CEPC 650MHz Klystron R&D

Zusheng ZHOU
On behalf of High Efficiency RF Source R&D Collaboration
Institute of High Energy Physics
Jan. 21, 2020
Outline

◆ 1st prototype tube
  • Manufacture completed
  • Conditioning progress

◆ High efficiency design
  • High voltage klystron
  • Multi-beam klystron
1st prototype tube
1st prototype tube

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

Design Parameters

<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 (µP)</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>±0.5</td>
</tr>
</tbody>
</table>

Mechanical design
Components manufacture

Modulator anode
Input coupler
Cooling pipe
Gun welding edge

Cavity body
Cavity nose
Coil
Collector
Gun subassembly

Focusing electrode and support assembly

Modulator anode assembly
Cavity and window components

Input coupler loop  
1st CAV  
2nd CAV  
3rd CAV  
4th CAV  
5th & 6th CAV  
Window
The measured frequency is within design scope.
Collector brazing
Gun processing

Temperature measurement

Gun processing
There is about 3% error between the measurement results and the simulation values. The excitation current of the solenoids will be adjusted to meet the design requirements.
Vacuum-Assy assembly

Component leak test

Cavity assemble

Collector assemble

Final welding

Completed assembly

Final assemble is completed on Oct.19
Prototype bake-out

Bake out is started from Oct.26 and finished on Nov.24.
Prototype bake-out

- Tube temperature (430°C)
- Filament current (30A)
- Vessel pressure (-6Pa)
- Tube Pressure (-8Pa)

Almost one month
Final assembly

- Klystron pinch off
- Lead shield
- Coil installation
- Water jacket installation
- Horizontal placement
- Remove assembly bracket
- Final placement on Dec. 11
Packing and Transportation

Before delivery

Leave factory on Dec.24(10:30)

Packing

Arrived IHEP on Dec.25(21:00)

Loading
Unloading and In place

Unboxing and unloading

Lifting

In place at 2nd floor of building 1 on Dec. 26
**Test condition preparation**

- High voltage power supply: ADS project
- High power load: ADS project (400kW max.)

- Interlock and data collection
- Water cooling and waveguide system connection
- LLRF and arc detector

High voltage conditioning is started from this year.
Test condition preparation

Test procedure

① Cathode Low-voltage emission test
② Vacuum treatment and cold voltage conditioning
③ High voltage conditioning
④ RF processing
⑤ Power and stability
Conditioning status

Until Jan.19

① Cathode Low-voltage emission test - FINISHED
② Vacuum treatment and cold voltage conditioning - FINISHED
③ High voltage conditioning - UNDERWAY
④ RF processing
⑤ Power and stability
High efficiency design
High efficiency design

GOAL

Scheme 1: With high voltage gun (110kV~120kV/9.1 A), low perveance

Scheme 2: MBK, 54 kV/20A electron gun

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

- High efficiency design

AJDISK(1D) EFF: 85.6%
KLYC(1D) EFF: 85.6%
EMSYS(2.5D) EFF: 81.4%
CST(3D) EFF (asymmetrical output): 78.2%

The 110kV design is almost finished and 3D efficiency is up to 78.2%. 120kV design is on going and expect higher efficiency.
# Multi-beam klystron

## Parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gun Voltage</td>
<td>kV</td>
<td>54</td>
</tr>
<tr>
<td>Beam number</td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Beam perveance</td>
<td>μP</td>
<td>0.2</td>
</tr>
<tr>
<td>Output power</td>
<td>kW</td>
<td>875</td>
</tr>
<tr>
<td>Gain</td>
<td>dB</td>
<td>44.2</td>
</tr>
<tr>
<td>Efficiency (3-D simulation)</td>
<td>%</td>
<td>80.7</td>
</tr>
</tbody>
</table>

## MBK Length

<table>
<thead>
<tr>
<th>Component</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF interaction</td>
<td>m</td>
<td>1.9</td>
</tr>
<tr>
<td>Gun</td>
<td>m</td>
<td>0.5</td>
</tr>
<tr>
<td>Collector</td>
<td>m</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>m</td>
<td><strong>3.4</strong></td>
</tr>
</tbody>
</table>
**Multi-beam klystron**

- 3-D PIC simulation predicts bandwidth of ±0.8 MHz

MBK bandwidth curve by CST
**Multi-beam klystron**

### Gun design

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>High voltage</td>
<td>kV</td>
<td>54</td>
</tr>
<tr>
<td>Current</td>
<td>A</td>
<td>8*2.5</td>
</tr>
<tr>
<td>Beam waist</td>
<td>mm</td>
<td>7.5</td>
</tr>
<tr>
<td>Filling ratio</td>
<td></td>
<td>0.625</td>
</tr>
</tbody>
</table>

### Electric filed on cavities

5MV/m
Multi-beam klystron

MBK output window design

The output window design is almost completed
## Multi-beam klystron

### Design progress status

<table>
<thead>
<tr>
<th>Design title</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>MBK beam dynamics</td>
<td>Goal 1: output power &gt; 800kW</td>
</tr>
<tr>
<td></td>
<td>Finished</td>
</tr>
<tr>
<td>Design on input and output cavity</td>
<td>Finished</td>
</tr>
<tr>
<td>Gun design</td>
<td>Finished</td>
</tr>
<tr>
<td>Design on output window</td>
<td>Finished</td>
</tr>
<tr>
<td>Coil design</td>
<td>In progress</td>
</tr>
<tr>
<td>MBK collector</td>
<td>In progress</td>
</tr>
</tbody>
</table>

We are fully prepared for future possibility of manufacture.
Summary

• The components machining, brazing, welding and final assembly for 1st prototype are finished in collaboration partner.

• The conditioning and commissioning of 1st prototype is started at the beginning of this year.

• The both schemes for high efficiency design are progressing well.

• The mechanical design for 2nd tube(high efficiency) will be start after completion of design review.

• The design of MBK is fully prepared for next stage.
Thanks for your attention!