The Accelerator Test Facility

Ilan Ben-Zvi

Accelerator Test Facility Head

The Accelerator Test Facility (ATF) is a user's facility dedicated to advanced accelerator R&D. Funding for the ATF is provided by the DOE Division of High-Energy Physics (~$1.8M/year) and the NSLS. The ATF is operated as a proposal-driven Program-Committee-reviewed Users'-Facility dedicated for long-term R&D in Physics of Beams. The ATF core capabilities include a high-brightness photoinjector electron gun, a 70 MeV linac, high power lasers synchronized to the electron beam to a picosecond level, four beam lines (most with energy spectrometers) and a sophisticated computer control system.

ATF users, from universities, national labs and industry, are carrying out R&D on Advanced Accelerator Physics and are studying the interactions of high power electromagnetic radiation and high brightness electron beams, including laser acceleration of electrons and Free-Electron Lasers. Other topics include the development of electron beams with extremely high brightness, photo-injectors, electron beam and radiation diagnostics and computer controls.

In the ten years of its service to the Physics of Beams community, the ATF users achieved numerous 'firsts' and technological breakthroughs as well as providing graduate education in physics of beam for many students (16 students from 8 universities graduated since 1992). As for ATF Operations, we provided nearly 1400 hours for ATF users in the last fiscal year.

This year we hosted the 21st ICFA Beam Dynamics Workshop on Laser-Beam Interactions, (June 11-15, 2001 at BNL and Stony Brook). This exciting event, chaired by Professor Tachishige Hirose of Tokyo Metropolitan University and Ilan Ben-Zvi is closely related to many of the research activities conducted at the ATF. An international program committee chaired by Igor Pogorelsky prepared the excellent scientific program of the workshop, and the Local Organizing Committee chaired by Marcus Babzien did a tremendous organizational job hat led to great participant-satisfaction.

The generation and acceleration of very high brightness electron beams is a key technology for the PERL upgrade, for short wavelength FELs as well as other applications, including linear colliders, Compton backscattering for the production of femtosecond x-rays, laser accelerators and more. A high brightness means that the electron bunch has a high density in 6-D phase space. To achieve high brightness beams, it is necessary to do the following: 1) Master the production of such beams in special electron guns. 2) Develop diagnostics that provide information of the 6-D distribution of electron bunches on sub-picosecond time scales. 3) Control the 6-D distribution of the bunch in various ways. 4) Accelerate the electrons to high energies without diluting the brightness.

The electron beam sources in most national and international laboratories are based on photoinjectors developed at BNL. In particular, recent guns such as the ones at SLAC, UCLA, University of Tokyo, the LEUTL facility at the APS, the SDL at the NSLS and of course at the ATF, are based on R&D carried out by Xijie Wang, the Deputy Head of the ATF.

In the following I will underscore some of the key experimental results obtained over the past year at the ATF.

A subject of intense research at the ATF is the photocathode RF gun, which is so critical for the new generations of light sources (PERL and FEL). ATF scientists have carried out research in the following areas of photocathode RF gun R&D:

- The brightness record of photoinjectors is held by the ATF at 0.8 microns at a charge of 0.5 nC ["Submicron emittance and ultra small beam size measurements at the ATF", V.Yakimenko, M. Babzien, I. Ben-Zvi, X.J. Wang, to be published in NIM].
- The DUV-FEL project operated its ATF-designed and built photoinjector.
- A promising new photocathode material has been developed - niobium metal. This material is promising not only in the "conventional" photoinjector, but also for all-niobium superconducting photoinjectors that promise a large duty factor. Such a gun is nearing completion in a collaborative SBIR and CRADA with Advanced Energy Systems, Inc.
- Preliminary design studies were performed at the BNL to develop a 120 Hz photocathode RF gun injection system for the X-ray SASE FEL project LCLS at SLAC. The design is based on the BNL gun IV; complete specifications for both RF gun and its laser system were developed based on our latest simulations.
- Emittance as a function of charge uniformity has been measured by creating a patterned laser illumination of the photocathode. This investigation shed light on the basic mechanism of the origin of non-thermal emittance in photoinjectors.

Creating a high-brightness beam is not the end of the story. One has to transmit it through accelerator components and maintain its brightness. For this purpose, ATF scientists have been developing specialized diagnostics such as slice-emittance diagnostics, phase space tomography (transverse and longitudinal as well as transverse phase space tomography of a beam slice) and investigating various wake field effects. The Rough Surface Wake Field measurement is an example of the latter. In this work, led by Feng Zhou, special beam pipes with artificial (and thus well controlled and understood) surface roughness were placed in the ATF beamline and characterized under varying electron charge and bunch length. The experimental results are already shedding new light on the rough-surface wakefield theory.

The Staged Electron Laser Acceleration (STELLA) experiment (AE20), lead by Wayne Kimura (STI Optronics) finished the successful demonstration of staging of two laser accelerator modules ["First Staging of Two Laser Accelerators", W.D. Kimura, A. van Steenbergen, M. Babzien, I. Ben-Zvi, L.P. Campbell, D.B. Cline, C.E. Dilley, J.C. Gallardo, S.C. Gottschalk, P. He, K.P. Kusche, Y. Liu, R.H. Pantell, I.V. Pogorelsky, D.C. Quimby, J. Skaritka, L.C. Steinhauer, and V. Yakimenko, Phys. Rev. Lett. 86 no. 18, 4041 (2001] and entered the next phase "STELLA-II", in which we expect over 10 MeV energy gain in a tapered wiggler with >80% capture of electrons and an energy spread of ~1%.

The High-Gain Harmonic-Generation FEL Experiment (AE10), led by Claudio Pellegrini, concluded its program with a detailed characterization of the saturation and observation of harmonics. ["Characterization Of A High-Gain Harmonic-Generation Free-Electron Laser At Saturation", A. Doyuran, M. Babzien, T. Shaftan, L.H. Yu, L.F. DiMauro, I. Ben-Zvi, W. Graves, E. Johnson, S. Krinsky, R. Malone, I. Pogorelsky, J. Skaritka, G. Rakowsky, X.J. Wang, M. Woodle, V. Yakimenko, S.G. Biedron, J. Jagger, V. Sajaev, I. Vasserman, Physical Review Letters 86 no. 26, 5902, 2001.]

The VISA FEL Experiment (AE24) achieved saturation in the near IR and made unique, detailed measurements of the harmonics of SASE FEL at saturation. ["Experimental Characterization of SASE FEL Harmonic Radiation at Saturation", A.Tremaine, P. Frigola, A. Murokh, C. Pellegrini, S. Reiche, J. Rosenzweig, M. Babzien, I. Ben-Zvi, E. Johnson, J. Skaritka, R. Malone, G. Rakowsky, X.J. Wang, R. Carr, M. Cornacchia, L. Klaisner, H.-D. Nuhn, R. Ruland, K.A.Van Bibber, L. Bertolini, J.M. Hill, G.P. Le Sage, M. Libkind and A. Toor, to be published in NIM]

The MINOS Detector Tests At The ATF, (AE28), headed by Milind Diwan, completed its mission. Detectors designed to monitor beam quality via muons and tolerate the high radiation environment of the MINOS/NuMI beamline at Fermilab were tested at the ATF facility for linearity, stability and saturation effects. The data show that the detectors will be an adequate solution for the beam monitoring of the MINOS neutrino beamline.

The Thomson Scattering Experiment (AE22), led by Igor Pogorelsky operated with the new ATF booster CO2 laser amplifier has been used for the first time in Thomson experiment. This experiment is done as a broad collaboration of BNL, Tokyo Metropolitan University, KEK, UCLA and the Hebrew University of Jerusalem. 3J of laser energy have been transmitted through the interaction point. That is 15 times higher then in the previous 1999 run, and the higher laser flux resulted in nearly proportional increase of the x-ray yield setting a new world record for relativistic Thomson scattering experiments.

In another aspect of the AE22 experiment, high-power CO_2 laser guiding in a capillary plasma-channel has been achieved. This technique is a widely recognized way towards next-generation laser-driven electron accelerators where electrons move collinearly with the laser beam. When the motion is changed to counter-propagation, laser and electron beams produce intense monochromatic x-rays via Thomson scattering. This process can benefit from plasma channel as well as allow the efficient use of relatively long laser pulses.

The Laser Linac experiment, AE27, headed by Yen-Chieh Huang of Tsinghua University in Taiwan performed laser damage test for the CO_2 Laser-driven Linear Accelerator and found that diamond had significantly larger damage-threshold for this laser. Thus diamond becomes the material of choice for the proposed CO2 laser-driven accelerator. The ultimate limit of this diamond accelerator at the CO2 laser wavelength is limited by the laser damage field, at about 200 MeV/m.

The Charged-Particle Optical-Detector Experiment (AE23), Spokesperson Yannis Semertzidis, achieved better than 10ps time resolution in observing the electron beam provided by the ATF in single shot mode. This progress was achieved in recent runs by using a streak camera and a pulsed laser to improve the bandwidth and the photon statistics, respectively.