PXIE MEBT 200Ω Kicker
Mechanical Design

A. Chen, P. Jones, G. Saewert, A. Shemyakin
Outline

• Specification & requirement
  o Tolerances
  o Cooling
  o vacuum

• Mechanical Design
  o Mechanical
  o Material choice
  o Vacuum seals

• Analyses
  Thermal/cooling

• Summary
**Requirement**

**Function Requirement (mechanical):**
- Insert Length (flange-to-flange): 650 mm
- Effective electromagnetic length: 500 mm
- Vertical gap:
  - 16 mm±0.2 between opposite electrodes
  - 13 mm±0.2 in protection electrode
- Protection electrodes
- Temperature monitoring

**Vacuum:**
- Self-sustain better than 1E-7 torr
- UHV compatible
- Low particulate practice?

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# Helix Specifications

<table>
<thead>
<tr>
<th>Item</th>
<th>Parameter</th>
<th>Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>#13 flat magnet wire dimensions, nom. ((W \times t))</td>
<td>.105 x .042</td>
<td>inches</td>
</tr>
<tr>
<td>2</td>
<td>Pitch ((P)). Tolerance of each turn location is with respect to the reference (one end of the ceramic spacer).</td>
<td>.376 ± .002 ((9.500 ± .050))</td>
<td>inches (mm)</td>
</tr>
<tr>
<td>3</td>
<td>Helix wire height above ground in the central section ((h))</td>
<td>.218 ± .002 ((5.537 ± .050))</td>
<td>inches (mm)</td>
</tr>
<tr>
<td>4</td>
<td>Copper tube central section OD (the helix “ground”)</td>
<td>1.116 ± .003 ((28.35 ± .1))</td>
<td>inches (mm)</td>
</tr>
<tr>
<td>5</td>
<td>Central section tube length having the OD value stated in item 4</td>
<td>18.988 ± .01 ((48.23 ± .03))</td>
<td>inches (cm)</td>
</tr>
<tr>
<td>6</td>
<td>Copper tube stepped-end OD at both ends, see item 4 in Section 1.2 and Figure 2</td>
<td>.800 ± .002 ((20.32 ± .050))</td>
<td>inches (mm)</td>
</tr>
<tr>
<td>7</td>
<td>Helix length, measured between wire centers where wire is clamped at both ends (52.5 turns)</td>
<td>19.74 ((501.4)) inches</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Approximate Microstrip wire total length, 52.5 turns</td>
<td>263 ((6.68)) inches</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Helix diameter, microstrip wire center-to-center</td>
<td>1.594 inches</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Electrode dimensions (copper or bronze)</td>
<td>.240 ± .002 x .7874 ± .002 x .020 ((6.096 ± .05 x 20 ± .05 x .508))</td>
<td>inches (mm)</td>
</tr>
<tr>
<td>11</td>
<td>Ceramic spacer thickness, approx. (thickness is 1/8 in. nom.)</td>
<td>.135 inches</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Ceramic spacer dielectric constant</td>
<td>5.5 ± .2</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Ceramic spacer thermal conductivity, minimum</td>
<td>50 (\text{W/m/K})</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Space between facing helix electrode surfaces of the two parallel helices</td>
<td>.630 ± .02 ((16 ± .5)) inches (mm)</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Minimum space between helix wire and enclosure surface—top, bottom and sides</td>
<td>2.5 ((63.5)) inches (mm)</td>
<td></td>
</tr>
</tbody>
</table>
### 200 Ohm Interconnecting Microstrip Transmission Lines

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Specification</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>Signal wire size</td>
<td>#16 solid round wire (dia. = .051 in.)</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Signal wire height above ground, wire center to ground surface</td>
<td>.350 ± .005 (8.89 ± .12)</td>
<td>inches (mm)</td>
</tr>
<tr>
<td>18</td>
<td>Ground strip, copper shim stock; width x thickness</td>
<td>.75 ± .01 x .010 (19 ± .12 x .254)</td>
<td>inches (mm)</td>
</tr>
<tr>
<td>19</td>
<td>Minimum space between microstrip signal wire and enclosure wall</td>
<td>1.0 (25.4)</td>
<td>inches (mm)</td>
</tr>
</tbody>
</table>
1. 6W electrical power dissipates along the helix.
2. 40W steady state beam absorption
3. 20J of accidental beam loss
Mechanical Design

FT of Protection electrodes

Protection Electrode (2)

Beam

Cooling FT

Pump Port

ViewPort (3)

Power FT(4)
Ground Tube with Brazed cooling tubing

Positioning Groves

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Ground tube with Ceramic Spacers, (Epoxy)

Ceramic Spacers:
Photoveel II (machinable AlN)
12 identical mid pieces
8 unique end pieces
Positioning Ceramic Spacers with Epoxy

End Disk

Ring Clamps

Ring Clamp
Helix

Positioning Key (Ceramic)

Macor Ceramic End Stands & Clamps

Project X

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Laser Welding Setup

Positioning electrodes on fixture

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Positioning Helix on fixture
Adding the Strongback
Laser Welding Setup

Reading for Laser welding

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Helix with Electrodes

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Laser Welded Electrode

2 point laser welding 0.02" dia.

Vacuum grade epoxy
Two Helixes on Base Plate

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Measurements of the helix temperature

- Suggestion: use a thermal imager, available at EE support (Bob Brooker)
  - Fluke Ti32
  - Temperature range -20°C to +600°C; spectral range 8 to 14 µm
- Requires a ZnSe window (0.55 – 18 µm)
  - For example, from CeramTec
- Check of calibration
  - Heat up the helix in vacuum with a DC current, using the helix resistance as indication of temperature
  - Measure with imager
  - Repeat with RF heating
Bench Test Setup

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# Materials choices

**Cu, (OFHC):** ground tube, excellent electrical and thermal conductivity  
**Stainless 304: Base Plates, CF flanges**  
**Alu 6061-T6: for vacuum box, EASY to machine**

<table>
<thead>
<tr>
<th></th>
<th>Thermal conductivity (w/m.k)</th>
<th>Thermal Expansion coefficient ($10^{-6}$/°C)</th>
<th>Electrically conductivity ($10^{-6}$ Ω.cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFHC</td>
<td>385</td>
<td>17.3</td>
<td>1.7</td>
</tr>
<tr>
<td>6061-T6</td>
<td>167</td>
<td>23.6</td>
<td>4.0</td>
</tr>
<tr>
<td>SS 304</td>
<td>16.2</td>
<td>17.0</td>
<td>72</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th></th>
<th>Photoveel II (helix spacers)</th>
<th>Macor (stands)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General Properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density (g/cm³)</td>
<td>2.56</td>
<td>2.52</td>
</tr>
<tr>
<td>Water Absorption (%)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Mechanical Properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bending Strength (MPa)</td>
<td>440</td>
<td>90</td>
</tr>
<tr>
<td>Young's Modulus (GPa)</td>
<td>157</td>
<td>67</td>
</tr>
<tr>
<td>Vickers Hardness (GPa)</td>
<td>2.3</td>
<td>4.5</td>
</tr>
<tr>
<td><strong>Thermal Properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. Operating Temperature (°C)</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>(In nonoxidizing atmosphere)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coefficient of Thermal Expansion (1/° C ×10⁻⁶)</td>
<td>1.4 (RT~400° C)</td>
<td>6.3-9.7</td>
</tr>
<tr>
<td>Coefficient of Thermal Conductivity (W/m ×K)</td>
<td>50</td>
<td>1.46</td>
</tr>
<tr>
<td><strong>Electrical Properties</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume Resistivity 25° C</td>
<td>2.2 × 10¹⁵</td>
<td>&gt;10¹⁷</td>
</tr>
<tr>
<td>300° C</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Dielectric Constant 10GHz</td>
<td>5.5</td>
<td>6.03</td>
</tr>
<tr>
<td>Dielectric Loss (×10⁻⁴)</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Q Factor (×10⁴)</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Dielectric Breakdown Voltage (KV/mm)</td>
<td>35</td>
<td>40</td>
</tr>
</tbody>
</table>
• **Seals:**
  o metal seals at feedthroughs on SS base plate
  o Brazing and welding on water cooling line
  o O-Ring on Al Vacuum Box with total permeation 8e-7 torr.l/s
• 4 ½” Port for IP 75 l/s Pumps to achieve 2e-8 torr without beam
• UHV handling with cautiousness of Low Particulate environment
Thermal Estimates

- Q = 46 watt (40 beam + 6 electrical)
- Over 52 (electrodes + turns)
  Heat each turn \( q = \frac{46}{52} = 0.88 \text{ watt} \)
- \( \Delta T = 10 \degree C \) for Photoveel II
  ~340 \degree C for Macor
- Instant temperature rise due to 20J beam loss
  \( \Delta T = 3.7 \degree C \)
- Water temperature rise 1.8\degree C with 0.1 gpm flow rate
Summary

1) The requirement can be met
2) Major modeling/assembly was done
2) Finish drawings for fabrication
   - Adding lifting: four locations on base plate for 3/8 eyebolts
   - Adding alignment sockets: 4 places
   - Detailing the cooling circuit
   - Detailing the wire termination
   - Detailing the supporting
   - Detail protection electrode circuit

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