# CEPC 650MHz Klystron R&D

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***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

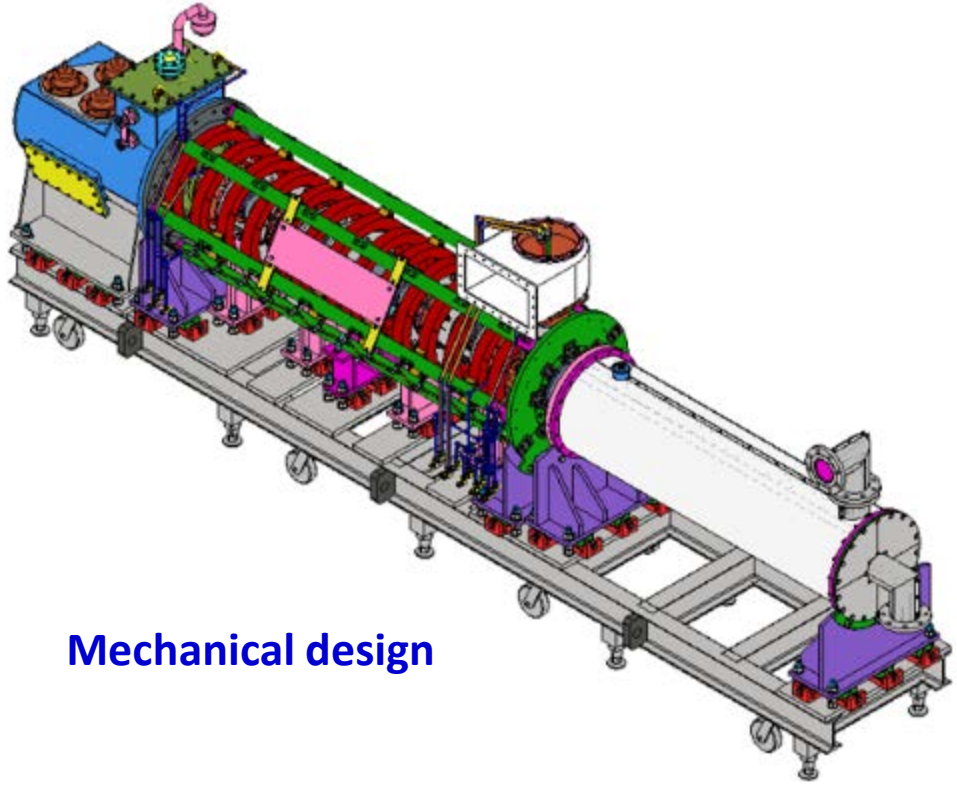
# 1st prototype tube

# 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

| Main parameters | Goal |
|---|---|
| Freq. (MHz) | 650 |
| Vk (kV) | -81.5 |
| Ik (A) | 15.1 |
| Perveance (μP) | 0.65 |
| Efficiency (%) | >60 |
| Output power (kW) | 800 |
| 1dB bandwidth (MHz) | ±0.5 |



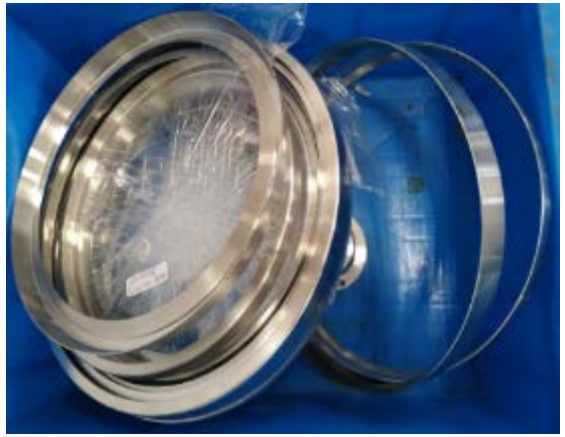
**Mechanical design**

# Components manufacture

Modulator anode

Input coupler

Cooling pipe



Gun welding edge

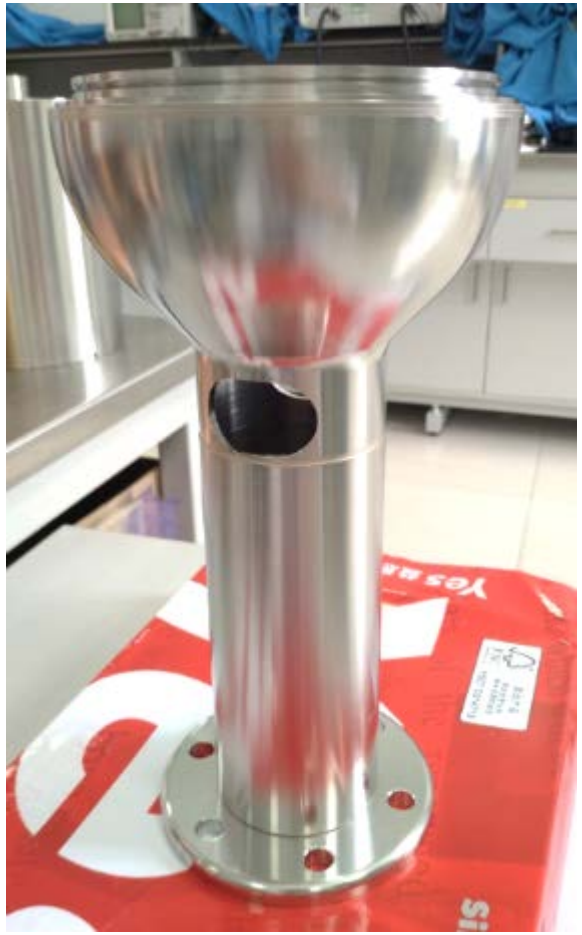
Cavity body

Cavity nose

Coil

Collector

# Gun subassembly



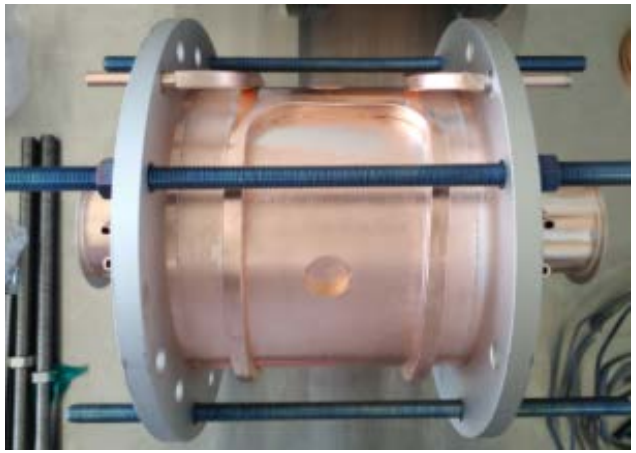
Focusing electrode and support assembly

Modulator anode assembly

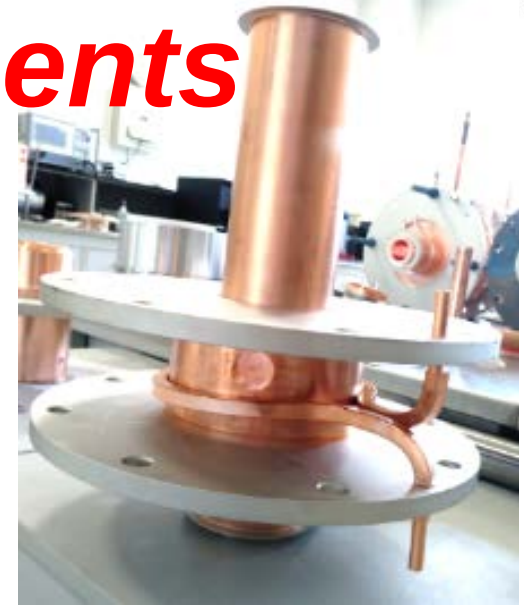
# Cavity and window components

Input coupler loop

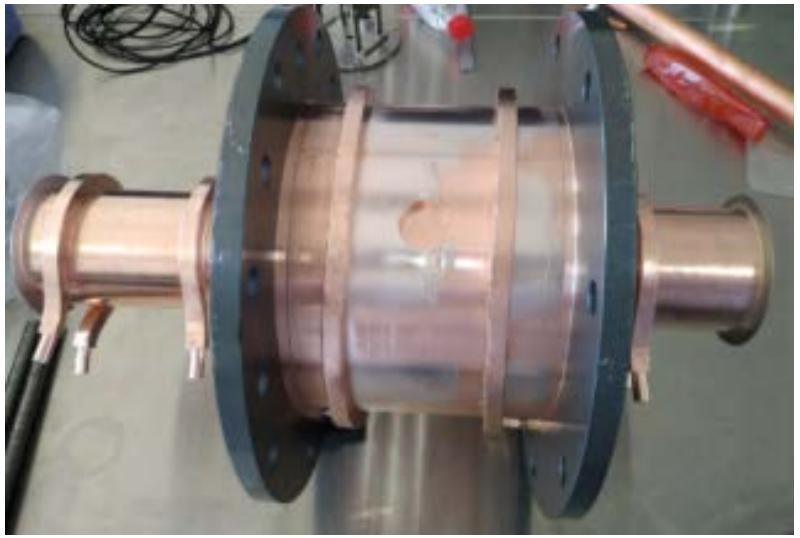
1st CAV



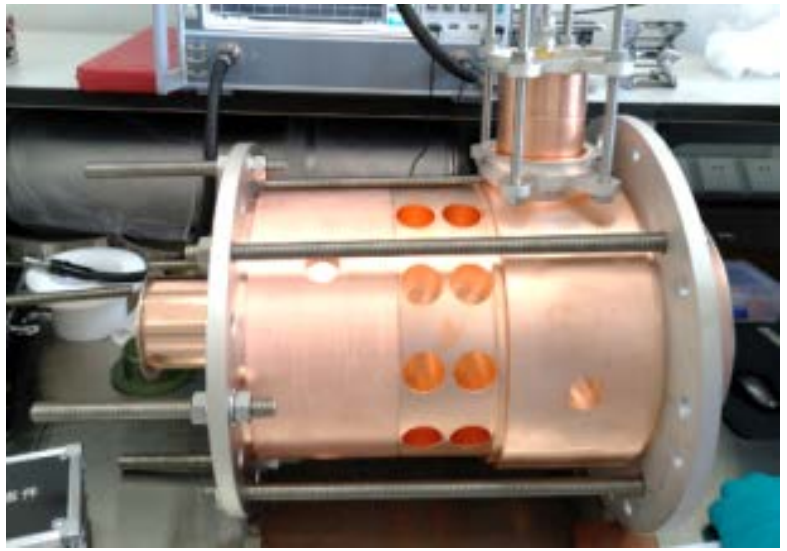
2nd CAV



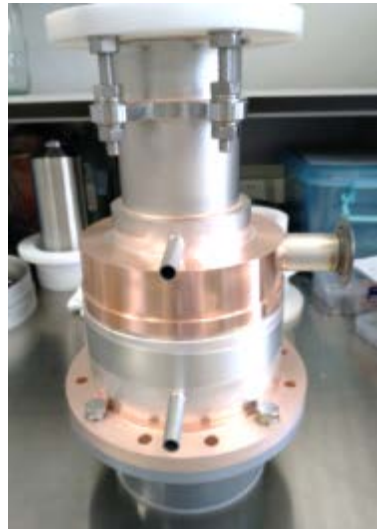
3rd CAV



4th CAV



5th & 6th CAV

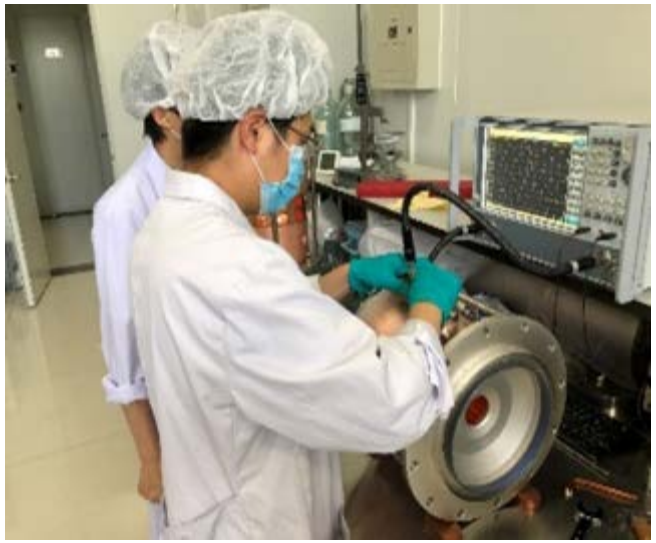


Window

# Cavity brazing and cold test

Cavity brazing

Leak test



Cold test

| Parameters | | 1st | 2nd | 3rd | 4th | 5th | 6th |
|---|---|---|---|---|---|---|---|
| Frequency（MHz） | Design | 650.5 | 649.5 | 1293.5 | 669.2 | 668 | 649.5 |
| | Measure | 650.2 | 649.29 | 1293.1 | 668.98 | 668.68 | 649.15 |
| $Q_e$ | Design | 291.4 | | | | | 67 |
| | Measure | 292.2 | | | | | 69.4 |

The measured frequency is within design scope.

# Collector brazing


Collector brazing

# Gun processing

Temperature measurement

Gun processing

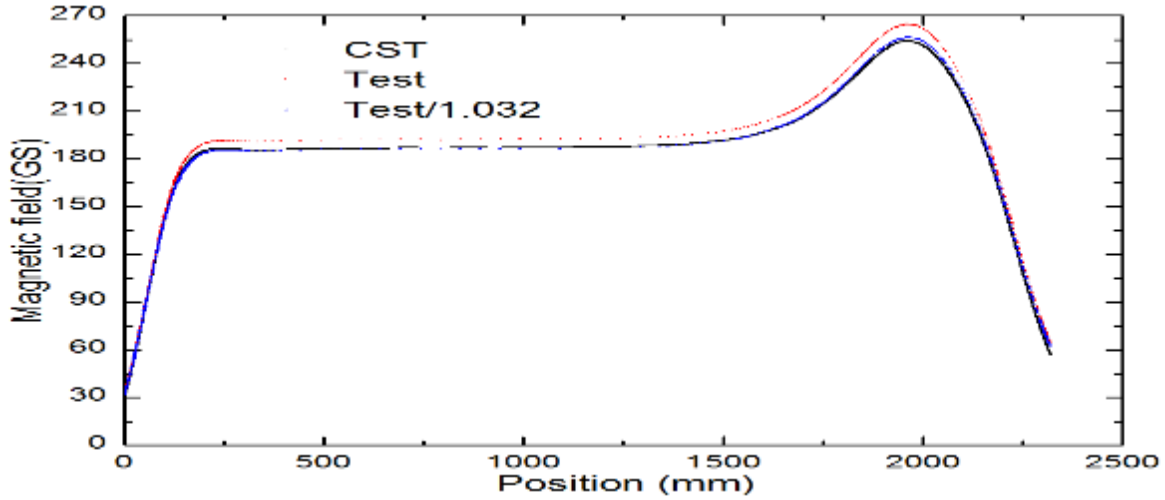
# Auxiliary components

Girder

Oil tank

Coil

Coil measurement




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.

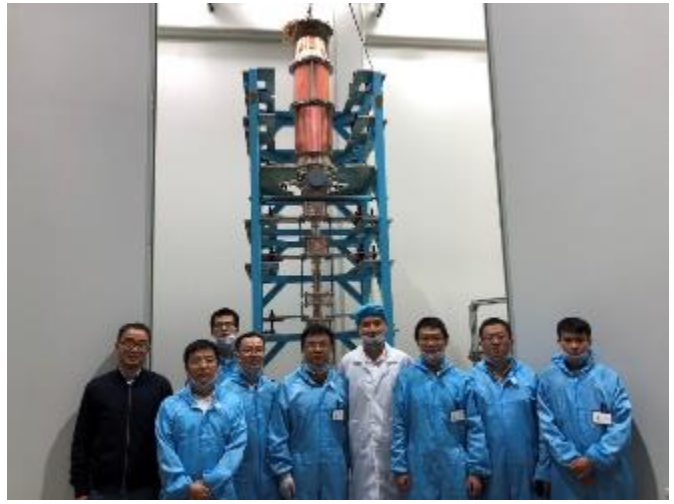
# Vacuum-Assy assembly

Component leak test

Cavity assemble

Collector assemble

Final welding

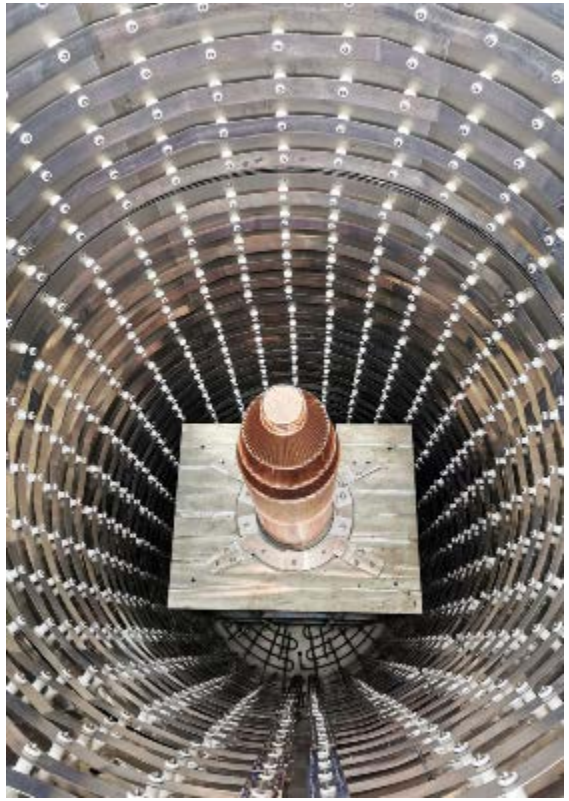


Completed assembly

Final assemble is completed on Oct.19

# Prototype bake-out

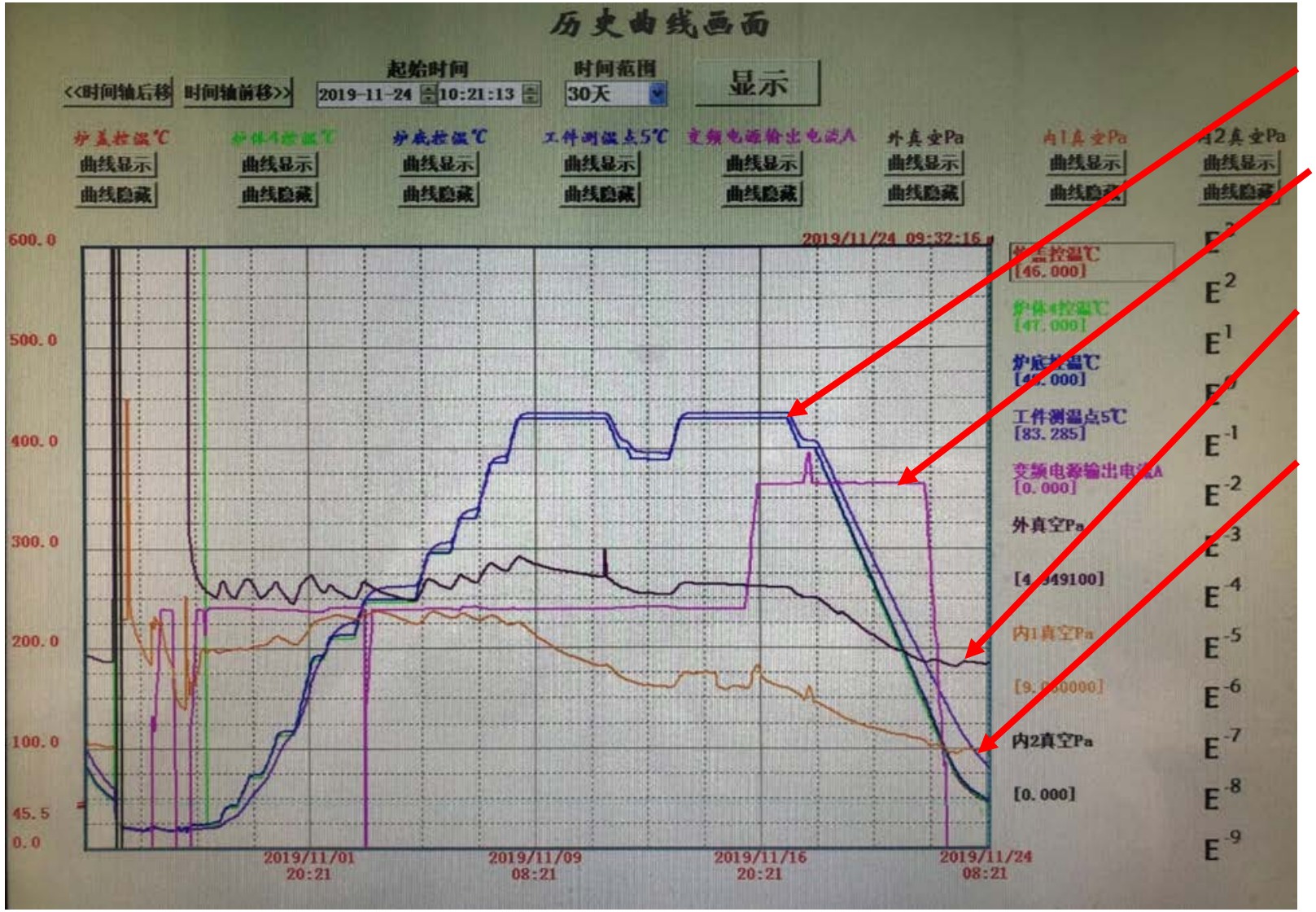
Prototype installation



Top view

**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

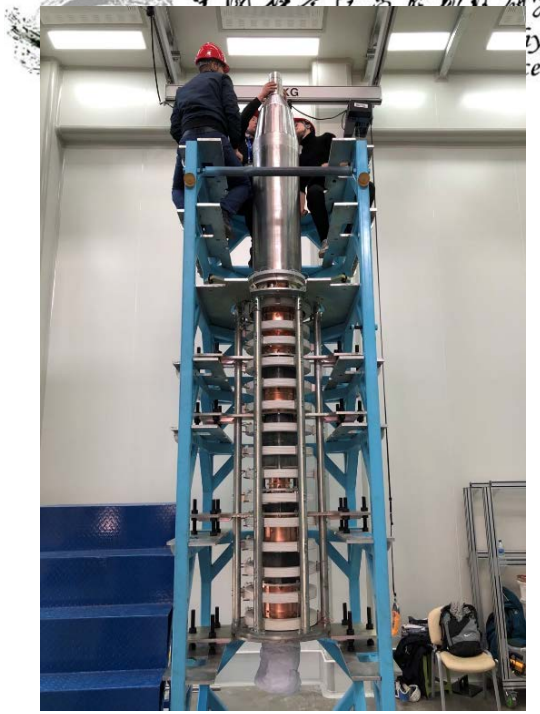
HKUST JOCKEY CLUB
INSTITUTE FOR ADVANCED STUDY

# Final assembly

Klystron pinch off

Lead shield

Coil installation

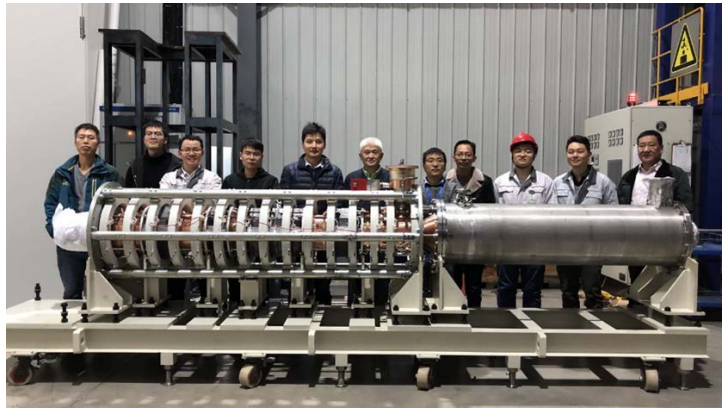


Water jacket installation

Vertical to horizontal

Horizontal placement

Remove assembly bracket



Final placement on Dec. 11

# Packing and Transportation

Before delivery

Packing

Loading

Leave factory on Dec.24(10:30)

Arrived IHEP on Dec.25(21:00)

# 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

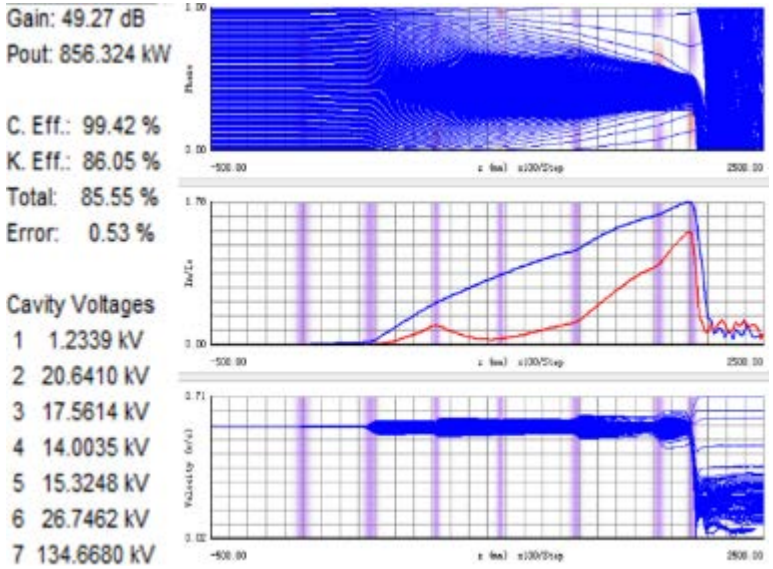
**Scheme 1：With high voltage gun (110kV~120kV/9.1 A), low perveance**

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

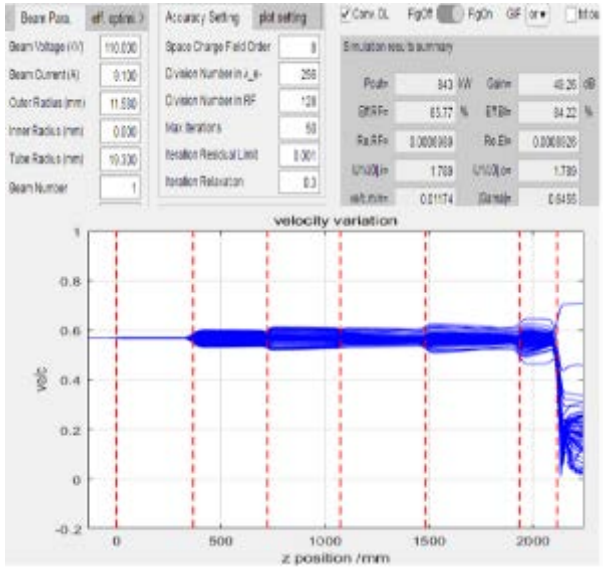
| Parameter | Scheme1 | Scheme2 |
|---|---|---|
| Freq. (MHz) | 650 | 650 |
| Voltage (kV) | 110 | 54 |
| Current (A) | 9.1 | 20(2.5×8) |
| Beam No. | 1 | 8 |
| Perveance (μP) | 0.25 | 1.6(0.2×8) |
| Efficiency (%) | ~80 | >80 |
| Power(kW) | 800 | 800(100×8) |

# High voltage klystron

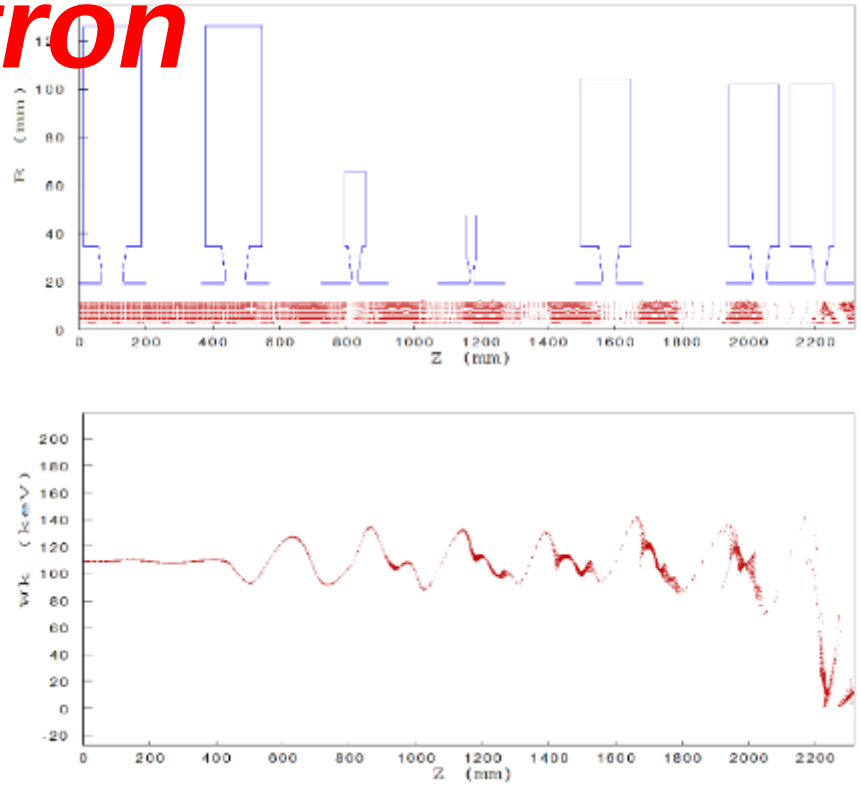
## ■ High efficiency design



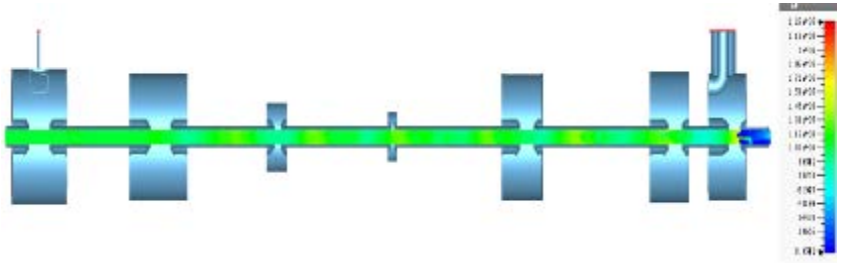

AJDISK(1D) EFF: 85.6%




KLYC(1D) EFF: 85.6%




EMSYS(2.5D) EFF: 81.4%

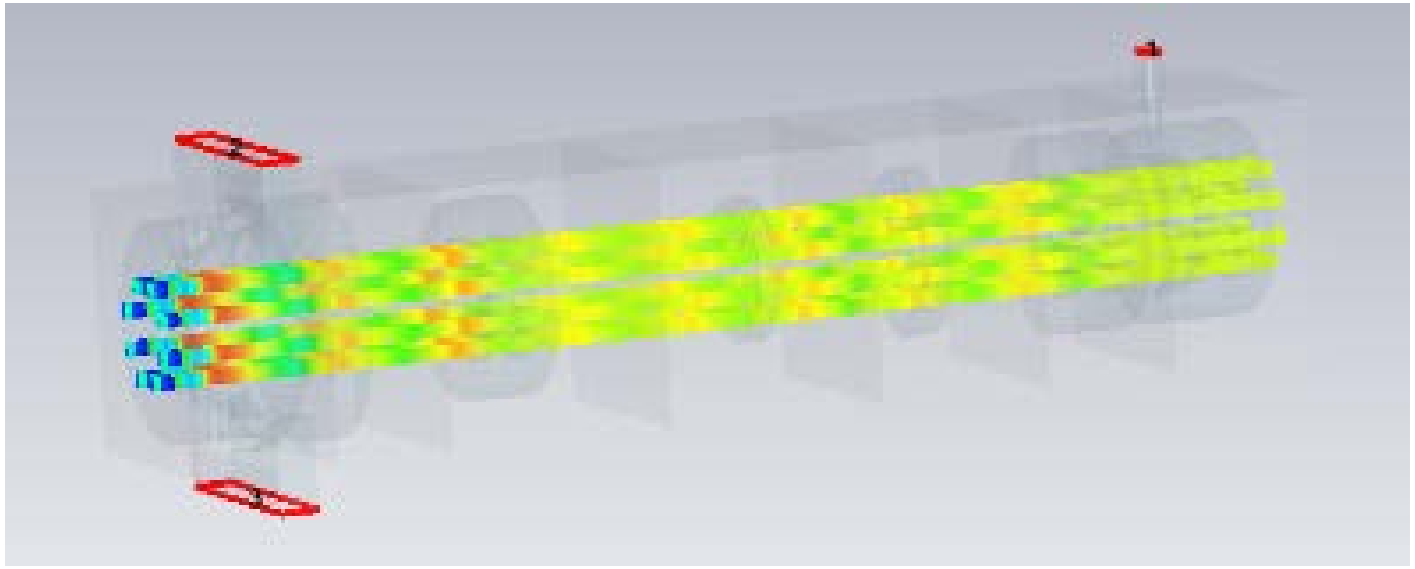


CST(3D) EFF(asymmetrical output): 78.2%

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

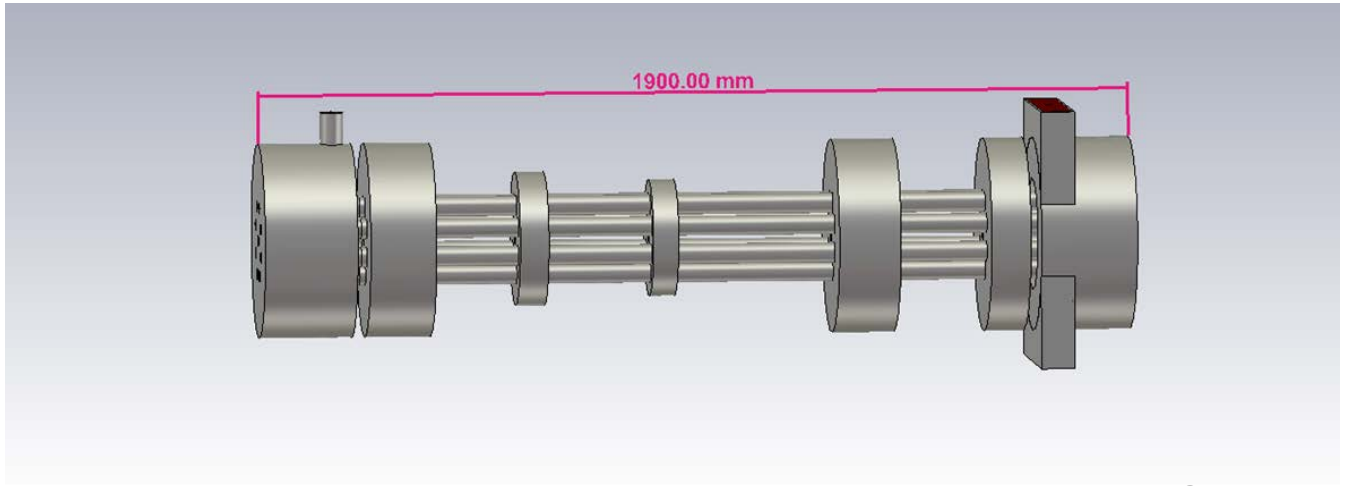
# Multi-beam klystron

| Parameters | Unit | Value |
|---|---|---|
| Gun Voltage | kV | 54 |
| Beam number | | 8 |
| Beam perveance | μP | 0.2 |
| Output power | kW | 875 |
| Gain | dB | 44.2 |
| **Efficiency(3-D simulation)** | **%** | **80.7** |



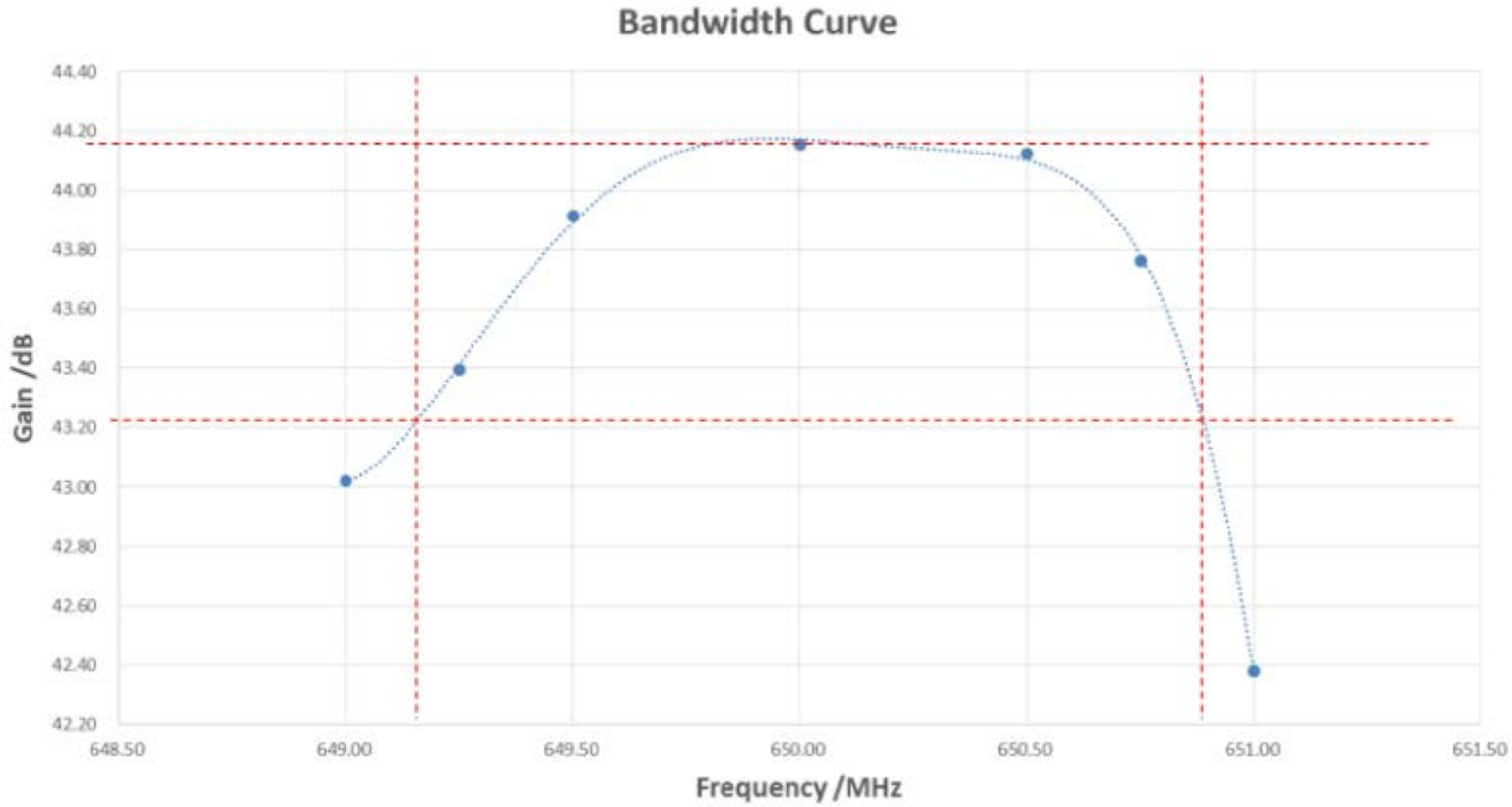
## MBK Length

| Component | Unit | Value |
|---|---|---|
| RF interaction | m | 1.9 |
| Gun | m | 0.5 |
| Collector | m | 1.0 |
| **Total** | **m** | **3.4** |



# Multi-beam klystron

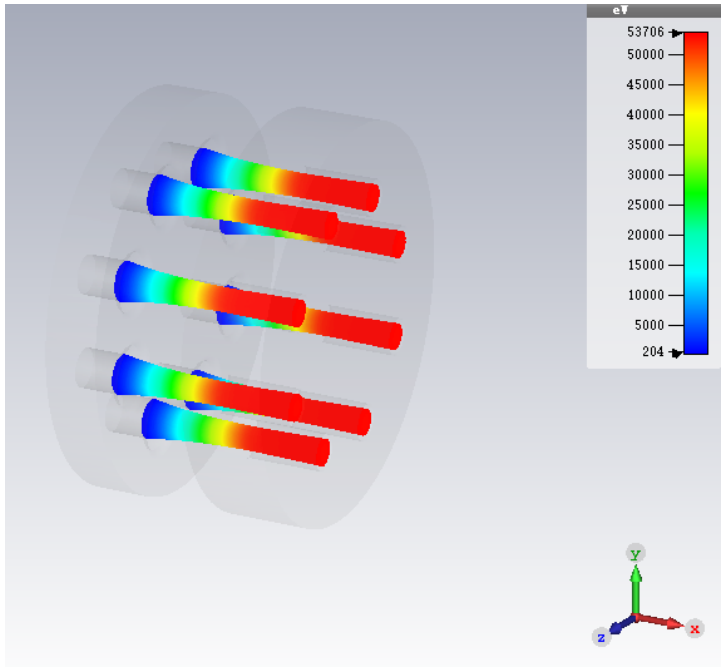
■ *3-D PIC simulation predicts bandwidth of ±0.8 MHz*




MBK bandwidth curve by CST

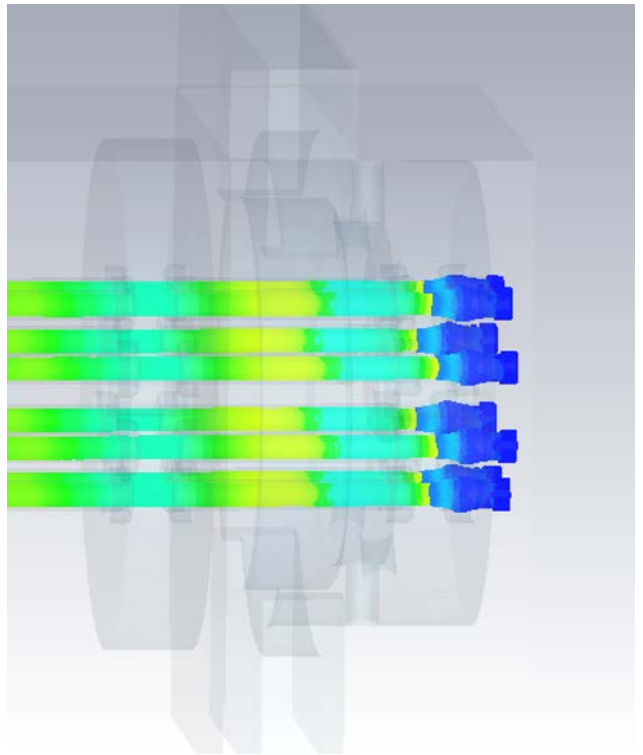
# Multi-beam klystron

## Gun design




| Parameters | Unit | Value |
|---|---|---|
| High voltage | kV | 54 |
| Current | A | 8*2.5 |
| Beam waist | mm | 7.5 |
| Filling ratio | | 0.625 |

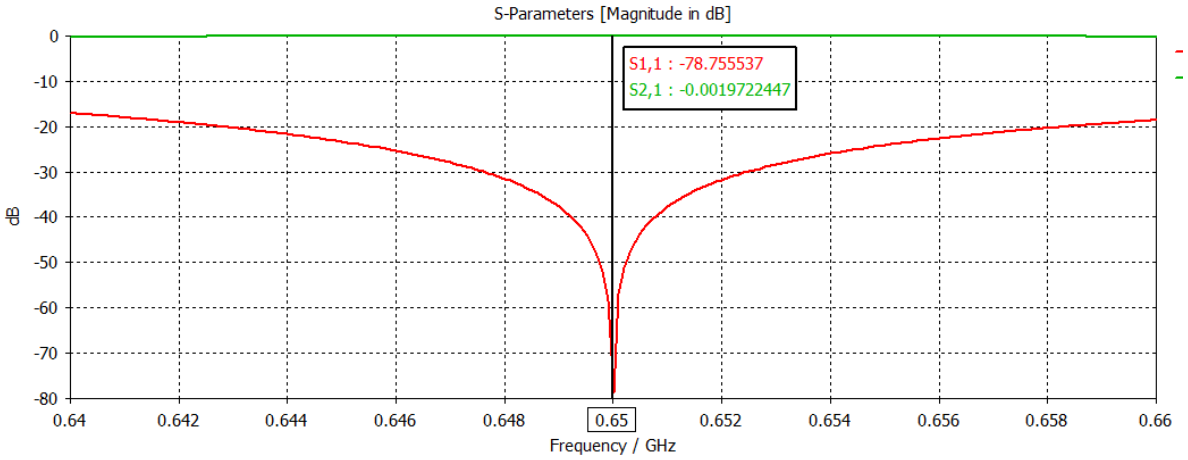
## Electric filed on cavities

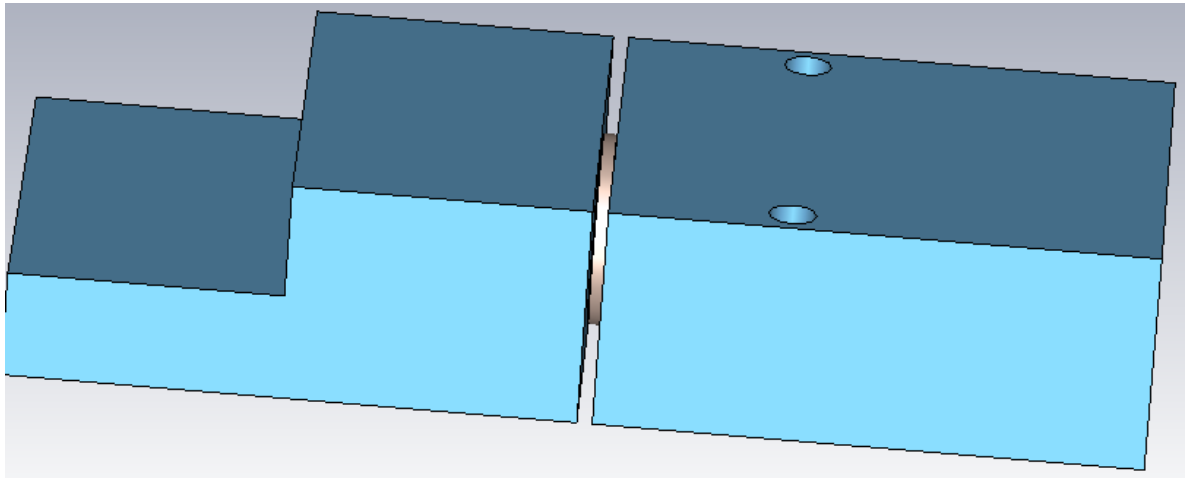


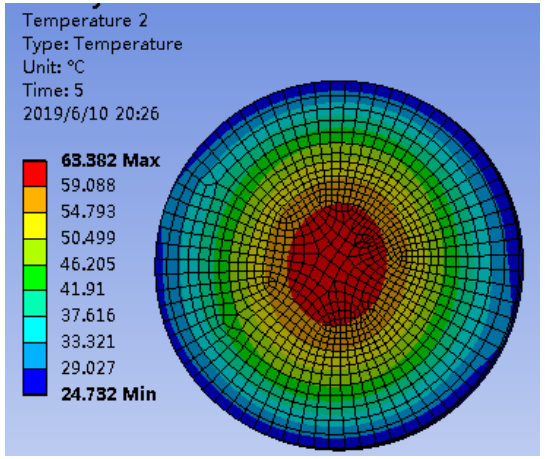
5MV/m

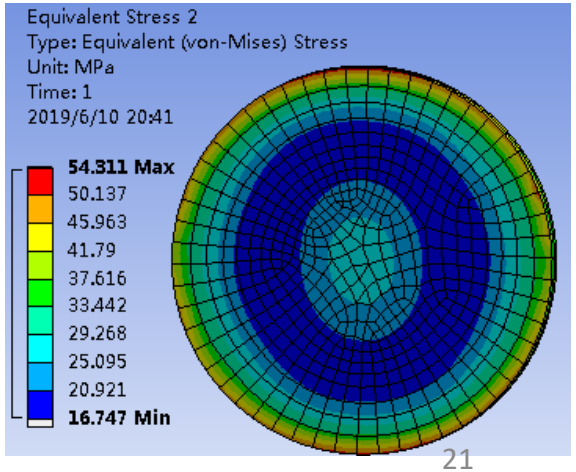
# Multi-beam klystron

## MBK output window design






**The output window design is almost completed**

# Multi-beam klystron

## Design progress status

| Design title | Status | |
|---|---|---|
| MBK beam dynamics | Goal 1 : output power> 800kW | Goal 2 :efficiency >80% |
| | Finished | Finished |
| Design on input and output cavity | Finished | |
| Gun design | Finished | |
| Design on output window | Finished | |
| Coil design | In progress | |
| MBK collector | In progress | |

**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!*