Eigenmode Calculations for a 1.5 Cell SRF Gun Derived from a TESLA Cavity

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Outline

▪ Motivation

▪ Computational model
  - Fundamental input power coupler
  - Pickup antenna as a field probe

▪ Numerical results
  - Electromagnetic fields along the cavity axis
  - Electromagnetic fields in the backplane of the half cell

▪ Summary / Outlook
Motivation

- Transition From Pulsed Operation to CW

Normal Conductive Gun


SRF Gun (Example)

https://www.hzdr.de/db/Cms?pOid=41402&pNid=2154
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Computational Model

- Model of a 1.5 Cell SRF Gun (from TESLA Cavity)

Info:
A symmetric mesh is generated by meshing only a quarter of the model and assembling the full mesh in an additional processing step.
Computational Model

- Model of a 1.5 Cell SRF Gun (from TESLA Cavity)

Example:
2.134.554 curved tetrahedral elements for the full mesh
Computational Model

- Model of a 1.5 Cell SRF Gun (from TESLA Cavity)
  - Cut view

\[ R = 39 \text{ mm} \]

Antenna Penetration
- positive: into the beam tube
- negative: into the waveguide
Numerical Results

- Model of a 1.5 Cell SRF Gun (from TESLA Cavity)
  - Tune Antenna Penetration (Example: $L = 45$ mm)

$$Q_{\text{ext}}$$

Sensitivity = $-2.3 \times 10^6 / \text{mm}$

$Q_{\text{Target}} = 10^7$

$P$ mm

-7.12 mm
Numerical Results

- Fields along the cavity axis

\[ \mathcal{R}\left[ E_x \right] \, \frac{V}{m} \]

- \( L = 45 \text{ mm}, P = -7.12 \text{ mm} \)
- \( L = 55 \text{ mm}, P = -2.13 \text{ mm} \)
- \( L = 65 \text{ mm}, P = 3.14 \text{ mm} \)
- \( L = 75 \text{ mm}, P = 9.16 \text{ mm} \)
Numerical Results

- Fields along the cavity axis

\[ \frac{\mathcal{S}[c_0 B_y]}{V/m} \]

L = 75 mm, P = 9.16 mm
L = 65 mm, P = 3.14 mm
L = 55 mm, P = -2.13 mm
L = 45 mm, P = -7.12 mm

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Numerical Results

- Fields along the cavity axis

\[
\Re \left[ \frac{E_z}{V/m} \right]
\]

- L = 45 mm, P = -7.12 mm
- L = 55 mm, P = -2.13 mm
- L = 65 mm, P = 3.14 mm
- L = 75 mm, P = 9.16 mm
Numerical Results

- HOM Coupler Variations

0x HOM

1x HOM

2x HOM
Numerical Results

- HOM Coupler Variations

![Diagram showing numerical results for monopole, dipole, and quadrupole HOM coupler variations.](image)
Numerical Results

- HOM Coupler Variations (zoom)
Outline

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  - Pickup antenna as a field probe

▪ Numerical results
  - Electromagnetic fields along the cavity axis
  - Electromagnetic fields in the backplane of the half cell

▪ Summary / Outlook
1.5 Cell Gun Cavity with Field Probe

- Probe
- Back Plane
- Beam Pipe
- $R_p = 70 \text{ mm}$

Info: A symmetric mesh is generated by meshing only a quarter of the model and assembling the full mesh in an additional processing step.
Numerical Modeling

- 1.5 Cell Gun Cavity with Field Probe

- Three half cells of a TESLA Cavity
- Mesh Refinement for Kirchhoff-Evaluation
- Beam Pipe
- Back Plane
1.5 Cell Gun Cavity with Field Probe

- Three half cells of a TESLA Cavity
- Mesh Refinement for Kirchhoff-Evaluation
- Beam Pipe
- Back Plane
Numerical Modeling

- Field Probe Parameter

- $D_{po} = 4 \text{ mm}$
  Inside diameter of the outer conductor

- $R = 1 \text{ mm}$
  Blending

- $D_{pi} = 1.65 \text{ mm}$
  Outside diameter of the inner conductor

- $Z_{p} = 4 \text{ mm}$
  Antenna penetration

Naming convention adopted from Alexey Sulimov, “SRF Gun Simulations of Probe”, October 12, 2018
Numerical Modeling

- Field Probe Mesh

Cavity Region

Waveguide Port

Pickup Antenna

Mesh Refinement Region
Numerical Modeling

- 1.5 Cell Gun Cavity with Field Probe

Mesh Distribution Beam Pipe

Mesh Distribution Backplane
Numerical Modeling

1.5 Cell Gun Cavity with Field Probe

Mesh Distribution Beam Pipe

Mesh Distribution Backplane
Numerical Modeling

- Mesh Distribution Backplane

\[ R_p = 70 \text{ mm} \]
Numerical Results

- External Quality Factor

\[ Q_{\text{ext}} \]

\[ P_{\text{port}} = 124 \text{ mW} \]

\[ P_{\text{port}} = 1.4 \text{ W} \]

\[ P_{\text{port}} = 15 \text{ W} \]

\[ P_{\text{port}} = 154 \text{ W} \]

\[ P_{\text{port}} = 1.27 \text{ kW} \]

Scaling:

\[ E_{\text{Cathode}} = 40 \text{ MV/m} \]

\[ R_p = 70 \text{ mm} \]
Numerical Results

• Electric Field Strength

\[ R_p = 70 \text{ mm} \]
Numerical Results

- Electric Field Strength

\[ R_p = 70 \text{ mm} \]
Numerical Results

- Electric Field Strength

\[ |\vec{E}| \]

View from inside the cavity onto the backplane

\[ R_p = 70 \text{ mm} \]
Numerical Results

- Electric Field Strength

\[ \frac{|\mathbf{E}|}{V/m} \]

\[ r \text{ mm} \]

\[ \text{Abs}(E) \]

\[ R_p = 70 \text{ mm} \]
Numerical Results

- Electric Field Strength

\[ R_p = 70 \text{ mm} \]
Numerical Results

- Electric Field Strength

$R_p = 70 \text{ mm}$
Numerical Results

- Electric Field Strength

\[
\frac{|\vec{E}|}{V/m} = 70 \text{ mm}
\]
Numerical Results

• Electric Field Strength

\[ \frac{|\vec{E}|}{\text{V/m}} \]

Comparison (gray dots):
Scaled electrostatic solution

\[ R_p = 70 \text{ mm} \]
Numerical Results

- Magnetic Flux Density

\[ R_p = 70 \text{ mm} \]
Numerical Results

- Magnetic Flux Density

\[ R_p = 70 \text{ mm} \]
Numerical Results

- Magnetic Flux Density

\[ c_0 |\vec{B}| \]

\[ R_p = 70 \text{ mm} \]
Numerical Results

- Magnetic Flux Density

\[ \frac{c_0|\vec{B}|}{V/m} \]

\[ r \text{ mm} \]

Abs(cB)

\[ R_p = 70 \text{ mm} \]
Numerical Results

- Magnetic Flux Density

\[ c_0 | \vec{B} | \]

\[ R_p = 70 \text{ mm} \]
Numerical Results

- Magnetic Flux Density

\[ c_0 | \vec{B} | \]

\[ R_p = 70 \text{ mm} \]
Numerical Results

- Magnetic Flux Density

\[ \frac{c_0 |\vec{B}|}{V/m} \]

![Graph showing magnetic flux density with \( R_p = 70 \text{ mm} \)]
Numerical Results

- Magnetic Flux Density

\[ c_0 |\vec{B}| \]

\[ \frac{V}{m} \]

\[ R_p = 70 \text{ mm} \]

Comparison (gray dots): Scaled magnetostatic solution
Numerical Results

- Fields along the cavity axis

\[ \frac{\mathcal{R}[E_{x'}]}{V/m} \]

- \( R_p = 50 \text{ mm} \)
- \( R_p = 60 \text{ mm} \)
- \( R_p = 70 \text{ mm} \)
- \( R_p = 80 \text{ mm} \)
- \( R_p = 90 \text{ mm} \)
Numerical Results

- Fields along the cavity axis

\[ \frac{\ImaginaryPart[c_0 B_y]}{V/m} \]

- \( R_p = 50 \text{ mm} \)
- \( R_p = 60 \text{ mm} \)
- \( R_p = 70 \text{ mm} \)
- \( R_p = 80 \text{ mm} \)
- \( R_p = 90 \text{ mm} \)
Numerical Results

- Fields along the cavity axis

\[ \frac{\Re[ E_{z'}]}{V/m} \]

\[ \text{Re}(E_{z'}) \]

- \( R_p = 50 \text{ mm} \)
- \( R_p = 60 \text{ mm} \)
- \( R_p = 70 \text{ mm} \)
- \( R_p = 80 \text{ mm} \)
- \( R_p = 90 \text{ mm} \)
Summary / Outlook

▪ Summary
  - Fundamental input power coupler
    The desired quality factor can be obtained with less serious coupler fields on the axis using a larger distance from the coupler to the cavity.
  - Pickup antenna as a field probe
    A drilled hole in the backplane disturbs the induced current distribution such that locally higher magnetic fields can be observed.

▪ Outlook
  - Further parameter studies to examine?
  - Export a field map around the axis.