3. CENTER FOR BEAM PHYSICS

ReportedApril 2005 by John Corlett, Program Head

The Center for Beam Physics (CBP) is a cornerstone program of the Accelerator and Fusion Research Division. The Center is vigorously engaged in a highly productive and tightly knit program of both theoretical studies and experimental research. We bring to bear expertise in accelerator physics and theory, accelerator modeling using high performance computing, beam electrodynamics and instrumentation, and laser-plasma acceleration that is targeted at critical needs of the accelerator-based scientific community.

Our activities range from support of presently operating accelerator facilities such as the Tevatron and PEP-II to the development of new initiatives and advanced accelerator concepts. We provide leadership for – and make significant contributions to – major High Energy Physics initiatives such as LHC, ILC, and muon accelerators, together with a leading-edge research effort in laser-driven, advanced accelerators. In a different arena, Center for Beam Physics staff are also making strong scientific leadership and technical contributions to new concepts for future light sources, developing critical accelerator physics and technologies necessary for next generation synchrotron radiation sources.

The Center is organized into five main groups (Figure 3-1)*: Accelerator Theory, Accelerator Modeling and Advanced Computing (AMAC), Beam Electrodynamics, Collider Physics,* and *l'OASIS*.[1] Our work is supported by state-of-the-art experimental facilities including a 100 TW, 10 Hz laser system in the l'OASIS Laboratory, as well as rf and beam instrumentation equipment at the Lambertson Beam Electrodynamics Laboratory.

The advanced simulations work is performed primarily under the auspices of DOE's highly successful Scientific Discovery through Advanced Computing (SciDAC) program, and it benefits greatly from strong collaboration with colleagues elsewhere in LBNL—notably, mathematicians and computer scientists in the Computing Research Division and the outstanding staff at NERSC. Each of these five main efforts is further described in this chapter. Additional information about the Center can be found on our web site: http://bc1.lbl.gov/CBP_pages/CBP

Scope and Results of CBP Efforts

The Center has a total FY05 budget of ~$8.2M and a staff of approximately 50 full- or part-time members, including scientists, engineers, technical, and administrative support staff, and students.

Training of postdoctoral fellows and students is an important part of the Center's mission; there are presently 4 postdocs (with 2 more expected shortly), 4 PhD

[1] In May 2005, l'OASIS became an AFRD program in its own right.

students, and 2 undergraduates in the Center. We typically host several national and international scientists and scholars each year. We benefit considerably from our proximity to the UC Berkeley campus and have one senior CBP staff scientist as a joint appointment with UC Berkeley Physics Department, in addition to several working relationships with faculty members and students.

The Center has maintained an exceptional record for productivity, which is reflected by the large number of its high quality publications. The work done by Center staff since January 2003 has been reported in approximately 150 publications, about one-third of these in refereed journals. A bibliography is provided at the end of this chapter, along with PDF files of the publications we judged most significant.

The staff at the Center also contribute extensively to the national and international accelerator communities through a variety of service and leadership roles. These include participation on program and organizing committees of major accelerator conferences and workshops, on machine advisory committees and various facility and program review committees, journal refereeing, and service to the International Committee on Future Accelerators, the American Physical Society, and various executive and technical boards.

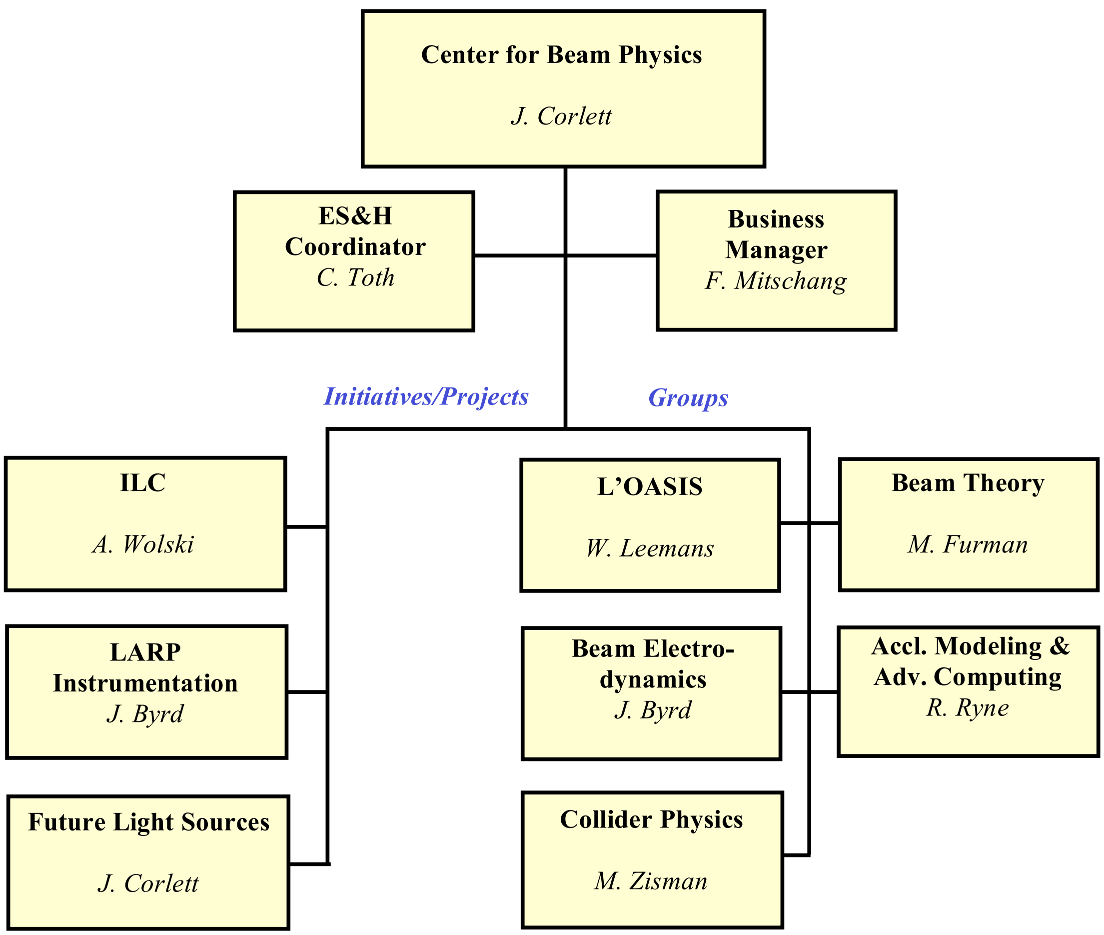

Figure 3-1. CBP comprises five standing groups and, according to need, a number of project/initiative teams.

Strategic View and Technical Progress

Historically, the Center for Beam Physics has been an incubator of new accelerator concepts that support, sustain and enable forefront science. As a strategic planning model, we work to continue this tradition. To do so, we maintain and build upon our ability to conceptualize, construct, commission and upgrade advanced accelerators. We apply these skills in a manner consistent with support of ongoing and future national needs as defined by the scientific community and the DOE/Office of Science *Strategic Plan* and *Facilities for the Future of Science* roadmaps. (It should be noted that 60% of the prioritized initiatives in the Strategic Plan involve accelerator-based science.) This approach is evident in each facet of the Center's activities, as summarized below.

This year an additional section highlights the work of the Accelerator Modeling and Advanced Computing Group, home of numerous activities of cross-cutting benefit to the Center and to others.

Laser –Based Accelerators: The l'OASIS Group

Reported by Wim Leemans, Group Leader

Editor's Note: In May 2005, after the original publication of this chapter for the annual director's review of AFRD, the l'OASIS Group became an AFRD program in its own right. Their 2005 schievements will be reported in a chapter of their own in spring 2006 and thenceforth.

The Center's work on laser-driven accelerators, carried out by the *l'OASIS Group* (Laser Optics & Accelerator Systems Integrated Studies), is focused on the development of laser-based physics and technology for advanced accelerators and fundamental laser-matter interaction physics. Research into all-optical electron production and acceleration (Figures 3-2 and 3-3) at the l'OASIS Laboratory offers hope for small footprint accelerators and ultrafast radiation sources in the future.

Ground-breaking results from the l'OASIS group recently included production of ultrashort bunches of tens of femtoseconds' duration, produced in a plasma channel a few millimeters long, with approximately 500 pC of charge, at energies around 100 MeV, an energy spread of ± 2%, and normalized emittance below 1-2 mm-mrad. Research with capillary plasma channel technology is underway to allow future development of 10 cm-scale accelerating sections, each of which may result in GeV energies of the accelerated electrons.

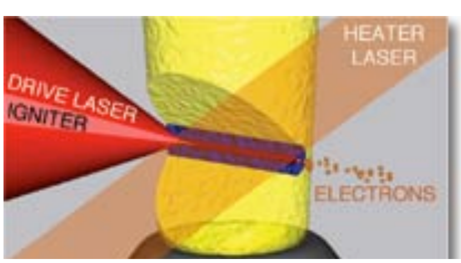

Figure 3-2. *Our laser-plasma accelerator technology uses three pulses from a multi-terawatt, multi-beam titanium:sapphire laser. They are fired in sequence into a plasma of tailored characteristics. First an igniter pulse forms a tiny plasma channel in hydrogen gas. Then a heater pulse expands the channel (also causing a density gradient, low on axis and and high toward the edges). After 500 picoseconds, with the density gradient mature and ions out of the way, an intense drive pulse sets up a wakefield upon which trapped electrons can "surf" to*

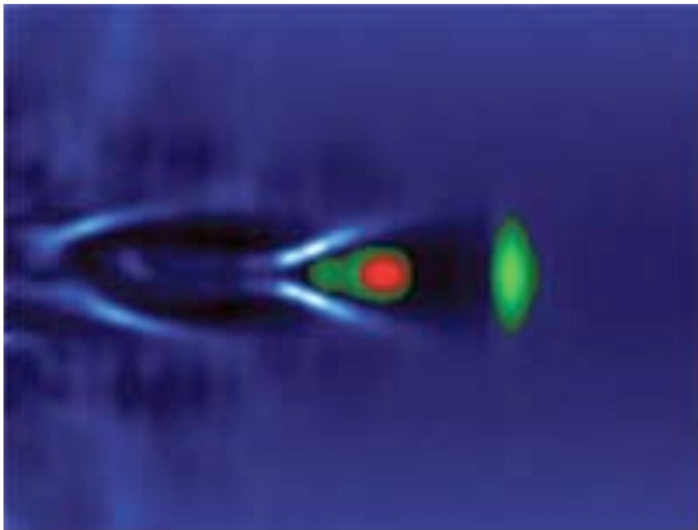

Figure 3-3. High-performance computing helps us understand and improve our laser-plasma accelerators. This simulation came from the code VORPAL, created by Tech-X Corp. and the University of Colorado-Boulder and run at LBNL's National Energy Research Supercomputing Center. A laser pulse (green) *travels from left to right, leaving behind a density modulation (blue and white) in the plasma. This wake can trap a bunch of electrons* (red) *that "surf" the modulation to high energies. A plasma density gradient set up by a "heater" laser pulse—denoted in this simulation by a slight variation of color from the beam axis to the edges—guides the laser and improves electron-beam quality. For more information see http://oemagazine.com/fromTheMagazine/mar05/feature.html and the papers cited at the end of this chapter, such as Nature* ***431****, 538-541 (2004).*

In addition to applications in the high-energy physics community, the high-energy, ultrafast electron bunches can also be used in conventional undulators, producing intense femtosecond intense x-ray pulses.

Throughout the next decade, we plan to continue development of laser-driven electron accelerators as well as compact, high-gradient ion accelerators based on laser interaction with solid targets. The laser based ion accelerator will be explored for its potential as a compact source for isochoric heating of targets for high energy density physics (see also Chapter 1).

We will also explore the laser-driven accelerator's potential use in the front ends of conventional ion accelerators, where it might alleviate the need for low phase velocity structures and thus improve ion beam quality. It may find further application as an economical and efficient source of radioactive beams for nuclear science.

These efforts will initially be centered around the existing l'OASIS Laboratory. It houses a multi-million dollar state-of-the-art Ti:sapphire based laser system that is unique in the US. It is equipped with up to 6 beam lines, shielded target areas (currently with two target chambers), and a remote control room.

We see the second phase as a dedicated user-style facility that could support several external users simultaneously, providing laser beamtime in the manner of existing "Large Scale European Facilities" such as at the VULCAN laser at Rutherford Appleton Laboratory (UK) and the LULI2000 laser at the Ecole Polytechnique (France). LBNL would be a node in a national network of such facilities, as proposed in the SAUUL report.[2]

[2] *The Science and Applications of Ultrafast, Ultraintense Lasers: Opportunities in Science and Technology Using the Brightest Light Known to Man* ("Report on the SAUUL Workshop"), July 2002. Available at http://www.sc.doe.gov/production/bes/chm/Publications/SAUUL_report_final.pdf

Future Colliders for High-Energy Physics

Involvement with conventional accelerators and colliders are important in the Center's strategy. We participate extensively in the development of future accelerator facilities that will be needed by the worldwide HEP community such as the Large Hadron Collider, the International Linear Collider, and the Super Neutrino Beam. Our roles include leadership and significant contributions to design, construction and commissioning. We also provide a modest level of support for ongoing HEP facilities such as the Tevatron and PEP-II.

Meeting Near-Term Needs through LARP

The Beam Electrodynamics, Accelerator Theory, Collider Physics, and Accelerator Modeling and Advanced Computing Groups

In support of near-term HEP objectives, we are part of the US LHC Accelerator Research Program (LARP) in which our involvement is expected to grow over the next few years. This DOE-supported activity follows on directly from our contribution to construction of the Large Hadron Collider, now nearing successful completion at CERN. Our principal activity in LARP, carried out by the *Beam Electrodynamics Group,* is the development of beam instrumentation needed to support LHC commissioning. A bunch-by-bunch luminosity monitor has already been designed and is being tested.

CBP contributions to the LARP program are also under way in the *Accelerator Theory* and *the Accelerator Modeling* and *Advanced Computing Groups*. Working together, these groups have developed a comprehensive parallel 3-D beam-beam code and used it to perform the first ever million-turn, million-macroparticle, strong-strong LHC simulation. Theory and simulations of electron cloud effects in the LHC have also combined into a key component of our LARP activities. An important goal for us is to couple these efforts to subsequent participation in LHC commissioning.

The Collider Physics group is participating in LHC commissioning planning for LARP. This group anticipates providing one or more accelerator physicists for the commissioning task at CERN, and is planning to gain experience via work at Fermilab in Tevatron Run II.

HEP in the Medium-term Future

Linear-Collider Damping Rings and the Accelerator Theory Group

In support of medium-term HEP objectives, the Center has developed a leadership role in R&D for damping rings for a future linear collider. Previously we had responsibility for design studies of the damping rings for the proposed Next Linear Collider, using normal-conducting rf technology. In 2004, the global community decided to focus effort on an International Linear Collider with superconducting rf technology in the main linac.

The expertise we developed for the NLC damping rings is very relevant to the rather different ILC damping rings, and in the short time since the technology decision, we have made a significant contribution to the new machine. The goal of our effort is for LBNL to be given responsibility for the accelerator physics, engineering design, construction, and commissioning of these extraordinarily challenging rings. At this stage, this work is carried out in the Center's *Accelerator Theory Group* and the *Beam Electrodynamics Group*.

One major damping-ring design challenge is achieving the necessary acceptance for the large positron beam produced from the source. The average injected beam power into the damping rings is around 225 kW; loss of even a small fraction of the beam on injection will quickly cause radiation damage to important components. A significant accomplishment this past year has been the design of a lattice that meets the key parameters for damping rates and equilibrium beam sizes, while keeping nonlinear effects small enough that particle trajectories are dynamically stable even at large distances from the nominal orbit and despite the large energy errors expected for individual particles in the injected beam.

The damping rings differ significantly from existing electron storage rings (for example, those in synchrotron light sources) in the length of wiggler magnets required to provide rapid radiation damping. Techniques developed in previous years for modeling nonlinear effects from the wigglers on particle trajectories are now being applied to the ILC damping rings, and will lead to an optimized design for the wigglers. The AMAC group is providing advanced simulation tools for parallel particle tracking, and these tools have been modified in collaboration with the Center's Accelerator Modeling and Advanced Computing (AMAC) Group to study space charge effects.

Compared to the rest of the machine, the damping rings have more effects that threaten the beam quality. Many of these effects—for example, coherent synchrotron radiation in the dipoles and instabilities driven by vacuum chamber impedance— are also relevant to accelerators used in other applications, notably synchrotron light sources. The specifications for beam stability in the ILC damping rings are extremely challenging, and meeting them will require advanced techniques that will be of wide benefit elsewhere.

The scale of the damping rings is indicated by estimates for the hardware costs, which are of order $300M. Construction of a linear collider would therefore provide the opportunity for a substantial contribution from LBNL for developing, delivering and commissioning the damping rings. The Center for Beam Physics is playing a leading role in coordinating the work effectively among different institutions across several time zones. As our work progresses, we build on the existing skills and leadership role of the Center, and strengthen our ability to contribute to other accelerator projects.

Laying Groundwork for the Long-Term Future of HEP

Muon Colliders and the Collider Physics Group

In support of long-term HEP objectives, the Center continues its leadership role in R&D for muon colliders, primarily through our *Collider Physics Group*. This work evaluates feasibility of technical approaches that will be needed to build an advanced muon storage ring to support research in neutrino science. A high-intensity muon storage ring is generally viewed as the ideal source of such neutrinos.

LBNL is the lead laboratory in the Neutrino Factory and Muon Collider Collaboration, and is among the sponsoring laboratories along with BNL and FNAL. The Center is extensively represented on all key technical and executive boards associated with both the Muon Collaboration and the Muon Ionization Cooling Experiment (MICE). If a muon-based accelerator were built in the US, LBNL would desire and expect to play a major role, including responsibility for a major subsystem, such as the front end (including decay channel, phase rotation, bunching, and cooling) or perhaps the storage ring.

LBNL plans to have a substantial role in MICE. We have responsibility for engineering design of the spectrometer solenoid for Phase 1 of MICE, and are to provide the RF-Coupling Coil (RFCC) modules for MICE Phase 2. Staff from the *Beam Electrodynamics* and the *Collider Physics Groups* conduct R&D in support of this effort, and considerable progress has been made this year. An LBNL-built 805 MHz cavity was tested at Lab G at Fermilab, and we have now nearly completed the fabrication of a 201-MHz cavity suitable for the cooling channel specifications of a neutrino factory. A 5-T solenoid that we designed continues to be used to support the rf cavity test program at Fermilab. Both the 5 T solenoid and the 805 MHz cavity have been relocated to the new MUCOOL Test Area (MTA) at Fermilab. The 201 MHz cavity will likewise be tested at the MTA starting this year.

Crosscutting Collaborations in Theory and Modeling

The AMAC, l'OASIS, and Theory Groups

Other distinguishing capabilities within the Center include our expertise in theory and modeling; these activities are carried out primarily in the *Accelerator Theory, l'OASIS*, and *Accelerator Modeling and Advanced Computing (AMAC) Groups*, This overarching expertise is essential to the success of our mission and is applied interactively throughout the activities of the Center.

AMAC operates at the interface between computational science and accelerator science. It works closely with the Computational Research Division and the National Energy Research Supercomputing Center and with other CBP groups, as well as other parts of AFRD, LBNL, and other institutions. Collaborations are key to its success. Its goal is to be a world leader in developing terascale accelerator modeling tools and applying those tools to solving the most important and challenging problems in accelerator science and technology.

Significant advances have been made by the *Accelerator Theory Group* in understanding the electron cloud effect and its impact on many existing and planned accelerators. The Group continues further detailed calibrations of the electron cloud simulations against measurements obtained at the CERN Super Proton Synchrotron in collaboration with CERN personnel during last year's run, progressing toward its goal of fully self-consistent terascale beam simulations of accelerators like PSR and the LHC. These simulations, which include impedances and electron-cloud effects, will help with commissioning and upgrade planning for machines like the Spallation Neutron Source and LHC.

Since October 2002, the Theory Group has participated with the Fusion Energy Program (see Chapter 1) in the integrated study of the electron-cloud effect. This activity, coordinated with Lawrence Livermore National Laboratory, is centered around the HCX driver accelerator located at LBNL, and it encompasses simulations, experimental measurements, and diagnostics developments.

The simulation tool being developed and compared with experimental results is a 3D self-consistent code that has very recently yielded a first-ever simulation of a realistic FODO cell of the arcs in the LHC. This tool is arguably the state of the art in the field, and the model it encompasses will continue to be augmented for ever more realistic and accurate simulations with a goal of a validated predictive tool.

Future Light Sources

Another important element of the Center's strategy relates to our activities in the development of accelerator science and technologies with application in future light sources. National facilities based on advanced accelerator technologies have been identified as highly attractive future "4th Generation" light sources (LBNL's Advanced Light Source being an exemplar of the third generation); see for example the report of the BESAC Subcommittee Workshop on 20-Year Basic Energy Sciences Facilities Roadmap, February 22-24, 2003. A future x-ray science facility at LBNL would enhance the existing substantial scientific activity at LBNL, provide a world-class resource in x-rays, and support the development of scientific and engineering infrastructure at Berkeley Lab.

Using the integrated resources available within the Center for Beam Physics, we have developed the conceptual designs for accelerator based facilities and related technologies for future generation light sources. This effort combines the analytical, computational, and experimental approaches from the *Theory, AMAC,* and *Beam Electrodynamics Groups*.

The critical areas we address are:

- Design of rf photocathode guns for production of high-brightness and high power (high repetition rate) electron beams.
- Development of integrated concepts for production of tailored electron beams by controlled use of laser systems in the rf photocathode gun.
- Design and demonstration of ultra-stable timing and synchronization techniques for accelerator facilities.
- Accelerator physics studies of systems for manipulation and control of the electron beam 6-D emittance.
- Physics studies of optical manipulation of electron beams to enhance radiation production.
- Physics studies of the production of wide-band and tunable temporally and spatially coherent radiation in free-electron lasers (FELs).

Concepts for Techniques and Facilities

Using these technologies, we have developed facility concepts that offer significant advantages. These advantages include a broad wavelength range from extreme ultraviolet to hard x-rays; tunability by using seed lasers and undulator tuning; synchronization between seed laser and sample pump laser; flexibility in pulse duration and in pulse repetition rate; and large flux per pulse using FEL sources.

We have developed concepts for ultra-short-pulse soft x-ray production by cascaded harmonic generation (as in LUX; see http://lux.lbl.gov/), current-enhanced self-amplified spontaneous emission (ESASE), and other free electron laser techniques designed to produce attosecond pulses of x-rays. These schemes provide enhanced performance and capabilities over existing methods for x-ray production.

We conceived and developed ESASE techniques that generate extremely high peak current (~1-10 kA) micro-bunches within an electron beam bunch, with only limited beam quality degradation due to collective effects. This technique has particularly attractive features for the LCLS project being built at SLAC, where the much shorter gain length results in more rapid saturation of the radiation field, easing requirements on the LCLS electron beam quality or reducing the undulator length needed.

Synchronization between the interrogating x-ray pulse and a sample pump laser pulse will be critical for high-resolution pump-probe experiments with ultra-short x-ray pulses on future light sources. Addressing this issue, we have designed and built a fiber-optic based system involving a master laser and stabilized optical distribution for providing precision timing signals and frequency references over ~100 m distance. Timing errors in 100-m fiber have already been reduced from several picoseconds to 200 femtoseconds, and we are actively incorporating a set of optical techniques to reduce these timing errors to tens of femtoseconds and lower. A concept to enable locking of remote lasers has been developed, transmitting low-power cw signals over the stabilized fiber link, and experiments are to begin in spring 2005.

To produce high brightness electron bunches at the high repetition-rate commensurate with laser pump-probe studies, we have conceived and developed the engineering design for an rf photocathode electron gun designed to operate at 10 kHz bunch repetition rate. In conjunction with rf cavity design work and beam dynamics studies, we have developed a phototcathode laser concept to produce tailored, high-brightness electron bunches through precise control over the spatial and temporal intensity profiles of laser pulses.

In addition to forefront research and leadership in accelerator physics and technology studies for future light sources, CBP staff are pursuing leadership roles and responsibilities in support of the LCLS hard x-ray FEL facility, and in the FERMI @ Elettra VUV-soft x-ray FEL facility proposed by Sincrotrone Trieste.

In Summary…

The Center for Beam Physics serves as a national resource supporting the accelerator-based scientific community. It is maintaining its historical role of leadership and contributions to the field and has a strategic approach to carry this tradition into the future.

The next section gives details of the recent accomplishments of the Accelerator Modeling and Advanced Computing group (AMAC), which we highlight this year because their activities have numerous cross-cutting benefits to other work in CBP and elsewhere.

The final two sections of this chapter list our featured publications—those papers that we thought representative of our best recent achievements. PDFs of the featured publications are included on this CD; just click the links to read those you find interesting. The last section gives a full bibliography.

Accelerator Modeling and Advanced Computing

The mission of the Accelerator Modeling and Advanced Computing (AMAC) group is to support the needs of the Department of Energy's Office of Science, especially its high-energy and nuclear physics programs, with regard to accelerator simulation, design, and analysis. Our core capability is Computational Accelerator Science, which involves the fusion of several fields, including, among others, accelerator physics, scientific computing, computer science, and applied mathematics. Our primary focus is computational beam dynamics. We develop codes such as IMPACT, MARYLIE/IMPACT, and BEAMBEAM3D, all of which run on high-end computing platforms (i.e., parallel computers), to solve some of the most demanding computational problems in accelerator science and technology.

AMAC's success has benefited greatly from strong collaboration with organizations within LBNL and elsewhere. Within CBP, we collaborate with the Theory Group, the l'OASIS Laboratory, the Beam Electrodynamics Group, and the ILC program. We also collaborate with beam physicists elsewhere in AFRD, notably in the Heavy Ion Fusion Virtual National Laboratory.

Our work also extends to the ALS Division, the Computational Research Division, and NERSC. Outside of LBNL, we have many collaborators, several of whom participate in the Accelerator Science and Technology project of the Scientific Discovery through Advanced Computing (SciDAC) program. These include SLAC, Fermilab, BNL, LANL, UCLA, USC, the University of Maryland, and Tech-X corporation. We also collaborate with international institutions such as KEK, RAL, GSI, and CERN.

AMAC's activities fall mainly into four categories: software development, algorithm development, software application, and community interaction. Here we take the opportunity to provide some additional detail in two of these areas: software development and algorithm development.

Software Development

AMAC develops and maintains state-of-the art, fully 3-D particle-simulation codes for modeling beams in a wide range of accelerator systems, including electron and ion machines, be they linacs, rings, or colliders. We use particle-in-cell (PIC) techniques to compute space-charge effects by depositing charge on a computational grid, solving Poisson's equation on that grid, and interpolating the fields back to the particle positions.

The use of PIC methods for modeling what are essentially collisionless systems is well established in computational beam physics, plasma physics, and astrophysics, and it is orders of magnitude more efficient than direct particle-particle methods. Even so, the need to deposit particles on a 3D grid leads to a large number of simulation particles (about a million for *low* resolution simulations). This in turn makes parallel computing essential for reasonable turnaround times and the ability to perform parameter scans.

AMAC currently develops and maintains three code packages: IMPACT (for modeling beams with space charge in accelerator components, beam transport systems, and linacs), MARYLIE/IMPACT (primarily for modeling beams in circular accelerators), and BEAMBEAM3D (for modeling beam-beam effects in colliders).

Impact

IMPACT[3] was originally developed by R. Ryne and others at Los Alamos National Laboratory in the 1990s to model beams with space charge in ion linacs. Responsibility has been taken over by J. Qiang of the AMAC Group, under whose leadership the code's capabilities have been greatly expanded. As a result, it is now in use at several institutions in the US, and it is gaining interest from international institutions such as KEK, RAL, and GSI. Recent activities include:

- Development of IMPACT-T, a version that uses time as the independent variable (in contrast to IMPACT, which uses axial distance z). It being used at several locations to model photoinjectors.
- Adding an energy binning function to IMPACT so as to model beams with large energy spread, e.g., beam bunches emerging from early laser/plasma experiments.
- Adding multi-charge-state capability to IMPACT (done for the Rare Isotope Accelerator project).
- Inclusion of several new Poisson solvers, including a solver that takes geometry into account. This was developed for the RIA project to model low energy beam transport of a beam out of an ECR ion source. An example is shown in Figure 3-4.

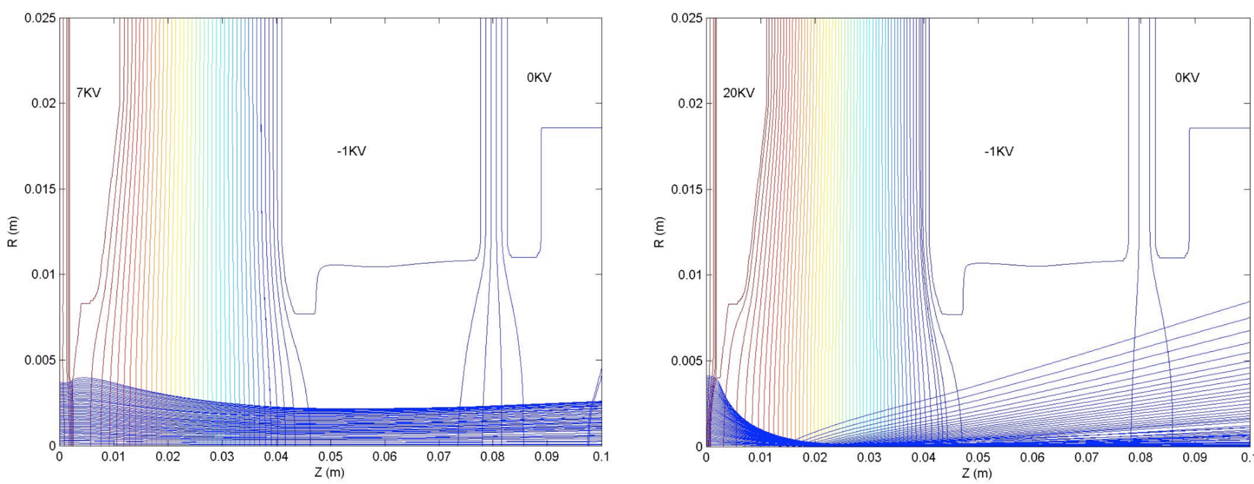

Figure 3-4. *IMPACT-T simulations of beam transport out of an ECR ion source, showing the effect of electrode voltage and the beam transport. This work was performed in collaboration with the Nuclear Sciences Division under a RIA R&D project.*

---

[3] J. Qiang, R.D. Ryne, S. Habib, and V. Decyk, "An object-oriented parallel particle-in-cell code for beam dynamics simulation in linear accelerators," *J. Comp. Phys.* **163**, 434-451 (2000).

MARYLIE/IMPACT

MARYLIE/IMPACT is a hybrid code that combines the Lie-algebraic high-order optics and tracking capabilities of MARYLIE with the 3D space-charge capability of IMPACT. It also contains IMPACT's rf cavity model, so the code can model beam with and without space charge, with and without acceleration. Recent activities include:

- Inclusion of a capability to read beamlines in the Standard Input Format (i.e. "MAD" format).
- Inclusion of an embedded 3D envelope code.
- Development of "automatic" commands that provide a simple way for the user to slice elements for space-charge calculations, make ray plots, and make lattice function plots.
- Development of a manual and a suite of examples.

BEAMBEAM3D

BEAMBEAM3D[4] is a comprehensive parallel PIC code for modeling beam-beam collisions in colliders. Developed by J. Qiang of AMAC, it provides a good example of the synergy of AMAC with the rest of CBP, as this code benefited from input by M. Furman (head of the CBP Theory Group).

BeamBeam3D has both weak-strong and strong-strong modeling capabilities, as well as the ability to model several types of collisions (head-on, crossing angle, and long-range). It has been used to model the Tevatron, PEP-II, RHIC, and the LHC. To provide a sense of the computational requirements, consider our ongoing beam-beam simulations of the LHC, which up to now have been performed on seaborg (an IBM/SP3 at NERSC) and cheetah (an IBM/SP4 at the CCS at ORNL). The largest simulations performed to date have used 2 bunches, using 2 million simulation particles per bunch, modeled for a total of 2 million machine turns, and assuming one interaction region (IR). A single simulation on 128 processors required more than 50 hours on cheetah and more than 100 hours on seaborg. We are currently pursuing the possibility of using a Cray X-1 at ORNL, which has the potential to be 10-15 times faster than seaborg, in order to perform multi-IP simulations and to perform simulations using multiple beam bunches. Recent enhancements to BEAMBEAM3D include:

- Incorporation of new Poisson solvers for improved performance and accuracy, including one based on an Integrated Green function and one based on a nonuniform grid.
- Ability to treat energy variation during collisions.
- Ability to treat multi-bunch trains and multiple collision points.

---

[4] J. Qiang, M.A. Furman, R.D. Ryne, "A Parallel Particle-In-Cell Model for Beam-Beam Interactions in High Energy Ring Colliders," *J.Comp.Phys.*198:278-294 (2004).

Algorithm Development

AMAC's main algorithmic requirements are related to Poisson solvers needed in our PIC codes.[5,6,7,8] Some of these algorithms are developed by collaborators, such as members of the SciDAC Applied Partial Differential Equations Center. Other algorithms, especially those that are somewhat accelerator-specific, are developed in-house. Examples of algorithms that we have developed include those based on integrated Green's functions (which are useful for modeling high-aspect ratio conditions) and shifted Green's functions (useful for modeling long-range beam-beam collisions), as well as algorithms for beams in toroidal pipes that use the ratio of the pipe radius to the radius of curvature as an expansion parameter, and solvers based on wavelets.

Wavelet-based Solvers

Work carried out by a member of AMAC (I. Pogorelov) under an LDRD project in collaboration with Northern Illinois University has resulted in the successful implementation of a 3D wavelet-based algorithm for the fast solution of the Poisson equation subject to inhomogeneous Dirichlet boundary conditions.[9]

Several factors led us to pursue the development of a solver operating in a wavelet basis. For example, multi-resolution representations of the Laplacian provide two important advantages: (i) the operator remains sparse in a wavelet basis, and (ii) preconditioners exist that are effectively diagonal in wavelet bases. Our preconditioned conjugate gradient (PCG) Poisson solver was designed to take full advantage of this combination of circumstances. And, because Poisson's equation has to be solved at every timestep, we were able to use the potential computed in the previous timestep as a good initial approximation for the iterative solution to the current one.

The solver was first tested as a stand-alone solver on two 3D model distributions--one used in galactic dynamics, the other in charged particle beam dynamics modeling. The solver was subsequently successfully integrated into the IMPACT suite of codes for 3D beam dynamics modeling, and applied to modeling the Fermilab/NICADD photoinjector. The results produced by both the standard distribution of IMPACT and by the version incorporating the wavelet-based PCG solver were found to be in excellent agreement in terms of a standard set of diagnostics (Figure 3-5).

---

[5] J. Qiang, M. Furman, and R. Ryne, "Strong-Strong Beam-Beam Simulation Using a Green Function Approach," *Phys. Rev. ST Accel. Beams*, vol 5, 104402 (October 2002).

[6] J. Qiang and R. Gluckstern, "Three-Dimensional Poisson Solver for a Charged Beam with Large Aspect Ratio in a Conducting Pipe," submitted to *Comp. Phys. Comm* (2004).

[7] McCorquodale P, Colella P, Grote DP, Vay JL, "A node-centered local refinement algorithm for Poisson's equation in complex geometries", submitted to *J. of Comp. Phys.* (2004)

[8] J. Qiang and R. Ryne, "Parallel 3D Poisson Solver for a Charged Beam in a Conducting Pipe," *Computer Physics Communications* 138, 18 (2001).

[9] [7] B. Terzic and I.V. Pogorelov, "Wavelet-Based Poisson Solver for Use in Particle-in-Cell Simulations," *in* Nonlinear Dynamics in Astronomy and Physics, J.R. Buchler and S.T. Gottesman, Eds.: Ann. N. Y. Acad. Sci. (*accepted*); preprint: http://www.math.fsu.edu/~bterzic/Research/tp2005.pdf (2004).

The new solver still needs to be optimized, and detailed comparisons of algorithm performance and accuracy still need to be done. To our knowledge, this work constitutes the first application of the wavelet-based multiscale methodology to 3D computer simulations in beam dynamics.

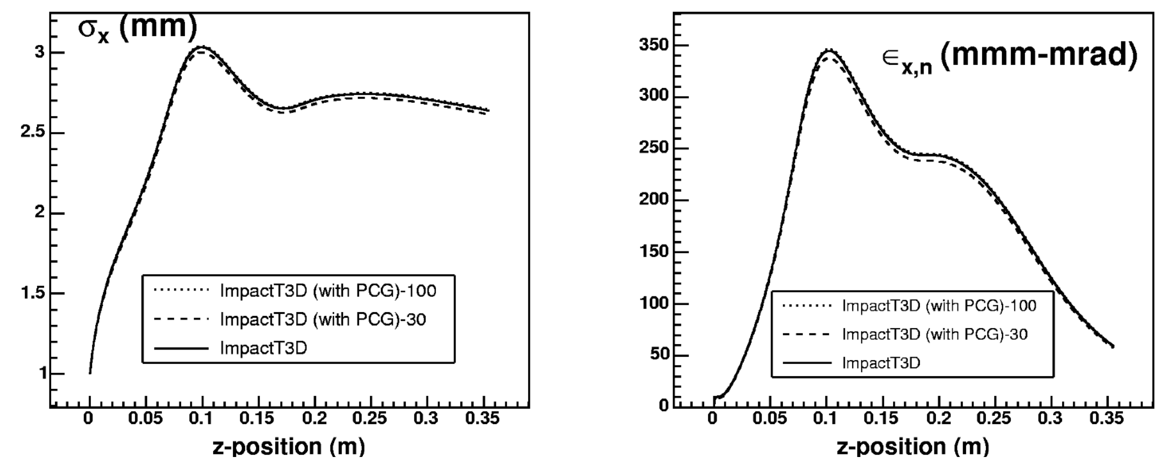

Figure 3-5. *Simulation results for the Fermilab/NICADD photoinjector done with the standard version of* IMPACT *(solid lines),* IMPACT *with preconditioned conjugate gradient (PCG) wavelet-based solver with 30x30 coefficients (dashed line), and PCG with 100x100 coefficients. Excellent agreement was found for quantities such as the rms beam size (*left*) and the rms emittance (*right*).*

High Aspect Ratio Poisson Solvers

Many beam-based systems involve high aspect ratios. Examples include flat beams, long beams in induction machines, and long beams in accumulator rings. Mathematically, some of the solvers that are now in widespread use lose accuracy unless a very large number of grid points are used in the "long" dimension, even though the beam density itself may vary slowly. The "Hockney algorithm" for treating open systems[10] represents one such algorithm that loses accuracy in high aspect ratio situations unless very many grid points are used. Work carried out by AMAC has shown that the use of an integrated Green's function (IGF) is a very promising approach to dealing with such systems.

A 2D example is shown in Figure 3-6. These plots show the error in the computed electric field, E_x, for a Gaussian charge distribution with an rms beam size of 1 mm in the x direction and 500 mm in the y direction. Notice that the vertical scale on the left hand plot (based on the Hockney algorithm using a 64x2048 grid) extends to 1, indicating errors between 10% and 100%. The vertical scale on the right-hand plot (based on the IGF method using a 64x64 grid) extends to only 0.01, indicating errors of less than 1%.

A quantitative comparison is more easily seen by comparing the results on a line through the Gaussian distribution near y=0; this is shown in Figure 3-7, using the Hockney algorithm with three grid sizes (64x2048, 64x4096, 64x8192) and the IGF method using a grid size of 64x64. In the central region the error using the Hockney method is nearly 10 times larger than the IGF method even when the grid size is 64x8192.

While the IGF approach requires more effort to set up, it is highly parallelizable. Furthermore, if the grid size is fixed, the setup time is negligible when amortized over many

[10] R.W. Hockney and J.W. Eastwood, *Computer Simulations Using Particles*, Institute of Physics Publishing, London, 1988.

thousands of time steps. In this case, neglecting the setup time, the IGF leads to *a performance increase of nearly 1000*. We have already verified (with the help of a symbolic algebra code) that the IGF approach can be extended to 3D. Such a solver is also expected to be useful in modeling certain astrophysical contexts, e.g. studying the morphology of disk galaxies, as well as galaxy mergers.

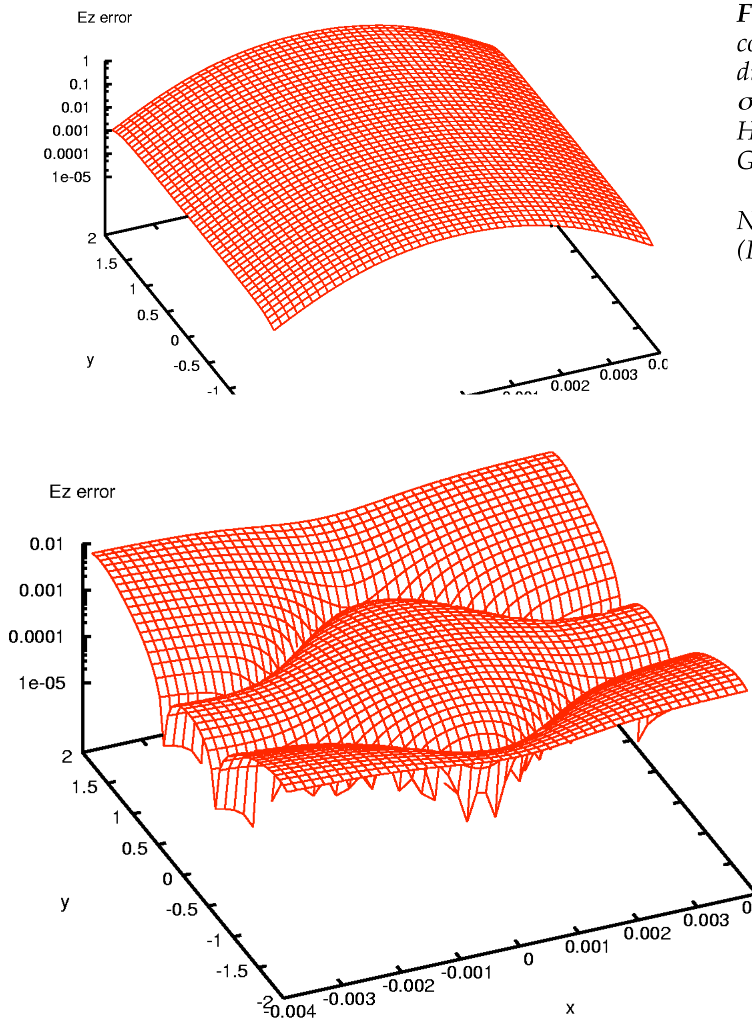

Figure 3-6. *Numerical error in the computed electric field of a Gaussian distribution of charge having rms sizes* σ_x*=1mm and* σ_y*=500mm.* Upper: *Hockney algorithm*. Lower: *integrated Green's function (IGF).*

Notice that the vertical scale in the lower (IGF) plot is 100 times smaller.

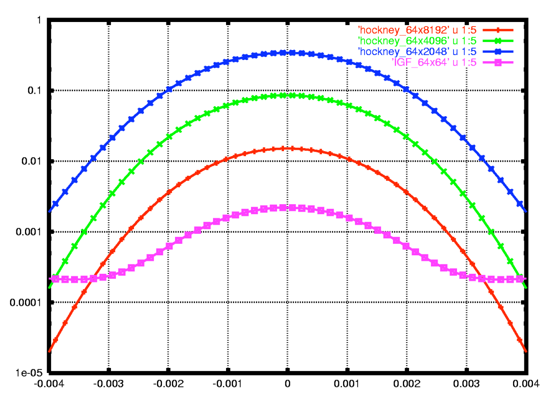

Figure 3-7*. Numerical error in the computed electric field of a Gaussian distribution of charge (*σ_x*=1mm and* σ_y*=500mm) comparing the Integrated Green Function (IGF) method with the Hockney algorithm. The plot shows the error in the x-component of electric field (vertical axis) plotted as a function of x (horizontal axis) along a line near y=0. Even using a grid size of 64x8192, the Hockney method is less accurate over most of the physical domain than the 64x64 IGF calculation.*

Featured Publications

These publications, chosen upon the advice of the Center's group leaders, best represent our accomplishments from summer 2004 (i.e., just after the last review) to spring 2005. This list is organized by research group. The collaborative nature of many of the Center's activities causes some publications to appear under more than one heading.

Beam Electrodynamics Group

F. Sannibale, J.M. Byrd, A. Loftsdottir, M. Venturini, M. Abo-Bakr, J. Feikes, K. Holldack, P. Kuske, G. Wustefeld, H.-W. Hubers, and R. Warnock, "A model describing stable coherent synchrotron radiation in storage rings," Physical Review Letters. **93**, 9 (27 August 2004), pp. 094801/1-4; LBNL-PUB-890.

J.M. Byrd, M.C. Martin, W.R. McKinney, D.V. Munson, H. Nishimura, D.S. Robin, F. Sannibale, R.D. Schlueter, W.G. Thur, J.Y. Jung, and W. Wan, "CIRCE: a dedicated storage ring for coherent THz synchrotron radiation," Infrared Physics & Technology, **45**, 5-6 (Oct. 2004), pp. 325-30; LBNL-53699.

J.-F. Beche, J. Byrd, P. Datte, S. De Santis, M. Placidi, V. Riot, R. Schoenlein, W. Turner, and M. Zolotorev, "A laser-based longitudinal density monitor for the Large Hadron Collider," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 – 9, 2004); LBNL-55209.

J. N. Corlett, W. A. Barletta, S. DeSantis, L. Doolittle, W.M. Fawley et al., "LUX – a design study for a linac/laser-based ultrafast x-ray source," in *Proceedings* of Fourth Generation X-Ray Sources and Optics II (Denver, CO, August 2004), SPIE Proc. Vol. 5534; LBNL-57430.

Collider Physics Group

I. Reichel, M.S. Zisman, M. Placidi, K. Gollwitzer, and S. Werkema, "Aperture studies for the AP2 anti-proton line at Fermilab," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 – 9, 2004), p. 1491; LBNL-54096.

M.S. Zisman, "Neutrino factory R&D in the U.S.," in *Proceedings* of NuFact03, 5th International Workshop on Neutrino Factories & Superbeams (Columbia University, New York, NY, June 5-11, 2003); AIP Conf. Proc. 721, p. 60; LBNL-53832.

M.S. Zisman, "R&D toward neutrino factories and muon colliders," in *Proceedings* of the 2003 Particle Accelerator Conference (Portland, OR, May 2003), IEEE Cat. No. 03CH37423 (IEEE, Piscataway, NJ, 2003), p. 361; LBNL-53126.

l'OASIS Group

C.G.R. Geddes, Cs. Toth, J. van Tilborg, E.H. Esarey, C.B. Schroeder, D. Bruhwiler, C. Nieter, J. Cary, and W.P. Leemans, "High quality electron beams from a plasma channel guided laser wakefield accelerator," Nature **431**, 538-541 (2004); LBNL-55732.

J. van Tilborg, C.B. Schroeder, E. Esarey, and W.P. Leemans,"Pulse shape and spectrum of coherent diffraction-limited transition radiation from electron beams," Laser Particle Beams **22**, 415-422 (2004); LBNL-55868.

J. Faure, J. van Tilborg, K.A. Kaindl, and W.P. Leemans, "Modelling laser-based table-top THz sources, optical rectification, propagation and electro-optic sampling," Optical & Quantum Electronics **36**, 8 (June 2004), pp. 681-97; LBNL-57136.

W.P. Leemans, E. Esarey, J. van Tilborg, P.A. Michel, C.B. Schroeder, Cs. Toth, C.G.R. Geddes, and B.A. Shadwick, "Radiation from laser accelerated electron bunches: coherent terahertz and femtosecond x-rays," IEEE Trans. Plasma Sci., accepted (2005); LBNL-56584.

C.G.R. Geddes, Cs. Toth, J. van Tilborg, E. Esarey, C.B. Schroeder, D. Bruhwiler, C. Nieter, J. Cary, and W.P. Leemans. "Production of high quality electron bunches by dephasing and beam loading in channeled and un-channeled laser plasma accelerators," *invited paper*, Phys. Of Plasmas (in press); LBNL-57062.

B.A. Shadwick, G.M. Tarkenton, E. Esarey, and C.B. Schroeder, "Fluid and Vlasov models of low temperature, collisionless laser-plasma interactions," *invited paper*, Phys. Plasmas, accepted (2005); LBNL-57061.

AMAC Group

J. Qiang, R.D. Ryne, and I. Hofmann, "Space-charge driven emittance growth in a 3D mismatched anisotropic beam," Phys. Rev. Lett. **92**, 174801 (2004), LBNL-51807.

T.P. Wangler, C.K. Allen, K.C.D. Chan, P.L. Colestock, K.R. Crandall, R.W. Garnett, J.D. Gilpatrick, W. Lysenko, J. Qiang, J.D. Schneider, M.E. Shulze, R.I. Sheffield, and H.V. Smith, "Beam-halo in mismatched proton beams," Nucl. Instrum. Meth. A **519**, 425 (2004); LBNL-56055.

J. Qiang, "Halo formation due to beam-beam interactions of beams optically mismatched at injection," Physical Review Special Topics: Accelerators and Beams **7,** 031001 (2004); LBNL-56054.

J. Qiang, M. Furman, and R. Ryne, "A parallel particle-in-cell model for beam-beam interactions in high energy ring colliders," accepted by J. Comp. Phys. (2004); LBNL-54598.

J.L. Vay, P. Colella, J.W. Kwan, P. McCorquodale, D.B. Serafini, A. Friedman, D.P. Grote, G. Westenskow, J.C. Adam, A. Héron , and I. Haber, "Application of adaptive mesh refinement to particle-in-cell simulations of plasmas and beams," Phys. of Plasmas (in press); LBNL-53551.

Theory Group

A. Wolski, G. Penn, A. Sessler and J. Wurtele, "Beam conditioning for free electron lasers: consequences and methods," Physical Review Special Topics: Accelerators and Beams **7,** 080701; LBNL-53899 (2004).

R. Cimino, I.R. Collins, M.A. Furman, M. Pivi, F. Ruggiero, G. Rumolo, and F. Zimmermann, "Can low energy electrons affect high energy physics accelerators?," Phys. Rev. Lett. **93**, 014801 (29 June 2004); CERN-AB-2004-012; LBNL-54594; SLAC-PUB-10350.

Y. Honda, A. Wolski, et al., "Achievement of ultralow emittance beam in the Accelerator Test Facility damping ring," Phys. Rev. Lett. **92**, 054802 (31 January-6 February 2004); LBNL-57214.

M. Babzien, I. Ben-Zvi, I. Pavlishin, I.V. Pogorelsky, V.E. Yakimenko, A.A., Zholents, and M. S. Zolotorev, "Optical stochastic cooling for RHIC," in T. Katayama and T. Koseki, eds., *Proceedings* of the International Workshop on Beam Cooling and Related Topics (Lake Yamanaka, Yamanashi, Japan, 2003), Nucl. Instrum. Meth. A **532**, 1-2, pp. 345-7; LBNL-57307.

A. A. Zholents and W. M. Fawley, "Proposal for intense attosecond radiation from an x-ray free-electron laser," Phys. Rev. Lett. **92**, 224801 (29 May-4 June 2004).

A.A. Zholents and W.M. Fawley, "Toward attosecond x-ray pulses from the FEL," in Sandra G. Biedron, Wolfgang Eberhardt, Tetsuya Ishikawa, Roman O. Tatchyn, editors, *Proceedings* of Fourth Generation X-Ray Sources and Optics II (Denver, August 2004), SPIE Proc. 5534 (Nov. 2004).

Corlett, John, William M. Fawley, Gregory Penn, Alexander A. Zholents , Weishi Wan, Matthias Reinsch, and Jonathan Wurtele, "Harmonic cascade FEL designs for LUX, a facility for ultrafast x-ray science," in *Proceedings* of the 2004 FEL Conference (Trieste, Italy, August 29-September 3, 2004; LBNL-55020_Conf.

Alexander A Zholents and William M. Fawley (LBNL); Paul J Emma, Zhirong Huang, and Gennady Stupakov (SLAC); and Sven Reiche (UCLA), "Current-enhanced SASE using an optical laser and its application to the LCLS," in *Proceedings* of the 2004 FEL Conference (Trieste, Italy, August 29-September 3, 2004); LBNL-54967.

Full Publications List

Publications from the last review (May 2004) to date are listed here, organized by group and then by level of scholarly review. Because of the collaborative and discipline-crossing nature of the Center, some publications are reported under more than one group.

Beam Electrodynamics Group

Refereed Publications

J. Byrd and S. De Santis, "An optical sampling technique for measuring the longitudinal beam density in a storage ring," submitted to Nucl. Instrum. Meth. A (August 2004); LBNL-56101.

F. Sannibale, J.M. Byrd, A. Loftsdotir, M, Venturini, M. Abo-Bakr, J. Feikes, K. Holldack, P. Kuske, G. Wustefeld, H.-W. Hubers, and R. Warnock, "A model describing stable coherent synchrotron radiation in storage rings," Physical Review Letters **93**, 094801 (Aug. 27, 2004), pp. 1-4; LBNL-PUB-890.

Unrefereed Conference Proceedings and Other Publications

F. Sannibale, J. M. Byrd, A. Loftsdottir, M. C. Martin, M. Venturini, "Fundamentals of coherent synchrotron radiation in storage rings," in *Proceedings* of the Eighth International Conference on Synchrotron Radiation Instrumentation (San Francisco, CA, August 25-29, 2003), American Institute of Physics Conf. Proc. **705**:141-144; LBNL-55823.

J. N. Corlett, W. A. Barletta, S. DeSantis, L. Doolittle, W.M. Fawley, et al., "LUX – a design study for a linac/laser-based ultrafast x-ray source," in Sandra G. Biedron, Wolfgang Eberhardt, Tetsuya Ishikawa, Roman O. Tatchyn, editors, *Proceedings* of Fourth Generation X-Ray Sources and Optics II (Denver, August 2004, SPIE Proc. 5534 (Nov. 2004).

J.-F. Beche, J. Byrd, P. Datte, S. De Santis, M. Placidi, V. Riot, R. Schoenlein, W. Turner, and M. Zolotorev, "A laser-based longitudinal density monitor for the Large Hadron Collider," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-55209.

J.-F. Beche, J. Byrd, , S. De Santis, P. Denes, M. Placidi, W. Turner, and M. Zolotorev, "Development of an abort gap monitor for high-energy proton rings," in *Proceedings* of BIW 2004, the 11th Beam Instrumentation Workshop (Knoxville, TN, 8-11 May 2004); LBNL-56562.

J.M. Byrd, "Luminosity monitor for the Large Hadron Collider," in *Proceedings* of BIW 2004, the 11th Beam Instrumentation Workshop (Knoxville, TN, 8-11 May 2004); LBNL-55825.

J.M. Byrd, M.C. Martin, W.R. McKinney, D.V. Munson, H. Nishimura, D.S. Robin, f. Sannibale, R.D. Schlueter, W.G. Thur, J.Y. Jung, and W. Wan, "CIRCE: a ring-based

source of coherent synchrotron radiation," in *Proceedings* of the Eighth International Conference on Synchrotron Radiation Instrumentation (San Francisco, CA, August 25-29, 2003), American Institute of Physics Conf. Proc. **705**:137-140.; LBNL-55826.

J.-F. Beche, J. Byrd, S. De Santis, M. Placidi, W. Turner, and M. Zolotorev, "Development of an abort gap monitor for the Large Hadron Collider," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-55208.J.-F. Beche, J. Byrd, P. Datte, S. De Santis, M. Placidi, V. Riot, R. Schoenlein, W. Turner, and M. Zolotorev, "A laser-based longitudinal density monitor for the Large Hadron Collider," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-55209.

Byrd, J.M., M.C. Martin, W.R. McKinney, D.V. Munson, H. Nishimura, D.S. Robin, F. Sannibale, R.D. Schlueter, W.G. Thur, J.Y. Jung, and W. Wan, "CIRCE: a dedicated storage ring for coherent THz synchrotron radiation," in *Proceedings* of the International Workshop on Infrared Microscopy and Spectroscopy with Accelerator-Based Sources (Lake Tahoe, CA, July 8-11, 2003), Infrared Physics and Technology **45** (5-6), 325-330 (2004); LBNL-53699.

J.M. Byrd, Z. Hao, M.C. Martin, D.S. Robin, F. Sannibale, R.W. Schoenlein, M. Venturini and A.A. Zholents, "Coherent infrared radiation from the ALS generated via femtosecond laser modulation of the electron beam," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-55688.

A.S. Loftsdottir, J. Byrd, and F. Sannibale, "Study of potential well distortion due to radiation impedance," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-55822.

l'OASIS Group

Refereed Publications

J. Faure, J. van Tilborg, K.A. Kaindl, and W.P. Leemans, "Modelling laser-based table-top THz sources, optical rectification, propagation and electro-optic sampling," Optical & Quantum Electronics **36**, no. 8, June 2004, pp. 681-97; LBNL-57136**.**

G. Fubiani, E. Esarey, C.B. Schroeder, and W.P. Leemans, "Beat wave injection of electrons into plasma waves using two interfering laser pulses," Phys. Rev. E **70**, 016402 (2004); LBNL-53506.

C.G.R. Geddes, Cs. Toth, J. van Tilborg, E. Esarey, C.B. Schroeder, D. Bruhwiler, C. Nieter, J. Cary, and W.P. Leemans, "Guiding of relativistic laser pulses by preformed plasma channels," submitted to Phys. Rev. Lett., submitted (2004); LBNL-57058.

C.G.R. Geddes, Cs. Toth, J. van Tilborg, E. Esarey, C.B. Schroeder, D. Bruhwiler, C. Nieter, J. Cary, and W.P. Leemans. "Production of high quality electron bunches by dephasing andbeam loading in channeled and unchanneled laser plasma accelerators," invited paper, Phys. Of Plasmas (in press, 2005); LBNL-57062.

C.G.R. Geddes, Cs. Toth, J. van Tilborg, E.H. Esarey, C.B. Schroeder, D. Bruhwiler, C. Nieter, J. Cary, and W.P. Leemans, "High quality electron beams from a plasma channel guided laser wakefield accelerator," Nature **431**, 538-541 (2004); LBNL-55732.

W.P. Leemans, E. Esarey, J. van Tilborg, P.A. Michel, C.B. Schroeder, Cs. Toth, C.G.R. Geddes, and B.A. Shadwick, "Radiation from laser accelerated electron bunches: coherent terahertz and femtosecond x-rays," IEEE Trans. Plasma Sci. (in press, 2005); LBNL-56584.

W.P. Leemans, J. van Tilborg, J. Faure, C.G.R. Geddes, Cs. Toth, C.B. Schroeder, E. Esarey, G. Fubiani, and G. Dugan, "Terahertz radiation from laser accelerated electron bunches," *invited paper*, Phys. of Plasmas **5**, 2899-2906 (2004); LBNL-54258.

C.B. Schroeder, E. Esarey, and B.A. Shadwick, "Warm wavebreaking of nonlinear plasma waves with arbitrary phase velocities," Phys. Rev. Lett., submitted (2004); LBNL-57059.

C.B. Schroeder, E. Esarey, and W.P. Leemans,"Electron beam conditioning by Thomson scattering," Phys. Rev. Lett. **93**, 194801 (2004); LBNL-54095.

C.B. Schroeder, E. Esarey, J. van Tilborg, and W.P. Leemans, "Theory of coherent transition radiation generated at a plasma-vacuum interface," Phys. Rev. E **69**, 016501 (2004); LBNL-53228.

B.A. Shadwick, G.M. Tarkenton, and E. Esarey, "Hamiltonian description of low temperature, relativistic plasmas," Phys. Rev. Lett. **93**, 175002 (2004); LBNL-55103.

B.A. Shadwick, G.M. Tarkenton, E. Esarey, and C.B. Schroeder, "Fluid and Vlasov models of low temperature, collisionless laser-plasma interactions," *invited paper*, Phys. of Plasmas, accepted (2005); LBNL-57061.

J. van Tilborg, C.B. Schroeder, E. Esarey, and W.P. Leemans,"Pulse shape and spectrum of coherent diffraction-limited transition radiation from electron beams," Laser Particle Beams **22**, 415-422 (2004); LBNL-55868.

Cs. Toth, J. Faure, J. van Tilborg, C.G.R. Geddes, C. Schroeder, E. Esarey, and W.P. Leemans, "Tuning of laser pulse shapes in grating-based compressors for optimal electron acceleration in plasmas," Opt. Lett. **28**, 1823-1825 (2003); LBNL-52178.

R.M.G.M. Trines, L.P.J. Kamp, T.J. Schep, W.P. Leemans, E.H. Esarey, and F.W. Sluijter, "Enhancement of high-energy electron production through suppression of Raman backscattering," Europhys. Lett. **66**, pp. 492–498 (2004); LBNL-52175.

Unrefereed Conference Proceedings and Other Publications

D.L. Bruhwiler, D.A. Dimitrov, J.R. Cary, E. Esarey, and W. Leemans, "Simulation of ionization effects for high-density positron drivers in future plasma wakefield experiments," in *Proceedings* of the 2003 Particle Accelerator Conference (Portland, OR, May 2003), IEEE Cat. No. 03CH37423 (IEEE, Piscataway, NJ, 2003), pp. 734-6; LBNL-53431.

J.R. Cary, R. Giacone, C. Nieter, D. Bruhwiler, E. Esarey, G. Fubiani, and W. Leemans, "All-optical beamlet train generation," in *Proceedings* of the 2003 Particle Accelerator Conference (Portland, OR, May 2003), IEEE Cat. No. 03CH37423 (IEEE, Piscataway, NJ, 2003), pp. 719-21; LBNL-53432.

E. Esarey, S. Tochitsky, H. M. Milchberg, and C. B. Schroeder, "Summary report of working group: laser-plasma acceleration," in V. Yakimenko, ed., *Proceedings* of the 11th Advanced Accelerator Concepts Workshop (Stony Brook, NY, June 2004), AIP Conf. Proceedings **737** (New York: Amer. Inst. Phys., 2004), pp. 223-230; LBNL-56569.

D.A. Dimitrov, D. L. Bruhwiler, J. R. Cary, P. Messmer, C. Geddes, W. Leemans and E. Esarey, "Particle-in-cell simulations of intense laser pulses coupling into plasma channels," in V. Yakimenko, ed., *Proceedings* of the 11th Advanced Accelerator Concepts Workshop (Stony Brook, NY, June 2004), AIP Conf. Proceedings **737** (New York: Amer. Inst. Phys., 2004), pp. 469-477; LBNL-57057.

E. Esarey, C.B. Schroeder, and W.P. Leemans, "Plasma cathode: colliding pulse optical injection," *invited chapter* in M. Uesaka, ed., Femtosecond Beam Science (World Scientific, in press), ISBN 1-86094-343-8; LBNL-52553.

E. Esarey, C.B. Schroeder, B.A. Shadwick, J. van Tilborg, C.G.R. Geddes, Cs. Toh, and W.P. Leemans, "Radiation generation from plasma-based accelerators," in *Proceedings* of ICOPS 2004, the 31st IEEE International Conference on Plasma Science (Baltimore, MD, June 28 – July 1, 2004); LBNL-57097.

E. Esarey, B.A. Shadwick, C.B. Schroeder, and W.P. Leemans. "Nonlinear pump depletion and electron dephasing in laser wakefield accelerators," in V. Yakimenko, ed., *Proceedings* of the 11th Advanced Accelerator Concepts Workshop (Stony Brook, NY, June 2004), AIP Conf. Proceedings **737** (New York: Amer. Inst. Phys., 2004), pp. 578-584; LBNL-56568.

G. Fubiani, E. Esarey, K. Nakamura, C.B. Schroeder, and W.P. Leemans, "Electron beam generation using two-pulse colliding-pulse injection and a plasma density gradient," in V. Yakimenko, ed., *Proceedings* of the 11th Advanced Accelerator Concepts Workshop (Stony Brook, NY, June 2004), AIP Conf. Proceedings **737** (New York: Amer. Inst. Phys., 2004), pp. 887-893; LBNL-57024.

C.G.R. Geddes, Cs. Tóth, J. van Tilborg, and W.P. Leemans, "Laser guiding at > 10^{18} W/cm^2 in plasma channels formed by the ignitor heater method," in *Proceedings* of CLEO/IQEC 2004, the Conference on Lasers and Electro-Optics and International Quantum Electronics Conference (San Francisco, CA, May 16 - 21, 2004); LBNL-51833.

C.G.R. Geddes, Cs. Toth, J. Van Tilborg, E. Esarey, C.B. Schroeder, D. Bruhwiler, J. Cary, and W.P. Leemans, "Laser guiding at relativistic intensities and wakefield particle acceleration in plasma channels," in V. Yakimenko, ed., *Proceedings* of the 11th Advanced Accelerator Concepts Workshop (Stony Brook, NY, June 2004), AIP Conf. Proceedings **737** (New York: Amer. Inst. Phys., 2004), pp. 521-527; LBNL-56157.

R. Giacone, J.R. Cary, C. Nieter, E. Esarey, G. Fubiani, W.P. Leemans, and C.B. Schroeder, "Generation of single pulse particle beams in a plasma channel by laser injection in laser wakefield accelerators," in *Proceedings* of the 2003 Particle Accelerator Conference

(Portland, OR, May 2003), IEEE Cat. No. 03CH37423 (IEEE, Piscataway, NJ, 2003), pp. 1885-7; LBNL-55069.

W.P. Leemans, "Laser wakefield accelerators: status and future," in *Proceedings* of ICOPS 2004, the 31st IEEE International Conference on Plasma Science (Baltimore, MD, June 28 – July 1, 2004); LBNL-57126.

Wim Leemans, "Advances in laser driven accelerator R&D," in V. Yakimenko, ed., *Proceedings* of the 11th Advanced Accelerator Concepts Workshop (Stony Brook, NY, June 2004), AIP Conf. Proceedings **737** (New York: Amer. Inst. Phys., 2004), pp. 11-28; LBNL-56226.

W.P. Leemans, C.G.R. Geddes, J. van Tilborg, M. Dickinson, S. DiMaggio, D. Syversrud, J. Wallig, N. Ybarrolaza, and Cs. Tóth, "L'OASIS Ti:sapphire laser facility: a multi-beam, multi-terawatt system for wake-field acceleration studies," in *Proceedings* of CLEO/IQEC 2004, the Conference on Lasers and Electro-Optics and International Quantum Electronics Conference (San Francisco, CA, May 16 - 21, 2004); LBNL-57114.

P. Michel, E. Esarey, C. B. Schroeder, Cs. Tóth, W. P. Leemans, and D. Schneider, "Thomson scattering from laser wakefield accelerators," in V. Yakimenko, ed., *Proceedings* of the 11th Advanced Accelerator Concepts Workshop (Stony Brook, NY, June 2004), AIP Conf. Proceedings **737** (New York: Amer. Inst. Phys., 2004), pp. 393-399; LBNL-56572.

K. Nakamura, K., G. Fubiani, C. G. R. Geddes, P. Michel, J. van Tilborg, C. Tóth, E. Esarey, C. B. Schroeder, and W. P. Leemans, "Laser triggered injection of electrons in a laser wakefield accelerator with the colliding pulse method," in V. Yakimenko, ed., *Proceedings* of the 11th Advanced Accelerator Concepts Workshop (Stony Brook, NY, June 2004), AIP Conf. Proceedings **737** (New York: Amer. Inst. Phys., 2004), pp. 901-906; LBNL-56575.

C. B. Schroeder, E. Esarey, and W. P. Leemans, "Beam conditioning for free-electron lasers via Thomson scattering," in V. Yakimenko, ed., *Proceedings* of the 11th Advanced Accelerator Concepts Workshop (Stony Brook, NY, June 2004), AIP Conf. Proceedings **737** (New York: Amer. Inst. Phys., 2004), pp. 628-634; LBNL-56570.

C.B. Schroeder, E. Esarey, B. A. Shadwick, and W. P. Leemans, "Trapping and dark current in plasma-based accelerators," in V. Yakimenko, ed., *Proceedings* of the 11th Advanced Accelerator Concepts Workshop (Stony Brook, NY, June 2004), AIP Conf. Proceedings **737** (New York: Amer. Inst. Phys., 2004), pp. 564-570; LBNL-56571.

B.A. Shadwick, G.M. Tarkenton, and E.H. Esarey, "Thermal effects in intense laser-plasma interactions," in V. Yakimenko, ed., *Proceedings* of the 11th Advanced Accelerator Concepts Workshop (Stony Brook, NY, June 2004), AIP Conf. Proceedings **737** (New York: Amer. Inst. Phys., 2004), pp. 449-455; LBNL-56584.

J. van Tilborg, G. Fubiani, C.G.R. Geddes, Cs. Tóth, E. Esarey, C.B. Schroeder, and W.P. Leemans, "High-energy coherent THz radiation from laser wakefield accelerated ultrashort electron bunches," in *Proceedings* of CLEO/IQEC 2004, the Conference on Lasers and Electro-Optics and International Quantum Electronics Conference (San Francisco, CA, May 16 - 21, 2004); LBNL-55864.

J. van Tilborg, C. G. R. Geddes, C. Tóth, E. Esarey, C. B. Schroeder, M. C. Martin, Z. Hao, and W. P. Leemans, "coherent transition radiation from a laser wakefield accelerator as an electron bunch diagnostic," in V. Yakimenko, ed., *Proceedings* of the 11th Advanced Accelerator Concepts Workshop (Stony Brook, NY, June 2004), AIP Conf. Proceedings **737** (New York: Amer. Inst. Phys., 2004), pp. 372-378; LBNL-56573.

Cs. Tóth, C.G.R. Geddes, J. van Tilborg, and W. P. Leemans, "A multi-beam, multi-terawatt Ti: sapphire laser system for laser wake-field acceleration studies," in V. Yakimenko, ed., *Proceedings* of the 11th Advanced Accelerator Concepts Workshop (Stony Brook, NY, June 2004), AIP Conf. Proceedings **737** (New York: Amer. Inst. Phys., 2004), pp. 978-982; LBNL-57056.

Cs. Tóth, J. van Tilborg, C.G.R. Geddes, G. Fubiani, C.B. Schroeder, E. Esarey, J. Faure, G. Dugan, and W.P. Leemans, "Powerful pulsed THz radiation from laser-accelerated relativistic electron bunches," Proc. SPIE **5448**, 491-504 (2004); LBNL-57055.

Cs. Tóth, J. Faure, J. van Tilborg, C. G. R. Geddes, C. B. Schroeder, E. Esarey, W. P. Leemans, "Asymmetric pulse shapes in grating-based CPA compressors and optimal electron acceleration in plasmas," in Ferenc Krausz, Georg Korn, Paul Corkum, and Ian A. Walmsley, eds., *Ultrafast Optics IV* (Berlin, Germany: Springer, 2004), pp. 351-358; LBNL-57054.

Theory Group

Refereed Publications

M. Babzien, I. Ben-Zvi, I. Pavlishin, I. Pogorelsky, V. Yakimenko, A. Zholents, and M. Zolotorev, "Optical stochastic cooling for RHIC using optical parametric amplification," Phys. Rev. Special Topics: Accelerators and Beams **7**, 012801; LBNL-54823 (2004).

M. Babzien, I. Ben-Zvi I. Pavlishin, I.V. Pogorelsky, V.E. Yakimenko, A.A., Zholents AA., and M. S. Zolotorev, "Optical stochastic cooling for RHIC," Nucl. Instrum. Meth. A **532**, 1-2, pp. 345-7; LBNL-57307 (2004).

M. Babzien, I. Ben-Zvi, I. Pavlishin, I.V., Pogorelsky, V.E. Yakimenko VE, A.A. Zholents, and M.S. Zolotorev, "Optical stochastic cooling for RHIC using optical parametric amplification," Phys. Rev. Special Topics: Accelerators and Beams **7**, 1; LBNL-54823 (2004).

W. Cheng, Y. Avitzour, Y. Ping, S. Suckewer, N. J. Fisch, M. S. Hur, and J. S. Wurtele, "Reaching the nonlinear regime of Raman amplification of ultrashort laser pulses," Phys. Rev. Lett. **94**, 045003 LBNL-57305 (2005).

R. Cimino, I.R. Collins, M.A. Furman, M. Pivi, F. Ruggiero, G. Rumolo, and F. Zimmermann, "Can low energy electrons affect high energy physics accelerators?," Phys. Rev. Lett. **93**, 014801 (Feb. 9, 2004); CERN-AB-2004-012; LBNL-54594; SLAC-PUB-10350.

L. Friedland, F. Peinetti, W. Bertsche, J. Fajans, and J. Wurtlele, "Driven phase space holes and synchronized Bernstein, Greene, and Kruskal modes," Phys. Plasmas **11**, 4305; LBNL-57302 (2004).

Y. Honda, A. Wolksi et al., "Achievement of ultralow emittance beam in the Accelerator Test Facility damping ring," Phys. Rev. Lett. **92**, 054802 (2004); LBNL-57214.

M.S. Hur, G. Penn, J.S. Wurtele, and R. Lindberg, "Slowly varying envelope kinetic simulations of pulse amplification by Raman backscattering," Phys. Plasmas **11**, 5204; LBNL-57304 (2004).

E. Keil and A. M. Sessler, "Muon acceleration in FFAG rings," Nucl. Instrum. Meth. A **538**, p. 159 (2005); LBNL-54798.

R.R. Lindberg, A.E. Charman, and J.S. Wurtele, "Robust autoresonant excitation in the plasma beat-wave accelerator: a theoretical study," arXiv:physics/0403081 (March 2004); LBNL-57303.

R. R. Lindberg, A.E. Charman, J.S. Wurtele and L. Friedland, "Robust autoresonant excitation in plasma beat-wave accelerator," Phys. Rev. Lett. **93**, 055001; LBNL-57311 (2004).

D. Mohl and A. M. Sessler, "Beam cooling: principles and achievements," Nucl. Instrum. Meth. A **532**, 1 (2004); LBNL-54830.

H. Okamoto, K. Okabe, Y. Yuri, D. Mohl and A. M. Sessler, "One-dimensional ordering of ultra-low density ion beams in a storage ring," Phys. Rev. E **69**, 066504 (2004); LBNL-54827.

J. Qiang, M.A. Furman, and R.D Ryne, "A parallel particle-in-cell model for beam-beam interaction in high energy ring colliders," J. Comp. Phys. 198, 1 (20 July 2004), pp. 278-294; LBNL-54598.

M. Venturini, R. Warnock, R. Ruth, and J. A. Ellison, "Coherent synchrotron radiation and bunch stability in a compact storage ring," Phys. Rev. Special Topics: Accelerators and Beams **8**, 014202 (2005); LBNL-54866.

R. Warnock, R. Ruth, M. Venturini, and J. A. Ellison, "Impedance description of coherent synchrotron radiation with account of bunch deformation," Phys. Rev. Special Topics: Accelerators and Beams **8**, 014402 (2005); LBNL-57213.

A. Wolski, G. Penn, A. Sessler, and J. Wurtele, "Beam conditioning for FELs: consequences and methods," Phys. Rev. Special Topics: Accelerators and Beams **7**, 80701; LBNL-53899 (2004).

A. A. Zholents and W. M. Fawley, "Proposal for intense attosecond radiation from an x-ray free-electron laser," Phys. Rev. Lett. **92**, 224801; LBNL-54084 (2004).

A.A. Zholents and G. Penn, "Obtaining attosecond X-ray pulses using a self-amplified spontaneous emission free electron laser," submitted to Phys. Rev. Special Topics: Accelerators and Beams (2005); LBNL-56773.

Unrefereed Conference Proceedings and Other Publications

S. Berg, E. Keil, D. Trbojevic et al., "Review of current FFAG lattice studies in North America," in *Proceedings* of the 17th International Conference on Cyclotrons and their Applications (Tokyo, Japan, Oct. 18 – 22, 2004); LBNL-57174.

J.M. Byrd, S. De Santis, J.-Y. Jung, M.C. Martin, W.R. McKinney, D.V. Munson, H. Nishimura, D. Robin, F. Sannibale, R.D. Schlueter, M. Venturini, W. Wan, and M.S. Zolotorev, "CIRCE, the coherent infrared center at the ALS," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-55603.

A.E. Charman, G.E. Penn, A. Wolski, and J. Wurtele, "Beam conditioning and harmonic generation in free electron lasers," in *Proceedings* of Frontiers of Nonlinear Physics 2004, July 2004; LBNL-57312.

J.N. Corlett, W.A. Barletta, S. De Santis, L. Doolittle, W.M. Fawley, P. Heimann, S. Leone, S. Lidia, D. Li, G. Penn, A. Ratti, M. Reinsch, R. Schoenlein, J. Staples, G. Stover, S. Virostek, W. Wan, R. Well, R. Wilcox, A. Wolski, J. Wurtele, and A. Zholents, "LUX - a recirculating linac-based facility for ultrafast x-ray science," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-55621.

J.N. Corlett, W.M. Fawley, G. Penn, A.A. Zholents, W. Wan, M. Reinsch, J. Wurtele, "Harmonic cascade FEL designs for LUX, a facilty for ultrafast x-ray science," in *Proceedings* of the 2004 FEL Conference (Trieste, Italy, August 29-September 3, 2004), pp. 637-9; LBNL-55020.

W. Fawley, A.A. Zholents, P. Emma, Z. Huang, G. Stupakov and S. Reiche , "Current-Enhanced SASE using an Optical Laser and its Application to the LCLS," in *Proceedings* of the 2004 FEL Conference (Trieste, Italy, August 29-September 3, 2004), pp. 582-585; LBNL-54967.

W. Fawley, A.H. Lumpkin, and D.W. Rule, "A concept for z-dependent microbunching measurements with coherent x-ray transition radiation in a SASE FEL," in *Proceedings* of the 2004 FEL Conference (Trieste, Italy, August 29-September 3, 2004), pp. 515-518; LBNL-55080.

W. Fawley, "Towards attosecond X-ray pulses from the FEL," LBNL-55689.

W. Fawley, "Design study of the bending sections between harmonic cascade FEL stages," LBNL-56171, June 2004.

W. Fawley, "Noise and temporal coherence evolution through a multi-stage harmonic cascade," abstract submitted to the 2004 FEL Conference (Trieste, Italy, August 29-September 3, 2004); LBNL-54968 Abs. (2004).

W. Fawley and R.J. Briggs, "Campaign to minimize the transverse impedance of the DARHT-2 induction linac cells," LBNL-56796 (February 2005).

W. Fawley and R. Briggs, "A simple model for induction core voltage distributions," July 2004; LBNL-55079.

M.A. Furman, "Closing remarks," in *Proceedings* of ECLOUD04, the 31st Internaional Committee for Future Accelerators (ICFA) Advanced Beam Dynamics Workshop on Electron-Cloud Effects (Napa, CA, 19-23 April 2004); LBNL-57165.

M.A. Furman, "ECLOUD04 workshop," Sec. 5.2.1 of ICFA Beam Dynamics Newsletter No. 33 , p. 215 (April 2004); LBNL-56110,

M.A. Furman, "Goals for the workshop," in *Proceedings* of ECLOUD04, the 31st Internaional Committee for Future Accelerators (ICFA) Advanced Beam Dynamics Workshop on Electron-Cloud Effects (Napa, CA, 19-23 April 2004); LBNL-57166.

M.A. Furman, "Electron cloud build-up in hadron machines," Sec. 5.2.1 of ICFA Beam Dynamics Newsletter No. 33, p. 70 (April 2004); LBNL-56109 (Aug. 2004).

Y. Honda, J.L. Nelson, M.C. Ross, A. Wolski, and M.D. Woodley, "Coupling correction in the KEK-ATF using orbit response matrix analysis," LBNL-57046, March 2005.

E. Keil, A.M. Sessler, and S. Berg, "Electron models of a FFAG muon accelerator," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-54819.

E. Keil, A.M. Sessler, and D. Trbojevic, "A non-scaling radial-sector fixed field alternating gradient (FFAG) ring for carbon cancer therapy," in *Proceedings* of FFAG'04, the FFAG Accelerator Workshop (KEK, Tsukuba, Japan, October 13-16, 2004); LBNL-57191 Abs.

E. Keil, A.M. Sessler, and D. Trbojevic, "Fixed field alternating gradient accelerators (FFAG) for fast hadron cancer therapy," abstract submitted to the 2005 Particle Accelerator Conference (Knoxville, TN, May 2005); LBNL-57176 Abs.

K.-J. Kim, B. Carlsten, D. Dowell , K. Flöttmann, K. Jensen, J. Petillo, A. Sessler, and G. Stupakov, "Towards advanced electron beam brightness enhancement and conditioning," Argonne National Laboratory Report ANL/APS/LS-305, February 2004; LBNL-57179.

X.-P. Li, H. Enokizono, H. Okamoto, and Y. Yuri, A.M. Sessler, and J. Wei., "Phonon modes and the maintenance condition of a crystalline beam," abstract submitted to the 2005 Particle Accelerator Conference (Knoxville, TN, May 2005); LBNL-57178 Abs.

R. Macek (*presenter*) and M.A. Furman, "Summary of the ECLOUD'04 workshop," *invited talk*, ICFA-HB2004, the ICFA Advanced Beam Dynamics Workshop on High Intensity and High Brightness Hadron Beams (Bensheim, Germany, October 18-22, 2004); LA-UR-04-8606; LBNL-57160 (2004).

S. Marks, M. Venturini, W. Wan, and A. Wolski, "Frequency map analysis of nonlinear dynamics in the NLC main damping rings," LBNL-56505, August 2004.

S. Marks, M. Venturini, and A. Wolski, "Dynamic aperture study for the NLC main damping rings," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-55882.

J.L. Nelson, M.C. Ross, A. Wolski, and M.D. Woodley, "Analysis of KEK-ATF optics and coupling using LOCO," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-55726.

J.L. Nelson, M.C. Ross, A. Wolski, and M.D. Woodley, "Beam-based alignment at the KEK-ATF damping ring," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-55728; SLAC-PUB-10587.

J.L. Nelson, M.C. Ross, A. Wolski, and M.D. Wooley, "Initial studies of nonlinear dynamics in the KEK-ATF wigglers," LBNL-57047, March 2005.

G. Penn, "Staged energy cascades for the LUX FEL," LBNL-55973.

G. Penn, M. Reinsch, J. Wurtele, J.N. Corlett, W.M. Fawley, A. Zholents, W. Wan "Harmonic cascade FEL designs for LUX," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004), p. 488; LBNL-56329.

G. Penn, M. Reinsch, and J.S. Wurtele, "Analytic Model of Harmonic Generation in the Low-Gain FEL Regime," in *Proceedings* of the 2004 FEL Conference (Trieste, Italy, August 29-September 3, 2004), p. 71-74; LBNL-56177.

S.O. Prestemon, D.S. Robin, R.D. Schlueter, C.A. Steier, and A.Wolski, "Study of row phase dependent skew quadrupole fields in Apple-II Type EPUs at the ALS," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-57210.

J. Qiang, M. Furman and R. D. Ryne, W. Fischer, and K. Ohmi, "Recent advances of strong-strong beam-beam simulation," in *Proceedings* of ICAP04, the 8th International Computational Accelerator Physics Conference (St. Petersburg State University, St. Petersburg, Russia, June 28-July 2, 2004); LBNL-56360 (2004).

I. Reichel and A. Wolski, "A reduced emittance lattice for the NLC positron predamping ring," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-55449.

J. Seeman, J. Browne, Y. Cai, J.N. Corlett, C. Steier, A. Wolski, M.S. Zisman, W. Kozanecki, and G. Wormser, et al., "Results and plans of the PEP-II B-factory," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004), p. 875; LBNL-57208.

C.A. Steier, P.G. Tenenbaum, A.Terebilo, J.L. Turner, A. Wolski, and G. Yocky, "Orbit response matrix analysis applied at PEP-II," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-57207.

D. Trbojevic, A. G. Ruggiero, E Keil, N. Neskovic, and A. Sessler, "Design of a non-scaling FFAG accelerator for proton therapy," in *Proceedings* of the 17th International Conference on Cyclotrons and their Applications (Tokyo, Japan, Oct. 18-22, 2004); LBNL-57177.

D. Trbojevic, S.J. Berg, M. Blaskiewicz, A.G. Ruggiero, E. Keil, C. Johnston, M. Cradock, S. Koscielniak, A. Garren, A. Sessler, and E.D. Courant, "A design principle for the non-scaling fixed field alternating gradient synchrotron," LBNL-57212.

Y. Vinokurov, G. Penn. J.Wurtele, E. Esarey, A.M. Sessler, and A. Wolski, "Beam conditioning and FEL studies using MAD and Genesis," abstract submitted to the 2005 Particle Accelerator Conference (Knoxville, TN, May 2005); LBNL-56733 Abs.

A. Wolski, "Lattice design for an ILC damping ring with 3km circumference," LBNL-56506, October 2004.

A. Wolski, "Lattices with large dynamic aperture for ILC damping rings," LBNL-57045, February 2005.

M. Venturini, "Longitudinal single-bunch instabilities in the NLC main damping rings," LBNL-55103 (2004).

M. Venturini, S. Marks, and A. Wolski, "Dynamical aperture study for the NLC main damping rings," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-55882.

M. Venturini and A. Wolski, "Dynamical map for combined function magnets with solenoid, dipole and quadrupole fields," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-55807.

A. Wolski and M.D. Woodley, "Normal form analysis of linear beam dynamics in a coupled storage ring," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-55727, SLAC-PUB-10589

A. Wolski and F. Zimmermann, "Summary of Workshop Session F on electron-cloud instabilities," in *Proceedings* of ECLOUD04, the 31st Internaional Committee for Future Accelerators (ICFA) Advanced Beam Dynamics Workshop on Electron-Cloud Effects (Napa, CA, 19-23 April 2004); LBNL-56002; CERN-2002-001, May 2004.

A. Wolski, "A simple way to characterize linear coupling in a storage ring," LBNL-54774, March 2004.

A. Wolski and F. Zimmermann, "Closed orbit response to quadrupole strength variation," LBNL-54360, January 2004.

R.L. Warnock, G.V. Stupakov, J.A. Ellison, and M. Venturini, "Linear Vlasov analysis for stability of a bunched beam," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-55806

A. Zholents, J.M. Byrd, W. Fawley, Z. Hao, M.C. Martin, D. Robin, F. Sannibale, R.W. Schoenlein, M. Venturini, M.S. Zolotorev, "Towards attosecond x-ray pulses from the FEL," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-55689

A. Zholents, J.M. Byrd, Z. Hao, M.C. Martin, D. Robin, F. Sannibale, R.W. Schoenlein, M. Venturini, M.S. Zolotorev, "Coherent infrared radiation from the ALS generated via femtosecond laser modulation of the electron beam," in *Proceedings* of the 2004

European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-57301.

F. Zimmermann, E. Benedetto, F. Ruggiero, D. Schulte, M. Blaskiewicz, L. Wang, G. Bellodi , G. Rumolo, K. Ohmi, S.S. Win, M.A. Furman, Y. Cai, M. Torino, F. Pivi, V.K. Decyk, W. Mori, A.F. Ghalam, and T. Katsouleas, "Review and comparison of simulation codes modeling electron-cloud build up and instabilities," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-55239.

Collider Physics Group

Refereed Publications

B. Dehning, J. Matheson, G. Mugnai, I. Reichel, R. Schmidt, F. Sonnemann, and F. Tecker, "Beam based alignment at LEP," Nucl. Instrum. Meth. A **516**, 9 (2004); LBNL-56099.

Unrefereed Conference Proceedings and Other Publications

G. Barr, E. Baynham, E. Black, T. Bradshaw, M.A.C. Cummings, M.A. Green, S. Ishimoto, Y. Ivanushenkov, W. Lau, and M. Zisman, "MICE Absorber and Focus Coil Safety Working Group design document: preliminary design and assessments," M. Zisman, ed.; LBNL-55860.

J.S. Berg, E. Keil, D. Trbojevic, and A.M. Sessler, "Review of current FFAG lattice studies in North America," in *Proceedings* of the 17th International Conference on Cyclotrons and their Applications (Tokyo, Japan, Oct. 18-22, 2004); LBNL-57174.

P. Fabbricatore, S. Farinon, U. Bravar, and M. A. Green. "The mechanical and thermal design for the MICE detector solenoid magnet system," IEEE Transactions on Applied Superconductivity **15**, No. 2 (in press); LBNL-57376 (2005).

M. A. Green, S. Q. Yang, G. Barr, U. Bravar, J. Cobb, W. Lau, R. S. Senanayake, and H. Witte, "The mechanical and thermal design for the MICE focusing solenoid magnet system," IEEE Transactions on Applied Superconductivity **15**, No. 2 (in press); LBNL-57396 (2005).

M.A. Green, G. Barr, W. Lau, R. S. Senanayake, and S. Q. Yang "The MICE focusing solenoids and their cooling system," in *Proceedings* of the International Cryogenic Engineering Conference (Beijing, China, 11-14 May 2004); LBNL-57380.

M.A. Green, S. Q Yang, and W. Lau, "Modeling free convection flow of liquid hydrogen within a cylindrical heat exchanger cooled with helium gas at 14 K," in *Proceedings* of the International Cryogenic Engineering Conference (Beijing, China, 11-14 May 2004); LBNL-57379.

M. A. Green, S. Q. Yang, and W. Lau, "Modeling the thermal mechanical behavior of a 300 K vacuum vessel that is cooled by liquid hydrogen in film boiling," in *Proceedings* of the International Cryogenic Engineering Conference (Beijing, China, 11-14 May 2004); LBNL-57378.

E. Keil, A.M. Sessler, and S.Berg, "Electron models of a FFAG muon accelerator," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-54819.

E. Keil, A.M. Sessler, and D. Trbojevic, "A non-scaling radial-sector fixed field alternating gradient (FFAG) ring for carbon cancer therapy," in *Proceedings* of the 17th International Conference on Cyclotrons and their Applications (Tokyo, Japan, Oct. 18-22, 2004); LBNL-57191.

D. Li., S. Virostek, M. Green, and M. Zisman, "Progress on rf coupling coil module design for the MICE channel," abstract submitted to the 2005 Particle Accelerator Conference (Knoxville, TN, May 2005); LBNL-56730 Abs.

M.A. Green, G. Barr, E. Baynham, J. Cobb *et al*., "Design issues for the superconducting focusing magnet that goes around the liquid hydrogen absorber for the Muon Ionization Cooling Experiment (MICE)," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004), p. 1765; LBNL-57377.

I. Reichel, M.S. Zisman, M. Placidi, K. Gollwitzer, and S. Werkema, "Aperture studies for the AP2 anti-proton line at Fermilab," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004), p. 1491; LBNL-54096.

I. Reichel and A. Wolski, "A reduced emittance lattice for the NLC positron pre-damping ring," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004); LBNL-55449.

J. Seeman, J. Browne, Y. Cai, J.N. Corlett, C. Steier, A. Wolski, M.S. Zisman, W. Kozanecki, and G. Wormser, et al., "Results and plans of the PEP-II B-Factory," in *Proceedings* of the 2004 European Particle Accelerator Conference (Lucerne, Switzerland, July 5 - 9, 2004), p. 875; LBNL-57208.

D. Trbojevic, A. G. Ruggiero, E Keil, N. Neskovic, X. Vinca and A. Sessler, "Design of a non-scaling FFAG accelerator for proton therapy," in *Proceedings* of the 17th International Conference on Cyclotrons and their Applications (Tokyo, Japan, Oct. 18-22, 2004); LBNL-57177.

M.S. Zisman, "Muon ionization cooling experiment (MICE)," in *Proceedings* of the 22nd International Linear Accelerator Conference (Lubeck, Germany, August 16-20, 2004); LBNL-56146.

AMAC Group

Refereed Publications

P. McCorquodale, P. Colella, D.P. Grote, and J.L. Vay, "A node-centered local refinement algorithm for Poisson's equation in complex geometries," submitted to J. Comp. Phys (2004).

E. Sonnendrucker, F. Filbet, A. Friedman, E. Oudet, and J.L. Vay, "Vlasov simulations of beams with a moving grid," Comp. Physics Comm. (in press).

J. Qiang, R.D. Ryne, and I. Hofmann, "Space-charge driven emittance growth in a 3D mismatched anisotropic beam," Phys. Rev. Lett. **92**, 174801 (2004); LBNL-51807.

J. Qiang, "Halo formation due to beam-beam interactions of beams optically mismatched at injection," Phys. Rev. Special Topics: Accelerators & Beams **7**, 031001 (2004); LBNL-56054.

J. Qiang, M. Furman, and R. Ryne, "A parallel particle-in-cell model for beam-beam interactions in high energy ring colliders," *J. Comp. Phys*. (2004); LBNL-54598.

J.L. Vay, P. Colella, J.W. Kwan, P. McCorquodale, D.B. Serafini, A. Friedman, D.P. Grote, G. Westenskow, J.C. Adam, A. Héron , and I. Haber, "Application of adaptive mesh refinement to particle-in-cell simulations of plasmas and beams," Phys. of Plasmas, in press (2004); LBNL-53551.

J.L. Vay, P. Colella, A. Friedman, D.P. Grote, P. McCorquodale, and D.B. Serafini, "Implementations of mesh refinement schemes for particle-in-cell plasma simulations"; Comp. Physics Comm. (in press); LBNL-54046 (2004).

J.L. Vay, J.C. Adam, and A. Héron, "Asymmetric PML for the absorption of waves. application to mesh refinement in electromagnetic particle-in-cell plasma simulations," Comp, Physics Comm. (in press); LBNL-52676 (2004).

J. Qiang and R. Gluckstern, "Three-dimensional Poisson solver for a charged beam with large aspect ratio in a conducting pipe," submitted to Comp. Phys. Comm; LBNL-54282 (2004).

J. Qiang, "Halo formation from mismatched beam-beam interactions," submitted to Phys. Rev. Special Topics: Accelerators & Beams; LBNL-54353 (2004).

Tawada, M; Cai, Y; Ohmi, K; Kamada, S; Qiang, J; and Oide, K,, "Study of the beam-beam limit in e+ e- circular colliders," in *Proceedings* of ICAP04, the 8th International Computational Accelerator Physics Conference (St. Petersburg State University, St. Petersburg, Russia, June 28-July 2, 2004), *Phys. Rev. Lett*. **92**, 214801 (2004); LBNL-55556.

K. Ohmi, M. Tawada, Y. Cai, S. Kamada, K. Oide, and J. Qiang, "Luminosity limit due to the beam-beam interactions with or without crossing angle," Phys. Rev. Special Topics: Accelerators & Beams **7**, 104401 (2004); LBNL-57267.

R. Garnett and J. Qiang, “Smooth Approximation with Acceleration in an Alternating Phase Focusing Superconducting Linac,” Nucl. Instrum. Meth. A **496**, 33 (2003); LBNL-50146.

Unrefereed Conference Proceedings and Other Publications

I. Hofmann, G. Franchetti, J. Qiang, and R.D. Ryne, “Self-consistency and coherent effects in nonlinear resonances,” in *Proceedings* of HALO’03, the 29th International Committee on Future Accelerators (ICFA) Advanced Beam Dynamics Workshop on Beam Halo Dynamics, Diagnostics, and Collimation (May 19-23, Montauk, NY); LBNL-54601 (2003).

M. Ikegami, T. Kato, Z. Igarashi, A. Ueno, Y. Kondo, J. Qiang, and R. Ryne, “Comparison of particle simulation with J-PARC Linac MEBT beam test results,” in *Proceedings* of HALO’03, the 29th International Committee on Future Accelerators (ICFA) Advanced Beam Dynamics Workshop on Beam Halo Dynamics, Diagnostics, and Collimation (May 19-23, Montauk, NY); LBNL-54600.

J. Qiang, M. Furman, and R.D. Ryne, “Recent advances and applications of beam-beam simulation codes,” in *Proceedings* of ICAP04, the 8th International Computational Accelerator Physics Conference (St. Petersburg State University, St. Petersburg, Russia, June 28-July 2, 2004); LBNL-55539a.

M. Tawada, Y. Cai, K. Ohmi, and J. Qiang, “Beam-beam simulation studies for PEP-II and KEKB,” LBNL-55558.

M. Tawada Y. Cai, K. Ohmi, J. Qiang, K. Oide, and S. Kamada, “Study of beam-beam interactions with or without crossing angle,” in *Proceedings* of ICAP04, the 8th International Computational Accelerator Physics Conference (St. Petersburg State University, St. Petersburg, Russia, June 28-July 2, 2004); LBNL-55557.

J. Qiang, “Strong-strong beam-beam simulation on parallel computer,” LBNL-57366, July 2004.

R.H. Cohen, A. Azevedo, A. Friedman, M.A. Furman, A.W. Molvik, P.H. Stoltz, and J.-L. Vay, “Simulating electron cloud effects in heavy-ion accelerators, 15th International Symposium on Heavy Ion Inertial Fusion (Princeton, NJ, June 7-11, 2004); LBNL-56056.

A.W. Molvik, F.M. Bieniosek, R.H. Cohen, S. Eylon,A. Faltens, A. Friedman, E. Henestroza, M. Kireeff Covo, J.W. Kwan, S.M. Lund, L. Prost, P.K. Roy, P.A. Seidl, J.-L. Vay, G. Westenskow, and S. Yu, “Experimental studies of electrons in a heavy-ion beam,” LBNL-55237 (July 2004).

A.W. Molvik, R.H. Cohen, A. Friedman, M. Kireeff Covo, S.M. Lund, F.M. Bieniosek, E.P. Lee, L. Prost, P.A. Seidl, J.-L. Vay, and M.A. Furman, “Progress in measuring electron cloud effects in HIF accelerators,” presented at the 45th Annual Meeting of the American Physical Society Division of Plasma Physics (Albuquerque, NM, Oct. 27-31, 2003); LBNL-53550.

J. Qiang, M.A. Furman, R.D. Ryne, W. Fischer, and K. Ohmi, “Recent advances of strong-strong beam-beam simulation,” in Proceedings of ICAP04, the 8th International Computational Accelerator Physics Conference (St. Petersburg State University, St. Petersburg, Russia, June 28-July 2, 2004); LBNL-56360.

J. Qiang, M. Furman, R.D. Ryne, W. Fischer, T. Sen, M. Xiao, "Parallel strong-strong/strong-weak simulations of beam-beam interactions in hadron accelerators," in *Proceedings* of HALO'03, the 29th International Committee on Future Accelerators (ICFA) Advanced Beam Dynamics Workshop on Beam Halo Dynamics, Diagnostics, and Collimation (May 19-23, Montauk, NY); LBNL-53638.

J. Qiang, R.D. Ryne, T. Sen, and M. Xiao, "Macroparticle simulations of antiproton lifetime at 150 GeV in the Tevatron," in *Proceedings* of the 2003 Particle Accelerator Conference (Portland, OR, May 2003), IEEE Cat. No. 03CH37423 (IEEE, Piscataway, NJ, 2003); LBNL-51808.

P.H. Stoltz, M.A. Furman, J.-L. Vay, A.W. Molvik, and R.H. Cohen, "Numerical simulation of the generation of secondary electrons in the High Current Experiment," Phys. Rev. Special Topics: Accelerators & Beams **6**, 5; LBNL-54710 (2004).

M. Venturini, J. Qiang, R. Ryne, and A. Wolski, "Space-charge effects in the ILC damping rings," in *Proceedings* of the 2003 Particle Accelerator Conference (Portland, OR, May 2003), IEEE Cat. No. 03CH37423 (IEEE, Piscataway, NJ, 2003); LBNL-56727 Abs.

T. P. Wangler, K.R. Crandall, R.W. Garnett, D. Gorelov, P. Ostroumov, J. Qiang, R. Ryne, R. York, "Advanced beam-dynamics simulation tools for the RIA driver linac, part I: low energy beam transport and radiofrequency quadrupole," in *Proceedings* of the RIA R&D Workshop (August 26-28, 2003, Washington, DC).

T.P. Wangler, C.K. Allen, K.C.D. Chan, P.L. Colestock, K.R. Crandall, R.W. Garnett, J.D. Gilpatrick, W. Lysenko, J. Qiang, J.D. Schneider, M.E. Shulze, R.I. Sheffield, and H.V. Smith, "Beam-halo in mismatched proton beams," Nucl. Instrum. Meth. A **519**, 425 (2004); LBNL-56055.