Superconducting Deflecting Cavities for the Electron-Ion Collider and Large Hadron Collider

Dr. Terry Grimm
President & Senior Scientist

Jerry Hollister
Chief Operating Officer

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Outline

• Company Details & Leadership
• Superconducting Electron Linacs
• Applications of Superconducting Electron Linacs
• Successful Commercialization of DOE SBIRs
• Superconducting Deflecting Cavity for EIC
• Summary
Niowave, Inc.

- Privately Owned
- 60,000 square feet
  - Engineering & design
  - Machine shop
  - Fabrication & welding
  - Chemistry facility
  - Class 100 Cleanroom
  - Cryogenic test lab
  - Accelerator test facility
    - 14,000 SF High Bay
    - 2.5 MW power
    - 4 K cryoplant

Lansing, Michigan Headquarters
Dr. Terry Grimm  
President & Senior Scientist  
- PhD from Massachusetts Institute of Technology  
- 20 Years experience in Department of Energy  
  - Superconducting Super-Collider  
  - National Superconducting Cyclotron Laboratory at MSU  
  - Numerous contracts with DOE at Niowave

Jerry Hollister  
Chief Operating Officer  
- Bachelors in Engineering from University of Michigan  
- Active duty Naval Officer for 6 years  
- Warranted Contracting Officer for US Navy  
- Current Trustee at Lansing Community College

Mark Sinila  
Chief Financial Officer  
- Bachelors in Business Administration from Albion College Honors Program  
- 20 years experience in business administration  
- Prior CFO for multi-state manufacturer
Superconducting Electron Linacs

**Turn-key Systems**

- Superconducting Linac
- Helium Cryoplant
- Microwave Power
- Target / User Facility
- Licensing

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Electron Beam Energy</td>
<td>0.5 – 50 MeV</td>
</tr>
<tr>
<td>Electron Beam Power</td>
<td>1 W – 1 MW</td>
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<tr>
<td>Electron Bunch Length</td>
<td>~50 ps</td>
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</table>
Superconducting Test Facility

UV Drive Laser Room
Radiation Monitoring
Cryogenic Setup
RF Equipment
July 3, 2012 Dedication
Niowave Test Facility

Dedication Ceremony
July 3, 2012
Superconducting Linacs

• NPS-Niowave SRF Injector Program
  – First superconducting linac designed, fabricated and tested entirely within industry
  – First delivered and operational SRF beam source at a US Navy facility
  – Second generation linac produced beam less than 2 years from first generation

Niowave Systems for Superconducting Electron Linacs

• Electron Guns & Injectors

• Niobium (In Stock)

• 4 K Cryogenic Systems

• Niobium Superconducting Cavities
Niowave produces superconducting cavities at a broad range of frequencies and geometries, and will customize to meet specific applications.

- Elliptical cavities
- Quarter-wave cavities
- Deflecting structures
- Single and multi-spoke cavities

Cavity frequencies:
- 28 MHz to 9.5 GHz
- 1.3 GHz 9-cell cavities for ILC
- 700 MHz Multi-Spoke for Electron Linacs
- 56 MHz Quarter-Wave Resonator for RHIC
- 400 MHz Deflecting Cavity for the LHC
Commercial Applications of Superconducting Electron Linacs

• Radioisotope production
  – Medical and Industrial

• Free electron lasers
  – Defense, Medical and Industrial

• X-ray sources
  – Defense, Medical and Industrial

• Large accelerators
  – Current DOE projects: Brookhaven, Fermi, Jefferson Lab, Large Hadron Collider
  – Future: FRIB, eRHIC, Project-X, ILC & many more
## Commercialization of SBIRs at Niowave

### DOE Office

<table>
<thead>
<tr>
<th>DOE Office</th>
<th>Phase I Selections</th>
<th>Phase II Selections</th>
<th>Phase III Commercialization to date</th>
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<tbody>
<tr>
<td>Nuclear Physics</td>
<td>6</td>
<td>5</td>
<td>$11,754 K</td>
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<tr>
<td>Basic Energy Sciences</td>
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<td>3</td>
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<tr>
<td>High Energy Physics</td>
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<td>$399 K</td>
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<td>Other</td>
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<td>$0</td>
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<td><strong>18</strong></td>
<td><strong>9</strong></td>
<td><strong>$12,509 K</strong></td>
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112 MHz electron gun

- First PhII SBIR for Niowave, 2008
- By the Office of Nuclear Physics
- Collaboration with BNL (Ilan Ben-Zvi)
- Has led to ($10.7 M in contracts to date (DOE, DOD, universities)

e-source for Coherent Electron Cooling at RHIC

Univ. of Wisconsin FEL electron gun

Navy SRF electron guns
Spoke cavity for electrons

- PhII SBIR for Niowave, 2009
- By the Office of Nuclear Physics
- Collaboration with Old Dominion University (Jean Delayen)
- Niowave now building spokes for Navy and isotope production linacs ($1 M in contracts to date)

700 MHz Double Spoke for Joint Technology Office (DOD)

Linear accelerator for Medical Isotope Production (SBIR PhI)
Crab Cavity for the LHC

- PhII SBIR for Niowave, 2010
- By the Office of High Energy Physics
- Collaboration with Old Dominion University (Jean Delayen)
- Niowave now building three LHC crab cavity designs

- 4-bar Crab for LHC (Daresbury)
- Quarter-Wave Crab for LHC (BNL)
- 499 MHz Deflecting Cavity (ODU/Niowave PhI STTR, then built at JLab)
A proposed electron-ion collider at Jlab will use the 12 GeV electron beam from CEBAF and inject it into collider rings where it would be brought to collide with a high-energy proton beam.

Reaching the luminosity of the designed machine will require crab cavities to collide the beams head-on while preserving the crossing angle at the interaction point.
The SRF Crab Cavity designed and built by the ODU-Niowave collaboration in this DOE STTR uses strong transverse electric fields to provide a linear deflection of the particle beam.
The 750 MHz crab cavity has now been tested in a vertical test cryostat at Niowave. The test setup is as shown at left.
750 MHz Crab Cavity Test

liquid He supply

cavity test Dewar

liquid nitrogen supply (to thermal shield)

RF control/measurement station

initial cooldown
The 750 MHz crab cavity reached an estimated maximum deflecting voltage >0.6 MV.
Summary

• Niowave supplies full 4K superconducting electron linacs for numerous commercial applications
  – Radioisotope Production
  – Free Electron Lasers
  – X-Rays

• These commercial applications are a direct result of the SBIR program
  – DOE Lab collaborations (intellectual support)
  – R&D funding