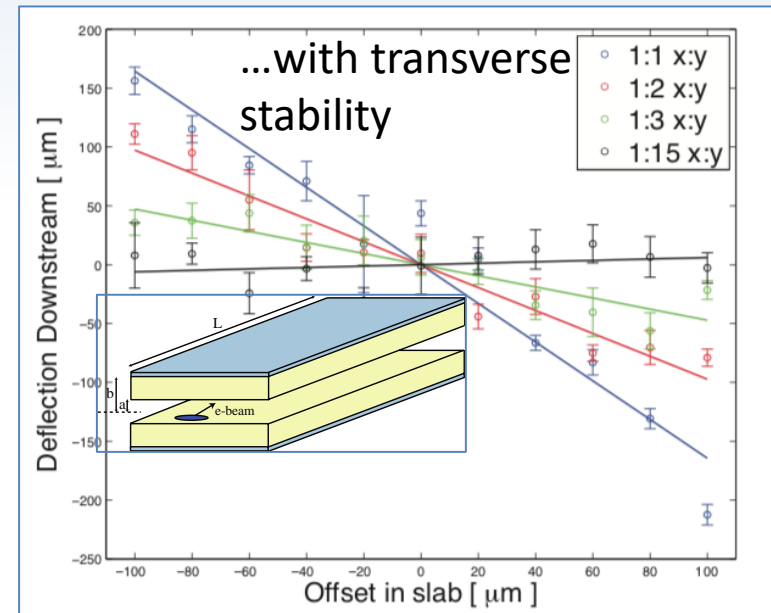
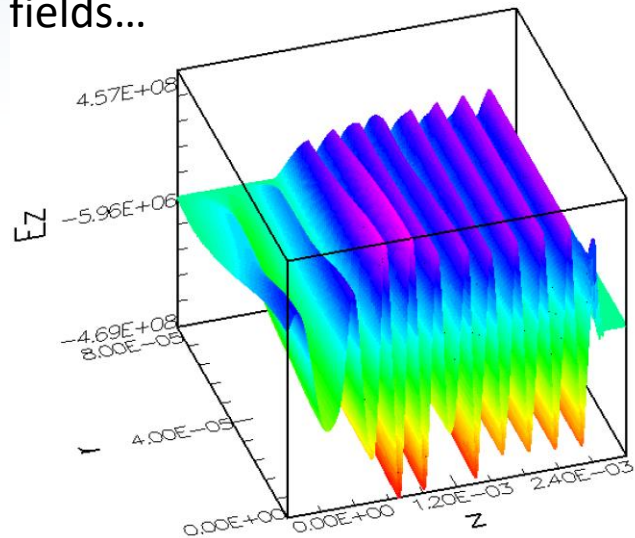


E321: Dielectric wakefield acceleration at GeV/m gradients

FACET-II Program Advisory Committee
Status Report

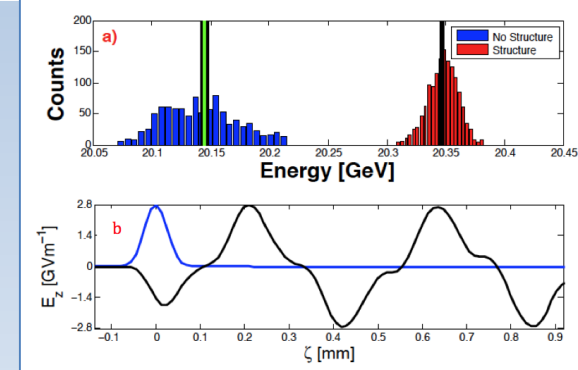
J. Rosenzweig, for the collaboration
October 28, 2020

GV/m fields...



Publications:

E201 to FACET-II E321

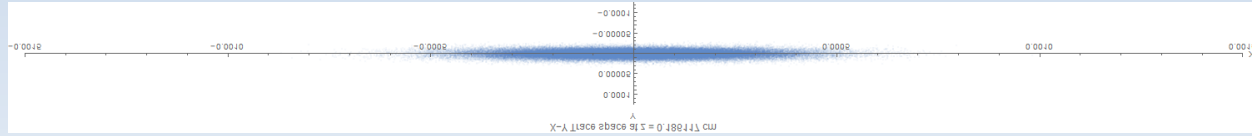


- G. Andonian, *et al.*, “Planar-Dielectric-Wakefield Accelerator Structure Using Bragg-Reflector Boundaries”, *Phys. Rev. Lett.* **113**, 264801 (2014)
- P. Hoang, *et al.*, “Experimental Characterization of Electron-Beam-Driven Wakefield Modes in a Dielectric-Woodpile Cartesian Symmetric Structure” *Phys. Rev. Lett.* **120**, 164801 (2018)
- B. O’Shea, *et al.*, “Observation of acceleration and deceleration in gigaelectron-volt-per-metre gradient dielectric wakefield accelerators”, *Nature Comm.* **7**, 12763 (2016)
- B. O’Shea, *et al.*, “Conductivity Induced by High-Field Terahertz Waves in Dielectric Material”, *Phys. Rev. Lett.* **123**, 134801 (2018)
- S. Baturin, *et al.*, “Analytical treatment of the wakefields driven by transversely shaped beams in a planar slow-wave structure”, *Phys. Rev. Accel. Beams* **21**, 121302 (2018)
- B. O’Shea, *et al.*, “Suppression of Deflecting Forces in Planar-Symmetric Dielectric Wakefield Accelerating Structures with Elliptical Bunches”, *Phys. Rev. Lett.* **124**, 104801 (2019)
- B. O’Shea, *et al.*, “Positron Cerenkov wakefield interaction at high field”, in preparation for *Phys. Rev. Lett.* (2020)
- G. Andonian, *et al.*, “Exploring high-field dielectric wakefield acceleration at FACET-II” in preparation *Phys. Rev. Accel. Beams* (2020)
- W. Lynn, *et al.*, “Transverse beam stability in an alternating-symmetry dielectric wakefield accelerator” in preparation (2020)
- M. Yadav, *et al.*, “Efficient outcoupling of terahertz radiation from relativistic beam driven dielectric lined waveguides” in preparation for *Phys. Rev. Accel. Beams* (2020)

FACET-II Science Goals: Near Term

- **Goal 1.** Investigate transverse effects that cause emittance growth and **beam breakup in long \sim GV/m structures** for drive beams of varying ellipticity.

- Can we build the tradeoff curves of E_z and F_{perp} ?



- **Target time:** 6 months

- **Success:** Characterization of transverse BBU for varying beam aspect ratios with >200 MeV acceleration, in 3 different structures. Preparation for advanced symmetry structures.

- **Goal 2.** Purposeful coupling to transverse mode (off-axis excitation) adds x-z correlation similar to TCAV for pulse length characterization. **Passive streaking**

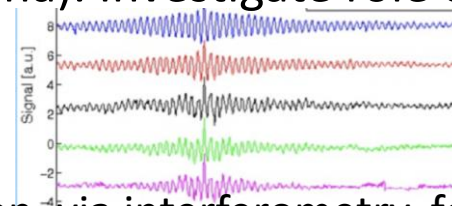
- Can this be useful for extreme beams? Fsec resolution at multi-GeV energies.

- **Target time:** 6 months

- **Success:** Quantitative data to correlate bunch length to self-streaked dimension. May be exploited by other groups at FACET-II.

- **Goal 3.** Complimentary studies on **high field damping effects** using low loss tangent materials (CVD diamond, SiO_2 , alumina). Investigate role of *pulsed heating* at boundary of metal/dielectric.

- **Target time:** 6-12mo



- **Success:** Cherenkov wake field characterization, via interferometry, for SiO_2 and CVD structures. Preparation for cryogenic material tests in coming years.

Experimental Timeline

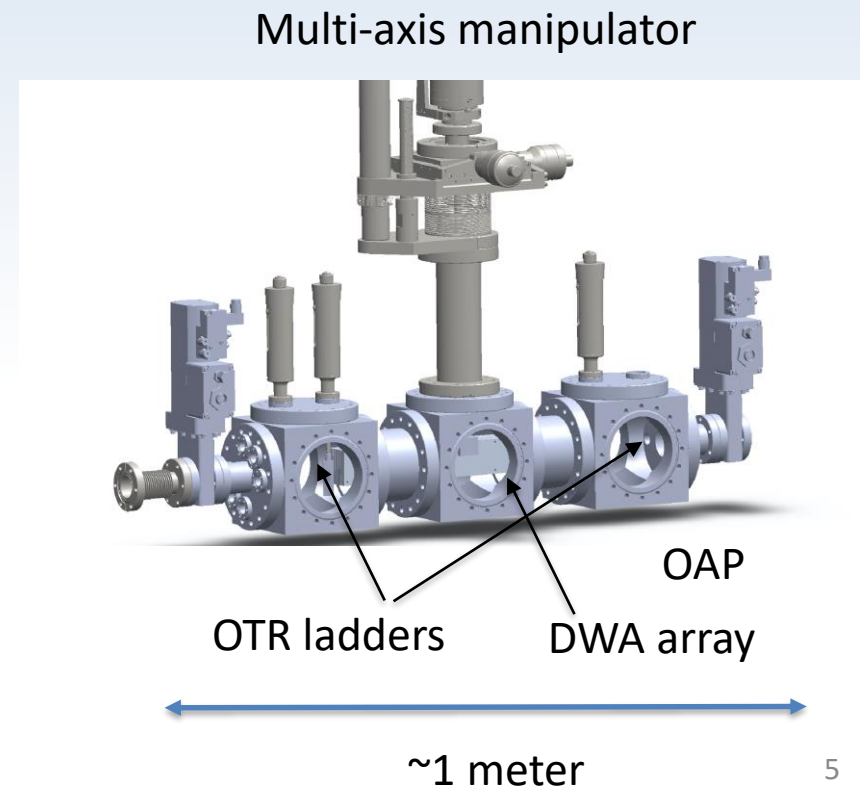
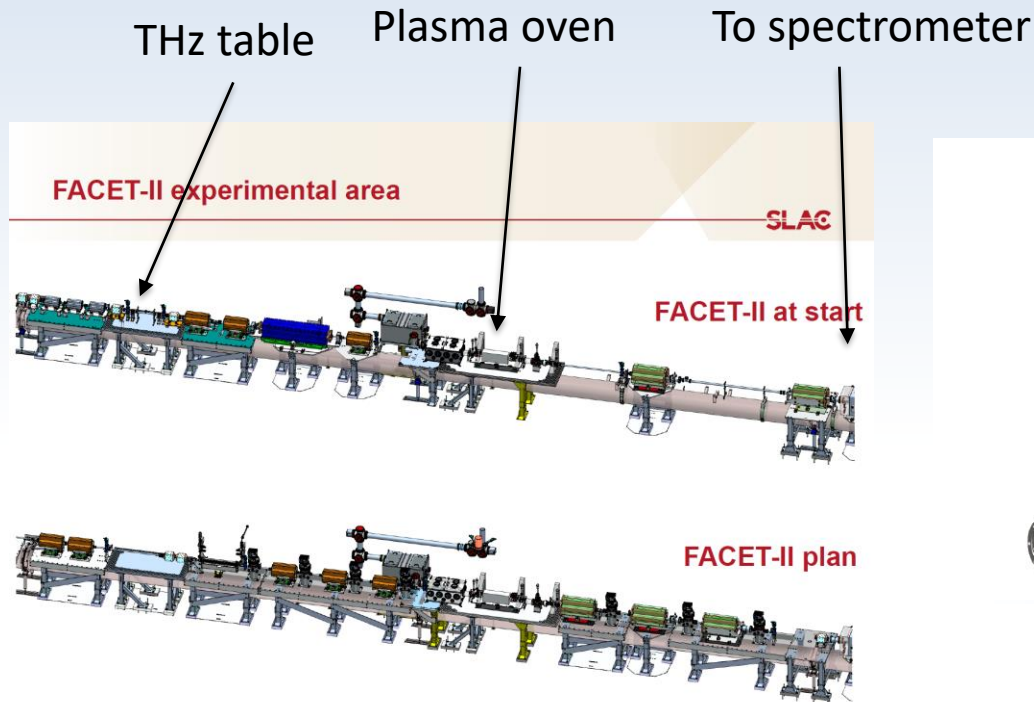
- Experimental design (90%): November 23, 2020
- Installation plan: December 1, 2020
- Ready for experimental review: December 1, 2020
- Ready for installation: January 11, 2021
- Ready for commissioning:
 - $Q=2$ nC, σ_x/σ_y = variable near 250×25 μm
 - Bunch length = > 25 μm
- First science:
 - $Q=2$ nc, σ_x/σ_y = variable: $300-600 \times 25$ μm
- Phases of the program permit flexibility in accepting 1st beam of varying parameters
 - Smaller σ_y accesses high field, higher frequency

Experimental layout

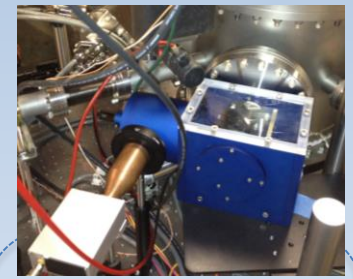
Located on **THz Table**, currently downstream of TCAV

Array of DWA-based diagnostics/experimental scenarios; common hardware

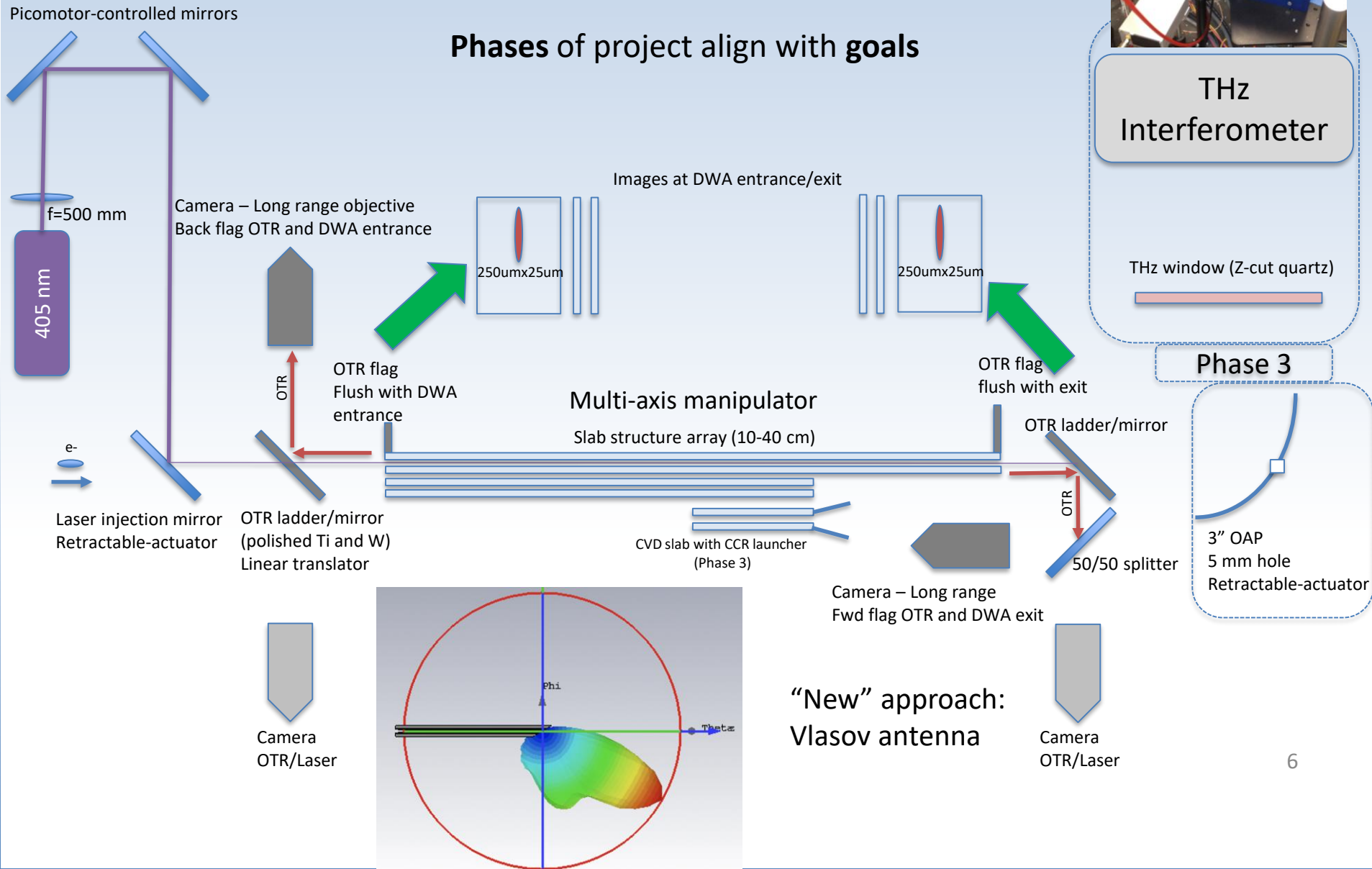
Vacuum to be compliant with TCAV requirements (UHV – 10^{-9} torr)



Experimental Layout



Phases of project align with goals



Diagnostics and observables

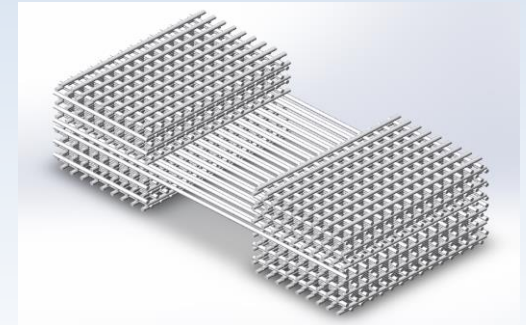
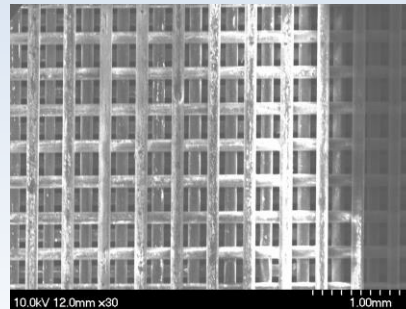
- BBU and passive streaking (Phases 1 and 2)
 - Profile (OTR, YAG) monitors downstream of DWA
 - Measure centroid and profile changes of beam
 - Charge (BPM or toroid) transport
 - >100 MeV energy change (spectrometer)
- High field-induced damping (Phase 3)
 - Coherent radiation interferometry (BLIS + pyro detectors) to detect direct wave damping
 - Study of differing dissipation for different materials
 - Probing the latching dissipation effect with witness beam; measure change in CCR damping vs. beam loading

Reference: Required Hardware

- Alignment laser module, optics, picomotors: ~\$6200 (picomotor qty: min. 4)
- UHV components and ion pumps
- OTR ladder linear translators (qty: 4)
- Cameras and objectives (qty: min. 4)
- Add-ons to existing (E-202) 3-axis Vacgen Omniax manipulator: \$7,500
 - Rotation: RD1/2 provides remaining required motion for vertically-aligned slabs: \$5,000
 - Sample holder, SH2: required for R2 (“roll”) motion: \$2,500
- UHV mirror (OAP) mount: \$3,000 (phase 3)

Potential future evolution beyond presented at PAC

- DWA program is rich and FACET-II beams allow exploration of key issues in DWA research, using existing setup *and* foreseen future
- Future goals:
 - Advanced structures
 - Photonics (DLA conn.)
 - Alternating symmetry
 - Cryo-DWA to for heating mitigation, higher fields
 - Radiation generation (Joule-class THz for pump-probe expts.)
 - Transverse wake probing; novel beam configurations
 - Staged DWA (beam focusing, monitoring)
 - Efficient positron DWA (asymmetry in charge response)
 - DWA-based chirper for plasma wake studies



Desired Facility Upgrades

- Recovery of foreseen 3 nC capability
- Large UHV chamber with lid; differentially pumped
- Cryogenic infrastructure in tunnel
- 6-axis manipulator with cryo-lines
- Asymmetric emittance (flat) beams

Collaboration and training

- UCLA
 - G. Andonian, A. Fukasawa, B. Naranjo, J. Rosenzweig, Y. Sakai, O. Williams
 - Students: W. Lynn, C. Hansel, G. Lawler, P. Manwani, M. Yadav (w/Liverpool)
- SLAC
 - C. Clarke, M. Hogan, B. O'Shea, V. Yakimenko
- NIU
 - S. Baturin, P. Piot
- MSU
 - S. Baryshev