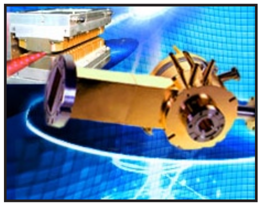
Introduction

Brookhaven National Laboratory's Accelerator Test Facility (ATF) is a user facility for accelerators and beam-physics. Researchers from national and foreign universities, the DOE's national laboratories, and small businesses can carry out their experiments here, thereby relieving their institutions and companies from the large investment in accelerators, lasers, control and diagnostics equipment, and trained accelerator operators, all of which BNL's ATF offers.



ATF in the Research Community

ATF users, from universities, national laboratories, and industry, are carrying out R&D on advanced accelerator physics, developing new radiation sources, and related subjects. From another point of view, the ATF serves as a laboratory for studying the interactions of high-power electromagnetic radiation and high-brightness electron beams, including laser acceleration of electrons and Free-Electron Lasers. Other work includes developing electron beams with extremely high brightness, photo-injectors, electron beam and radiation diagnostics, and computer controls. A further major goal of this research is to increase the numbers and excellence of accelerator scientists in the United States. The proposed work plan is drawn up to take advantage of the expertise of ATF's users and, with them, to establish close collaborations with many leading universities. A blue-ribbon Program Committee guides all research at theATF. In the ten years of its service to the Physics of Beams community, ATF users achieved numerous 'firsts' and technological breakthroughs, as well as providing graduate education for many students (21 students from 11 universities graduated since 1992). ATF Operations typically offer users about 1100 hours of beam time per year.

A View of Brookhaven

Brookhaven National Laboratory is a multipurpose research laboratory funded by the U.S. Department of Energy. Located on a 5,300 acre site on Long Island, New York, the Laboratory operates large-scale facilities for studies in physics, chemistry, biology, medicine, applied science, and advanced technology.

Brookhaven's 3,000 scientists, engineers, and support staff are joined each year by more than 4,000 visiting researchers from around the world.

An Aerial view of Brookhaven National Laboratory

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

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BROOKHAVEN
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Managed for the U.S. Department of Energy
by Brookhaven Science Associates,
a company founded by
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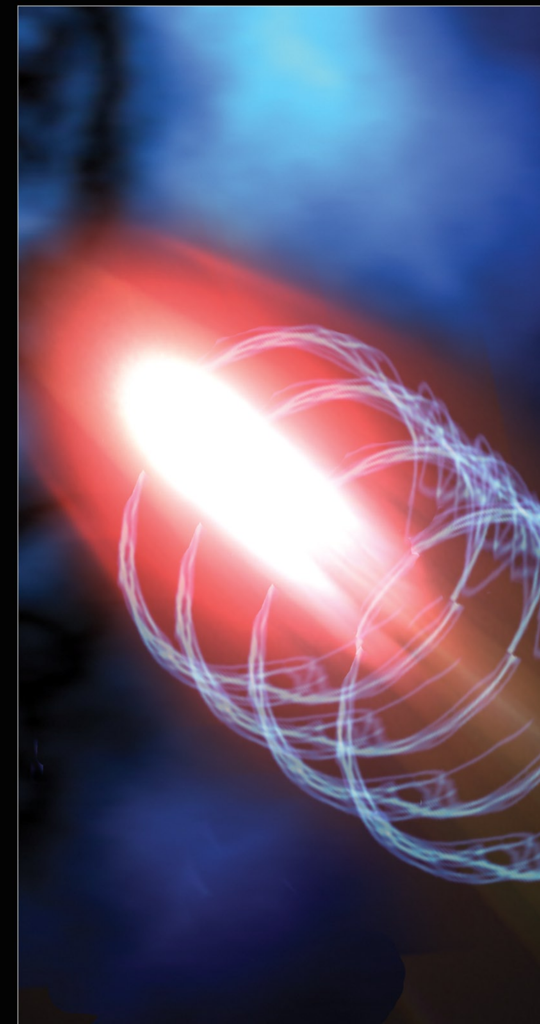

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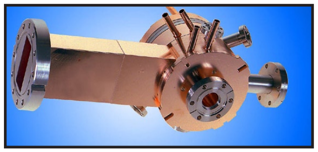
Photoinjector

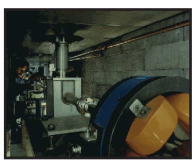
The basic principle of the PI is simple: short bunches of electrons are generated by laser pulses incident on a photocathode located inside an RF accelerating structure. The structure is operated at a high accelerating field to make the electron bunch relativistic in a short distance. Thanks to the combination of the high surface field on the cathode and the high yield of electrons made possible by photo emission, a very large current density, J ~ 10 to 10,0000 A/cm^2, is possible. This current density is much larger than that possible by thermionic emission (about 10 A/cm^2). The normalized thermal rms brightness Bn, (for Bn a cathode effective temperature T) is proportional to the current density. Therefore a PI can deliver a very



large brightness. For example, photoinjectors using the 'emittance compensation'technique, can provide peak currents of over 100 amperes with a normalized rms emittance of one pi-mm-mrad. A series of S-band photoinjectors have been designed, fabricated and tested at ATF. **Gun IV: above left.**

Electron Beam

The ATF provides a very-high brightness electron beam in four beam lines, synchronized with high-power lasers. The electrons are produced by a photoinjector, whose photocathode is illuminated by a frequency quadrupled Nd:YAG laser. Two S-band (2856 MHz) linac sections accelerate the electrons. The beam can be manipulated in the transport line to match it into one of the experimental locations in the



experiment hall. There are more than 40 quadrupoles along 4 transport lines to match the beam to the particular experiments. More than 50 high-resolution profile monitors measure the beam's distributions.

Lasers

Many experimental programs at ATF study the interactions of the picoseconds- long electron and laser beams. The ATF has two lasers, both with unique properties: A Nd:YAG laser and a CO2 laser. The Nd: YAG Laser (abbreviated as YAG) serves as the illumination source for the ATF's photoinjector and also operates an electro-optiv switch in the CO2 laser. The YAG light can also be delivered to the experiment hall for use in experiments. This laser has an exceptionally high stability and a great versatility in generating variable length pulse trains with adjustable amplitude. An actively mode-locked CW YAG oscillator generates a train of 1 nJ, 12 ns spaced pulses of linearly-polarized radiation synchronized with the linac RF field. A Pockels cell switch, in combination with a polarizer, cuts out single 15 ps FWHM pulses at a 3 Hz repetition rate. After a 4-pass preamplifier and a double-pass amplifier, pulses acquire 30 mJ of energy. Part of this energy is directed through second and, then, fourth harmonic crystals to a photocathode generating ~10 ps electron bunches. The other portion is split to control the picosecond slicing system. With the slicing system, we produce short, high power pulses in the CO2 laser.

While a few GW of available laser power is enough for the initial proof-of-principle experiments that are scheduled at the ATF, for more advanced experiments, a much more powerful laser would be needed. Therefore, the ATF is constructing a modified CO2 laser system approaching the terawatt power level. It could also be used in plasma wake field accelerators to generate multi GeV/m gradients. Optoel, Inc., St. Petersburg, Russian Federation, manufactured the compact picosecond terawatt CO2 laser. The CO2 laser oscillator and picosecond pulse slicing system supply a seed pulse into the preamplifier. The output from the preamplifier output makes a few additional passes in the 10 atmosphere main amplifier, to expand the beam to ~50 cm2.

Experiments

Approved/Active

•Photocathode R&D
•Study of Compton Scattering of Picosecond Electron and CO2 Beams
•Ultra-fast Detection of Relativistic Charged particles by Optical Techniques
•A SASE-Free Electron Laser Experiment, VISA, at the ATF Linac
•Laser Driven Cyclotron Autoresonance Accelerator
•Electron Beam Pulse Compression Based Physics at the ATF
•Structure-based Laser Driven Acceleration in a Vacuum
•Optical Diffraction-Transition Radiation Interferometry Diagnostics for Low Emittance Beams
•Particle Acceleration by Stimulated Emission of Radiation (PASER)
•Multi-bunch Plasma Wakefield Acceleration at ATF
•Laser Wakefield Acceleration Driven by a CO2 Laser

Completed/Terminated

•Staged Electron Laser Acceleration
•High Gain Harmonic Generation FEL
•Inverse FEL Accelerator
•Ultrafast Imaging System
•Inverse Cherenkov Acceleration
•Far Infrared Radiation Source
•Study of Spiking Phenomena in FELs
•New Generation Photocathode RF Gun Test Program
•Room temperature, pulsed Microwiggler
•Micro-undulator FEL Experiment
•Intelligent Control System for Accelerators
•Laser Grating Accelerator Experiment
•MINOS Beam Monitoring Detectors
•Smith-Purcell Effect Experiment
•Stimulated Dielectric Wakefield Accelerator
•Nonlinear-Compton Scattering

Approved/Nonactive

•Coherent Smith-Purcell Radiation as an Electron Bunch Diagnostic Technique
•Beam Position Monitors for Linear Colliders

Feasibility

•Vacuum Acceleration
•ODR / OTR
•Plasma wake field acceleration
•Magnetized beam transport
•Parametric X-ray generation from target, SUNY
•Magnetized beam transport, RHIC/BNL
•Emmitance optimization using active transverse laser shaping, Duke, Univ.
•CO2 Laser induced EUV, Kyushu Univ.
•Application of thin SiC films to sub-wavelength lithography and compact particle acceleration, Univ. of Texas
•High Harmonic Generation of VUV Photons for Ultra-high Resolution Angular Resolved Photoemission Spectroscopy, NSLS, SUNY
•LDRD: Optical stochastic cooling of the Gold ion beams in RHIC