Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Fulfilling the Mission of Brookhaven's ATF

DOE's SC User Facility for Accelerator Stewardship

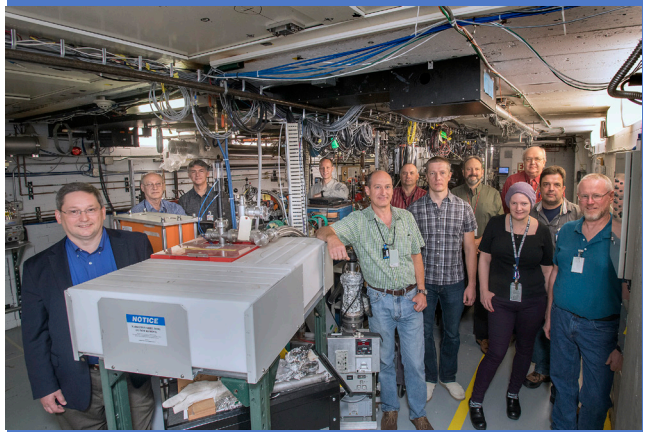
Mark Palmer

NAPAC 2022

@BrookhavenLab

The Accelerator Test Facility

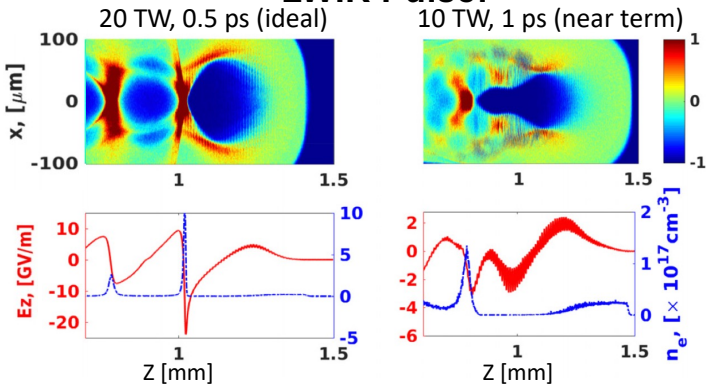
ATF: A DOE Office of Science User Facility



- Designated a DOE National User Facility in 2015
  https://www.bnl.gov/bnlweb/pubaf/fact_sheet/pdf/FS-ATF.pdf
- Capabilities in:
  - **Novel particle acceleration techniques**
    R&D for smaller, more cost-effective accelerators including:
    - Plasma and dielectric wakefield acceleration
    - Direct laser acceleration
    - Inverse free-electron lasers and more…
  - **High-brightness radiation sources**
    New techniques to produce electromagnetic radiation from THz to X-rays:
    - FEL R&D
    - Inverse Compton scattering
    - THz radiation from dielectric structures and more...
  - **Beam manipulation and beam instrumentation**
    Sophisticated longitudinal and transverse beam manipulation capabilities
    - Wide range of beam parameters enabling development and testing of advanced accelerator hardware, beam diagnostics and detectors
  - **Ion generation and acceleration**
    - Experimental hardware for producing supersonic hydrogen gas jets provides capabilities for generating mono-energetic multi-MeV proton beams
  - **Ultrafast Electron Diffraction/Microscopy**
    Technique for characterizing materials that is complementary to x-ray sources
    - Developmental beam line and experimental station for diffraction and imaging studies with MeV-class electron beams

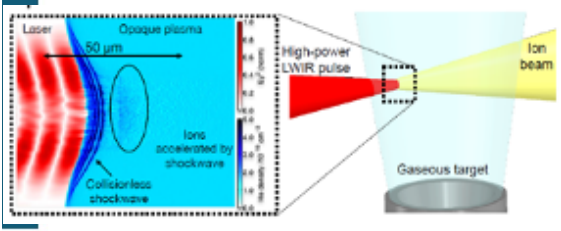
Long Wave Infrared (LWIR) Driven Science

Electron acceleration in blowout regime enabled by LWIR Pulse:



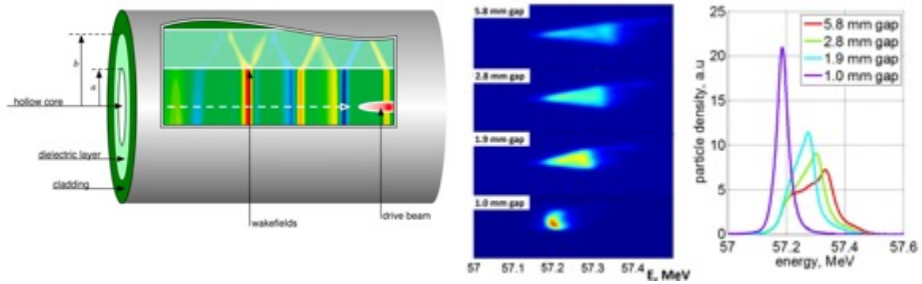
Large bubbles enable energy-spread and polarization preservation

Ion Acceleration: Collisionless Shocks in gaseous targets used to obtain low-energy-spread ion beams



Electron-Beam Driven Science

Dielectric Wakefield Acceleration

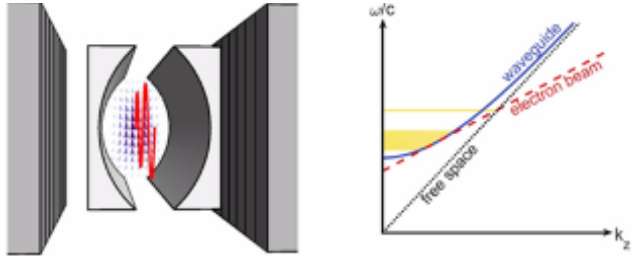


S. Antipov et al., PRL 112, 144801 (2014)
Chirp suppression @ BNL ATF

Primary Research Thrusts:

- Transverse instabilities and beam breakup
- Material and geometry advances to extend structure breakdown limit

Efficient Beam-Based THz Generation



Waveguide inside an undulator creates “zero slippage condition” for the EM THz wave with the e-beam velocity. (intersection point of dispersion curves)

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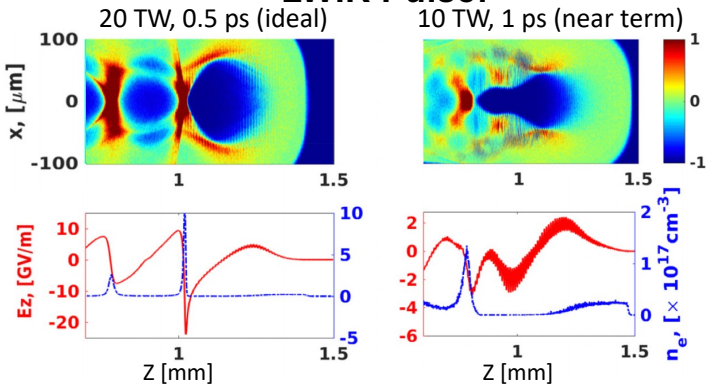

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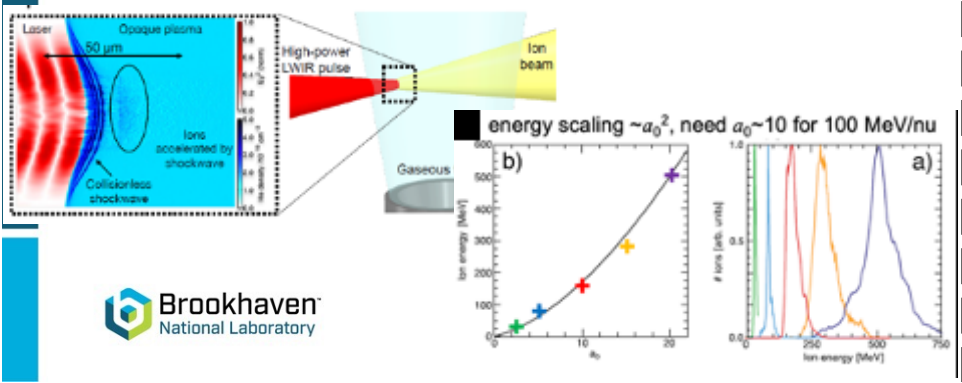

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Electron-Beam Driven Science

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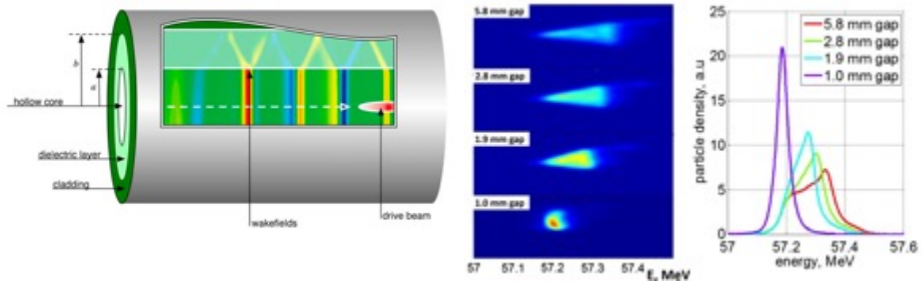

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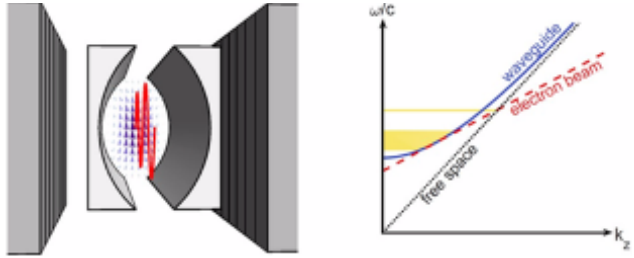

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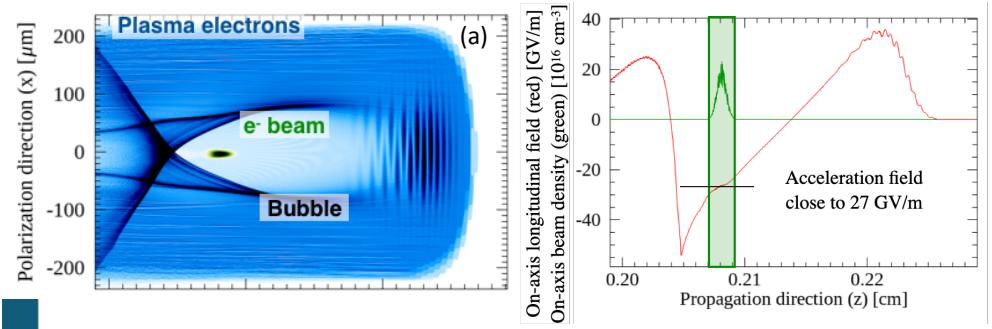
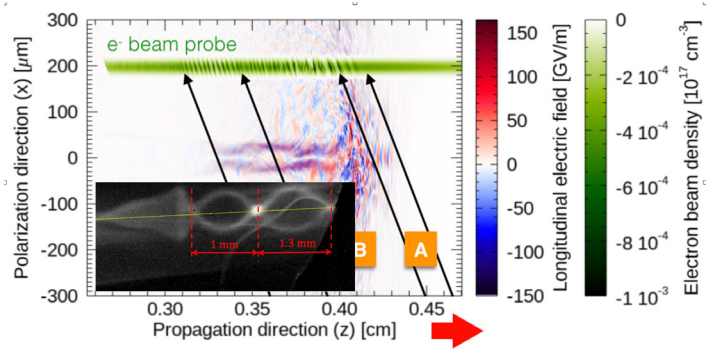
LWFA Injection and Diagnostics

Quality preservation of electrons injected in the wake

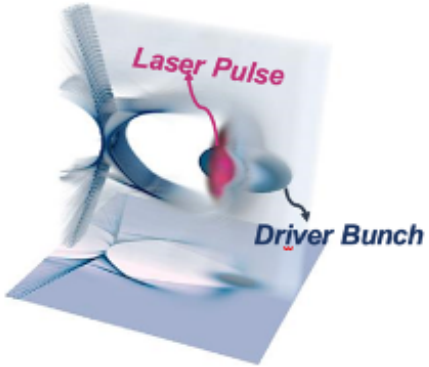


Direct probing of the fields inside the wake

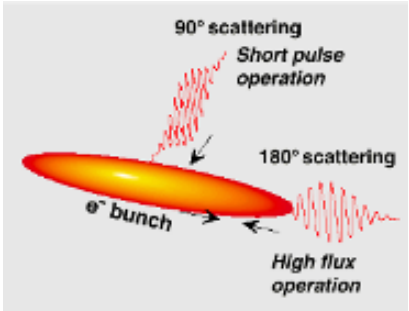


Direct Laser Acceleration

Coupling of the laser energy through ion channel to the electrons (the DLA effect) increases the interaction length of a beam driven plasma accelerator in the so-called synergistic electron bunch/laser-pulse wakefield acceleration scheme



Inverse Compton Scattering



ATF Facilities are ideal for studying

- Nonlinear ICS effect (due to LWIR)
- Two-color ICS
- Study of finer structures of ICS spectral radiation

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ATF Current Capabilities & Potential Upgrade Paths

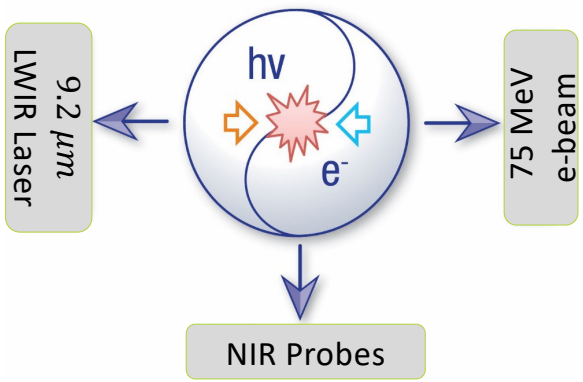
Current Capability

5 TW, 2 ps CO_2 laser pulses at the output of the final amplifier, up to 2.5 TW delivered to users

Upgrades

<u>Current Efforts:</u> 5 TW delivered to users

<u>3 Year Goal:</u> 10-20 TW of CO_2 laser power with sub-ps pulse length delivered to users



Current Capability

<u>Nd:YAG:</u> 1-5 mJ, 1-15 ps pulse length delivered

<u>Ti:Sapphire:</u> 15 mJ, ≤100 fs pulses delivered

Commissioning underway

<u>Ti:Sapphire:</u> 100 mJ energy upgrade

Current Capability

0.1-2 nC, pulse length down to ~ 100 fs, ϵ_n ~1 mm-mrad, repetition rate of 1.5 Hz

Future Upgrade

<u>3 Year Goal:</u> Bunch length ~ 30 fs

<u>Desired Upgrades:</u> energy to ~ 125 MeV, T-CAV on both user beam lines

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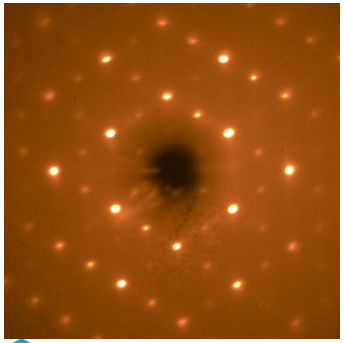
ATF MeV UED Beam Parameters

	BNL	SLAC	MSU
Beam energy, MeV	3	3.68	0.03
N e^- per pulse	1.25 E+6	3.8E+5	500
Temporal resolution, fs	180	102	300
Beam size diameter, μm	300 (100 best)	400 (10 best)	20-40
Max repetition rate	48	120 (180 best)	1,000
N e^- per sec per μm^2	880	360	400
Advantage	short bright pulse	short bright pulse	DC (no jitter)



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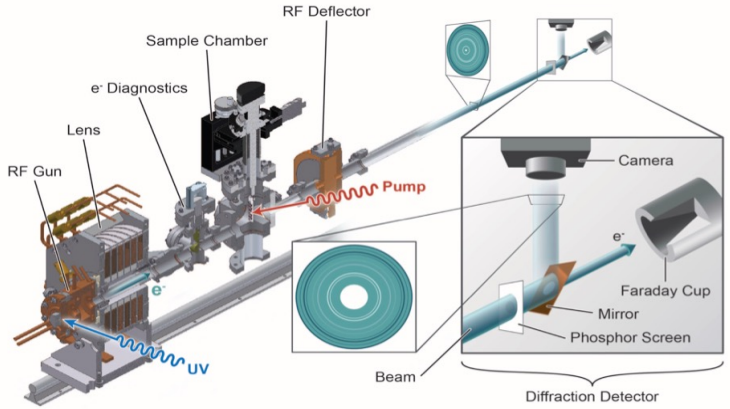
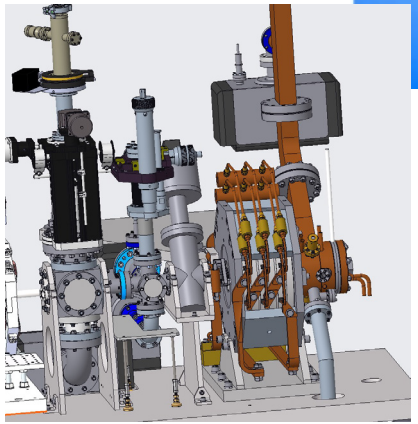
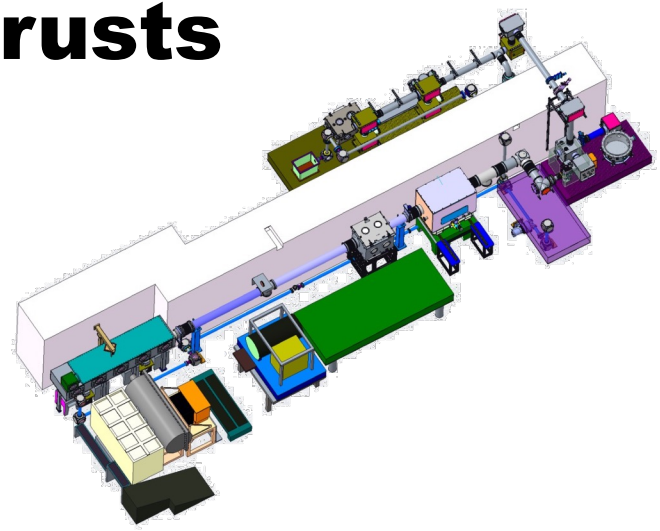




Major Facility Upgrade Thrusts

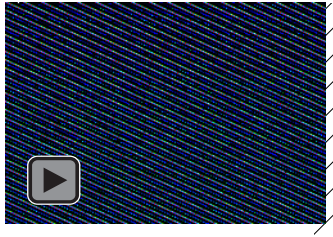
guided by the ATF Science Planning process

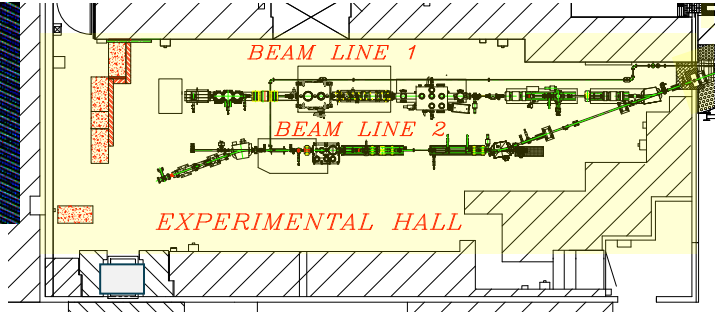


- Laser R&D program
  - CO_2 laser power upgrade to ≥25 TW peak power with pulse-width <500 fs

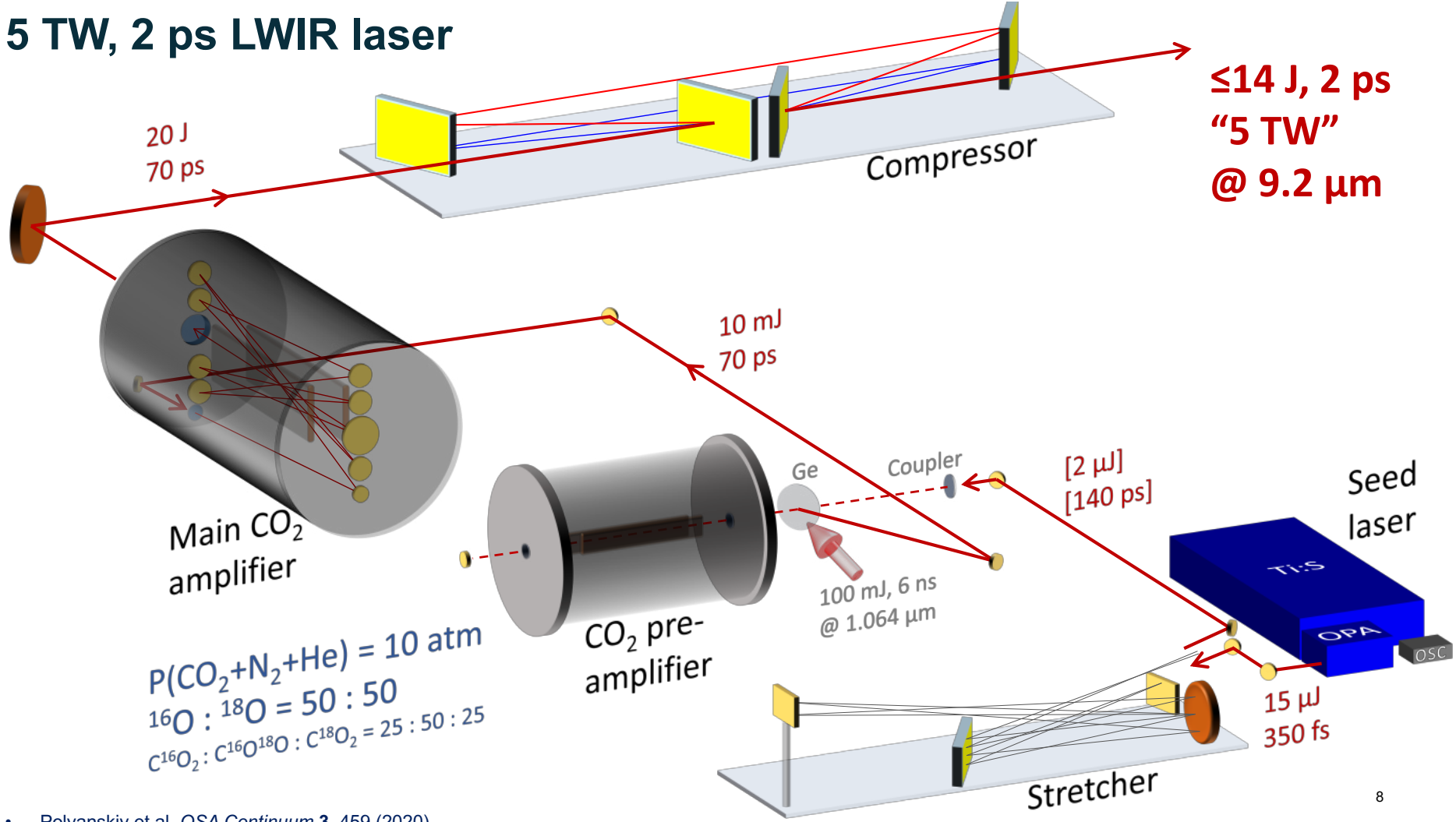
    First femtosecond multi-TW LWIR laser!

    This would enable a world-leading research program into advanced particle acceleration
    See next slide
  - Completing in vacuum NIR and LWIR laser beam transport to user experiments to ensure the best beam quality
- Electron Beam
  - Continue to move towards providing more highly compressed beams (~30 fs bunch)
  - Exploit and expand short bunch diagnostic capabilities
  - Enable *complete flexibility in primary and secondary beams*
- UED/UEM
  - Focus on unique UED measurement options for users
    - Wavelength flexible OPA pump laser
    - Improved system performance
  - Apply AI/ML techniques to both beam line tuning and real-time structural analysis
  - Support the UEM development program being pursued for BES use
  - Implement a new plan to steward the UED by end of 2022





5 TW, 2 ps LWIR laser



- Polyanskiy et al. *OSA Continuum* **3**, 459 (2020)

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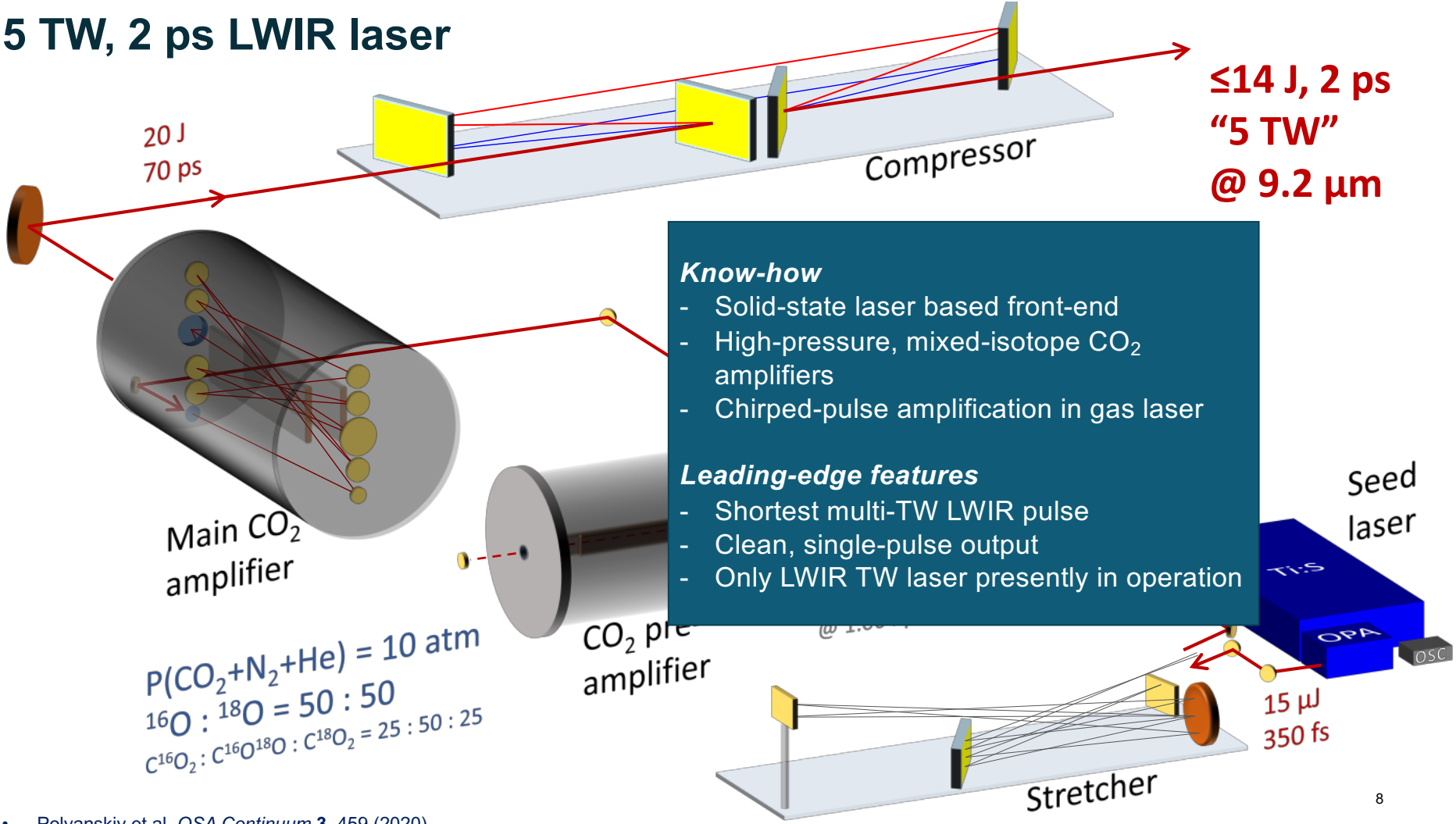


Know-how

- Solid-state laser based front-end
- High-pressure, mixed-isotope CO_2 amplifiers
- Chirped-pulse amplification in gas laser

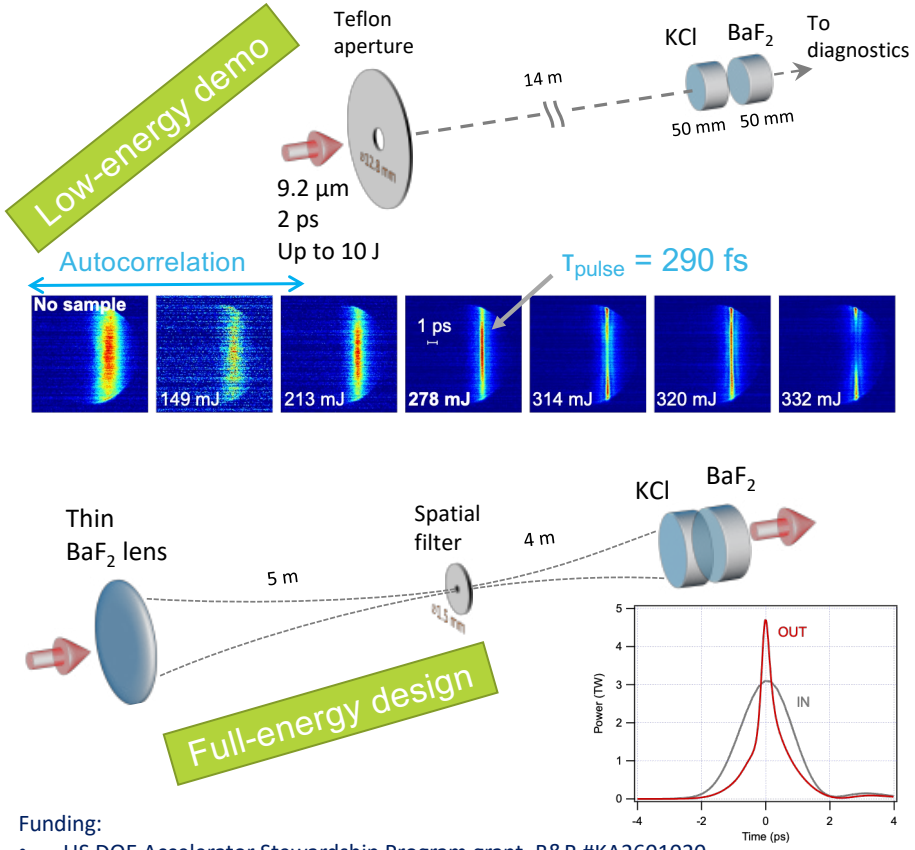
Leading-edge features

- Shortest multi-TW LWIR pulse
- Clean, single-pulse output
- Only LWIR TW laser presently in operation

- Polyanskiy et al. *OSA Continuum* **3**, 459 (2020)

LWIR laser R&D toward 10+ TW, <1 ps

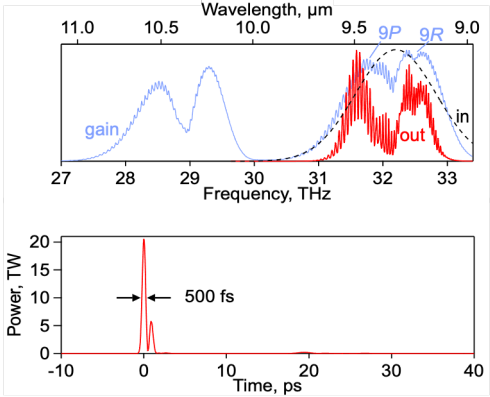
Thrust A: post-compression



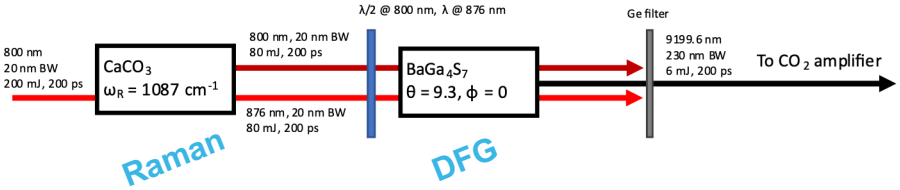
Funding:
- US DOE Accelerator Stewardship Program grant, B&R #KA2601020
- BNL Laboratory Directed Research and Development grant #20-010

Thrust B: 2-branch amplification

- Single CO_2 amplifier
- Amplification only ~10^3 (*small gain narrowing*)



- Need ~10 mJ seed @ 9.3 μm



Funding:
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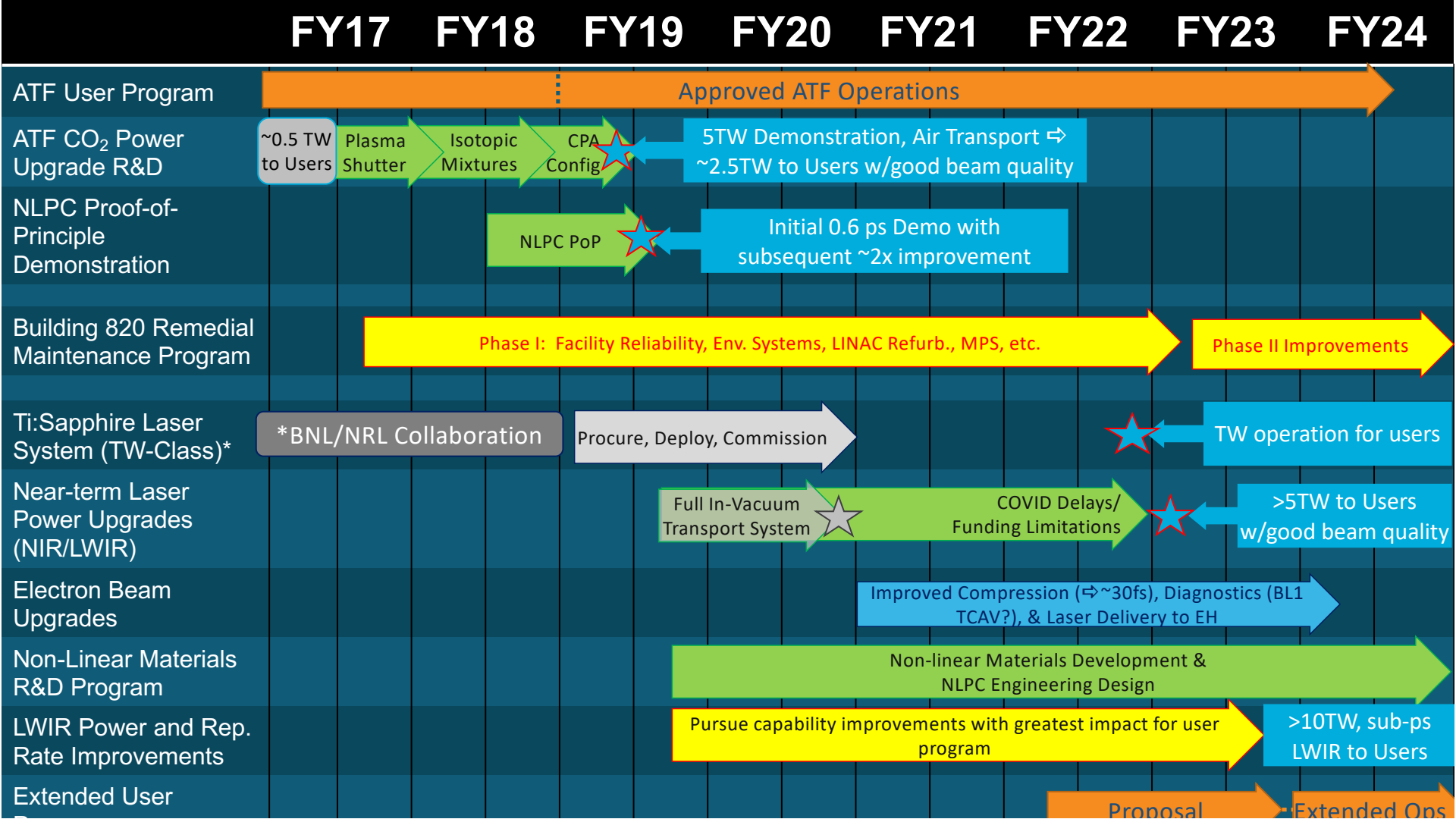

FY17
FY18
FY19
FY20
FY21
FY22
FY23
FY24
ATF User Program
Approved ATF Operations
ATF CO_2 Power Upgrade R&D
~0.5 TW to Users
Plasma Shutter
Isotopic Mixtures
CPA Config
5TW Demonstration, Air Transport ⇨ ~2.5TW to Users w/good beam quality
NLPC Proof-of-Principle Demonstration
NLPC PoP
Initial 0.6 ps Demo with subsequent ~2x improvement
Building 820 Remedial Maintenance Program
Phase I: Facility Reliability, Env. Systems, LINAC Refurb., MPS, etc.
Phase II Improvements
Ti:Sapphire Laser System (TW-Class)*
*BNL/NRL Collaboration
Procure, Deploy, Commission
TW operation for users
Near-term Laser Power Upgrades (NIR/LWIR)
Full In-Vacuum Transport System
COVID Delays/ Funding Limitations
>5TW to Users w/good beam quality
Electron Beam Upgrades
Improved Compression (⇨~30fs), Diagnostics (BL1 TCAV?), & Laser Delivery to EH
Non-Linear Materials R&D Program
Non-linear Materials Development & NLPC Engineering Design
LWIR Power and Rep. Rate Improvements
Pursue capability improvements with greatest impact for user program
>10TW, sub-ps LWIR to Users
Extended User
Proposal
Extended Ops

Some Comments

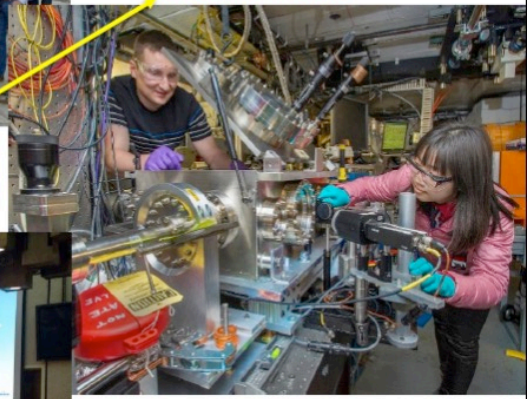
Office of Accelerator R&D and Production
SC-25
Eric Colby

- ATF now operates under ARDAP (SC-25: Accelerator R&D and Production Office)
  - Mission is to support both science and technology R&D by our accelerator and laser user community
- After delivering ~3000 user hours in FY21, FY22-23 will see reduced operations availability due to Accelerator Readiness Review Preparations (a new requirement for all *legacy* accelerator facilities at BNL)
- In mid-FY23, the UED facility will be spun off as an independent facility outside the ATF portfolio
- The facility continues an incremental upgrade program to establish a unique multi-beam suite of capabilities
  - With critical parameters for each capability matched to support the user community research program
  - We expect to hold our next Science Planning Workshop sometime in CY2023

Initiating User Experiments

www.bnl.gov/atf/ Apply → get approved → get beam time

Your experiment



User's and Proposal Steering Committee meetings

Please join us in November for AAC’22

Registration links being sent this week!

Web-site at: aac2022.org

Brookhaven National Laboratory

Useful Links

- Request for attendance
- Workshop Registration
- AAC History

Join the AAC Email List

Search | Search

LONG ISLAND

63°

clear sky
humidity: 56%
wind: 21mph N
H 69 • L 65

71°	66°	65°	74°
TUE	WED	THU	FRI

20th Advanced Accelerator Concepts Workshop (AAC’22)

Sponsored by the IEEE Council on Superconductivity

November 6-11, 2022

Hyatt Regency Long Island, Hauppauge, NY

The AAC’22 workshop is a by-invitation biennial forum for intensive discussions on long-term research in advanced accelerator physics and technology. This research supports the development of capabilities for the basic sciences, from photon science to high energy physics, as well as the development of compact accelerators for industrial, medical and security applications.

This year’s meeting will host multiple working groups exploring advanced acceleration techniques, particle sources, beam instrumentation and control methods, radiation generation, and computational modeling. Additional groups will focus on the technology requirements and test facilities required to advance research and capabilities in these areas.

Please check back regularly for updates as the Organizing Committee finalizes the workshop program.

Thank you for your attention!