Outline

• The FACET ASF Area
• Two bunch plasma wakefield acceleration
• Positron acceleration
• Trapped particles
• Future possibilities
Plasma Accelerator Experiments will take place in the Sector 20 ASF Area

At FACET we will produce and accelerate a discrete bunch – not just a few electrons at all phases

Challenges:
- Drive bunch needs to be substantial enough to both ionize the vapor and drive a large amplitude wake
- Witness bunch needs to be half-plasma period behind ~ 100µm for 1E17 plasma!
FACET ASF uses a three stage bunch compression process

Very similar to FFTB/SPPS operation

Single FFTB Bunch Sampled All Phases of the Wake Resulting in ~ 200% Energy Spread
Exploit Position-Time Correlation on e- bunch to create separate drive and witness bunch

1. Insert tantalum blade as notch collimator
2. Do not compress fully to preserve two bunches separated in time

A variation of the notch collimator was recently demonstrated at BNL ATF

(P. Muggli, V. Yakimenko et al submitted for publication)
Use a combination of 6D particle tracking in ELEGANT combined with EGS4 to simulate the collimator(s)

Two bunches
Sigma z 18µm ea.
Separation ~150µm
Charge ratio ~ 3:1

FACET Notch Collimator drive bunch comparable to state of the art

LCLS Accelerator Schematic

6 MeV
$\sigma_z = 0.83 \text{ mm}
\sigma_y = 0.05 \%$

135 MeV
$\sigma_z = 0.83 \text{ mm}
\sigma_y = 0.10 \%$

250 MeV
$\sigma_z = 0.19 \text{ mm}
\sigma_y = 1.6 \%$

4.3 GeV
$\sigma_z = 0.022 \text{ mm}
\sigma_y = 0.71 \%$

13.6 GeV
$\sigma_z = 0.022 \text{ mm}
\sigma_y = 0.01 \%$

Commission Mar-Aug 2007
Commission Jan-Aug 2008

Courtesy of Paul Emma
FACET Experiments will accelerate a discrete bunch of particles with narrow energy spread

Plasma Accelerators are not just very-high frequency structures

Incoming beam properties partly define the structure:
dimensions, field amplitude, transformer ratio...

Full understanding requires experimentation, observation and simulation
PWFA Mechanism Different For A Positron Beam

Positron Focusing varies with radius and position along the bunch

- Ideal Plasma Lens in Blow-Out Regime
- Plasma Lens with Aberrations

E-162 Data

High Gradient Positron Acceleration

- First experiments will attempt to repeat E-167 with positrons
  - Not trivial when consider difference in plasma electron response:

- Second phase will use two bunches (notch collimator will work equally well with e- or e+)
  - Measure halo formation and emittance growth with DSOTR & quad scan in x-plane of dispersed beam to isolate accelerating portion of the wake
Hollow Channel Plasmas may offer better accelerating wakes and reduce emittance growth

- Potential for larger accelerating fields and less aberrated focusing
- Synergy with DWA which may work equally well with e- & e+
- Challenge for plasma source development in field ionized regime
- Potential to engage new users/collaborators:

Guiding characteristics of an acoustic standing wave in a piezoelectric tube

C. M. Fauser, E. W. Gaul, S. P. Le Blanc, and M. C. Downer
University of Texas at Austin, Department of Physics, Austin, Texas 78712

Positron Acceleration in Electron Beam Driven Wakes is possible in the weakly non-linear regime
Generating closely-spaced mixed-species bunches is simplified by creating the positrons in the plasma

EGS5 Simulation of electron and positron energy spectra and phase space after 0.5mm tantalum target
Wakefield structure naturally selects the positrons with appropriate phase space and accelerates them to high energy.

Distance into plasma

2mm 9.8cm

Positron Energy Spectrum
After 1m

Plasma electrons

Beam electrons

Foil produced positrons

New Phenomena: Trapped Particles

Electrons Are Trapped at He Boundaries and Accelerated Out of the Plasma

Two Main Features
- 4 times more charge
- >10^4 more light!

Two energy populations (MeV & GeV)

Note: Primary beam is also radiating!
Visible Light Spectrum Indicates Time Structure of Trapped Electrons

\[ \Delta \omega = 2\pi \]

\[ Bunch \ \text{Spacing} = c\tau \approx 70 \ \mu m, \]

\[ \text{plasma wavelength}, \lambda_p = 64 \ \mu m. \]

OSIRIS Simulations:
- He electrons in several buckets
- Spaced at plasma wavelength
- Bunch length \( \sim fs \)

Trapped Particles Have Short Time Structure

High Brightness Electron Source?
- Multi-GeV Energy
- fs pulse length
- Normalized Emittance 10 smaller than the drive beam

Designing next generation experiments to better understand and produce more of them!
OSIRIS Simulations indicate the high-quality trapped particle bunches are destroying themselves trying to get out

Can Be Optimized by Varying Beam and Plasma Parameters

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Drive Beam Trapped Particles

Peak at 11 GeV FWHM ~%4

2µm FWHM!

20 Year FACET Program

Results of this program will guide future facility upgrades...
Future upgrades will be guided by results

Possibilities:
- Lower damping ring energy
  - Better compression, higher peak current
- Enhanced LCLS style photoinjector
  - Multiple bunches, bunch trains, shaped pulses with added flexibility
- ASSET type experiment with e-e+, 5cm dz @ Li09 chicane, coast to FACET IP
  - Positron acceleration in electron wakes with ‘real beam’ of positrons
- NLC/ILC style FF
  - Sub-micron spots @ IP for ion motion studies
- Holography of e+ wakes, EO sampling

From the FFTB Program
Over 25 Peer reviewed publications covering all aspects of beam plasma interactions: Focusing (e- & e+), Transport, Refraction, Radiation Production, Acceleration (e- & e+)

Major Accomplishments
The FACET PWFA Program will address many of the current questions pertaining to a PWFA-LC.