Diagnostics Challenges for FACET-II*

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Introduction

FACET-II is a prospective user facility at SLAC National Accelerator Laboratory. The facility will focus on high energy, high brightness beams of electrons and positrons and their interaction with plasma and lasers.

The accelerator is designed for high energy density electron beams with peak currents of approximately 50 kA and potentially greater than 100 kA when optimised for peak current delivery.

The bunches are focused down to below 10µm x 10µm transverse spot size at an energy of 10 GeV.

Subsequent phases of the facility will provide positron beams above 10 kA peak current to the experiment station.

Experiments will require well characterised beams however the high peak current of the electron beam can lead to material failure in wirescanners, optical transition radiation screens and other instruments critical for measurement or delivery. The radiation environment and space constraints also put additional pressure on diagnostic design.

Beam Parameters for initial FACET-II operation and full design range (in brackets)

Parameter	Electrons	Positrons
Beam Energy [GeV]	10 (4.0-13.7)	10 (4.0-13.7)
Bunch Charge [nC]	2 (0.7-5.0)	1 (0.5-1.5)
Transverse beam size [µm]	10 (6-20)	20 (7-25)
Bunch Length [µm]	20 (1-20)	20 (7-20)
Peak Current [kA]	>10 (10-100)	>10 (12-15)

FACET User Facility Upgrade

The existing FACET (facility for advanced accelerator experimental tests) uses the first two-thirds of the SLAC linac to accelerate electrons and positrons up to 20 GeV for delivery to experiments.

Starting 2017, FACET-II anticipates starting construction with the aim to resume the electron program in 2019 and positron program in 2020. The FACET-II project is currently in its conceptual design phase.

FACET-II will use a RF photocathode gun and injection system for the electrons resulting in lower emittance, smaller bunch lengths and overall improved beam quality.

The experimental program will build upon the success of FACET which has seen significant breakthroughs in plasma wakefield acceleration (PWFA) and dielectric wakefield acceleration (DWA) and carried a broad scientific program including diagnostics development and pump-probe experiments using broadband terahertz (THz) radiation.

Unparalleled peak current in the world

FACET-II's High Peak Currents and short bunches

Delivery Challenge: > 100 kA peak current

Particle tracking in *Impact-T* and *Lucretia* show that the design performance of FACET-II can result in peak currents in excess of 100 kA.

→ Desired by experimental program

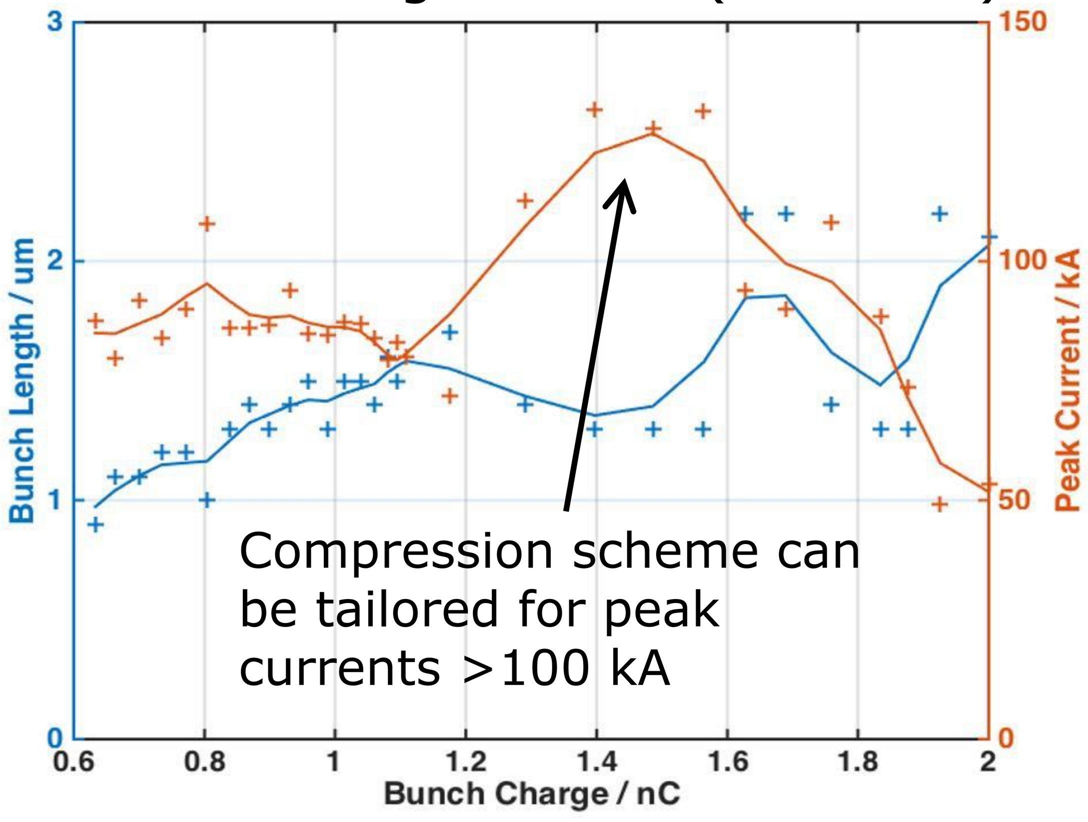
→ How can the beam be measured without destroying the diagnostic?

Delivery Challenge: < 1 µm bunch length

Particle tracking in *Impact-T* and *Lucretia* show that the design performance of FACET-II can result in sub-micron bunch lengths with collimation in the compressor chicanes.

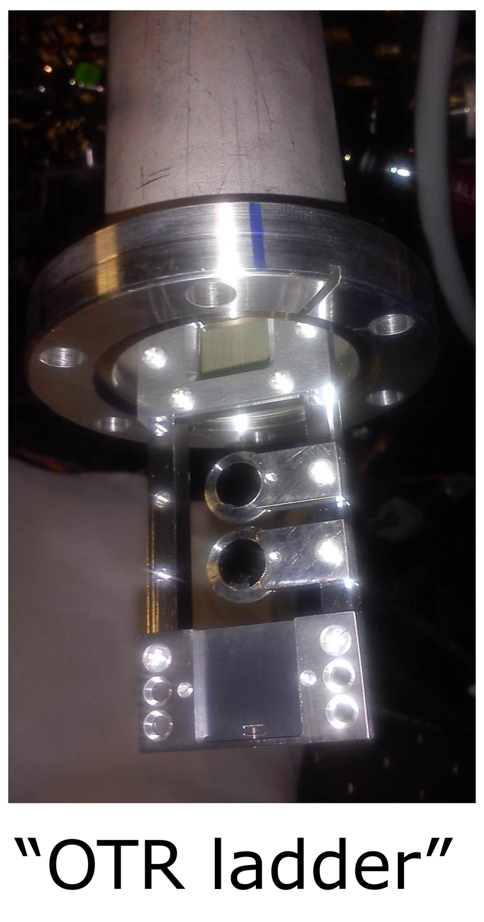
→ What diagnostic has resolution to match?

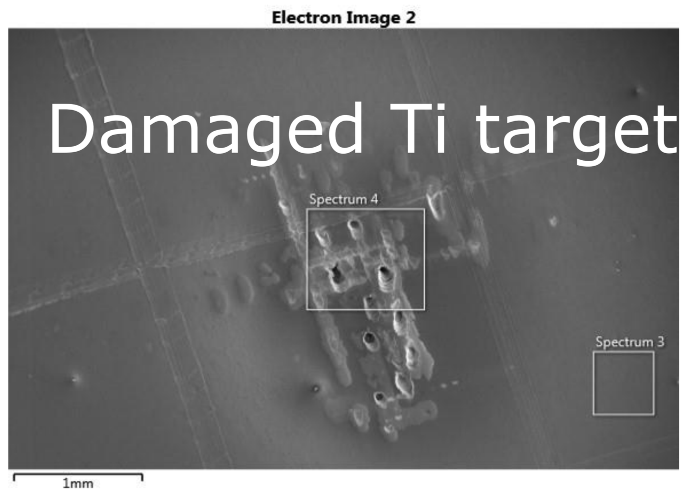
FACET-II design studies (electrons):

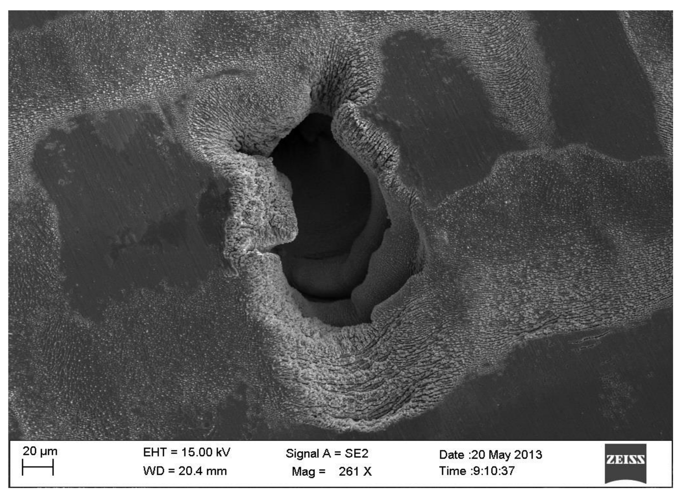


Lessons from FACET

Optical Transition Radiation (OTR) Profile Monitors





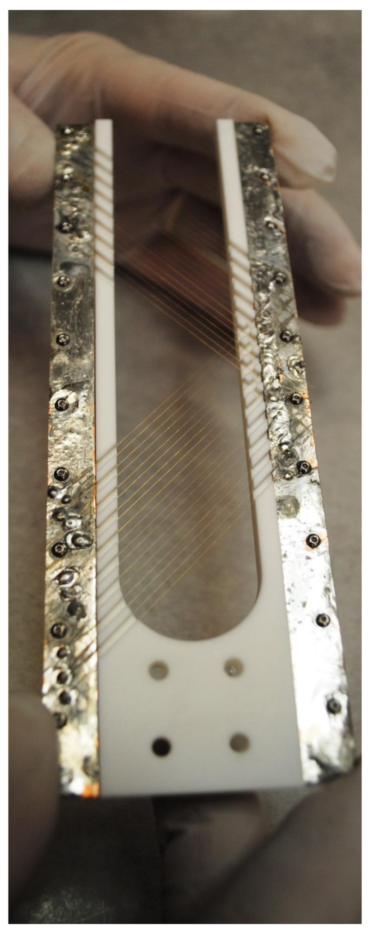


The FACET electron beam (peak current >10 kA) regularly damaged titanium targets used for OTR. Shown above (right top and bottom) are images of a damaged titanium target 500µm thick. Multiple beam shots are evident. Surface damage would occur with a single shot.

To mitigate, screens were typically only used away from the beam focus to tune out tails. Multiple screens were installed on an "OTR ladder" to reduce interruptions to delivery (above, left).

Wirescanners

The preferred diagnostic for measuring transverse beam size at the focus was a wirescanner. Gold coated 60µm tungsten wires were used. Beam damage to tungsten was rare; typically the gold melted but the tungsten was undamaged. Occasional breaks motivated the development of a wire card with multiple wires on the same principle as the OTR ladder.



→ FACET operated at the limits of materials using redundancy as mitigation

Acknowledgments

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