Pushing CW beam current limit of TESLA SRF Cavities with Nb3Sn and NbTiN Coating of the HOM Antennas

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Thin Films SRF 2022, 19-23.09.2022
• MESA & ALICE using ELBE-type cryomodules
• Refurbishment of SRF cavities at HIM
• Coated HOM antennas for MESA
• Summary & Outlook
Mainz Energy-recovering Superconducting Accelerator

MAGIX:
2 recirculations ER mode
105 MeV @ 1 (10) mA

Enhanced Elbe cryomodules
12.5 Mv/m
$Q_0 > 1.25 \times 10^{10}$

P2:
3 recirculations
155 MeV @150 μA (pol.)

nc injector: 5 MeV
150 μA (pol.)
1 (10) mA
Accelerators and Lasers in Combined Experiments

<table>
<thead>
<tr>
<th>Injector</th>
<th>8 MeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM</td>
<td>26.65 MeV</td>
</tr>
<tr>
<td>Beam</td>
<td>35 MeV @13 μA</td>
</tr>
<tr>
<td>$Q_0$</td>
<td>$5 \times 10^9$</td>
</tr>
<tr>
<td>$f$</td>
<td>1.3 GHz</td>
</tr>
<tr>
<td>Time in operation</td>
<td>2005 - 2016</td>
</tr>
</tbody>
</table>

We would like to thank the Daresbury Laboratory for their generous gift.

P. McIntosh et al., "SRF SYSTEM OPERATION ON THE ALICE ERL FACILITY AT DARESBURY", 2009
ELBE-type cryomodule

1. Helium port
2. Titanium Helium tank (1.8 K)
3. 9-cell 1.3 GHz Nb TESLA cavities
4. Bellow between the two cavities
5. Nitrogen port (77 K liquid N)
6. RF couplers
7. Vacuum pump

A. R. Goulden et al., „INSTALLATION AND COMMISSIONING OF THE SUPER CONDUCTING RF LINAC CRYOMODULES FOR THE ERLP“, 2008
Refurbishment of the ALICE module

MESA Enhanced ELBE-type Cryomodules (MEEC):
• Helium port (Joule-Thomson valve)
• Faster DESY/Saclay tuner (higher beam currents)
  → diameter of Helium tank changed
• New HOM antennas
• Cavity contamination leads to field emission @7 MV/m

→ Clean room treatment!
Clean room infrastructure at HIM

- Personal entrance (ISO 6)
- Material entrance (ISO 7)
- Clean room 1 (ISO 6)
- Ultrasonic bath (USB) system
- High pressure rinse (HPR)
- Personal airlock
- Material gate
- Clean room 2 (ISO 4)
Cavity handling in the clean room - USB

(1) Cavity on the robot arm
(2) USB with 5% Tickopur and T = 40°C
(3) rinsing with ultra pure water

→ Outer surface is particle and oil free
Cavity handling in the clean room - HPR

(1) HPR setup lance moving vertically; cavity rotates around

(2) Cavity after 2 days drying in clean room 2 (ISO 4)

HPR:
• 1h duration
• up to 100 bar

→ Cavity brought to Darmstadt
→ Successful treatment!
Refurbishment of the ALICE module

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HOM Antennas

Left:
• Design from RI
• Cyocera feedthrough with flange and antenna tip
• 25 mm tip length

Right:
• DESY Design
• 29.56 mm tip length
**HOM Couplers - Simulations**

Power stored in HOMs:

\[ P_{HOM} = N \times q \times k \times I \]

- **N**: #beams; **q**: bunch charge; **k**: loss factor;
- **I**: average beam current

→ 30% of \( P_{HOM} \) outcoupled by HOM feedthrough

---

**Table:**

<table>
<thead>
<tr>
<th>( I ) [mA]</th>
<th>( q ) [pC]</th>
<th>( P_{HOM} ) [mW]</th>
<th>( P_{Feedthrough} ) [mW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.7</td>
<td>30.8</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>77</td>
<td>3080</td>
<td>1000</td>
</tr>
</tbody>
</table>

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HOM antenna coating with \( \text{Nb}_3\text{Sn} \) and \( \text{NbTiN} \):

→ Better HOM damping and higher \( T_C \)

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T. Stengler "Entwicklung eines supraleitenden Beschleunigermoduls für denrezirkulierenden Betrieb am MainzEnergy- Recovering Superconducting Accelerator (MESA) ", PhD. Thesis, Mainz 2020

C. Stoll "Beam dynamical behaviour of the MESA SRF structures under recirculating operation" PhD. Thesis, Mainz 2020
HOM Couplers - Simulation

Goal:
Reduce heating of HOM Antenna
→ Prevent quench of whole CM

How:
Antenna coating with Nb3Sn/NbTiN on Nb/Cu Antennas

Ongoing CST simulation

<table>
<thead>
<tr>
<th>Property</th>
<th>Nb</th>
<th>Nb3Sn</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_C$ [K]</td>
<td>9.2</td>
<td>18.3</td>
</tr>
<tr>
<td>$\kappa_0$(0K)</td>
<td>1.4</td>
<td>34</td>
</tr>
<tr>
<td>$\xi_0$ [nm]</td>
<td>39</td>
<td>5.7</td>
</tr>
<tr>
<td>$\lambda_L$ [nm]</td>
<td>27</td>
<td>65-89</td>
</tr>
</tbody>
</table>

Coated Antennas Expectation of HOM Antenna Coatings

Current HOM Antennas fulfill ERL at 1 mA

10 mA need improved HOM decoupling

$T_{NbTiN} = 18.3\, K$

$T_{NbTiN} = 11.8\, K$

$T_{Nb} = 9.2\, K$

$T_{NbTiN} = 11.2\, K$

$T_{NbTiN} = 13.8\, K$

$T_{NbTiN} = 18.3\, K$

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$T_{NbTiN} = 11.8\, K$

$T_{Nb} = 9.2\, K$
Summary & Outlook

- Oil in Helium tank
- Disassembly of the ALICE Module

6 cell cavity:
- HPR treatment was successful!

→ Successfull Cavity refurbishment

2021

- HOM antennas with \( \text{Nb}_3\text{Sn} \) and \( \text{NbTiN} \) coating (\( \text{Nb}/\text{Cu} \) core)
- 2022 coated HOM antennas in Hamburg and Darmstadt

2022

- HPR and vertical cold test in 2022
- Acetone treatment for helium tank

2023+

HOM tests in ALICE module
Thank you for your attention!

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We would like to thank the Daresbury Laboratory for their generous gift.