CEPC Klystron Development

Zusheng Zhou
On behalf of High Efficiency RF Source R&D Collaboration
Institute of High Energy Physics
Sep. 26, 2018,
HKUST, Hong Kong
Outline

◆ Strategy and plan
  • 650MHz/800kW meets CEPC project demands
  • >80% efficiency

◆ Progress of 1st prototype development
  • Beam dynamic, beam optics and cooling system
  • Mechanical design, infrastructure preparation

◆ Design progress on high efficiency klystron
  • Optimization using different methods
  • Multi-Beam Klystron consideration
### Strategy and plan (2016 to 2021)

**3 or more klystron prototypes**

<table>
<thead>
<tr>
<th>Year</th>
<th>Prototypes</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
</tr>
<tr>
<td>2017</td>
<td>4&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>2018</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
</tr>
<tr>
<td>2019</td>
<td>5&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>2020</td>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
</tr>
<tr>
<td>2021</td>
<td>6&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

- **Step 1**: 1<sup>st</sup> prototype
- **Step 2**: 2<sup>nd</sup> and 5<sup>th</sup> prototypes
- **Step 3**: 3<sup>rd</sup> and 6<sup>th</sup> prototypes
- **More**: Beyond the scope of the chart
Progress of 1\textsuperscript{st} prototype development

Conventional method based on 2nd harmonic cavity in order to investigate the design and manufacture technologies for high power CW klystron.

<table>
<thead>
<tr>
<th>Main parameters</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freq. (MHz)</td>
<td>650</td>
</tr>
<tr>
<td>Vk (kV)</td>
<td>-81.5</td>
</tr>
<tr>
<td>Ik (A)</td>
<td>15.1</td>
</tr>
<tr>
<td>Perveance ((\mu)P)</td>
<td>0.65</td>
</tr>
<tr>
<td>Efficiency (%)</td>
<td>&gt;60</td>
</tr>
<tr>
<td>Output power (kW)</td>
<td>800</td>
</tr>
<tr>
<td>1dB bandwidth (MHz)</td>
<td>(\pm 0.5)</td>
</tr>
</tbody>
</table>
Dynamics for 1st tube

1D optimization on the dynamics and cross checked by 2D & 3D

1D AJDISK
73% efficiency

3D CST
65% efficiency

2D EMSYS
68% efficiency
Gun design

Results for beam optics using different codes and thermal-structure analysis using ANSYS

<table>
<thead>
<tr>
<th>Main parameters</th>
<th>DGUN</th>
<th>EGUN</th>
<th>MAGIC2D</th>
<th>CST</th>
<th>Design goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam waist radius (mm)</td>
<td>17.8</td>
<td>17.48</td>
<td>17.48</td>
<td>17.64</td>
<td>17.5</td>
</tr>
<tr>
<td>Perveance (µPerv)</td>
<td>0.64</td>
<td>0.64</td>
<td>0.65</td>
<td>0.64</td>
<td>0.65</td>
</tr>
<tr>
<td>Current density</td>
<td>&lt;0.45</td>
<td>0.39~0.43</td>
<td>0.65</td>
<td>&lt;0.5</td>
<td></td>
</tr>
<tr>
<td>Current uniformity</td>
<td>9.8%</td>
<td></td>
<td></td>
<td></td>
<td>&lt;10%</td>
</tr>
</tbody>
</table>

Beam optics: Beam profile shows laminar flow, Ripple rate < 5%

Thermal deformation

Electron beam trajectory without RF drive
**Focusing coils**

- Designed by 2D and cross checked by 3D, very good consistency obtained
- 15 regular coils with 1 bucking coil near the gun
Cavity chain and it’s cooling system

- RF design and cooling analysis conducted
- Grooved nose cone for each cavity to suppress the multipacting effect

Cavity chain cooling scheme

Cooling pipes distribution

Temperature distribution
Collector and window

- ~2m long collector to sustain 1.23MW full beam power

>800 kW sustainable CW RF power and <1.05 VSWR @ 650 ± 0.5MHz
Mechanical design progress

• 3D model and 2D drawings are ready for manufacturing

2D drawings

3D model
Infrastructure preparation

- The bid opening date for baking furnace is Thursday and then contract will be signed.
- Construction period is less than 8 month.
- All the procedures for the construction of the plant have been completed.
- Construction period is less than 4 month.
High efficiency design

Schemes of 3 designs

- Scheme 1: Optimize cavity chain by using the same gun as 1st tube
- Scheme 2: With high voltage gun (110 kV/9.1 A), low perveance
- Scheme 3: MBK, 54 kV/20 A electron gun

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Scheme 1</th>
<th>Scheme 2</th>
<th>Scheme 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freq. (MHz)</td>
<td>650</td>
<td>650</td>
<td>650</td>
</tr>
<tr>
<td>Voltage (kV)</td>
<td>81.5</td>
<td>110</td>
<td>54</td>
</tr>
<tr>
<td>Current (A)</td>
<td>15.1</td>
<td>9.1</td>
<td>20 (2.5×8)</td>
</tr>
<tr>
<td>Beam No.</td>
<td>1</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Perveance (µP)</td>
<td>0.65</td>
<td>0.25</td>
<td>1.6 (0.2×8)</td>
</tr>
<tr>
<td>Efficiency (%)</td>
<td>&gt;70</td>
<td>~80</td>
<td>&gt;80</td>
</tr>
<tr>
<td>Power (kW)</td>
<td>800</td>
<td>800</td>
<td>800 (100×8)</td>
</tr>
</tbody>
</table>
Scheme 1

- Same gun with the 1st tube
- Optimization

- 8 CAV/1 2nd harmonic CAV/80%/3.1m
- 10 CAV/2 2nd harmonic CAV/80%/2.9m
- 8 CAV/2 2nd harmonic CAV and 1 3rd harmonic CAV/80%/2.2m
Scheme 2

- Based on CSM, with 2nd and 3rd harmonic cavities
- Better bunching with shorter length
- AJDISK/EMSYS/CST 86%/81%/77%
- Reduce beam aperture and beam size
- KLYC 1D/ KLYC 2D/ EMSYS 82.6%/80.8%/81%
Scheme 3

- Based on CSM, with 2nd and 3rd harmonic cavities
- Perveance is 0.2 µPerv

CSM: 7 CAV / 1.8m / 87.6%
CSM: 8 CAV / 2.4m / 88.5%
Summary

• All drawings of the 1\textsuperscript{st} prototype has finished and it will be processed and manufactured in the machine shop.

• The manufacturing of the 1\textsuperscript{st} prototype will be completed next April because of the delays (from many months) of construction of baking furnace.

• The three different schemes for the high efficiency klystron design are ongoing simultaneously.

• The manufacturing of the 2\textsuperscript{nd} prototype will be started based on the most mature scheme as soon as possible.
Thanks for your attention!