Rare Isotope Accelerator (RIA)
Cryomodules

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March 2005
Outline

- Rare Isotope Accelerator (RIA) specifications
- Comparison between RIA and ERL’s
- RIA cavity designs
- RIA cryomodule designs
  - Elliptical cavity, coupler and tuner
  - Superconducting solenoids and quads
  - Construction and test results
- 805 MHz tetrode amplifier
- Summary
RIA Specs

• Heavy ion linac (protons through uranium)
  – Beam energy greater than 400 MeV/u (v/c=0.72)
  – Beam power up to 400 kW (target limited/radiation)

• Continuous wave
  – Due to current limitations in ion source
  – $^{238}$U$^{88,89,90+}$ 0.37 mA at end of linac

• 1400 MV superconducting linac
  – v/c=0.025-0.72
  – Quarter, half-wave and elliptical cavities
Comparison between RIA and ERL’s

• Similar
  – CW (tuner, lower peak fields, no dynamic Lorentz)
  – High loaded-Q (microphonics, power couplers, amplifiers)

• Different
  – Beam break up due to regenerative high current
    • HOM damping
  – Beam velocity
    • RIA longitudinal beam break up
    • LLRF vector sum control of energy gain
  – RF frequency
    • RIA 805 MHz based on SNS and longitudinal acceptance
RIA SRF Cavities

Legnaro

MSU

$\beta_{\text{opt}} = 0.041$

80.5 MHz

MSU

$\beta_{\text{opt}} = 0.085$

80.5 MHz

MSU

$\beta_{\text{opt}} = 0.285$

322 MHz

MSU/JLAB

$\beta_{\text{opt}} = 0.49$

805 MHz

SNS

$\beta_{\text{opt}} = 0.63$

805 MHz

SNS

$\beta_{\text{opt}} = 0.83$

805 MHz
Prototype $\beta=0.47$ Cryomodule

- LN2 Supply/Return
- Sensor & Instrumentation Port
- Helium Dewar
- Helium Supply
- Support Link
- Outer Magnetic Shield
- Thermal Intercept Shield
- Inner Magnetic Shield
- Alignment Viewport
- Titanium Alignment Rails
- Beta - 0.47
- Superconducting Cavity
- Cavity Tuner
  - Mechanical - Slow
  - Piezoelectric - Fast
- Fundamental Power Coupler & Moveable Transmission Line Transformer

12 inches
30 cm
$\beta = 0.47$ Tuner-Cavity-Power Coupler

Tuner

He Vessel

Power Coupler
\[ \beta = 0.47 \text{ Module Assembly} \]
$\beta = 0.47$ Module Assembly
$\beta=0.47$ Module Assembly
β=0.47 Module Assembly (Feb 04)
**Experimental Results**

<table>
<thead>
<tr>
<th></th>
<th>Cavity #1</th>
<th>Cavity #2</th>
<th>Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Q_{ext, \text{fixed}}$</td>
<td>$1.4 \times 10^7$</td>
<td>$1.3 \times 10^7$</td>
<td>$2 \times 10^7$</td>
</tr>
<tr>
<td>$Q_{ext, \text{transformer}}$</td>
<td>$6 \times 10^4$ - $6 \times 10^9$</td>
<td></td>
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<tr>
<td>df/dp (kHz/torr)</td>
<td>0.36</td>
<td>0.46</td>
<td></td>
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<tr>
<td>Lorentz</td>
<td>-16</td>
<td>-14</td>
<td></td>
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<tr>
<td>(2 K, Hz/(MV/m)^2)</td>
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**Static Heat Leak**
- 10-11 W @ 2 K
- 9 W @ 4.3 K
(includes LHe reservoir)

**Design**
- 4-Cavity cryomodule: 15 W
- 2-Cavity prototype: 9 W

**RIA Design Gradients**
- $E_a = 10$ MV/m
- $E_p = 32.5$ MV/m
- $B_p = 64.2$ mT
- $Q_o = 7 \times 10^9$
- $P_o = 21.6$ W

**RF Measurements on the $\beta=0.47$ Cavities at 2 K after RF processing.**
External/room temperature tuner

Coarse Tuner Exercises on Cavity #2 at 4.22K

- Expanding Cavity
- Compressing Cavity

\[ f_0 = 805.585 \text{ MHz} \]

Piezo Tuner Measurements on Cavity #2 at 4.20K

- First Cycle
- Second Cycle

\[ f_0 = 805.554 \text{ MHz} \]

Coarse tuner \(\sim 1\) MHz

Fine tuner \(\sim 10\) kHz

90 µm piezoelectric (PI)
SC Focusing Elements

Solenoid
9 Telsa
Bore: 4.0 cm
Effective Length: 10 cm
w/ 0.1 kG-m dipole
Shielding: Active,
Niobium, Cryoperm®10

Quadrupole
31 T/m
Bore: 4.0 cm
Effective Length: 5 cm
Built at MSU
Shielding: Iron,
Cryoperm®10
805MHz 10kW Amplifier

- THALES TH382 air-cooled vacuum tetrode w/ a TH18482 cavity
Summary

• Rare Isotope Accelerator (RIA) R&D deals with many of the same issues as ERLs
  – CW
    • Cryomodule designs
    • External tuners (no dynamic Lorentz detuning)
  – High loaded-Q
    • Low power amplifiers (~10 kW)
    • Power couplers
    • Microphonics control (more tomorrow)
  – Focusing elements (solenoid and quadrupole)