation through non-collinear optical mixing in a frequency-doubling crystal, along with the imaging telescope and the image dissector. The image is that of the region of the nonlinear crystal in which second-harmonic light was generated.

During the summer, after the spectrometer system was developed in our laboratory, we tested it using an FEL beam at Stanford that operates in the 3–12 μm region of the spectrum. In fall 1993, we used the system to measure the FEL's wavelength stability on a micropulse-to-micropulse basis and to study the sideband stability. These issues are important in the design of advanced FELs, such as the one that might be added to the Chemical Dynamics Research Laboratory proposed by LBL. Although data analysis is not yet complete, preliminary inspection indicates that, as expected, spectral sidebands develop when an IRFEL is operated close to saturation.

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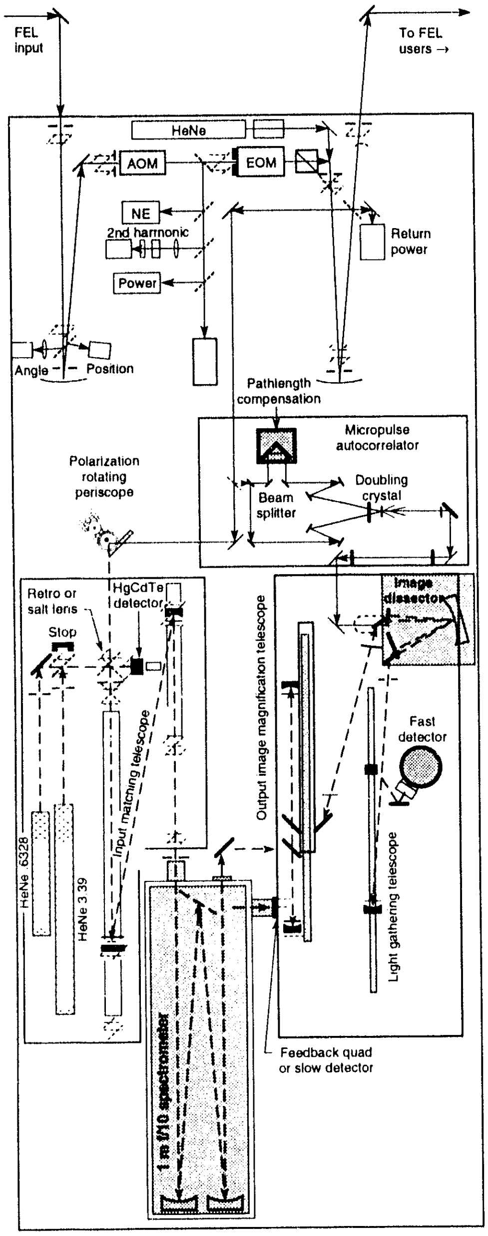
* A term for a small, rapid change in energy during a pulse, historically based in radio transmission of Morse code.



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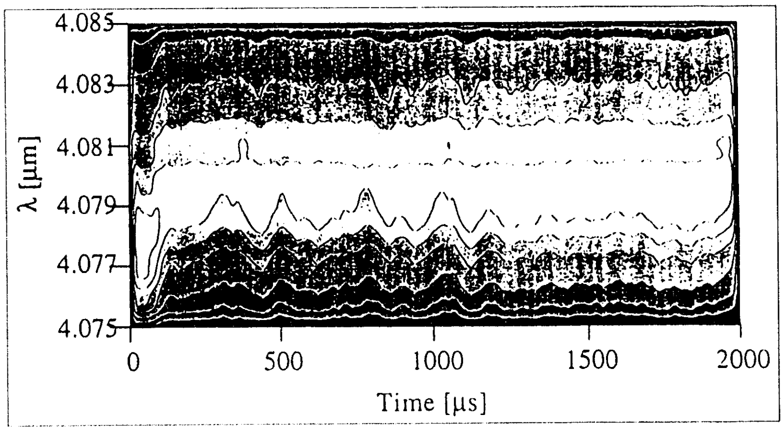

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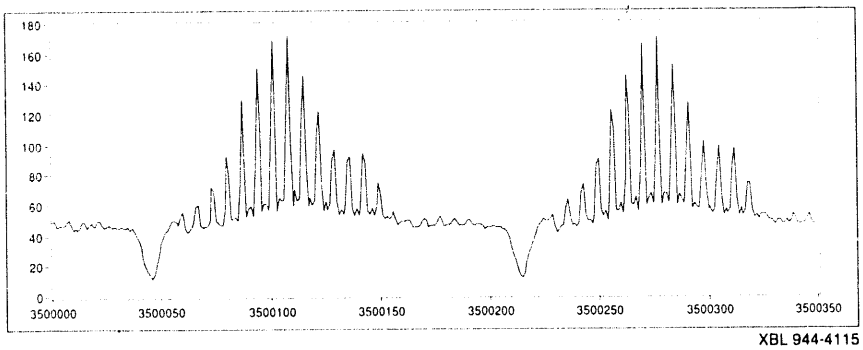
Figure 3-4. The LBL-Stanford collaboration in FEL diagnostics has resulted in a system that measures the optical spectrum of every individual micropulse during the complete macropulse. Experiments have been conducted on measuring the wavelength stability of the FEL with this system. *Above*, the wavelength of the FEL output is plotted as a function of time, with shading indicating intensity. The plot *below* details the spectra of two consecutive micropulses (separated by 85 ns). The spectral information is given by the envelope, the spiky structure being an artifact of the image dissection technique. In addition, the system has been used to study sideband development and evolution towards chaos as a function of desynchronization.



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Beam Electrodynamics

As greater demands are made on the performance of accelerators—such as PEP-II with its extreme integrated luminosity or the Relativistic Heavy Ion Collider (RHIC) with its intense heavy-ion beams at high energy—it becomes ever more important to understand potentially disruptive rf phenomena within the beam chamber and to perform various rf manipulations that monitor and control the beam. The Beam Electrodynamics Group within the Center approaches these problems through analysis, simulation, and experimentation.

An area of special interest is the understanding and control of the potentially disruptive electromagnetic interaction between the beam and the conductive walls of the vacuum chamber and various devices. Other specialties include the design and development of rf systems for stochastic beam cooling and other aspects of beam monitoring and control.

In 1993, the group continued its lead role in the design of rf and feedback systems for PEP-II, along with studies of beam impedances, feedback systems, and intensity-dependent effects at the ALS. Their history of contribution to the Tevatron continued with a study of a stochastic beam-cooling upgrade and improved beam diagnostics. And, in a new effort aimed at improving the beam's luminosity lifetime (and therefore user service) at RHIC, they began studying possibilities for stochastic cooling of intense, bunched heavy-ion beams.

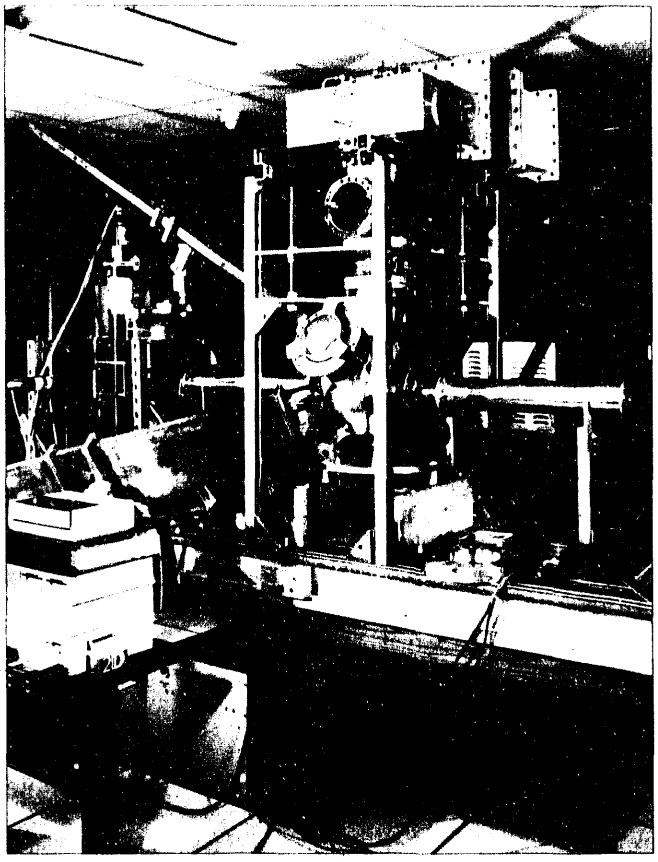
Progress in PEP-II RF Systems

The major rf-design challenge posed by PEP-II is control of coupled-bunch motions. The higher-order resonance modes of the rf cavities can drive a hundred or so unwanted beam motions at a growth rate thousands of times faster than the damping that naturally occurs in the accelerator. The first step toward stabilization is to reduce the shunt impedances of the higher-order modes by several orders of magnitude without corresponding degradation of the desired fundamental mode. Removal of the remaining instabilities will then be within the reach of a practical feedback system. To reduce the shunt impedance of the higher-order modes, we attach waveguides to the cavity to couple these modes to an external resistor.

Figure 3-5 shows a low-power prototype. Extensive measurements designed to examine which modes are damped and whether there is interference with the fundamental mode have shown good damping of the strongest longitudinal and transverse higher-order modes and also good agreement with calculations. The measurements were made with low-power prototype loads. The study of these loads continues; we are using an innovative broadband measurement technique that we developed to determine the complex permittivity and permeability of rf-absorbing materials. Recently we have begun the engineering design of full-power loads and a full-power test model of the cavity.

In addition to the problems caused by higher-order modes, the desirable fundamental mode of the rf cavity may itself drive beam instabilities, as some coupled-bunch modes fall within the width of the fundamental resonance. This problem, endemic to large-diameter rings, must be addressed with active rf feedback around the cavity and its driver. The design of both longitudinal and transverse feedback systems is underway in collaboration with SLAC. Computer simulations using measured data on the higher-order modes indicate that the problem of suppressing coupled-bunch modes, although difficult, can indeed be solved. The data are obtained from beam signals at the ALS, where we have been testing prototypes of the longitudinal feedback system and will soon test prototypes of the transverse system.

Figure 3-5. The PEP-II rf cavity accelerates the beam with the fundamental mode while diverting the disruptive higher-order modes into external ferrite loads that absorb the microwaves. (The cavity is the central sphere with the beampipe running through it; the "wings" contain the loads.) This low-power prototype was used for extensive tests to examine which modes are damped and whether there is interference with the fundamental mode. The tests yielded encouraging results and showed good agreement with calculations, so as the study of the prototype continues, we have pushed forward on the engineering design of full-power test models of the cavity and loads. Simulation is also useful. This finite-element model of part of a load design shows standing waves and absorption regions by the electric-field strength (the cores of the semicircles are maxima, the black parts minima). It reveals that essentially no power is dissipated in the last 30% of the load, which is therefore superfluous—an important finding for a device that must be installed in the limited space of the PEP tunnel. The standing waves are weak, and most of the incident power is indeed absorbed in the ferrite.



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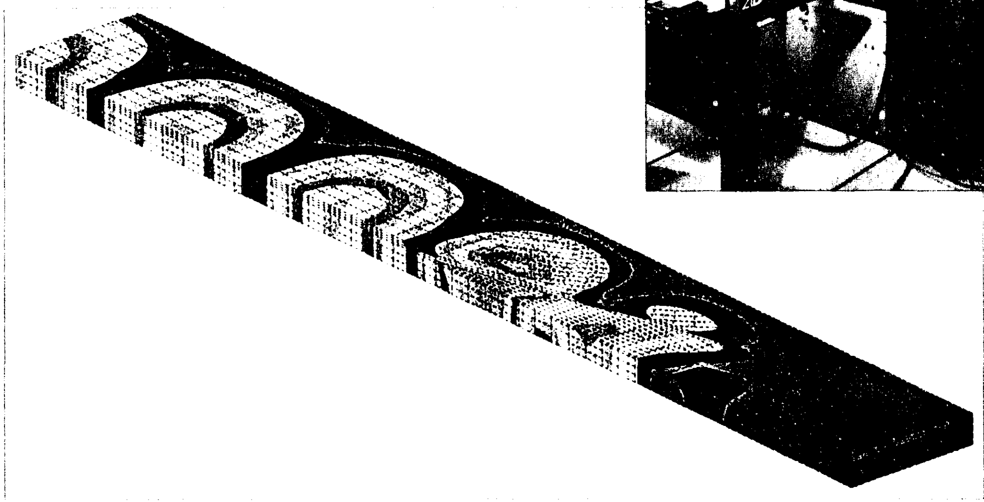

XBL 944-4116

Support for the Advanced Light Source

In addition to using ALS beam signals to test prototype PEP-II systems, we have continued our support of ALS commissioning and improvement. Using detailed knowledge, derived from our previous work, of the beam-impedance characteristics of the storage ring and the higher-order modes of the rf cavities, we have calculated and simulated the coupled-bunch beam dynamics of the machine. Building upon this achievement, we are designing a three-axis damping system to control coupled-bunch motion. The system measures errors in the position and phase of each bunch and applies the appropriate feedback. The transverse part of the system has been designed and components are being manufactured; work on the longitudinal part is under way.

Fermilab Antiproton Cooling System

The latest achievement in our ongoing collaboration with Fermilab is the design of a biplanar electrode system for more rapid cooling of the beam for the antiproton source.* LBL was involved in the initial design of pickup and kicker electrodes for this cooling system and has been continually engaged in analyzing the system's performance and seeking ways of improving it.

In earlier years, we had demonstrated that, for power-limited cooling systems, it is more efficient and cost-effective to double the number of cooling electrodes than to double the operating frequency, whereupon we developed biplanar electrodes that could effectively double the number of electrodes without using any more space. This scheme, with the existing 2–4 GHz electronics, appeared to yield better results than would a system with uniplanar electrodes and completely reworked 4–8 GHz electronics. Calculations indicate that the resulting performance would exceed the needs of any anticipated upgrade to the Tevatron complex, including the proposed new main injector. The validity of our beam-cooling calculations was affirmed by comparing the results with cooling data from Fermilab. In 1993, we began studying the performance of a prototype module. Full production awaits the results of the study and a go-ahead decision by Fermilab.

We have also designed a dual-cavity Schottky detector, based on a single-cavity design that we had tested successfully at Fermilab in the late 1980s, for measuring signals from the proton and antiproton beams independently. (In the Tevatron, the two beams rotate in opposite directions in a single beam pipe.) By using two of these detectors at different places in the storage ring and combining the phase information appropriately, the Schottky signals from the proton and antiproton beams may be separated and analyzed independently. Here, too, production awaits the results of performance studies and a subsequent decision by Fermilab.

Heavy Ion Beam Cooling for RHIC

In RHIC, currently under construction at the Brookhaven National Laboratory, stored beams ranging in mass from protons to Au^{79+} will be used for studies of nuclear phenomena in heavy ion collisions. Gold-on-gold collisions will be of particular importance for studies of the quark-gluon plasma, which are directed towards an understanding of the transition between nuclear matter and elementary particles. For highly charged ions like gold, intrabeam Coulomb scattering can cause beam growth and particle loss, which lead in turn to rapid luminosity deterioration. For much of the scientific program, long beam lifetime—as much as 10 hours—with well-maintained luminosity is essential or at least desirable. As part of the proposed program in Ion Beam Technologies for Nuclear Physics (see Chapter 5, "Ion Beam Technology," of the *1993 AFRD Summary of Activities*), we propose to study stochastic beam cooling to address this concern.

The RHIC design uses two rf systems. One provides acceleration at the harmonic number h = 342; the other operates at 196 MHz and serves to keep the bunches short and almost constant in length during storage. In one scenario, to achieve the full design luminosity while cutting cost, the maximum available rf voltage in storage mode is limited to 6 MV. Subsequently, based on experience acquired with the operation of the collider, more rf

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* Beam cooling means measuring the "temperature" or internal motion of the particles in the beam and applying feedback to reduce this motion, thereby increasing intensity.

cavities, possibly superconducting, could be added up to a maximum total voltage of 16 MV. This voltage limit is required to minimize beam loss in the case of Au beams. Stochastic beam cooling might, however, prove more cost-effective.

During the last decade, stochastic cooling has been developed into a practical means for reducing beam emittance and controlling growth of momentum spread without loss of particles. In RHIC, it would keep the beam dimensions well within the magnet aperture and the bucket height and would lengthen the luminosity lifetime. One expects that a stationary and stable equilibrium density will develop when the emittance growth rate due to intrabeam scattering just matches the damping rate due to cooling. Estimates of the achievable damping rates for momentum cooling have been made, assuming a 4–8 GHz bandwidth. The use of momentum cooling, given 6 MV of storage rf, would reduce beam loss enough for a twofold luminosity gain at top energy. Further luminosity gains would require the addition of transverse cooling.

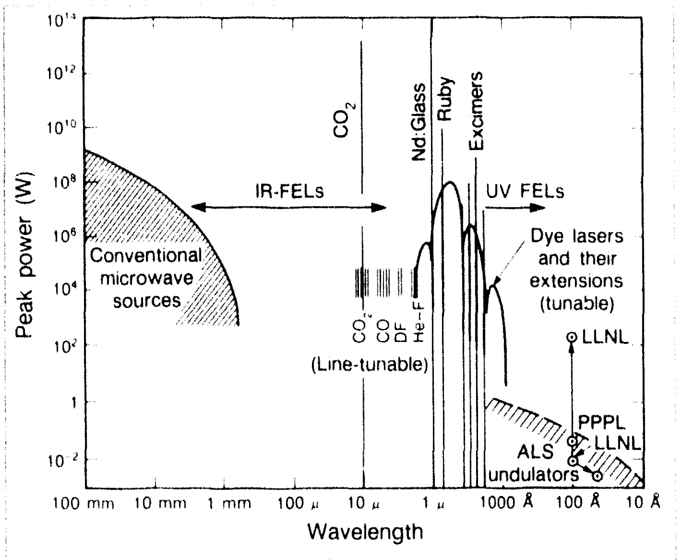
Our proposal establishes an R&D plan aimed at stochastic cooling of bunched beams in RHIC, especially for collider-mode running with Au beams. The initial effort (FY 1994 and 1995) emphasizes further study and conceptual design. The ultimate goal is to be operationally ready to implement such a system, should it prove necessary, after commissioning and operational start of the collider in late 1990s. Meanwhile, some crucial collider diagnostics will be designed and fabricated as part of a prototyping program, so beam and luminosity monitoring will be possible from the first day of commissioning.

Free-Electron Lasers and Other Radiation Sources

As mentioned in the earlier section on the Beam Test Facility, radiation sources beyond or complementary to the ALS are of great interest. They might be higher in some aspect of performance, smaller and cheaper, or useful in some hard-to-cover part of the spectrum (Figure 3-6). Investigating the possibilities for radiation sources has been a long-standing part of our work. Achievements in 1993 included further simulation and experimentation in various aspects of infrared free-electron lasers (IRFELs), studies of FELs that could operate at wavelengths as short as x-rays, and fundamental characterization of how coherent radiation propagates through optical elements.

Much of our current work was born of a design effort aimed at a high-stability tunable IRFEL for the Chemical Dynamics Research Laboratory (CDRL). That effort was mothballed in 1992, with a refined conceptual design published and archived for possible future use by the CDRL. Several resulting areas of inquiry proved to be of continuing interest and broader importance to the FEL community, including studies of superconducting rf cavities, laser-driven photocathodes, and optical resonators. We also reinvigorated our interests in high-gain FELs at higher frequencies (ultraviolet through x-rays) and in the fundamentals of optical radiation.

Figure 3-6. Many important phenomena could be probed if gaps in the spectral coverage of present-day radiation sources were filled by new sources that offered high power, consistent stability of power and wavelength, and narrow, precise bandwidth. Free-electron lasers are emerging as a promising approach to this problem. Our studies have emphasized FELs for the infrared region (especially important for chemical physics), and in recent years have increasingly focused on the technical challenges and scientific potential of FELs for the ultraviolet region and beyond.



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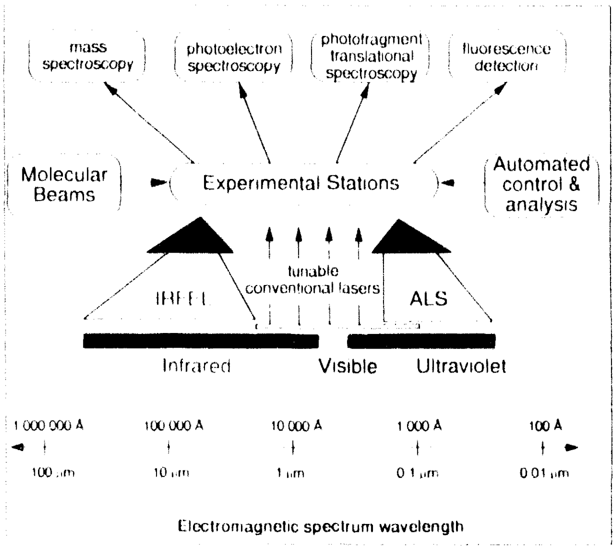

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Single-Pass Amplification: The Key to Short-Wavelength FELs

One of the biggest obstacles to using FELs much beyond the infrared part of the spectrum has been the need for highly reflective mirrors at the ends of the oscillator cavity. Mirrors that work at near-normal incidence at those wavelengths tend to be inefficient. Recent advances in laser-driven rf photocathode electron sources have made it possible to produce electron beams that are bright enough (referring to a combination of high power and low emittance) for extremely-high-gain FEL amplifiers. This might solve the problem because if enough gain could be obtained in a single pass, mirrors would not be needed. It seems possible, at least in principle, to generate coherent radiation at wavelengths shorter than 1000 Å with peak power levels ranging from hundreds of megawatts to several gigawatts—far greater coherent power than synchrotron radiation sources can provide.

We have carried out an extensive analytical and numerical study of such an amplifier in both the exponential-growth and the saturation regimes, and have extended our one-dimensional model of self-amplified spontaneous emission (the basic principle underlying the FEL) to a full three dimensions. This work has yielded the first exact 3-d solution for amplifier gain and FEL eigenmodes, taking into account the effects of beam emittance, beam energy spread, and betatron focusing. Through extensive simulations with the 3-d code TDA, we have also obtained a universal scaling law for FEL gain and an empirical formula for the saturation power.

These studies have laid the groundwork for a fundamental understanding of the start-up and amplification processes in FELs and have provided efficient tools for designing and optimizing high-gain FELs. The tools are currently being used in a feasibility study for an x-ray FEL, based on the existing linacs at the Stanford Linear Accelerator Center, that would operate in the "water window," a low-absorption slice of the spectrum that is of great interest to microscopists.

To develop one of the key enabling technologies for stand-alone high-gain FELs, we have been working with AFRD fusion energy researchers to characterize photocathode materials. With barium photocathodes we obtained electron quantum efficiencies as high as 10^{-3}, and we studied the dependence of the quantum efficiency on the polarization and angle of incidence of the nitrogen laser beam. Experiments with lanthanum hexaboride cathodes are now underway.

Optical Resonator R&D

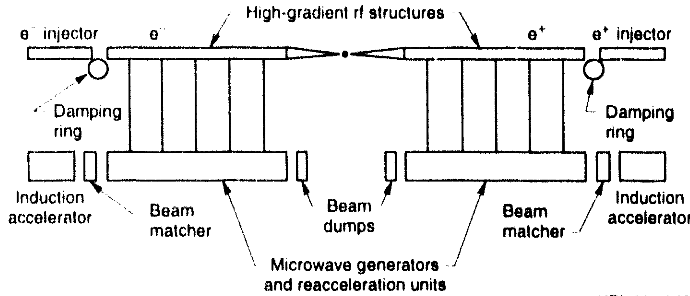
In our ongoing studies of optical resonators for FELs, we completed a versatile simulation code known as SWORD (Small Workshop for Optical Resonator Design). This code, developed in preliminary form as a design tool for the hole-coupled resonator in the CDRL IRFEL, has been broadened, enhanced, and bench-tested with a scaled experiment. It is now suitable for most kinds of optical resonator development. The CEBAF/LBL collaboration is using it to the design of a confocal ring resonator for their proposed IRFEL. We are using it to study a novel resonator configuration that we designed—a "double-confocal resonator," suitable for either chemical lasers or FELs, that is optimized for driving the Thomson backscattering source at the ALS Beam Test Facility.

High-Energy Collider Physics

Of the many ideas that have been proposed for the electron-positron colliders of the next century, the two-beam accelerator, or TBA, appears to be one of the more promising. Figure 3-7 illustrates the concept. The first of the two beams is a "drive" beam generated by an induction linac. It has high current but relatively low energy (perhaps 3 kA at 10 MeV in a full-scale TBA). This beam is passed through either an undulator-based free-electron laser (FEL) or a relativistic klystron (RK), generating microwave power on the order of 1 GW per meter of length. The power is applied to an adjacent high-gradient acceleration structure, which accelerates a second electron beam to high energy. Today, the TBA technology is in the early stages of development; designs are being developed and evaluated by researchers in the Center's High-Energy Collider Physics Group, in collaboration with colleagues from LLNL and from KEK, the high-energy physics laboratory in Japan.

In addition to the TBA, we have been studying a number of other ideas in and related to high-energy collider physics, such as the plasma focus described earlier, muon colliders, gamma colliders, spinoff concepts for FELs, and frontiers of electron-beam cooling. In several areas of our work, we are pursuing opportunities to collaborate with Former Soviet Union scientists, especially in various aspects of the TBA and FELs.

Figure 3-7. As shown in the TBA sketch (right), 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. The diagram below shows the progress of the drive beam through the rf-generating devices (FEL wigglers in this example) and the reacceleration units that replenish the drive beam in between.



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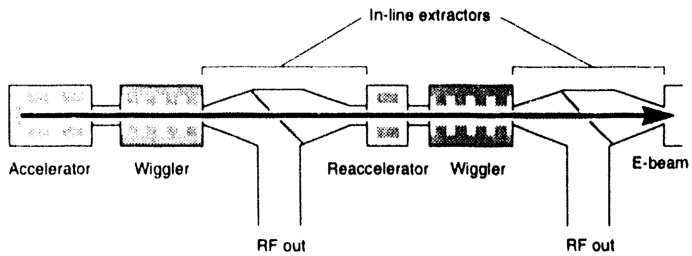

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Transversely Modulated RK

Initially the TBA/RK work involved longitudinal bunching of the drive beam, provided by the Advanced Test Accelerator (ATA) linac at LLNL. This longitudinal bunching is adequate for low energies, but at moderate energies (greater than 3 MeV or so) it becomes less effective. To extend our work to higher energies, we have been experimenting with a transverse chopper cavity or "choppertron," built according to our designs by Haimson Research. In 1991 trials, the choppertron produced impressive peak power—some 400 MW—but the pulses at such power levels were less than 10 ns in length; in 1992 we determined that the problem was beam breakup caused by a spurious higher-order mode generated in the output structure at 13.6 GHz. To solve the problem, we have added a damping structure; in 3-MeV experiments on ATA, we obtained 30-ns pulses at 120 MW. These pulses had a phase jitter of about 2°, which implies good spectral purity. This satisfying demonstration of high power output from an RK provides a good basis for our continuing R&D program. We continue investigating damping structures that could remove the higher-order mode without damping the desired mode, perhaps enabling us to simultaneously achieve the hundreds-of-megawatts power and the tens-of-nanoseconds pulse lengths.

In 1993, we began design and simulation of an important aspect of the TBA concept, namely, reacceleration of the "spent" drive beam, which is economically critical. Figure 3-8 shows the layout of the reaccelerator. The actual experiment will require increasing the drive-beam energy to 5 MeV.

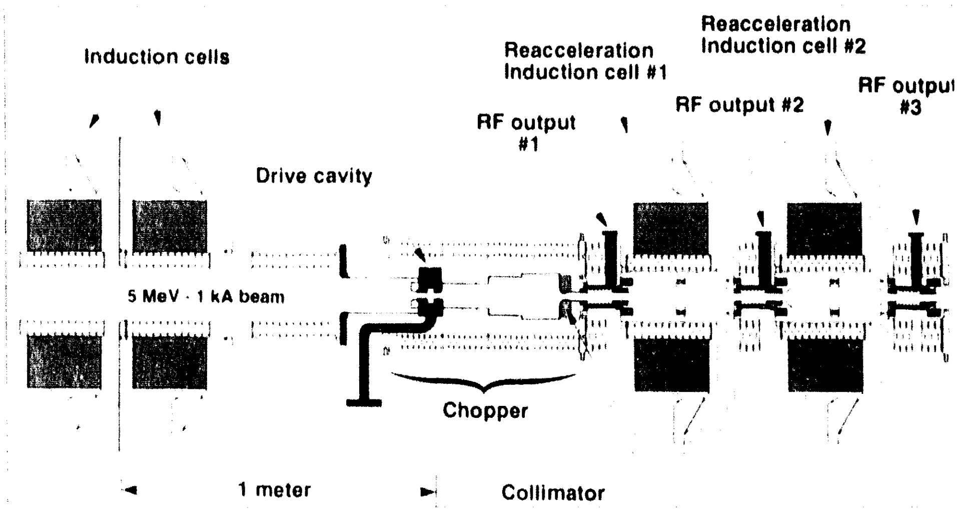

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Figure 3-8. The "spent" drive beam in the TBA retains considerable energy and most of its original current, so reaccelerating it and tapping rf power from additional RKs would be very attractive economically. In 1993 we began design and simulation of a reaccelerator. In addition to construction of the reacceleration hardware, the actual experiment will require operating LLNL's Advanced Technology Accelerator at 5 MeV rather than the 3 MeV we have been using.

Standing-Wave and Multicavity FELs

The FEL, explored in our original TBA research, remains a proven candidate with great potential. We are developing an idea, called the "standing-wave FEL," in which the radiation is trapped in a standing-wave rf cavity (rather than the usual traveling-wave structure) and beat-coupled to a nearby high-gradient acceleration structure. Figure 3-9 illustrates the idea, which is undergoing analysis and theoretical study. The work focuses on such topics as beam breakup instabilities and sensitivity to changes in various parameters—especially the dependence of microwave amplitude and phase upon FEL parameters. No experimental program is anticipated in the near term.

We have recently begun analyzing a multicavity standing-wave FEL concept. In particular, we expect that it will be much better at generating

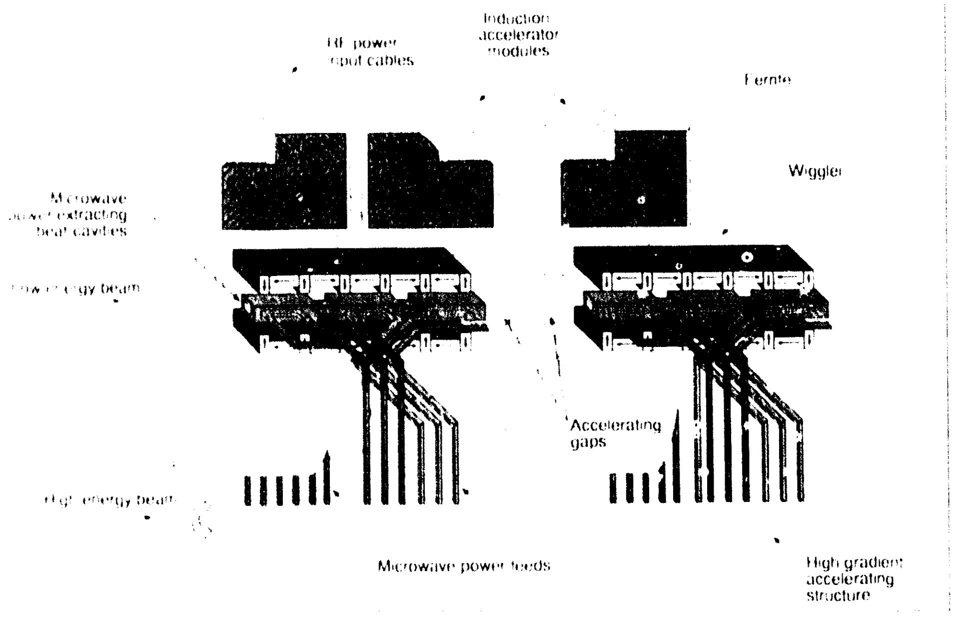

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Figure 3-9. The FEL, which was the rf-power generator in our original TBA research, remains a proven candidate with great potential. We are developing an idea, called the "standing-wave FEL," in which the radiation is trapped in a standing-wave rf cavity (rather than the usual traveling-wave structure) and beat-coupled to a nearby high-gradient acceleration structure. This concept is undergoing analysis and theoretical study, focusing on such topics as beam breakup instabilities and sensitivity to changes in various parameters—especially the dependence of microwave amplitude and phase upon FEL parameters. No experimental program is anticipated in the near term.

harmonics than an FEL run in the traveling-wave or "amplifier" mode. A multicavity standing-wave FEL could be implemented by resonating the first few cavities at the fundamental, thus producing significant bunching, and resonating the next few cavities on a selected harmonic.

Beam Conditioning

The gain of an FEL or other resonant electron-beam device is limited by the spread in longitudinal velocity and, hence, the energy spread and emittance of a three-dimensional beam. The electron-beam emittance must be less than the wavelength of the radiation from the device divided by 4π. In practice, the energy spread of the beam often makes only a small contribution to the total spread in longitudinal velocity, so we realized that the beam could be "conditioned" with special rf cavities. These cavities would impart more acceleration to the particles traveling longer paths, reducing the spread in *longitudinal* velocity caused by beam emittance.

In previous years, we analyzed this idea with a simple numerical model for beam transport, assuming ideal rf cavities; analyzed an FEL to evaluate its performance with reduced axial-velocity spread; and computationally analyzed a cavity geometry that promises to greatly increase the beam-cavity coupling. We are now planning experiments to test the feasibility of a beam-conditioning cavity, perhaps at the Test Beam Facility described earlier in this chapter, perhaps at the Accelerator Test Facility at Brookhaven National Laboratory.

Seeking to obtain a crystalline beam (as described below), two groups—one in Aarhus, Denmark, and the other in Heidelberg, Germany—have begun using a laser to cool a stored beam longitudinally. Both have been able to achieve longitudinal "temperatures" (a measure of random motion within the beam bunch) in the millikelvin range. Transverse temperatures remain above 1000 K. Conditioner cavities could prove to be the ideal complement for this technique; because they couple transverse and longitudinal motion, they should allow laser cooling in all three dimensions, an idea that we are pursuing.

If a beam were made sufficiently cool, then the particles would in theory form a crystal lattice as the focusing forces imparted by the accelerator overwhelm the Coulomb forces within the beam. However, even though this subject has been discussed in workshops and in the literature for a decade or more, beam physicists have not paid great attention to it. We began investigating the phenomenon in 1993 because advances in laser cooling might bring it within the grasp of experimentalists before long. Our studies included computer modeling with molecular dynamics codes; an elucidation, for the first time, of the storage-ring and beam-cooling parameters needed; and the effects of storage-ring straight sections. We continuing our theoretical examinations of the subject while working closely with the experimental groups at Aarhus and Heidelberg that are attempting to crystallize beams.

Exotic Colliders

One of our most exciting areas of research has been the exploration of exotic colliders, including a muon collider and a gamma-gamma collider.

A muon collider may be thought of as a "Higgs factory"; muons have a stronger coupling to the Higgs sector than do electrons, which implies much greater data rates than could be obtained with an electron collider. Muon collisions are also not expected to be radiation-limited, unlike the higher leptons. However, the challenges in accelerator technology are considerable. Muons are produced from beams of either protons or electrons striking a production target; the resulting beams occupy a large transverse phase space and therefore must be cooled considerably. However, since even at 100 GeV, muons only last about 2 ms before decaying, ionization cooling is likely to be the only practical method. Figure 3-10 illustrates a muon collider based on electroproduction that, according to our thinking, might result in cooled muon beams of sufficient energy and intensity to yield worthwhile physics.

Another scheme might open up new physics opportunities for the "traditional" electron-positron collider configuration: colliding gamma rays with each other or with electrons. (Gamma rays are energetic enough for their particle duality to be significant in this respect.) The greatest challenge is creating a sufficiently intense burst of gamma rays. This could be accomplished by Compton backscattering of a powerful burst of energetic (near-visible) light against a highly focused, hundreds-of-GeV electron beam. We will host a workshop on gamma-gamma colliders in March 1994 to explore this idea further, with particular emphasis on FELs and chemical lasers for generating the intense burst of light.

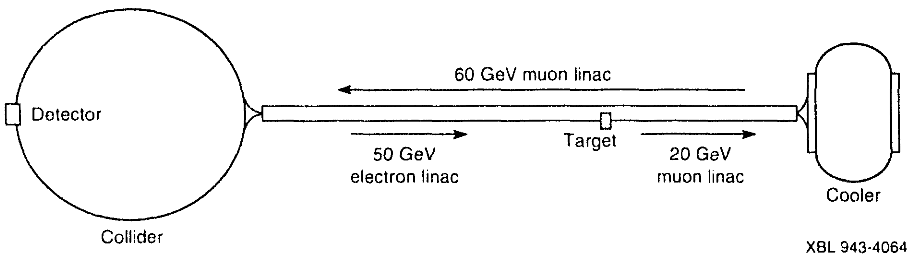

Figure 3-10. This concept for a muon-antimuon collider based on electroproduction may someday serve as a "Higgs factory" for high-energy physics. The need for beam cooling, combined with the 2-ms lifetime of muons, poses formidable (and interesting) challenges in accelerator physics and technology.

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