Accelerator Test Facility

Vitaly Yakimenko
October 6-7, 2010
ATF User meeting
ATF Organization Chart

DOE BES
J. Misewich, ALD -(Contact)

DOE HE,
S. Vigidor, ALD - (Contact)

T. Ludlam
Chair, Physics Department

L. Littenberg
HEP Ass. Chair, Physics Dept.

R. Palmer
ATF Program Director

External program
committee
W. Leemans, Chair

V. Yakimenko
Director ATF, Accelerator

K. Tuohy
Group Secretary

M. Fedurin
Physicist, Accelerator

M. Woodle
Engineer Mechanical

C. Swinson
Research Associate, Accelerator

A. Karostoshevsky,
Mechanical designer

M. Montemagno
Engineer Electrical

R. Malone
Computer Control

M. Montemagno
Engineer Electrical

K. Kusche
Safety Engineer

G. Stenby
Technician Electr./Mech.

P. Jacob
Technician Mech./Laser

I. Pogorelsky,
Physicist, Laser

M. Polyansky,
Physicist, Laser

M. Babzien
Engineer, Laser

M. Babzien
Engineer, Laser

M. Babzien
Engineer, Laser

M. Babzien
Engineer, Laser

M. Babzien
Engineer, Laser

Management/
oversight

Full time staff

Resent hire

Part time

Needed

Vitaly Yakimenko
Nd:Yag Laser and e-beam operational days are plotted.

CO2 operations were requiring Nd:Yag beam in April-August’09.

Days with parallel operation of CO2 and e-beam experiments are counted as one.
2009 Modulator fire at ATF

- Fire started due to failure of the high voltage capacitor in the pulse forming network of the Linac modulator.
- The modulator was completely destroyed
- Replacement modulator was built ~6 month before the fire (cost of parts ~$100K)
- Recertification, cleanup, upgrades (~$60K)
- Interlock systems disabled power to minimize chance of fire and made it safe for fire fighters.
- Operator on duty followed instructions prioritizing personal safety.
- Factors affecting the outcome were:
  - No high voltage trained person was in the building at the time of the capacitor failure. (Both of the planned hires)
  - Replacement capacitors were ordered 2 days before the fire (at ~25% of the specified life time).
- Lasers were not affected and after recertification of interlocks restarted operations within days
- e-beam operation were halted from February till September 2009.
New capabilities

• CO2 laser now delivers 4J, 4ps, 1 TW single pulse beam
• 90 MeV electron beam is delivered to Compton interaction
• <0.5degree RF phase stability is demonstrated over 1 hour
• Multichannel Frame grabber system including GigE and PI EM CCD (Electron Multiplication= Single photon) cameras is available
• ...

• Updated User and Students Room
**I-Q vector modulators upgrade**

**Gun I-Q modulator:**
- New software control was developed and recalibrate for new software control

**Linac I-Q modulator:**
- Old I-Q was replaced
- New software control was developed and recalibrate for new software control

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<tr>
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<th>Old control</th>
<th>New control</th>
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<tr>
<td>rms($\Delta A$)</td>
<td>0.140 dB</td>
<td>0.031 dB</td>
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<tr>
<td>max($\Delta A$)</td>
<td>0.475 dB</td>
<td>0.098 dB</td>
</tr>
<tr>
<td>rms($\Delta \phi$)</td>
<td>0.851°</td>
<td>0.316°</td>
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<tr>
<td>max($\Delta \phi$)</td>
<td>2.73°</td>
<td>1.22°</td>
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<thead>
<tr>
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<th>Old I-Q and control</th>
<th>New I-Q and control</th>
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<tr>
<td>rms($\Delta A$)</td>
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<td>max($\Delta A$)</td>
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<td>rms($\Delta \phi$)</td>
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<tr>
<td>max($\Delta \phi$)</td>
<td>2.70°</td>
<td>0.565°</td>
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Vitaly Yakimenko (6/30)
Control system (feedback)

- Multibunch slicing demanded tighter stability in gun and linac phases, beyond normally acceptable slow drifts.
  - Solution: Implement computer feedback loops to compensate
  - Results: Successful runs of multibunch PWFA and DWF experiments
Cameras

PWFA experiment had need for video cameras with higher dynamic range.

• Solutions:
  – User / ATF staff collaborated to select new, higher dynamic range, reputable yet economical camera
  – Users purchased cameras
  – ATF resolved vendor issues, integrated cameras into unified vendor-neutral frame grabber/control system framework

• Results
  – Improved diagnostic for many experiments
  – New cameras now available to all users

"Basler Scout scA1400 gm"
– 1392 x 1040 pixels; 12-bit
– GigE Vision open standard network interface

"Princeton Instruments ProEM"
– 1024 x 1024 pixels; 16-bit
– TCP/IP network interface; proprietary protocol
Control system (Frame grabbers)

Need to upgrade driven by increased sophistication of user experiments, and the need to make video display management more user-friendly

Problems:
• Old systems was 2 single-channel 8-bit analog frame grabbers; in use since late 90s.
• Normal trigger for frame grabbers was e-beam timing; Alternative triggers (CO2 laser, plasma, etc.) required manual cable re-patching
• User experiments called for need to capture multiple images in parallel per beam pulse (e.g., image of high energy slit, plasma, etc.)

Solutions:
• 8 new independent 10-bit analog frame grabbers
• Support for networked cameras (GigE Vision and PVCAM-based)
• New switching system to route triggers (e-beam, CO2, user-defined) to any frame grabber or camera
• Video can be routed to monitors in MCR, EH, CO2, FEL areas
Other New / Improved Capabilities and Plans

• Laser system logging PC collect data locally, but also feeds main control system

• New vacuum system controllers, interlocks
  – Control, readback, and setpoint management

• Extended support for users' RS-232 based devices
  – More channels; handle complicated handshaking correctly

• Future work:
  – Upgrade of the control system main computer
  – Mathematica interface to control system for automated data acquisition
Planned/Funded upgrades

- **X band**

  (delivery: December'10; testing: January; Operations: May'11)

  - support infrastructure at ATF is nearly complete: Modulator, shielding wall penetrations for waveguide, low level RF...
  - Will allow for well characterized properly compressed electron beam.
  - X band power requiring devices can run at ATF:
    - Extreme resolution deflector cavity
    - Breakdown effects on high brightness beam
    - Photoinjector

- **Ti:Sf:**

  (delivery: February; CO2 operations: May)

  - CO2 seed simplification
  - x10 CO2 beam intensity upgrade
  - Plasma diagnostics for Multi-bunch PWFA
X band Layout

Vitaly Yakimenko
X band (progress at SLAC)

- Section with couplers, loads, ... was delivered to ATF in December’09.
- Klystron will go to bake this week
- Bake takes 3 weeks
- RF processing takes about 2 months
- Should be delivered to ATF in December
Motivations for long term facility development

• Ion beams generated by RPA (CO2 laser, experimental stations, space)

• Coherent Compton or FEL with Laser Undulator (CO2 Laser and photo injector)

• PWFA and DWFA with high density microbunched beam (energy upgrade)
Monoenergetic ion beam by Radiation Pressure Acceleration from $\text{H}_2$ gas jet

$$E_{\text{max}} (\text{MeV}) \sim a_0^2$$
**CO2 upgrade path**

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<td>5</td>
<td>5</td>
<td>10&lt;sup&gt;IV&lt;/sup&gt;</td>
<td>25 &lt;sup&gt;V&lt;/sup&gt;</td>
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<tr>
<td>Duration [ps]</td>
<td>2 x 5&lt;sup&gt;I&lt;/sup&gt;</td>
<td>5&lt;sup&gt;II&lt;/sup&gt;</td>
<td>5</td>
<td>2&lt;sup&gt;IV&lt;/sup&gt;</td>
<td>0.5 &lt;sup&gt;V&lt;/sup&gt;</td>
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<td>1</td>
<td>5</td>
<td>50</td>
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<tr>
<td>$a_0$</td>
<td>1.2</td>
<td>1.7</td>
<td>2.2&lt;sup&gt;III&lt;/sup&gt;</td>
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<tr>
<td>$E_p$ [MeV]</td>
<td>1.5</td>
<td></td>
<td>5</td>
<td>25</td>
<td>250</td>
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</table>

I. Laser pulse was split into two due to imperfect amplification spectrum.

II. Isotopic mixture was used to demonstrate single pulse amplification.

III. Improved laser focusing is expected to increase laser intensity.

IV. Ti:Sf seed laser is purchased (Sep. 2010) to shorten CO2 seed to 1 ps. Shorter seed would allow for better laser energy extraction.

V. Additional amplification stage and/or laser pulse plasma chirping/compression need to be developed to reach this stage (not funded).
Coherent Compton or FEL with Laser Undulator

Measured CCD images
Nonlinear and linear x-rays

\[ \frac{N_X}{N_e} \approx 0.35 \text{ in experiments at ATF/ no Coherence} \]

Can the e-beam/laser interaction over few mm lead to electrons bunching and coherent interaction?

X ray FEL in 5mm

C. Pellegrini at SLAC FLS workshop: “yes, but e-beam brightness and lasers are very challenging”
Summary of numbers for LFEL

Electron beam energy

X-ray energy:

3D emittance

Number of x rays per electron

Electron beam current

Laser wavelength:

Laser energy

Laser duration (e2e flattop):

Saturation length

Number of x rays per electron

X ray energy:

\[
\begin{align*}
E_e &= 77.3 \text{ MeV} \\
\varepsilon_{nc} &= 30.7 \text{ nm} \\
I_e &= 1.5 \text{ kA} \\
\lambda_{\text{laser}} &= 10.6 \mu\text{m} \\
E_{\text{laser}} &= 30 \text{ J} \\
\tau_{\text{laser}} &= 30 \text{ ps} \\
L_{\text{sat}}(3\text{mm}) &= 4.8 \text{ mm} \\
\frac{E_e}{E_X(3\text{mm})} \cdot \rho(3\text{mm}) &= 8.6 \\
E_X(3\text{mm}) &= 10 \text{ KeV}
\end{align*}
\]
Resonant wavelength variation

~2% wavelength variation due to change in the laser intensity is not acceptable
One can chirp the laser:

\[ \sim 6\% \text{ laser chirp (0.5 ps BW) will keep wavelength within 0.1\% over the gain length.} \]

Combination of chirping and longitudinal shaping is needed.
ATF Terawatt CO$_2$ Laser Story (past and present)

- 25 MeV Protons
- 250 MeV Protons
- LWFA
- VLA
- High gradient IFEL
- Coherent Compton

- LACARA
- EUV source
- PASER
- HGHG
- STELLA
- Nonlinear Thomson scattering
- Ion and Proton source
- Thomson X-ray source
- IFEL accelerator
- Inverse Cherenkov accelerator
- 25 MeV Protons

1995-2010
Emittance

SASE @1µm

IFEL

ICA

HGHG

Thomson X-ray source

STELLA

Dielectric WFA

VISA

Plasma WFA

Smith Purcell experiment

Micro bunching

Coherent Compton

0.5 µm

1 µm

2 µm

4 µm


Vitaly Yakimenko
Space issue
Example of Bldg. 939
Plans (unfunded)

• Photo injector laser replacement with Ti:Sf based system
  – Simplified maintenance, operations
  – Longitudinal shaping

• Photo injector R&D

• ATF move into new building
  – Reasonable experimental hall
  – Space for CO2 experiments
  – Energy upgrade to ~300 MeV
    • Over-dense regime
    • Reduce relative effects of wake fields (CTR, CSR, ...)

• CO2 power upgrade to 50J/500fs (plasma chirping/optical pumping...)
  – 500MeV protons RPA (Medical, DTRA,...)
  – “High charge” LWFA electrons
## Schedule of this meeting

<table>
<thead>
<tr>
<th>Title</th>
<th>Start</th>
<th>PI</th>
<th>Substitute Institution</th>
<th>Substitute Presenter</th>
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<tr>
<td>Executive session</td>
<td>8:30</td>
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<td>Vitaly Yakimenko</td>
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<tr>
<td>ATF talks</td>
<td>9:00</td>
<td>Vitaly Yakimenko</td>
<td>HEP/BE</td>
<td>Marcus Babzien</td>
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<td>ATF Status and plans</td>
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<td>New Ti:Sf laser</td>
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<td>Vitaly Yakimenko</td>
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<td>Mikhail Polyanskiy</td>
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<td>Vitaly Yakimenko</td>
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<td>Mikhail Polyanskiy</td>
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<td>Monoenergetic ion beam generation from a gas jet</td>
<td>11:10</td>
<td>Zulfikar Najmudin</td>
<td>EU/HEP 25</td>
<td>Igor Pogorelsky</td>
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<td>Waavelength scaling in experiments with foils</td>
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<td>EU/HEP 36</td>
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<td>Studies of post-solitons in laser/plasma interaction</td>
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<td>Zulfikar Najmudin</td>
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<td>Igor Pogorelsky</td>
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<td>Study of hot electron transport and subsequent ion acceleration</td>
<td>12:05</td>
<td>Zulfikar Najmudin</td>
<td>EU/HEP 3</td>
<td>Igor Pogorelsky</td>
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<td>Diagnostic s</td>
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<td>Single shot interferometer</td>
<td>12:15</td>
<td>Gerard Andonian</td>
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<td>Alex Murokh</td>
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<td>Compton</td>
<td>13:45</td>
<td>Massimo Carpinelli</td>
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<td>Beam manipulation/testing</td>
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<td>Dmitri Kayran</td>
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<td>16:45</td>
<td>Alexander Temnykh</td>
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### 10/7/2010

**Executive session**

**Plasma wake field**

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<th>Time</th>
<th>Duration</th>
<th>Title</th>
<th>Presenter</th>
<th>Institution</th>
<th>Status Report</th>
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<td>8:30</td>
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<td>Status of the multi-bunch PWFA</td>
<td>Patric Muggli</td>
<td>USC</td>
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<td>HEP 23</td>
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<td>9:00</td>
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<td>Optical Measurement of Plasma Wave Structure Produced by the Multi-bunch Driven PWFA</td>
<td>Rafal Zgadzaj</td>
<td>UT</td>
<td>status report</td>
<td>HEP 6</td>
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<td>9:35</td>
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<td>Progress toward the Current Filamentation Instability (CFI) experiment</td>
<td>Brian Allen</td>
<td>USC</td>
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**Dielectric wake field**

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<td>DWF as a radiation source</td>
<td>James Rosenzweig</td>
<td>UCLA</td>
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<td>HEP 11</td>
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<td>10:10</td>
<td>0:20</td>
<td>high gradint DWFA with microbunched beam</td>
<td>Alexei Kanareykin</td>
<td>Euclid Techlabs</td>
<td>proposal</td>
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**X band/high gradient**

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<tr>
<td>11:00</td>
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<td>X-band deflector</td>
<td>James Rosenzweig</td>
<td>Radia Beam</td>
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<td>High gradient S-band linac</td>
<td>Alex Murokh</td>
<td>Radia Beam</td>
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<td>Surface wave accelerator and surface Cherenkov radiation source based on SiC</td>
<td>Gennady Shvets</td>
<td>UT</td>
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**Other**

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<td>Experimental Study of Electron-Beam Micro-bunching Dynamics and Shot-Noise Suppression Effect</td>
<td>Avi Gover</td>
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<td>Laser Acceleration in Vacuum</td>
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**Working lunch**

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**Executive session**

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**Adjourn**

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Conclusions (past)

- CO2 laser at TW level with a well characterized single pulse operations.
- Very stable (fraction of a degree over an hour) RF operations
- Diagnostics capability improved

- Mono energetic protons observed from a gas jet
Conclusions (6-12 month plans)

• X band power will be available
  – Highly compressed e-beam
  – Longitudinal e-beam characterization
  – User experiments with X band power...

• Ti:Sf laser system
  – ~5-10 TW CO2 laser beam
  – Plasma diagnostics
Conclusions (1-5 years)

• Space upgrade
  – Better conditions in e-beam experimental hall
  – Experimental hall for laser experiments
  – Experiments with ~50 MeV protons

• CO2 laser upgrade
  – chirping/compression
  – New amplification stage

• e-Beam energy upgrade
  – Blow out regime in multibuch PWFA
  – Overcoming limit of wake fields, space charge...
Thank You