SRF cavities at Peking University

SRF Group
Institute of Heavy Ion Physics, Peking University
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Outline

1. History of R&D on superconducting cavities
2. SRF cavities fabricated recently
3. Future Plan
4. Summary
History of SRF activities at PKU

SRF Lab founded

1988

1994

2000

2002

2003

2004

2005

2006

2007

2008

2009

2×3.5cell

2×9cell

Multi-cell cavities technology
Test results of large grain cavities (high gradient, high Q)

- **1.5GHz single-cell (36.6 MV/m)**
- **1.3GHz single-cell (43.5 MV/m)**
- **1.3GHz 2-cell (40 MV/m)**
- **1.3GHz 3.5-cell (23.5 MV/m)**
2. SRF cavities fabricated recently
PKU2: large grain 9-cell cavity

TESLA type, fabricated by Peking University in 2009, tested at Jlab 2010-2011
PKU-2 (large grain) was tested twice on different days, but same treatment: 80 micron BCP, 600° C 10 hrs hydrogen degassing, 50 micron BCP, HPR RF test at 2K, Eacc 18.5 MV/m with Q₀ 9E9, Quench.
Test 2

Optical Inspection: Defects near Equator EBW
800°C x2 hr + EP 30 µm + 120°C x48 hr
RF test, maximum gradient of 22.4 MV/m
High Q₀
At 15 MV/m: 2.3E10 (2K); 3.5E10 (1.8K)
At 20 MV/m: 2.0E10 (2K); 3.2E10 (1.8K)

Note: Field emission onset 15 MV/m,
Maximum X-ray dose rate < 100 mR/m. No more mode mixing observed during final power rise.
Result of further processing and testing:

- 16% improvement in Eacc
- More than a factor of 2 improvement in Q0 at Eacc > 19 MV/m
Optical inspection

Where are they from?

- Tuning?
- EB welding?

- 2 new LG cavities are being fabricated
  - Improve machining and EB welding
  - Post-treatment
Fine grain 9-cell cavities
First 9-cell cavity PKU1: 23 MV/m
PKU3: fine grain 9-cell cavity

- Fabricated at PKU 2009, tested at Jlab in 2010
- 120 \( \mu \text{m} \) EP+800 °C x2hr+Light EP 25 \( \mu \text{m} \)+120°C x 48 hr
- 1\text{st} test max. Eacc 20 MV/m @ \( Q_0=2.3\text{E9} \), limited by FE
Second RF Test

- Re-HPR 2 times
- Low field $Q_0=8.4E9$ at 2K
- Max $E_{acc}$ 20.5 MV/m during first power rise at 2K, limited by radiation.
- Max $E_{acc}$ reached 28.6 MV/m at $Q_0$ 4E9, 1.8K, limited by RF cable.
- Low field $Q$ 2-3 time lower than expected -due to the material?
- Strong field emission- maybe caused by sharp edges in the iris EBW regions

[Courtesy Rong-Li Geng]
First 9-cell cavity with end groups in China reaching a gradient usable for ILC

A milestone in SRF technology in China

http://newsline.linearcollider/readmore_20100909_atw.html

A 1.3-gigahertz TESLA-type nine-cell niobium superconducting cavity, named PKU3, as the third nine-cell cavity fabricated by the superconducting radiofrequency (RF) group at Peking University, Beijing, China, achieved an accelerating gradient of 28.6 megavolts per metre (MV/m) at an unloaded quality factor of $4 \times 10^9$ in its second vertical test at Jefferson Lab (JLab), USA on 9 August 2010. This cavity is the first nine-cell cavity with end group components in China reaching a gradient usable for the ILC.

The cavity is made of high-purity niobium from Orient Tantalum Industry Corp. (OTIC), Ningxia, China. The fabrication of the cavity was finished in the middle of 2009. After field flatness pre-tuning with the Peking University tuning facility, PKU3 was sent to JLab in April 2010 for performance evaluation.
High current cavity
# 5–cell high current cavity
(Collaboration with ANL)

<table>
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<th>parameters</th>
<th>mid-cell</th>
<th>end cell</th>
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<td>115.4</td>
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<tr>
<td>Riris</td>
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<tr>
<td>A</td>
<td>38</td>
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<tr>
<td>a</td>
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<td>D</td>
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Simulations

Parameters

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<tr>
<td>R/Q (ohm)</td>
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<td>Epk/Eacc</td>
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<td>Bpk/Eacc mT/(MV/m)</td>
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<td>G Factor</td>
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<td>Coupling coefficient (%)</td>
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<td>K/ for $\sigma_z = 1 \text{mm}$</td>
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<td>$k_\perp$ for $\sigma_z = 1 \text{mm}$</td>
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Field Flatness: 98%

Field distribution of fundamental mode
Simulations

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Field distribution of fundamental mode
Simulations

\[ \frac{R}{Q} \times Q_e < 10^4 \ \Omega \]
\[ \frac{R}{Q} \times Q_e / f < 1.4 \times 10^5 \ \Omega / (cm^2 \cdot GHz) \]
\[ \frac{R}{Q} \times Q_e / f < 4 \times 10^6 \ \Omega / (cm^4 \cdot GHz) \]
After fabrication, 87%, 1297.80MHz, (goal:1298.6MHz)

After tuning: 98.6%, 1298.65MHz
low beta cavities
The stiffening ribs structures of PKU SSC.

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<th>PKU SSC Mark II</th>
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<td>Transit time factor</td>
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<tr>
<td>G [Ω]</td>
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<td>88</td>
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<tr>
<td>R/Q₀ [Ω]</td>
<td>179</td>
<td>211</td>
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<tr>
<td>E&lt;sub&gt;peak&lt;/sub&gt;/E&lt;sub&gt;acc&lt;/sub&gt;</td>
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<td>2.86</td>
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<tr>
<td>B&lt;sub&gt;peak&lt;/sub&gt;/E&lt;sub&gt;acc&lt;/sub&gt; [mT/(MV/m)]</td>
<td>5.22</td>
<td>3.90</td>
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</tbody>
</table>
Preliminary cold test: 3 MV/m
[at Jlab, P. Kneisel]
3. Future plan
Current Facilities for SRF researches

- Clean room
- Pure water
- Tuning sys.
- High temp. furnace
Planed Facilities for SRF researches

VTS

BCP
Cavities in future projects

- High accelerating gradient cavity: 9-cell TESLA type
- High current cavity: 5cell or 7 cell
- High power main coupler
- Low beta cavities: spoke, QWR
Ningxia Orient Superconductor Technology Co., Ltd.
(Founded by OTIC and PKU, Feb. 2011)

- More and more requirement for SC cavities (ADS, XFEL, ILC, ...)
- Industrialization is necessary
- Ningxia OTIC and PKU cooperate for many years
  - Nb material (since 2002)
  - Large grain cavity (since 2005)
  - Multi-cell SRF cavities (since 2006)
- Establish a Company
**OTIC**
- material preparation
- Deep drawing, machining
- EB welding
- High temperature treatment

**PKU**
- RF measurements
- quality control
- Surface treatment
- Cold test
Summary

- Progresses on SRF cavities have been made at Peking University in recent years
  - 9-cell TESLA type cavities are fabricated, max. gradient 28.6 MV/m
  - A 5-cell prototype cavity for high current is fabricated for ANL
  - Sing-spoke cavities are fabricated for proton acceleration

- Promote the industrialization process in China
- More cavities will be design and fabricated
We give great thanks to the colleagues who help us continuously

- P. Kneisel (Jlab)
- R.-L. Geng (Jlab)
- R. Rimmer (Jlab)
- D. Proch (DESY)
- Ningxia OTIC colleague
- J. He (HIT)
- ......
Thank you for your attention!
single-cell cavities, QWR (before 2005)

Since 2005, TESLA-type multi-cell SRF cavities with Chinese niobium (Ningxia OTIC)
  - Development of SRF technique
  - Setup of facilities for fabrication of SRF cavities
  - SRF specialists

High current cavity

Spoke cavity
Large Grain Nb
Reseaches on Large Grain Nb Cavity
(Collaboration with OTIC and Jlab)

- 2002, researches on high pure niobium
- 2005, start researches on large grain niobium cavities
- Ningxia OTIC LG niobium
Cryogenic System

- Commissioning of Cryogenic system: March – June 2010
- Commissioning of Cryogenic system with DC-SC injector (w/o beam): Jan-April 2011
- Lequefaction rate: 120 l/h
- Cooling capacity: 58W @ 2 K
- Upgrade is necessary for vertical test stand
Accumulated Key techniques for fabrication of cavities

Fitting stiffening ring tool
A new hall in Ningxia