Progresses on China ADS Superconducting Cavities

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Outline

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2. Spoke012 cavity
3. Spoke021 cavity
4. Spoke040 cavity
5. 650MHz $\beta=0.82$ 5-cell cavity
6. High power input couplers
7. Summary
1. Introduction

Roadmap of China ADS (2011)

Phase I
- R&D Facility
- RFQ+HWR(CH)
- RFQ+Spoke

Phase II
- Experiment Facility
- Integration
- Integral test
- Phase II target
- 2017
- 50 MeV
- ~2022
- 0.6~1 GeV
- 100 MWt

Phase III
- DEMO Facility
- Phase III target
- ~2032
- 1.2~1.5 GeV
- ≥1 GWt

Verification of two ways

TTC meeting on CW SRF
The proton accelerator is being built by IHEP and IMP together.

This project began from 2011.
## Parameters of ADS SC Cavities

<table>
<thead>
<tr>
<th>Cavity type</th>
<th>Spoke012</th>
<th>Spoke021</th>
<th>Spoke040</th>
<th>Elliptical063</th>
<th>Elliptical082</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geometry $\beta$</td>
<td>0.12</td>
<td>0.21</td>
<td>0.40</td>
<td>0.63</td>
<td>0.82</td>
</tr>
<tr>
<td>Apertures (mm)</td>
<td>35</td>
<td>40</td>
<td>50</td>
<td>90</td>
<td>100</td>
</tr>
<tr>
<td>$E_{\text{peak}}/E_{\text{acc}}$</td>
<td>4.54</td>
<td>3.88</td>
<td>3.30</td>
<td>2.60</td>
<td>2.12</td>
</tr>
<tr>
<td>$B_{\text{peak}}/E_{\text{acc}}$ (mT/(MV/m))</td>
<td>6.37</td>
<td>8.13</td>
<td>8.34</td>
<td>4.73</td>
<td>4.05</td>
</tr>
<tr>
<td>$G(\Omega)$</td>
<td>61</td>
<td>87</td>
<td>104</td>
<td>193</td>
<td>236</td>
</tr>
<tr>
<td>$R/Q(\Omega)$</td>
<td>142</td>
<td>206</td>
<td>244</td>
<td>304</td>
<td>515</td>
</tr>
</tbody>
</table>
2. Spoke012 Cavity

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$Q_0$(4.2K)</th>
<th>$Q_0$(2K)</th>
<th>$E_{acc}$</th>
<th>Loaded BW</th>
<th>$df/dp$ (jacketed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>5e8</td>
<td>3e9</td>
<td>7 MV/m</td>
<td>460 Hz</td>
<td>40 Hz/torr</td>
</tr>
</tbody>
</table>

Two Prototypes

Cavity + Helium Vessel
Cavity Design

Electric and magnetic field

Deformation under one atm & 300kg tuning force

Stress under one atm & 300kg tuning force
Fabrication (1)

Spoke (before EBW)

Coupler arc

Spoke arc

Endwall

Spoke
Fabrication (2)

Circle of cavity

Cavity

Trimming
Post processing

Cavity

Ultrasonic Cleaning

Bulk BCP, 150 um
HPR
Class 100 Dry
Transfer to Oven
UHV 800°C, 4h Annealing

Repeat

Light BCP, 20 um
HPR
Class 100 Dry
Final Assembly and Leak Check
Baking, 140°C × 48h
VTF RF Testing

BCP

HPR
Vertical test

Hanging cavity

LLRF of test

Top of the dewar in the test
Multipacting during the test

![Graph showing multipacting during the test]

- **Hard barrier, 6 hours of pulsed conditioning, Q₀ improved little**
- **Soft barrier, easy to be removed through conditioning**
- **Not smooth**
Multipacting simulation by Omega3P

Resonant Energy (eV)

Eacc (MV/m) 1.45 2.9 4.35 5.8 7.25 8.7

Secondary electron energy section
Test results

At 4.2K, $Q_0 = 5.8 \times 10^8$ @ $E_{acc} = 6$ MV/m.

More efforts need to increase the Q value of the cavity.
Things to do in near future

- More Spoke012 cavities.
- 4.2K horizontal test (Autumn 2013).

Components under machining

Cryostat for horizontal test
3. Spoke021 cavity

- **Design Object:**
  - $E_{acc} = 8 \text{MV/m}$,
  - $Q_0 > 5 \times 10^8$ (4.2K),
  - $Q_0 > 5 \times 10^9$ (2K).

**Electric field**

**Magnetic field**

**Deformation**

Under 1 atm & 800kg tuning force
Fabrication

Rolling the cylinder
Pulling the port blend

Forming the end plate & nose-cone

Nb SST brazed joint

Squeezing the spoke pole

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Chinese Academy of Sciences
Next to do

- Surface treatment (Manual polishing, BCP, Annealing, HPR,) (June~July, 2013)
- Baking and Vertical test (end of July, 2013)
- Horizontal test (middle of 2014)
4. Spoke040 cavity

- Design Object: $Q_0 > 5 \times 10^9$ (2K), $Q_0 > 5 \times 10^8$ (4.2K) @ $E_{acc} = 7.7$ MV/m.
- The RF design has been finished.
- The mechanical design is under optimization.
- Experience of Spoke012 should be used.
5. 650MHz $\beta=0.82$ 5-cell cavity

- Design Object (2K): $E_{acc}=15\text{MV/m}$, $Q_0>3\times10^9$.

With stiffening ring $r=8.52\text{ cm}$:
$$K_L=-0.327\text{Hz/(MV/m)}^2$$

Without stiffening ring:
$$K_L=-1.04\text{Hz/(MV/m)}^2$$
Fabrication

- Finish cavity dies.
- Finish half-cell deep drawing.
- Finish fabrication and welding procedure design.
- Finish half-cell BCP and frequency measurement.
- Finish main parts EB welding of the cavity.

It’s planned to do the vertical test late 2013.
6. High power input couplers

- Two kinds of couplers are under fabrication.
  - Two prototype couplers for HWR cavity (developed by IMP) had been tested up to 20kW with CW RF power in July 2012.
  - Two prototype couplers for Spoke cavity have been tested up to 10kW with CW RF power in Jan. 2013.

<table>
<thead>
<tr>
<th>Cavity type</th>
<th>Frequency (MHz)</th>
<th>Power (kW)</th>
<th>Qext</th>
<th>Connecting type</th>
</tr>
</thead>
<tbody>
<tr>
<td>HWR (IMP)</td>
<td>162.5</td>
<td>15,CW,TW</td>
<td>~7.0E5</td>
<td>Coaxial waveguide, YX50-105-1</td>
</tr>
<tr>
<td>SPOKE</td>
<td>325</td>
<td>10,CW,TW</td>
<td>~7.0E5</td>
<td>Coaxial waveguide, $\frac{3}{8}$,50Ω</td>
</tr>
</tbody>
</table>
Coupler for HWR cavity

Maximum tested power: 20 kW, CW

3D mechanical model

Prototype coupler fabricated

High power test stand

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Coupler for Spoke cavity

High power test stand

Maximum tested power: 10 kW, CW

3D mechanical model
7. Summary

- During the last 2 years, progress has been achieved for the ADS SC cavities in IHEP.
- In the future, much more efforts should be paid to the ADS SC cavities.
- Broad and deep collaboration over the world are expected.
Thanks for your attention!