X-band Microwave Accelerator Cavity

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Background

- Microwave or radio frequency (RF) accelerating cavities are driven by an input signal which induces a time-varying electric field in order to accelerate a beam of charged particles.

- The purpose of this project was to establish the infrastructure to design and manufacture these accelerator cavities at the University of Maryland.

The engineering needed for particle physics

Fabricated in the IREAP machine shop
Design

• Cavity should be designed to operate in the **X-band frequency** range which spans from **8 – 12 GHz**
• Resonance modes were first calculated analytically for a cylindrical cavity
• Once there was **agreement between analytic methods and ANSYS simulation** results, the cavity design was refined
Design

• Analytic methods
  • LC lumped circuit analogy
  • Maxwell’s equations with Bessel functions
  • Balian-Bloch formula

<table>
<thead>
<tr>
<th>Cavity 5</th>
<th>6/14/17</th>
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<tbody>
<tr>
<td>Input</td>
<td>LC</td>
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<tr>
<td>100</td>
<td>w (rad/s)</td>
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<tr>
<td>5</td>
<td>10.95E+9</td>
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Design

• A simple **reentrant cavity** design was created and tested using **ANSYS HFSS Eigenmode** and **Drivenmodal** simulations

• Several iterations of the cavity design were made before one was chosen to be manufactured

Simulation

• The cavity was designed to operate in its $\text{TM}_{02}$ resonance mode
• The frequency of operation in simulation was found to be $12.713 \, \text{GHz}$
Simulation

• In simulation the cavity, beam tube, and waveguide were modeled as vacuum within a block of copper material
Manufacturing

• A **3D printed model** of the cavity was created shortly after the design was finished.

• The model was also used to judge tool clearance before the aluminum model was constructed.

• The first cavity was machined out of two aluminum disks using the **CNC lathe and CNC mill** in the IREAP machine shop.
Manufacturing

- Tool path
- Material
Testing

• The aluminum cavity was tested with a network analyzer to find the resonant frequency and S11 value at resonance
• A bead pull device was also made and used to test the cavity
Conclusion and Future Work

• The resonant frequency of the physical model was found to be \textbf{shifted 0.116 GHz higher} than the simulation

• Attention should be focused on \textbf{better coupling between the waveguide and cavity}

• In the future a copper cavity will be fabricated and tested

• \textbf{Multi-cell accelerator designs} will be the focus of future work