High-Power Superconducting Electron Linacs for Commercial Applications

Chase Boulware, John Diemer, Amanda Grimm, Rob King, Bill Peters, Mike Zamiara, Terry Grimm, and the rest of the team at Niowave, Inc.

North American Particle Accelerator Conference
September 2019
Lansing, Michigan, USA
High-Power SRF Linacs for Commercial Applications

• Radioisotope production with high-power electron beams
  • Isotope production targets
  • Radiochemical separation techniques

• Commercial superconducting accelerator technology
  • Continuous-wave electron guns
  • Liquid helium refrigerators
  • Microwave sources
  • SRF cavities and cryomodules
  • Recirculating beamline designs
Radioisotope Production with High-Power Electron Beams

Superconducting Electron Linac

Isotope Production Target Station

Radiochemistry and Target Fabrication
Niowave manufactures radioisotopes from radium and uranium

- Uses a superconducting electron linear accelerator without the need for a nuclear reactor

### Radium targets (Ra-226)

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<tbody>
<tr>
<td></td>
<td>Ac-225</td>
<td>10 d</td>
</tr>
<tr>
<td></td>
<td>Rn-222</td>
<td>3.8 d</td>
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<tr>
<td></td>
<td>Po-210</td>
<td>138 d</td>
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<td></td>
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<tr>
<td>α emitters</td>
<td>Bi-210</td>
<td>5.0 d</td>
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<tr>
<td></td>
<td>Bi-213</td>
<td>46 m</td>
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<tr>
<td></td>
<td>Bi-214</td>
<td>20 m</td>
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<tr>
<td></td>
<td>Pb-214</td>
<td>27 m</td>
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**Available in 2021**

### Uranium targets (U-235, U-238)

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<tbody>
<tr>
<td></td>
<td>Mo-99</td>
<td>Pr-143</td>
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<tr>
<td></td>
<td>Sr-89</td>
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<td>Nd-147</td>
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<td></td>
<td>Te-127</td>
<td>Pm-149</td>
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<td></td>
<td>I-131</td>
<td>many more</td>
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<td>Xe-133</td>
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**Available in 2021**
Isotope Production Targets

U₃O₈ fuel rods interchangeable with Ra(NO₃)₂ solution
Radiochemical Separations

Separation facilities include a closed-loop uranium fuel cycle. Radioisotopes are separated and the uranium is converted back into fuel pellets. (See WEPLM20 by Bill Peters et al. for more details)
In this design, a magnetic arc (at left) brings the beam through the accelerator a second time, reducing costs for the cryomodule and refrigerator.

more details in TUPLH03 (Robert Hipple et al.)
Thermionic Gun and DBA [1]

- thermionic cathode takes advantage of high-duty cycle SRF operation (10%-100%)
- electron bunches from the cathode are shortened by gating fields (DC, fundamental RF, harmonic RF) at the cathode

Image of the beam at the selection aperture where the dispersion is maximal.
Thermionic Gun and DBA [2]

- bunches are further filtered in a solenoid-based double-bend achromat
- more details in TUPLH03 (Robert Hipple et al.) on the interesting issues involved in using solenoids to do this
Helium Refrigerator/Cryocooler Systems

- 51 W and 114 W helium refrigerators in operation
- Developed with Linde – Collins cycle, with robust reciprocating piston expander
- Vacuum insulated, nitrogen shielded, low-loss cryolines
- Modular cryolines allow quick switch between linac tests
- Long term operation ready:
  - 5000 hr. major maintenance interval
  - No warmup for short term maintenance
Microwave Power

- Solid-state supplies to 5 kW
- Tetrode amplifier to 60 kW
- Magnetrons >100 kW
- Klystrons to >1 MW

see WEPLM58 (Mike Neubauer et al., Muons, Inc.)
Niowave started out building cavities and cryomodules for this community, both through direct contracts and collaborative SBIR/STTR projects.
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Two-pass Accelerator Design

Superconducting Electron Linac

to/from Helium Cryoplant

from Microwave Power

Electron Source

High-power Electron Beam

more details in TUPLH03 (Robert Hipple et al.)

In this design, a magnetic arc (at left) brings the beam through the accelerator a second time, reducing costs for the cryomodule and refrigerator.
Isotope Production

Successfully operational fully coupled system:

- Superconducting linac coupled to UTA
- Neutron production verified and validated
- $\alpha$ and $\beta$ emitters produced
Conclusions

- As the cost of superconducting RF accelerators continue to come down, commercial applications are increasingly attractive.
- Niowave, Inc. is focused on using SRF electron machines to drive radioisotope production targets and make beta and alpha emitters for medicine.
- **WE ARE HIRING FOR A VARIETY OF TECHNICAL AND MANAGEMENT POSITIONS.**

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