Accelerator Research

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for
Accelerator Research Department A (ARD-A)
Accelerator Research Department B (ARD-B)
Advanced Computing Department (ACD)

DOE High Energy Physics Program Review
June 14-16, 2005

Outline

- Introduction to Accelerator Research at SLAC
- Highlights from ARD-A
- Highlights from ARD-B
- Highlights from ACD
- Conclusion

Accelerator Research at SLAC

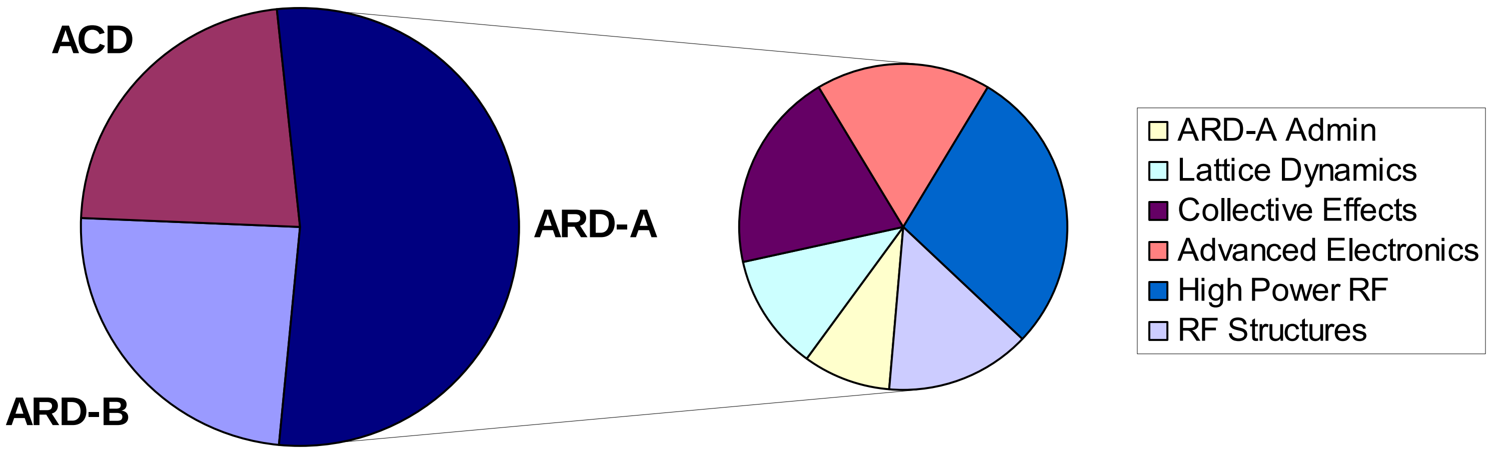
- Pushes the envelope of operating accelerators
  - PEP-II + flavor factories world wide—all operating facilities
  - SPPS and Spear3
- Develops the Accelerator Technology and Beam Physics for next generation facilities.
  - ILC, LCLS
- Pushes Advanced Accelerator Research
  - Plasma Acceleration
  - Laser Acceleration
  - Ultra-bright beam physics
- Pushes the state of the art in computational tools
  - With broad impact near, mid and far term.

Brief Overview of Departments

- Accelerator Research Department-A (Ron Ruth)
  - Pushes the capabilities of operating facilities
  - Develops the Beam Physics and Accelerator Technology for the next generation.
  - Selected topics of Advanced Accelerator Research
- Accelerator Research Department-B (Bob Siemann)
  - Performs experimental research on new ideas for high gradient acceleration of particle beams
  - Potential of long-range but far reaching impact.
- Advanced Computing Department (Kwok Ko)
  - Develops the next generation of computational tools
  - Uses these tools for accelerator development.

Human Resources

Science—62 Admin—4	Faculty	Staff	Research Associates	Graduate Students
ARD-A	3 + 2 Emeritus	18	2	5
ARD-B	1	4	1	9
ACD		13		2

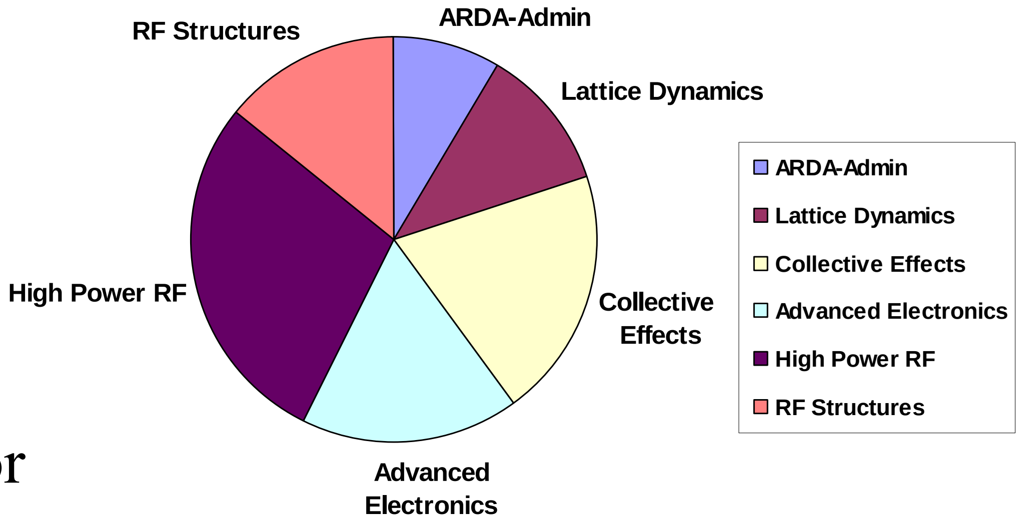


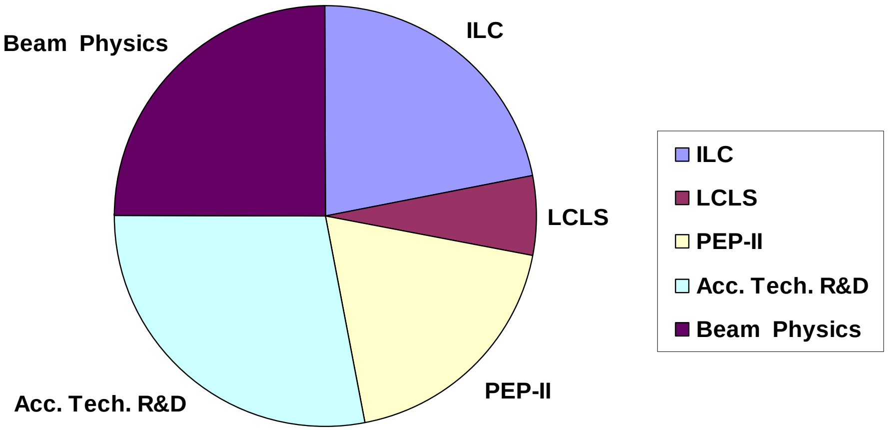
Accelerator Research Facilities

- The SLAC Linac—unique world facility
- PEP-II—Pushes storage ring state of the art
- FFTB—model final focus, now Adv. Acc. Research
- NLCTA—beams for Adv. Acc. Research plus power for high-gradient studies plus ILC.
- Klystron Test Lab—RF technology development
- SPPS—ultra-short bunches of electrons/photons
- Later, LCLS—bright beam preservation, coherent effects

Accelerator Research Department-A

- Organized into five primary groups →
- Much collaboration across group boundaries.
- Collaborate on all accelerator activities throughout SLAC
- Program split is shown →
- Beam Physics—Ultra Bright +
- Acc. Tech.– High Gradient +





Lattice Dynamics Group

3 physicists and 1 computer specialist

2004-2005 achievements:

- 20 published papers including 4 in refereed journals
- Two invited talks at EPAC 2004 and PAC 2005

Highlights of recent activities:

- Maintained and upgraded SPEAR3 and PEP-II lattices
- Developed a precision method: model independent analysis (MIA) to improve the machine optics for PEP-II
- Developed a self-consistent simulation code for beam-beam effects at PEP-II
- Designed a new dogbone damping ring with improved acceptance and extraction lines for ILC
- Studied and proposed a phase-2 collimation system to reduce the impedance for LHC

Near-term goals:

- Lead the lattice design efforts for selecting a baseline configuration of damping rings for ILC
- Continue the beam-beam simulation to optimize the luminosity of PEP-II
- Extend MIA to include dispersion and Improve the machine optics for PEP-II
- Continue the design the ILC extraction lines
- Improve the efficiency of collimation system for LHC

Long-term vision:

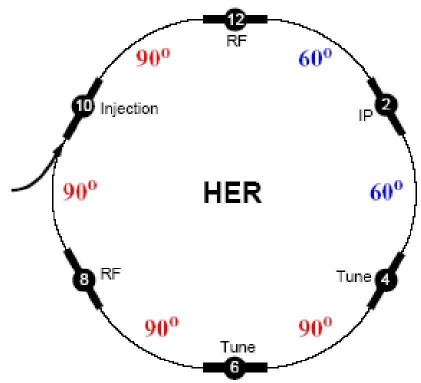
- To continue to develop and apply the most sophisticated Lattice Dynamics tools
- To on site facilities, such as LCLS
- To future facilities for HEP--ILC

Lattice Design for PEP-II, SPEAR-3 and ILC

PEP-II upgrade

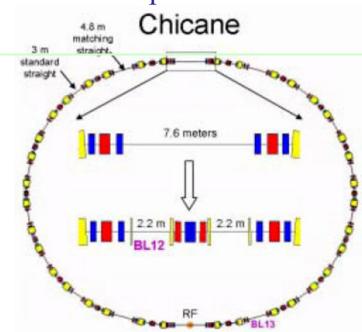
- New 90° cells in four arcs.
- 30% lower momentum compaction factor.
- 16% smaller bunch length.
- Designed for a higher luminosity with low β-function at IP.
- Scheduled for machine implementation.

HER with 90° cells in four arcs

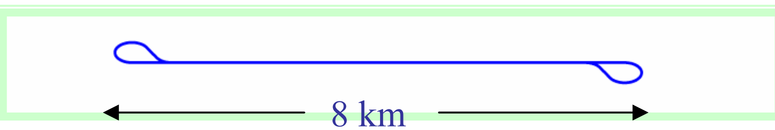


SPEAR-3 lattice upgrade

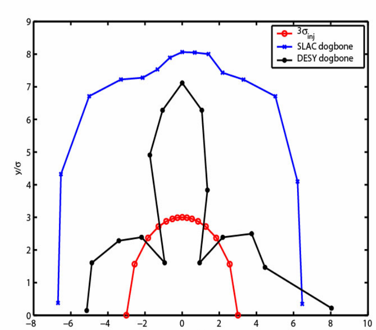
The upgrade lattice for SPEAR-3 has been designed to provide a double waist low-β optics in the East Pit straight section for high brightness, small gap, hard X-ray undulators. Machine implementation has been scheduled.



New ILC 17 km dogbone damping ring



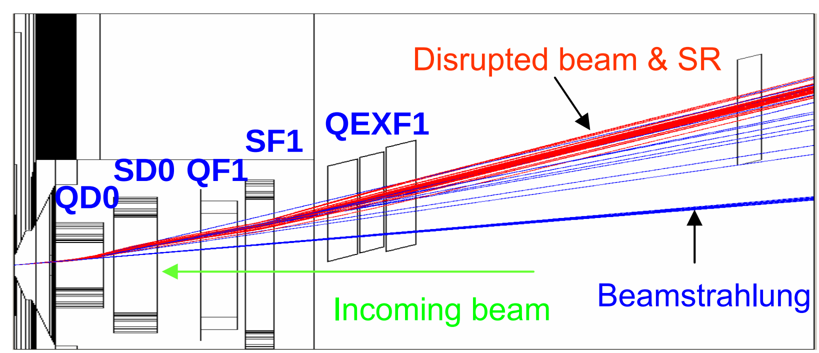
- New ILC damping ring design based on a detuned π-cell and non-interlaced sextupoles.
- Significantly improved on-momentum dynamic aperture with non-linear wigglers (compared to DESY design).
- Further plan includes improvement of off-momentum dynamic aperture, study of lattice tolerances and wiggler specifications.



Dynamic aperture

ILC extraction line design

We have designed the initial optics for the ILC extraction lines for 20 mrad and 2 mrad crossing angles. These designs provide large beam acceptance required for the high power disrupted beams (11-18 MW) with large energy spread (>60%), and include the energy and polarization diagnostics.



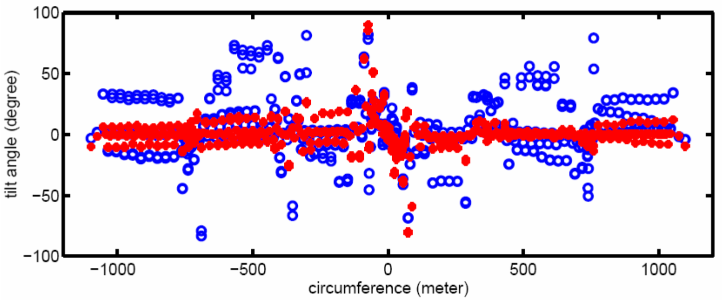
Model-Independent Analysis (MIA)-- PEP-II optics measurement and improvement

MIA takes advantage of high-precision betatron-motion signals from turn-by-turn BPM buffer data.

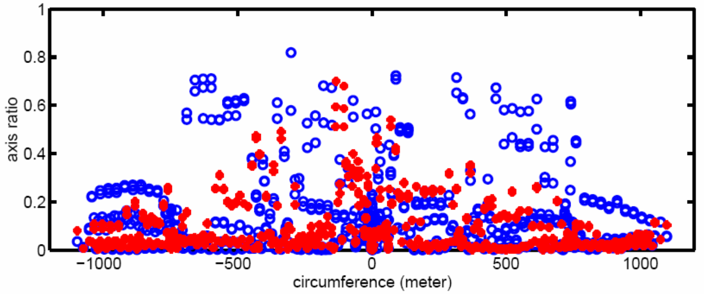
MIA obtains a computer virtual accelerator that matches the real accelerator optics → finds an improvement solution → applies the solution to improve the real accelerator.

MIA has contributed to key PEP-II optics improvement –-- fixing beta beats, improving linear couplings, and bringing LER to near half-integer working tunes for significant improvement of PEP-II luminosity.

Taking advantage of a separable high-precision synchrotron- motion signal, MIA is under upgrading to include dispersion.



An example: LER Coupling Ellipse tilt angles (above) at all double-view BPMs after an orbit steering (blue), and expected improvement (reduced angles) with a MIA solution (red).

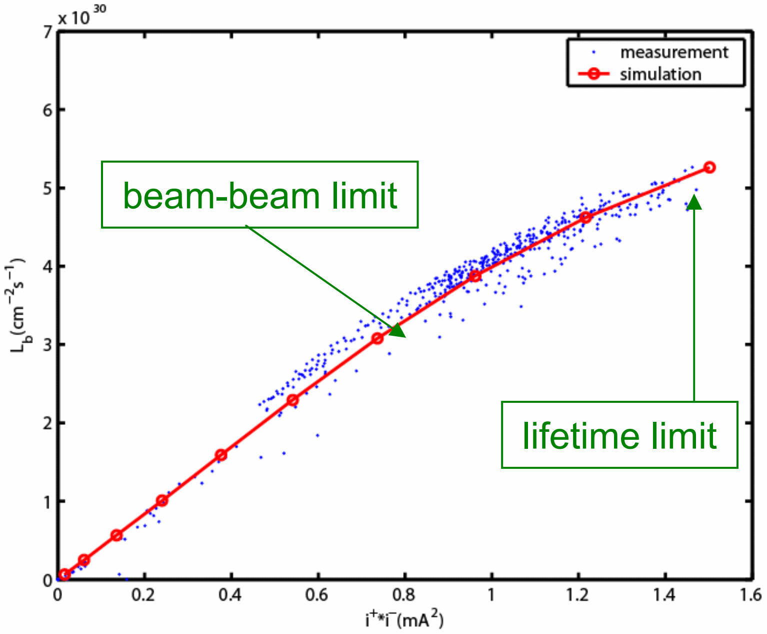


LER Coupling Ellipse axis ratios at all doubl-view BPMs after an orbit steering (blue), and expected improvement (reduced ratios) with a MIA solution (red).

Self-Consistent Simulation of Beam-Beam Effects for PEP-II

- Arbitrary beam distributions in three dimensions based on particle-in-cell method
- Parallel computing using Message Passing Interface on PC clusters or supercomputers at NERSC
- Well calibrated against many different experiments including parasitic collisions and crossing angle
- Used for providing guidance of improving luminosity of PEP-II and predict its future performance
- Being extended to include nonlinear lattices and calculation of beam-beam lifetime
- Used by others for PEP-II and BEPC-II

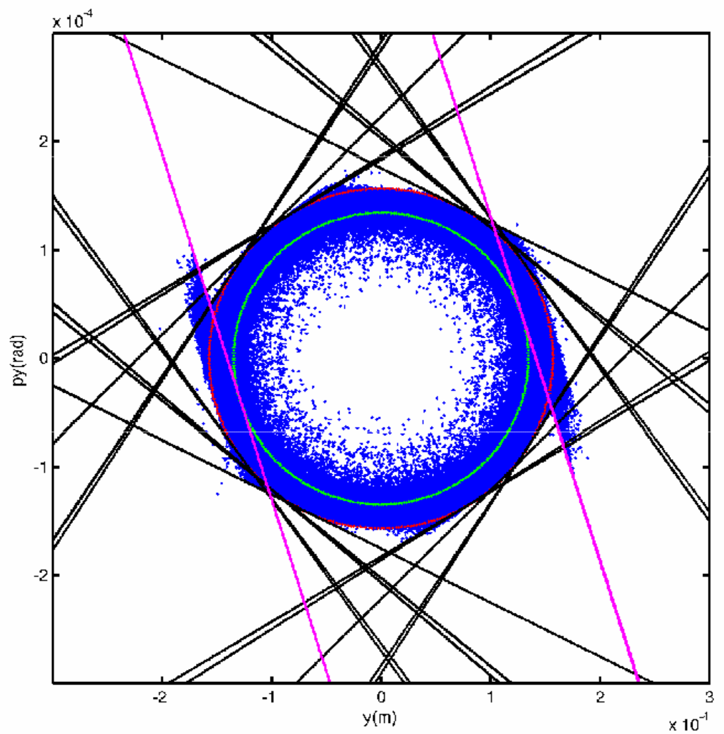
Bunch luminosity



Measured in period of 24 hours, 11/21/03, 1230 bunches in every Two buckets

Simulation of LHC Collimation System

Secondary Halo



simulation with realistic collision lattice and collimators at 7 Tev.

- The phase I collimation system will limit the beam current to a half of its design value because of high impendence of collimators made with carbon.
- SLAC is proposing to use NLC consumable copper collimators as an alternative for the phase II system.
- We are designing an efficient two-stage collimation system and developing a prototype of collimator at SLAC as a part of US LHC Accelerator Research Program.
- Progress has been made to understand the efficiency of the collimation system.

Collective Effects Group

- Impedance calculations, beam instabilities, and FEL theory
- 5 staff, 1 visitor, 1 student
- 51 publications in 2004-05, 13 in refereed journals

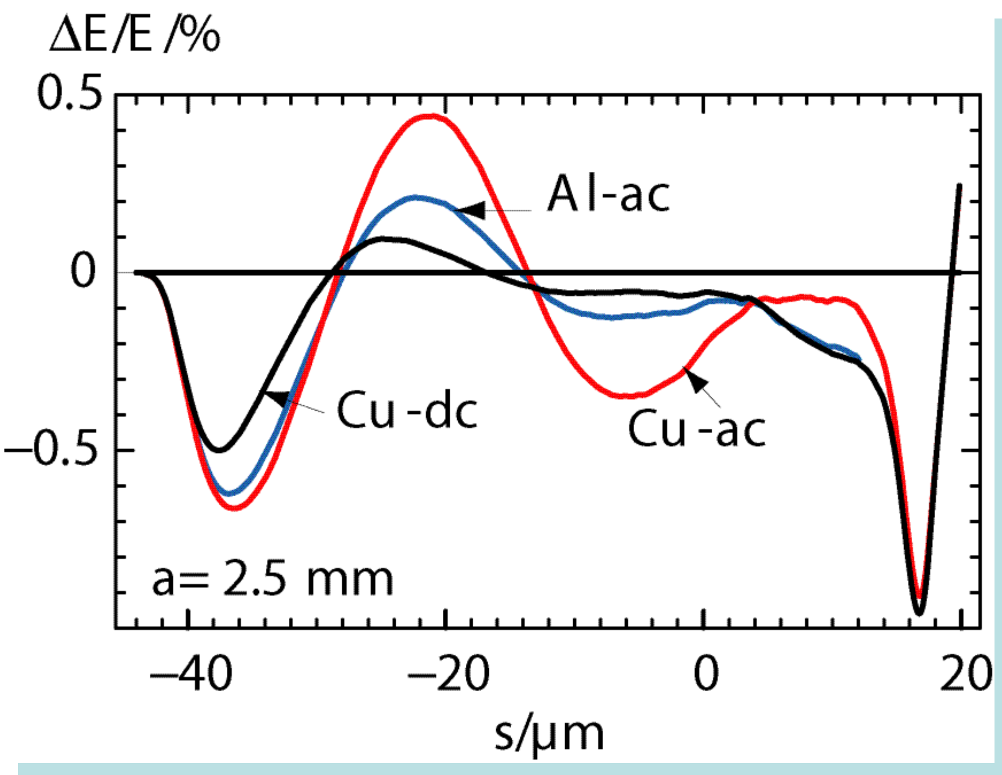
Future plans

- Methods of producing higher power and shorter saturation length in SASE FELs
- Further investigations into micro-bunching instabilities
- Physics of energy spread and emittance limitations of the RF guns
- CSR effects in beam dynamics
- Theory of wakefields for short bunches with application for ILC collimators.

Recent achievements

- Resistive wall wakefields in the LCLS undulator
- FEL theory with slowly varying beam and undulator parameters
- Proposal of a low-charge bunch regime for the LCLS
- CSR in light sources and linear collider damping rings
- Dust particle dynamics in storage rings
- Suppression of the secondary emission yield to mitigate electron cloud effects

Resistive wall wakefield in the LCLS undulator



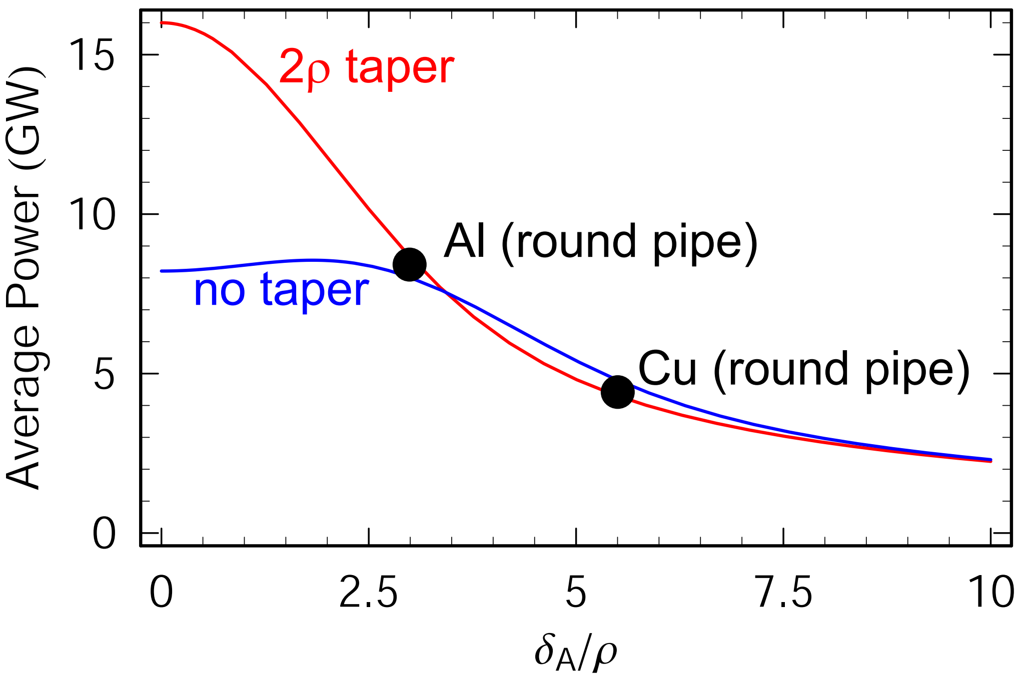
At high frequency the metal conductivity becomes a function of frequency (ac conductivity). This effect results in increased wakefield for the LCLS beam in the undulator.

K. Bane, G. Stupakov, SLAC-PUB-10707

Induced energy deviation due to the wake within the 70 micron long beam inside the LCLS undulator for various materials of the wall, with and without ac conductivity. The accumulated energy spread for copper is large enough to interfere with the process of photon emission.

Effect of AC Resistive Wall Wake on SASE Analytical Treatment

- SASE FEL theory was extended to include the effect of slow variation of beam energy and/or undulator strength
- It was found that undulator tapering can increase the saturation power of x-rays

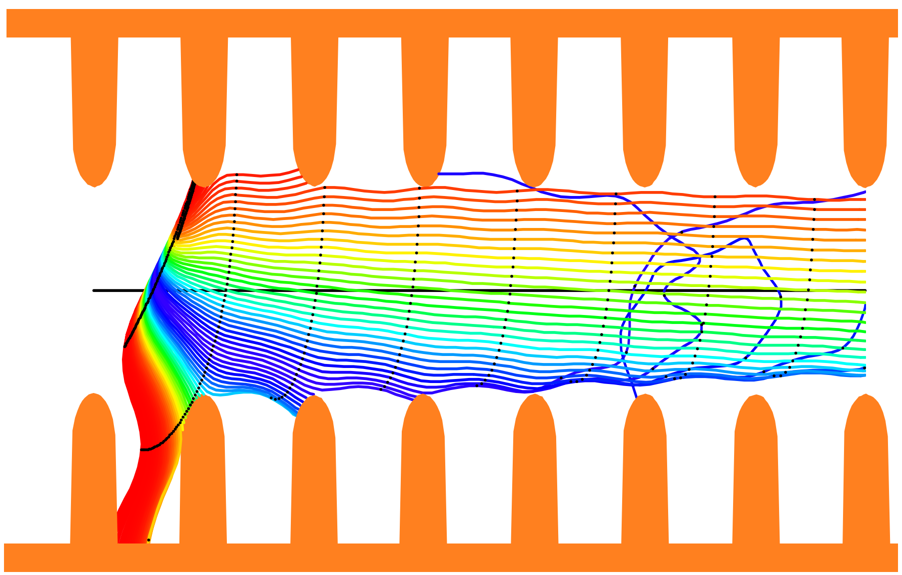


For small wake amplitude, 2ρ taper doubles the saturation power over the no taper case

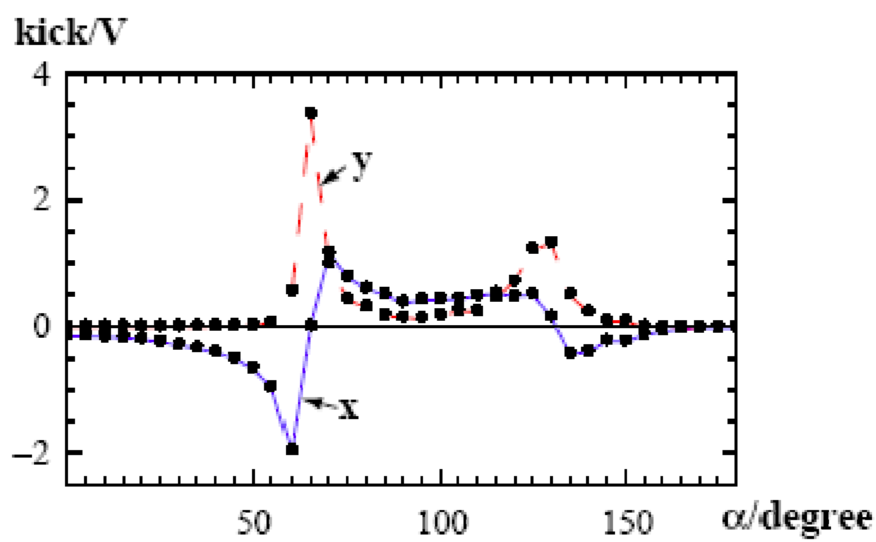
Z. Huang, G. Stupakov, PRST-AB, 2005

Dark currents in X-band RF structures

"Dark current" electrons emitted from irises of an X-band accelerating structure may have various deleterious effects, one of which is an interaction with the primary electron (or positron) bunch. Kicks to the beam centroid caused by the field of the dark current dilute the beam emittance. Our simulations showed that contribution of dark currents is small compared to other sources of emittance growth.



V. Dolgashev, K. Bane, J. Wu,
G. Stupakov, T. Raubenheimer, PRST-AB, 2005



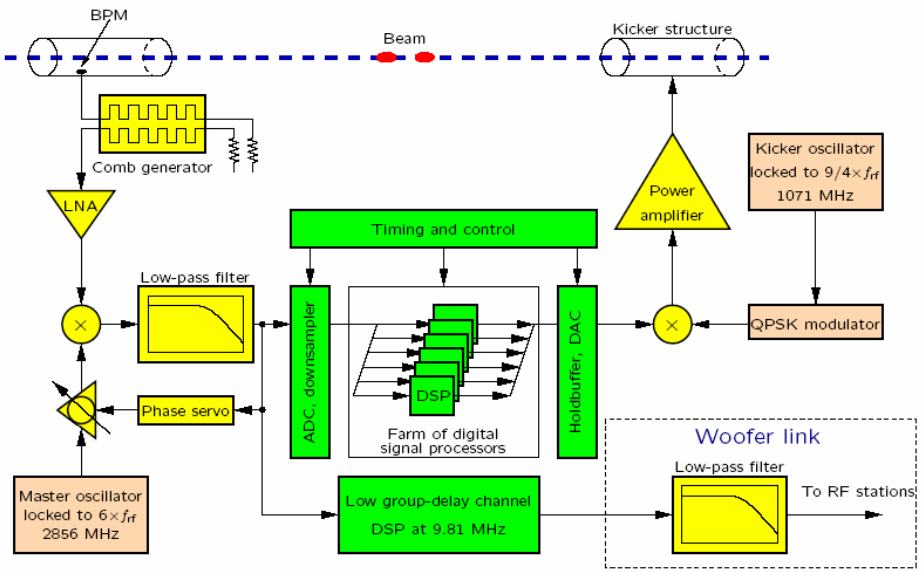
ARDA Advanced Electronics - Overview

Group - 4 SLAC Staff, 2 Ph.D. Students

14 publications 2004-2005 (invited talk at PAC 2005). Taught 3 Stanford Applied Physics and 2 USPAS courses.

D. Teytelman won the 2003 APS Dissertation Prize in Beam Physics (our second Ph.D. APS Dissertation Prize)

Active international collaboration on technology development and measurements



Recent Achievements

PEP-II RF- Beam Dynamics, RF system stability modelling, high current instability control.

Technology Development

- Gboard - next generation 1.5 GS/sec. reconfigurable processor - critical technology prototyped
- Low Group Delay Woofer - developed, commissioned - increases PEP-II currents and luminosity via low-mode stability
- Klystron Linearizer - developed, prototypes ready for beam tests in LER. Improves direct feedback impedance control

Long Range Vision - development of reconfigurable high-speed signal processing systems for accelerators and light sources. Leadership role in beam instability dynamics and control. Development of wideband electronic and optoelectronic technology for ultrafast applications.

ARDA Advanced Electronics Major Activities in 2003/2005

PEP-II High Current Instability studies, RF- Beam Dynamics, RF system stability modelling

- Coupled-bunch studies (HOM driven instabilities), tuning/configurations of LFB systems
- Fault file analysis tools and RF diagnostics
- LLRF model-based configuration tools, station tuning, operations oversight
- Predictions for operations, evaluation of future operating conditions
- Tutorial course on PEP-II LLRF systems taught to 48 SLAC Accelerator and Operations Staff

Technology Development

- Gboard -1.5 GS/sec. reconfigurable processor - critical technology prototyped - in test
- Low Group Delay Woofer - Augments PEP-II instability feedback-developed, commissioned
- Klystron Linearizer - Increased Impedance reduction- prototypes ready for beam tests in LER

Publications

- Conference papers (EPAC and PAC), Journal papers, Internal MAC reviews, Internal talks

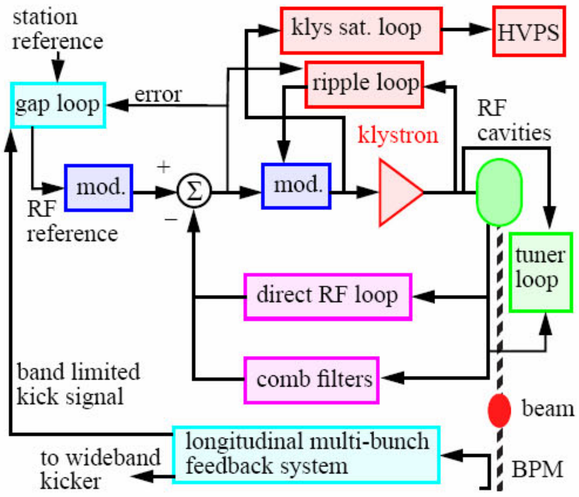
Teaching (Stanford Applied Physics, US Particle Accelerator School)

Staffing - Recruitment and hire of 2 new SLAC staff with RF and Control engineering expertise

PEP-II LLRF Systems

Our group has taken over the analysis, configuration, fault diagnosis, and new technology development for these critical systems

- Heavily Beam loaded
- State of the art in Impedance control via direct and comb feedback
- Multiple complex regulation loops
- Stability issues for RF loops, RF-Beam interactions, and low-mode coupled bunch instabilities.



The LLRF in PEP-II includes fast analog, fast digital and slow digital control loops. Impedance control via the direct and comb loops.

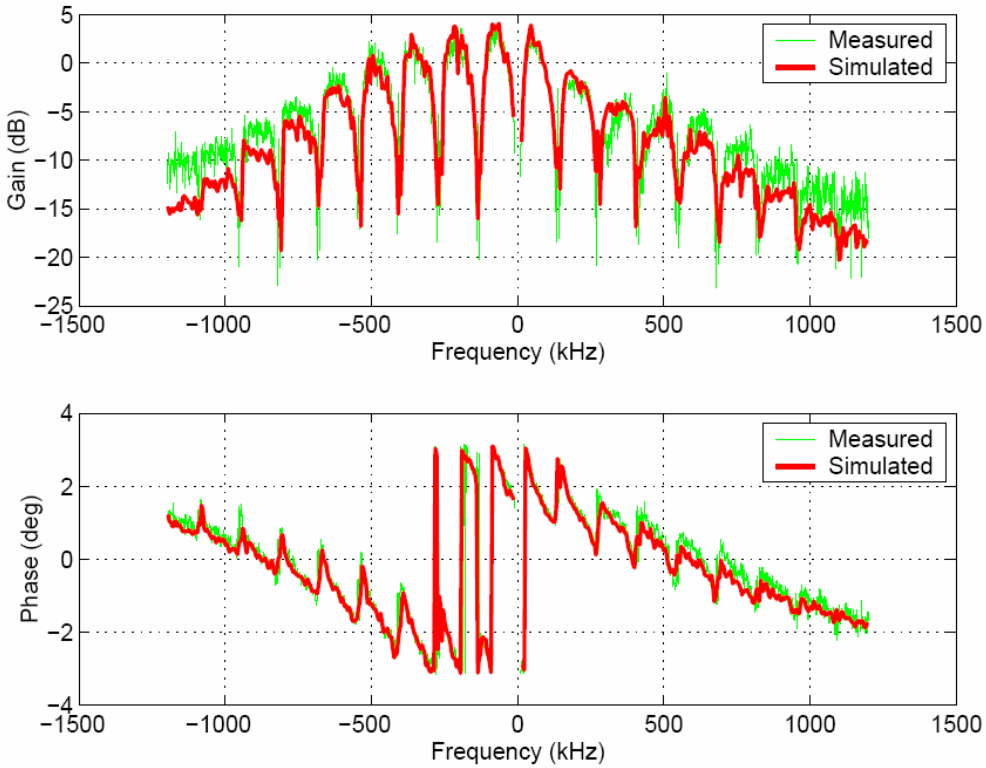
Contributions

- New model based configuration techniques
- Fault analysis methodology, reporting
- Analysis of operating points, estimations of technology limits (PEP-II luminosity increases via increased currents)
- New technology (LGDW, Klystron Linearizer)
- RF Tutorial for SLAC Operations and Accelerator Staff (2 day course,48 attendees)

Development of time-domain RF system model

Main limitation in predicting longitudinal stability at higher beam currents is the uncertainty in estimating the growth rates of the fundamental-driven eigenmodes

Impedance reduction via the LLRF feedback loops is critical, however the effectiveness of these loops is difficult to predict due to klystron saturation.



Recent efforts

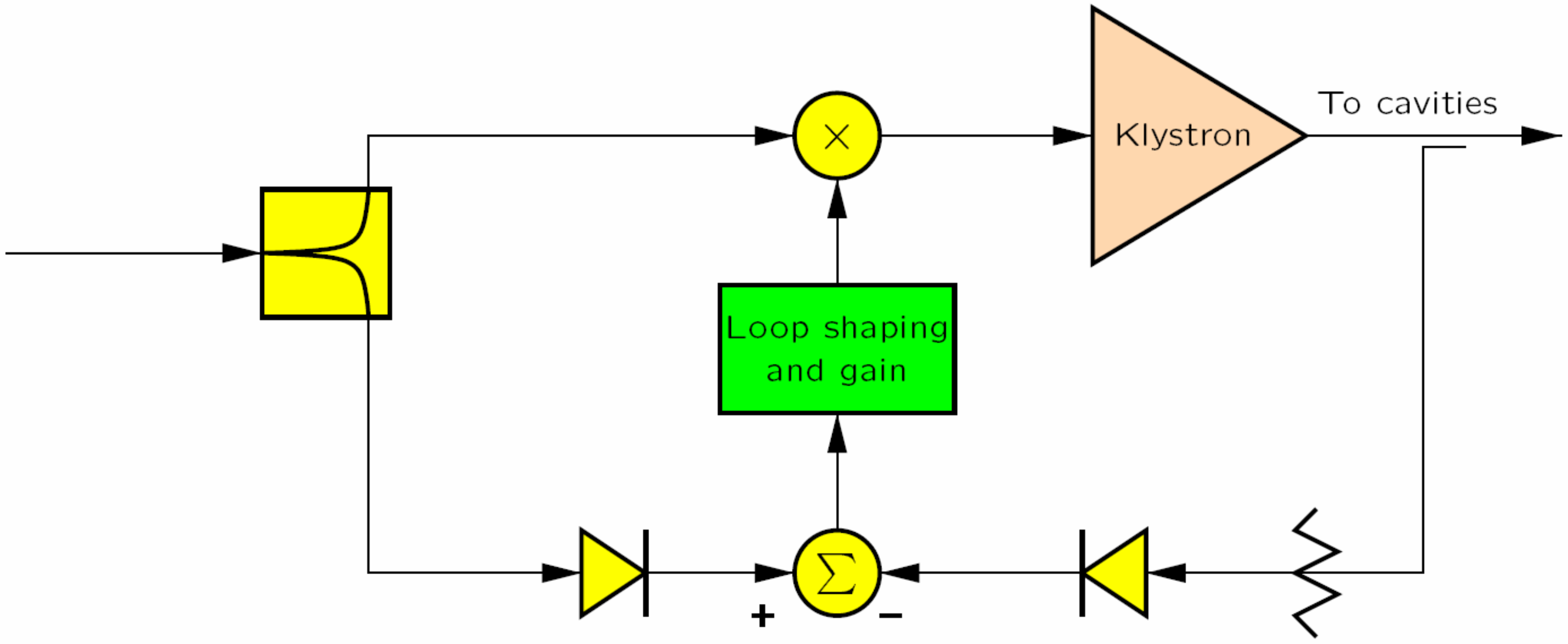
- **time-domain model consistent with the current RF system topology.**
- **As a test run the time-domain model using parameters extracted from an RF station transfer function measurement**
- **Transfer function extracted from the time-domain simulation data agrees very well with the transfer function of the physical station.**

Klystron linearizer: block diagram

In the past year we have developed a new technique to improve the impedance control of the RF direct loops by linearizing the high power klystron

Compare the input of the klystron and the output, use amplitude modulator to make the two match. Linearizes the klystron so that large- and small-signal gains are identical. Feedback does increase the effective klystron delay.

Full-power test stand data, 5 prototype processors in place in LER for beam tests



RF Structures Group

Group: 1 Faculty Member, 4 SLAC Staff

27 papers have been published in recent couple of years, 1 course was taught in US Accelerator School.

Highlights of Recent Achievements

- Played a leading role in the NLC main linac structure R&D.
- Designed, fabricated and tested 50 X-Band accelerator structure sections.
- Supported high gradient study program to meet the NLC 65 MV/m requirement.
- As a technical breakthrough, the Damped Detuned Structures provide a superior solution for any low emittance, high beam loading accelerator

Swift Adjustment in R&D after ITRP Decision.

- Proposed an improved design for L-Band normal conducting accelerating system for ILC positron source.
- Worked on positron beam dynamics studies for increasing the yield.
- Studied on wakefield-beam interaction in the superconducting L-band structures.
- Worked on the structure related work for the LCLS project.
- Engineering support to SLAC projects.

Challenging Years Ahead

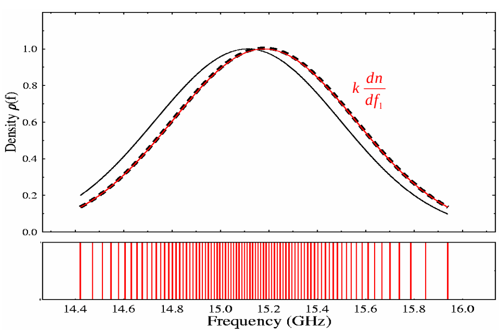
- Design, fabricate, tune and high power test L-Band accelerator sections for ILC positron source pre-accelerator.
- Contribute to the CDR of the RF accelerator system of the ILC positron source.
- Support the accelerator structure related work for the LCLS project.
- Simulation and analysis of wakefield-beam interaction for the ILC linac.
- Participate in the collaboration for CLIC structures and High Gradient development

Accelerator Structure R&D for NLC

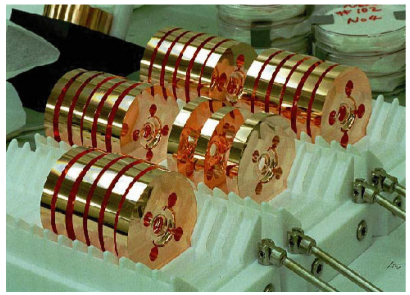
• Played a leading role in the NLC main linac structure R&D.

• Designed, fabricated and tested 50 X-Band accelerator structure sections. (Among them, 8 were made with KEK collaboration and 12 were fabricated by FNAL).

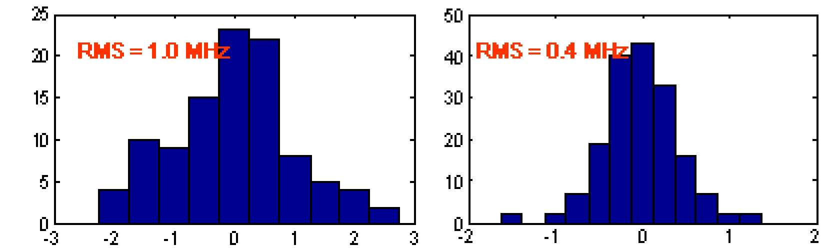
•As a technical breakthrough, the Damped Detuned Structures provide a superior solution for any low emittance, high beam loading accelerator.



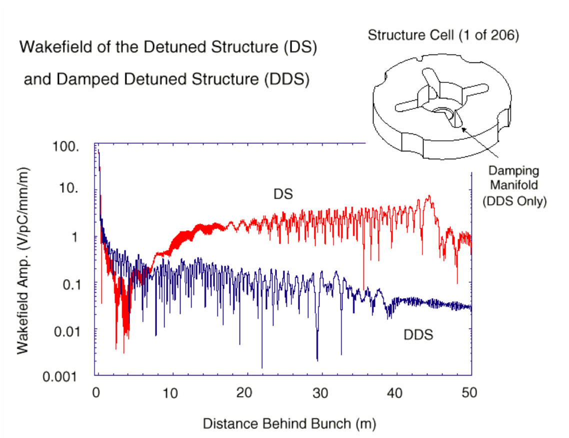
Dipole mode distribution for Detuned Structure



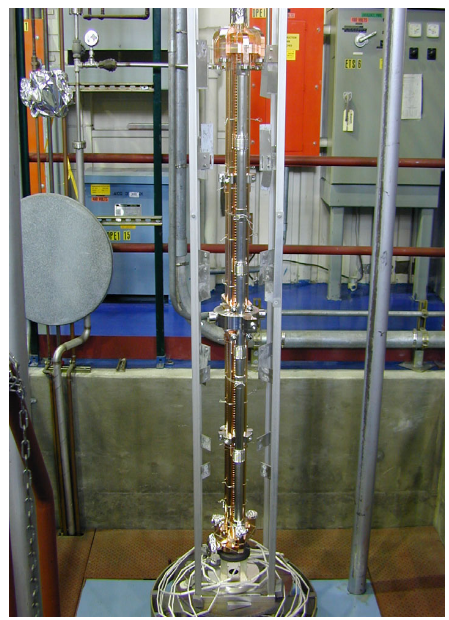
Cells ready for diffusion bonding



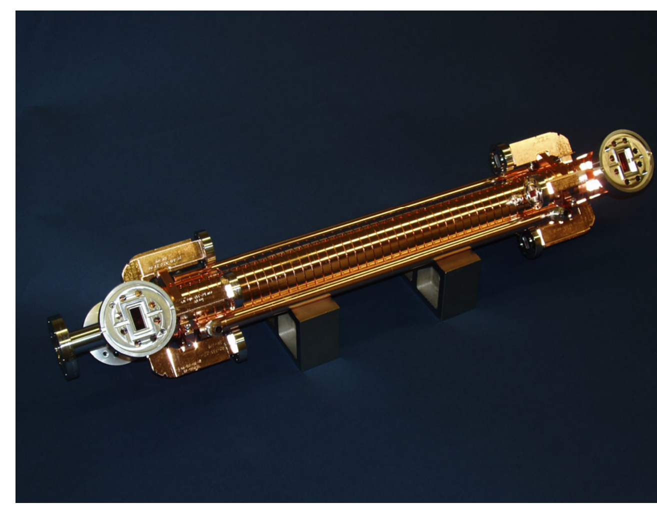
Deviations of cell dipole mode frequencies for precision (left) and regular (right) turning cells (Require < 3 MHz RMS)



Dipole mode wakefields for Detuned and Damped Detuned Structure



Final brazing



Prototype structure for NLC main linac

L-Band Normal Conducting Accelerating Structures for ILC e+ Source

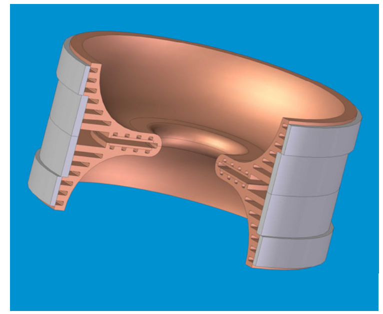
• Proposed an Improved Alternative Structure Design for Positron Source with Mechanical Simplicity, Effective Cooling and Lower Pulsed Heating:

  • Capture sections: Simple π mode short SW sections.
  • Pre-Acceleration: High phase advance TW structures.

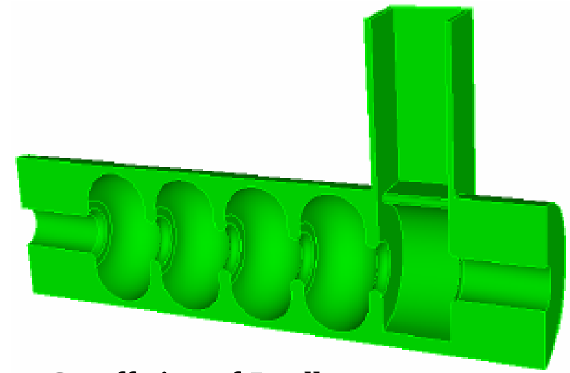
• Design and fabricate L-Band testing structures.

• Contribute ILC CDR for positron source design.

The 5-Cell Structure will be completed by the end of 2005

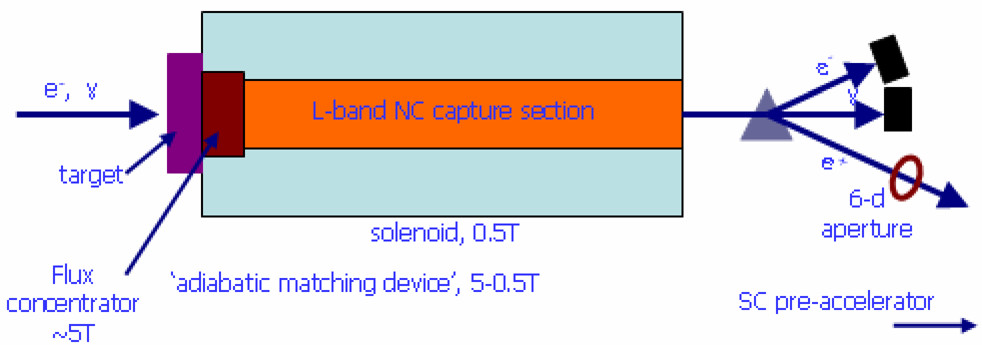


Cell cooling design



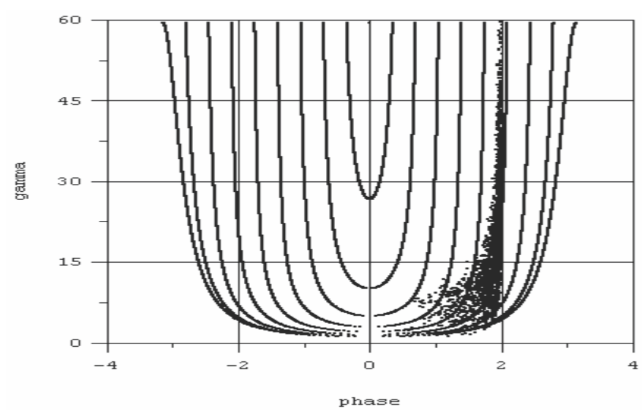
Cutoff view of 5-cell structure

Phasing the positron capture section so that it initially decelerates and bunches the positrons can shorten the bunch and produce a positron bunch with much smaller longitudinal emittance.



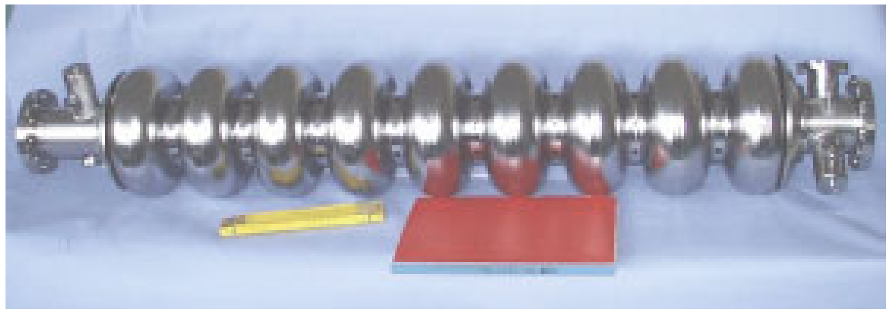
Generic layout of the positron source.

Our R&D is on the RF structures of Pre-accelerator from target to 250 MeV stage



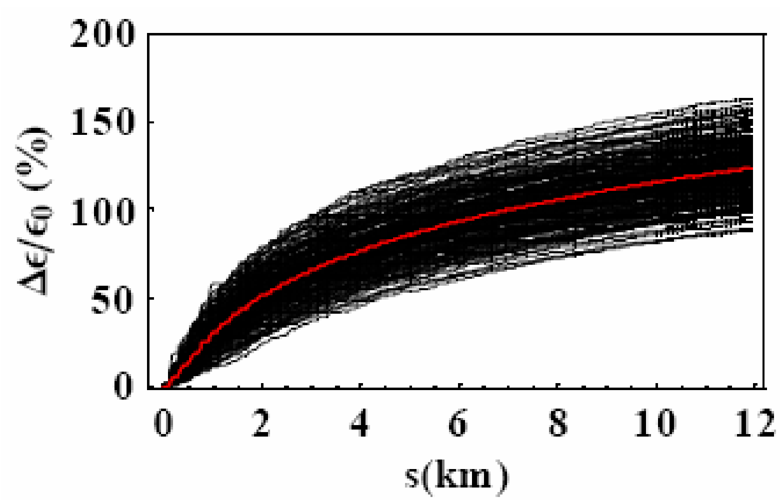
Phase space for positrons interring accelerator

Circuit Theory to Model ILC Superconducting Accelerator Superstructures

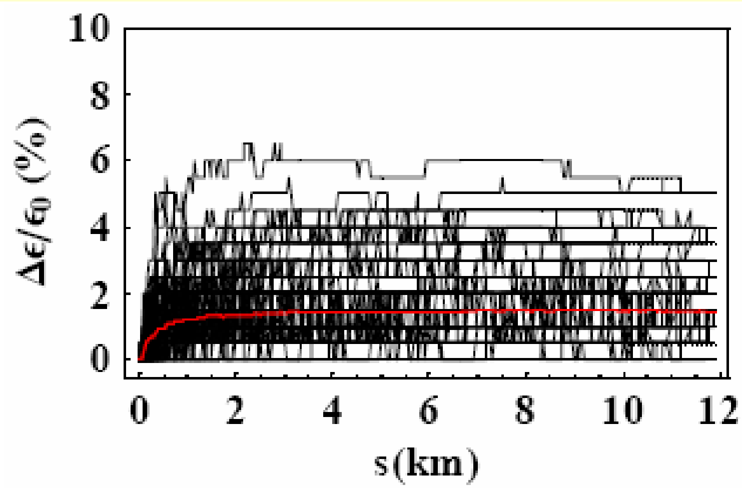


TESLA superconducting structure

We have modeled the beam dynamics of the wakefield-beam interaction. Initial results indicate that considering the coupling of the horizontal to the vertical motion of the beam, randomizing the azimuthal position of the Higher Order Mode (HOM) couplers may be essential to prevent severe emittance dilution.



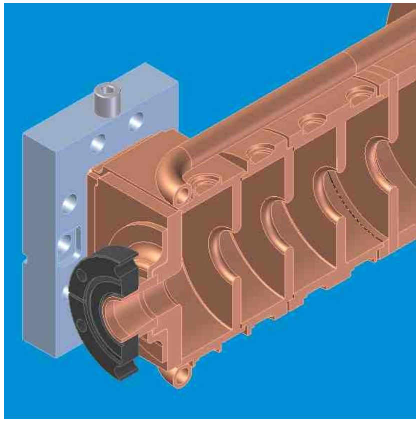
Precise Azimuthal Alignment of HOM Couplers



All HOM Couplers Are Randomly Aligned

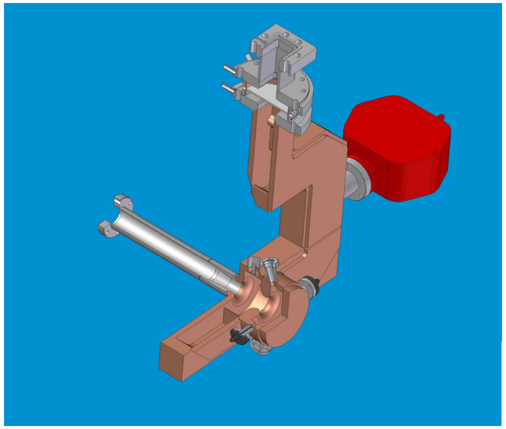
Support SLAC RF Structure Related Work

- Support any structure related work at SLAC.
- Measured and evaluated two 9.5 ft S-Band accelerator sections for LCLS new beam line
- Important suggestions: LCLS injector structure design.
- Will measure and evaluate six 3m S-Band accelerator sections in order to pick 2 as booster sections
- Will tune and characterize two booster sections after modification with new double input waveguides.
- Will tune and characterize the LCLS RF gun.
- Will characterize two RF deflectors for LCLS.

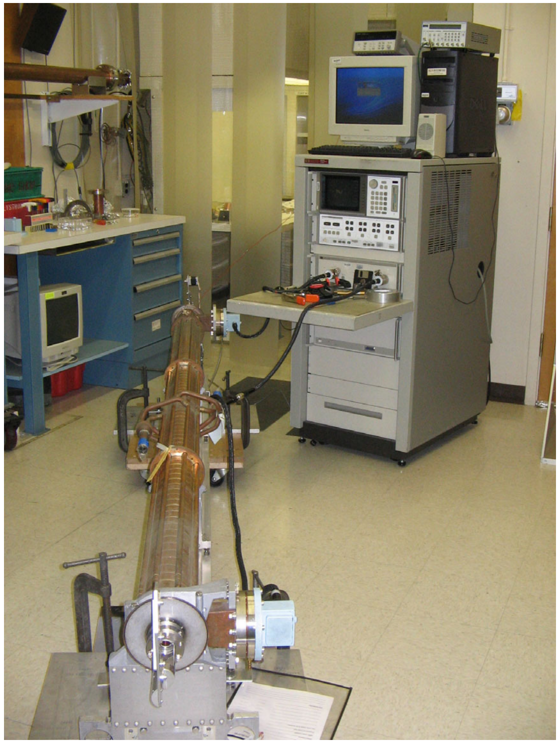


Double input structures for injector booster of LCLS

RF Deflector sections



RF Gun with double input waveguides.



A 9.5 ft S-Band section under test

High Power RF Group

2 Faculty Members, 3 Staff, 2 Post Docs, 2 graduate students, 1 retired

30 publications during 2004 (6 in peer-reviewed Journals) , 3 invited talks during 2004, won the US particle accelerator school prize of achievement in 2003

Highlights: recent achievements

- World record in RF generation
- Low-field RF couplers
- Experimental analysis and simulation for the RF breakdown process
- A new spatially-combined devices for high-power semiconductor switches.
- Design of Bragg optical accelerating structures

Near Term Activities

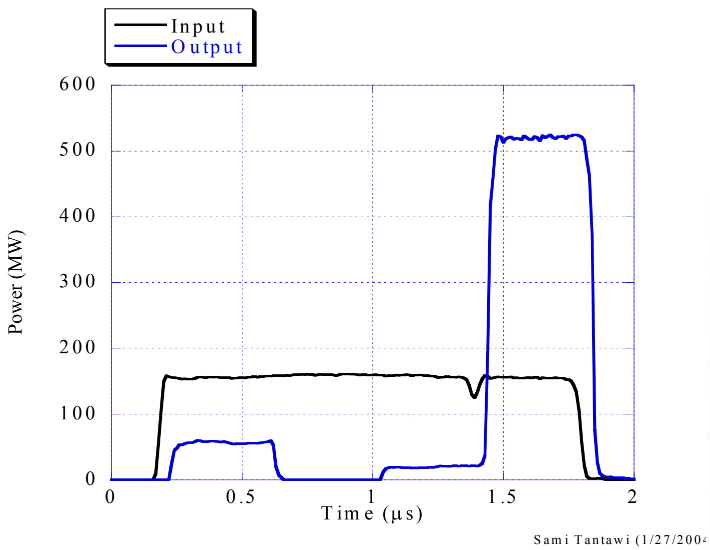
- RF Undulator exploration
- Optical Accelerators design and fabrication
- Ultra-High Power solid-state devices
- High Gradients for Multi-TeV LC
- Advanced concepts for ILC.

Long Range Vision

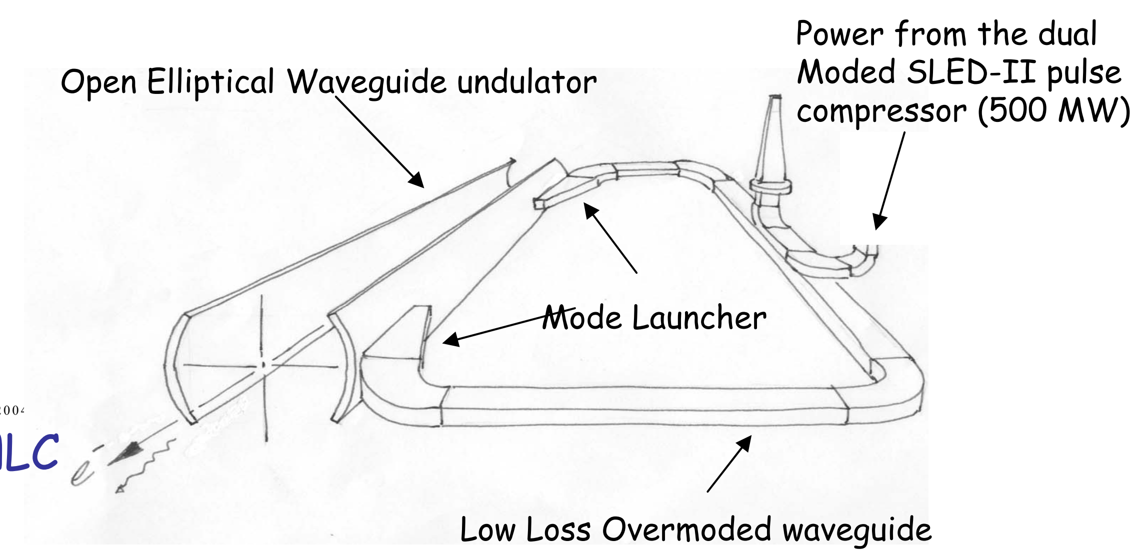
- ***RF Undulators***: experiment at the NLCTA
- ***Optical Accelerators***: fabricating and testing a practical device using micro-processor technology.
- ***Active Pulse Compression***: ultra-high-power semiconductor devices, including RF sources
- ***High Gradient Research***: High Gradient studies for Multi-TeV LC
- ***Advanced Concepts for the ILC***: Input coupler, RF distribution system, and fast kickers.
- ***Fundamental Research in Superconducting Materials***

RF Undulator

- RF undulator idea is old.
  - Recent advances in high power rf pulse compression systems at x-band => RF undulator practical for SASE FEL
- RF undulator--many attractive properties
- We plan to study this type of undulator.
  - We will also propose an experiment at the NLCTA enclosure using the existing infrastructure for e-beam and rf sources.



Experimental output of the NLC high power pulse compressor

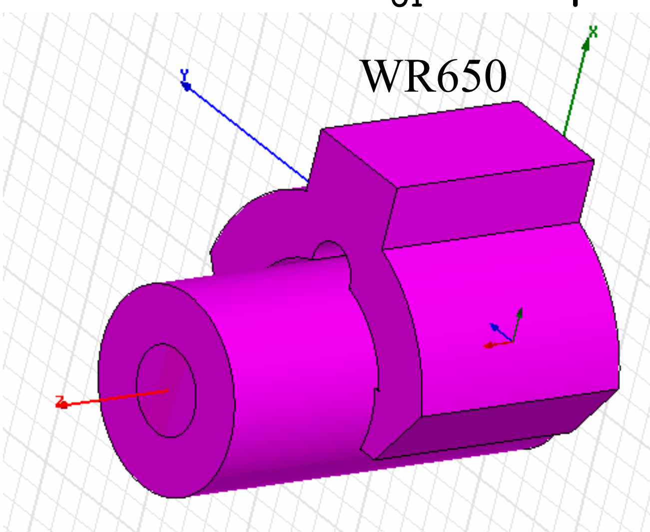


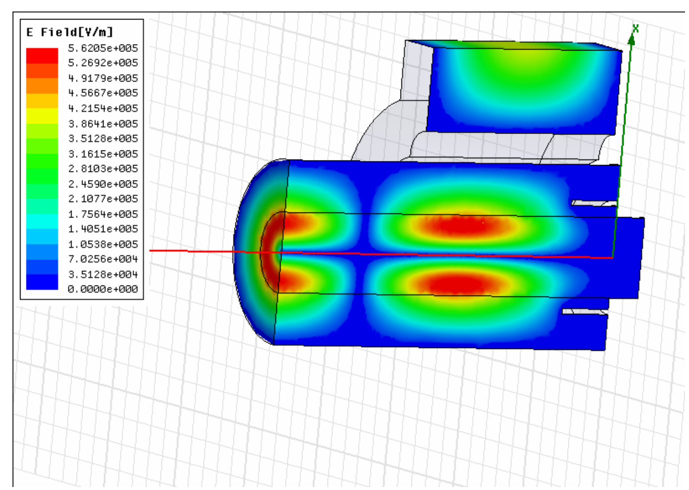
Advanced concepts for ILC

- New concepts for Fundamental mode couplers
- Fast RF Kickers for the damping Ring
- Analyzed the RF distribution system and shown the feasibility of eliminating ~21,000 circulators. The concept is being examined/adopted by KEK

Novel Coupler Concept

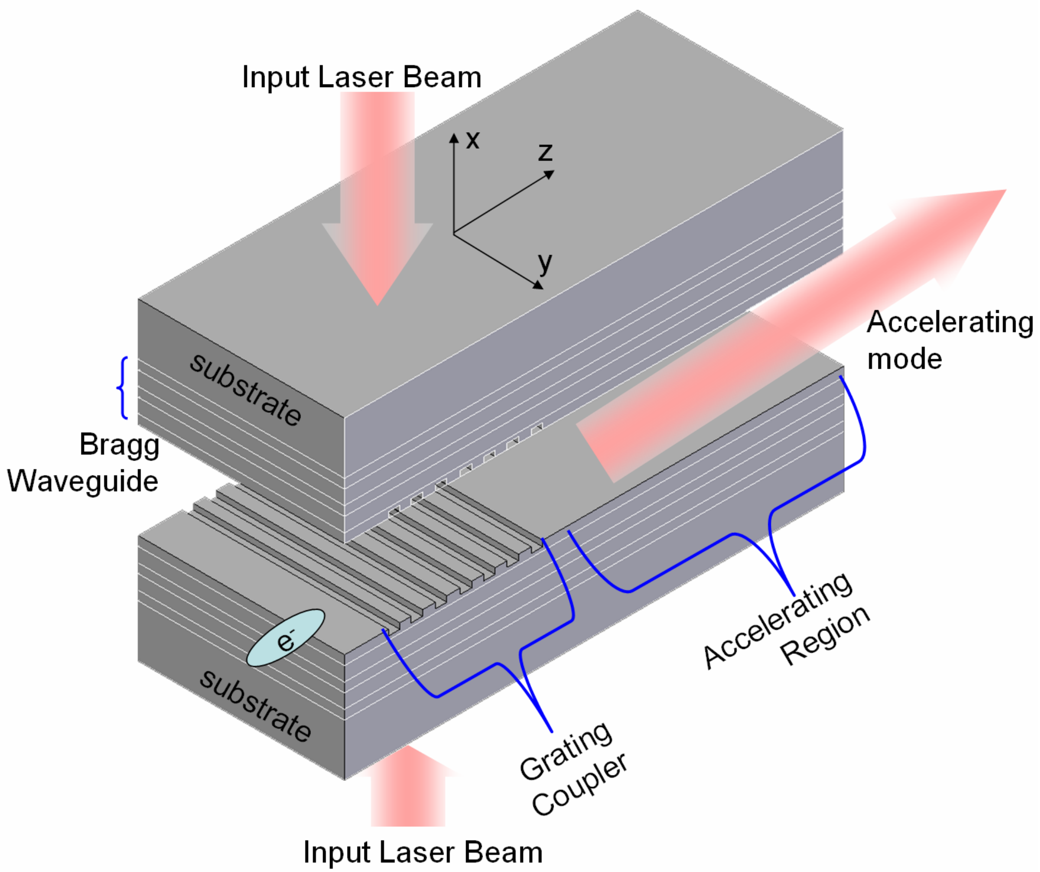
- No Normal fields at the surface
- Mechanical and <u>thermal</u> isolation between section are possible
  - Because the TE_{01} mode permits gaps





Optical Dielectric Accelerator

- Low intrinsic loss at near infrared ~ 0.2dB/km
- High damage threshold supports accelerating gradient ~ 1GV/m
- High power laser source available

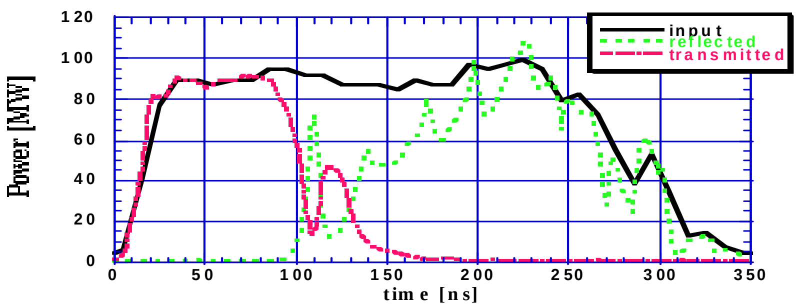


Optical all-dielectric planar accelerator structure

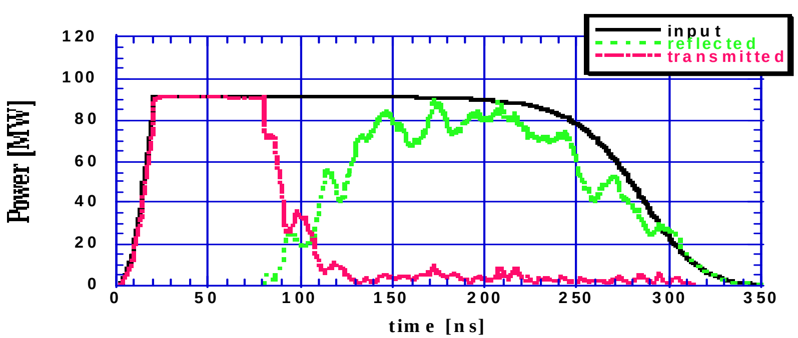
- Accelerating mode guided by the Bragg waveguide
- Grating coupler couples laser light from the side and converts it to accelerating mode
- Waveguide and coupler can be fabricated with micro-processing technology

High Gradient Study

- Studied breakdown limits in waveguides vs. Geometry and materials
- Credible simulations that represent experimental data for the field-particle interactions during the breakdown event.
- We will continue of experimental and theoretical investigations of the phenomena using single cell traveling-wave structure (a simple structure that capture the physics of a real accelerator structure), with the goal of understanding the physics of the breakdown phenomena. Hence, the hope for accelerators with much higher gradients than the current state-of-the art



Measurements, 24 April 2001,18:13:40, shot 45



3D PIC simulations, 4x4 mm emitting spot, electron current 7kA, copper ion current 30A

Single Cell TW Structures

Accelerator Research Department B
At-a-glance

Who We Are

1 Faculty member
4 Staff physicists
1 Postdoctoral Associate
9 Graduate students
1 administrative assistant

What we do

Experimental investigation of novel concepts for high-gradient particle acceleration:

- Beam-driven plasma acceleration
- Laser-driven accelerator structures

Publications:

48 since May 2004

* 9 Refereed papers (7 to *Phys. Rev.*, 1 *Science*, 1 *JoP B*)
* 39 Conference papers

Graduate Theses since May 2004

•**Wei Lu**, M.S., UCLA, "Some Results on Linear and Nonlinear Plasma Wake Excitation: Theory and Simulation Verification".
•**Chenkun Huang**, M.S., UCLA, "Development of a Novel PIC Code for Studying Beam-Plasma Interactions".
•**Caolionn O'Connell**, Ph.D., Stanford, "Field Ionization of Neutral Lithium Vapor Using a 28.5 GeV Electron Beam", June 2005.

Service since May 2004

• Editor of *Physical Review Special Topics -- AB*
• Technical review committees for Tevatron, SNS
• Reviews of LBNL, BNL, Muon Collider
• SBIR and HEP grant reviews
• DPB Executive and Education Committees
• Conference session conveners/group leaders for AAC, APS, and DPF
• Conference Committees for AAC, APS, DPF, PAC, and RF
• SLAC Liaison to local city government; local science fair judging…

Refereed Publications since May 2004

1. P. Muggli, B. E. Blue, C. E. Clayton, S. Deng, F.-J. Decker, M. J. Hogan, C. Huang, R. Iverson, C. Joshi, T. C. Katsouleas, S. Lee, W. Lu, K. A. Marsh, W. B. Mori, C. L. O'Connell, P. Raimondi, R. H. Siemann, and D. Walz, "A Meter-Scale Plasma Wakefield Accelerator Driven by a Matched Electron Beam", Physical Review Letters **93**, 014802 (2004)
2. R. H. Siemann, "Energy Efficiency of Laser Driven Structure Based Accelerators" Physical Review Special Topics – Accelerators and Beams, **7**, 061303 (2004)
3. Y. C. Neil Na, R. H. Siemann, and R. L. Byer, "Energy Efficiency of an Intracavity Coupled, Laser-Driven Linear Accelerator Pumped by an External Laser", Physical Review Special Topics – Accelerators and Beams, **8**, 031301 (2005)
4. R. H. Siemann, T. Plettner, and R. L. Byer, "The Impact of Einstein's Theory of Special Relativity on Particle Accelerators", Journal of Physics B: Atomic, Molecular and Optical Physics, **38**, S741 (2005)
5. C. M. S. Sears, E. Colby, B. Cowan, R. H. Siemann, J. E. Spencer, R. L. Byer, and T. Plettner, "High Harmonic Inverse Free Electron Laser Interaction at 800 nm", submitted to Physical Review Letters
6. T. Plettner, R. L. Byer, E. Colby, B. Cowan, C. M. S. Sears, R. H. Siemann, and J. E. Spencer, "Visible-laser acceleration of relativistic electrons in a semi-infinite vacuum", submitted to Physical Review Letters
7. M. J. Hogan, C. D. Barnes, C. E. Clayton, F.-J. Decker, S. Deng, P. Emma, C. Huang, R. H. Iverson, D. K. Johnson, C. Joshi, T. Katsouleas, P. Krejcik, W. Lu, K.A. Marsh, W. B. Mori, P. Muggli, C. O'Connell, E. Oz, R. H. Siemann, and D. Walz, "Multi-GeV Energy Gain in a Plasma Wakefield Accelerator" submitted to Physical Review Letters
8. A.L. Cavalieri, D.M. Fritz, S.H. Lee, P.H. Bucksbaum, D.A. Reis, J. Rudati, D.M. Mills, P.H. Fuoss, G.B. Stephenson, C.C. Kao, D.P. Siddons, D.P. Lowney, A.G. MacPhee, D. Weinstein, R.W. Falcone, R. Pahl, J. Als-Nielsen, C. Blome, S. D¨usterer, R. Ischebeck, H. Schlarb, H. Schulte-Schrepping, Th. Tschentscher, J. Schneider, O. Hignette, F. Sette, K. Sokolowski-Tinten, H.N. Chapman, R.W. Lee, T.N. Hansen, O. Synnergren, J. Larsson, S. Techert, J. Sheppard, J.S. Wark, M. Bergh, C. Caleman, G. Huldt, D. van der Spoel, N. Timneanu, J. Hajdu, R.A. Akre, E. Bong, P. Emma, P. Krejcik, J. Arthur, S. Brennan, K.J. Gaffney, A.M. Lindenberg, K. Luening, and J.B. Hastings, "Clocking Femtosecond X-Rays", Physical Review Letters, **94**, 114801 (2005)
9. A.M. Lindenberg, J. Larsson, K. Sokolowski-Tinten, K.J. Gaffney, C. Blome, O. Synnergren, J. Sheppard, C. Caleman, A.G. MacPhee, D. Weinstein, D.P. Lowney, T.K. Allison, T. Matthews, R.W. Falcone, A.L. Cavalieri, D.M. Fritz, S.H. Lee, P.H. Bucksbaum, D.A. Reis, J. Rudati, P.H. Fuoss, C.C. Kao, D.P. Siddons, R. Pahl, J. Als-Nielsen, S. Duesterer, R. Ischebeck, H. Schlarb, H. Schulte-Schrepping, Th. Tschentscher, J. Schneider, D. von der Linde, O. Hignette, F. Sette, H.N. Chapman, R.W. Lee, T.N. Hansen, S. Techert, J.S. Wark, M. Bergh, G. Huldt, D. van der Spoel, N. Timneanu, J. Hajdu, R. A. Akre, E. Bong, P. Krejcik, J. Arthur, S. Brennan, K. Luening, and J.B. Hastings, "Atomic-Scale Visualization of Inertial Dynamics", Science, 15 April 2005, 392-395

Community Service

Eric Colby

DPB Executive Committee Member-at-large
DPB Newsletter Editor, March 2005
RF2005 Program Committee Member
APS April Meeting Session Organizer, 2005
DOE HEP Review Consultant (LBNL, February 16-17), 2005
DPF Conference Convener, 2004
Advanced Accelerator Concepts Workshop Organizing Committee Member, 2005
DOE SBIR Proposal Reviewer, 2005
DOE HENP Grant Renewal Reviewer, 2005
PRST-AB, IEEE Trans. Plasma Science, PRE, and Physics of Plasmas paper referee

Mark Hogan

Advanced Accelerator Concepts Workshop Organizing Committee Member, 2005
Physical Review and Physical Review Letters paper referee
DOE SBIR Proposal Reviewer, 2005
DOE Grant Proposal Reviewer, 2004
Reviewer ISTC Proposal for State Department via LANL

Robert Noble

Consultant for DOE annual review of BNL HEP program, April 2005
Co-organizer with T. Katsouleas of High Energy Density/Exotic Accel. Working Group for AAC04, June 2004
Reviewer for DOE annual review of muon collider collaboration funding

Stephanie Santo

Assistant to Editor, *Physical Review Special Topics - Accelerators and Beams*, 2003 –
Organizing Committee Member, 2003 Particle Accelerator Conference

Robert Siemann

Senior Member Institute of Electrical and Electronics Engineers, 2005
Conference Chair, 2003 Particle Accelerator Conference
Organizing Committee, 2005 Particle Accelerator Conference
Editor, *Physical Review Special Topics - Accelerators and Beams*, 1998 –
Chair, Accelerator Systems Advisory Committee of the Spallation Neutron Source, 1998-
DOE Tevatron Operations Review, March 2005.
Chair, American Physical Society Committee to Select a New Editor for *Reviews of Modern Physics*, 2005.

James Spencer

DOE SBIR Proposal Reviewer, 2005
Physical Review and Physical Review Letters paper referee
SLAC Ambassador to Menlo Park Chamber of Commerce
Judge for Santa Cruz County and San Jose Science Fairs
DPB Education Committee Member

E163: Laser Acceleration at the NLCTA

PIs: Robert H. Siemann (50%), SLAC & Robert L. Byer, Stanford

Staff Physicists
Eric R. Colby (100%), Spokesman
Robert J. Noble (30%)
James E. Spencer (70%)

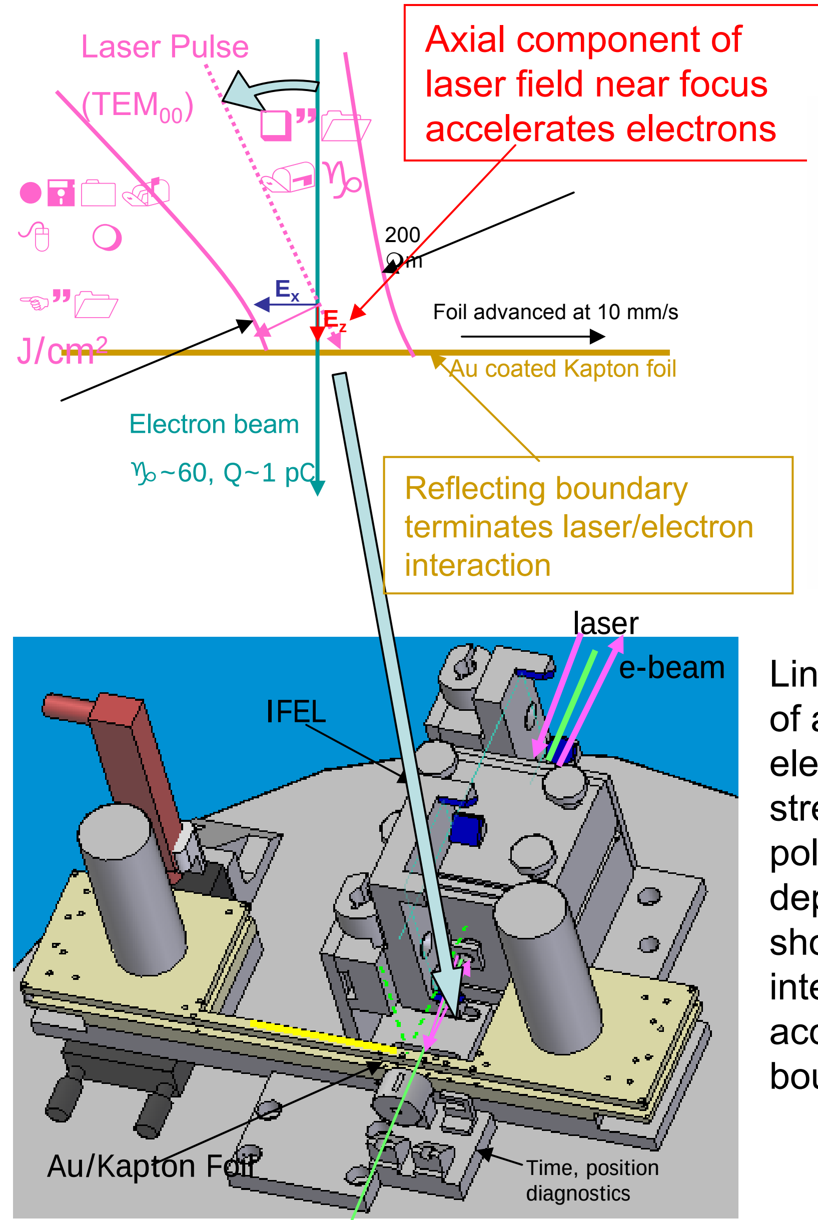
Staff Engineer
Dieter Walz (CEF, 10%)

Postdoctoral RAs
Rasmus Ischebeck (50%)

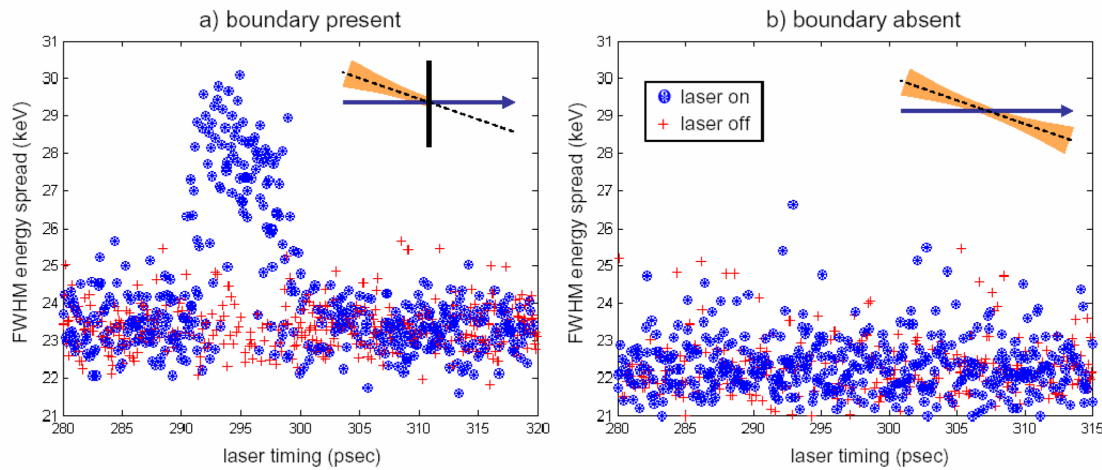
Graduate Students
Ben Cowan
Melissa Lincoln
Neil Na
Chris Sears
Ning Wu

Collaborators
Tomas Plettner (Stanford University)
Jamie Rosenzweig (UCLA)
Sami Tantawi (ARDA)
Zhiyu Zhang (ARDA)

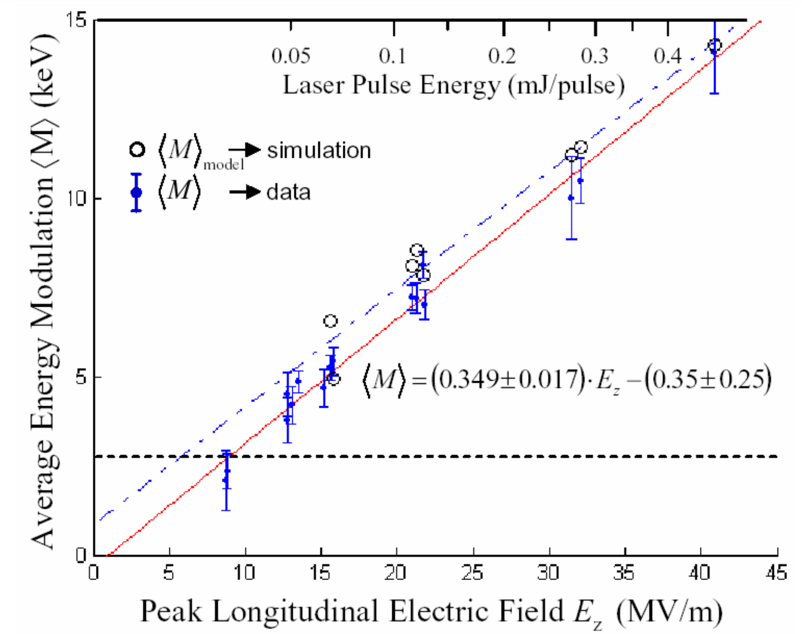
LEAP/E163: First Demonstration of Inverse Transition Radiation Acceleration



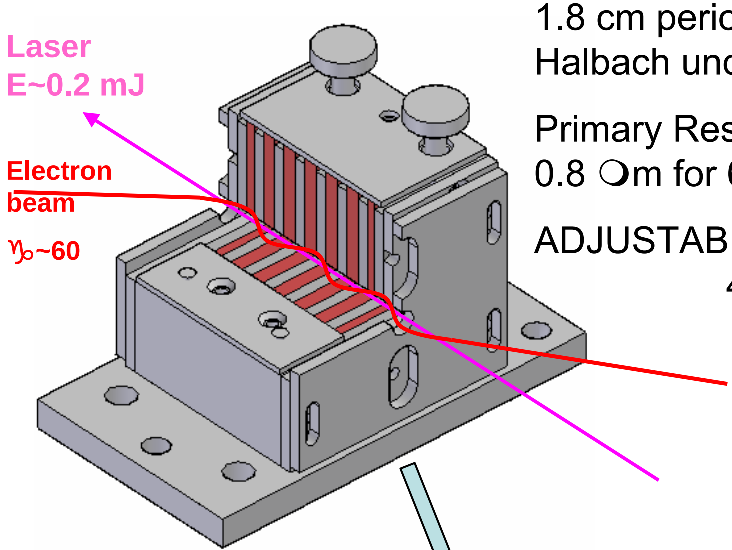
Observation of ITR Interaction



Linear dependence of acceleration on electric field strength, and strict polarization dependence (not shown) establish the interaction as linear acceleration at the boundary.



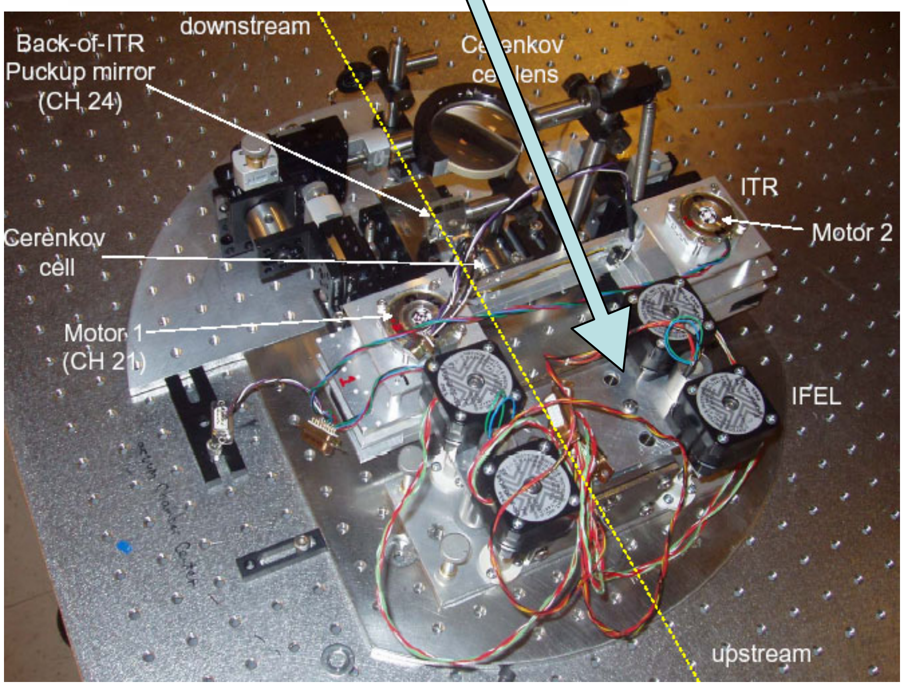
LEAP/E163: First Demonstration of High-Harmonic IFEL Interaction

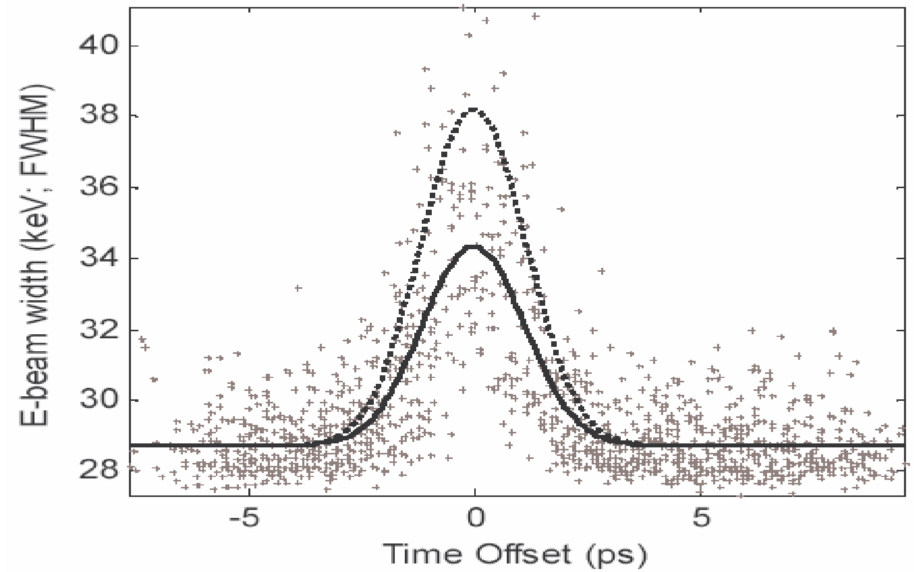


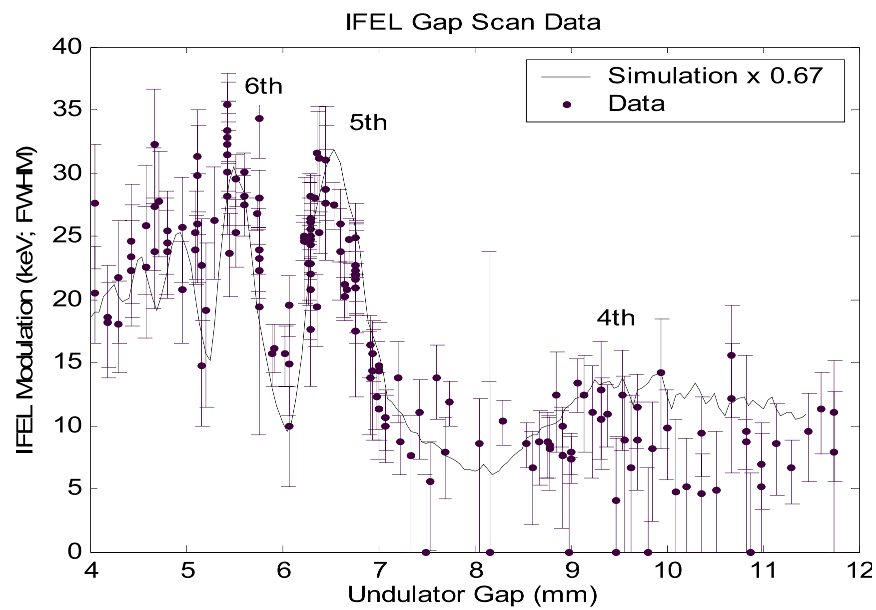
1.8 cm period Hybrid-Halbach undulator

Primary Resonance at 0.8 μm for 60 MeV e$^-$

ADJUSTABLE GAP: 4.4-11.0 mm



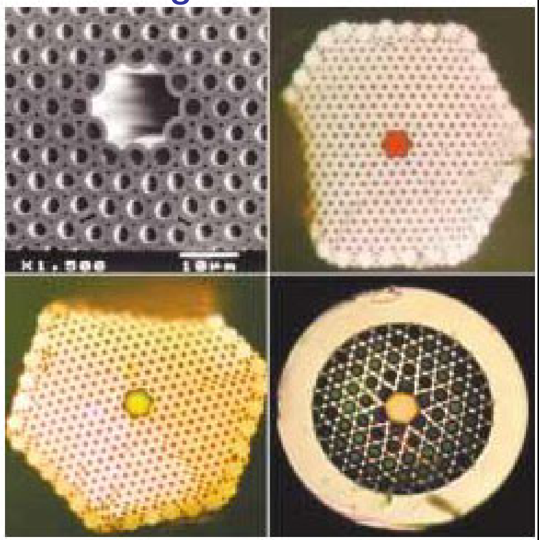




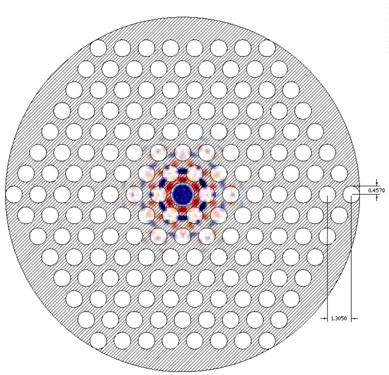
Laser Accelerator Structures for HEP

Photonic Band Gap Fibers are the subject of intensive research, and can be designed to propagate only the accelerating mode.

P. Russell, “Holey fiber concept spawns optical-fiber renaissance”, *Laser Focus World,* Sept. 2002, p. 77-82.

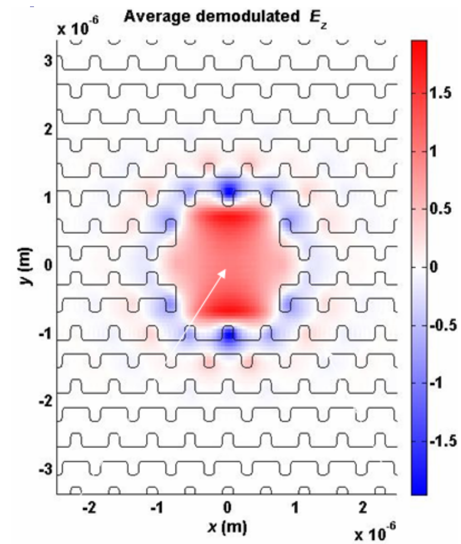


A scanning electron micrograph of guiding hollow-core PCF with core diameter 15 ?m (top left); guided colors are seen in the core when white light was launched into two fibers of slightly different sizes (top right and bottom left); practical recent hollow-core PCF has solid outer cladding (bottom right).



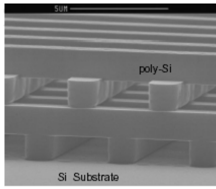
X. Lin, Phys. Rev. ST-AB, **4**, 051301, (2001).

Semiconductor lithography is capable of highly accurate, complex structure production in materials with good damage resistance and at

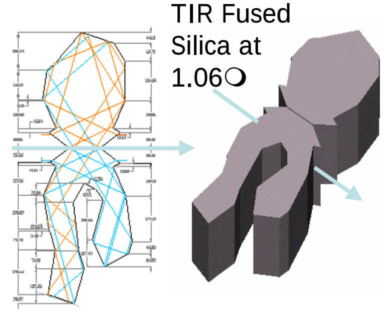


B. Cowan, Phys. Rev. ST-AB, **6**, 101301, (2003).

S. Y. Lin *et. al*., Nature **394**, 251 (1998)

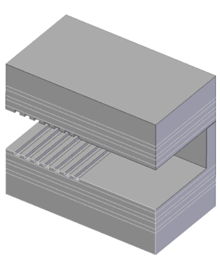


TIR Fused Silica at 1.06❍



Microarray accelerator

T. Plettner



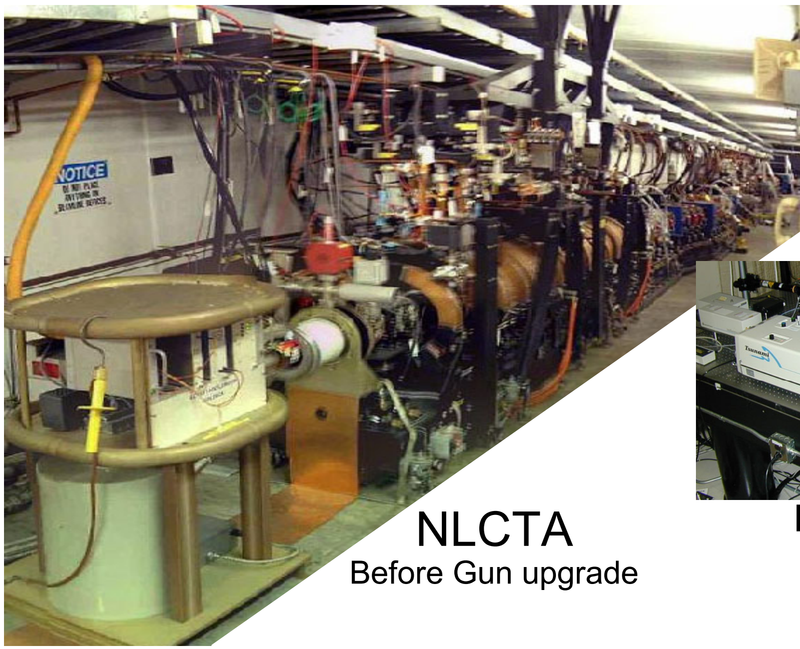
Planar Bragg Waveguide

Z. Zhang (ARDA)

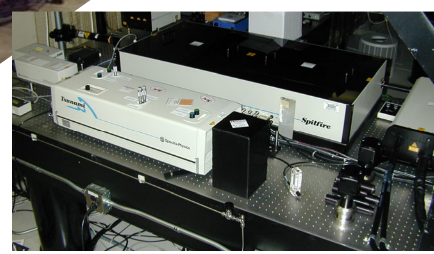
E-163: Laser Acceleration at the NLCTA

E-163 Scientific Goal: Investigate physical and technical issues of laser acceleration using dielectric structures

Build a test facility with high-quality electron and laser beams for users



NLCTA
Before Gun upgrade



Laser System

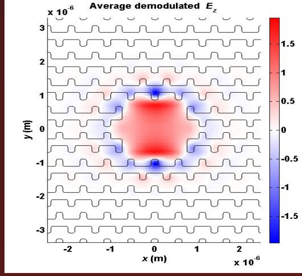
New 600 s.f. Experimental Hall
- 60 MeV electron beams, 1 ps, 10^{-4} $\Delta p/p_o$
- 7 GW Ti:Sapphire laser, 120 fs

- Gun upgrade has begun; expect first electron beam within two months
- Experimental beamline buildup to start in September
- First laser acceleration experiments early in CY2006

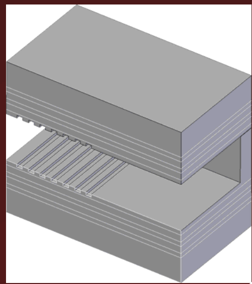
Work supported by Department of Energy contracts DE-AC02-76SF00515 (SLAC) and DE-FG03-97ER41043-II (LEAP).

SLAC

Stanford University

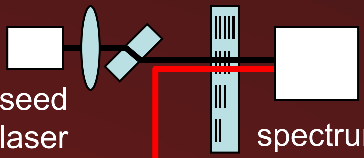


3D Photonic Crystal



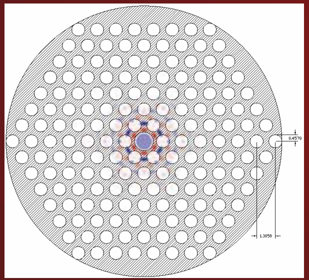
Planar Bragg Waveguide (ARDA)

Center for Integrated Systems
- Complete semiconductor lab



Efficient Wavelength Doubling

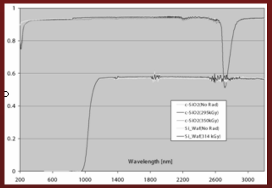
Structure Testing at the NLCTA (E-163)



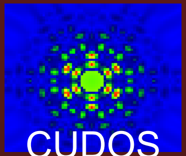
Photonic Crystal Fiber

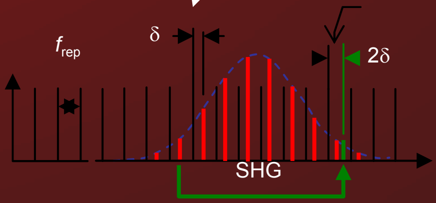
E163: Laser Accelerators

Stanford Photonics Center
- Byer/Fejer Group – nonlinear optics, photonics, nanofabricated optics, …



Rad-hard optical materials





Laser Phase Locking

The University of Sydney
Australia

Telecom Industry

IMRA America, Inc. – materials for test; fabricate first accel. Fiber (30k$)

Crystal Fibre A/S – materials for test, sample fibers

E-164X: Plasma Wakefield Acceleration in the FFTB

PIs: Mark Hogan (SLAC), Chan Joshi (UCLA) and Tom Katsouleas (USC)

SLAC Faculty
Robert Siemann (25%)

Staff Physicist
Mark Hogan (100%)

Engineer
Dieter Walz (CEF, 10%)

Postdoctoral RAs
Rasmus Ischebeck (50%)

Students
Chris Barnes
Ian Blumenfeld
Keil Kirby
Caolionn O'Connell

Non-ARDB SLAC Staff (<10% time)
Franz-Josef Decker, Paul Emma, Rick Iverson and Patrick Krejcik

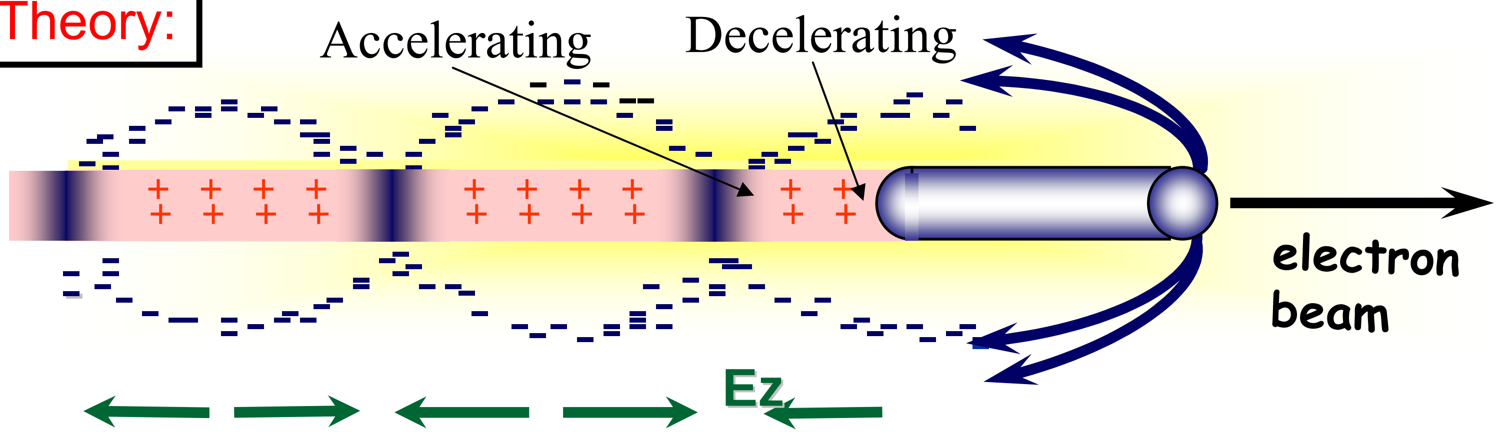
University Collaborators (Faculty, Physicists and Engineers)
UCLA: Chris Clayton, Ken Marsh and Warren Mori
USC: Patric Muggli

University Students
UCLA: Chengkun Huang, Devon Johnson, Wei Lu and Miaomiao Zhou
USC: Suzhi Deng and Erdem Oz

PWFA:
Plasma Wakefield Acceleration

- ❑ Looking at issues associated with applying the large focusing (MT/m) and accelerating (GeV/m) gradients in plasmas to high energy physics and colliders
- ❑ Built on E-157 & E-162 which observed a wide range of phenomena with both electron and positron drive beams: focusing, acceleration/de-acceleration, X-ray emission, refraction, tests for hose instability…

Linear PWFA Theory:

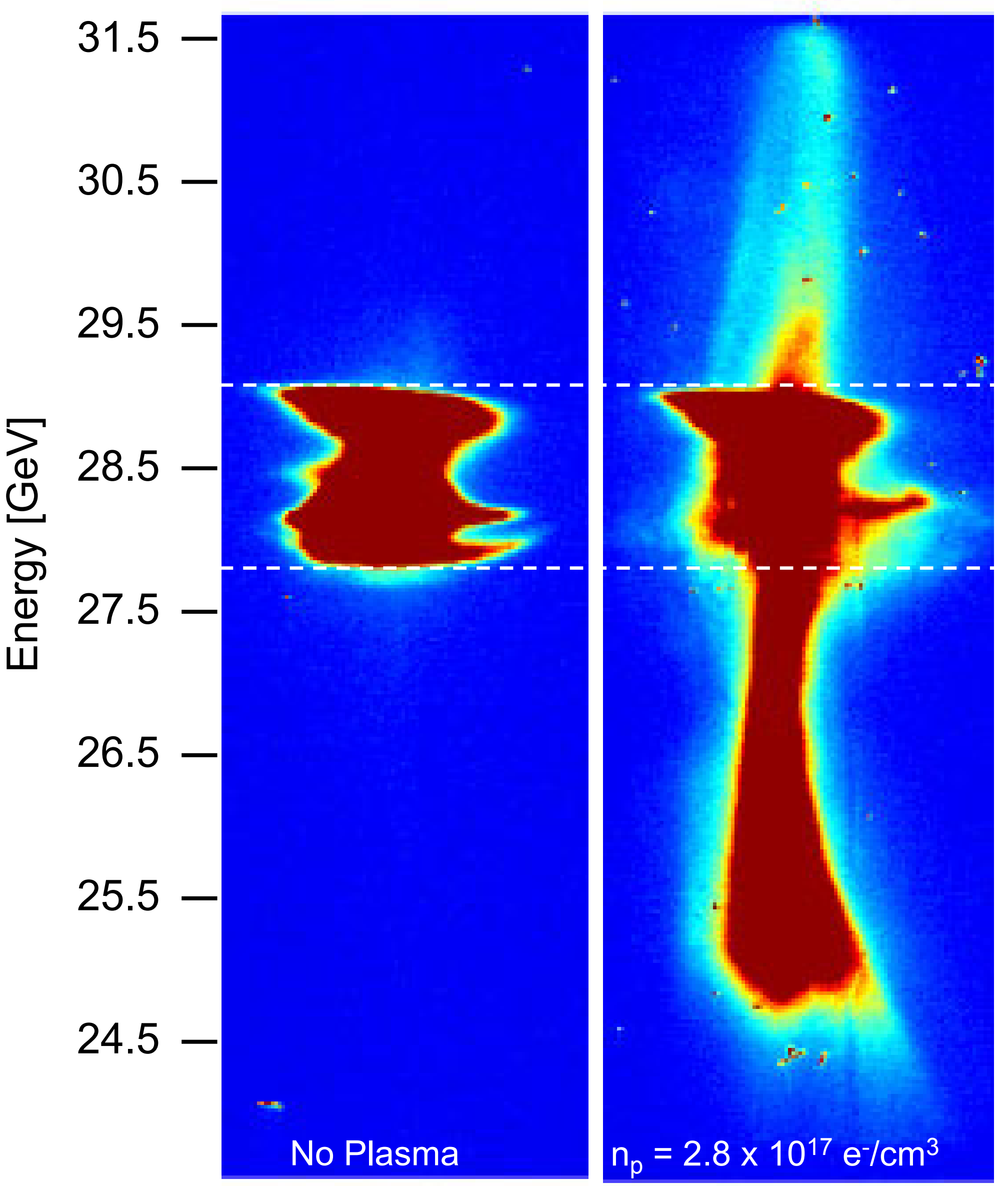


- $E_{z,linear} \propto \frac{N}{\sigma_z^2}$ ↓ Short bunch!
- For $k_p\sigma_r << 1$ and $k_p\sigma_z \cong \sqrt{2}$ or $n_p \propto \frac{1}{\sigma_z^2}$

E_z: accelerating field
N: # e^-/bunch
σ_z: gaussian bunch length
k_p: plasma wave number
n_p: plasma density
n_b: beam density

- ❑ A single bunch from the linac drives a large amplitude plasma wave which focus and accelerates particles
- ❑ For a single bunch the plasma works as an energy transformer and transfers energy from the head to the tail

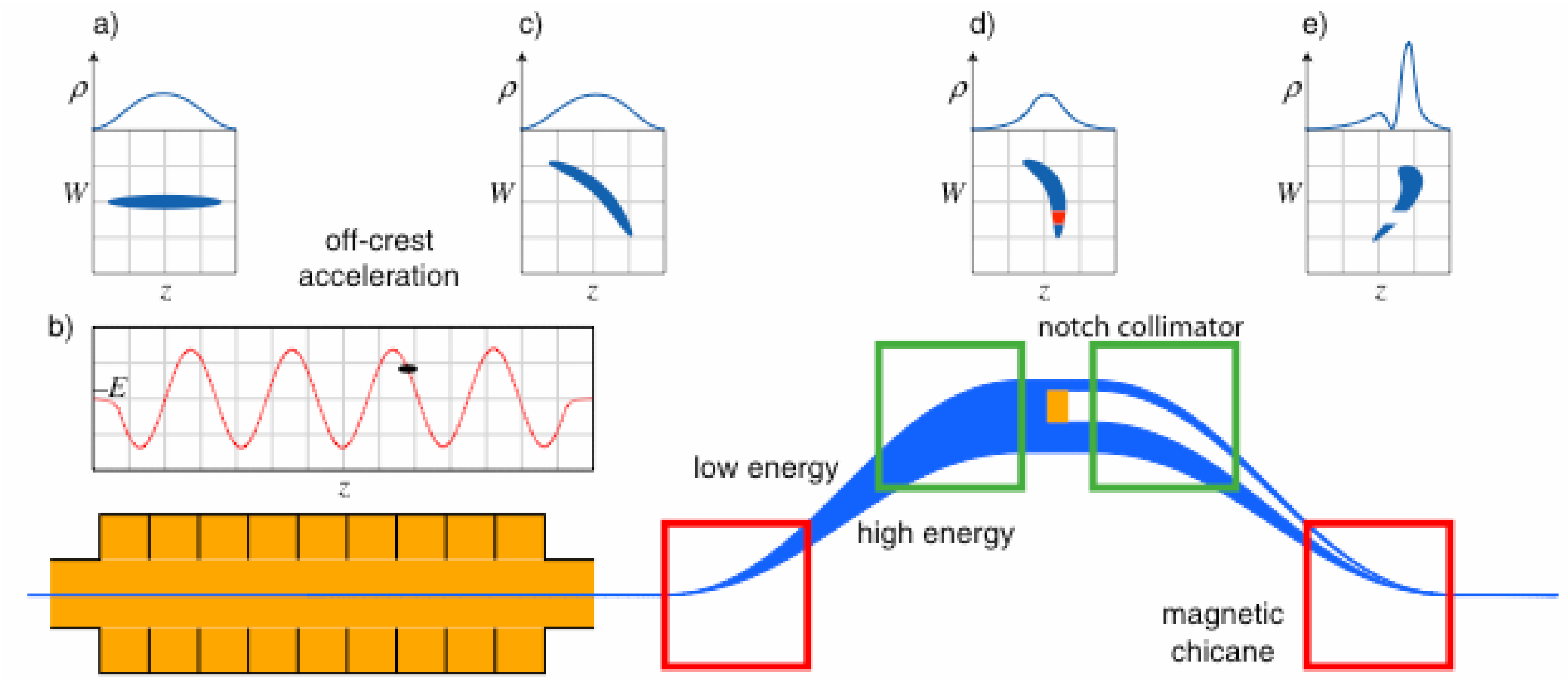
Accelerating Gradient > 27 GeV/m! (Sustained Over 10cm)



- **Large energy spread after the plasma is an artifact of doing single bunch experiments**
- **Electrons have gained > 2.7 GeV over maximum incoming energy in 10cm**
- **Confirmation of predicted dramatic increase in gradient with move to short bunches**
- **First time a PWFA has gained more than 1 GeV**
- **Two orders of magnitude larger than previous beam-driven results**
- **Future experiments will accelerate a second "witness" bunch**

Future Experiments

- **Increased energy aperture in the FFTB (Summer 2005)**
  - Try for 10 GeV energy gain!
  - Test for instabilities (electron hose etc…)
- **Two bunches via notch collimator in linac chicane or FFTB (Early 2006)**



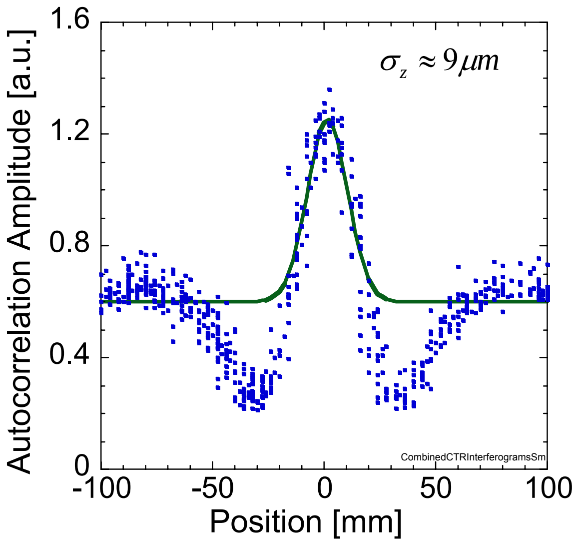
Plasma Wakefield Accelerator Research Summary

Over the past 5 years

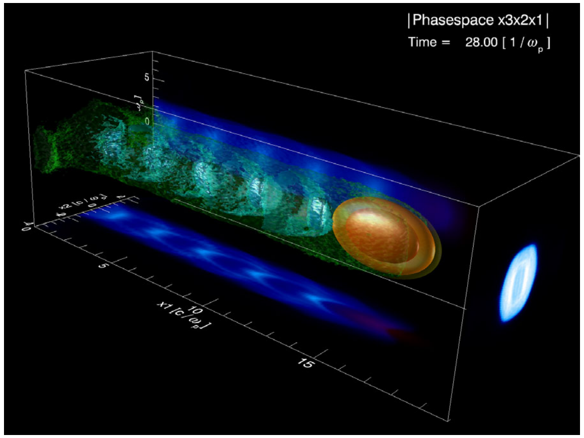
***20 Peer reviewed publications** covering all aspects of beam plasma interactions:*
Focusing (e^- & e^+), Transport, Refraction, Radiation Production, Acceleration (e^- & e^+)

This years accomplishments

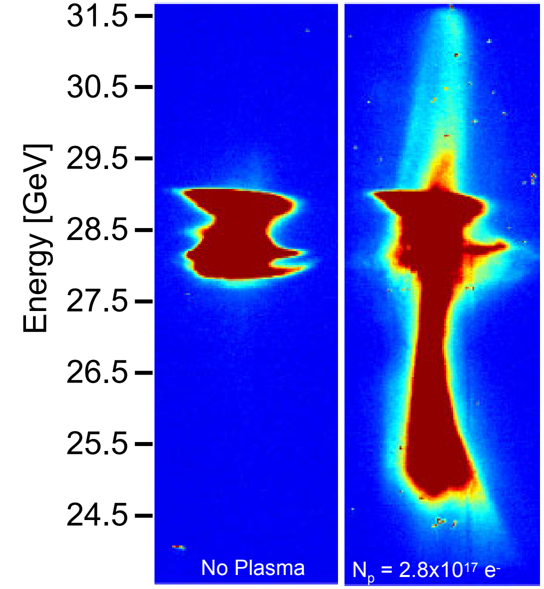
First measurement of the SLAC Ultra-short Bunch Length



Demonstration of Field Ionized Plasma Source

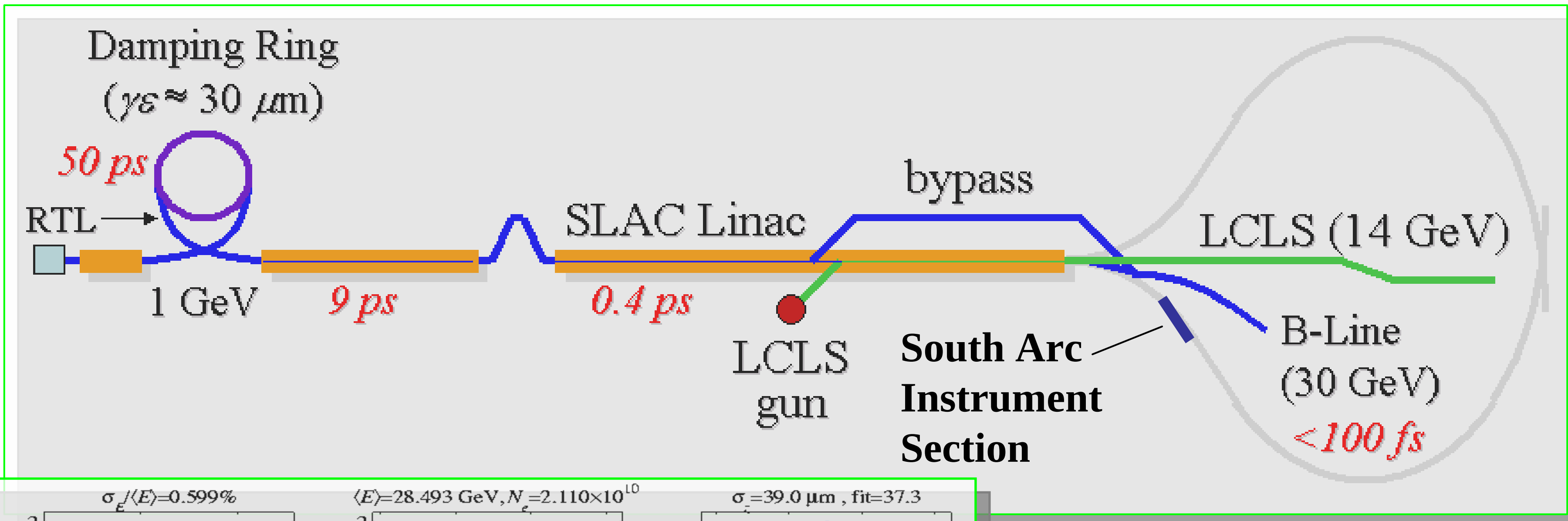


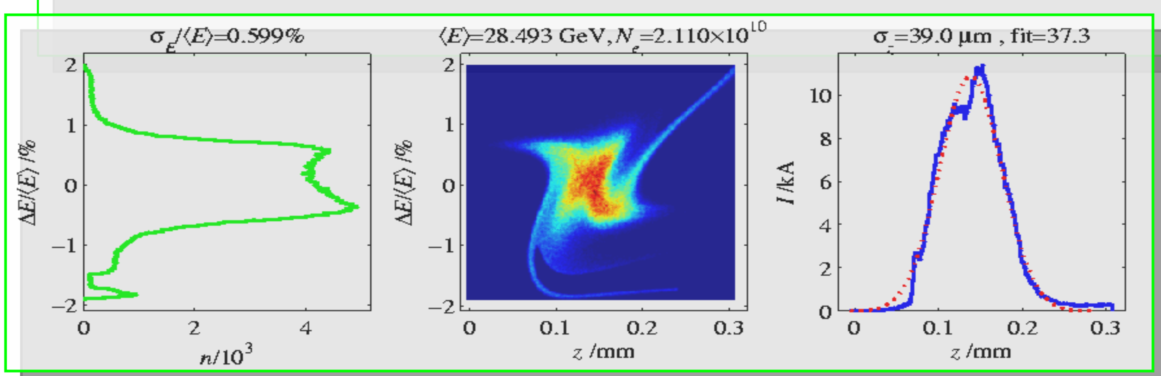
Measured Accelerating Gradients > 27 GeV/m (over 10cm) in a PWFA



SABER Test Beam Options in the LCLS Era

- Full linac beam to new B-Line or South Arc with LCLS turned off.
- LCLS compressed bunches (14 GeV) could be shared with test beams.
- 30 GeV beam could bypass LCLS to new test beam facilities (requires a new Bypass Line from Sector 20 to BSY).





Compressed bunches through new B-Line to BTR [optics simulation by P. Emma].

Advanced Computations Department

*Formed in 2000 to focus on **high performance computing** with the mission to:*

- *Develop new simulation capability to support accelerator R&D at SLAC & accelerator facilities across the Office of Science,*
- *Advance computational science to enable ultra-scale computing on SC's flagship computers (NERSC, ORNL)*
- *Share resources with community and educate/train future computational scientists.*

Support: Base program, SciDAC, Accelerator projects, SBIR + others

Personnel:15 people/13 FTE (5 computational physicists,
7 computer scientists,
2 graduate students,
1 admin/technical assistant)

Output: 3 PhD thesis, 5 papers, 3 reports, 30 talks/posters (2003-05)

SLAC

SciDAC Scientific Discovery through Advanced Computing

ACD - R&D Overview & SciDAC

***High Performance Computing** (NERSC, ORNL)*

Modeling and Simulation | **Parallel Code Development** | **Computational Science**

Accelerators

- SLAC
- FNAL
- ANL
- Jlab
- MIT
- DESY
- KEK
- PSI

ACD

- Accelerator Modeling
- Computational Mathematics
- Computing Technologies

SBIR - STAR Inc

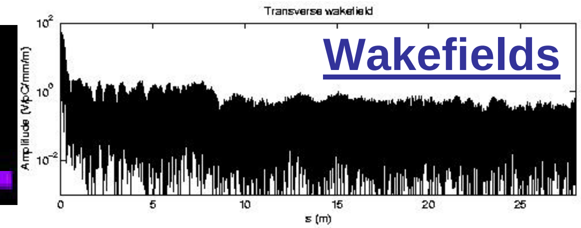
SciDAC

- LBNL
- LLNL
- SNL
- Stanford
- UCD
- RPI, CMU
- Columbia
- UWisconsin

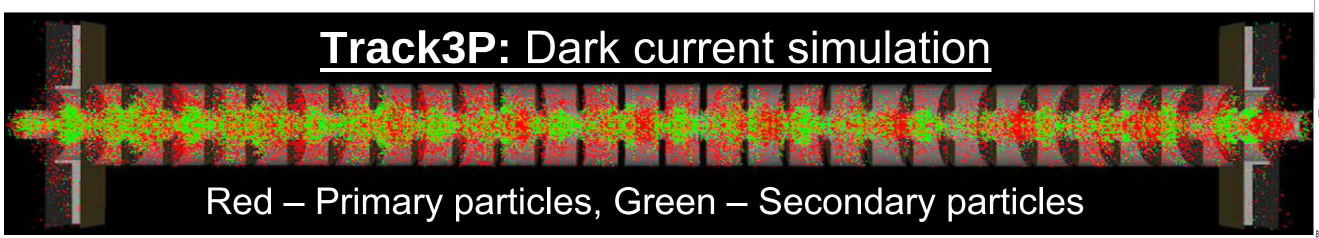
SciDAC Scientific Discovery through Advanced Computing

ACD - NLC Structure Modeling

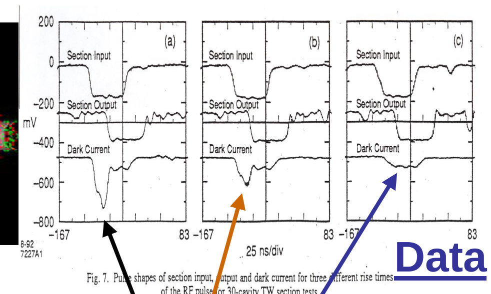
NLC 55-cell DDS

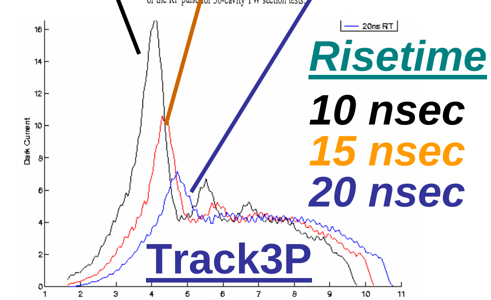


Tau3P/Omega3P *computed the long-range dipole wakefields in the entire 55-cell DDS for the* ***1st time*** *to verify the NLC baseline design in wakefield suppression by damping and detuning.*

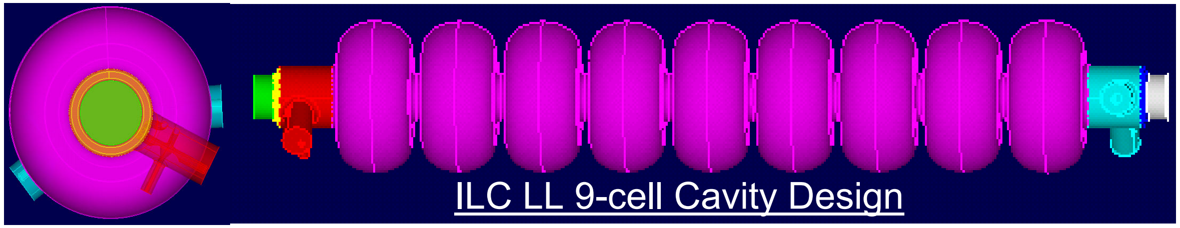


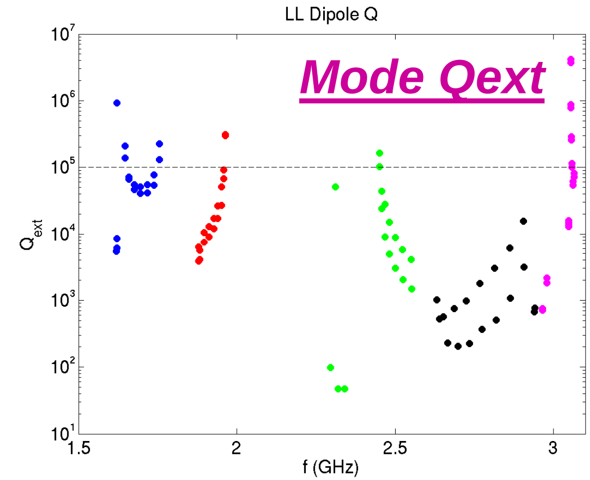
Dark current pulses were simulated for the ***1st time*** *in a 30-cell X-band structure with* ***Track3P*** *and compared with data. Simulation shows increase in dark current during pulse risetime due to field enhancement from dispersive effects.*





ACD - ILC and LCLS Cavity Design



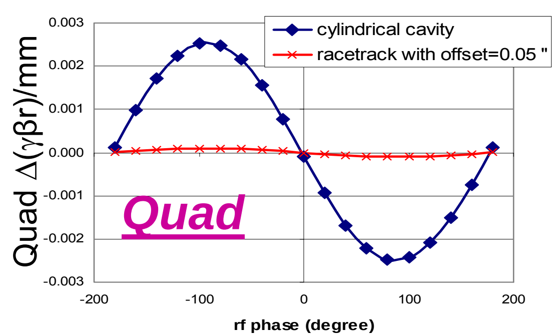


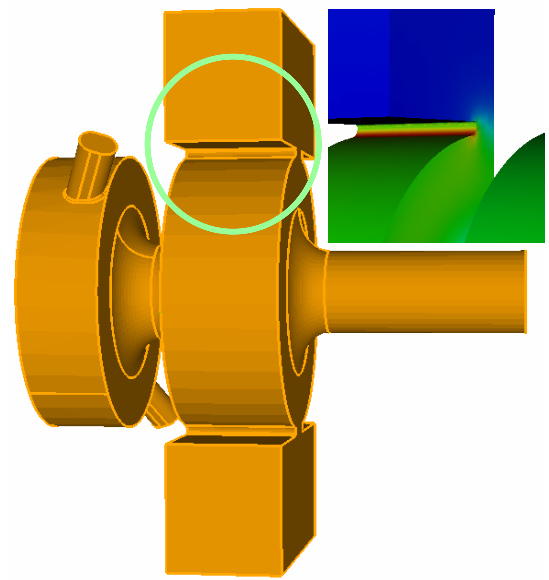
*An <u>international collaboration</u> (DESY, KEK, FNAL, Jlab, SLAC) is working on a **<u>L</u>ow-<u>L</u>oss cavity** (23% lower cryogenic loss) as a viable option for the ILC linac. ACD is calculating the **HOM damping** for the DESY and KEK designs.*

*ACD designed the **<u>LCLS RF Gun</u>** cavity that:*

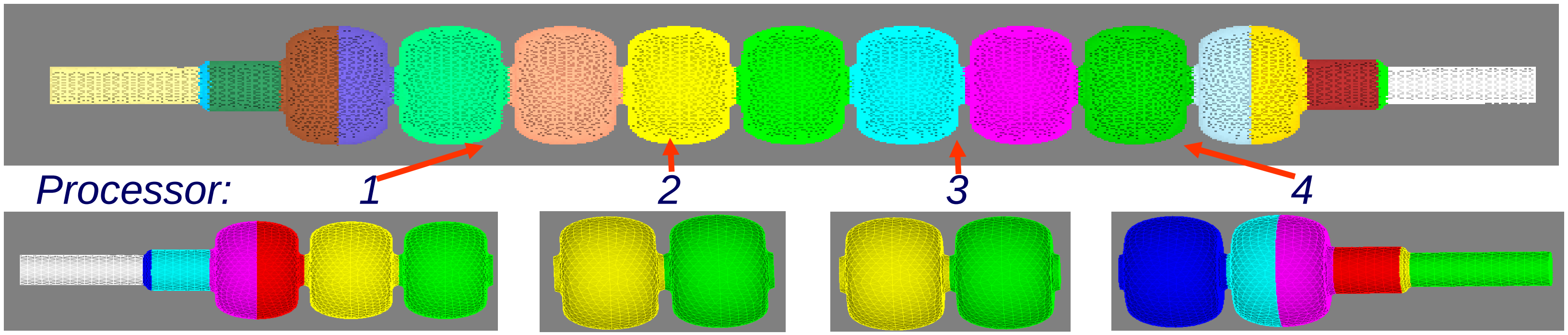
- <u>reduces pulse heating</u> by rounding the iris.

- <u>minimizes dipole and quadrupole fields</u> via a racetrack dual-feed coupler design.





ACD - Parallel Meshing & Eigensolvers



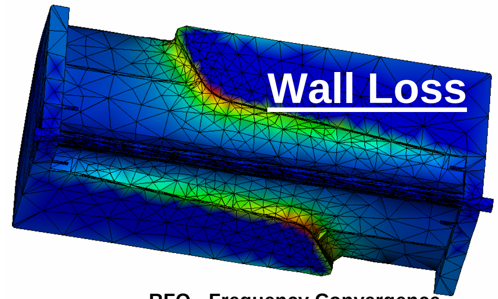
*To model multiple ILC cavities a **parallel meshing capability** has been developed with SNL and UWisconsin (PhD thesis) to facilitate the generation of LARGE meshes on the supercomputer directly.*

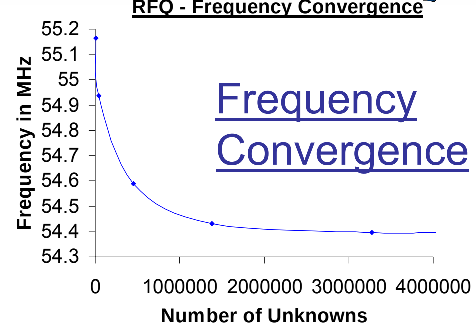
- Omega3P
  - Lossless
    - ISIL w/ Refinement
    - ESIL
  - Lossy Material
  - Periodic Structure
    - Implicit Restarted Arnoldi (Lossy Material, Periodic Structure)
  - External Coupling
    - SOAR
    - Self-Consistent Loop

*A comprehensive **parallel eigensolver** is under development with LBL, UCD & Stanford for solving complex RF cavities to ultra-high accuracy and has been applied to numerous accelerator cavities.*

ACD - Refinement & Visualization

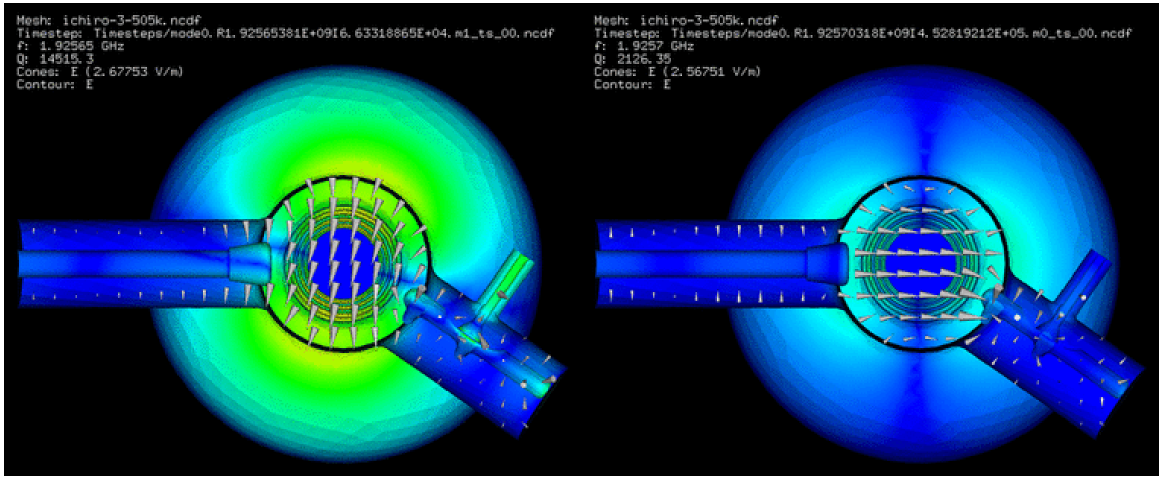
***Adaptive Mesh Refinement** in **Omega3P** provided accuracy gain of 10 & 2 in frequency and wall loss calculations for **RIA's RFQ** with faster convergence. Better predictions can reduce the number of tuners and their tuning range, and improve cooling design*





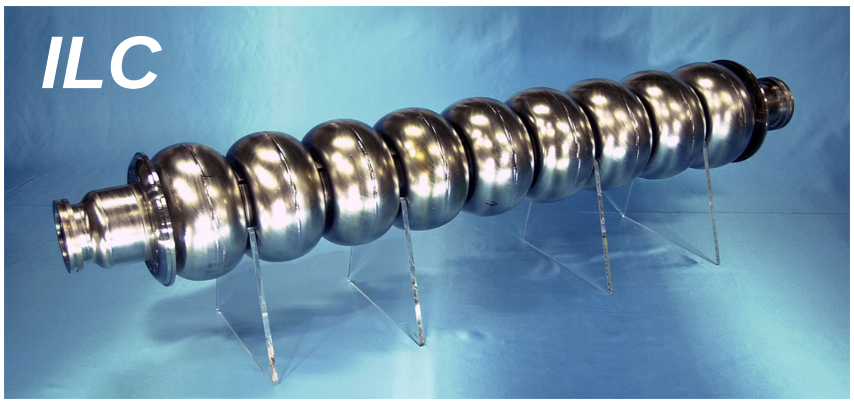
*Graphics tools for rendering **LARGE, multi-stream, 3D unstructured data** have been developed to support accelerator analysis.*

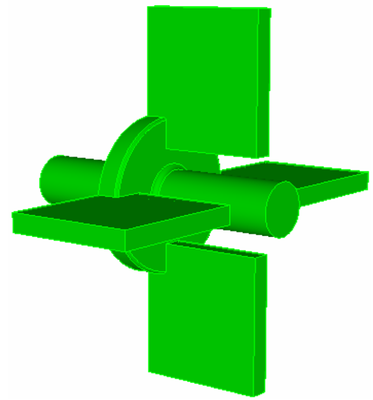
Mode rotation (in space and time) exhibited by the two polarizations of a damped dipole mode in ILC cavity



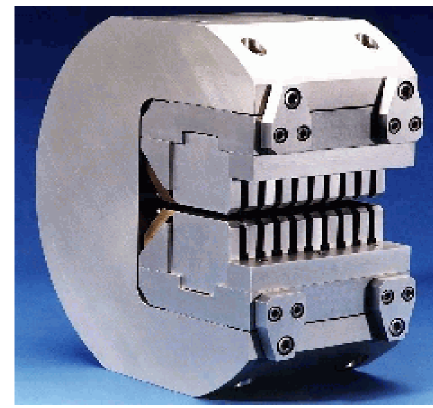
ACD Goals

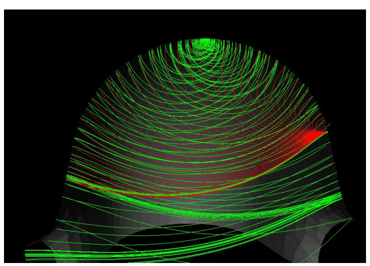
- *Continue to support Accelerator Science across SC*
- *Continue SciDAC collaborations in Computational Science*
- *Involve in Astroparticle Physics & Photon Science*





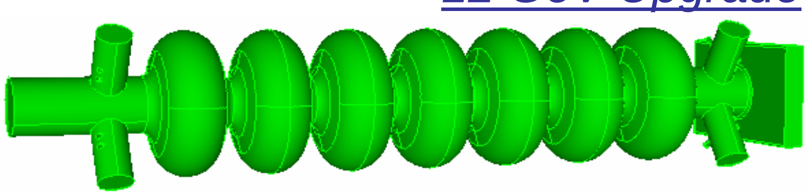
BPM & Wakefields in LCLS Undulator



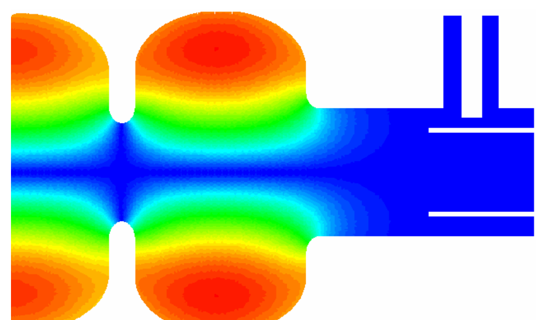


ILC LL Cavity & Cryomodule

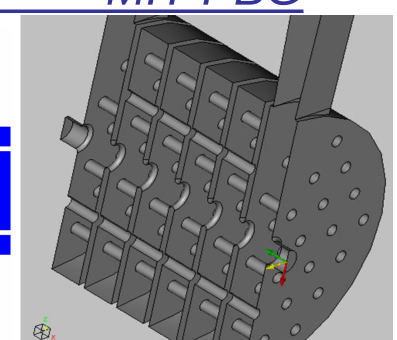
Cavity for Jlab 12 GeV Upgrade



XFEL SC RF Gun



MIT PBG



Conclusion

- Accelerator Research at SLAC
  - Extends fully across the Laboratory's programs
  - Pushes the reach of operating facilities
  - Gives birth to emerging new capabilities
  - Explores the advanced accelerator frontier
  - Pushes the state of the art in computation
  - Has a broad impact world-wide
- We aspire to develop accelerator capability for the HEP community
  - which begins with today's accelerator science and facilities,
  - which encompasses the ILC,
  - but also extends far beyond the ILC to multi-TeV capability.