Status of High Gradient Tests of Normal Conducting Single-Cell Structures

Valery Dolgashev, Sami Tantawi (SLAC)
Yasuo Higashi (KEK)

Robert Siemann Symposium and ICFA Mini-Workshop,
July 7th - 10th, 2009
SLAC National Accelerator Laboratory
This work is made possible by the efforts of SLAC’s

– A. Yeremian, J. Lewandowski of *Accelerator Technology Research*


– Z. Li, *Advanced Computation*

**In collaboration with:**

– B. Spataro, *INFN, Frascati*
Outline

• Introduction
• Strategy
• Results
Single Cell Accelerator Structures

Goals
• Study rf breakdown in *practical* accelerating structures: dependence on circuit parameters, materials, cell shapes and surface processing techniques

Difficulties
• Full scale structures are long, complex, and expensive

Solution
• *Single cell Traveling wave (TW) and single cell standing wave (SW)* structures with properties close to that of full scale structures
• Reusable couplers

We want to predict breakdown behavior for practical structures
Reusable coupler: $\text{TM}_{01}$ Mode Launcher

Pearson’s RF flange

Cutaway view of the mode launcher

Two mode launchers

Surface electric fields in the mode launcher

$E_{\text{max}} = 49 \text{ MV/m for 100 MW}$

S. Tantawi, C. Nantista
High Power Tests of Single Cell Standing Wave Structures

Tested

• Low shunt impedance, $a/\lambda = 0.215$, 1C-SW-A5.65-T4.6-Cu, 5 tested
• Low shunt impedance, TiN coated, 1C-SW-A5.65-T4.6-Cu-TiN, 1 tested
• Three high gradient cells, low shunt impedance, 3C-SW-A5.65-T4.6-Cu, 2 tested
• High shunt impedance, elliptical iris, $a/\lambda = 0.143$, 1C-SW-A3.75-T2.6-Cu, 1 tested
• High shunt impedance, round iris, $a/\lambda = 0.143$, 1C-SW-A3.75-T1.66-Cu, 1 tested
• Choke with 1mm gap in high gradient cell, 1C-SW-A5.65-T4.6-Choke-Cu, 2 tested
• Low shunt impedance, made of CuZr, 1C-SW-A5.65-T4.6-CuZr, 1 tested
• Low shunt impedance, made of CuCr, 1C-SW-A5.65-T4.6-CuCr, 1 tested
• Highest shunt impedance copper structure 1C-SW-A2.75-T2.0-Cu-SLAC-#1, 1 tested
• Photonic-Band Gap, low shunt impedance, 1C-SW-A5.65-T4.6-PBG-Cu, 1 tested
• Low shunt impedance, made of hard copper 1C-SW-A5.65-T4.6-Clamped-Cu-SLAC#1, 1 tested
• Low shunt impedance, made of molybdenum 1C-SW-A5.65-T4.6-Mo-Frascati-#1, 1 tested
• High shunt impedance, choke with 4mm gap, 1C-SW-A3.75-T2.6-4mm-Ch-Cu-SLAC-#1, 1 tested
• Low shunt impedance, made of CuAg, 1C-SW-A5.65-T4.6-CuAg-SLAC-#1, 1 tested

Now 21\textsuperscript{th} test about to start,
low temperature brazed , high shunt impedance hard CuAg structure
1C-SW-A3.75-T2.6-CuAg-KEK-#1
Next experiments, as for 8th July 2009

Reproducibility tests:
High shunt impedance, elliptical iris, 1C-SW-A3.75-T2.6-Cu
High shunt impedance, round iris, 1C-SW-A3.75-T1.66-Cu
Low shunt impedance, made of CuZr, 1C-SW-A5.65-T4.6-CuZr
Three high gradient cells, low shunt impedance, 3C-SW-A5.65-T4.6-Cu

Geometry tests:
Three cells, WR90 1mm gap choke coupling to power source, 3C-SW-A5.65-T4.6-Cu-WR90
One cell one-side WR90 coupled 1C-SW-A3.75-T2.6-OneWR90-Cu
3-cell symmetrically WR90 coupled 2C-SW-A3.75-T2.6-TwoWR90-Cu

Materials:
High shunt impedance, made of CuZr, 1C-SW-A3.75-T2.6-CuZr
High shunt impedance, made of CuAg, 1C-SW-A3.75-T2.6-CuAg
High shunt impedance, made of hard CuAg, 1C-SW-A3.75-T2.6-Low-Temp-Brazed-CuAg
Parameters of periodic structures, $E_{acc}=100$ MV/m

<table>
<thead>
<tr>
<th>Name</th>
<th>A2.75-T2.0-Cu</th>
<th>A3.75-T1.66-Cu</th>
<th>A3.75-T2.6-Cu</th>
<th>A3.75-T2.6-Ch-4mm-Cu</th>
<th>A5.65-T4.6-Choke-Cu</th>
<th>A5.65-T4.6-PBG-Cu</th>
<th>A5.65-T4.6-Cu</th>
<th>T53VG3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stored Energy [J]</td>
<td>0.153</td>
<td>0.189</td>
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<td>0.294774</td>
<td>0.333</td>
<td>0.311</td>
<td>0.298</td>
<td>0.09</td>
</tr>
<tr>
<td>Q-value [x1000]</td>
<td>8.59</td>
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<td>2.75E+05</td>
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<tr>
<td>Max. Electric Field [MV/m]</td>
<td>203.1</td>
<td>266</td>
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<td>217.5</td>
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<td>Losses in one cell [MW]</td>
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<td>3.173</td>
<td>3.60</td>
<td>2.554</td>
<td>0.953</td>
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<td>3.885</td>
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<td>a/lambda</td>
<td>0.105</td>
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V.A. Dolgashev, 12 May 2009
Results

1C-SW-A5.65-T4.6-Clamped-Cu-SLAC#1
1C-SW-A3.75-T2.6-4mm-Ch-Cu-SLAC-#1
1C-SW-A5.65-T4.6-Mo-Frascati-#1
1C-SW-A5.65-T4.6-CuAg-SLAC-#1
Copper alloys

Clamped structure, hard copper,
1C-SW- A5.65-T4.6-Clamped-Cu-SLAC-#1
Mechanical design: David Martin
Comparison of peak pulse heating for two 1C-SW- A5.65-T4.6-Cu structures and 1C-SW- A5.65-T4.6-Clamped-Cu, *shaped* pulse, flat part 150 ns
Comparison of peak pulse heating for three 1C-SW- A5.65-T4.6-Cu structures and 1C-SW- A5.65-T4.6-Clamped-Cu

V.A. Dolgashev 11 March 2009
Damaged “patches”
D4d_B1RB_IMG3D, 1C-SW- A5.65-T4.6-Clamped-Cu, Lisa Laurent
Erosion of joint between pressed cell
Geometry test

4mm choke structure
1C-SW-A3.75-T2.6-4mm-Ch-Cu-SLAC-#1
Before: Choke with 1mm gap

1C-SW-A5.65-T4.6-Cu-Choke
1C-SW-A5.65-T4.6-Cu-Choke
10 MW input

Maximum magnetic field 628.5 kA/m
(SLANS 627.5 kA/m)

Maximum electric field 289 MV/m
(SLANS 297.7 MV/m)

Resonance at 11.42053 GHz
( SLANS 11.424 GHz)

$\beta = 1.03832$
( SLANS 1.045)

Over-coupled loaded $Q$
Unloaded $Q=7,933$
( SLANS 7,933.5)

$\frac{11.42053}{0.00293429} = 3.892 \times 10^3$

$\frac{11.42053}{0.00293429} \frac{1 + 1.03832}{1} = 7.933 \times 10^3$

V.A. Dolgashev, 25 September 2007
Choke vs. no Choke

1C-SW-A5.65-T4.6-Cu-KEK-#2

1C-SW-A5.65-T4.6-Ch-Cu-SLAC-#1
Next choke structure: 1C-SW-A3.75-T2.6-Cu-4mm-Choke, 10 MW losses

Maximum magnetic field 604 kA/m
(SLANS 602.065 kA/m)

Maximum electric field 347 MV/m
(SLANS 350.85 MV/m)

Resonance at 11.420947 GHz  \( \beta = 0.861 \)
(SLANS 11.42391 GHz)

Under-coupled loaded Q
Unloaded Q=8,605
(SLANS 8,668)

V.A. Dolgashev, 18 September 2008
Parameters of *periodic* structures, $E_{acc}=100$ MV/m

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V.A. Dolgashev, 12 May 2009
Gradient comparison between 1C-SW-A3.75-T2.6-Cu-SLAC-#1 and 1C-SW-A3.75-T2.6-4mm-Ch-Cu-SLAC-#1

V.A. Dolgashev, 20 May 2009
Comparison of A3.75 structure without choke and with 4mm choke

V.A. Dolgashev, 20 May 2009
New materials

Molybdenum structure

1C-SW-A5.65-T4.6-Mo-Frascati-#1
Status report on SALAF technical activity during the second half of 2008

S. Bini, P. Chimenti, V. Chimenti, R. Di Raddo, V. Lollo, B. Spataro, F. Tazzioli
Comparison of peak pulse heating for two copper and one molybdenum 1C-SW- A5.65-T4.6-Cu structures, \textit{shaped} pulse, flat part 150 ns

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{comparison_graph}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.8\textwidth]{gradient_graph}
\end{figure}
Copper alloys

Soft CuAg structure,
1C-SW-A5.65-T4.6-CuAg-SLAC-#1,

Disclaimer: This is “working” data, it is not final in any way
150 ns flat Study of breakdown rate transients, 150 ns flat
the data will be corrected later using beadpull results

V.A. Dolgashev, 1 July 2009
A5.65-T4.6-CuAg-SLAC-#1 flat pulse
the data will be corrected later using beadpull results

V.A. Dolgashev, 1 July 2009
Comparison of A5.65-T4.6-CuAg-SLAC-#1, 150ns flat pulse with other A5.65-T4.6 structures

the data will be corrected later using beadpull results

V.A. Dolgashev, 1 July 2009
Comparison of A5.65-T4.6-CuAg-SLAC-#1, with A5.65-T4.6 structures made of CuCr and CuZr, the data will be corrected later using beadpull results.

V.A. Dolgashev, 1 July 2009
Ratio of All breakdowns to first breakdowns for A5.65-T4.6-CuAg-SLAC-#1, the data will be corrected later using beadpull results.
Correlated breakdowns
Ratio of All breakdowns to first breakdowns for

1-C-SW-A5 .65-T4 .6-Clamped-Cu-SLAC #1

1-C-SW-A5.65-T4.6-Cu-Frascati-#2
Ratio of All breakdowns to first breakdowns for

1-C-SW-A5 .65-T4 .6-Clamped-Cu-SLAC #1

1-C-SW-A5.65-T4.6-PBG-Cu-SLAC-#1

V.A. Dolgashev, 8 July 2009
Travelling Wave parallel coupled structure
Summary

We have a test setup with short turn-around time that produces useful data. The stand started working January 2007 and now 20th structure is installed, low temperature brazed, high shunt impedance hard CuAg structure

1C-SW-A3.75-T2.6-CuAg-KEK-#1