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FIRST BEAM TO FACET*

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Abstract

The SLAC 3km linear electron accelerator has been reconfigured to provide a beam of electrons to the new Facility for Advanced Accelerator Experimental Tests (FACET) while simultaneously providing an electron beam to the Linac Coherent Light Source (LCLS). On June 23, 2011, the first electron beam was transported through this new facility. Commissioning of FACET is in progress.

THE NEED FOR FACET

The high energy electron and positron beams from the SLAC linac have been in demand by researchers from many different scientific communities for many years. In the mid-1990s, the SLAC Final Focus Test Beam (FFTB), later combined with a bunch compressor system in Sector 10, opened up new areas of research in beam and plasma physics and provided a facility for the development of new beam diagnostic techniques. However, in 2006, the FFTB transport system had to be dismantled to make way for the Linac Coherent Light Source (LCLS). As a replacement for the FFTB, FACET has been constructed to provide the facilities and beams needed to continue these research programs and eventually to deliver bunches of electrons and positrons on the same linac pulse, a feature not previously available with the FFTB. To make FACET possible, the 3km linear electron accelerator was cut at the two-thirds point to provide beams to two independent programs. The first two-thirds of the linac can now provide beams of electrons or positrons to FACET, while the last third can operate independently for the LCLS.

Figure 1 is a schematic representation of the SLAC linac, showing the location of the new FACET facility, along with the LCLS systems and other existing facilities.

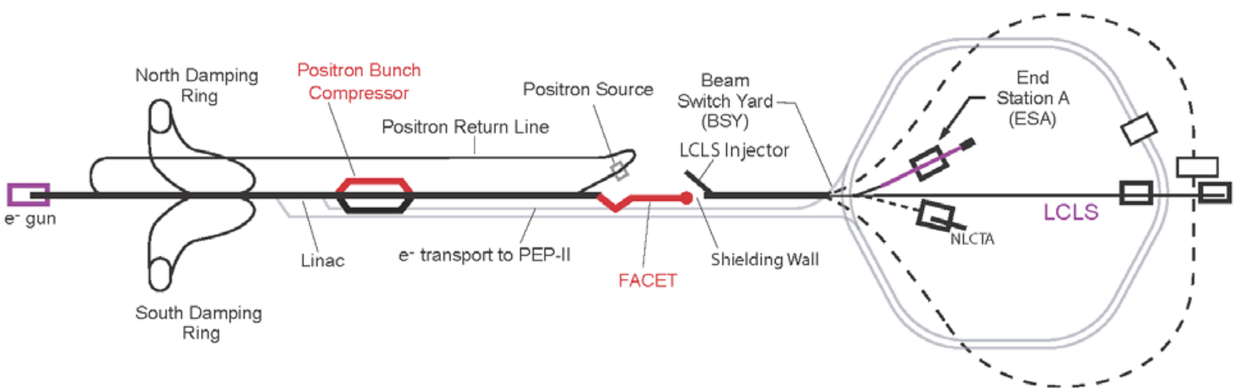

Figure 1: Schematic representation of the SLAC Linear Accelerator Facility, showing the new FACET area and the future location of the positron compressor chicane (indicated in red) (not to scale).

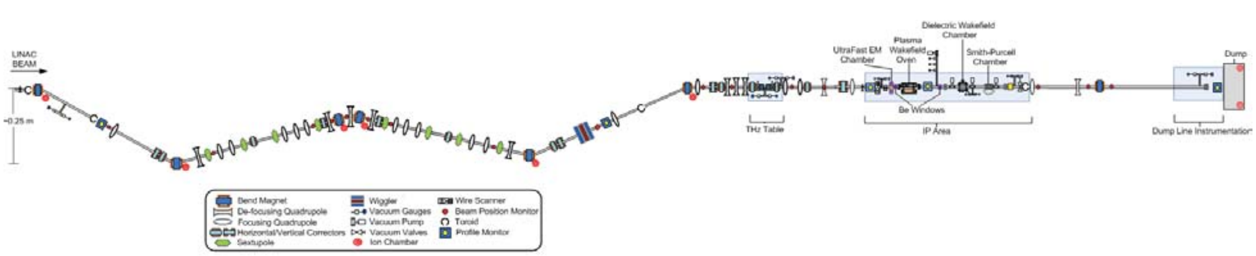

Figure 2: Schematic representation of the FACET beam transport and focusing system in Sectors 19 and 20 (not to scale).

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Figure 2 is a schematic illustration of the new beam transport and focusing system installed in the linac tunnel, beginning in Sector 19 and extending through Sector 20. It consists of a W-shaped chicane, which provides the final stage of longitudinal bunch compression, and contains sextupoles for second-order chromatic corrections. The chicane is followed by a sequence of quadrupole magnets to focus the beam to the desired spot size at the interaction point (IP). Most of the quadrupoles have individual power supplies, which allow for a wide range of optical configurations. Downstream of the IP area are a vertical bend and focusing quadrupoles which form a spectrometer for the outgoing electron beam before it reaches a dump. Immediately preceding the dump is a table suitable for supporting experimental equipment, such as a detector for neutral electromagnetic radiation produced in the IP area.

SEPARATION OF LCLS AND FACET

As originally designed, the entire linac tunnel had to be locked and interlocked to exclude people as a condition for accelerating a beam. The last third of the linac runs nearly continuously to support LCLS programs whenever the linac is available, and this demand for uninterrupted linac operation is likely to continue indefinitely. In contrast, the FACET users are likely to need frequent entries into the tunnel to install, adjust, and modify their experimental apparatus as the science program evolves. To reconcile these incompatible requirements, a massive shielding wall was installed in the tunnel near the downstream end of Sector 20, just upstream of the LCLS injection point, and a major reconfiguration of the personnel protection system (PPS) was implemented to allow for access to the area upstream of the shielding wall while the LCLS is operating. In addition, a stairway was installed in an equipment access shaft in Sector 19 to allow for easy personnel access to the FACET tunnel area.

Persons working in the FACET area upstream of the wall are well shielded from any radiation that might back-scatter from the LCLS injection area in Sector 21. However, the converse is not true; no one is allowed in the tunnel downstream of the wall when a beam is present in the FACET area. This exclusion is enforced by the interlocking features of the upgraded PPS system.

FACET CONSTRUCTION

Last year, essentially all the accelerator components from the BAS-II dump near the end of Sector 19 to the new shielding wall at the end of Sector 20 were dismantled to make room for the FACET transport magnets, beam diagnostics, and other instrumentation. The 10-foot-long copper accelerator structures were removed and carefully stored for future use. Cooling water pipes were cut back and capped or bypassed, rectangular RF waveguide and vacuum manifold hardware was removed, and a large number of cables and conduits were removed or rerouted.

While this work was happening in the tunnel, the electrical distribution and cooling water systems in the Klystron Gallery above were upgraded, and magnets, vacuum equipment, and diagnostic instruments from decommissioned SLAC Linear Collider (SLC) and FFTB systems were refurbished and prepared for use in FACET. Earlier this year, this equipment was installed in the tunnel, along with new vacuum chambers and mechanical and electrical systems. Figures 3 and 4 are photographs taken in the tunnel before the tunnel was cleared and after the FACET components were installed.

Figure 3: Sector 20 before the accelerator systems were removed to make way for FACET. The linac is visible above the much larger alignment light pipe.

Figure 4: Sector 20 with the new FACET magnets installed.

FIRST OPERATION

The first two-thirds of the linac, the new FACET equipment, and the LCLS facility are all operated by the same Operations team from the same control room using the same control system. The control system modifications that were introduced for the LCLS are based on the EPICS architecture. Similarly, the control system additions needed for the new FACET systems in

Sector 20 were also implemented using EPICS. The damping rings and most linac systems needed for FACET, however, continue to use the earlier SCP-based architecture developed for the SLC.

Starting in June, 2011, the vacuum system was pumped down, the new beam transport system magnets were energized, and the various diagnostic instruments were tested and calibrated to the extent practical. When the electron beam was turned on and accelerated, it was first directed into the existing "scavenger" line, which was used in the past to transport electrons to the positron production target. This transport line can be used as a momentum-defining spectrometer to assist in setting up and steering the beam down the linac. When the beam had been established with a charge of 2×10^{10} electrons/pulse and energy of nearly 20 GeV, it was directed into the FACET area and steered through the compressor chicane. On June 23, the beam reached the dump.

Since then, various technical problems have been identified and corrected, instruments have been tested and calibrated with the beam, and beam-based alignment studies have been carried out for all the quadrupole magnets. Figure 7 illustrates a typical beam cross section observed on the OTR profile monitor near the IP. Also shown are horizontal and vertical projections of the observed spot and Gaussian fits to the projections.

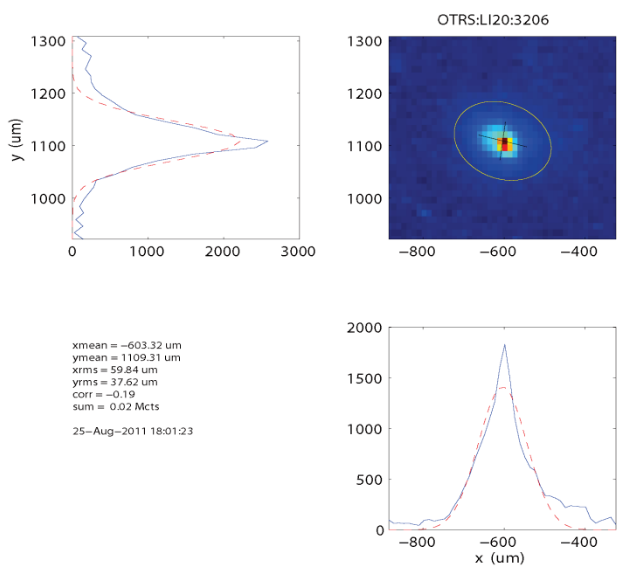

Figure 5: Beam profile measured with an OTR screen near the IP.

Table 1 summarizes beam parameters observed recently. The beam energy achieved is a somewhat arbitrary choice and can be adjusted relatively easily as needed. The repetition rate has been limited to 10 Hz to limit the production of residual radioactivity, but this rate can be raised to 30 Hz at any time. The next challenge in the commissioning program will be to further reduce the longitudinal and transverse dimensions of the beam at the interaction point.

Table 1: Summary of FACET Beam Parameters

	Design	Achieved
Energy	20-23 GeV	19.65 GeV
Particle type	Electrons (and later positrons)	Electrons
Charge per pulse	2×10^{10} (3 nC) e^- or e^+ per pulse	2×10^{10} (3 nC) e^- per pulse
Repetition rate	30 Hz	10 Hz
Spot size $\sigma_x \times \sigma_y$	20 x 10 μm	60 x 40 μm
Bunch length σ_z	15 – 40 μm	40 μm

SUMMARY

On June 23, 2011, an electron beam was successfully transported through the new FACET system to a dump in Sector 20 in the linac tunnel. This was achieved while the last third of the linac, operating from the same control room, but with a separate injector system, was providing an electron beam to the Linac Coherent Light Source (LCLS), demonstrating that concurrent operation of the two facilities is practical. With the initial checkout of the new transport line essentially complete, attention is now turning toward compressing the electron bunches longitudinally and focusing them transversely to support a variety of accelerator science experiments.

ACKNOWLEDGMENTS

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