SRF Technology Industry Developments in China

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Outline

• ILC related SRF projects in China

• Chinese SRF industry (not complete list)
  • Niobium (Ningxia OTIC)
  • Cavity (OTIC/PKU, HERT/IHEP, HIT/SARI)
  • Coupler (HERT, HPI, AIR)
  • Cryomodule (Wuxi)

• Summary
ILC SRF related Projects in China

**FEL projects and 1.3 GHz cryomodules** (LCLS-II type, similar to ILC)
- **Shanghai SHINE** (in construction, 2018-2025): 5 + 75 CMs
- **Shenzhen SXFEL** (approved, 2021-2028): 4 + 26 CMs
- **Dalian DALS** (R&D, 2022-2027?): 2 + 10 CMs

~ 1000 9-cell cavities & couplers, 120 CMs: 10 % of ILC250 CMs before 2026

**Future 1.3 GHz cryomodules**
CEPC Booster ring: 12 + 32 CMs
New XFEL/ERL projects …
Shanghai HIgh repetitioN XFEL and Extreme light facility

Three Large Facilities
We are going to see three large scale SRF based facilities worldwide

construction during 2009 – 2016 in operation since 2017
cw upgrade after 2025 (? , tbc)

under construction since 2014
first lasing expected in 2021
HE 8 GeV upgrade until 2026

SHINE SARI
under construction since 2018
to be commissioned in 2025
goal: cw and 8 GeV

From Hans Weise of DESY
SHINE SRF Infrastructure at Shanghai

1. supporting intense R&D for SRF techs needed for SHINE and future
2. capacity for 600 cavities VT, 75 modules assembly & HT in 2–3 years
3. beam test with gun + 1-2 modules

Cavity chemical processing is at Wuxi, 150 km from SHINE

**Components assembly**

- SHINE SRF Buildings 3 halls w/ 3000 m²
- Hall #1: module assembly 2xVT caves 2xHT
- Hall #2: 2 x VT caves 2xHT or beam test
- Cryoplant for RF test 700W@2K reached 2020

**Main devices**

- Clean room tools
- Cryogenic test for components
- VT dewer
- Assembly tool
- FPC conditioning device
- HT feed-cup

**CM installation & transportation test**

- Tools for CM installation
- Loading for CM (Shanghai)
- Mock-up tunnel
- CM test after transportation (Dalian)
Shenzhen XFEL

- Proposed by Institute of Advanced Science Facilities in Shenzhen (IASF)
- Fully funded by the Shenzhen government since Sept 2020
- 2.5 GeV CW SRF accelerator
- 26 1.3 GHz Cryomodules and 2 3.9 GHz Cryomodules
- ~300 SRF cavities
- Technical Design Report (TDR) will be released in June 2021
- Primary schedule: 2021-2028
- One management with DALS (next page)
Dalian Advanced Light Source (DALS)

- Proposed by Dalian Institute of Chemical Physics (DICP)
- 1.0 GeV CW SRF accelerator
- Ten 1.3 GHz Cryomodules & two 3.9 GHz Cryomodules
- ~100 SRF Cavities
- Dedicated cryoplant

- R&D project (2021-2024)
- One horizontal test bench
- One vertical test cryostat
- One injector test bench
- ~ 20 SRF cavities
- Refrigerator ordered

DATF hall
Cryo-hall
Injector test facility

DALS Accelerator Test Facility (DATF) funded by the local government and under construction
IHEP PAPS SRF Facility

• 4500 m² SRF Lab. Facility installation and commissioning now. Operation soon.
• 400 cavities and couplers testing per year. 20 cryomodule assembly and testing per year.
## Ningxia OTIC Niobium
\(\text{(Orient Tantalum Industrial Co., Ltd.)}\)

<table>
<thead>
<tr>
<th>Products</th>
<th>Annual capacity</th>
<th>Spec.</th>
<th>Remark</th>
</tr>
</thead>
</table>
| RRR Nb sheet   | 30 Tons         | RRR40, RRR250, RRR300 | Max. size: 1000x1000xT mm  
Min. thickness: 2.5 mm |
| RRR Nb tube    | 10 Tons         | RRR40, RRR250, RRR300 | Max. diameter: 120 mm  
Max. length: 250 mm  
Min. wall thickness: 2.5 mm |
| RRR Nb rod     | 10 Tons         | RRR40, RRR250, RRR300 | Max. diameter: 200 mm  
Min. diameter: 4 mm   |

**2011**  **DESY – XFEL:**  8 tons RRR300 Nb sheets, 30% of the project  
**2012**  **Michigan State University – FRIB:**  8.5 tons RRR250 Nb sheets, 70% of the project  
**2014**  **Fermilab - LCLS II:**  5 tons RRR300 Nb sheets, 50% of the project  
**2017**  **INFN & STFC – ESS:**  10 tons RRR300 Nb sheets, 100% of the project  
**2019**  **IBS – RISP, CERN – HL-LHC, Fermilab – PIP-II ,SCK CEN-MYRRHA :** RRR300 niobium material procurement in progress

We had built the business relationship with many great customers such as DESY, MSU, Fermilab, JLAB, INFN, STFC, CERN, TRIUMF, RI, E.ZANON, IHEP, IBS, RRCAT etc.
E_{acc} of all 6 cavities near or larger than 28 MV/m
Q_0 \sim 1.6-2.4\text{E}10 \text{ @ 16 MV/m}
OTIC Cavity Treatment Infrastructure

BCP

HPR

EP (IHEP)

Annealing

N-Doping

EP Single Cell
• Five EP 9-cells > 30 MV/m, max 36 MV/m, reach ILC spec.
• Six Mid-T Furnace Bake 9-cells: 3.4~4.5E10@16~22 MV/m, beyond LCLS-II and LCLS-II-HE spec.

Annual capacity: 200 cavities
HERT Cavity Infrastructure
HIT/SARI 9-cell Cavity

BCP FG 9-cell cavities
SHINE Surface treatment facility at WXCX, Wuxi

- A surface-treatment platform is under construction in Wuxi.
- Aiming at dealing with all the procedures after cavity fabrication, and before vertical test.
- Main facilities: BCP, EPs, US, UPW, HPR, vacuum furnaces, clean rooms, optical inspector, tuning machine, waste disposal facility etc.

SHINE-Wuxi facility: Functional

- Four main areas: normal area, clean rooms, chemistry areas and waste disposal.

From Dong Wang of SARI

With help from INFN-LASA; E.ZANON; KEK; DESY and many domestic institutions.

Main devices (1)

- EIA permit and acid use qualification achieved;
- BCP small EP and big EP devices are under commissioning with acids;

Main devices (2) – pass the acceptance

- Movable clean room (ISO7)
- Small furnace
- Ultra pure water
- Clean room (ISO7) – 200 m²
- Clean room (ISO4) – 100 m²
• 1.3 GHz variable input couplers high power tested to CW 14 kW TW, 7 kW SW.
• Four couplers completed. Another four couplers under fabrication.
• Coupler copper plating (especially bellow) meet the specifications.
HERT Coupler

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Inner conductor</th>
<th>Warm outer conductor</th>
<th>Cold outer conductor</th>
</tr>
</thead>
<tbody>
<tr>
<td>RRR after annealing</td>
<td>Pipe:30 – 80</td>
<td>141</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Bellow:30~80</td>
<td>239</td>
<td>55</td>
</tr>
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<tr>
<td>Thickness of copper plating</td>
<td>Pipe:30μm±20%/150μm±20%</td>
<td>130~170</td>
<td>27~33</td>
</tr>
<tr>
<td></td>
<td>Bellow:30μm±30%/150μm±30%</td>
<td>110~190</td>
<td>23~36</td>
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</table>
• Ceramic window TiN sputtering meet the specifications.

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Test Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness of TiN Coating</td>
<td>10 nm (7-15 nm)</td>
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</table>

• Measurement of SEEC on ceramic samples

*Image of a chart showing the comparison of Secondary Electron Emission Coefficient on IHEP ceramics.*

- HERT Coupler

*Image of HERT Coupler samples.*

*Image of a chart showing the Secondary Electron Emission Coefficient.*

4 times measurement at each cathode voltage
Anhui Huadong Polytechnic Institute

HPI Coupler
1.3 GHz Couplers performance:

- Pulse conditioning test: peak power 28 kW, 20% duty cycle.
- Travelling wave Continuous wave test: 14 kW, maintenance time is 6 hours, no interlock.
- Standing wave Continuous wave test: 7 kW, maintenance time is 12 hours, no interlock.
• Euro-XFEL: 58 CMs in 2010-2012
• FRIB: 52 CMs and cryogenic valves and transfer lines
• LCLS-II: 38 1.3 GHz CMs and three 3.9 GHz CMs
• SHINE: three prototype CMs
Summary

• Chinese industry can make cavities, couplers, cryomodules etc. that meet ILC spec.

• Chinese industry and labs will produce more than 100 1.3 GHz cryomodules (~1000 9-cell cavities and couplers) in next five years for the domestic projects: world largest 1.3 GHz SRF industry mass production before ILC construction.

• Remained work to prepare for ILC construction:
  • increase high gradient cavity yields (90% > 1E10@35 MV/m), part of high Q cavities go EP baseline test first for high gradient research
  • ILC high gradient cryomodule prototyping (1E10@31.5 MV/m)
  • cavity pressure vessel code
  • R&D on higher Q at higher gradient (>2E10@35~40 MV/m)