SLAC Accelerator Research Department B

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Overview:

SLAC Accelerator Research Department B (ARDB) performs experimental research in high gradient acceleration. High gradient RF, laser driven structures and plasma based accelerators are explored. Much of the ARDB work is performed at SLAC facilities in collaboration with other principal investigators. Our collaborators in the ARDB research program and the ORION Center for Advanced Accelerator and Beam Physics Research are: Profs C. Joshi, W. Mori and J. Rosenzweig of UCLA, T. Katsouleas of USC, and R. Byer of Stanford.

Summary of Current Activities:

Plasma Wakefield Acceleration (SLAC Experiments E157, E162, E164 and E164X)

These experiments are studies of the interactions of electron and positron beams with plasmas performed by a UCLA/USC/SLAC collaboration. E157 was the first of these experiments. It was followed by E162 and E164, which have completed data taking, and the program will continue with E164X. All of these experiments take place in the SLAC Final Focus Test Beam (FFTB) using 28.5 GeV electron or positron beams. The FFTB and high energy beams are unique aspects of these experiments. The incoming and outgoing beams are well-characterized with a variety of detectors.

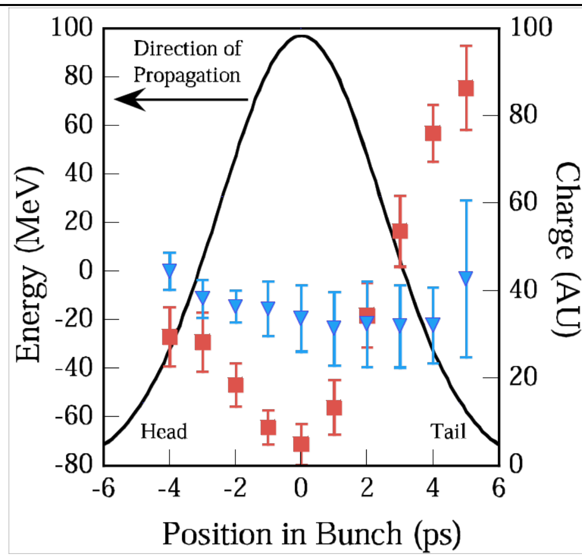
E157 and E162 used a 1.4 m long lithium plasma, and together they gave the opportunity to study many aspects of the beam-plasma interaction at the scale of interest to a plasma accelerator. There were eight data taking runs extending through 2001, and data analysis has been the recent focus of these experiments. Recently published results include: a concept for a plasma-wakefield based energy doubler,[1] measurements of transverse focusing of electron beams,[2,3] X-ray production by electrons traversing the plasma,[4] an overview of the high energy density plasma science that has been in these experiments,[5] and transport and acceleration of positron beams[6,7]. Three graduate students (Brent Blue, UCLA, Seung Lee, USC, and Shoquin Wang, UCLA) received PhD degrees for their work on E157 and E162.

The next experiment in this series is E164, which completed data taking in November, 2003. The goal of E164 is to reach higher gradients by employing shorter bunches and higher density plasmas. The short, high current bunch, $1.5X10^{10}$ electrons in a 10 to 20 micron long bunch (!), is produced with a bunch compressor chicane in the SLAC linac. The plasma density must be increased to keep the plasma wavelength approximately the same as the bunch length. Data have been taken with lithium, hydrogen and xenon plasmas. Tunneling ionization of the plasma by the beam fields is routinely observed. The data from E164 are being analyzed at the present time. The experimental work will continue with experiment E164X that is tentatively scheduled to run in Spring 2004.

Laser Electron Acceleration Project (LEAP) and E163

The Laser Electron Acceleration Project (LEAP) is a Stanford/SLAC experimental program that has the goal of building accelerators based on near IR lasers in the 1 to 2 micron wavelength range. There is an enormous commercial market for near-IR lasers from telecommunications and laser machining, and this market is producing rapid advances and significant cost reductions. The LEAP goal is to develop accelerator structures and acceleration mechanisms that will benefit from these developments.

The first stage of LEAP has been a proof-of-principle experiment located at the superconducting accelerator on the Stanford campus. There was a one-week long run in June 2002, and



High gradient plasma acceleration of a positron beam (B. Blue et al, ref. [7]). With the plasma off (blue triangles) there is a slight head-tail energy chirp of 20 MeV. When the plasma is on (red squares), the front half of the beam loses energy driving the plasma wave, while the back half of the beam is accelerated by the plasma wave. The accelerating gradient is 56 MeV/m. The black line is the charge distribution within the bunch.

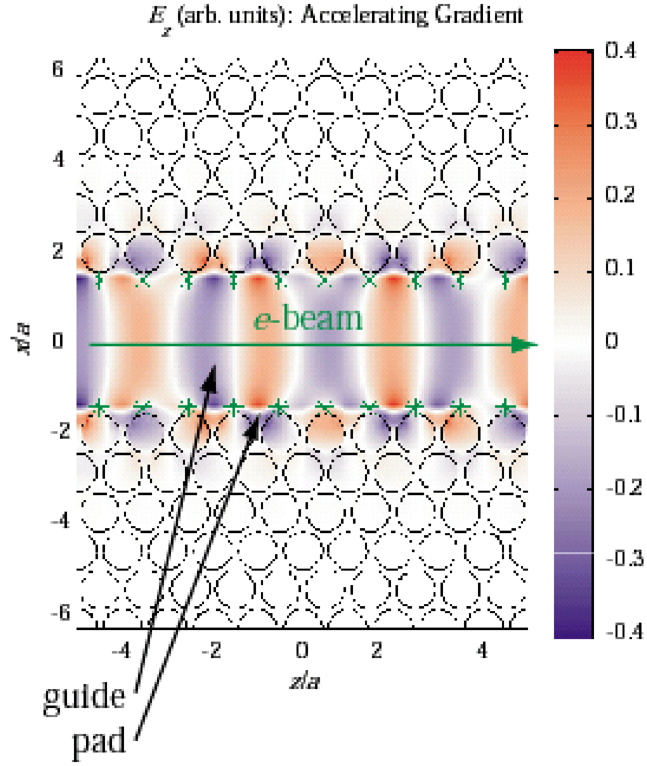
significant amounts of data were taken, but there was no convincing evidence of acceleration. However, we have learned a great deal about techniques and instrumentation for laser acceleration experiments, and Tomas Plettner, a Stanford graduate student, received his PhD degree for this work.

SLAC experiment E163 has been approved to provide the electron beam needed for long-term progress. E163 would continue the proof-of-principle studies and follow that with demonstration of optical bunching at 1 micron and acceleration using a lithographically fabricated multi-cell structure. E163 is presently under construction. It calls for modifications of the SLAC Next Linear Collider Test Accelerator (NLCTA), and the building of a shielded enclosure for performing experiments. The shielding enclosure has been design for a 60 MeV, 1 nC beam. It is located to the north of the NLCTA and has been completed recently. The LEAP apparatus will be moved from the Stanford campus to SLAC when appropriate. The major E163 technical system is a photoinjector with associated drive laser and RF system. All of these are well on the way to completion, and E163 data taking could begin within a year.

There are important issues related to laser acceleration that can be addressed without an electron beam, and we continue to work on them. Recent activities included measurements of laser and radiation damage of materials,[8] Inverse Free Electron Laser bunching of beams, lithographic fabrication of structures, general considerations for laser driven accelerators, and photonic crystal accelerators. Work in many of these areas has been presented at conferences, and papers on photonic crystal optical fibers[9] and lithographically fabricated photonic crystals have been published.[10]

High Gradient RF Technology

This was the last year of activity in this area with the final analysis and publication of the results on surface pulsed heating of copper RF cavities.[11] The results are that damage was measured after 56 million pulses with a temperature rise of 120 K and after 86 million pulses



A photonic crystal accelerator structure geometry with a speed-of-light waveguide mode. (B. M. Cowan, ref. [10]) The circles delineate the vacuum holes, and the blue/red coloring denotes the accelerating *Ez* component. The asterisks show the damage sites, where the field magnitude in the dielectric is maximized.

with a temperature rise of 82 K. David Pritzkau received his PhD degree from Stanford and the 2003 APS Division of Physics of Beams PhD Prize for this work.[12]

The ORION Center for Advanced Accelerator and Beam Physics Research and the ORION Facility

Advanced accelerator research, with its goal of understanding the physics and developing the technologies for reaching higher energies, is essential for the future of particle physics. The ORION Center is a Stanford/UCLA/USC/SLAC collaboration devoted to advanced accelerator and beam physics research. A critical mass of researchers from diverse scientific backgrounds will be brought together with state-of-the-art beams, apparatus and computing. The ORION Center holds the promise of significant advances through rapid assessment and development of new acceleration concepts.

ORION Center experiments will take place at the FFTB and the ORION Facility. The FFTB experiments will exploit the apparatus developed for E157, E162, etc. The ORION Facility is a proposed user-oriented facility for advanced accelerator research that will be based on the NLCTA. The facility will provide 60 MeV beams in a Low Energy Hall and nominal 350 MeV beams in a High Energy Hall. The E163 photoinjector is based on an ORION design, and it will serve the entire facility with modest upgrades. In addition, the E163 beam line will be the extraction line for the Low Energy Hall. Diagnostics and data acquisition systems developed for E157, etc and E163 will be available to researchers at the ORION Center.

Current ARDB Scientific Staff

Robert Siemann	Professor, SLAC and Stanford Applied Physics
Eric Colby	W. K. H. Panofsky Fellow
David Fryberger	SLAC Staff
Mark Hogan	SLAC Staff
Robert Noble	SLAC Staff
Dennis Palmer	SLAC Staff
James Spencer	SLAC Staff
Christopher Barnes	Graduate Student (Stanford)
Alex Butterwick	Graduate Student (Stanford)
Benjamin Cowan	Graduate Student (Stanford)
Atsushi Fukasawa	Graduate Student (Tokyo)
Mehdi Javenmard	Graduate Student (Stanford)
Devon Johnson	Graduate Student (UCLA)
Caolionn O'Connell	Graduate Student (Stanford)
Christopher Sears	Graduate Student (Stanford)
Ning Wu	Graduate Student (Stanford)

Publications & References

1 S. Lee *et al*, "Energy Doubler For A Linear Collider", Physical Review Special Topics - Accelerators and Beams **5**, 011001 (2002).
2 C. E. Clayton *et al,* "Transverse Envelope Dynamics Of A 28.5 Gev Electron Beam In A Long Plasma", Physical Review Letters **88**, 154801 (2002)
3 C. O'Connell *et al*, "Dynamic Focusing Of An Electron Beam Through A Long Plasma", Physical Review Special Topics – Accelerators and Beams **5**, 1121301 (2002)
4 Shouqin Wang *et al,* "X-Ray Emission From Betatron Motion In A Plasma Wiggler", Physical Review Letters **88**, 135004 (2002)
5 C. Joshi *et al,* "High Energy Density Plasma Science With An Ultra-Relativistic Electron Beam", Physics of Plasmas **9**, 1845 (2002).
6 M.J. Hogan *et* al, "Ultrarelativistic-Positron-Beam Transport through Meter-Scale Plasmas", Physical Review Letters **90**, 205002 (2003).
7 B. E. Blue *et al*, "Plasma Wakefield Acceleration of an Intense Positron Beam" Physical Review Letters **90**, 214801 (2003)
8 E. Colby *et al*, "Gamma Radiation Studies on Optical Materials", IEEE Trans. Nucl. Sci. (2002).
9 Xintian Eddie Lin "Photonic band gap fiber accelerator" Physical Review Special Topics – Accelerators and Beams, **4**, 051301 (2001).
10 Benjamin M. Cowan, "Two-dimensional photonic crystal accelerator structures", Physical Review Special Topics – Accelerators and Beams, **6**, 101301 (2003).
11 D. P. Pritzkau & R. H. Siemann, "Experimental Study of RF Pulsed Heating on Oxygen Free Electronic Copper", Physical Review Special Topics – Accelerators and Beams **5**, 112002 (2002)
12 David Peace Pritzkau, "RF Pulsed Heating", PhD in Applied Physics from Stanford University. David is now a Senior Test Engineer at Big Bear Networks in Sunnyvale, CA.