Accelerator Physics Overview

J. Galambos

Accelerator Advisory Committee, May 7-9, 2013
Outline

• 2012-2013 Progress
  • Selected accelerator physics activities
  • Community involvement

• RFQ detuning incident
Longitudinal Twiss Measurement in the Linac (Shishlo)

- Use BPM amplitude signal as a measure of bunch length (strength of induced signal ~ bunch length)

Measured SCL input Twiss below, seems to work!

<table>
<thead>
<tr>
<th>XAL Units</th>
<th>Alpha</th>
<th>Beta</th>
<th>Emittance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>0.21</td>
<td>6.07</td>
<td>0.30*10^{-6}</td>
</tr>
<tr>
<td>Measured</td>
<td>0.25+0.03</td>
<td>10.1 (+4.1,-1.8)</td>
<td>(0.97+0.21)*10^{-6}</td>
</tr>
</tbody>
</table>

Submitted to PRST-AB
SCL RF Setup – Automated!

T. Gorlov

- Process of setting each klystron (1-per-cavity) phase is beam based process – involving scan
  - Original setup took a few days
  - Last 1-2 years reduced to fraction of 1 day
  - Now ~ 30 minutes

Also get more information now during the scans –
  e.g. used in new Twiss measurement method
### Open XAL – Collaboration

#### T. Pelaia, C. Allen

**Primary development at SNS**

<table>
<thead>
<tr>
<th>Target Date</th>
<th>Task</th>
<th>Progress (as of Apr 25, 2013)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 3, 2010</td>
<td>Workshop at SNS</td>
<td></td>
</tr>
<tr>
<td>Oct 31, 2010</td>
<td>Project Creation and Architecture</td>
<td>100%</td>
</tr>
<tr>
<td>Dec 31, 2010</td>
<td>Website Development</td>
<td>100%</td>
</tr>
<tr>
<td>Feb 15, 2011</td>
<td>Application Framework Migration</td>
<td>100%</td>
</tr>
<tr>
<td>Apr 30, 2011</td>
<td>New Online Model Implementation</td>
<td>100%</td>
</tr>
<tr>
<td>Sep 30, 2011</td>
<td>Fix All Compiler Warnings with Strictest Settings</td>
<td>100%</td>
</tr>
<tr>
<td>Feb 28, 2012</td>
<td>JSON Framework Implementation</td>
<td>100%</td>
</tr>
<tr>
<td>Feb 28, 2012</td>
<td>Common Package Migration</td>
<td>100%</td>
</tr>
<tr>
<td>Oct 31, 2012</td>
<td>New Service Implementation</td>
<td>100%</td>
</tr>
<tr>
<td>Dec 13, 2012</td>
<td>Workshop at FRIB</td>
<td></td>
</tr>
<tr>
<td>Dec 31, 2012</td>
<td>Common Services Migration</td>
<td>100%</td>
</tr>
<tr>
<td>Jun 30, 2013</td>
<td>Milestone 1 Tickets</td>
<td>67%</td>
</tr>
<tr>
<td>Dec 31, 2013</td>
<td>Milestone 2 Tickets</td>
<td>5%</td>
</tr>
</tbody>
</table>
Python-ORBIT Development and Support

A. Shishlo, J. Holmes, S. Cousineau

• ORBIT is a high intensity beam simulation code developed at SNS, used around the world (FNAL, CERN, ISIS, J-PARC, GSI, LANL, CSNS, …)
  – Supported by SNS physics group
  – Being ported to a more modern, more easily maintainable structure (python script interface)
  – Background activity for 3-4 years, past year concerted effort, nearing completion
  – Linac simulation supported!

“Joe Physicist” Assessment

<table>
<thead>
<tr>
<th>Level</th>
<th>Comparison with old ORBIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>User only</td>
<td>Easier, more flexible, more powerful</td>
</tr>
<tr>
<td>Python level developer</td>
<td>Same difficulty, more flexible, more powerful</td>
</tr>
<tr>
<td>Core C++ developer</td>
<td>More difficult (more levels of structure)</td>
</tr>
</tbody>
</table>
Emphasize Benchmarks Measured Data

Ring Simulations - Collective Effects:

ORBIT – Measured Profile benchmark – low intensity

ORBIT – Measured Profile benchmark – high intensity

Linac simulations - starting

Horizontal size comparison

Longitudinal size comparison
Ring Injection Stripping: Excited state H⁰

M. Plum

- SNS injection design minimizes impact of excited state losses
  - Large impact on upgrade design
  - But how important is it really – need to measure!

200→400 μg/cm² C foil

0.25 T magnetic field

1→10% H⁰

0% H⁻ (also 1% of beam missing foil) are transported to injection dump

95% have n ≤ 3: decay to the H⁰ GS and are transported to the injection dump

3% have n = 4,5: can Stark strip to H⁺ outside ring acceptance

2% have n > 6: instantaneously Stark strip to H⁺ and are captured into the ring

90→99% H⁺: captured into the ring
**H0* Loss Measurements:**

- Difference between 1\textsuperscript{st} foil pass and subsequent passes = excited state loss
- Measured loss not severe for baseline, or purposefully high H0* loss setups
Nonlinear lattices / Integrable Optics, Gaining Community Attention

V. Danilov, S. Nagaitsev, *PRSTAB* 2010, Selected as one of best papers of 2010

- Avoid resonances – allow large tune spread
- In general these are non-trivial solutions, identified a practical implementation
- Proposed electron beam experiment at FNAL: IOTA
High Power “Look-Aheads” Ongoing

AAC 2012: Resume high power beam studies in the ring

June 2012 – RF supported full pulse

- Setup the RF to support the full pulse length
- Plan to try again May 30-31, aim for 1.1 – 1.2 MW for ~ 1 day
Stripper foil development program

M. Plum, et al.

- Foils are fabricated at ORNL using CVD
  - Testing new lithography patterns to reduce foil shaking and curling
  - Testing boron doping to improve foil conductivity
  - New foils in machine used with about 1 month period

- Simulating with beam the 1.4 MW heat load
  - Modeling (Y. Takeda from KEK)
  - E-beam lab setup

- Concerns
  - Foil lifetime – increasing powers
  - Shaking and curling / wrinkling
Simulated Full Power Foil Heating

M. Plum

- By using “sub-optimal” injection painting we increased the foil traversals to simulate increased foil heating expected at 1.4 MW – for 8 hours

Foil image during test
Beam power is ~850 kW, equivalent heat load for 1.4 MW

Foil image at 850 kW with nominal painting
Laser Stripping Re-Started
(M. Plum’s talk)

AAC 2012: Explore ways of bringing more accelerator science and technology graduate students and post-docs to the SNS.

• Successful HEP accelerator R&D grant through the University of Tennessee
  – S. Cousineau is the PI
  – 3 year, $825 k
  – Post Doc + grad student support

• Demonstrated a 10 ns laser stripping in 2005

• Planning an intermediate 10 μs demonstration
  – Lattice insert for experiment
  – Beam Studies to produce correct optics needed
  – Laser development efforts (e.g. Fabry-Perot light recycling)
Beam Damper System Studies

Z. Xie, C. Deibele

• Damper system may be needed for high intensity applications

• Beam Transfer Function (BTF) measurement
  – Characterize beam response to kick
  – Recently converted to a digital system

\[
\begin{align*}
y & = x - 1 \\
y & = \frac{x_1}{2} \\
y & = x - 1 \\
y & = \frac{x_1}{2}
\end{align*}
\]
Measured BTF Mystery

- Transfer function bifurcation occurs at high intensity
- Not understood

BTF at 500 turns, high intensity
High Intensity Beam Simulations

*(R. Potts, S. Cousineau)* PhD dissertation project

Performing systematic study of beam evolution versus*:  
- Intensity  
- Transverse betatron tune  
- Initial emittance aspect ratio

ORBIT simulation connection with experiment challenging because:
  
- Measurable profiles don’t contain distribution details.  
- Evolution sensitive to precise parameter knowledge.  
- No analytic theory governing distribution evolution.
Interesting space charge phenomena observed at intensities > $1 \times 10^{13}$ ppp.

- Shot to shot variation of transverse profiles (see below).
- Coupling between planes.
- Dynamics sensitive to initial conditions.

Harp shot-to-shot vertical profiles for identical beam configuration
(Space charge studies, March 2013. ~1.3e13 ppp)
Accelerator Community Involvement (2012-2013)  
Physics, Instrumentation, Ion Source

• Workshop / Conference Organization
  • Stockli - Symposium on Negative Ions Beams and Sources 2012, Workshop on Performance Variations of H- Sources
  • Pelaia: Open XAL workshop
  • Galambos: 2013 Accelerator Applications (session organizer), 2012 LINAC SPC, Convener HEP Snowmass 2013 working group on proton machine capabilities, SPC Tech. and components of ADS
  • Cousineau: ICAP IOC, NAPAC SPC,
  • Plum – ICFA HB2012 convener
  • Holmes – USPAS organizing committee, ICFA HB2012 convener, IOC CERN Space Charge 2013.

• Beam Measurements
  • Gas luminescence detector development for ESS
  • ITER radiation detector

• Hosted visitors
  • FNAL (LEBT), FNAL (profiles / emittance), J-PARC (foils), ESS (Instrumentation + physics), U-Md (high intensity modeling), CERN (H- injection)
Accelerator Community Involvement (2012-2013)  
Physics, Instrumentation, Ion Source

• Reviews
  • Aleksandrov: PAC’13 Scientific Program Committee, IFMIF Beam Diagnostics Design Review, FRIB Beam Diagnostics Design Review, FRIB Independent Readiness Review
  • Galambos: ESS TAC5,6 and 7, CSNS TAC, C-ADS TAC, MYRHHHA International Design Review, ESS diagnostic review, ESS Accelerator Physics Review, FNAL PXIE review Project-X MAC, HEP General Accelerator R&D review
  • Plum: J-PARC ATAC, ORNL enriched stage isotope production facility

• Taught courses
  • Stockli: CERN school, Ion Sources

• Committee Membership
  • Cousineau: APS DPB Executive Committee Member at Large, (2010 – 2013), PRST-AB editorial board member (2013 - 2016)
  • Galambos: ANS AAD Executive Committee Member (2013 - 2016)
  • C. Deibele: Editorial board IEEE Microwave Theory & Techniques, IEEE board for PE exams

• Student Mentoring
  • 1 PhD graduated, 3 PhD students ongoing
  • 1 Post-doc
  • 5 Undergrad and high school interns
AP Summary

- Accelerator physics activity still moving forward, even though power ramp-up has stalled
- Important to keep physics staff engaged to enable reaching the short-term 1.4 MW level and longer term 3 MW operation
RFQ Detuning - reprise

• We had 2 earlier RFQ detuning incidents
  – 2003 (cooling) and 2009 (maintenance)
  – Required retuning the RFQ to return to resonance
  – Initiated spare procurement

• There appears to have been another occurrence
  – Systematic reduction of RFQ exit current observed, beginning about 1.5 years ago
  – Comparison of beam current transmission from historical levels showed reduction
  – RFQ Field profile measurements indicate another anomaly
  – Transmission vs. RFQ power also changed from historical measurements
  – But, this time the structure can operate at correct frequency
RFQ Beam Transmission Indicates a Problem

M. Stockli

- Input current measured by collected charge of fully chopped beam at LEBT exit, exit current measured by current monitor
  - Same technique used in 2010
- Systematic reduction in transmission

Source:
RFQ Field Measurement Indicates a Problem

- Clear indication of field tilt from expectation
- At low energy end some non-quadrupole mode?
RFQ Power Scans Indicate a Problem

- We are operating significantly below “transmission saturation” RF power level
  - Resonance control (cooling) cannot support too large an input power
  - Nervousness about too large an increase in power before retune and spare RFQ procurement
RFQ Detuning Summary

- It happened again – we are quite concerned
  - RFQ power archive records indicate that it happened during the 2011 summer outage
- We plan to retune the RFQ this summer
- This incident puts more importance on the spare RFQ (see Y. Kang’s talk)
- Spare RFQ test plans
  - RF test: this summer-fall, see Y. Kang’s talk
  - Beam tests: late 2013, 2014, see S. Aleksandrov’s talk on test stand plans