Progress on high efficiency klystron

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Outline

- **R&D status**
  - High efficiency klystron manufacture status
  - High power test stand status
  - MBK status
- **Future plan**
- **Summary**

R&D Status

High efficiency klystron

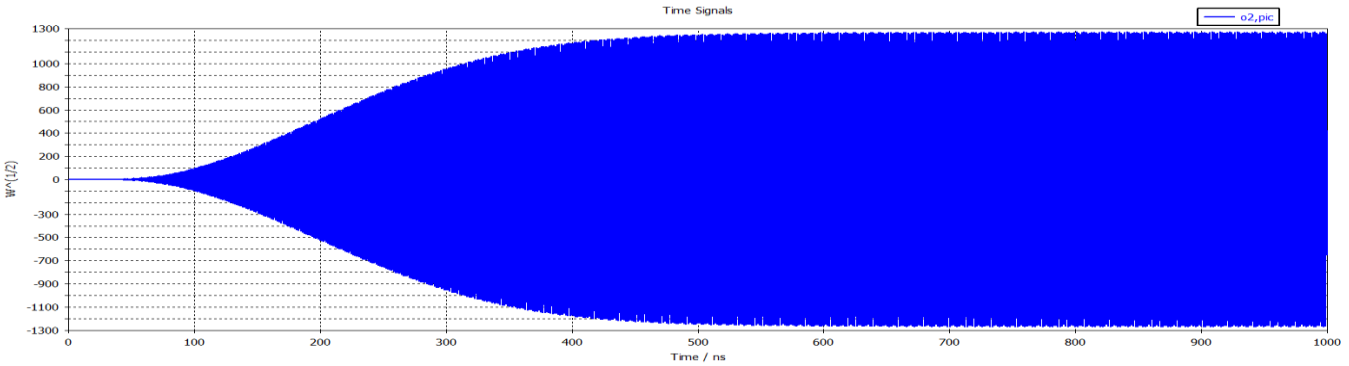
Design parameters

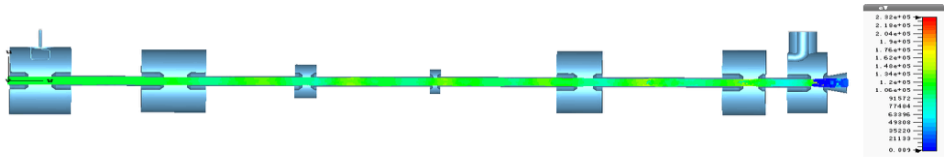
① CST 3D efficiency: 77%

② Output power: 808.3kW(Beam power 1.05MW)

③ Gain(3D): 48.3dB

④ Bandwidth(2.5D): ≥0.8MHZ





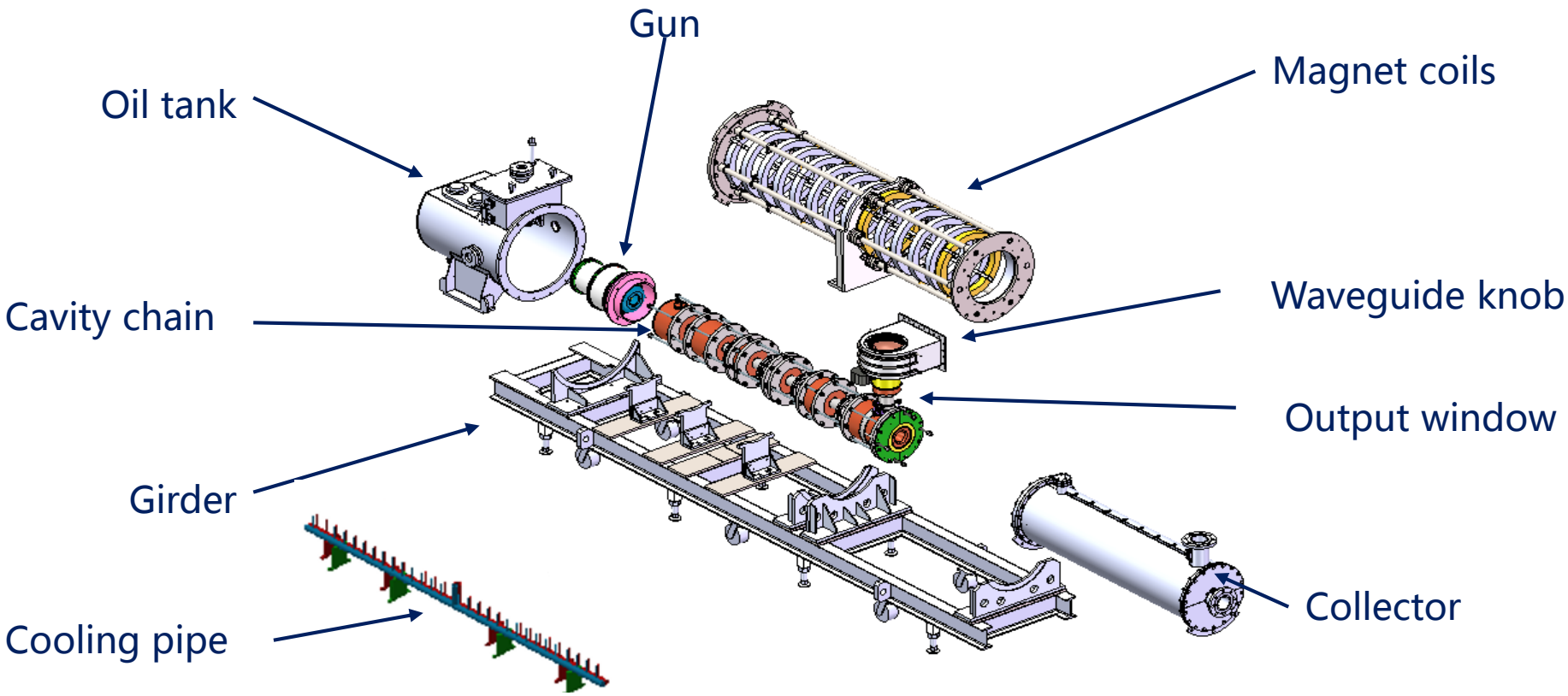
Manufacture status

① The high efficiency klystron prototype is being fabricated in Chinese company.

② The klystron prototype has been completely manufactured and being baking out in the baking furnace. It will be delivered to PAPS site for high power conditioning and test next month.

Mechanical design

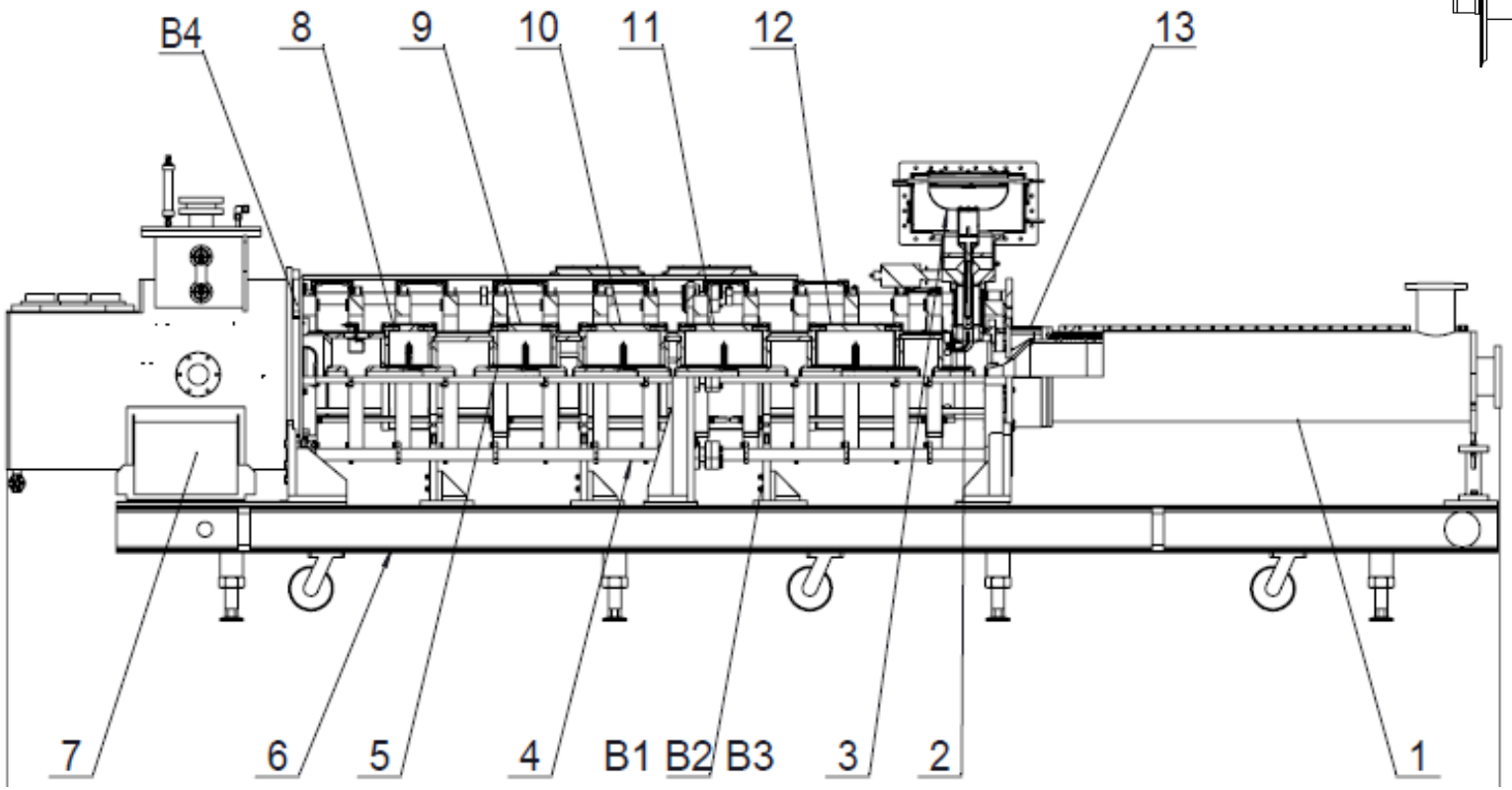
After completing mechanical design at the end of 2020, klystron prototype manufacture is collectively started.



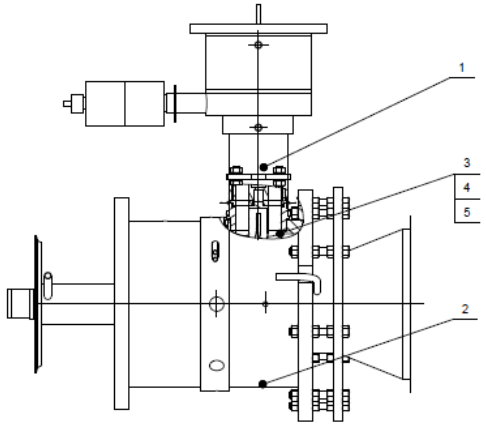
Klystron parts

Mechanical drawing

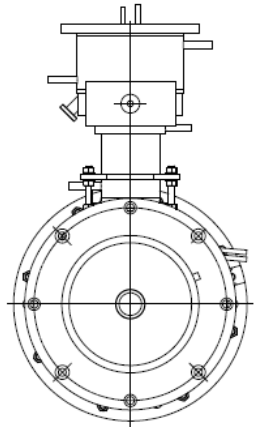
Klystron mechanical drawing

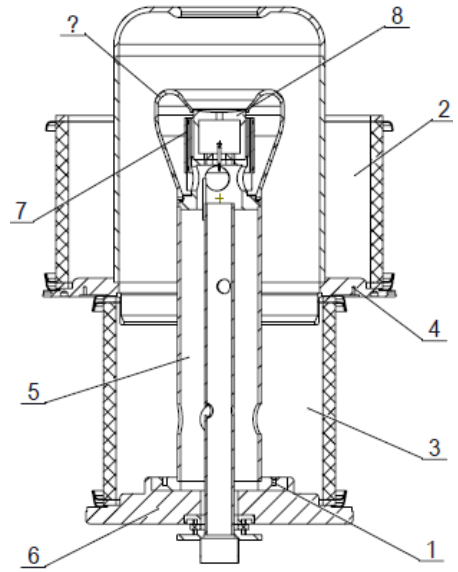


Klystron layout



Cavity





Gun

Fabrication status

Electron gun

Modulator anode

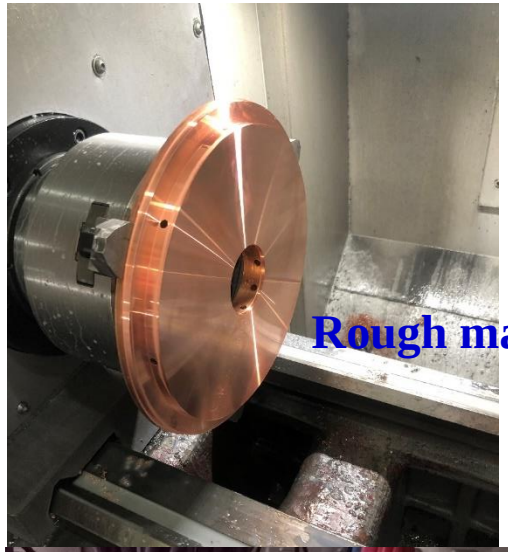
Cathode Assy.

Ceramic insulator

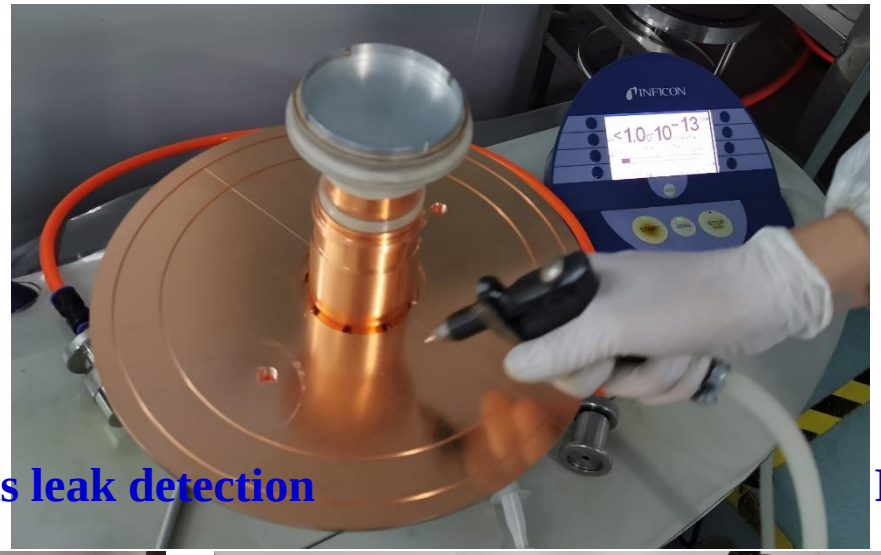
Focusing electrode

Fabrication status

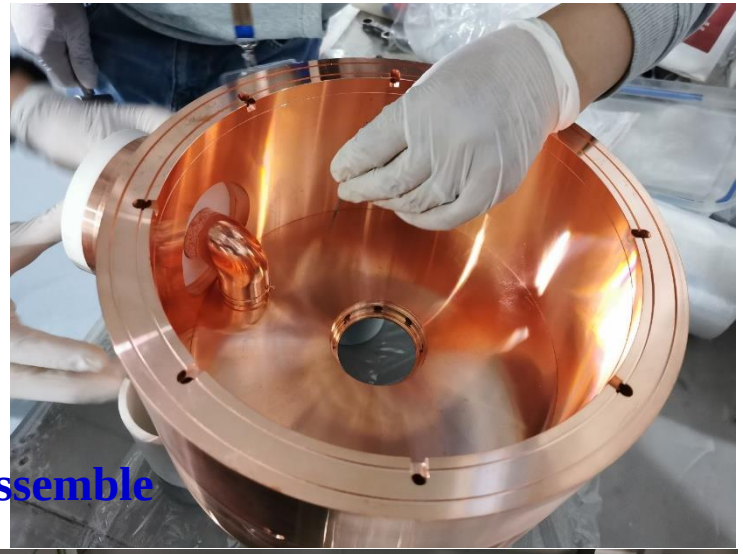
Cavity chain



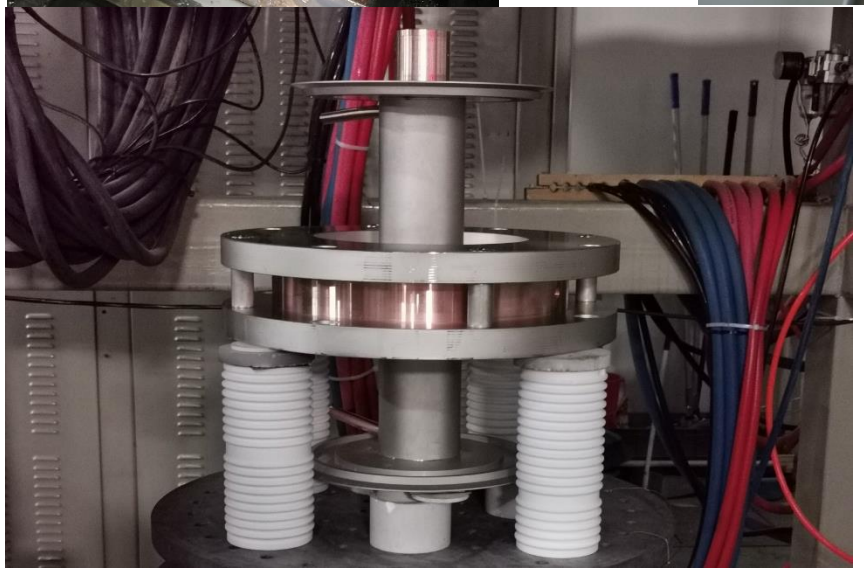
Rough machining



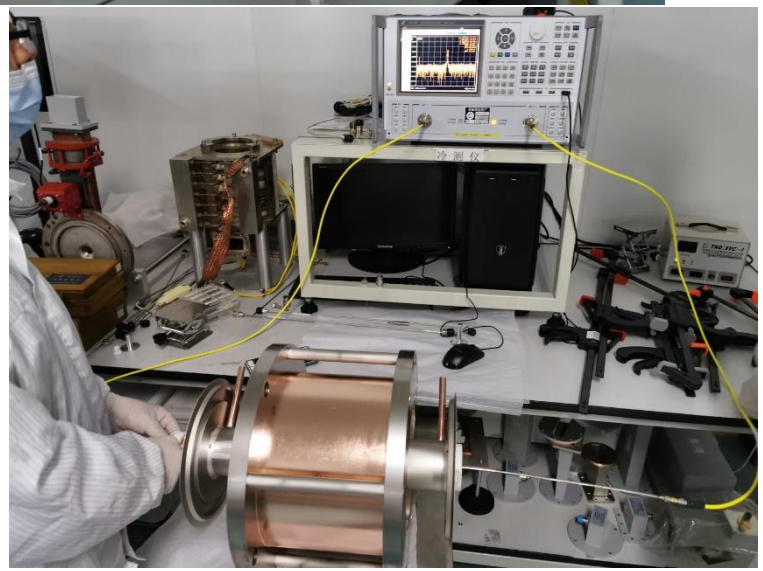
Parts leak detection



Parts assemble



Cavity brazing

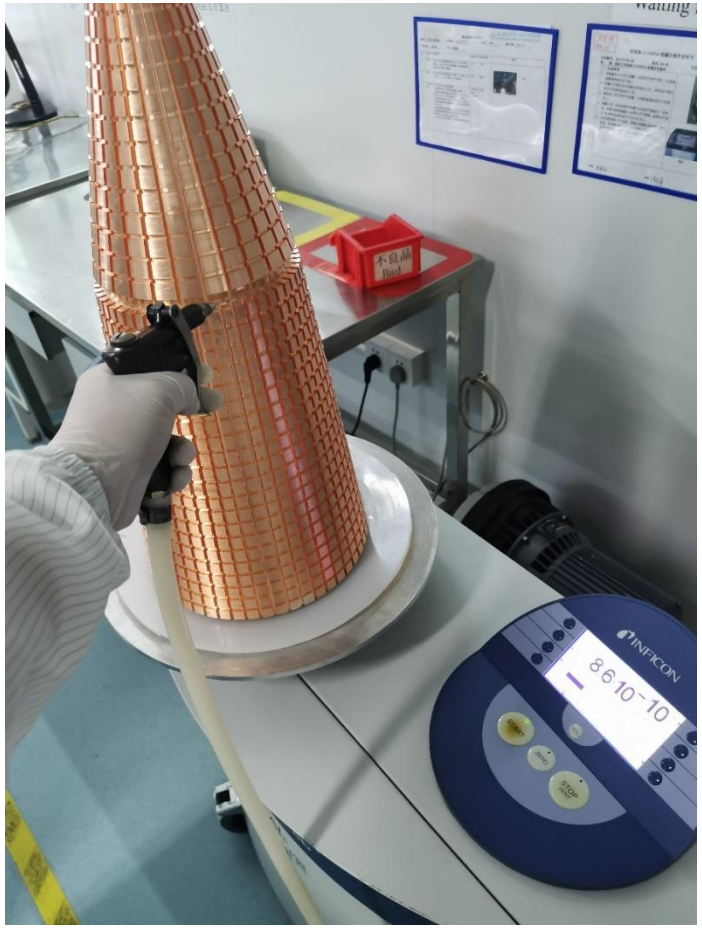


Cold test

Storage with nitrogen

Fabrication status

Collector



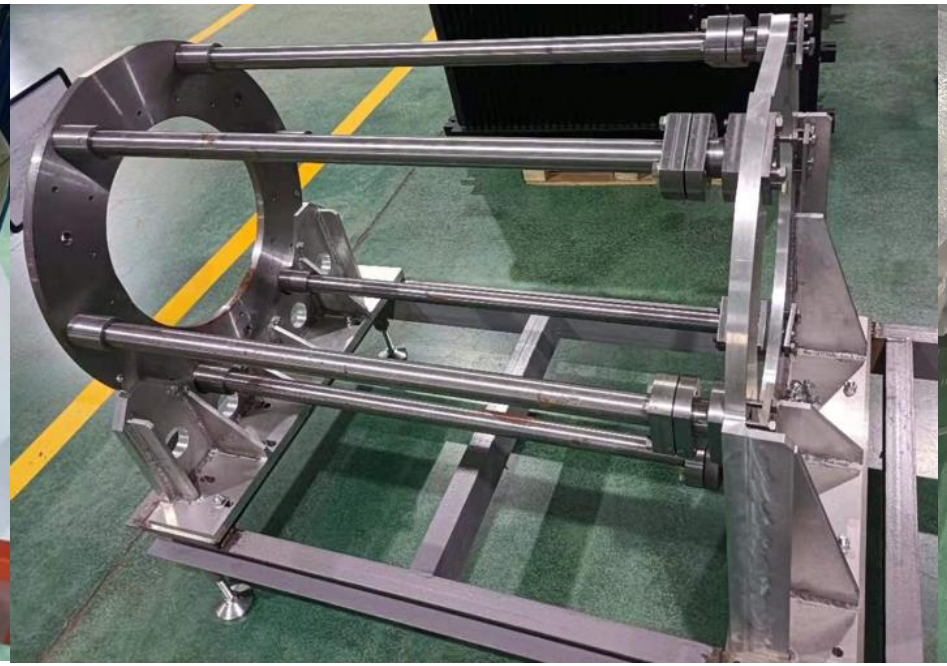
Collector body

Water jacket

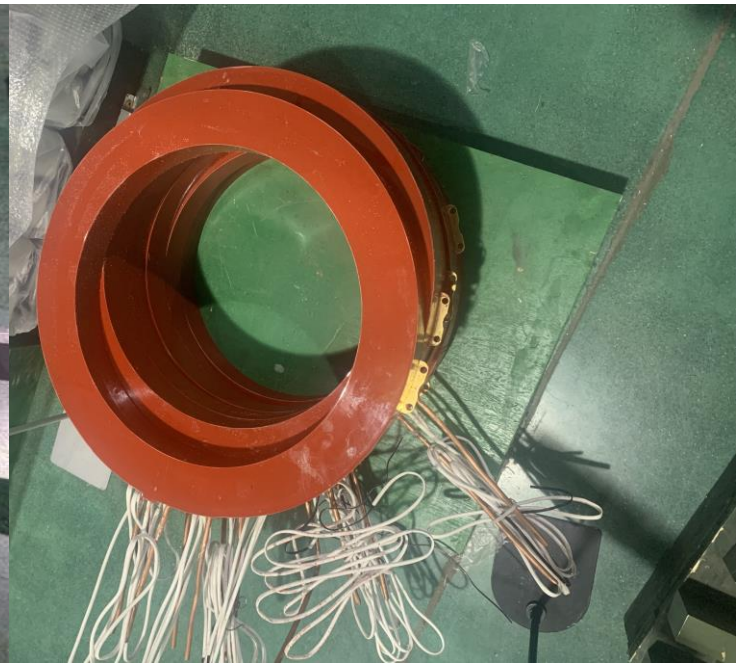
Fabrication status

Focusing magnet

Magnetic bar



Support



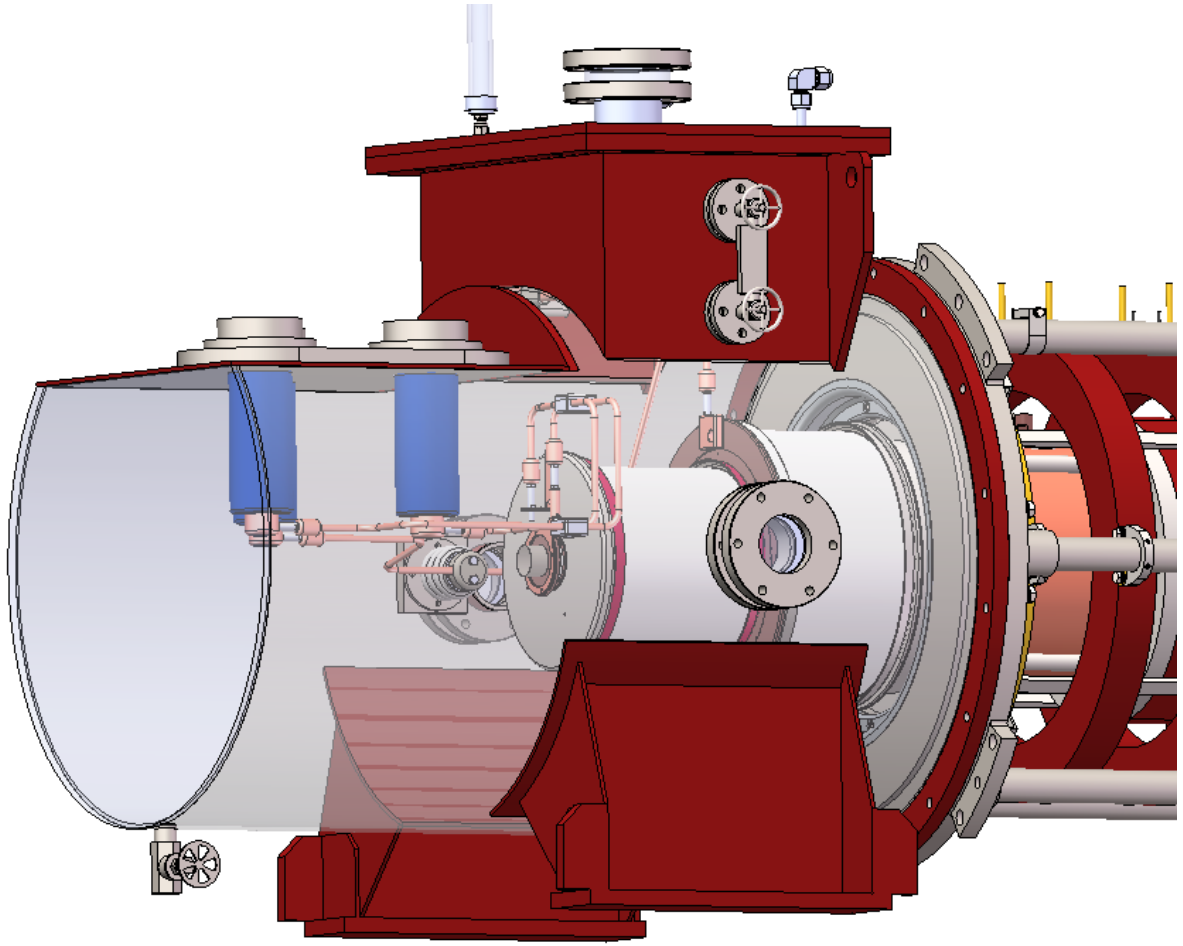
Coils

Fabrication status

Klystron girder

Fabrication status

Oil tank



Oil tank 3d drawing

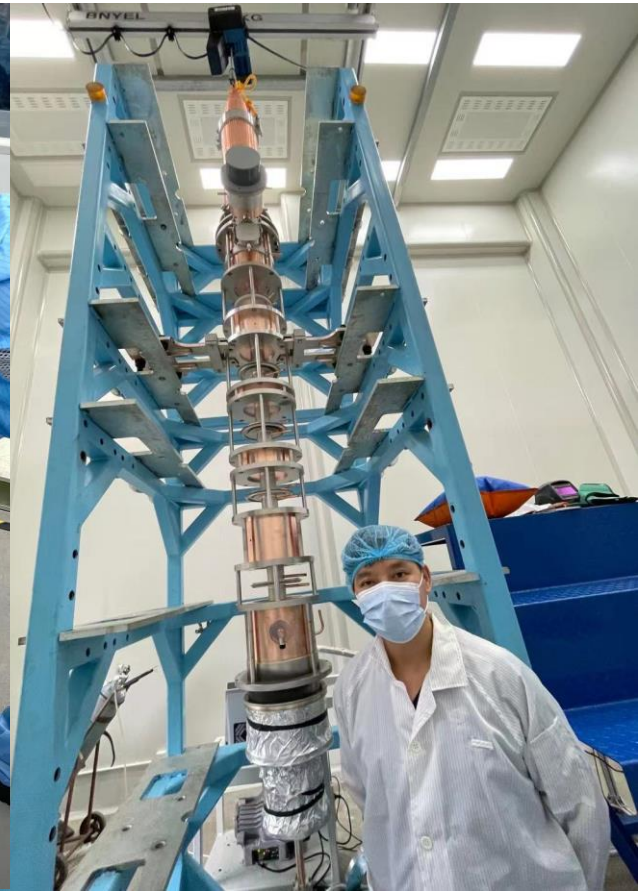
Electron gun processing

Jul. 16, Cathode Temp. 975 degree C @Fil. 27V/6A

Klystron final assembly

Jul. 16-17, klystron final assembly



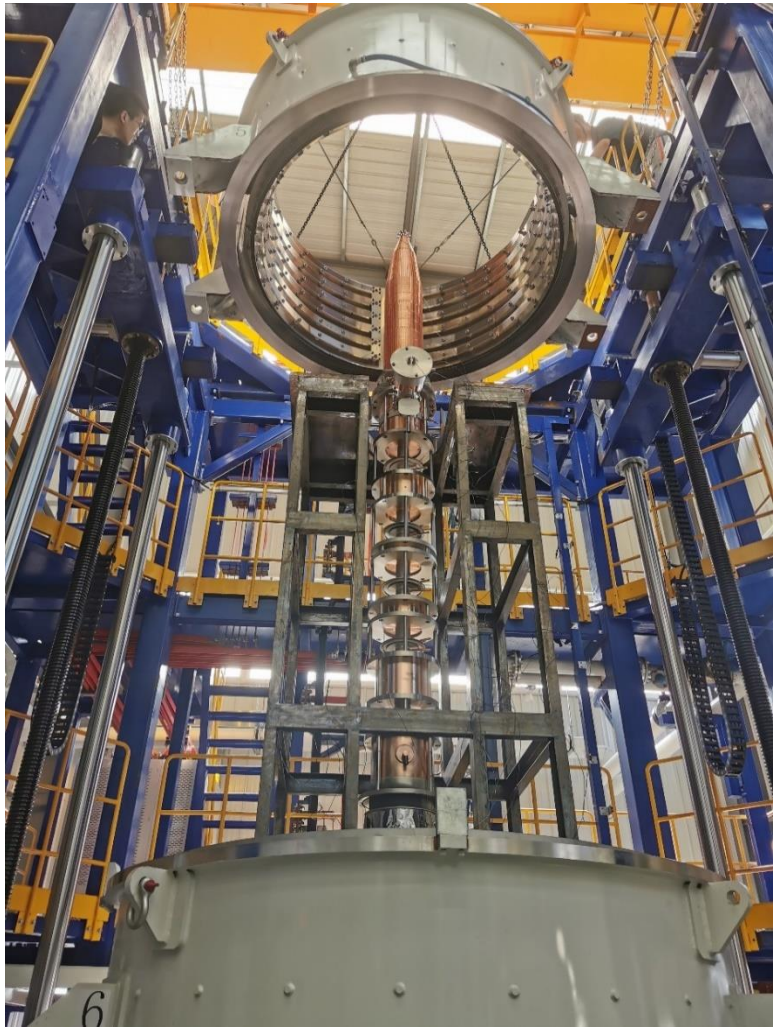



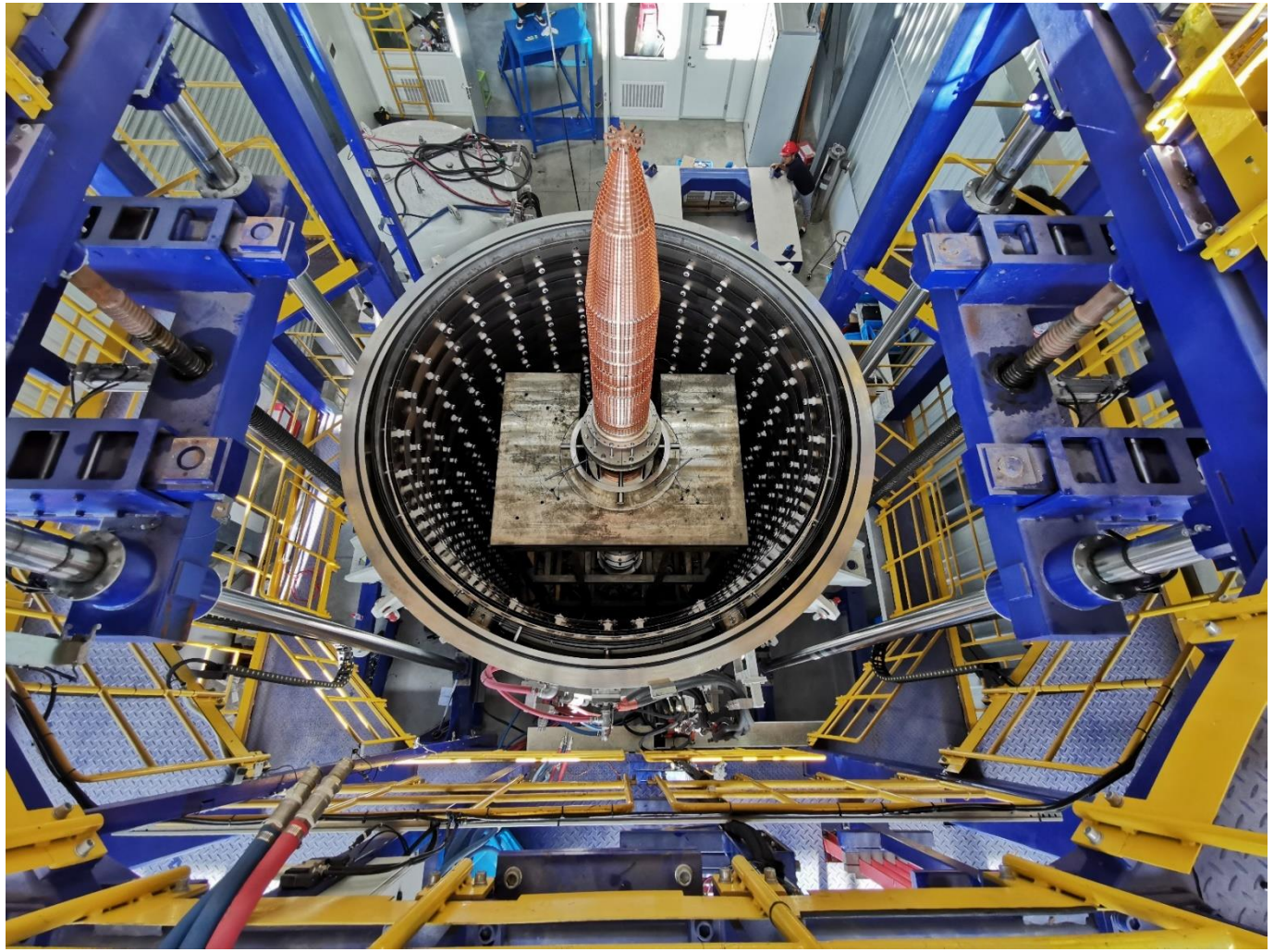
Klystron final assembly

Jul. 17-18, welding, leakage detecting and move to furnace

Klystron final assembly

Jul. 20, furnace preparation

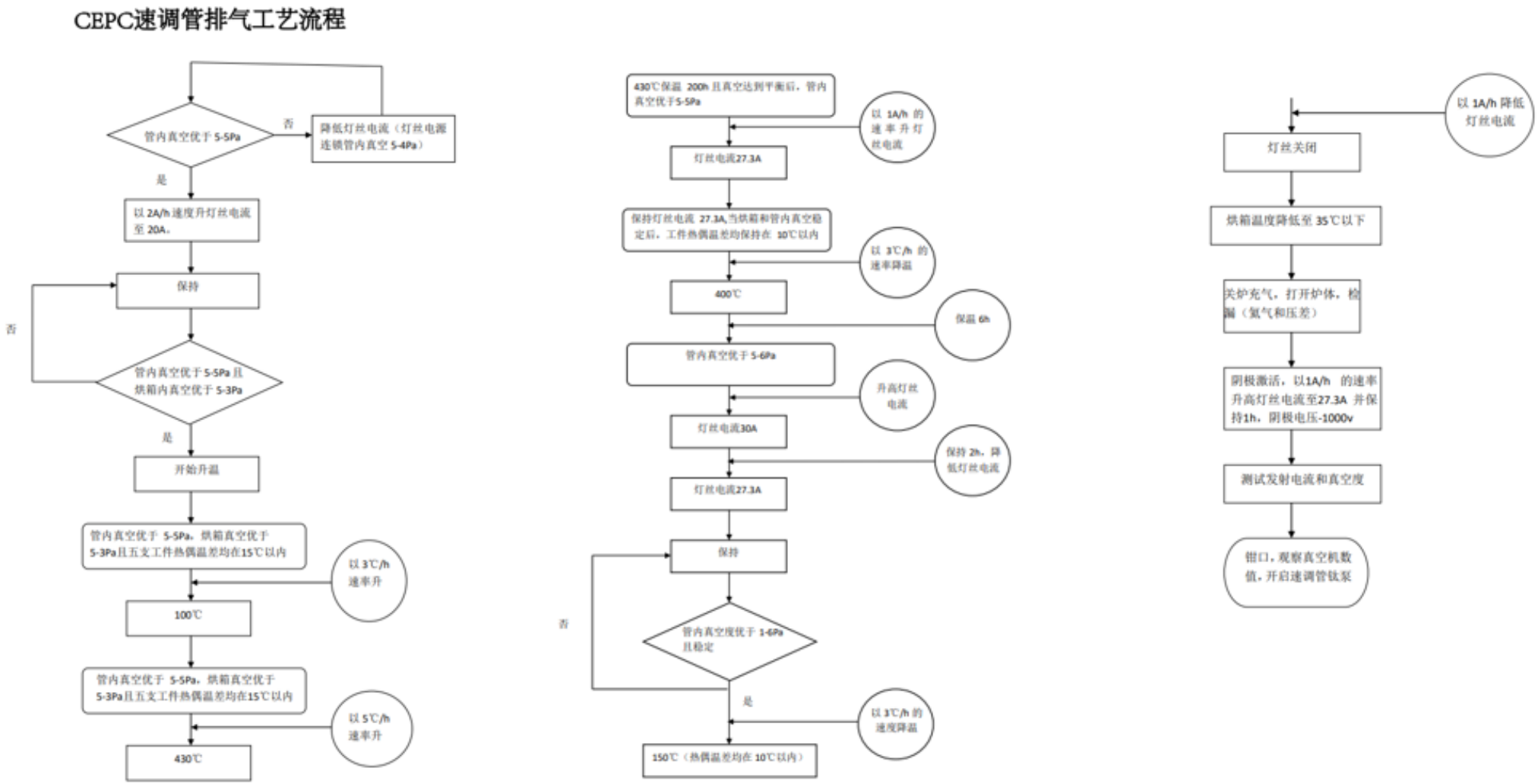




Klystron baking out

Baking processing is started from Jul. 26

Now temp. is 90 degree C



High power test stand

130kV/16A PSM power supply is under adjusting and testing in PAPS site.

PSM Power Supply @PAPS site

Multi-beam klystron

1) Design Parameters

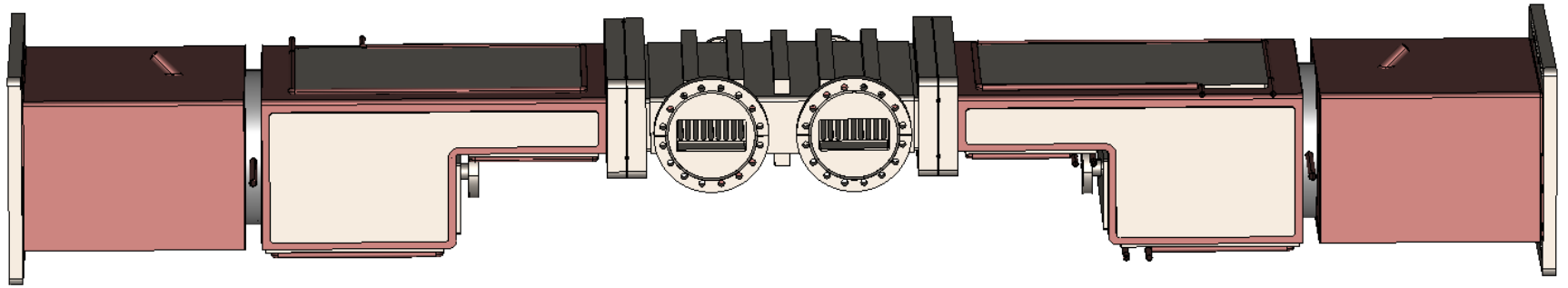
Parameters	Unit	Value
Gun Voltage	kV	54
Beam number		8
Beam perveance	μP	0.2
Output power	kW	800
1dB bandwidth (3-D simulation)	MHz	±0.75
Efficiency(3-D simulation)	%	80.5

The MBK physical design is finished, including the interactive cavity, electron gun, focusing solenoid, window and collector. The final efficiency is about 80.5% with 3d simulation code.

Multi-beam klystron

2) Current status

- The physical design review has been completed.
- The mechanical design of MBK is in progress.
- The output-window prototypes and the test bench is under manufacturing.

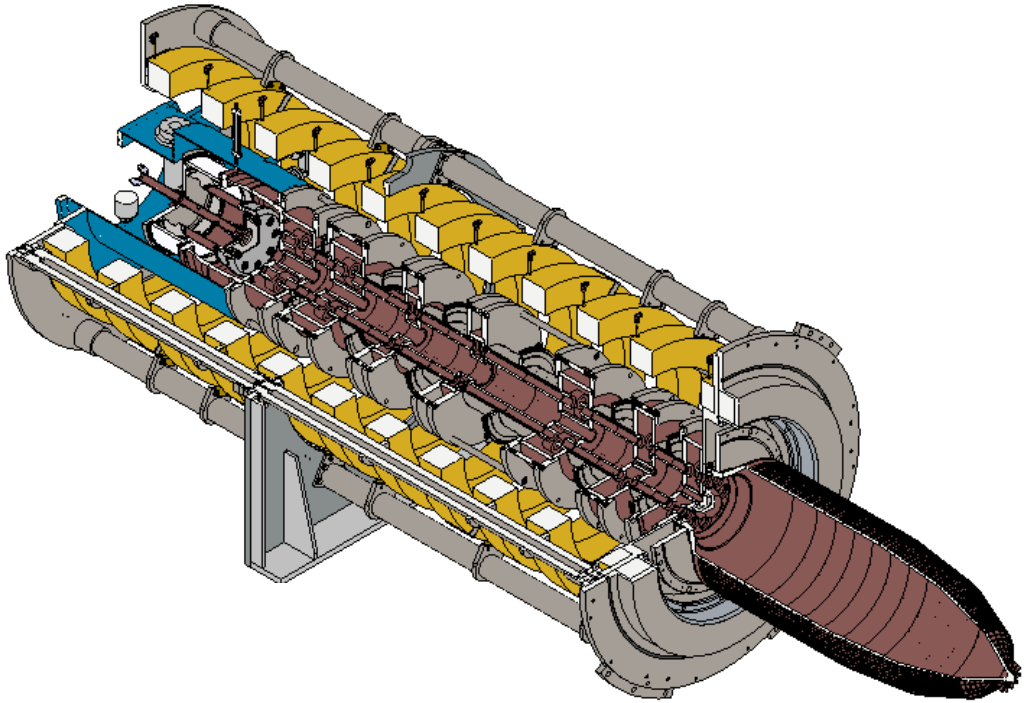


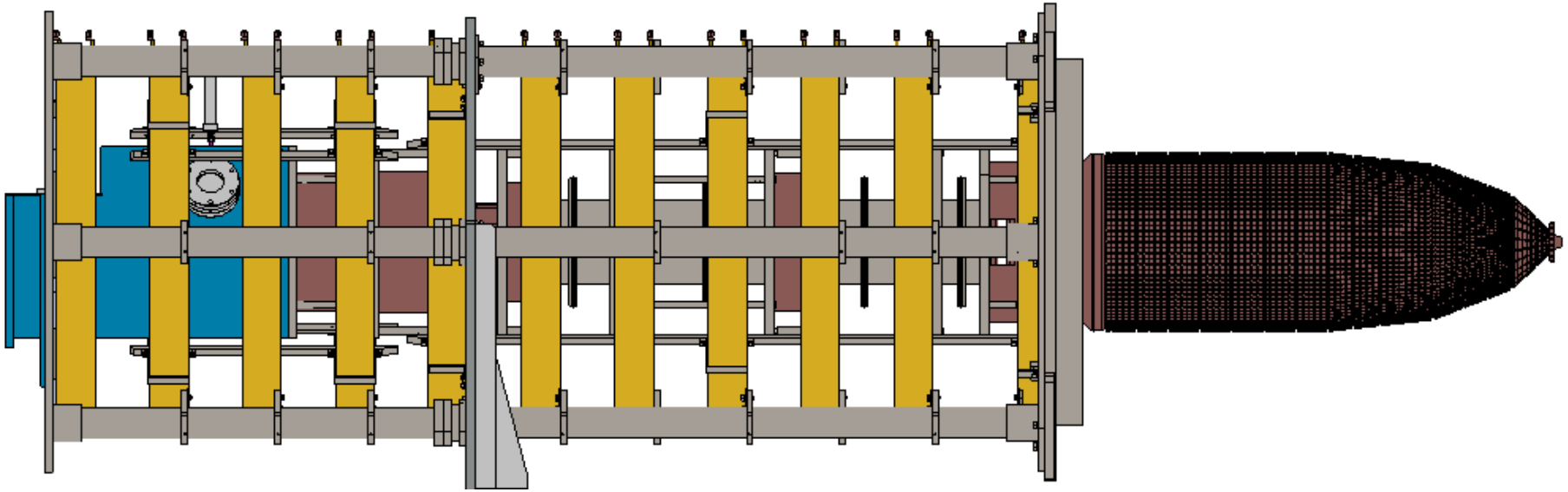
Test bench of the output-window prototype

Multi-beam klystron

3) 3d mechanical drawing

- The preliminary 3d mechanical drawing is finished.





Multi-beam klystron

4) Physical design review

◆ Review meeting was held on Jul.23.

专家意见：

1. 建议进行电子枪仿真的时候，考虑加入阴极的边缘效果。
2. 建议用二维软件复算三维软件的电子注光学仿真结果，仿真中注意网格的划分对仿真结果的影响。
3. 建议完成多注速调管的误差分析，包括腔频率误差和聚焦磁场误差，为机械设计提供指标和要求。
4. 建议 Beam tester 设计中加长电子枪和收集极之间的距离，beam-tester 的验证目标是电子枪的发射，电子注的传输和收集极。
5. 建议计算和寻找二极电子枪内部的有害模式。
6. 建议用简易小油缸替代强迫风冷却和硅胶绝缘方案，便于防尘和冷却。

650MHz 800kW 高效率连续波多注速调管物理设计评审意见

2021 年 7 月 23 日，CEPC 速调管项目组在中科院高能所组织召开了 650MHz/800kW 高效率连续波多注速调管物理设计评审会。来自日本 KEK、中科院空天研究院、中电科第 12 研究所和中科院高能所的 5 位专家（名单见附件），听取了项目组成员王盛昌作的《650MHz/800kW 高效率连续波多注速调管物理设计》报告，该多注速调管仿真效率达到 80.5%，输出功率超过 800kW。专家组经质询和讨论，一致认为该物理设计方案合理可行，通过评审。请项目组根据专家的建议进一步完善设计，同时开始工程设计和样管加工制造。

650MHz/800kW 高效速调管工艺设计评审专家：

丁耀根　中国科学院空天研究院（组长）

福田茂树　日本高能物理研究所（KEK）（视频）

李冬凤　中国电子科技集团第十二研究所

王九庆　中国科学院高能物理研究所

慕振成　中国科学院高能物理研究所

评审组长：丁耀根

日期：2021/7/23

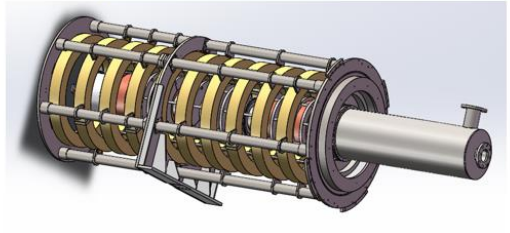
Multi-beam klystron

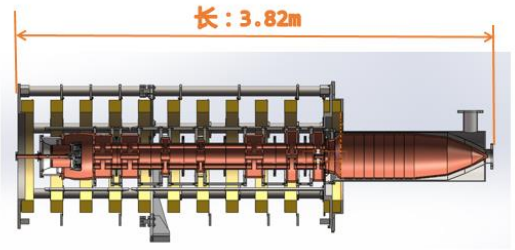
5) Process design review

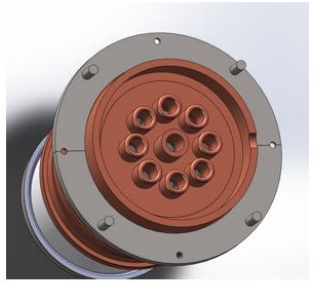
- **Review report is preparing.**

多柱速调管机械设计

速调管整体结构



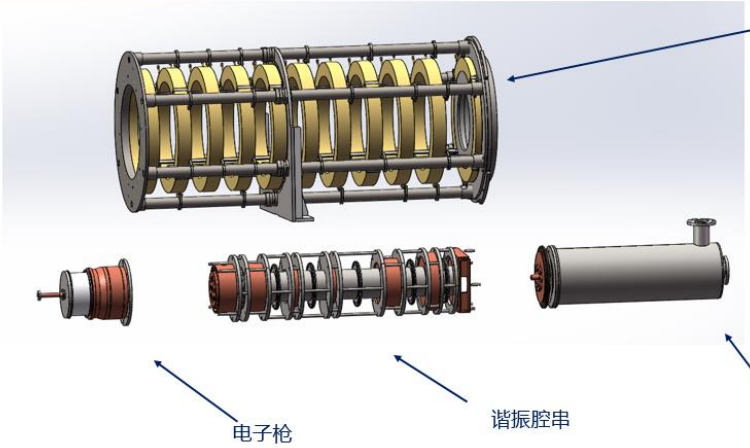




- 长×宽×高：目前长度设计已达到3.82m，其他尺寸待定。
- 如左图，该速调管有8只漂移管，因此该速调管体积以及重量等都会较大

多注速调管机械设计

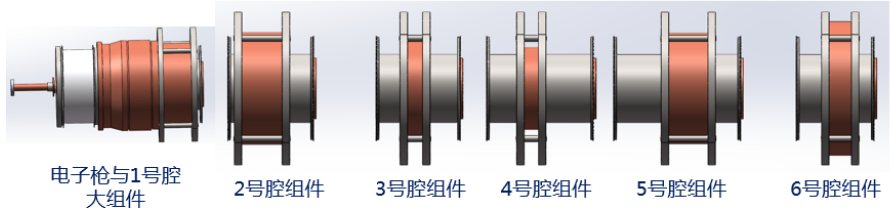
速调管的组成

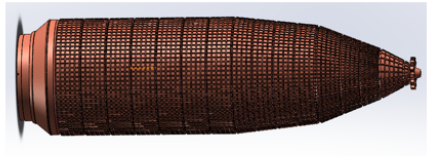


- 速调管整体结构按部件可大致分解为电子枪、谐振腔串、收集极、螺线管等，另外的输出窗、电真空组件（进烘烤平台）、运行支架及冷却水系统等正在设计中。

多注速调管机械设计

速调管进炉排气部分





收集极

- 管芯部分总长待定、重量待定，按组件装配工艺可分解为：电子枪与1号腔组件、2号腔组件、3号腔组件、4号腔组件、 5号腔组件、6号腔组件、 “7号腔+双输出窗”大组件及收集极组件等

Future plan

Future plan

The klystron with RF power conversion efficiency:

Main methods:

① Smaller perveance and the weaker space charge effect.

② Multi-beam klystron.

NOW WORK @IHEP

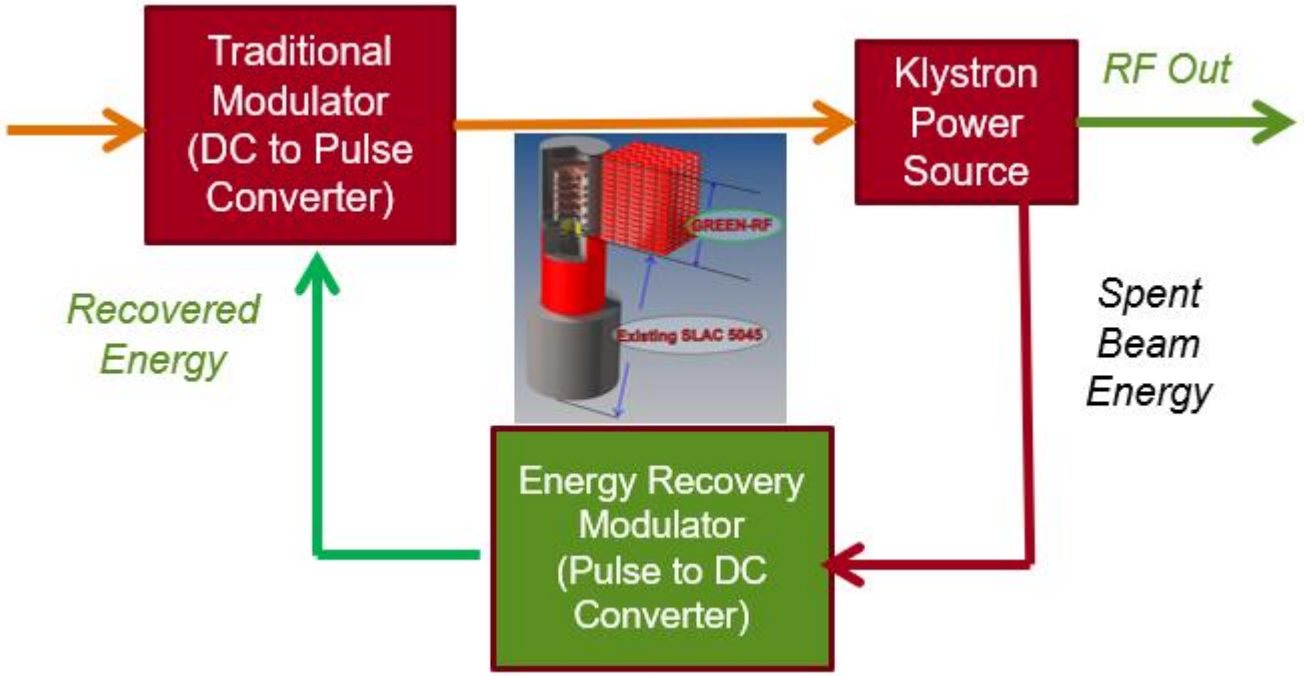
Efficiency goal: 77%

Efficiency goal: 80%

Future plan

① In order to **further** improve the efficiency of klystron, on the basis of improving the efficiency of high-speed modulator, the power dissipated in the collection stage is recovered to the high-voltage power supply / modulator.

② The waste energy collected can be reused.



Future plan

For klystron

① So called MSD (Multi-stage Depressed Collector) klystron was developed to improve the efficiency.

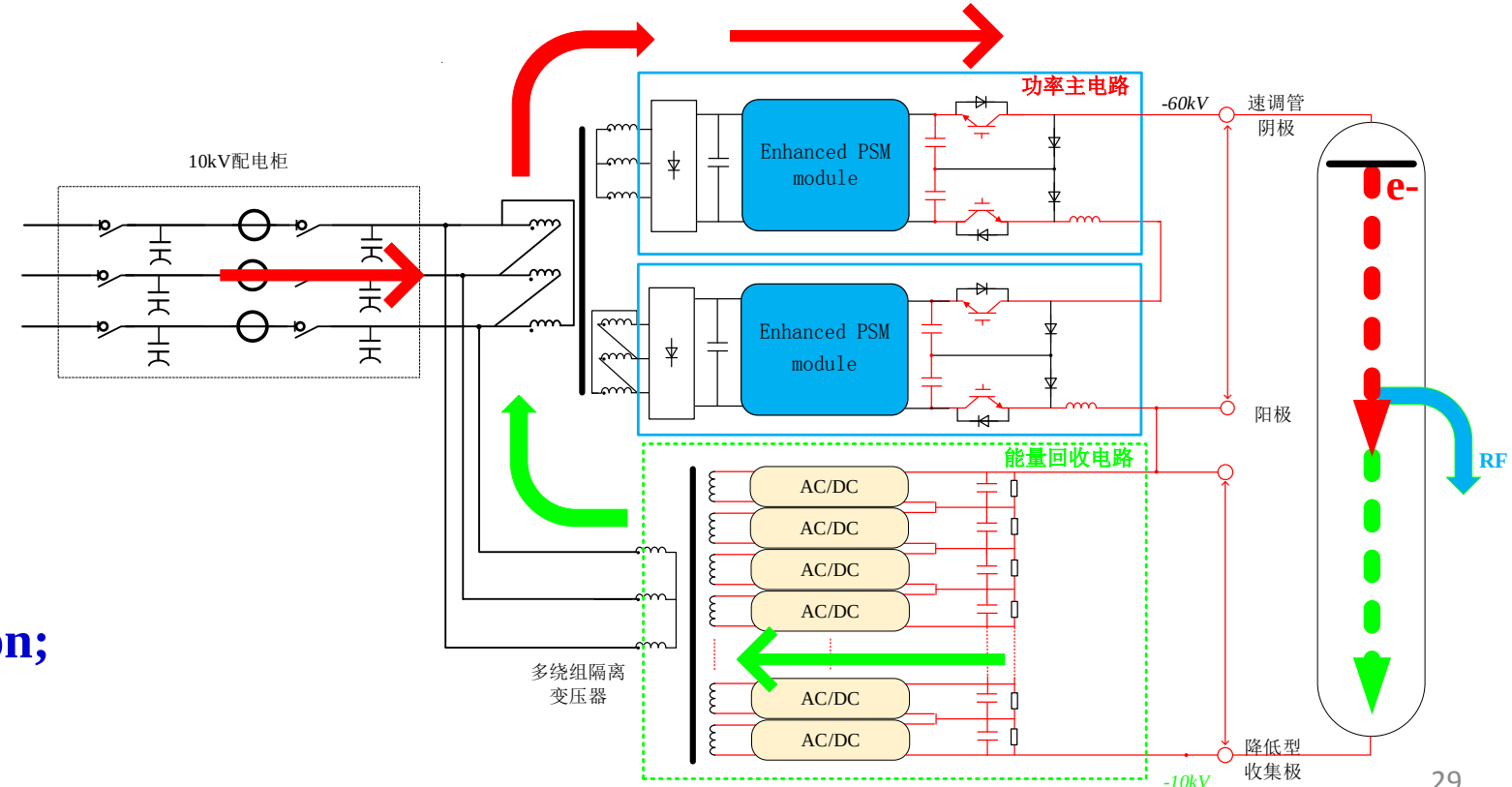
② Our target is to improve klystron efficiency with MSD method in the **unsaturated region**.

Future plan

For power supply

① Depressed collector/potential depression technology is the way that dissipated power in the collector is back to PS by depressed collector potential.

- ➢No recycling mode;
- ➢Start up initial mode;
- ➢Recycling mode;
- ➢Recovery mode of pulse operation;



Schematic diagram

Summary

① The manufacture of high efficiency klystron prototype will be completed at the end of next month.
② MBK will be immediately manufactured after design review.
③ The scheme of energy recovery power supply is proposed and a small prototype module is developing in IHEP.
④ Depressed collector method will be used for klystron improvement based on high efficiency klystron design in the near future.

Thanks for your attention!