A Compact Wakefield Measurement Facility:
An update
(LCRD 2.33)

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Collaborators

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  - Jonathan Walsh#, Ya-chieh (Jen) Hsin# (students)

- **Argonne National Lab**
  - John Power, Wei Gai, Jim Simpson, Haitao Wang, Glenn Decker#

- **Fermilab**
  - Dave Finley, Harry Carter, Nikolay Solyak

#new members
**Purpose:** A facility for making Wakefield Measurements of NLC structures

**Technique:** Direct Wakefield Measurement

- To find the **longitudinal wake function** measure the change in energy of the witness beam.

- To find the **transverse wake function** measure the deflection of the witness beam.

**Compact:** using ~10 MeV electron beams
How to get high resolution ...

1. High Drive Charge
   \[ \Delta \theta_z(t) = \frac{\gamma}{\gamma + 1} \left( -\frac{eQ_d L_s W_{ll,0}(t)}{E_w} \right) \]

2. Low Witness Energy
   \[ \Delta \theta_y(t) = \frac{\gamma}{\gamma + 1} \left( -\frac{eQ_d L_s W_{\perp,1}(t)}{E_w} \right) \Delta y_d \]

3. Good Angular Measurement Resolution
   - Longitudinal Wake Function per unit length.
   - Transverse Wake Function per unit length.
Prototype version of *compact facility* at the Argonne Wakefield Accelerator

Main Modifications Needed

1. Drive Gun

4 MeV, 0.1 nC Witness Beam

2. Downstream Measurement System

16 MeV, 100 nC Drive beam
First Modification

The Drive Gun

Operating Mode
High Brightness Source

Drive Gun (recently commissioned)
- \( Q_0 \sim 20,000 \) (measured)
- \( E_z \sim 80 \text{ MV/m} @ 12 \text{ MW} \)
- Vacuum \( \sim 4 \times 10^{-10} \text{ Torr} \)

Drive Beam Requirements
- \( \varepsilon_n < 4 \mu \text{m} \)
- \( Q \sim 2 \text{ nC} \)
- \( T \sim 18 \text{ MeV} \)

Source Work
- Simulations (done)
- Beam measurements

1½ Cell 1.3 GHz Gun

I.D. = 6 mm (radius = 3mm)

Beam Envelope

NLC Structure

L = 1 m

1/7/2004

John Power, ALCPG 2004 Winter Workshop, SLAC
Beam Diagnostics Summary
(Recent Work)

- Used a modified "3-screen technique" that includes space charge.
- Emittance was analyzed for two different conditions.

<table>
<thead>
<tr>
<th>Laser spot size (mm)</th>
<th>Gun forward power (mV)</th>
<th>Gun Phase (deg.)</th>
<th>Charge (nC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>200</td>
<td>243</td>
<td>0.4 – 0.6</td>
</tr>
<tr>
<td>1.425</td>
<td>215</td>
<td>230</td>
<td>0.7 – 0.9</td>
</tr>
</tbody>
</table>

*bad bi-directional coupler
*relative phase
*large charge fluctuation
Drive Beam Emittance Measurement

AWA test stand beamline
Typical Drive Beam Spots

Significant dark current makes background subtraction difficult
Fit to data with Trace 3D
(includes space charge, but no slice emittance)

**Fit to Data**

- $q=0.00\text{nC} \rightarrow e\text{RMS}=20\ \text{mm mrad}$
- $q=0.25\text{nC} \rightarrow e\text{RMS}=17\ \text{mm mrad}$
- $q=0.50\text{nC} \rightarrow e\text{RMS}=13\ \text{mm mrad}$
- $q=0.75\text{nC} \rightarrow e\text{RMS}=5\ \text{mm mrad}$
- $q=1.00\text{nC} \rightarrow \text{no fit}$

$e=0$

$E = 6\ \text{MeV}$

$R = 1\ \text{mm}$

*Charge jitter limited resolution of this technique*
Comparison to Parmela Envelope

![Graph showing comparison to Parmela Envelope with Z (cm) on the x-axis and rms_X (mm) and rms_n_emittance (mm-mrad) on the y-axis. The graph includes curves for different energies (6 MeV, 7 MeV, 8 MeV) and markers indicating specific points on the curves.](image-url)
Envelope sensitivity to laser spot uniformity

Fit to LFD230 Envelop
Charge=1nC, Ez=70MV/m, R-spot=1.425mm, Phase_rf=50

[Graph showing envelope sensitivity to laser spot uniformity with labels for hot spot, cold spot, and uniform]
Preliminary emittance estimations

- Trace 3D envelopes in good agreement with data, but does not include slice emittance
  - 5 - 15 µm using TRACE 3D.

- Parmela envelopes in rough agreement with measured data, but a wide range of emittances
  - 2 – 8 µm based on PARMELA
Second Modification

Downstream Measurement System
1. **Pre-align beams** through the NLC structure to the straight-through *Zeroing BPM*

2. **Witness beam leading:** Center Witness beam on *Witness Beam Zeroing BPM* using *H* and *V*

3. **Witness beam trailing:**

   - *W* \( \Pi \): Use *H* to keep witness centered on WB-ZBPM
   - *W* \( \perp \): Use *V* to keep witness centered on WB-ZBPM

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1/7/2004  
John Power,  
ALCPG 2004 Winter Workshop,  
SLAC
Downstream Measurement System Work

- **Zeroth order design beamline (past)**
  - Reported on at last workshop (Cornell) and PAC 2003
  - Longitudinal resolution $\rightarrow$ 2.5 V/pC/m
  - Transverse resolution $\rightarrow$ 0.3 V/pC/m/mm (~equivalent to ASSET).

- **Zeroing BPM (present)**
  - Resolution $\sim$100 $\mu$m (OK, but 10 $\mu$m better!)
  - Hired two students to study & select best technology.

- **More thorough design of beamline (future)**
  - Design & Construction hardware (Magnets, Vacuum Chamber, etc)
**BPM Calibration**

**Instructor:** Glenn Decker (APS)

**Students:** Jon & Jen (U of C)

**RF Signal Generator**
- $f = 2.856$ GHz
- $P = +10$ dBm

**Apparatus for calibrating the BPM**

- Oscilloscope
  - Ch. 1
  - Ch. 2
  - Ch. 3
  - Ch. 4.
  - TOP
  - BOTTOM
  - LEFT
  - RIGHT

- Stripline BPM
- Circulator
- Translation stage
- 50 $\Omega$
- Vertical micrometer
- Horizontal micrometer
BPM Calibration

Oscilloscope
Ch. 1  Ch. 2  Ch. 3  Ch. 4.
TOP  BOTTOM  LEFT  RIGHT

RF Signal Generator
f = 2.856 GHz
P = +10 dBm

50 Ω

BPM

circulator
BPM calibration

SUM = TOP + BOTTOM
DIFF = TOP - BOTTOM

TOP
BOTTOM
SUM
DIFF
DIFF/SUM

micrometer position (1/10th of an inch)
Summary

The AWA facility could be used to build a prototype version of a high resolution wakefield measurement facility.

Done:
1. Zeroth-order design (Longitudinal resolution $\rightarrow 2.5$ V/pC/m, Transverse resolution $\rightarrow 0.3$ V/pC/m/mm).
2. High-brightness beam simulations

In progress:
1. High-brightness drive beam diagnostics
2. Zeroing BPM study, selection, and installation

Future:
1. More thorough design of measurement system
2. Install hardware: 2 BPM’s, 2 magnets, vacuum chamber, etc.