Research Activity: Accelerator and Detector Research

Division: Scientific User Facilities
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Portfolio Description:

This activity supports basic research in accelerator physics and x-ray and neutron detectors. Research seeks to achieve a fundamental understanding beyond the traditional accelerator science and technology to develop new concepts to be used in the design of new accelerator facilities for synchrotron radiation and spallation neutron sources. Research includes studies of the creation and transport of ultra-high brightness electron beams to drive Self Amplified Spontaneous Emission (SASE) Free Electron Lasers (FELs) such as the Linac Coherent Light Source (LCLS). Collective electron effects as micro-bunch instabilities from coherent synchrotron and edge radiation are key areas of interest as they can degrade the beam brightness. Beam bunching techniques such as magnetic compression or velocity bunching are also vital to the operation of the LCLS and other FELs. Research is supported to develop fast THz measurement instruments which will determine the longitudinal and transverse structure of femtosecond electron bunches leading to an increase in tuning speed of the various bunch compressive stages at the LCLS. The Accelerator Test Facility (ATF) at Brookhaven National Laboratory (BNL) is partially supported so that studies in these areas can be carried out. In the area of neutron science, there is research to develop improved high intensity, low emittance proton sources for the Spallation Neutron Source (SNS) and other accelerator-driven neutron sources such as the Los Alamos Neutron Science Center (LANSCE). More efficient proton sources can increase the reliability and lifetime due to lower RF power requirements. To exploit fully the fluxes delivered by synchrotron radiation facilities and the SNS, new detectors capable of acquiring data several orders of magnitude faster are required. Improved detectors are especially important in the study of multi-length scale systems such as protein-membrane interactions as well as nucleation and crystallization in nanophase materials. They will also enable real-time kinetic studies and studies of weak scattering samples.

Unique Aspects:

The accelerator and detector research is carried out to improve the output and capabilities of synchrotron radiation light source and the neutron scattering experiments at facilities that are the most advanced of their kind in the world. Together, they serve more than 7,000 users annually from academia, Department of Energy (DOE) national laboratories, and industry, a number that has more than tripled in the past decade and that can more than double again in the next decade as current facilities and those under construction are fully instrumented. These light sources and neutron scattering sources represent the largest collection of such facilities operated by a single organization in the world. Conception, design, construction, and operation of these facilities, which in current costs are in the hundreds of millions to in excess of a billion dollars, are among the core competencies of the BES program.

Relationship to Other Programs:

This activity strongly interacts with BES programmatic research that uses synchrotron and neutron sources. This includes research in atomic physics, condensed matter and materials physics, chemical dynamics, catalysis, geosciences, high-pressure science, environmental sciences, engineering, biosciences, and much more. It also interacts with other DOE offices, especially in the funding of capabilities whose cost and complexity require shared support. The BNL ATF is jointly funded by the High Energy Physics (HEP) Program and BES. There is also collaboration with the National Science Foundation (NSF) on Energy Recovery Linac (ERL) research. There is a coordinated effort between DOE and NSF to facilitate the development of x-ray detectors. There are ongoing industrial interactions through DOE Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR) Program awards for the development of x-ray detectors.

Significant Accomplishments:

Bunch compression and coherent radiation studies at the ATF using a University of California at Los Angeles (UCLA) chicane have led to the first observation of multi-THz coherent edge radiation. Measurements of phase space distortions from acceleration fields have been carried out and will serve as a basis for FEL bunch length diagnostics. A holographic THz Fourier transform spectrometer test bed at Thomas Jefferson National Accelerator Facility was completed, the first required step for developing single shot device to completely characterize bunch shapes. Both of these diagnostic advances are targeted towards the LCLS. Other research relevant to the SNS includes the development of an advanced ^{3}He neutron detector prototype that has shown that the ionization mode works in two-dimensions for thermal neutron detection and is capable of measuring pulse height distributions with the best ever energy resolution in this mode. Gigabyte per second data rates will be achievable from this device. There were also advances in developing a higher output, high brightness H^- source for the SNS that circumvents RF antennae issues. Highly promising results have been obtained by extracting H^- ions directly from a microwave-driven plasma behind an electrostatic screen filter. The H^- ion current extracted was three times higher that of the present SNS source at comparable power.

Mission Relevance:

This research supports the most fundamental of research needs, i.e., the need to characterize materials at the atomic and molecular level. In order to understand, predict, and ultimately control materials properties, it is necessary to determine the atomic constituents of materials, the positions of the atoms in materials, and how the materials behave under the influence of external perturbations such as temperature, pressure, chemical attack, and excitation by photons, electrons, and other particles

Scientific Challenges:

- The development of new accelerator concepts is crucial to the design and upgrade of synchrotron light sources and neutron scattering facilities.
- In the design and commissioning of new FELs such as the LCLS, experimental studies must be conducted on the creation and transport of ultra-high brightness electron beams to drive SASE.
- Start-to-end simulations of the SASE electron source, transport, and SASE FEL give details of the physics mechanisms and provide benchmark models for the x-ray FEL.
- New detectors capable of using the high data rates associated with high brightness sources will increase beamline efficiencies and user throughput.
- Detectors must also be developed that are capable of acquisition of all required x-ray data from a single femtosecond LCLC pulse.

Funding Summary:

Dollars in Thousands

FY 2005	FY 2006	FY 2007 Request
4,000	2,119	3,000

Projected Evolution:

X-ray and neutron scattering will continue to play a central role in the growth of BES programmatic science. The facilities will need continuous growth in terms of accelerator upgrades, and x-ray and neutron detectors to fully exploit the high fluxes of x-rays and neutrons. The set of instruments associated with these facilities provides unique scientific and technical capabilities, rarely available in other parts of the world. These facilities need to be kept in an optimal operational mode in order to maintain and increase the tremendous scientific achievements they have facilitated.

The SNS will be for years to come the most important neutron spallation source in the world. It is important to be prepared for full use and judicious increases in the capabilities of the SNS as recommended by all advisory committees to DOE. Accelerator and detector research will enable these upgrades.

The instrumentation and scientific needs required by the future operation of the LCLS at the Stanford Linear Accelerator Center need to be identified and addressed. Finally, the LCLS will have properties vastly exceeding those of current x-ray sources in three key areas: peak brightness, coherence, and ultrashort pulses. The peak brightness of the LCLS is 10 orders of magnitude greater than current synchrotrons; the light is coherent or “laser like” enabling many new types of experiments; and the pulses are short (230 femtoseconds with planned improvements that will further reduce the pulse length) enabling studies of fast chemical and physical processes. These characteristics open new realms of scientific applications in the chemical, material, and biological sciences including fundamental studies of the interaction of intense x-ray pulses with simple atomic systems, structural studies on single nanoscale particles and biomolecules, ultrafast dynamics in chemistry and solid-state physics, studies of nanoscale structure and dynamics in condensed matter, and use of the LCLS to create plasmas.