Building a Second Harmonic Radio Frequency Cavity for the Booster

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Outline

1. Radio Frequency Cavity Basics
2. Perpendicular Cavity Tuning
3. Comparison Between Real and Model Cavity
4. Calculating Permeability
5. Power Amplifier Basics
6. Building a Temperature Probe
Radio Frequency (RF) Basics

- Short
- Outer Conductor
- Accelerating Gap
- Inner Conductor
- B-Field
- E-Field

Beamline
Tuning the Cavity

• What do we do when the beam speeds up??

\[ v = \frac{c}{\mu \epsilon} \]

\[ \frac{\lambda}{4} \omega = \frac{c}{\mu \epsilon} \]

• Changing \( \mu \) changes the resonant frequency of the cavity!

\( v \): speed of light in medium
\( c \): speed of light in vacuum
\( \mu \): permeability
\( \epsilon \): permittivity
\( \lambda \): wavelength
\( \omega \): angular frequency
Perpendicular Biased Tuning

Solenoid

Outer Conductor

Ferrite Rings

Inner Conductor
Why Second Harmonic Cavity?

Use wave physics to create a more square wave for injection.

A rectangular bucket has larger area and reduces space charge effects.

Phase-Space plots from C. Y. Tan.
Why We Want a Model

• Designing a new cavity
  – Perpendicular Biased
  – Second Harmonic (76-106 MHz)

• Want to study the cavity
  – Q-Value
  – Shunt Impedance
  – Higher Order Modes

• Small solenoid means model has different dimensions in ferrite section
Real and Model Cavity Cross-Section

Cavity Designs Courtesy of Gennady Romanov and Kevin Dule
Poisson Superfish Simulations (LANL)

- Investigating
  - Change in dimensions
  - Fundamental frequency
  - Change in $\mu$
  - Difference between Real and Model

Real Cavity 438.89 MHz 5/4 $\lambda$ Resonance

High Electric Field at Accelerating Gap
Ferrite Permeability Study

- Measured: Q-value, Resonant Frequency

\[ \mu = \mu' - i \mu'' \]

Tuning parameter

Lossy component

\[ \mu' = \frac{1}{\varepsilon} \left[ \frac{c}{4\ell f} \right]^2 \]

\[ \mu'' = \left( \frac{1}{Q} - 1 \times 10^{-4} \right) \mu' - F(f, \text{Dim.}) \]

Function of frequency and cavity dimensions
Calculating permeability

Real $\mu''$ experiment and calculations by Yuri Terechkine and Gennady Romanov

$\mu''$ as a function of $\mu'$

- Real $\mu''$
- Calculation
- Algebraic $\mu''$
- Approximation

106 MHz
76 MHz
Power Amplifier Basics

Existing 53 MHz Power Amplifier

76 MHz Power Amplifier Design

Difference is in load position and resonator shape
Power Dissipation to Temperature

Specific Heat Equation

\[ \Delta T = \frac{Q}{mc} \]

- Using the rate of water flow in the cooling solve for \( mc \)

- Power is the rate of change of energy \( \frac{dQ}{dt} \)

T: Temperature  
Q: Heat Added  
m: Mass  
c: Specific Heat  

https://xkcd.com/643/
Current State of Electronics

- RTD probe readout electronics complete
- Troubleshooting complete

Conclusions

• Comparison study of real and model cavity with Superfish
• Permeability study of the ferrite
• Power Amplifier
  RTD electronics complete

Future Work

- Assembly of physical model cavity
- 76 MHz Power Amplifier testing
- Study higher order modes in the model cavity
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