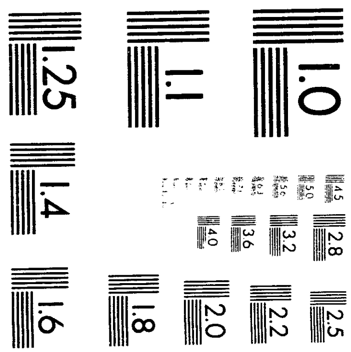

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LBL-34255
UC-411

Center for Beam Physics

1992

Accelerator and Fusion Research Division
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June 1993

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(After PUB-713,
March 1993)

CENTER FOR BEAM PHYSICS

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CONTENTS

FOREWORD

"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 focussing energy. The Center is dedicated to exploring and investigating 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 as well as for the very sake of understanding the science of focussing and directing energy. 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 which are important both for probing the fundamental interactions and for the wide range of disciplines now turning to synchrotron radiation sources and free electron lasers. Accordingly, 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 and the life sciences.

Yet another important mission of the Center is education of students and 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 of 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 core support to laboratory facilities and initiatives e.g. core accelerator physics and systems support to the Advanced Light Source (ALS), technical support for 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: (i) the Lambertson Beam Electrodynamics Laboratory, (ii) the CBP Laser-Optics Laboratory and (iii) the Beam Test Facility at the ALS. Formal external collaborations include: (i) SLAC-LBL-LLNL PEP-II studies, (ii) Stanford-LBL-BNL-TRW on FEL SCRF technology, (iii) LBL-Stanford on FEL diagnostics, (iv) CEBAF-LBL on IRFEL studies and (v) 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. The following pages provide a flavor of our multifaceted activities during 1992.

Swapan Chattopadhyay
Head, Center for Beam Physics

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-power-level, 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 set-up 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

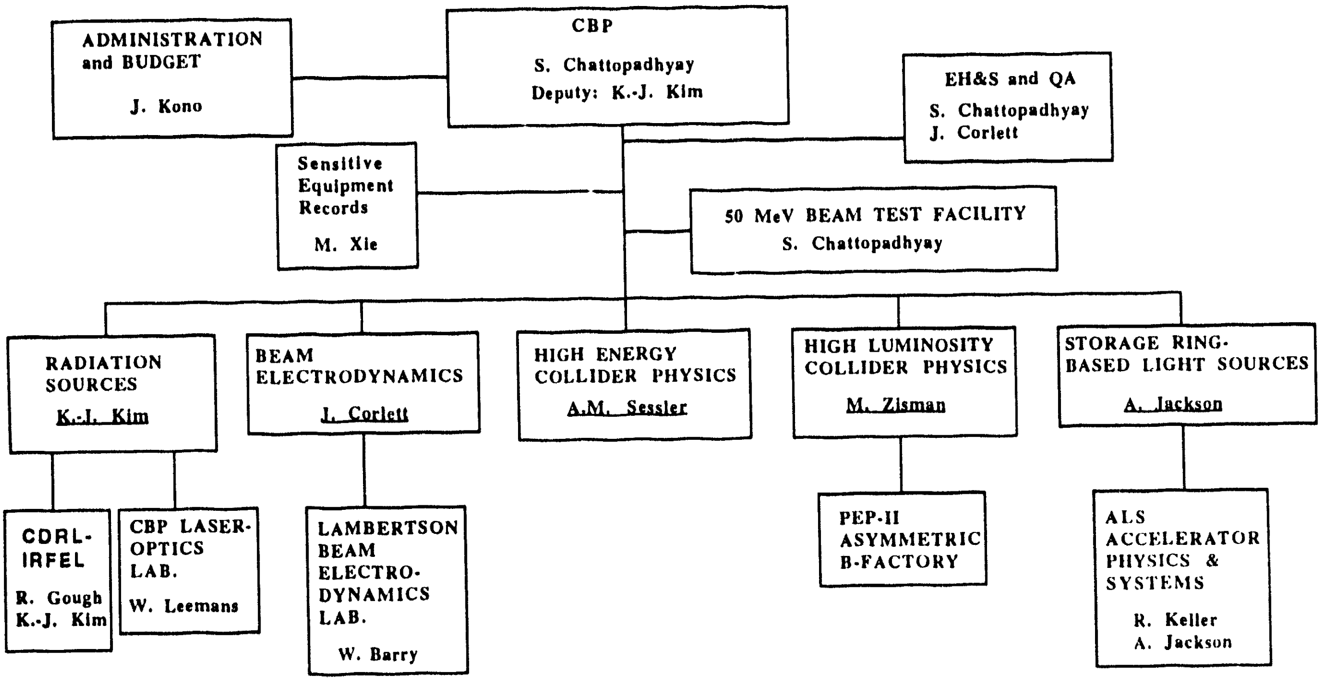
The library contains selected reference and textbooks on beams, plasmas, lasers, accelerator physics, dynamics, etc., as well as a few technical journals, recent preprints and conference proceedings. It is also used as a mini conference room.

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 (Asymmetric Particle Interaction Accelerator Research Yard) by LBL physicist A.A. Garren previous to the present project title. It is also used regularly for biweekly Center for Beam Physics seminars.

3/16/93

CENTER for BEAM PHYSICS
Organization



CENTER FOR BEAM PHYSICS

Roster

Scientists and Engineers

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

Technical Support

HARNDEN, C. Warren
MASSOLETTI, Dexter
SMITHWICK, James
WISE, James

Students

DUNN, Jason
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GOVIL, Richa
LAMON, Ken
LIDIA, Steve
WALLACE, Eric

Administrative Support

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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.

Research interests: colliders at the energy and luminosity frontiers, ultrashort-pulse X-ray sources, radiation processing of chemical and nuclear wastes.

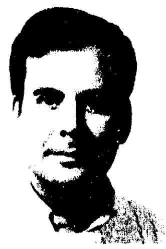
Selected publications: "Luminosity Limitations in Hadron Supercolliders," to be published in Supercolliders and Superdetectors, W. Barletta and H. Leutz, ed., World Scientific, 1993.

"Characteristics of a High Energy $\mu^+\mu^-$ Collider Based on Electroproduction of Muons" (with A.M. Sessler), LBL Report No. 33613, for submission to *Nucl. Instrum. Meth.*, (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. Meth.* and *Proceedings of the 14th International Free Electron Laser Conference*, Kobe, Japan, (Aug. 1992).

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

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



Walter C. Barry
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Joined LBL in 1992

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

Research interests: accelerator instrumentation, 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," *Proceedings of the 1991 Advanced Beam Instrumentation Workshop,* KEK National Laboratory for High Energy Physics, Tsukuba, Japan, April 22-24, 1991.

"A General Analysis of Thin Wire Pickups for High Frequency Beam Position Monitors," *Nucl. Instrum. Meth.* Vol. A301, No. 3, March 15, 1991.

"Characteristic Impedance and Loss Data for a Common Stripline Pickup Geometry" (with S. Y. R. Liu), *Nucl. Instrum. Meth.*, Vol. A288, Nos. 2, 3, March 15, 1990.

"Perturbation Method for the Measurement of Longitudinal and Transverse Beam Impedance" (with G. Lambertson), *Proceedings of the 1987 IEEE Particle Accelerator Conference* (March 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 (January 1986).

Johan A. Bengtsson
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Joined LBL in 1989

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

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

Selected publications: "Application of Symbolic Computation to the Search of Complicated Primitives: the Example of the Betatron Integrals" (with B. Autin), *Comput. Phys. Commun.*, 48 (1988).

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

"Achromatic and Isochronous Electron Beam Transport for Tunable Free Electron Lasers" (with K.-J. Kim), *Nucl. Instr. & Meth. in Phys. Res. A* , 318 (1992).

"Non-Linear Transverse Dynamics for Storage Rings with Applications to the Low-Energy Anti-proton Ring (LEAR) at CERN," CERN 88–05 (1988).

"Absolute and High Precision Measurements of Particle Beam Parameters at CERN Anti-proton Storage Ring LEAR Using Spectral Analysis with Correction Algorithms" (with E. Asseo and M. Chanel), IVth European Signal Processing Conference F-38402 Saint Martin d'Heres, Sept. 5–8, 1988.

"Modeling in Control of the Advanced Light Source" (with E. Forest, H. Nishimura and L. Schachinger), IEEE 1991 Particle Accelerator Conference, San Francisco, California, May 6–9, 1991.

John M. Byrd
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Ph.D., Physics, Cornell University, 1992.

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

Selected publications: "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 Decoherence at CESR" (with D. Sagan), *Proc. of the 1991 IEEE Particle Accelerator Conference* (May 1991).

"Cornell Synchrotron Tune Correction" (with C. Dunnam and R. Meller), *Proc. of the 1990 Accelerator Instrumentation Conference* (October 1990).

"An Uncoupled, Round Beam, Electron Accelerator Lattice" (with D. Sagan, and R. Talman), *Proc. of the 3rd Advanced ICFA Beam Dynamics Workshop* (June 1989).

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Ph.D., Physics, University of California, Berkeley, 1982. Attaché Scientifique, 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 Association 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 Femtosecond X-Rays by 90° Compton Scattering" (with K-J. Kim and C. Shank), LBL-33074, to be published in *Nucl. Instr. Methods in Phys. Res.*

"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).

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Joined LBL in 1988

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

Major awards: Japan Accelerator Society Annual Award.

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

Selected publications: "User's Guide for New ABCI, Version 6.2 (Azimuthal Beam Cavity Interaction)," CERN Report CERN SL/92–49 (AP) and LBL–33091 (1992).

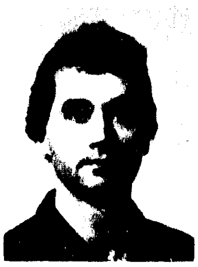
"Three-Dimensional Theory of Small-Signal, High-Gain Free Electron Laser Including Betatron Oscillations" (with K.-J. Kim and M. Xie), to be published in *Phys. Rev. A*, *46*, p. 6662 (1992); Lawrence Berkeley Laboratory Report LBL-32329 (1992).

"Renormalized Theory of Beam-Beam Interaction 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*, *226*, p. 223 (1984).

"Analytical Approach to the Overshoot Phenomenon for a Coasting Beam in Particle Accelerators" (with K. Yokoya), *Phys. Rev. D*, *28*, p. 2141 (1983).



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

Research interests: free-electron lasers, particle accelerators and plasma physics, studies of photocathode RF guns.

Selected publications: "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.*, 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.*, 67, p. 3082 (1991).

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

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Joined LBL in Dec. 1991

BSc, Physics, Liverpool University, 1983. Microwave engineer, EEV Co. Ltd, 1983–1986. Accelerator physicist, Daresbury Laboratory, U.K., 1986–1991.

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" (witl. J. Byrd), to be presented at the Particle Accelerator Conference, Washington, DC (May 1993).

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

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

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

"SRS–2 Performance and Achievements" (with V.P. Suller et al.), Particle Accelerator Conference, Chicago (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 (June 1988)

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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: "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).

"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 G.R. Neil, S. Fornaca, H.R. Thompson, Jr., T.I. Smith, H.A. Schwettman, C.E. Hess, J. Frisch and R. Rohatgi), (with H. Boehmer, M.Z. Caponi, S. Fornaca, J. Munch, G.R. Neil, B. Saur and C. Shih), *J. Appl. Phys.* (June 1987).

"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).

Etienne Forest
Staff Scientist
MS 71–259
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Joined LBL in 1985

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

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

Selected publications: "The UCLA ϕ Factory Collider" (with A. Amiry, C. Pellegrini and D. Robin), to be submitted to *Phys. Rev.* (1993).

"Construction of Symplectic Maps for Non-linear Motion of Particles in Accelerators" (with J.S. Berg, R.L. Warnock and R.D. Ruth), submitted to *Phys. Rev.* (1993).

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

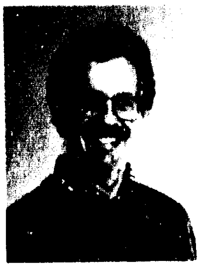
"Symplectic Integration in Complex Wigglers" (with K. Ohmi), KEK Report 92–14 (1992).

"A Contemporary 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), submitted to the Fourteenth Int'l FEL Conference in Kobe, Japan, August 23–18, 1992, to appear in a special issue of *Nuclear Instruments and Methods, Section A*, Elsevier North Holland Science Publishers B.V.

"The Absolute Bare Minimum for Tracking in Small Rings" (with M. Reusch, D. Bruhwiler and A. Amiry), submitted to *Part. Accel.* (1992).

"Application of the Yoshida-Ruth Techniques to Implicit Integration and Multi-Map Explicit Integration" (with M. Reusch and J. Bengtsson), *Phys. Lett. A* (1991).



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Joined LBL in 1984

Ph.D., Theoretical Particle Physics, University of California, Santa Cruz, 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, working full-time at CBP on the PEP-II project.

Research interests: beam-beam interaction; longitudinal 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 *Proceedings of the 15th Intl. Conf. on High-Energy Accelerators*, Hamburg, July 1992.

"Beam-Beam Issues in Asymmetric Colliders," invited talk, *Proc. of the B Factories: State of the Art*, Stanford, California, April 1992, p. 109.

"RAMPRF: a Program for Synchronous Acceleration," *Proc. 1991 Particle Accelerator Conference*, San Francisco, p. 300 (May 1991).

"Hourglass Effects for Asymmetric Colliders," *Proc. 1991 Particle Accelerator Conference*, San Francisco, p. 422 (May 1991).

"A Possible Symplectic Coherent Beam-Beam Model" (with A. W. Chao and K.Y. Ng), *Proc. European Particle Accelerator Conference*, Rome, p. 684 (June 1988).

Alper Garren
Senior Scientist
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Joined LBL in 1955

Ph.D., Physics, 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-PUB-30730 (May 1991).

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

"Low Momentum Compaction Lattice Study for the SSC Low Energy Booster" (with E.D. Courant and U. Wienands), *Proc. of 1991 Particle Accelerator Conference* (May 1991).

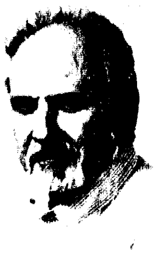
"Site-Specific Conceptual Design of the Superconducting Supercollider," SSCL-SR-1056 (July 1990).

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

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

"Lattice Of The NaI Proton Synchrotron," *Proc. of 1969 Particle Accel. Conference*.

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



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Joined LBL in 1980

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

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

Selected publications: "Higher-Order Mode-Damping Studies on PEP-II B-Factory RF Cavity" (with R.A. Rimmer et al.), contribution to 1992 European Particle Accelerator Conference.

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

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

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

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

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

"A High-Frequency Schottky Detector for Use in the Tevatron Collider" (with G.R. Lambertson), *Proceedings of 1990 Workshop in Accelerator Instrumentation*.

Richard A. Gough
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Joined LBL in 1970
Program Head
Special Projects, 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 Superconducting Linear Accelerator for an Infrared Free Electron Laser of the Proposed Chemical Dynamics Research Laboratory at LBL" (with S. Chattopadhyay, R. Byrns, R. Donahue, J. Edighoffer, E. Hoyer, K.-J. Kim, W. Leemans, J. Staples, B. Taylor, and M. Xie), 16th International Linac Conference, Ottawa, Ontario, Canada, August 23–28, 1992.

"Design Overview of Highly Stable Infrared Free Electron Laser at LBL" (with K.-J. Kim, M. Berz, S. Chattopadhyay, J. Edighoffer, C. Kim, A. Kung, W. Stein, and M. Xie), *Proc. of Twelfth International Free Electron Laser Conference*, Paris, France, September 17-21, 1990.

"Medical Heavy Ion Accelerator Proposals," *Proc. of 1985 Particle Accelerator Conference*, Vancouver, B.C., Canada, p. 3282 (May 1985).

"Performance of the Oxygen Injector for the CERN Linac I" (with B. Wolf, K. Leible, P. Spädtke, J. Klabunde, B. Langenbeck, N. Angert, J. Staples, R. Caylor, D. Howard, R. MacGill, J. Tanabe, C. Hill, P. Tetu, M. Weiss, and R. Geller), *Nucl. Instr. and Methods, A258* (1987).

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

Selected publications: "Ideas for Future Synchrotron Light Sources" (A. Jackson et al.), 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 Polarized Photon Beam," *Nucl. Instrum. Meth.*, 129 (1975).

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Joined LBL in 1981

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

Affiliations: IEEE, LBL representative to the National Consortium for Graduate Degrees for Minorities in Science and Engineering, Inc. (GEM)

Research interests: microwave technology with accelerator applications, computer-aided engineering, multi-bunch feedback systems.

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

"Novel Electrode Design for a 4–8 GHz Stochastic Cooling System" (with D. Goldberg, G. Lambertson, F. Voelker), *Bull. Am. Phys. Soc.*, 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 13–15, 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, March 21–23, 1983.

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Dr. rer. nat., Experimental Physics, University of Kiel, Germany, 1973.

Awards: Three patents on ion sources and components.

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

Current activities: Commissioning of the ALS (Advanced Light Source) electron accelerators, a 50 MeV linac, a 1.5 GeV booster synchrotron, and a 1-1.9 GeV storage ring. Evaluation of magnetic field data for the accelerators under construction. Definition of survey and alignment procedures, creation of ideal component data, and evaluation of survey data for the ALS accelerators.

Selected publications: "Survey and Alignment of the Advanced Light Source in Berkeley," *Nucl. Instr. Meth. in Phys. Research B56/57*, p. 422 (1991).

"Magnetic Data Analysis for the ALS Lattice Magnets," *IEEE #91CH3038-7*, p. 2113 (1991).

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

"Ion Extraction Systems: Optics and Design," *Nucl. Instr. Meth. in Phys. Research 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).

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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," to be published in the *IEEE Particle Accelerator Conference* (1993).

"Advanced Light Source Instrumentation Overview," *Proceedings of the 1992 Accelerator Instrumentation Workshop*.

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

"Dynamic Aperture of the ALS Booster Synchrotron," *Proceedings 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," *Proceedings of the European Particle Conference*, p. 863(1988).

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

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Ph.D., Elementary Particle Physics, University of Maryland, 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-Picosecond X-rays by 90° Compton Scattering" (with S. Chattopadhyay and C.V. Shank), LBL-33074.

"Stability and Performance of CDRL-FEL" (with M. Xie), *Nucl. Instr. Methods, A304*, p. 146 (1991).

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

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

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

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

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

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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.

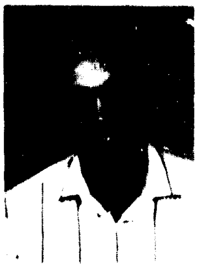
Selected publications: "Electron Spin Resonance of Gamma-irradiated Single Crystal of L-Alanine," *Kor. Appl. Phys.*, Vol. 6, No. 3 (1993).

"ESR Study of the Proton-Deuteron Exchange Reaction 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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M.S., Physics, University of California, Berkeley, 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.*, 249, p. 537 (1992).

"Higher Order Mode Damping Studies on the PEP-II B-Factory RF Cavity" (with Rimmer, Goldberg, Voelker, Kroll, Pendleton, Schwarz, Adams, and DeJong), 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, *1991 IEEE Particle Accelerator Conference*, 4, p. 2537 (1991).

"Higher Order Mode Damping in a Pill Box Cavity" (with Rimmer and Voelker), 1991 *IEEE Particle Accel. Conf.*, 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).

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

Major awards: American Physical Society Simon Ramo Award 1992.

Research interests: beam-plasma interaction, generation of light, non-linear optics, non-linear dynamics, study of plasma lens focusing, generation of short pulse X-rays through inverse compton scattering, advanced optical diagnostics and resonators for FEL's.

Selected publications: "Ultrahigh Gradient Acceleration of Injected Electron by Laser-Excited Relativistic Electron Plasma Waves" (with C.E. Blayton, K.A. Marsh, A. Dyson, M. Everett, A. Lal, R. Williams and C. Joshi), *Physical Review Letters*, 70, p. 37 (1993).

"Non-linear Dynamics of Driven Relativistic Electron Plasma Waves" (with C. Joshi, W. B. Mori, C. E. Clayton and T. W. Johnston), *Physical Review A, 46*, p. 15 (September 1992).

"Experiments and Simulations of Tunnel-Ionized Plasmas" (with C. E. Clayton, W. B. Mori, K. A. Marsh, P. K. Kaw, A. Dyson and C. Joshi), *Physical Review A, 46*, pp. 1091–1105 (1992).

"Plasma Physics Aspects of Tunnel-Ionized Gases" (with E. Clayton, W. B. Mori, K. A. Marsh, A. Dyson, and C. Joshi), *Physical Review Letters, 68*, pp. 321–324 (1992).

"Stimulated Compton Scattering from Pre-formed Underdense Plasmas" (with C. E. Clayton, K. A. Marsh and C. Joshi), *Physical Review Letters, 67*, pp. 1434–1437 (1991).

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

Research interests: analytical and numerical studies of space charge and high frequency electromagnetic problems related to microwave devices such as gyrotrons, relativistic klystrons and FEL.

Selected publications: "Space Charge Instabilities in Gyrotron Beams" (with T.M. Antonsen, Jr.), *Phys. Fluids B* (1993).

"Theory of Gyro-Traveling-Wave Tubes at Cyclotron Harmonics" (with G.S. Nusinovich), *Int. J. Electron,* **72** (5–6), p. 895 (1992).

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

"Large-Signal Theory of Gyro-Traveling-Wave Tubes at Cyclotron Harmones" (with G.S. Nusinovich), *I.E.E.E. Tran. Plasma Sci.*, **20** (3), p. 170 (1992).

"Efficiency of Frequency Up-Shifted Gyrodevices: Cyclotron Harmones Versus CARMS" (with G.S. Nusinovich and P.E. Latham), presented on *Infrared & Millimeter Wave Conference*, (December 1992).

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Joined LBL in 1991

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

Awards: Daniel Guignier Prize, 1991.

Research interests: nonlinear dynamics; accelerator 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, March 21–29, 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, June 11–16.

"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, March 20–23.

"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., Physics, University of Tokyo, 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,* 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," 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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Joined LBL in 1988

Ph.D., Electrical Engineering, Lancaster University, UK, 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: "RF Cavity Development for the PEP-II *B*-Factory," *Proc. Int. Workshop on B-Factories*, BFWS92, KEK, Japan, Nov. 17–20, 1992.

"Higher Order Mode Damping Studies on the PEP-II B-Factory RF Cavity" (R. Rimmer et al.), *Proc. 1992 Europ. Part. Accel. Conf.*, Berlin, Germany, March 24–28, 1992.

"An RF Cavity for the B-Factory" (R. Rimmer et al.), *Proc. 1991 U.S. Part. Accel. Conf.*, May 6–9, San Francisco.

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

"Beam Impedance Measurements on the ALS Curved Sector Tank" (R.A. Rimmer et al.), *Proc. 1990 Europ. Part. Accel. Conf.*, June 12–16, Nice, France, LBL-28192.

"Determination of Failure Mechanisms of RF Cavity Aperture Windows," *Proc. 1989 IEEE Part. Accel. Conf.*, March 20–23, Chicago.

"High Power Microwave Window Failures," Ph.D. Thesis, Lancaster University, UK, (available on microfilm from the university library) (October 1988).

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Joined LBL in 1991

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

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

Selected publications: "Quasi-Isochronous Ring Flavor Factories" (with C. Pellegrini), *Rare and Exclusive B and K Decays and Novel Flavor Factories* (1992).

"Isochronous Storage Rings and High-Luminosity Electron-Positron Colliders" (with C. Pellegrini), *CP Violation and Beauty Factories and Related Issues in Physics*, Annals of the New York Academy of Sciences, Vol. 619 (1991).

"Quasi-Isochronous Storage Ring" (with C. Pellegrini), *Nuclear Instruments and Methods, A301*, p. 27–36 (1991).

"Energy Density Enhancement in a Quasi-Isochronous Storage Ring" (with C. Pellegrini), *Proceedings of the 1990 IEEE* Particle Accelerator Conference (1990).

"Conceptual Design of a High Luminosity 510 MEV Collider" (with C. Pellegrini and M. Cornacchia), *Proceedings of the 1990 IEEE Particle Accelerator Conference* (1990).

"A High Luminosity Superconduction Mini-Collider for Phi Meson Production" (with C. Pellegrini et al.), *Proceedings of the 1990 IEEE Particle Accelerator Conference* (1990).

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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 Modeling 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, 48, Corpus Christi, TX (1991)

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

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

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Joined LBL in 1962

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

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

Selected publications: "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, pp. 2978–80.

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

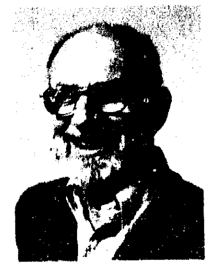
"Wakefield Effects in the Two-Beam Accelerator" (with A. Sessler), *NIM*, A244, pp. 323–29 (1986).

"Acceleration of Uranium at the Bevalac" (with J. Alonso et al.), *Science, 217*, pp. 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).

"The Status of the SuperHILAC" (with H. Grunder), *Proc. of the 1976 Proton Linac Accel. Conf.*, Chalk River AECL-5677, pp. 54–61 (1976).

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



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Ph.D., Theoretical Physics, Columbia University, 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: "Transverse Resistive Wall Instability in the Two-Beam Accelerator" (with D.H. Whittum and V.K. Neil), *Phys. Rev. A, 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. Instr. & Meth. in Phys. Res. A306 (1991).*

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

"Photon Storage Cavities" (with K-J. Kim), *Nucl. Instr. & Meth. in Phys. Res. 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. Instr. & Meth. in Phys. Res. A318* (1992).

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M.S., Electrical Engineering, University of California, Berkeley, 1949.

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

Selected publications: "ALS Longitudinal Kickers," presented at the 1992 Accelerator Instrumentation Workshop, LBL, Berkeley, CA, Oct. 27–30, 1992, LBL-33088.

"Higher Order Model Damping Studies on the PEP-II B-Factory RF Cavity" (with R. Rimmer, D. Goldberg, G. Lambertson, et al.), presented at the 3rd European Particle Accelerator Conference, Technical University of Berlin, Germany, March 24–28, 1992, LBL-32549.

"Calculations on RF Cavity Feedback Using Simple Analytic Model" (with Glen 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, June 12–16, 1990, LBL-28190.

"A High-Frequency Schottky Detector for Use in the Tevatron" (with D.A. Goldberg, W. Barry, and G.R. Lambertson), presented at the Particle Accelerator Conference, Washington, D.C., March 16–19, 1987, LBL-22273.

"An Array of 1 to 2 GHz Electrodes for Stochastic Cooling" (with T. Henderson and J. Johnson), presented at the 1983 Particle Accelerator Conference, Santa Fe, NM, March 21–23, 1983.

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Ph.D., Electrophysics, University of Electronic Science and Technology of China, Chengdu, China, 1987.

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

Selected publications: "Conditioner for a Helically Transported Electron Beam," to be published in the *Proceedings of the Third Workshop on Advanced Accelerator Concepts* (1992).

"The Problem of Stability of the Equilibrium Helical Orbit in Free-electron Lasers," *Sinica Physica* (1992).

"Comment on 'Gyrokinetics of Transverse-Magnetic-Mode Gyrotron, Gyropeniotron, Cyclotron Autoresonance Maser and Non-wiggler Free-Electron Laser Amplifiers'," *Phys. Fluids B3*, p. 498 (1991).

"Comment on 'New Class of Unstable Orbits of the Equilibrium Electrons in Free-Electron Lasers'," *Appl. Phys. Lett., 57*, p. 837 (1990).

"Small-Signal Analysis of a Free-Electron Cyclotron Resonance Laser," *Phys. Rev. A, 38*, p. 215 (1988).

"Free-Electron Cyclotron Resonance Lasers," *Appl. Phys. Lett., 53*, p. 1911 (1988).

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

Research interests: free electron lasers, optics, synchrotron radiation.

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

"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).

"Self-Amplified Spontaneous Emission for Short Wavelength Coherent Radiation," (with K-J. Kim), *LBL report,* No. 32288, (1992).

"Three-Dimensional Simulation of a Hole-Coupled FEL Oscillator," (with S. Krishnagopal, K-J. Kim, and A. Sessler), *Nucl. Instrum. Meth.*, *A318*, p. 661, (1992).

"Hole Coupling Resonator for Free Electron Lasers" (with K-J. Kim), *Nucl. Instrum. Meth. A 304*, p.792, (1991).

"Stability and Performance of CDRL-FEL," (with K-J. Kim), *Nucl. Instrum. Meth. A 304*, 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).

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Ph.D., Experimental Physics, Institute of Nuclear Physics, Novosibirsk, Russia, 1983. 1983–1992: Scientist at INP, Novosibirsk.

Research interests: accelerators, dynamics of the charged particle beams, B-Factory.

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

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

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

"Synchrotron Radiation Masking on Asymmetric 6.5 × 4.3 – GeV B-Factory" (with V. Blinov and A. Matveev), *IEEE*, v. 4, p. 2342 (1991).

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

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: "Physics and Technology Challenges of B$\bar{B}$ Factories," *Proc. of 1991 Part. Accel. Conf.*, San Francisco, CA, May 6–9, 1991, p. 1. Also in Lecture Notes in *Physics*, Vol. 400, ed. M. Dienes, M. Month, and S. Turner, Springer-Verlag, Berlin, 1992, p. 600.

"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*, San Francisco, CA, May 6–9, 1991, p. 84.

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"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, April 6–10, 1992.

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"ZAP User's Manual" (with S. Chattopadhyay and J. Bisognano), Lawrence Berkeley Laboratory Report No. LBL-21270, December, 1986, unpublished.

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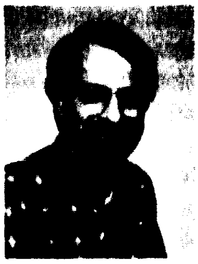

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Research interests: accelerator physics, QCD at the HERA machine in Germany.

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Graduate student at *Universita' degli Studi di Milano,* now at the Lawrence Berkeley Lab. as a Visiting Scholar for one year.

Research interests: study of beam dynamics in relativistic klystrons and free electron lasers, computer modeling of beam transport and field dynamics in relativistic klystrons and SWFEL.

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

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A.B., University of California at Berkeley, Physics.

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

Research interests: free-electron lasers; high energy beams in accelerators; semi-conductor lasers.

Selected publications: "Macroparticle Theory of a Standing-Wave Free-Electron Laser Two-Beam Accelerator" (with K. Takayama and A.M. Sessler), *Nucl. Instr. and Meth. in Phys. Res.*, A320 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, August 23-28, 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, August 23-28, 1992.

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Research interests: theoretical beam physics. Ph.D. thesis topic: Particle and Radiation Dynamics of Isochronous Storage Ring Free Electron Lasers.

Selected publications: "Removal of Singularities from Taylor Series," LBL Report No. 27689, ESG Note-77, August 1989.

"Lie Series in an Extended Region of Phase Space," *Journal of Physics A: Mathematical and General*, 23, p. 3875 (1990).

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

Research interests: variable-polarization insertion devices; partially-coherent, high intensity radiation sources; modelling and simulation of magnetic fields and synchrotron radiation sources.

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Senior, University of California, Berkeley.

Research interests: laser physics and optics.

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, January 16-23, 1993, LBL Report No. 33603.

"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, August 23-18, 1992, LBL Report No. 32285.

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Photocathode and Plasma Lens Studies — K. Leung, LBL
Short Wavelength FEL Collaboration — H. Winick, SSRL, Stanford

Publications

(1991-1993)

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Publications - External Notes

K.-J. Kim, "Spectral Bandwidth in Free Electron Laser Oscillators, submitted to the *Physical Review Letters*, Jan 1991, LBL-30192.

E. Forest, J. Bengtsson and M. F. Reusch, "Application of the Yoshida-Ruth Techniques to Implicit Integration, Multi-Maps Explicit Integration and to Taylor Series Extraction," submitted to *Phys. Letter A*, April 1991, LBL-30616.

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M.H.R. Donald and A. Garren, "APIARY B-Factory Lattice Design," IEEE Particle Accel-erator Conference, May 6-9, 1991, LBL-30698.

M.A. Furman, "Hourglass Effects for Asymmetric Colliders, IEEE Particle Accelerator Conference, May 6-9, 1991, LBL-30833.

M.A. Furman, "RAMPRF: A Program for Synchronous Acceleration," IEEE Particle Accelerator Conference, May 6-9, 1991, LBL-30812, SSCL-471.

M. Furman, and N. Mahale, "Superconducting Super Collider Laboratory," IEEE Particle Accelerator Conference, May 6-9, 1991, LBL-30794, SSCL-409 Rev.

A.A. Garren and M.H.R. Donald, "Apiary B Factory Lattice Design," IEEE Particle Accelerator Conference, May 6-9, 1991, LBL-30665.

A.A. Garren, and M. Sullivan, "APIARY B-Factory Separation Scheme," IEEE Particle Accelerator Conference, May 6-9, 1991, LBL-30730.

G. Rangarajan, A.J. Dragt, and F. Neri, "Invariant Metrics for Hamiltonian," IEEE Particle Accelerator Conference, May 6-9, 1991, LBL-30705.

M. Zisman, S. Chattopadhyay, A.A. Garren, G. Lambertson, E. Bloom, W.J. Corbett, M. Cornacchia, J.M. Dorfan, W.A. Barletta, D. Mohl, C. Pellegrini, D. Rice, and M. Sands, "Electron-Positron Factories," IEEE Particle Accelerator Conference, May 6-9, 1991, LBL-30858.

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M. Furman, "Beam-Beam Studies for the Proposed SLAC/LBL/LLNL B Factory, to be published in the *Proceedings of the 7th ICFA Workshop on Beam Dynamics UCLA*, May 13-16, 1991, LBL-30981.

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K.-J. Kim, "Exploiting the Polarized Nature of Synchrotron Radiation," Workshop on Application of Circularly Polarized Photons at ALS with a Bend Magnet Source LBL, June 10-11, 1991, ESG-143.

K.-J. Kim, "Polarized Nature of Synchrotron Radiation presented at SPIE's 36th Annual International Symposium "Production and Analysis of Polarized X-Rays, July 21-26, 1991, LBL-31242.

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Y.-H. Chin, K.-J. Kim and M. Xie, "Three-Dimensional Free Electron Laser Dispersion Relation Including Betatron Oscillations," submitted to the Thirteenth International Free Electron Laser Conf., Aug. 25-30, 1991, LBL-30673.

K.-J. Kim, "FEL Gain Taking into Account Diffraction and Electron Beam Emittance, Generalized Madey's Theorem," submitted to the Thirteenth International Free Electron Laser Conf., Aug. 25-30, 1991, LBL-30628.

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M. Xie, and K.-J. Kim, "Performance of Hole-Coupled Resonator in Presence of FEL Gain," submitted to the Thirteenth International Free-Electron Laser Conf., Aug. 25-30, 1991 (Apr. 1991), LBL-30672a.

K-J. Kim, "Symmetric and Asymmetric Multiperiod Wigglers in Long Wavelength Limit," submitted to Nuclear Institute and Methods, September 1991, LBL-31299.

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L. Schachinger, "Summary of the Working Group on Modeling and Simulation, presented at the Fifth Advance ICFA Beam Dynamics Workshop, (Nov. 1991), LBL-31665, LSAP-119.

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V.G. Baryshevsky and I. Dubovskaya, "Diffraction Phenomena in Spontaneous and Stimulated Radiation by Relativistic Particles in Crystals (Review)," Dec. 1991, LBL-31695.

I. Dubovskaya, "Coherent Generation of Visible Radiation by Relativistic Electron Beams in a Solid Space-Periodic Target," Dec. 1991, LBL-31694.

M. Furman, "Proposal for Experiments at Tristan on Beam-Beam Issues for Future B-Factories," (Feb. 1992), PUB-5332 and ABC-61.

K. Takayama, R. Govil and A. Sessler, "Macroparticle Theory of a Standing Wave Free-Electron Laser Two-Beam Accelerator, *Nuclear Instruments and Methods in Physics Research*, Feb. 1992, LBL-32044.

K.-J. Kim, "Accelerator Technology For Bright Radiation Beam," invited paper presented at La Jolla International School of Physics, "Research Trends in Physics: Coherent Radiation Generation in Particle Accelerators, Feb. 11-13, 1992, LBL-31925.

S. Chattopadhyay and K.-J. Kim, "Generation of Sub-Picosecond X-Rays," Workshop on the 4th Generation Light Sources, SSRL/SLAC, February 24-27, 1992, LBL-31968.

K.-J. Kim, "Calculation of Peak Power for Short Wavelength FELs," Workshop on the 4th Generation Light Sources, SSRL/SLAC, February 24-27, 1992, LBL-31969.

J. Dorfan, A. Hutton, M. Zisman, and W.A. Barletta, "PEP-II Asymmetric B Factory: R&D Results," 3rd European Particle Accelerator Conf., Technical University of Berlin, Germany, 24-28 March, 1992, LBL-32098, ABC-75, SLAC-PUB-5785, LLNL-UCRL-JC-110287.

A. Jackson, "Ideas for Future Synchrotron Light Sources," presented at the European Particle Accelerator Conference in Berlin, Germany, March 24-28, 1992, LBL-31172.

R. Rimmer, D. Goldberg, G. Lambertson, F. Voelker, N. Kroll, R. Pendelton, H. Schwarz, F. Adams, and M. De Jong, "Higher Order Mode Damping Studies on the PEP-II B Factory RF Cavity," 3rd European Particle Accelerator Conference Technical University of Berlin - Germany, 24-28 March, 1992, LBL-32549, and ABC-74.

Y.H. Chin, "Effects of Parasitic Beam-Beam Interaction during the Injection Process at the PEP-II B Factory," *Proceedings for "B Factories: The State of the Art in Accelerators, Detectors, and Physics,"* Stanford, CA, April 6-10, 1992, LBL-32468.

G. Lambertson, "Bunch-Motion Feedback for B-Factories," B-Factories: The State of the Art in Accelerators, Detectors and Physics," Stanford, April 6-10, 1992, LBL-33359.

S. Krishnagopal, Y.H. Chin, "Bench Marking Beam-Beam Simulations Using Coherent Quadrupole Effects," Workshop on B-Factories, Stanford, CA, April 6-10, 1992, LBL-32516, ABC-73.

M. Zisman, "B Factory RF System Design Issues," International Conference on B Factories: The State of the Art in Accelerators, Detectors, and Physics," Stanford, April 6-10, 1992, LBL-32446 and ABC-72.

Y.H. Chin, "Beam-Beam Dynamics during the Injection Process at an Asymmetric Ring Collider," APS, April 20-24, 1992, LBL-31754a.

M. Furman, "Beam-Beam Effects in Asymmetric Colliders," APS, April 20-24, 1992, LBL-31752a.

M. Furman, "Beam-Beam Issues in Asymmetric Colliders," B-Factories: The State of the Art in Accelerators, Detectors and Physics," Stanford, April 6-10, 1992, and also the APS, Washington, April 20-24, 1992, LBL-32561, and ABC-77.

S. Krishnagopal, "Coherent Beam-Beam Simulations," APS, April 20-24, 1992, LBL-31747a.

A.M. Sessler, "Linac-Based VUV FELs — A Review," APS, April 20-24, 1992, LBL-31696a.

Y.H. Chin, K.-J. Kim and M. Xie, "Three-Dimensional Free Electron Laser Theory Including Betatron Oscillations," submitted to *Physical Review A*, (May 1992), LBL-32329.

C. Wang, "Conditioner for a Helically Trans-ported Electron Beam," May 1992, LBL-32222.

M. Furman, Y.H. Chin, J. Eden, W. Kozanecki, J. Tennyson, and V. Ziemann, "Closed Orbit Distortion and the Beam-Beam Interaction," June 1, 1992, LBL-32435 and ABC-49.

G. Rangarajan and A. Sessler, "Sensitivity Studies of a Standing-Wave Free-Electron Laser," Workshop on Advanced Accelerator Concepts, Pt. Jefferson, NY, June 14-20, 1992, LBL-32463.

J. Wurtele, D.H. Whittum, and A.M. Sessler, "Impedance Based Analysis and Study of Phase Sensitivity in Slow-Wave Two-Beam Accelerators," Third Workshop on Advanced Accelerators, Pt. Jefferson, NY, June 14-20, 1992, and to be published in the Proceedings, June 1992, LBL-31848.

P. Eberhard and S. Chattopadhyay, "Asymmetric Phi Factories — A Proposed Experiment and Its Technical Feasibility," submitted to the 15th International Conference on High Energy Accelerators, July 20-24, 1992, LBL-32250.

M. Furman, Y.H. Chin, and J. Eden (LBL), J. Tennyson and V. Ziemann (SLAC), and W. Kozanecki (CEN-Saclay and SLAC), "Beam-Beam Diagnostic from Close Orbit Distortion," 15th International High Energy Accelerator Conference, July 20-24 (Feb. 92), LBL-31888, SLAC-PUB-5472, and ABC-80.

S. Krishnagopal, R.H. Siemann, "An Investigation of Coherent Quadrupole Beam-Beam Effects," Fifteenth International Conference on High Energy Accelerators, Hamburg, Germany, July 20-24, 1992, LBL-32581.

J. S. Wurtele, D. Whittum and A.M. Sessler, "Common Analysis of the Relativistic Klystron and the Standing-Wave Free-Electron Laser Two-Beam Accelerator," Fifteenth International Conference on High Energy Accelerators, Hamburg, Germany, July 20-24, 1992, LBL-32580.

M. Zisman (LBL), R. Bell, J. Dorfan, A. Hutton (SLAC), and W. Barletta (LLNL), "The PEP-II Asymmetric B Factory Design Update and R&D Results Free-Electron Laser Two-Beam Accelerator," 15th International High Energy Accelerator Conference, July 20-24, LBL-31934a.

M. Zisman, R.A. Bell, J. Dorfan, H. Schwarz, W.A. Barletta and M. Calderson, "PEP-II Asymmetric B Factory: Design Update and R&D Results," 15th International Conference on High Energy Accelerators (HEACC'92), Hamburg, Germany, July 20-24, 1992, LBL-32559, ABC-76, SLAC-PUB-5852, LLNL-UCRL-JC-111380.

W. Barletta, A. Sessler and L.-H. Yu, "Physically Transparent Formulation of a Free-Electron Laser in the Linear Gain Regime," 14th International Free Electron Laser Conf., Kobe, Japan, August 23-28, 1992, LBL-32221.

W. Barry, J. Edighoffer, S. Chattopadhyay, and S. Fornaca, "Field Profile and Loading Measurements on Higher Order Modes in a Two Cell 500 MHz Superconducting Structure," 16th International Linac Conf. held in Ottawa, Ontario, Canada, Aug. 23-28, 1992, LBL-32178.

S. Chattopadhyay, K.-J. Kim, R. Byrns, R. Donahue, J. Edighoffer, R. Gough, E. Hoyer, W. Leemans, J. Staples, B. Taylor, and M. Xie, "Design of a Superconducting Linear Accelerator for an Infrared Free Electron Laser of the Proposed Chemical Dynamics Research Laboratory at LBL," 16th International Linac Conference, Aug. 23-28, 1992, LBL-32182a.

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F. Voelker, "ALS Longitudinal Kickers," The 1992 Accelerator Instrumentation Workshop, Lawrence Berkeley Laboratory, Berkeley, CA, Oct. 27-30, 1992, LBL-33088

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Contents

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4.

CENTER FOR BEAM PHYSICS

TWO MAJOR ACCELERATOR-BASED INITIATIVES are being assisted by the Center for Beam Physics,* a divisional center that performs multifaceted exploratory studies of the physics of accelerators and beams. PEP-II, a proposed B-meson "factory" based on the Positron-Electron Project ring at the Stanford Linear Accelerator Center, has been the subject of ongoing research. Meanwhile, a long-standing interest in free-electron lasers and high-brightness electron and photon sources has led to the detailed design of an infrared free-electron laser (IRFEL), which is proposed as part of the Chemical Dynamics Research Laboratory. The IRFEL investigations have led to productive collaborations with Stanford University, Brookhaven National Laboratory, the Continuous Electron Beam Accelerator Facility, and TRW, Inc.

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High-Luminosity Collider Physics
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Y.-H. Chin
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M. Furman
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High-Energy Collider Physics
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Y.-H. Chin
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E. Atkins-Orvis
M. Condon
M. Mara-Ann
D. Moretti

* Engineering Division

* The Center was formerly known as the Exploratory Studies Group.

To meet the technical challenges of these initiatives and to generally enhance LBL's capabilities in particle- and photon-beam research, the Center made several additions to its experimental capability in 1992 and early 1993. In addition to upgrading the beam electrodynamics laboratory and setting up an optics lab, the detailed design of the Advanced Test Beam Facility was finished and construction was started. This facility will get "double the money's worth" out of the 50-MeV ALS linac by using it for beam physics experiments during the considerable spans of time between the ALS injection cycles. Many experiments are possible; immediate plans include generation and detection of x-ray pulses as short as tens of femtoseconds (a long-standing interest) and focusing of a beam by using plasma lenses.

Members of the Center have been involved in the ALS project from the outset and make up its technical core, the Accelerator Systems Group. With the design of the accelerators complete, they have continued to play major roles in guiding construction, programming the control system, and commissioning.

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 PEP-II rf and feedback design efforts. It also contributed significantly to rf, impedance, and feedback work at the ALS, and worked on beam-cooling improvements for the Tevatron's antiproton source.

B-Factory Studies

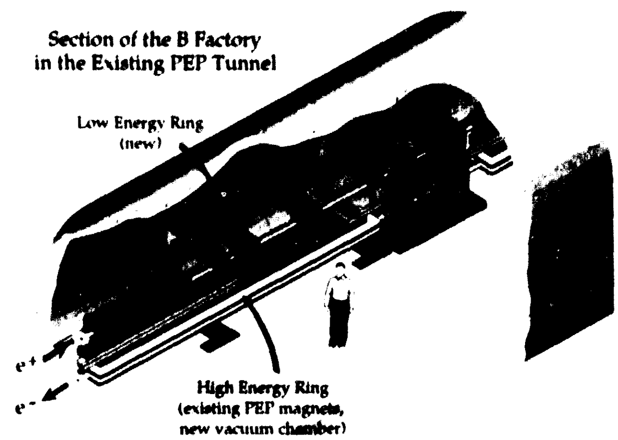
The worldwide high-energy physics community has become increasingly interested in "B factories," which would produce $B\bar{B}$ pairs for fundamental studies of charge-parity (CP) violation and rare B-meson decays. Several schemes for copious $B\bar{B}$ production in electron-positron collisions have been advanced in the literature. In collaboration with the Stanford Linear Accelerator Center (SLAC), Lawrence Livermore National Laboratory (LLNL), and Caltech, the Center is designing a facility based on one of the most promising schemes: PEP-II, a collider with one high-energy ring and one low-energy storage ring. This energy-asymmetric collider, built in the PEP tunnel at SLAC and re-using many PEP components, would be scientifically and economically attractive.*

Conceptual Design Overview

During 1992, 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 4-1. 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.

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

Figure 4-1. The proposed asymmetric B factory, PEP-II, would be built in the Positron-Electron Project tunnel and would use a substantial amount of the existing hardware for the PEP collider. Recent LBL work in the multi-institutional PEP-II collaboration has emphasized refinement of the magnetic-lattice designs of the two rings and extensive studies of beam-beam interaction. (Artist's impression courtesy SLAC)



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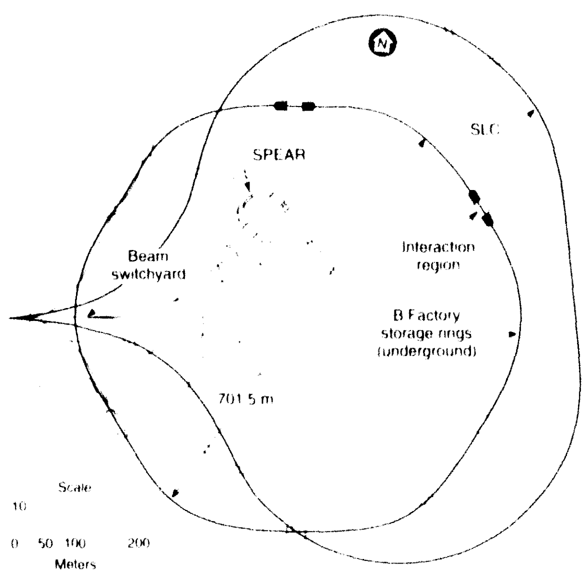

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In principle, all the relevant parameters—the ratio of the cross sections of the two beams, the beam currents, the beam-beam tune shifts, the beam energies, and the vertical beta functions at the interaction point—are adjustable. In practice, however, the beam-beam tune shift cannot be increased beyond a certain value, which has been determined experimentally in many colliders to lie in the range of 0.02 to 0.06. Similarly, a collision energy at the ϒ(4S) resonance implies that the product of the beam energies must be 28 GeV^2. Thus, only three parameters—the beam-size ratio, the beam current, and the vertical beta function at the interaction point—are fully at the discretion of the accelerator designer.

The chosen luminosity, 3×10^{33} cm^{-2} s^{-1}, has been shown to be adequate for the study of the key physics issue, CP violation. Given the limitations caused by the beam-beam interaction—which we take for our design to correspond to a maximum tune shift of 0.03—a substantial increase in luminosity implies that the high-current beam must be divided into a large number of individual bunches (1658 in our design). This approach involves a design in which the single-bunch parameters (emittance, bunch length, current, tune shift, etc.) are well within present practice for colliders. Our choice of 1658 bunches lies in a safe middle ground between the extremes—it does not exacerbate coupled-bunch instabilities, nor does it have problems with single-bunch effects.

For PEP to serve as the high-energy ring, several of its systems must be significantly upgraded to deal with these issues. Foremost among these are the rf and vacuum systems. The high luminosity leads to extreme heat loads caused by synchrotron radiation; a great deal of engineering work has been performed by our collaborators to solve the resultant cooling and vacuum problems. There are also implications for the rf system of the high-energy ring. It will operate at a frequency of 476 MHz to phase-lock the storage ring rf system to that of the 2856-MHz injector (the "two-mile linac" that is also used to inject the Stanford Linear Collider). This choice of frequency minimizes injection phase errors, which contribute significantly to the power demands of the multibunch feedback system. The rf system will consist of 20 single-cell cavities; the cavity design itself is aimed at minimizing the higher-order-mode impedance contribution of the rf system.

The interaction region is designed in such a way that the beams collide head on. During 1992, a great deal of effort has gone into studying the beam-beam interaction and into refining the lattice designs of the two rings and the interaction region. These three subjects are closely related.

B Decays and CPT Symmetry

Judging particle interactions by the standards of the familiar, macroscopic world, one would think that if a process and the participating objects 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 a 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 an unusual quark, the "strange" quark, which is not found in the group of quarks that make up ordinary matter. The K decays in a wide variety of fashions (it is axiomatic that every decay mode that is not explicitly forbidden must occur eventually). In a few of these modes, the K^0 decays a few tenths of a percent differently than the 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 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, whose technical challenges are described elsewhere in this chapter.

The ultimate goal of this research is to enhance 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 was not born with equal, evenly distributed quantities of matter and antimatter that would annihilate each other whenever they interacted. 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. Such will be the implications of the research at PEP-II.

Lattice Design

The basic lattice designs of both rings were completed in earlier years; the primary effort during 1992 was, and remains, optimization of the lattices (particularly that of the low-energy ring). Using simulation tools that we had developed to analyze the dynamic behavior of particles circulating in storage rings, we found that the low-energy ring was not as dynamically stable as the high-energy ring. These tools are based on single-particle tracking, and fully account for nonlinearities, magnetic-field imperfections, and magnet-position errors. (Beam-beam interaction is ignored at this stage of the design.)

Significant strides have been made toward understanding the problem. Good dynamic behavior requires a stable aperture at least 10 times the natural beam size. However, one cannot make a positron beam that is of the same quality as the electron beam; its natural emittance and energy spread are each roughly 1.5 times larger. Therefore, all else being equal, one must achieve a larger aperture in the low-energy ring than in the high-energy ring. In addition, the stronger focusing of the low-energy ring requires stronger sextupole magnets in order to correct the linear chromaticity. As a result of this correction, the low-energy ring has more nonlinear chromaticity, as well as a greater tune shift under amplitude variations, than the high-energy ring. All this reduces the available dynamic aperture.

Our present results show that, to control these effects, it is necessary to have a local chromaticity-compensation scheme in both planes near the interaction point. Such a scheme requires sextupole magnets in the interaction-region straight section. They must be placed in such a way as to correct the chromaticity arising from the interaction-region quadrupole magnets without generating higher-order tune shifts. Our simulations have shown this scheme to be the best method of improving the dynamic aperture. As we approach a final design for the interaction region, the challenge we face is to implement this scheme while respecting the geometrical constraints imposed by the existing tunnel and by the relative position of the two rings.

Beam-Beam Interaction Studies

While working on the lattice design, we also intensified our studies of beam-beam effects. We have made a great deal of progress on a simulation approach that complements the lattice studies by providing detailed simulation of beam-beam dynamics but neglecting magnet nonlinearities. These beam-beam studies are based on multiparticle tracking simulations, so they require much more computation than the single-particle dynamic-aperture studies. Ideally we would like to combine the two approaches into one consistent whole; we intend to develop the necessary tools for this unification during 1993.

Most of these studies were based on multiparticle simulations in the linear-lattice approximation. In the ongoing detailed-design effort, a good deal of additional progress has been made on various issues, including the existence of an adequate "working point" in the multivariate parameter space, adequacy of the beam separation at the parasitic collision points, beam-beam interaction during injection, departures from full equality of the four beam-beam parameters, and an experimental proposal at TRISTAN* to test the effects of the beam-beam force on the closed orbit.

In search of a working point, we performed tune scans over a wider region of the tune plane than we had in the initial effort that produced the 1991 *Conceptual Design Report*. A working point above the half-integer, with

* Transposable Ring Intersecting STorage Accelerators in Nippon, a collider in Japan

fractional tunes $(\nu_x, \nu_y) = (0.64, 0.57)$ for both beams, was shown to give adequate luminosity and has been adopted. The "old" working point, $(\nu_x, \nu_y) = (0.09, 0.05)$, also gave acceptable beam-beam dynamics, but it was deemed to be too close to the integer, where we would expect to encounter serious closed-orbit instabilities. Ongoing simulations suggest that making the working points slightly different for the two beams will give even better performance.

Because of the relatively close bunch spacing, the bunches experience glancing collisions in the horizontal plane on their way into and out of the interaction point; we call these "parasitic collisions" (PCs). Although each beam experiences several of these collisions, the PC closest to the interaction point is the most disruptive. In the earlier interaction-region design, the separation of the two beams at the first PC was specified to be 2.8 mm. Early simulations showed that if this distance were too small, the PCs could be quite detrimental to luminosity. Although the simulations proved that 2.8 mm was adequate, they also showed that if the distance were slightly smaller, the beam blowup could become substantial. For this reason the design of the interaction region has been upgraded to provide a much more comfortable 3.5-mm separation.

When the beams are injected, they are displaced transversely from their nominal orbits by a distance of approximately eight times their diameter. Therefore, if the injection were in the horizontal plane, the beams could collide head on, or almost head on, at the PC points. Simulations showed that, indeed, beam-beam-induced beam blowup was substantial during the first few damping times. When a vertical injection option was simulated, the beam-beam effect was found (as we had expected) to be much less severe, so the design now calls for vertical injection.

The design for PEP-II, which is asymmetric in energy, currently uses the same values in both rings for each of the four beam-beam tune shift parameters because this causes the beam-beam dynamics to resemble those of symmetrical colliders, which are well understood. Furthermore, this equality has the practical advantage of constraining many other parameters. Recent simulations suggest, however, that if the beam-beam parameters were somewhat different from each other, luminosity performance could be improved. We have explored two approaches thus far. In the first, the horizontal and vertical beam-beam parameters are kept equal to each other, but are different in the two beams. In the second, the horizontal and vertical beam-beam parameters are different from each other, but are kept equal for the two beams.

Simulations for both cases suggest that better performance can be obtained in the first case by using a slightly smaller beam-beam parameter for the positron beam and in the second case by using a slightly smaller vertical beam-beam parameter for both beams. The possible effects of these choices upon other design parameters have been identified but not yet quantitatively evaluated. Undoubtedly some combination of the two approaches, or a third approach in which all four beam-beam parameters are different, will prove to be optimal, so our studies continue. Already we know from these simulations that the beam-beam dynamics remain well behaved when the four parameters are not equal, indicating that, at least, our initial requirement for equality in these parameters has some room for adjustment.

Because the beams travel in different vacuum chambers in an asymmetric collider, the beam orbits near the interaction point need to be controlled to a much greater degree than in symmetric colliders to ensure head-on collisions. A feedback scheme used in the Stanford Linear Collider, based on the observation of the beam-beam-induced orbit deflection, has been extended to the PEP-II design and shown to be promising. The basic idea is to measure the beam-beam-induced distortion of the closed orbits of the two beams at many points well away from the interaction point. These measurements can guide the operation of a feedback "lever" to keep the beams in collision. An experiment to test this idea at TRISTAN is expected soon.

In summary, most of the challenges of the PEP-II design have been addressed satisfactorily, and technical solutions are in hand. We are continuing the detailed engineering design and fabrication of various components for testing purposes. Some areas of the conceptual design, which was submitted to the Department of Energy in February 1991, have been refined during 1992. Further suggestions for improvements continue to be put forth as the accelerator physics and other technical issues become better understood.

Chemical Dynamics Research Laboratory

The Chemical Dynamics Research Laboratory (CDRL) is a key new facility in the multilaboratory Combustion Dynamics Initiative, which is being put forward by the DOE's Division of Chemical Sciences. The research proposed for the laboratory (sidebar) is aimed at gaining a rigorous, molecular-level understanding of chemical reactions.

The CDRL is proposed for LBL, with significant participation by Sandia National Laboratories, two institutions with complementary strengths. Sandia researchers will be responsible for the construction and operation of some of the experimental equipment and will play key roles in the scientific program and the transfer of combustion technology to industry. The Center's role in this national user facility is twofold. The Advanced Light Source will supply the CDRL with VUV and soft x-ray light from two beamlines. Experiments at the CDRL could also be greatly enhanced by a proposed infrared free-electron laser (IRFEL), which personnel from the Center are designing as a second-phase addition to the facility. Researchers from other LBL divisions, most notably the Chemical Sciences Division, will join colleagues from the University of California at Berkeley and other institutions in conducting the scientific program.

Research Prospects

The CDRL, with its advanced lasers, will complement the ALS, which upon completion will be the world's brightest source of soft x-rays for basic and applied research. Collaborative CDRL researchers from industry, universities, and national laboratories will use the unique features of ALS x-ray beams—high spectral brightness and very short pulse length (nominally tens of picoseconds). Undulators in the storage ring will provide somewhat spatially coherent radiation—sometimes referred to as "laserlike"—that is broadly tunable across the soft-x-ray to ultraviolet regions of the electromagnetic spectrum.

The CDRL experimental systems will be used for dynamic, spectroscopic, and structural studies of highly reactive molecules. Many of these are created during the early stages of combustion. These studies will take place in an experimental hall where light from the IRFEL or infrared chemical lasers, the ALS, and advanced conventional lasers at various wavelengths (Figure 4.3) can all be directed into experiment stations to study the dynamics of fast-moving chemical processes in detail. Such fundamental knowledge—which is beyond the reach of existing experimental facilities—is crucial for improving the efficiency of combustion and controlling the formation of pollutants, among other issues.

Scientists from other LBL divisions, the University of California at Berkeley, and Sandia National Laboratory Livermore are developing the CDRL research program. Research results will feed directly into U.S. industries concerned with cleaner combustion, alternative fuel supplies, reduced pollution, and improved industrial processes. This is important not only to industry but also to government, since many regions of the nation face significant economic curtailment during the coming decades if air pollution from mobile and stationary sources is not controlled more effectively. The CDRL can provide a foundation of fundamental understanding that will enable long-term success in solving these problems.

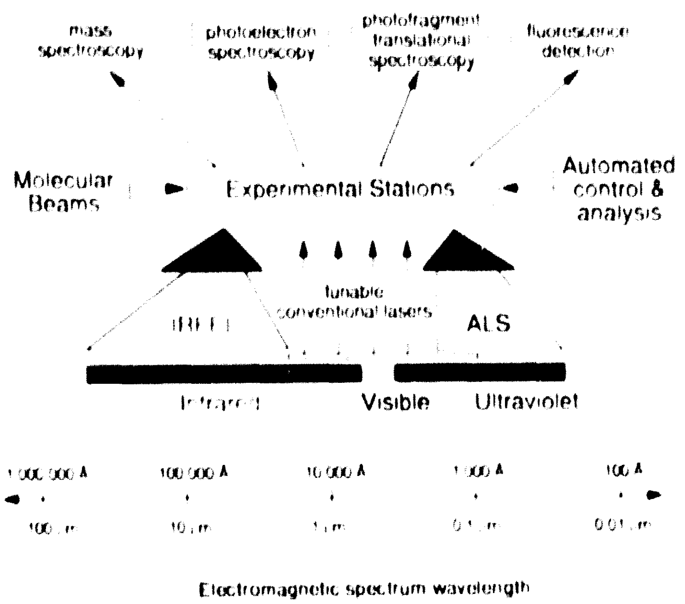

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Figure 4-3. A key to the scientific potential of the CDRL is the unprecedented integration of several technologies over a wide spectral range. Tunability, synchronization capabilities, and time resolution on the order of picoseconds are among the other important features of the proposed facilities. The lower-energy region of the infrared (different portions of which are of interest for different kinds of research) could be covered with chemical lasers; the proposed IRFEL would offer broad tunability over a wide range, in addition to high power.

CDRL: A Unique Combination of User Facilities

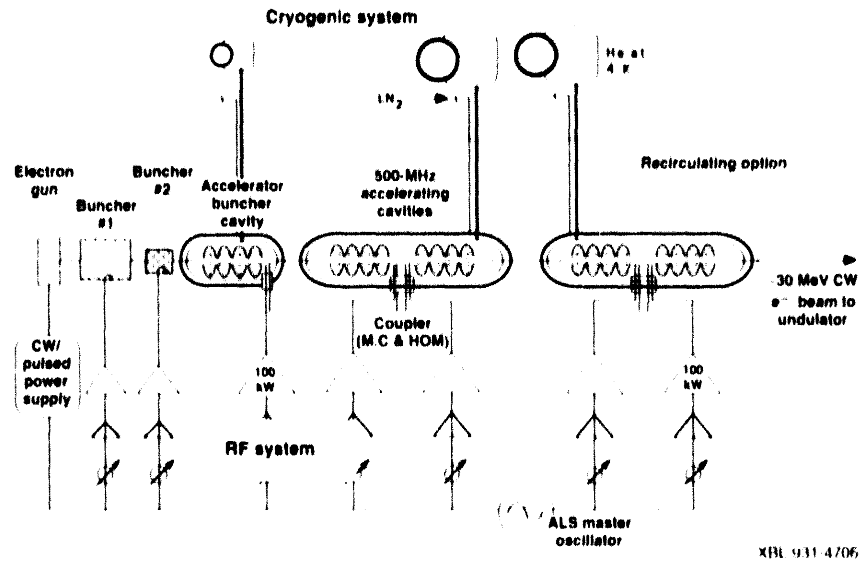
Research in such areas as gas-phase reaction dynamics, combustion, isotope separation, and industrial processing is generally dependent upon advanced technologies and techniques. The CDRL will bring the key technologies together for the first time. At its heart could be an IRFEL, which has been the subject of a great deal of work by our group. The IRFEL, together with two ALS beamlines, optical lasers, and molecular-beam machines, will enable research that has a great impact on our understanding of pure and applied chemical dynamics.

The CDRL will occupy a new building adjacent to the ALS so that photon beams from both the ALS and the proposed IRFEL (which would go in a shielding vault in the basement of the new building) can be delivered to the experimental stations. The ALS beamlines have been another area of study and development by our group, in collaboration with the ALS staff and the Center for X-Ray Optics in LBL's Materials Sciences Division. Advanced optical lasers are being designed by colleagues from both the University of California at Berkeley Chemistry Department and Sandia National Laboratories. These collaborators have been deeply involved in the design of experimental facilities and in the development of the research program.

IRFEL Design Progress

Since the original conceptual design was published in February 1990, we have revised it to incorporate an accelerator with 500-MHz superconducting rf cavities (Figure 4-2). The primary reason for the move from the less-expensive room-temperature technology was the user requirement for photon-beam wavelength stability. Their requirement for stability to within 1 part in 10^4 translates into an electron-beam energy fluctuation of less than 5 parts in 10^5. By reducing cavity losses due to wall resistance to nearly zero, the superconducting accelerator technology also allows continuous-wave (cw) operation. Pulses are desired for the CDRL application, so cw operation is best interpreted as a means of increasing the average power, permitting more data to be obtained in a given time.

Figure 4-2. Recent thinking about the CDRL IRFEL points toward a new design based on 500-MHz niobium-titanium superconducting linac structures. The superconducting technology allows continuous operation (with various pulsed modes and the ability to serve multiple experiments) and lends itself to a recirculation loop. Downstream of the accelerator apparatus shown here, coherent infrared radiation is produced with a variable-gap undulator and an optical cavity with a broadly tunable hole-coupled outcoupling scheme. Also shown here is an indication of how the new design might fit in the basement shielding vault of the CDRL building proposed earlier; the beam dumps are shown but the cryogenic systems, which would be outside the vault, are not.



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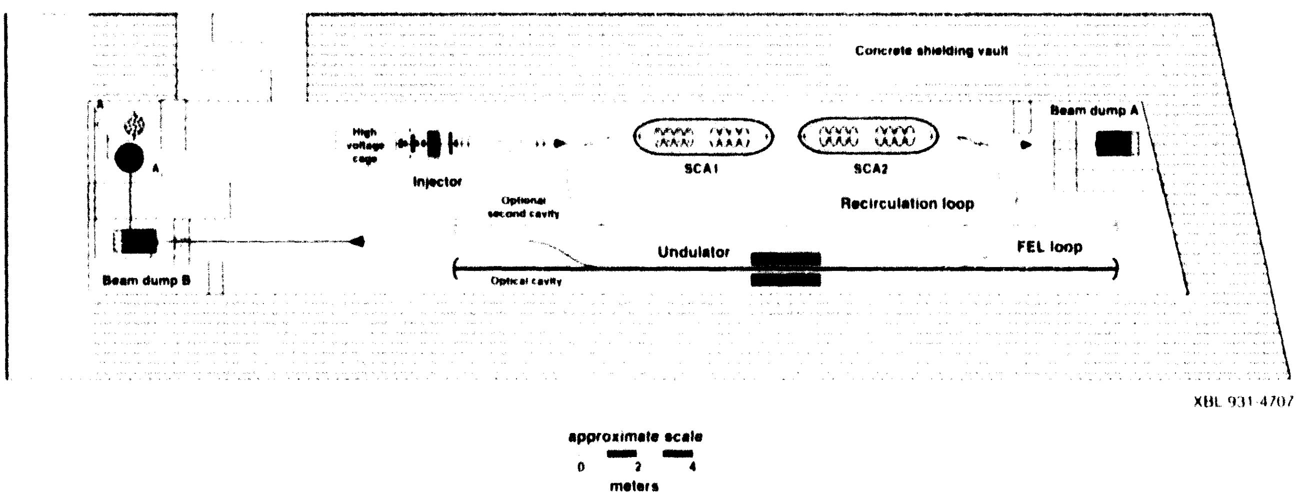

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The pulse train can be tailored to meet the experimenter's needs in a variety of ways, including synchronization with the ALS pulses. This flexibility will allow simultaneous service to multiple users. The IRFEL's micropulse duration is 33 ps, with a repetition rate of 6.6 MHz. Infrared radiation is produced with a variable-gap undulator and a 24.6-m-long optical cavity with a broadly tunable outcoupling scheme. Table 4-1 summarizes the parameters of the new IRFEL design.

Particular attention was paid to stability and tunability, which are crucial for the users' needs. A detailed analysis of the effect of the electron beam fluctuation upon the optical performance was carried out through analytic calculation and numerical simulation. Also studied were various sources of fluctuations in the gun, bunchers, and accelerating sections, as well as feedback and feedforward schemes to reduce these fluctuations. The superconducting design proved superior to the 1990 room-temperature design, which had an electron-beam energy stability of 1 part in 10^{-3}. Thus the 500-MHz superconducting design appears to be the best choice for our purposes.

Table 4-1. Some Characteristics of the Proposed CDRL IRFEL

Accelerator	
RF frequency (MHz)	500
Maximum energy (MeV)	~ 55
Micropulse	
FWHM energy spread	0.35% at 55 MeV
FWHM duration (ps)	33
Repetition rate (MHz)	6.6
Output	
Wavelength λ (μm)	3–50
Linewidth	transform-limited
Bandwidth stability δλ/λ	10^{-4}
Intensity stability δI/I	< 0.1
Average power (W)	600

The FEL design must provide wide wavelength coverage while minimizing operational interruptions. At a fixed electron energy, the wavelength can be tuned by about a factor of two by varying the magnet gap of the undulator. For rapid fine tuning, we can change the electron beam energy by ± 1%, varying the photon wavelength by ± 2%. By operating the accelerator at any of four different energies (55.3, 39.1, 27.7, or 19.6 MeV) and using these tuning techniques, we can cover a wavelength range of 3 to 50 μm.

The beam reaches about 30 MeV in its first pass through the pair of superconducting rf cavities. With an extra, in-phase recirculation pass, it reaches about 55 MeV, greatly extending the short-wavelength capability of the IRFEL. In another operational mode, the recirculated beam could instead be introduced into the cavities 180° out of phase with the rf. This would decelerate the beam, putting its power back into the rf cavities in a sort of flywheel effect for use on the next pulse. The electron beam, and hence the optical beam, would become quite powerful.

Our work on the recirculation scheme is beginning to address such important issues as isochronous beam transport and safe dumping of energetic, intense beams. We and our potential users are also studying the scientific implications of operation at this high power. The design effort has spawned several experimental programs, including an LBL-Stanford collaboration on development of novel diagnostics for FEL optical pulses, a Stanford-LBL-TRW-BNL collaboration on optimization of superconducting cavities for FEL, an LBL experimental study of hole-coupling and resonator modes, and a joint LBL-CEBAF test bed for demonstrating superconducting IRFEL technologies.

Test Beam Facility

The ALS injection complex includes a traveling-wave linac that produces a 50-MeV electron beam. After the storage ring has been filled, the injection complex will be idle for the useful lifetime of the stored beam, which is expected to be several hours. A variety of interesting experiments could be conducted with that beam, including plasma focusing, tests of accelerator structures, and generation of "chirped" photon pulses. Accordingly the Center is building the Test Beam Facility, a DOE-funded initiative using the ALS linac. The facility will use the linac between injection cycles for a highly productive and cost-effective program in beam physics with minimal disruption to ALS operations.

Research Program

Many interesting experiments could be performed with this conveniently available, short-pulsed, low-emittance electron beam. These two investigations are planned for the initial research program: a plasma focus and the generation of short x-ray pulses through Compton scattering.

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 diaphragms and differential pumping combine to taper the plasma density. 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 the effect of plasma return currents on the effectiveness of the focusing can provide insight into the usefulness of plasmas in reducing beam-beam interaction.

The design of the plasma source and diagnostics is currently under way. Two candidate sources are an rf discharge source and a photoionization source driven by an excimer laser. The plasma properties will be measured using Langmuir probes and a 65-GHz Michelson interferometer.

Another experiment at the facility will use the ALS linac's beam for an ALS-like purpose: the generation of x-rays. 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 shortness of the electron beam. For the ALS linac beam, the shortest photon pulses 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° Compton scattering with a visible laser (Figure 4-4). 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. A short-pulse solid-state laser (τ_L = 200 fs, E = 100–200 mJ) is being designed by the femtosecond laser laboratory in LBL's Materials Sciences Division. Also being designed is an x-ray detector that offers femtosecond time resolution. In cooperation

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

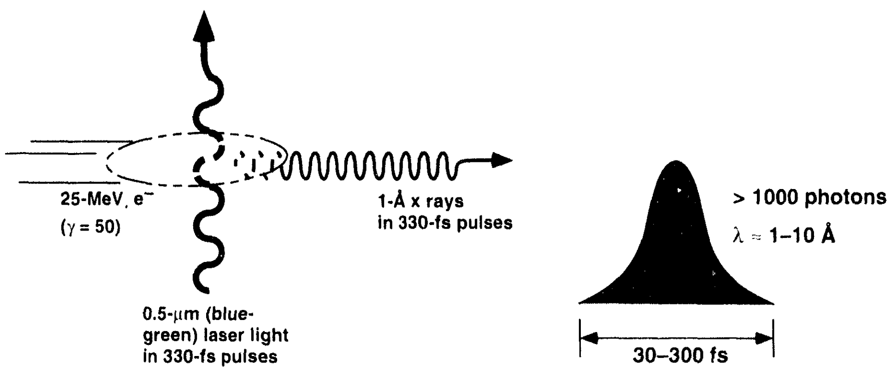


Figure 4-4. One of the most intriguing experiments for the Advanced Test Beam Facility is production of sub-picosecond x-ray pulses through 90° Compton scattering of a visible laser beam against the 50-MeV electron beam.

with LBL's Center for X-ray Optics, we are examining ways to direct the beam onto detectors and experimental apparatus. 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 FELs, and the "chirping"* of conveniently long (10-ps) electron-beam bunches to produce photon pulses much shorter than that.

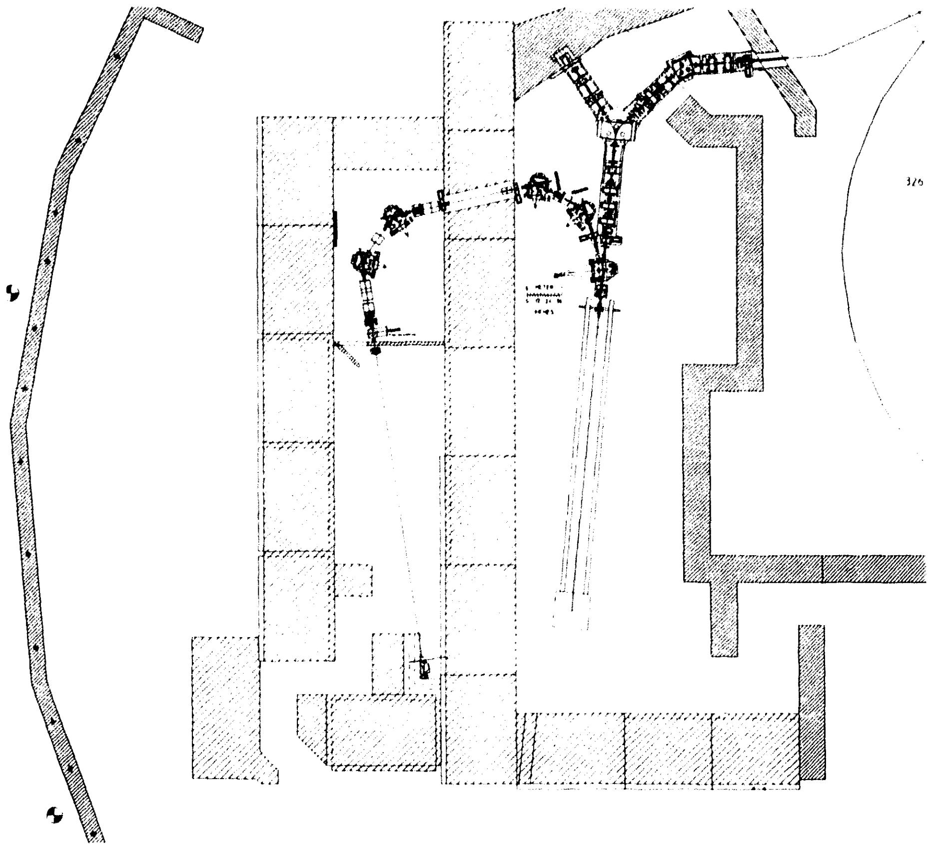
Facility and Operations

Figure 4-5 shows the overall layout of the Test Beam Facility. We have been designing the beamline components while studying the proposed experiments and deciding how best to reconcile their somewhat different implications for the magnetic lattice of the transfer line. For example, the plasma-focus experiment requires several transverse measurements of the electron beam (which therefore should be perturbed as little as possible downstream of the focus), whereas the Compton-scattering experiment requires separation of the electron and x-ray beams downstream of the interaction point.

We anticipate that most experiments will be entirely transparent to ALS operations, involving no changes in the electron-gun and linac settings. Some special experiments might call for temporarily changing the relative amplitude and phase settings of the two linac tanks; others might require the gun pulser and the grid voltage to be turned up to their maximum capacity in terms of charge extraction and pulse-train length. The linac will remain under the overall control of the ALS throughout.

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

Figure 4-5. Because the ALS is based on a storage ring, the injector linac will be idle much of the time. This affords a highly cost-effective opportunity to develop a facility for beam-physics research. This diagram shows the probable layout of the Advanced Test Beam Facility, which is now moving from design into construction. The facility will support a variety of experiments, such as plasma focusing of an electron beam and the production of ultrashort x-ray pulses using 90° Compton scattering of a visible laser beam off an electron beam.



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Optics Experiments

The Center for Beam Physics has greatly expanded its experimental capabilities with a new optics laboratory that will serve many efforts, including the design of the proposed CDRL IRFEL and the development of optical components for the Test Beam Facility described in the previous section. Two projects have been carried out thus far: bench testing of the Fox-Li code HOLD and development, together with Stanford University, of advanced optical diagnostics for FELs.

Bench Testing of HOLD

Hole coupling was selected for the CDRL IRFEL's optical resonator after extensive computer simulation, primarily using the code HOLD. To validate these simulations, we performed scaled experiments by injecting a visible HeNe laser beam into a stable cavity, as shown in Figure 4-6. We studied two cases: a Gaussian near-concentric symmetric resonator and a hole-coupled resonator with degenerate higher-order modes. The first case, with its simple geometry, allowed direct comparison with analytical results and HOLD output and was also useful for benchmarking the diagnostic equipment. The second case provided an effective means of exercising the code and also yielded intrinsically useful results, since mode degeneracy should be avoided for good FEL operation.

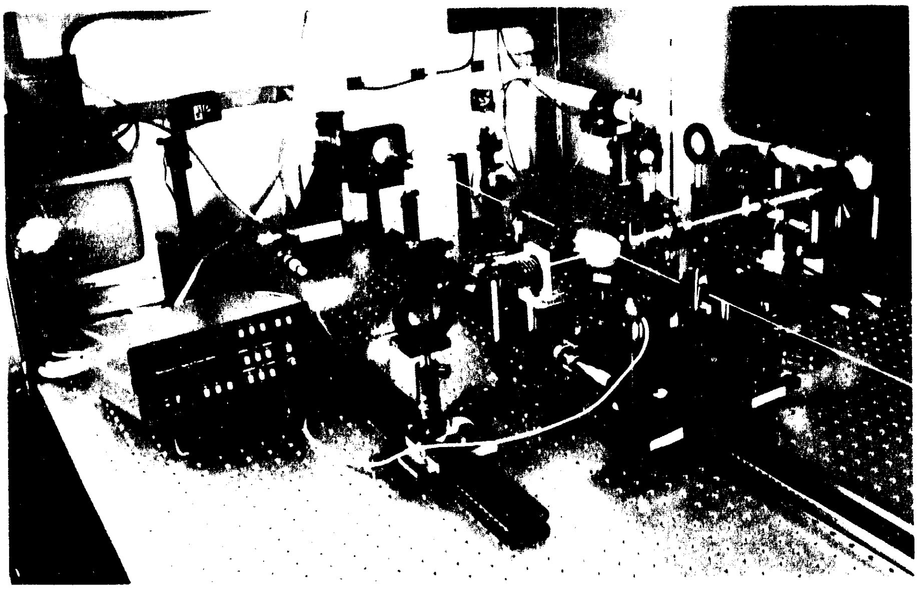


Figure 4-6. To validate analytical solutions and code simulations, we performed scaled experiments by injecting a visible HeNe laser beam into a stable cavity. The experiments have enabled us not only to verify the Fox-Li code known as Horo, but also to gain some insights into avoidance of degenerate higher-order modes in FELs.

The measurements agreed reasonably well with Horo calculation of intracavity and outcoupled mode profiles and other parameters. We observed mode degeneracy as evidenced by an intracavity mode profile that alternated between two higher-order modes, and related it to our deliberate choice of stability parameter, outcoupling hole size, and intracavity aperture size. Future experiments will concentrate on improving the laser stability, suppressing cavity mirror vibrations, and achieving better pointing accuracy so that we can accurately study the actual design parameters of the CDRL IRFEL.

Advanced Optical Diagnostics for FELs

Working with colleagues from Stanford University, we 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 4-7.

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. Here the image is that of the region of the nonlinear crystal in which second-harmonic light was generated.

After the spectrometer system was developed in our laboratory, we tested it using an FEL beam at Stanford in September and October. Preliminary results indicate that the single-element detector with integrating sphere

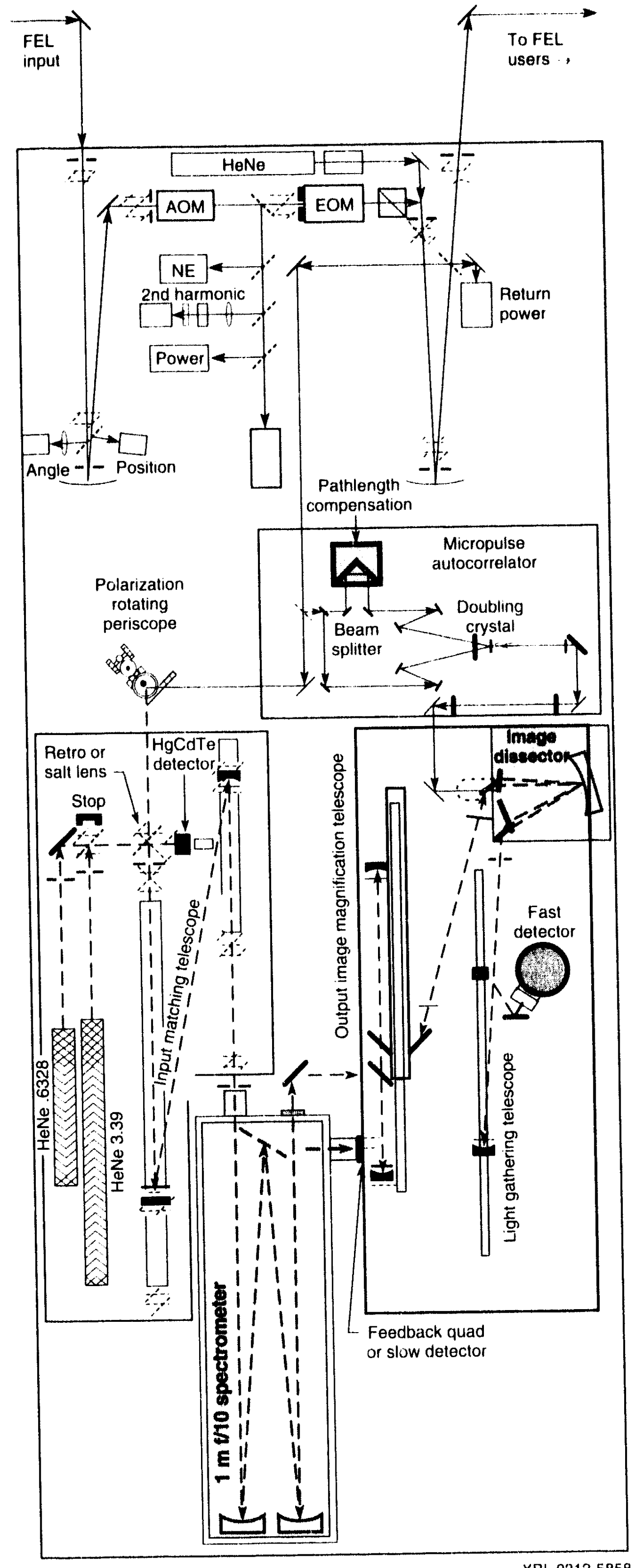


Figure 4-7. The LBL-Stanford collaboration in FEL diagnostics has resulted in a system that can perform both spectral analysis and pulse-width measurement of the optical output. Preliminary results from testing with an FEL beam at Stanford have been encouraging.

has the requisite sensitivity and rise time. A micropulse spectrum with 5 spectral "bins," or sets of data in different parts of the spectrum, was obtained. Further improvements to the spectrometer and its user interface will be tested in another FEL run at Stanford early in 1993, and we are also about to begin building the single-pulse autocorrelator system for pulse-width measurements.

Accelerator Physics for the ALS

Members of the Center for Beam Physics have been involved in the Advanced Light Source from the outset, focusing primarily on the immediate needs of the project but also investigating many basic physics issues involving high-brightness electron storage rings that have numerous insertion devices. Much of this research is highly generic and is relevant, for the most part, to any third-generation source, as well as to storage-ring-based free-electron lasers and to compact damping rings envisioned for high-energy linear colliders.

RF Measurements and Feedback Systems

Because of the high beam current and short bunch length in the ALS, it is important to minimize the beam coupling impedance of the vacuum-vessel components. If this impedance were high, it might excite coupled-bunch and single-bunch instabilities, and the electromagnetic energy deposited in the vacuum vessel by the beam (hundreds of kilowatts are potentially available) might cause excessive heating. Our Beam Electrodynamics group has studied many ALS structures, beginning at the design stage, a process that includes computer modeling and measurements of some actual components by launching waves down a coaxial wire. Our most recent achievement was measuring the higher-order modes of a spare ALS rf cavity. With these measurements we determined the effectiveness of damping (which is accomplished with high-pass filters connected to the input power waveguide) and obtained the data necessary for accurate simulation of coupled-bunch motion.

The information is being put to use in the design of damping systems. In the ALS, bunch-by-bunch damping schemes will be implemented for all three axes so that errors in the position and phase of each bunch can be measured and corrected. Computer simulations and calculations of the beam behavior, which used the data on the higher-order modes of the rf cavity, suggest that the beam instabilities can be safely contained with the proposed feedback systems. Tests of the longitudinal feedback system are planned on the ALS in the near future. This system was developed in cooperation with SLAC, and a similar scheme will be used for the PEP-II collider described earlier in this chapter.

The device that will apply the feedback to the beam is a "kicker," which consists of a pair of coaxial electrodes approximately a quarter-wavelength long connected by half-wavelength delay lines. This structure uses only one-fourth the power of a single-electrode design for a kick of the same amplitude. Low-power measurements of a prototype confirm the predicted performance, and a production unit is being made. Transverse kickers are also being designed.

Injector Commissioning Experience

Members of our Center working on the ALS project have been closely involved in the commissioning of the 50-MeV injection linac and the 1.5-GeV booster synchrotron. This process (see Chapter 3 of the *AFRD Summary of Activities*) is essentially complete; we are now studying the beam dynamics of the injection system and taking as many opportunities as possible to gain operational experience with it. By building our understanding of this complicated system, we will be able to commission the storage ring efficiently in early 1993 and then provide smooth, reliable operations after the facility opens to users.

Beam Electrodynamics

As greater demands are made on the performance of accelerators—such as increased luminosity, as in PEP-II, or lower emittance, as in the ALS—it becomes ever more important to understand potentially disruptive rf phenomena within the beam chamber and to perform various rf "gymnastics" to monitor and control the beam. 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. The Beam Electrodynamics group within the Center approaches these problems through analysis, simulation, and experimentation. In 1992 they contributed to PEP-II by leading the design of rf and feedback systems, analyzed beam impedance and feedback issues at the ALS, and continued their history of contribution to the Tevatron by studying a stochastic beam-cooling upgrade.

B-Factory Contributions

The major rf-design challenge posed by PEP-II is control of coupled-bunch motions. In each of the three directions (horizontal, vertical, and longitudinal), these motions have 1658 modes that may be driven strongly by the higher-order resonances of the rf cavities. Each higher-order cavity mode can drive a hundred or so of these 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 4-8 shows a design for such a cavity and a low-power prototype, designed and analyzed with the aid of the MAFIA code and Kroll-Yu processing of the output. Extensive measurements designed to examine which modes are damped and whether there is interference with the fundamental mode have shown good agreement with expectations; for example, the strongest longitudinal mode, TM_{011}, was predicted to have a loaded Q of less than 30 and was measured to have a loaded Q of approximately 28 (suppressed by more than three orders of magnitude from the unloaded case). We developed a bead-pull perturbation apparatus to measure the impedances of the cavity modes and to map field profiles for mode identification. We are now designing a high-power test model to verify fabrication and

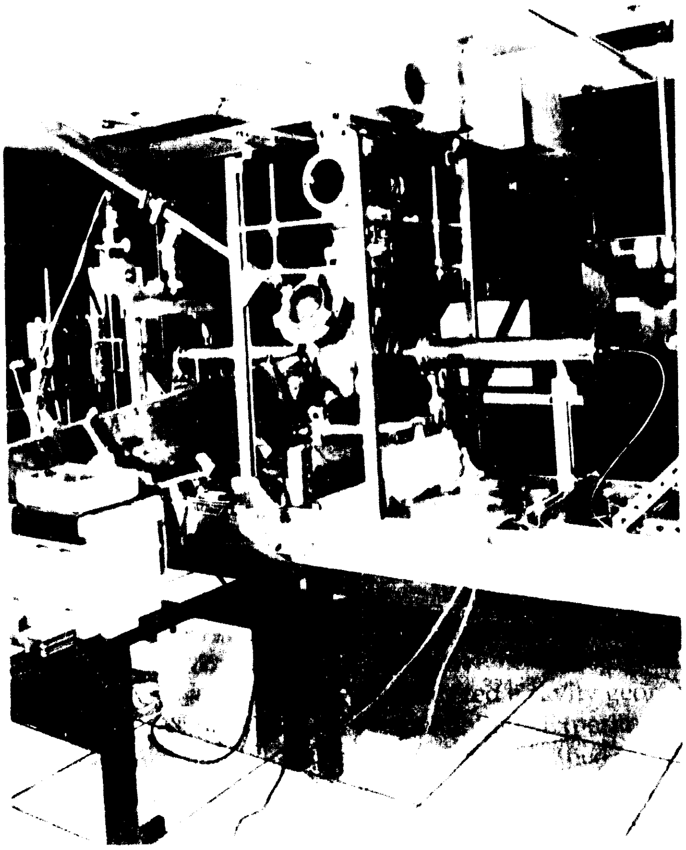


Figure 5. [illegible]

[illegible] of 1.5 GV. It can also be used for further studies of the external loads that dissipate the higher order mode power.

Coupled bunch modes that fall within the width of the fundamental resonance cause an additional, intrinsic impedance. This problem, endemic to large-diameter rings, must be addressed with active rf feedback around the cavity and its driver, a problem that we are now studying in collaboration with SLAC and LLNL. The design of the longitudinal feedback system is proceeding in collaboration with SLAC, and work on the transverse feedback system is about to begin. Computer simulations and calculations of the longitudinal beam motion using the measured higher order mode data have shown that the specified feedback system can safely contain the instabilities excited under the expected worst-case conditions, which occur at injection. The effects of noise on the system are being investigated. It appears that the problem of suppressing coupled bunch modes, although difficult, can indeed be solved.

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 1992, we completed a detailed design and cost estimates for the electrode system and began studying the performance of a prototype module. Full production awaits the results of the study and a go-ahead decision by Fermilab.

FEL Accelerating Cavities

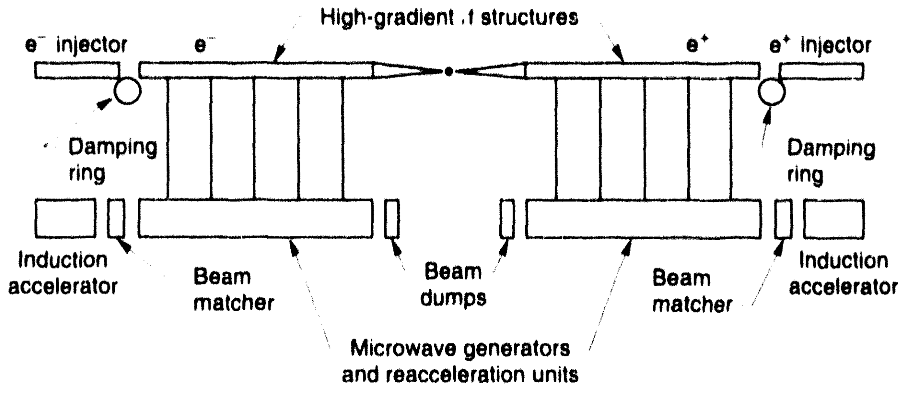
As mentioned in the earlier section on the proposed CDRL IRFEL, minimization of fluctuations in the energy and intensity of an FEL requires stringent maintenance of electron-beam stability. This in turn has implications for the rf cavities in the accelerator and other aspects of the accelerating system. For instance, coupled-bunch motions driven by the higher-order modes of the rf cavity may be excited in a recirculating beam, causing rf voltage fluctuations that make the energy of the beam fluctuate. As part of our collaboration with Stanford, Brookhaven, and TRW, we have performed various experiments in FEL technology.

A two-cell superconducting rf cavity, similar to a cavity of the IRFEL, has been studied extensively with our bead-pull perturbation apparatus in search of higher-order modes. These modes can be damped by putting probes at appropriate locations in the beampipes at the ends of the cavity and connecting them to external resistive loads. A similar copper cavity has been used to study a network for input impedance matching and phase adjustment. In 1993, together with Stanford, we will measure the quality factors of the higher-order modes of this niobium cavity at superconducting temperatures.

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 4-9 illustrates the concept. The first of the two beams is a "drive" beam, generated by an induction linac, that 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 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

* 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.



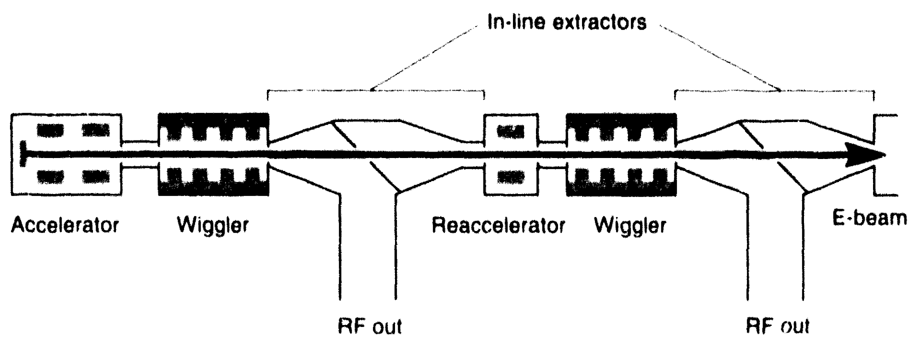
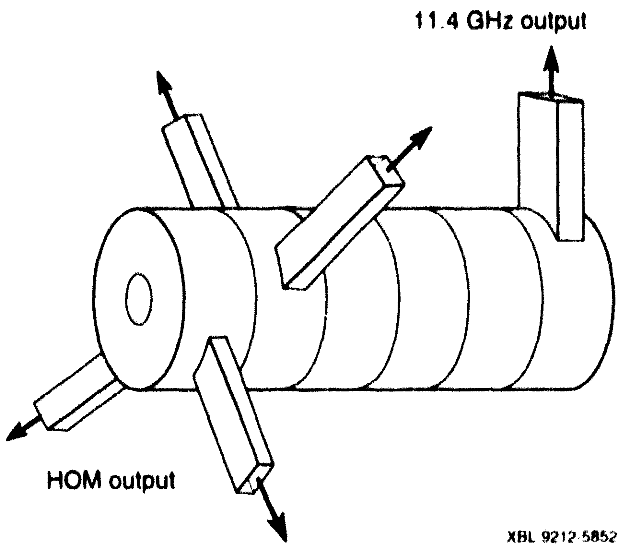


Figure 4-9. As shown in the TBA sketch *above*, a high-current, low-energy drive beam is used for generating rf power that is applied to a high-gradient acceleration structure, where a low-current load beam is accelerated to high energy. The diagram *below* shows the progress of the drive beam through the rf-generating devices (FEL wigglers in this example) and the reacceleration units that replenish the drive beam in between.

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.

Transversely Modulated RK

Initially the TBA/RK work involved longitudinal bunching of the drive beam. This 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. We determined that the problem was beam breakup caused by a spurious higher-order mode generated in the output structure at 13.6 GHz. We have since added a damping structure (Figure 4-10) that removes this higher-order mode; in 3-MeV experiments on the Advanced Technology Accelerator at LLNL, 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 are 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.



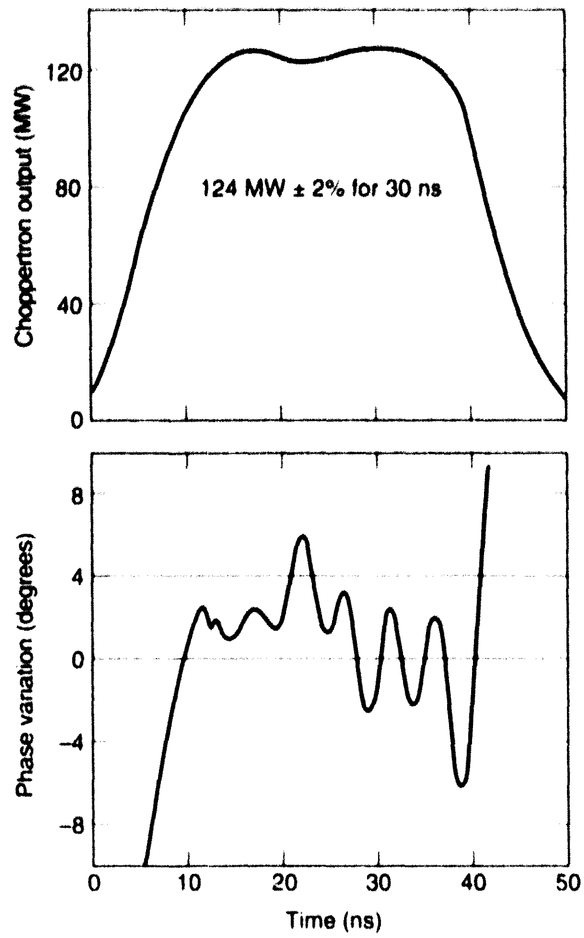


Figure 4-10. When the choppertron was equipped with this structure, a highly disruptive higher-order mode was effectively damped, enabling a 30-ns pulse of 11.4 GHz microwaves at 120 MW. The low phase jitter (about ± 2°) indicates good frequency stability. The next step is to improve the efficiency of the damper so that the power level in the fundamental mode returns to the hundreds-of-megawatts level achieved (in much briefer pulses) without the damper. (After LLNL illustrations)

Standing-Wave FEL

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 and beat-coupled to a nearby high-gradient acceleration structure. This concept is currently undergoing intense analysis and theoretical study, with no experimental program anticipated in the near term.

Horizons for the TBA

The work done on the TBA since we conceived of it 10 years ago has validated the basic concept and the use of either an RK or an FEL as the source of rf power. However, there remains a vast amount of research and development before the TBA can be used in high-energy physics. Here are some of the planned near-term investigations.

- Re-acceleration of the "spent" drive beam (useful for economic reasons) will be examined in a planned 1993 experiment at LLNL.
- There is much theoretical and experimental work to be done in extraction of microwaves from the power source. A demonstration of repeated extraction is being studied at LLNL.

- Sensitivity studies to determine the importance of various parameters will be important. A great deal of theoretical work has been done; coming years will see more studies on real apparatus.
- Economic matters will be significant in the eventual decision on whether to build a full-scale TBA and in the technological choices within such a project. We are working with LLNL on these issues.

A collaboration with KEK is under way, using an FEL from which up to 30 MW can be extracted at 8.6 GHz.

Beam Conditioning

The gain of a free-electron laser 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 is often small, so 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. We have analyzed this idea with a simple numerical model for beam transport, assuming ideal rf cavities. We have also analyzed an FEL to evaluate its performance with reduced axial-velocity spread; these studies lead us to expect distinct improvements from beam conditioning. During 1992 we computationally analyzed a cavity geometry that promises to greatly increase the beam-cavity coupling. Experiments to test the feasibility of a beam-conditioning cavity are being planned for the Accelerator Test Facility at Brookhaven National Laboratory.

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