BEAM TEST FACILITIES FOR R&D IN ACCELERATOR SCIENCE AND TECHNOLOGIES

Snowmass Accelerator Frontier
- AF1: Beam Physics, Education and Outreach
- AF6: Advanced Colliders

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ABSTRACT

Demonstrating the viability of emerging accelerator science ultimately relies on experimental validation. A portfolio of beam test facilities at US National Laboratories and Universities, as well as international facilities in Europe and Asia, are used to perform research critical to advancing accelerator science and technology (S&T). These facilities have enabled the pioneering accelerator research necessary to develop the next generation of energy-frontier and intensity-frontier User Facilities. This report provides an overview of the current portfolio of beam test facilities outlining: the research mission, the recent achievements, and the upgrades required to keep the US competitive considering the large investments in accelerator research around the world.

MISSION

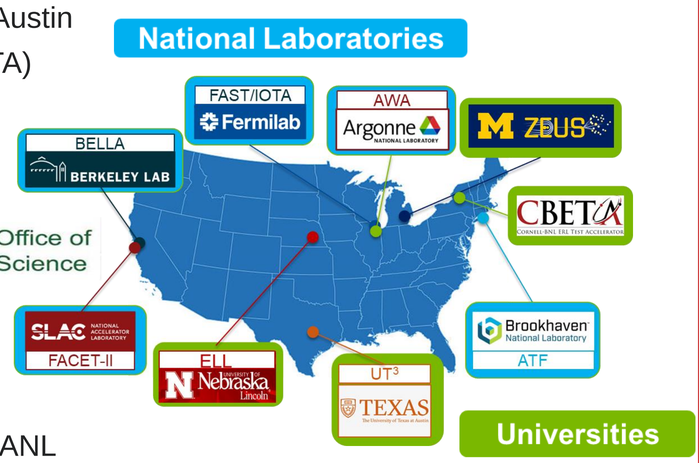
1. Providing experimental test beds to carry out basic research in advanced accelerators and beam physics.
2. Developing the S&T needed to enable the next generation of science facilities and accelerator applications.
3. Educating and training future scientists and engineers.

FACILITY LOCATIONS

The Beam Test Facility mission is carried out at several beam test facilities located at U.S. National Laboratories and Universities

Universities

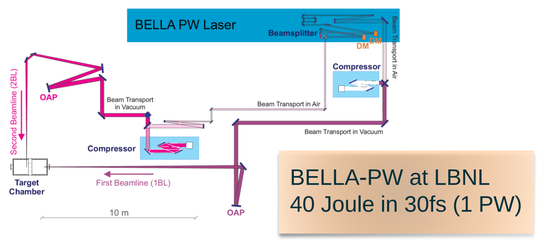
- Texas Petawatt Laser, University of Texas at Austin
- The Cornell-BNL ERL Test Accelerator (CBETA)
- Extreme light laboratory, Lincoln, Nebraska
- ZEUS user facility, University of Michigan



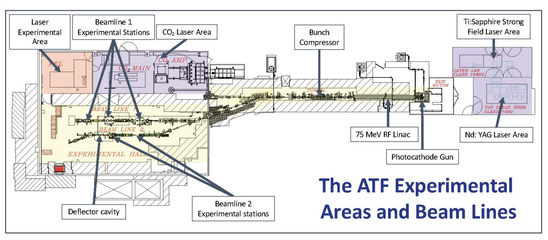
National Laboratories

- Accelerator Test Facility (ATF) at BNL
- The Argonne Wakefield Accelerator (AWA) at ANL
- The Berkeley Lab Laser Accelerator (BELLA) Center at LBNL
- The Fermilab Accelerator Science and Technology facility (FAST) at FNAL
- The Facility for Advanced Accelerator Experimental Tests II (FACET-II) at SLAC

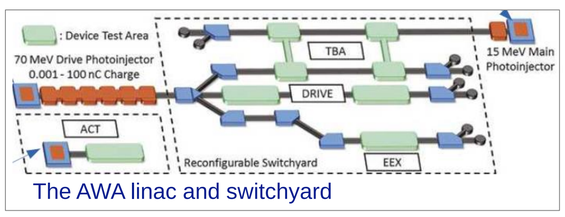
FACILITY LAYOUTS



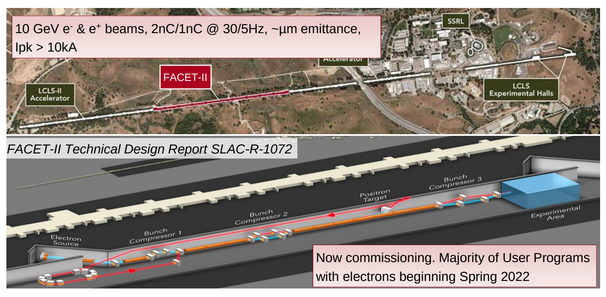
BELLA-PW at LBNL
40 Joule in 30fs (1 PW)

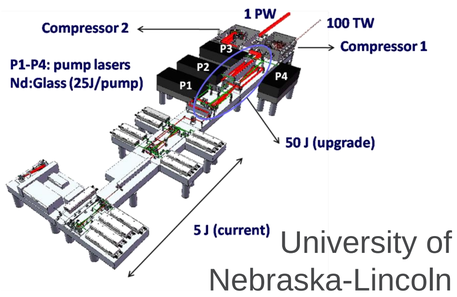


The ATF Experimental Areas and Beam Lines

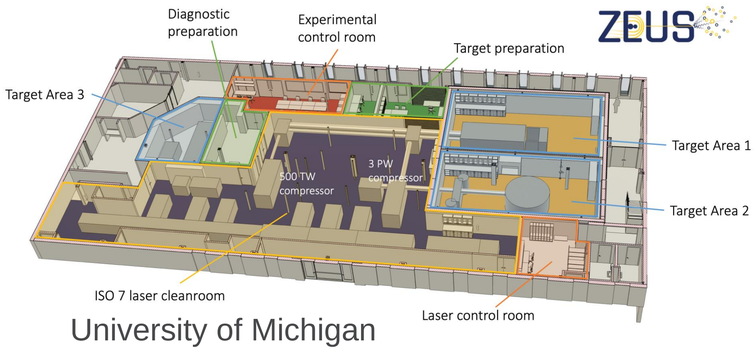


The AWA linac and switchyard

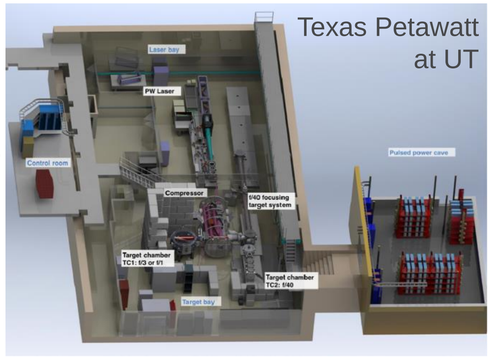




University of Nebraska-Lincoln



University of Michigan



Research Thrusts & Facility Capabilities

Research thrust	ATF	AWA	BELLA	FACET-II	FAST
Advanced Acceleration					
LWFA	✓(MeV)		✓(GeV)		
PWFA	✓(MeV)	✓(MeV)		✓(GeV)	
SWFA	✓(MeV)	✓(MeV)		✓(GeV)	
IFEL	✓				
staging	✓	✓	✓		
positron acceleration				✓	
Particle Source Development					
plasma-based e- sources		✓	✓	✓	
ion acceleration w/ lasers	✓		✓		
Inverse Compton Scattering	✓		✓	✓	
γ ray via filamentation				✓	
coherent X rays from plasmas		✓	✓	✓	
Beam Physics					
phase-space cooling		✓			✓
single $e-$ & crystalline beams					✓
integrable nonlinear optics					✓
extreme bunch compression				✓	
Diagnostics & Beam Control					
novel diagnostics	✓	✓	✓	✓	✓
ML/AI: virtual diagnostics		✓	✓	✓	✓
ML/AI: improve efficiency		✓	✓	✓	
bunch-current shaping	✓	✓	✓	✓	
phase-space/emit. exchange	✓				

Capabilities	ATF	AWA	BELLA	FACET-II	FAST
operation model					
National user facility	✓			✓	
Accelerator stewardship	✓			✓	
Collaboration		✓	✓		✓
Beams & Accelerators					
~ 100-MeV e^-	✓	✓	✓		✓
~ 10-GeV e^-			P	✓	
~ 10-GeV e^+				P	
high-charge (~ 100 nC) e^- bunches		✓			
proton beams			P		P
NCRF S-band and X-band	✓				
NCRF L-band and X-band		✓		✓	
SCRF L-band and X-band					✓
storage ring					✓
Lasers					
TW-class 800-nm laser (Ti:Sapphire)	✓	✓	✓	✓	
PW-class 800-nm laser (Ti:Sapphire)			✓		
TW-class 10 μm laser (CO_2)	✓				
Plasmas					
plasma capilaries (length [cm])	✓(2)	✓(2)	✓(20)		
gas jets	✓		✓	✓	
heat-pipe oven	✓		✓	✓	
hollow channel		✓		✓	

Capabilities	ELL	Texas	ZEUS
Beams & Accelerators			
~ 100-MeV e^-	✓	✓	P
~ 10-GeV e^-			P
proton beams	✓	✓	P
Lasers			
TW-class 800-nm laser (Ti:Sapphire)	✓		P
PW-class 800-nm laser (Ti:Sapphire)	✓		P
PW-class 1057-nm laser (Nd:glass)		✓	
Plasmas			
plasma capilaries (length [cm])			
gas jets	✓	✓	P
heat-pipe oven			
hollow channel			

Layout of the FAST facility at FNAL.

WHAT DOES THE FUTURE HOLD?

THE PROMISE

- AAC aims for GeV/m and beyond at high efficiency
  - SWFA, PWFA and LWFA are advancing rapidly
- ABP aims to improve the beam Intensity, Quality, Control & Prediction
  - enabling discoveries in Elementary Particle Physics, Nuclear Physics, and Materials Sciences

NEXT STEPS

- International Competition from Europe and Asia in AAC is on the rise
- Beam Test Facilities Upgrades are needed

REFERENCES

[BEAM TEST FACILITIES] Clarke, Christine, Eric Esarey, Cameron Geddes, G. Hofstaetter, M. J. Hogan, Sergei Nagaitsev, M. Palmer et al. "US advanced and novel accelerator beam test facilities." *Journal of Instrumentation* 17, no. 05 (2022): T05009.(https://iopscience.iop.org/article/10.1088/1748-0221/17/05/T05009)

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[ABP] Nagaitsev, S., Z. Huang, J. Power, J-L. Vay, P. Piot, L. Spentzouris, J. Rosenzweig et al. "Accelerator and beam physics research goals and opportunities." *arXiv preprint arXiv:2101.04107* (2021).

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