GARD Beam Test Facilities

Christine Clarke[1], Eric Esarey[2], Cameron Geddes[2], Mark J. Hogan[1], Sergei Nagaitsev[3,4], Mark Palmer[5], Philippe Piot[6,7], John Power[7], Carl Schroeder[2], Navid Vafaei-Najafabadi[8], Alexander Valishev[3], and Vitaly Yakimenko[1]

[1]SLAC National Accelerator Laboratory, [2]Lawrence Berkeley National Laboratory, [3]Fermi National Accelerator Laboratory, [4]The University of Chicago, [5]Brookhaven National Laboratory, [6]Northern Illinois University, [7]Argonne National Laboratory, [8]Stony Brook State University

Numerous reports, including May 2014 report of the HEP Particle Physics Project Prioritization Panel (P5) [1] recommended "…**Support the discipline of accelerator science through advanced accelerator facilities** ..." and "…**Pursue accelerator R&D with high priority Focus on outcomes and capabilities that will dramatically improve cost effectiveness for mid-term and far-term accelerators**." To accomplish this mission, accelerator facilities with high quality beam parameters are essential to support the necessary research into new acceleration techniques with the potential to dramatically reduce the size and cost of future colliders.

Five beam test facilities, supported by GARD in support of SC mission, provide access to a suite of complementary and diverse capabilities for a broad community of scientists representing universities, industry and National laboratories to:

1. Advance accelerator technologies for the next generation of SC research facilities;
2. Basic research in accelerator and beam physics;
3. Education and training for future scientists and engineers.

The *Accelerator Test Facility (ATF)* at Brookhaven National Laboratory [2] serves the US DOE Accelerator Stewardship program [3] and develops advanced acceleration methods for leptons and ions as well as high-energy photon sources. The ATF provides access to three classes of experimental facilities: long-wave infrared high-power laser at ~ 9.2 µm, a high-brightness linac-driven 80MeV electron beam, and near-IR laser sources. This combination of capabilities enables programs on particle and photon source development, wakefield acceleration, inverse Compton scattering, and laser-driven plasma ion acceleration.

The *Argonne Wakefield Accelerator (AWA)* [4] is dedicated to the investigation of collinear (CWA) and two-beam (TBA) beam-driven acceleration. It focuses on the underlying beam-dynamics challenges (e.g. beam-current shaping and bright- and high-charge-beam generation) along with the development of accelerating structures (dielectric waveguides, metamaterials, ...) for efficient high-peak-power RF generation (TBA) or beam acceleration (CWA). AWA has demonstrated unprecedented beam-transformer ratios (>5) in both DWFA and PWFA setups. Likewise, it has produced GW peak-power RF-pulse for TBA application and demonstrated staging in a TBA configuration. AWA also applies the developed technologies to other applications (FELs and compact accelerators) and synergistically supports other advanced-accelerator concepts.

The *BELLA Center* [5] at LBNL has been performing research on laser-plasma accelerators (LPAs) for over two decades. The main research objectives are the development of LPA modules at the 10 GeV level and the staging (coupling) of LPA modules, which are two essential R&D components for a future plasma-based linear collider. The current laser systems at the BELLA Center include the BELLA PW laser and two independent 100 TW systems. Upgrades are underway to the BELLA PW beamline to allow the delivery of two synchronized pulses on target, enabling staging, and a short focal length capability, enabling experiments at ultrahigh intensity. The BELLA Center is also pursuing a new facility, kBELLA, consisting of a 1 kHz, few J, 30 fs, high average power laser for the demonstration of a high rep-rate, precision LPA and subsequent applications. The BELLA Center functions as a collaborative research center and is part of LaserNetUS.

The Fermilab Accelerator Science and Technology facility, FAST [5], consists of a storage ring, IOTA, capable of operating with both protons and electrons with beam momentum range 50 -150 MeV/c and two injector linacs (electrons and protons). The IOTA research goals are mostly focused on the challenges, posed by future high-intensity machines, such as beam instabilities and losses. The IOTA storage ring is unique in its flexibility and performance. It has a circumference of 40 m and a relatively large aperture (50 mm). It is easily reconfigurable to accommodate the installation of 1-3 concurrent experiments. The focusing lattice was designed to have significant flexibility to enable a wide variety of studies. IOTA can store electrons up to 150 MeV or protons at 2.5 MeV (kinetic).

The *Facility for Advanced Accelerator Experimental Tests II (FACET-II)* [6], an upgrade of the FACET facility at SLAC National Accelerator Laboratory, operates as an Office of Science National User Facility. FACET-II will provide beams optimized for the next generation of PWFA experiments and will be the only facility in the world capable of providing 10-GeV electron and positron beams in support of accelerator science R&D. It allocates roughly half of the beam time towards investigating plasma wakefield acceleration. The other half is dedicated to a diverse set of research programs enabled by high energy high intensity electron and positron beams.

The capabilities of a particular facility are developed with the focus on specific aspects of the HEP mission. Collaboration among the research programs to develop concepts and take advantage of diverse capabilities at various facilities is beneficial to all accelerator research programs within the DOE. For example, the AWA facility offers synergistic opportunities with plasma-based acceleration. The staging and bunch shaping for high transformer ratio capabilities mean that the facility can be used for initial demonstration at low energies of these technology elements for both PWFA and LWFA technologies.

Beam test facilities will continue the mission to train the next generation of leaders in accelerator physics. This is accomplished through partnership with universities. Developing the workforce with skills to build and operate the next generation of SC research facilities requires specialized facilities suitable for hands-on training. It is important to expose university-based researchers to the opportunities available with a career in accelerator science, including direct training and co-mentoring of undergraduate and graduate students.

Roadmaps for Advanced Concepts were developed following the previous P5 and are outlined in the 2016 DOE Advanced Accelerator Development Strategy Report [7]. These roadmaps highlight the key R&D challenges in an order of phased complexity in line with the expected availability of experimental facilities. An effort to re-examine priorities, developing updated roadmaps for R&D and identifying needs for demonstration and beam test facilities is expected following P5. As advanced acceleration techniques continue to mature, as first applications will be brought online and as concepts move to the conceptual and technical design level, a technology demonstration facility will have to be developed and operated to fully inform these designs.

[1] https://www.usparticlephysics.org/wp-content/uploads/2018/03/FINAL_P5_Report_053014.pdf
[2] https://www.bnl.gov/atf/
[3] https://science.osti.gov/-/media/hep/hepap/pdf/201706/Colby_HEPAP_AccStwd_201706.pdf?la=en&hash=31DBE185275250E2462F85A776D63F8A08DB3888
[4] https://www.anl.gov/awa
[5] https://bella.lbl.gov
[5] https://www.snowmass21.org/docs/files/summaries/AF/SNOWMASS21-AF1-012.pdf
[6] FACET-II facility for advanced accelerator experimental tests, Phys. Rev. Accel. Beams 22, 101301 (2019)
[7] https://www.osti.gov/servlets/purl/1358081