RF Power Upgrade for CEBAF at the Jefferson Laboratory

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CEBAF (circa 2010)
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Upgrade halls

Upgrade existing arc
New ‘arc 10’

5 new zones

Double capacity of CHL

5 new zones

5 new zones

Upgrade existing arc

Injector

Central Helium Liquifier (Refrigeration)

Existing RF ‘zones’ (20)

Existing RF ‘zones’ (20)

Hall A

Hall B

Hall C

6 GeV
Upgrade halls
Upgrade existing arc
New ‘arc 10’

6 GeV → 12 GeV

Hall A
Hall B
Hall C

CEBAF (circa 2013)

Central Helium Liquifier (Refrigeration)

Hall D + new beam transport

Hall D

Upgrade existing arc

Double capacity of CHL

Existing RF ‘zones’ (20)

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Major RF changes

- Add ten ‘C100’ cryomodules (8 x 7 cell cavities, 100 MeV acceleration per cryomodule)
- Ten new RF systems
  - Includes new designs for high power and low level elements
  - New high power RF source needed to provide 13kW CW to each cavity @ 1.497Ghz
  - New high voltage DC power supplies
  - Waveguide components (isolators, couplers, tuners, HOM filters… mostly new designs)
  - Mechanical assemblies, water manifolds, etc.
Tube or solid state?

Solid state:
- Cost of development? Size?
- Transistors go obsolete quickly, drop in replacements unlikely.

IOT:
- Better efficiency than a klystron, but lower gain therefore a more expensive pre-amp needed.
- Reliability of non-UHF IOT?
- Not built at 1.5GHz, limited history other than UHF
- Cost of IOT higher than klystron

Klystron:
- Current 5kW design reliable (average >150k hours as of 2008)
- Common design elements (same gun), backwards compatibility of power supplies (with slight modification)
  - Filament and Mod Anode power supplies
How many sources of RF?

1 per cavity  
(current system)  
Minimum impact of failures

1 per zone/linac  
Larger impact  
High power splitters  
Amplitude and phase regulated to high precision.

Additional controls and high power modulator found to be more $$$ than individual RF sources.
RF System overview

- Drive From LLRF
- To LLRF
- Dual Coupler
- Load
- Detector
- Reflected Coupler
- Transition
- Klystron
- Driver
- Driver PS
- Filament PS
- Mod Anode PS
- Instrumentation
- To Control System
- RF Out to SC cavity
- HPA

- HV DC (-14.5 kV)
- Prime Power 480/120 VAC
- Solenoid Power
- LCW (cooling)
Challenges

- New equipment must fit into existing space
- CEBAF was originally conceived as a 4 pass/25 zone per linac machine at 4GeV
- Built as a 5 pass/20 zone per linac machine to save money
- Linac buildings and tunnel were built for 25 zones
- Upgrade will fill empty slots

- New RF must fit the same footprint
- Larger klystrons, larger DC power supply, …
Planned layout

Control racks, PSU’s…

Manifolds

Klystrons

Waveguide components

Cathode power supply

1 zone
Auxiliary power supplies
# Klystron Requirements

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Old req</th>
<th>New req</th>
<th>Actual value</th>
<th>Units</th>
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<tbody>
<tr>
<td>Power</td>
<td>5 &amp; 8</td>
<td>13</td>
<td>13</td>
<td>KW</td>
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<tr>
<td>Center frequency</td>
<td>1497</td>
<td>1497</td>
<td>MHz</td>
<td></td>
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<tr>
<td>Bandwidth, -1dB</td>
<td>5</td>
<td>5</td>
<td>MHz</td>
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<tr>
<td>Bandwidth, -3 dB</td>
<td>6</td>
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<tr>
<td>0.5 dB incremental gain at</td>
<td>4</td>
<td>10</td>
<td>kW</td>
<td></td>
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<tr>
<td>Efficiency (at rated power)</td>
<td>32</td>
<td>&gt;50</td>
<td>50.9</td>
<td>%</td>
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<tr>
<td>Gain</td>
<td>38</td>
<td>&gt;42</td>
<td>dB</td>
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<td>Harmonics</td>
<td>-20</td>
<td>-20</td>
<td>dBC</td>
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<tr>
<td>Beam voltage</td>
<td>11.6</td>
<td>&lt;16</td>
<td>14.5</td>
<td>kV DC</td>
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<td>Heater voltage</td>
<td>7.3</td>
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<td>7.0</td>
<td>V DC</td>
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<tr>
<td>Modulating anode</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
<td></td>
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<tr>
<td>Isolated collector</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Cavities</td>
<td>4</td>
<td>5</td>
<td></td>
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<tr>
<td>Focus magnet</td>
<td>PM</td>
<td>EM</td>
<td>873</td>
<td>Watts</td>
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</tbody>
</table>
225kW DC power supply

- Used to power klystron cathode
- Resonant mode switcher
- 4 separate supplies, each powering 2 klystrons
  - One can trip, remainder stay on
- Voltage adjustable to -15kV
  @ 3.75A (15A total)
- Supply has origins in electrostatic precipitators, 1000+ units in the field
- Low stored energy
- Quick turn off in event of arc
- No crowbar required
- Good diagnostics
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RF Schedule

- 6 month down
- 12 month down

installation
commissioning with cryomodule (during downs)

12GeV
Current status (as of March 2011...)

- First article Klystron in house and being tested
- First article cathode power supply in house and installed
- Isolators all in house and awaiting installation
- Waveguide contract awarded, first delivery in April
- HOM filter first article due in June
- Mechanical assemblies all in house, awaiting installation
- Solenoid power supply first article due late March
- Filament PSU’s, Mod anode PSU’s tested and awaiting installation
- Interface boards ordered, awaiting delivery
- Most cables and connectors ordered, awaiting delivery