The ALPHA facility at Indiana University
New Capabilities for
Dose Rate Testing

Indiana University
S. Clark
NSWC Crane

10 May 2011
Strategic Systems

NSWC Crane is the leader in the Navy Strategic Systems community for failure and material analysis of space and high reliability electronics and the integration of Commercial Off-the-Shelf products.

NSWC Crane supports:
• Guidance Systems
• Missile Systems
• Fire Control Systems
• Navigation Systems
• GPS Systems
• Radiation Tolerant Electronics

Thru:
• Design Modeling and Simulation
• Design of Radiation Tolerant Microelectronics
• Design of High-Reliability Microelectronics
• Application and Integration of Commercial Off-the-Shelf Technology
• Systems Engineering
• Inertial Sensor Expertise
• Satellite and Missile Electronics Radiation Testing
• Failure and Material Analysis
• Component Reliability and Quality Analysis
• Component Destructive Physical Analysis
• GPS Receiver Integration

NSWC Crane is assigned as the:
• Leader in Radiation Tolerant Electronics
• Leader in Commercial Off-the-Shelf Technology
• "911" Engineering Activity for Strategic Systems Program Office
NSWC Crane’s Strategic Mission

support testing of electronics in various radiation environments – both manmade and natural.

Natural Environments

Solar Protons
Galactic Cosmic Rays (Neutrons)

Man Made Environments

Neutrons
Gamma Rays
## Current Crane Capabilities

<table>
<thead>
<tr>
<th>Capabilities</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dose Rate (Rad/s)</td>
<td>$1 \times 10^{12}$</td>
</tr>
<tr>
<td>Pulse Width (narrow)</td>
<td>10-50 nS</td>
</tr>
<tr>
<td>Pulse Width (wide)</td>
<td>1-5 uS</td>
</tr>
<tr>
<td>Beam Spot Size</td>
<td>40 mm</td>
</tr>
<tr>
<td>Pulse Rep Rate</td>
<td>10 shots/sec</td>
</tr>
<tr>
<td>Energy</td>
<td>40-60 meV</td>
</tr>
</tbody>
</table>

*Most powerful electron accelerator in the Department of Defense*

**Moore’s Law**

- **1989** - 20 MHz 80386
- **2007** - 3.7 GHz Pentium

Linac – 1.3 GHz Klystrons
Overview

• Goals
  – Eliminate RF Modulation
  – Provide higher dose rates for survivability testing.
  – Provide higher fidelity test environment
    • More uniform beam
    • Larger area beams
    • More hospitable test environment
    • Low electronic noise

• Solution
  – Couple a linac with a electron storage ring
    • Long pulse mode (up to 4 μS) – Debunching
    • Short Pulse mode (0.1-50 nS) – High dose rate (＞10^{12} Rad/s)
  – Use non linear optics to shape beam
    • Eliminate masking and associated secondary scattering
    • More efficient use of beam
Long Pulse Operation

<table>
<thead>
<tr>
<th>Requirement</th>
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<tbody>
<tr>
<td>Instantaneous Dose Rate</td>
<td>$0.4 \times 10^{10}$ Rad/s</td>
</tr>
<tr>
<td>Beam Size</td>
<td>$6.45$ cm$^2$</td>
</tr>
<tr>
<td>Pulse Length</td>
<td>$4$ $\mu$S</td>
</tr>
<tr>
<td>Repetition Rate</td>
<td>$10$ Hz</td>
</tr>
<tr>
<td>LINAC Current</td>
<td>$0.068$ A</td>
</tr>
</tbody>
</table>
Debunching

Injection

Extraction

Alpha Injection Line Measurement

\( \frac{dI}{dt} \)
Short Pulse Operation

**Requirement**

- Instantaneous Dose Rate: $1 \times 10^{12}$ Rad/s
- Beam Size: 16 cm$^2$
- Pulse Length: 25 nS
- Repetition Rate: 0.0016 Hz (10 min period)
- Stored Charge: 1000 nC
Dose Rate

Long Pulse Operation

\[
\text{Dose Rate} = \left(3.73 \times 10^{11} \frac{\text{Rad}}{\text{s}} \frac{\text{cm}^2}{\text{amp}}\right) \frac{I}{A}
\]

Short Pulse Operation

\[
\text{Dose Rate} = \left(3.73 \times 10^{11} \frac{\text{Rad}}{\text{s}} \frac{\text{cm}^2 \cdot \text{ns}}{\text{nC}}\right) \frac{Q}{A \cdot T}
\]

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<th>Long Pulse Operation</th>
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<td>Instantaneous Dose Rate</td>
<td>0.4 (10^{10}) Rad/s</td>
<td>1 (10^{12}) Rad/s</td>
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<tr>
<td>Beam Size</td>
<td>6.45 cm(^2)</td>
<td>16 cm(^2)</td>
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<td>Pulse Length</td>
<td>4 (\mu)S</td>
<td>25 nS</td>
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10 May 2011
Beam Delivery
Non-linear Beam Spreading

Octopole Magnet for nonlinear beam spreading
Beam size can be adjusted in x and y direction using quadrupole magnets.

Matching the Device

Crane’s ELDRS Test Chip
Test Area

Timeline for Completion

• June 2011 – Circulating beam in ring
• Oct 2011 – Extraction of Stored beam
• Dec 2011 – Phase II Linac installed
• Jan-Jun 2012 – Commissioning and validation studies
• July 2012 – Ready for testing programs
Conclusions

• Alpha delivers new capabilities for dose rate testing
  – Reduced RF structure (>10%)
  – High transient dose rates ($10^{12}$ rad/s @25 nS and 16 cm$^2$)
    • Note $D \propto \frac{1}{A \ast t}$
  – Clean test environment
    • No masking
    • Reduced secondary scattering
Tuesday, May 10

8:00 – 8:30  Continental Breakfast
8:30 – 8:40  Introductory Remarks – Paul Sokol
8:40 – 8:45  Welcoming Remarks – Sarita Soni (Vice Provost for Research – Indiana University Bloomington, Associate Vice President – Indiana University)
8:45 – 9:00  Opening Comments – Steve Clark
9:00 – 9:45  Description of ALPHA – Paul Sokol

9:45 – 10:15  Break
10:15 – 11:00  Tour of ALPHA
11:00 – 11:20  Radiation Safety – Andrew Edwards
11:20 – 11:40  Device Test Area – Chandra Romel
11:40 – 12:15  Discussion

12:15 – 1:30  LUNCH
1:30 – 2:15  Beam Characterization – Patrick McChesney
2:15 – 2:35  Controls and Interfaces – Max Ellis
2:35 – 2:45  Discussion

2:45 – 3:15  Break
3:35 – 4:15  User Needs I
4:15 – 5:00  Panel Discussion – Paul Sokol
5:00 – 6:00  Travel to Stone Age Institute

6:00 – 7:00  Reception
7:00 – 9:00  Dinner
**Wednesday, May 11**

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<th>Time</th>
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<tr>
<td>8:00 – 8:30</td>
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<tr>
<td>8:30 – 9:15</td>
<td>User Needs II</td>
</tr>
<tr>
<td>9:15 – 10:00</td>
<td>User Needs III</td>
</tr>
<tr>
<td><strong>10:00 – 10:30</strong></td>
<td><strong>Break</strong></td>
</tr>
<tr>
<td>10:30 – 11:15</td>
<td>Correlation Studies – Steve Clark</td>
</tr>
<tr>
<td>11:15 – 12:00</td>
<td>Meeting Summary and Action Items</td>
</tr>
<tr>
<td><strong>12:00</strong></td>
<td>Meeting End</td>
</tr>
</tbody>
</table>