Progress with RF Characterisation facility at STFC

7th IFAST WP9 Meeting
1st-2nd December 2022

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Facility Reminder

- Measurements of $R_s$ with RF-DC compensation using Nb choke cavity (3 choke or 2 choke)
- Aim to test planar samples 90 - 130 mm diameter (100 mm is ideal size) with 2 day turnaround between tests
- So far allows $R_s$ measurements of
  - $f_0 = 7.8$ GHz
  - $T_S = 4$ to 10 K
  - RF Power up to 1 W
  - $B_{s, pk} \leq 1$ mT

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Facility Upgrades – 2 Choke Cavity & Sample-Cavity Gap

- **Cavities:**
  - Studying difference in performance between 2 and 3 choke cavities – both cavities haven’t received full treatment
    - CST
    - Experimentally (effect of polishing, heat treatment...)
  - At 5 K:
    - $R_s$ (2 choke) $\sim$ 600 $\mu$Ω,
    - $R_s$ (3 choke) $\sim$ 120 $\mu$Ω
  - 2 choke cavity sent to IJCLab for full treatment

- **Sample-Cavity Gap Optimisation:**
  - Wish to maximize % of RF power dissipated on sample
  - Highest power dissipation on the sample for a gap of 0.5 mm.
  - Significant leakage through gap > 4 mm
  - Sample measurements can still happen even if choke fails or cavity quality is poor
Facility Upgrades - RF Bunker

• Potential to increase $B_{\text{peak}}$ (overlap with QPR):

<table>
<thead>
<tr>
<th></th>
<th>$Q$</th>
<th>$P_{\text{cav, max}}$ (W)</th>
<th>$B_{\text{peak}}$ (mT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present state</td>
<td>$7 \times 10^5$</td>
<td>0.3</td>
<td>1.1</td>
</tr>
<tr>
<td>With PLL</td>
<td>$3 \times 10^6$</td>
<td>0.3</td>
<td>1.7</td>
</tr>
<tr>
<td>Improve cavity Q</td>
<td>$6 \times 10^6$</td>
<td>0.3</td>
<td>3.6</td>
</tr>
<tr>
<td>Increase CW Power</td>
<td>$6 \times 10^6$</td>
<td>1</td>
<td>8.1</td>
</tr>
<tr>
<td>Increase CW Power</td>
<td>$6 \times 10^6$</td>
<td>1.5</td>
<td>9.9</td>
</tr>
<tr>
<td>Pulsed power</td>
<td>$6 \times 10^6$</td>
<td>5</td>
<td>18</td>
</tr>
</tbody>
</table>

• Higher fields difficult at our frequency & Qs
• A new bunker would allow for present RF power safety limits to be exceeded
Bulk Nb Samples

Bulk Nb 1

![Graph showing $R_s (\mu\Omega)$ vs $T_{Sample} (K)$ for Bulk Nb 1 (Pre-MP), Bulk Nb 1 (Post-MP), Bulk Nb 2, and BCS.]

Pre-MP

Post-MP

Courtesy of O. Hryhorenko (IJCLab)
Nb on Cu Samples

- High impulse magnetron sputtering (HiPIMS)
- 130 mm diameter diamond turned Cu disks.

$R_s$ (μΩ)

$T_{Sample}$ (K)

$\sim 500 ^\circ C$

$\sim 330 ^\circ C$

Bulk Nb 1 annealed at $\sim 600 ^\circ C$
Nb/AlN/NbTiN Multilayers

Thicknesses:
- MP Bulk Nb: 3 mm
- AlN: ~10 nm
- NbTiN: ~180 nm

Deposition temperature: 600-650 °C
Possibility to estimate $T_c$ whilst keeping cavity temperature fixed
Nb/AlN/NbTiN Multilayers

- Additional ~ 620 nm NbTiN deposited → total = 800 nm NbTiN on existing layers
- Deposition temperature: 600-650 °C

$R_s (\mu \Omega)$ vs $T_{Sample}$ (K)
Nb/AlN/NbTiN Multilayers

$T_c \sim 16.9 \text{ K}$

$T_c \sim 16.1 \text{ K}$

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From planar samples to real cavities

- **Aim**: Best performing flat samples → split cavities

- **3 sets of samples:**
  - Nb coated planar samples →
    - Tested with choke cavity
    - Up to 3 planar samples per week!
  - Split cavity deposited with planar magnetron & planar target
    - SRF test
  - Split cavity deposited with cylindrical magnetron & tubular target
    - SRF test
Future Plans

• Continuing RF testing of planar thin films:
  – Nb/AlN/NbTiN
  – Nb$_3$Sn
  – Nb
  – Etc
• Moving facility to an RF bunker early 2023 will allow for higher peak fields (overlapping with QPR)
• Will accept samples from IFAST partners on disks 90-130 mm diameter (up to 10 mm thickness)
  – We can provide unpolished or polished (will take longer) Cu
  – Contact: daniel.seal@cockcroft.ac.uk
• Any good samples could be given to Arturs for laser treatment at RTU
• Facility paper in progress
Thank you for listening