The R&D on TEM-type SRF cavities for high-current applications at IHEP

Feisi He

On behalf of colleagues in IHEP SRF group
Institute of High Energy Physics (IHEP)
Outline

- Background
  - Spoke cavities for CADS project
  - QWR for HEPS project
- Fabrication and quality control
- Post processing
- Vertical test statistics
- Operation with beam
Spoke cavities for CADS linac

- IHEP is in charge of the CADS injector-I linac (14 spoke012 cavities), and the CM4 of the main linac (6 spoke021 cavities)
Spoke cavities for CADS linac (2)

<table>
<thead>
<tr>
<th></th>
<th>Spoke 012</th>
<th>Spoke 021</th>
<th>Spoke 040</th>
<th>Spoke 024</th>
<th>HWR 325</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta_0$</td>
<td>0.14</td>
<td>0.24</td>
<td>0.46</td>
<td>0.24</td>
<td>0.14</td>
</tr>
<tr>
<td>$E_p/E_{acc}$</td>
<td>5.0</td>
<td>4.4</td>
<td>3.9</td>
<td>4.0</td>
<td>4.6</td>
</tr>
<tr>
<td>$B_p/E_{acc}$</td>
<td>6.9</td>
<td>9.4</td>
<td>9.2</td>
<td>6.4</td>
<td>4.8</td>
</tr>
<tr>
<td>$G-\Omega$</td>
<td>60</td>
<td>71</td>
<td>104</td>
<td>81</td>
<td>73</td>
</tr>
<tr>
<td>$R/Q-\Omega$</td>
<td>150</td>
<td>191</td>
<td>265</td>
<td>206</td>
<td>197</td>
</tr>
</tbody>
</table>

Note: $E_{acc}$ normalized with $\beta_0 \lambda$;
QWR cavity for HEPS project

- 166MHz is chosen due to on-axis beam accumulation
- Challenges: Reasonable size & HOM damping
QWR cavity for HEPS project (2)

Two-step approaches:
1. Proof-of-Principle (PoP) cavity: Production technics, surface treatment
2. Prototype cavity: including higher order mode coupler/absorber

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Design</th>
<th>Nominal</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF frequency</td>
<td>166.6 MHz</td>
<td></td>
</tr>
<tr>
<td>Operating temperature</td>
<td>4.2 K</td>
<td></td>
</tr>
<tr>
<td>$R_{sh}/Q_0 (=V^2/P_c)$</td>
<td>136 $\Omega$</td>
<td></td>
</tr>
<tr>
<td>$G (=R_s\cdot Q_0)$</td>
<td>54.8 $\Omega$</td>
<td></td>
</tr>
<tr>
<td>RF voltage [MV]</td>
<td>1.5</td>
<td>1.2</td>
</tr>
<tr>
<td>Eacc [MV/m]</td>
<td>14.5</td>
<td>11.5</td>
</tr>
<tr>
<td>Epeak at $V_c=1.5$MV [MV/m]</td>
<td>42</td>
<td>34</td>
</tr>
<tr>
<td>Bpeak at $V_c=1.5$MV [mT]</td>
<td>64</td>
<td>51</td>
</tr>
</tbody>
</table>
Fabrication of IHEP ADS spoke cavities

**Design** → **Fabrication** → **Post processing** → **Assembly**

- **LHe vessel**
- **Single cavity test**

**Material**
- Certification from vendor
- Eye inspection

**Technology**
- Defect inspection and grinding before final EBW
- Deep drawing, annealing, machining, frequency control, grinding, EBW

**Quality control**
Surface quality control

- Before final EBW it is the last chance to get easy access to the cavity inner surface
- Defect, e.g. pits in diameter 0.1mm, could be addressed by eye inspection. Sometimes magnifier or very light BCP helps to find defects.
Frequency control

- Frequency tuning is typically done by stacking parts together before EBW, and trim the cylindrical part after frequency measurement.

Reference [18]
HEPS QWR Cavity production

Nb sheet (RRR>300)  Deep drawing  Cavity

HPR port plate

Port flanges

Outer cylinder
Post processing of Spoke cavities

- BCP in Ningxia OTIC; re-HPR and clean assembly in IHEP
Post processing of QWR cavity

BCP

Annealing

Leak check

Frequency tuning

HPR

Vacuum assembly

Baking

SRF2017, July 19th, 2017, Lanzhou, China
VT results of the spoke012 cavities

- MP conditioned in 1 hour with variable coupler
- $E_{acc}$ increased by 2 MV/m with better cooling
- 120C baking increases $Q_0$ by about 50-100%
- At 2K, $Q_0$ is 6 times higher, $B_p \sim 125$ mT achieved.

Spoke012 4.2K VT, Designed $Q_0 = 5 \times 10^6$ @ $E_{peak} = 31.5$ MV/m

Spoke012 <4K VT results
Spoke021 testing results

- MP conditioned in 1 hour
- Design target consistently exceeded
- Bp of 120mT and Rres of 7nΩ achieved at 2K
QWR VT result

Max $E_{\text{peak}}$ reached: 86 MV/m
Max $B_{\text{peak}}$ reached: 131 mT
Residual resistance: 2.3 nΩ

![Diagram of QWR VT result with graphs showing Q0 at 2K and Q0 at 4.2K]
Spoke cavity conditioning and operation

- Cavity conditioning at 4K typically takes 1-2 days
- Cavity was conditioned to 8MV/m before beam operation (FE for cav 1-4#, administrative for Cav5-14#)
- On CW beam operation of 2mA@10MeV mode, average cavity gradient is 6MV/m, i.e. $E_p \sim 27$ MV/m
Thanks for your attention!