

Annul Work Report

(Oct. 2019-Oct. 2020)

Zusheng Zhou (周祖圣)

Institute of High Energy Physics

Dec. 5, 2020

◆ Work list

① CEPC high efficiency klystron

- Klystron prototype manufacture and high power test
- Klystron test facility
- High efficiency design

② Other work

- HEPS electron gun development
- BEPCII high power test stand update

◆ Funding support

◆ Conference talk

◆ Publication list

◆ Project management and coordination

Klystron prototype manufacture and high power test

Prototype milestone

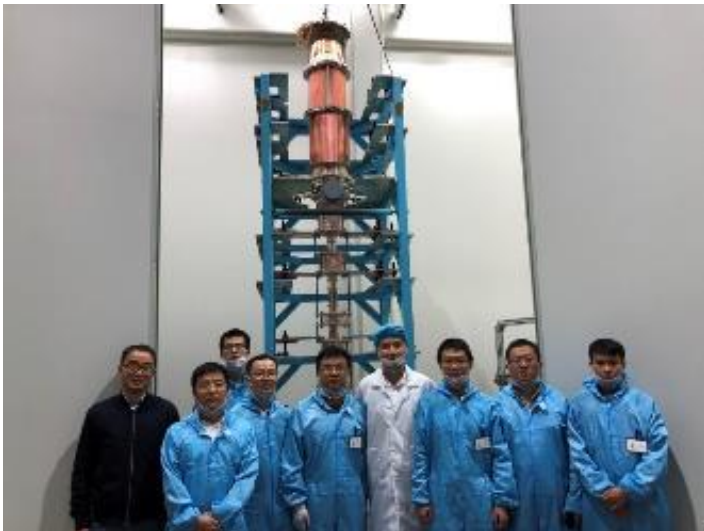
- ◆ Oct. 2017 Design report
- ◆ May. 2018 Mechanical design review
- ◆ Oct. 2019 Parts processing
- ◆ Nov. 2019 Baking out
- ◆ Dec. 2019 Delivery to IHEP
- ◆ Mar. 2020 High power test (400kW CW and 800kW pulsed)
- ◆ Sep. 2020 High power test (490kW CW)

Prototype manufacture

- ① The 1st klystron prototype has been completely manufactured and delivered to IHEP at the end of 2019.
- ② The prototype is **largest size** and **highest CW power** klystron in China and also **first time** to manufacture this kind of klystron.

Prototype manufacture

- ① The 1st klystron prototype has been completely manufactured and delivered to IHEP at the end of 2019.
- ② The prototype is **largest size** and **highest CW power** klystron in China and also **first time** to manufacture this kind of klystron.



Vacuum-Assy assembly



Bake out



Final assembly



High power test

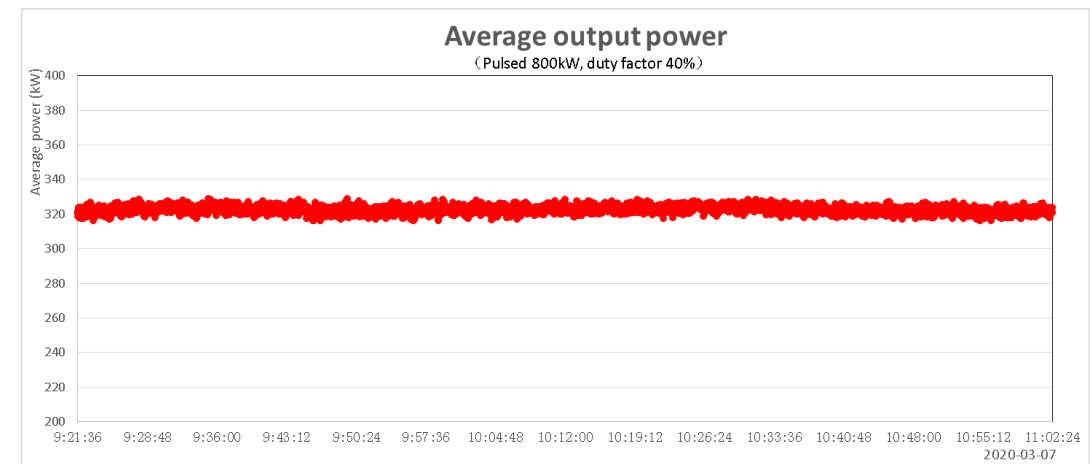
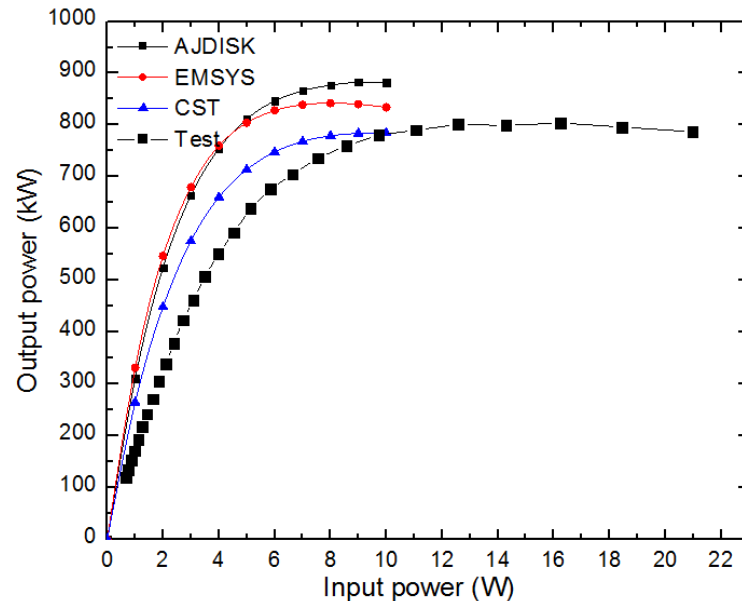
- ① High power test is started from beginning of this year.
- ② The 400kW CW power and 800kW pulsed power are tested on Mar. 9 2020.
- ③ The 490kW CW power are tested on Sep. 2 2020.

High power test

Parameters	Design	Test
Operating frequency (MHz)	650	650
Beam Voltage (kV)	81.5	80
Beam Perveance ($\mu\text{A}/\text{V}^{3/2}$)	0.65	0.7
Efficiency	$\geq 60\%$	62
Saturation Gain(dB)	≥ 45	47
Output power(kW)	800	800
1 dB Bandwidth(MHz)	≥ 1	1.8



High power test stand



Pulsed 800kW



您现在的位置: 首页 > 新闻动态 > 高能新闻 > 2020年高能新闻

CEPC 650MHz速调管首支样管完成脉冲功率800kW和连续波功率400kW测试

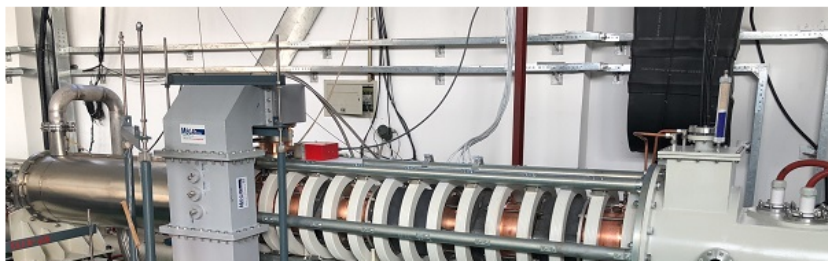
2020-03-10 | 文章来源: 加速器中心 | 【大 中 小】

2月27日和3月7日, 环形正负电子对撞机(Circular Electron and Positron Collider, CEPC) 650MHz速调管首支样管于输出功率分别达到连续波400kW和脉冲800kW(占空比40%), 在800kW功率下, 微波转换效率62%, 1dB带宽>1.0 MHz, 增益>43dB。CEPC 650MHz速调管样管脉冲功率800kW和连续波400kW测试成功, 标志着我国在P波段连续波速调管自主研发方面取得突破, 填补了国内空白, 也是国际上首支650MHz连续波速调管。

CEPC 650MHz速调管样管研制采用产学研联合创新模式, 由中科院高能所完成设计, 电子所承担电子枪和谐振腔串加工, 昆山国力大功率器件工业技术研究院有限公司承担收集极及相关附属设备加工, 并在昆山市政府的支持下, 建设了所需的装配厂房和排气台。2019年10月在昆山国力完成总焊、排气和后装配, 12月25日运抵高能所, 2020年1月6日开始加电调试。在2020年春节后疫情关键时期, 项目组人员在做好个人防护的同时, 加班加点, 在完成速调管冷高压老练、高压老练和连续波400kW功率输出后, 进行了800kW占空比40%的功率测试。

自1964年在谢家麟领导下成功研制出中国第一支大功率速调管以来, 国产速调管取得了长足发展, 部分国产速调管已成功运行于大科学装置中, 但在P波段(0.3GHz-1.0GHz)连续波速调管方面依然完全依赖进口, 随着大型环形对撞机方案的提出, 高效率连续波速调管成为国际前沿热点, CEPC 650MHz速调管首支样管的测试成功, 也为正在开展的高效率连续波速调管研制积累了宝贵经验, 打下了坚实的基础, 也是CEPC TDR(Technical Design Report)阶段关键技术瓶颈的重要突破。

CEPC 650MHz速调管首支样管的研制受王贻芳科学家工作室经费和高能所科技创新项目经费支持。



中新网·梳理天下新闻

中科院高能所成功研发中国首支P波段大功率连续波速调管

中国新闻网

2020-03-12 18:22:43

中新社北京3月12日电 (记者 孙自法) 记者12日从中国科学院高能物理研究所(中科院高能所)获悉, 该所备受关注的环形正负电子对撞机(CEPC)项目研发出650兆赫兹(MHz)速调管样管, 近日已完成脉冲功率800千瓦(kW)和连续波功率400千瓦测试。

这是中国自主研发的首支P波段(300-1000兆赫兹)大功率连续波速调管, 也是推进环形正负电子对撞机关键技术突破不可或缺的一步, 并为下一步发展国际领先水

High power test

- ① The RF output power reached 800kW (duty factor 40%) with 62% efficiency.
- ② The successful testing of the first prototype has also accumulated valuable experience and laid a solid foundation for the ongoing development of high efficiency klystron.
- ③ It's also an important breakthrough in key technology in the CEPC TDR phase.

Klystron test facility

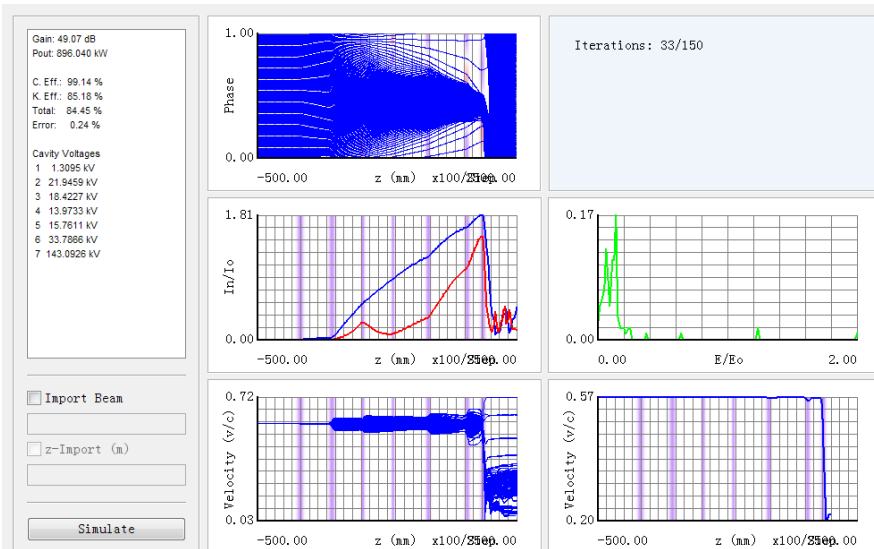
- ① The klystron prototype is used for Chinese made high power load conditioning and commissioning.
- ② The klystron prototype will be used for conditioning and commissioning of klystron window and coupler of SC cavity.



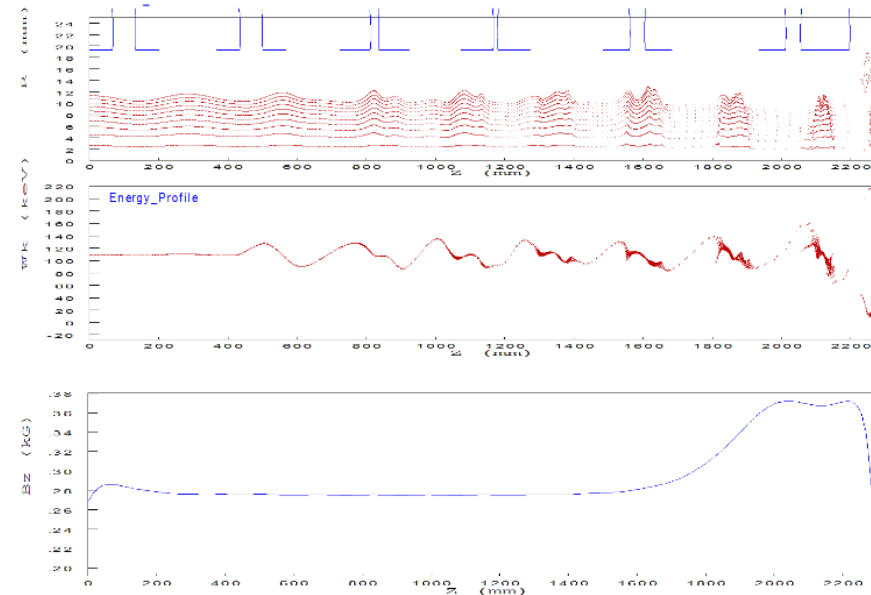
High efficiency design

① High voltage klystron

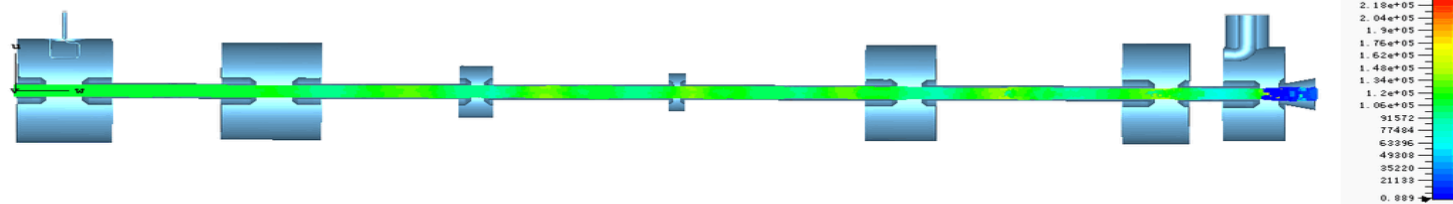
Final design



AJDISK(1D) EFF: 84.5%



EMSYS(2.5D) EFF: 79.3%



Positions	
Type:	Energy
Max:	232.4e+03
Local max:	171.2e+03
Sample:	1/40
Time [ns]:	998
T_end [ns]:	1000
Particles:	2987906

CST(3D) EFF: 77%



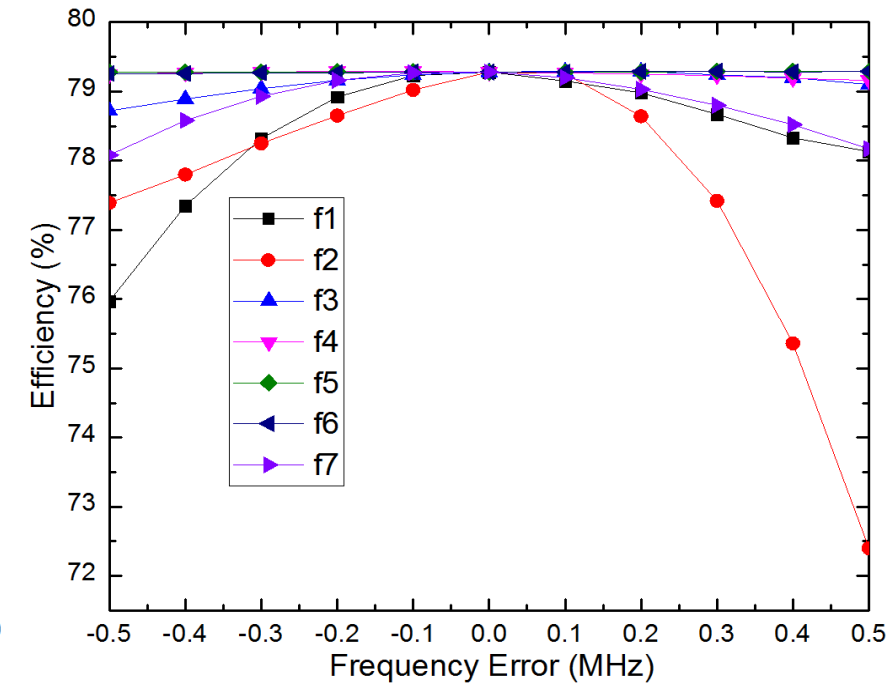
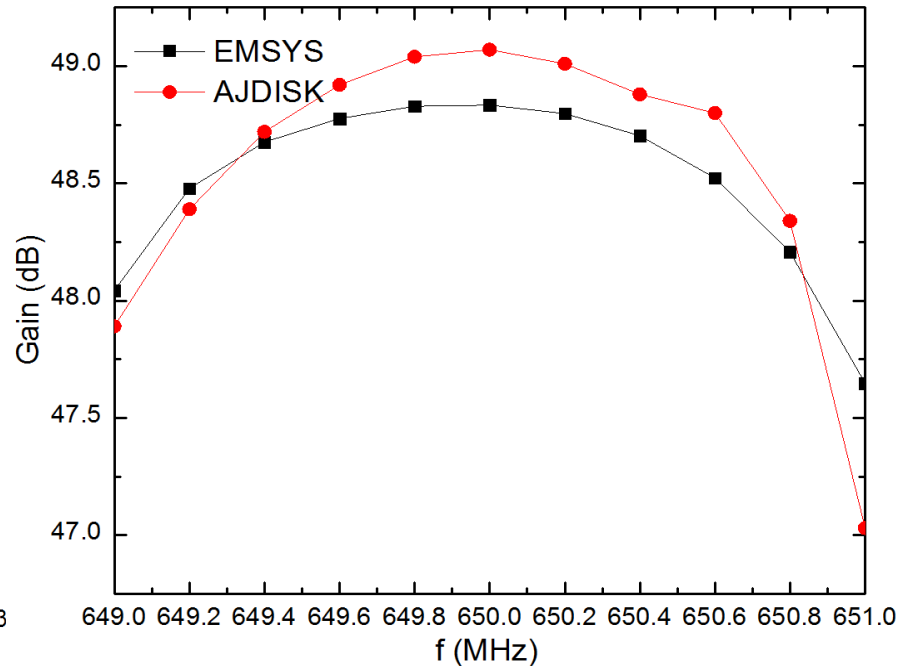
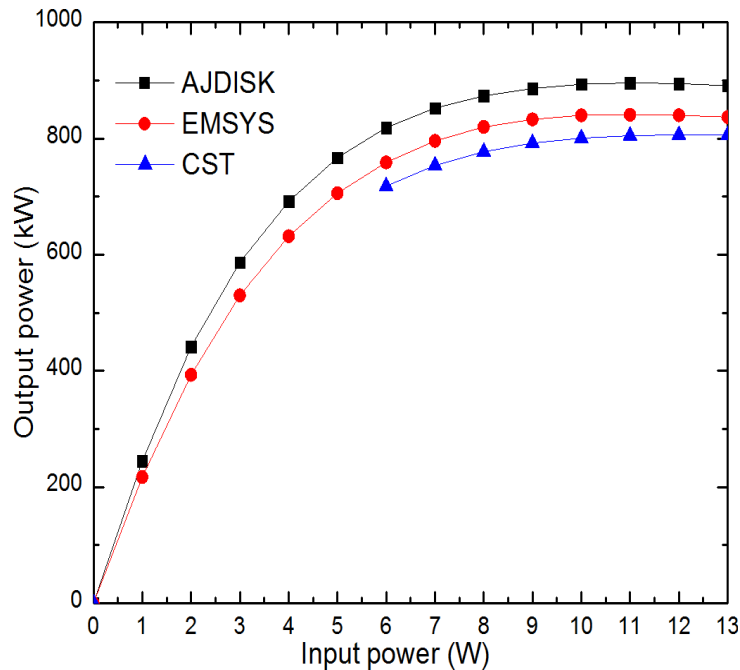
① High voltage klystron

Final design

Gain(3D):48.3dB

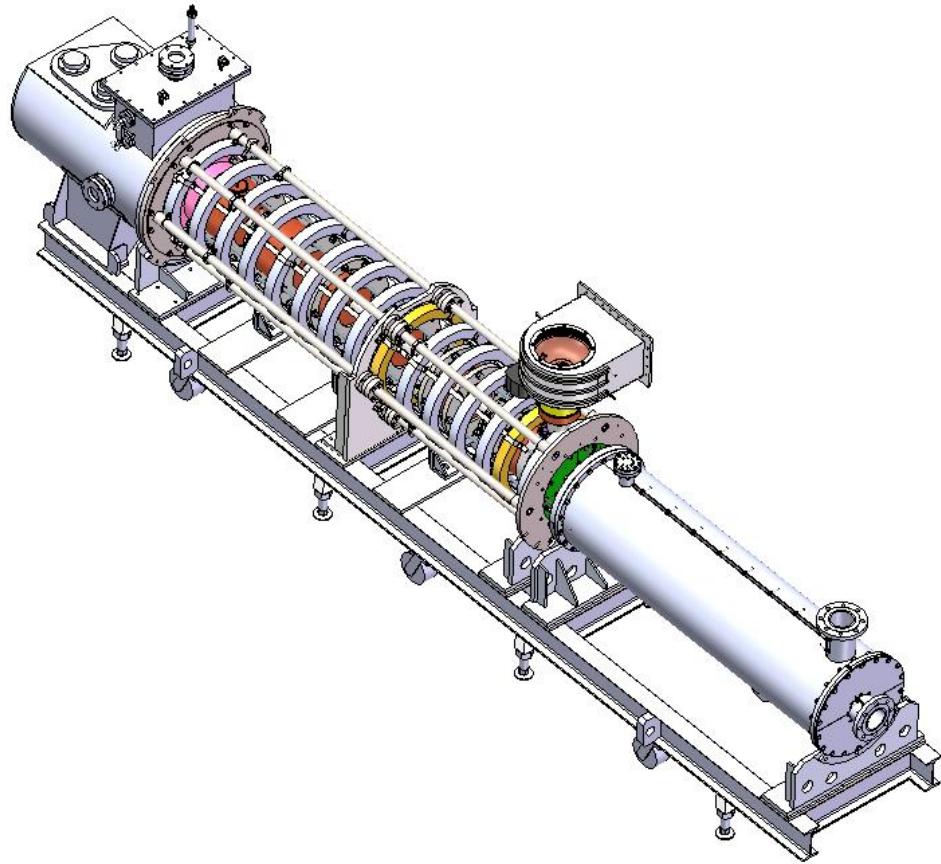
Bandwidth(2.5D): $\geq 0.8\text{MHz}$

Frequency tolerance : f1, f2, f7 $\pm 0.2\text{MHz}$, others $\pm 0.5\text{MHz}$

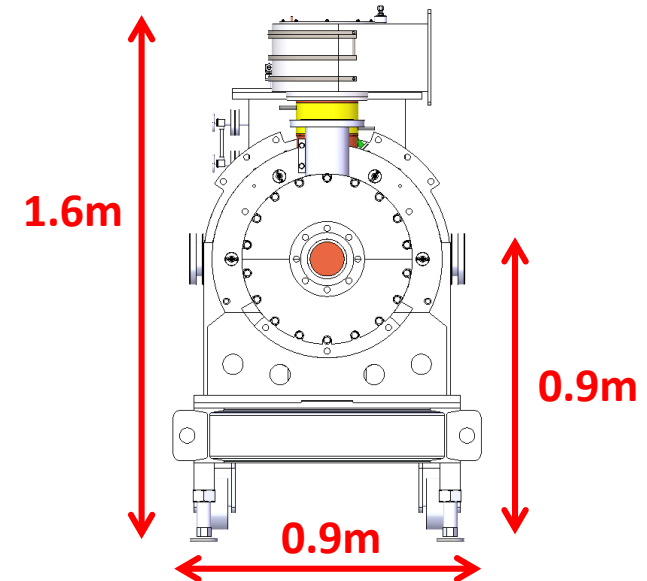
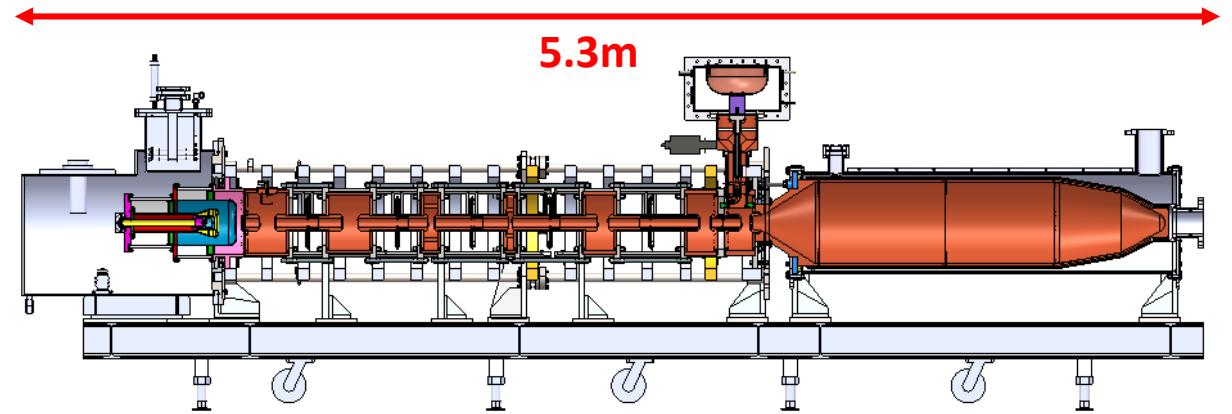


① High voltage klystron

Mechanical design review



Size: L 5.3m * W 0.9m * H 1.6m
Weight: 4.5t without oil



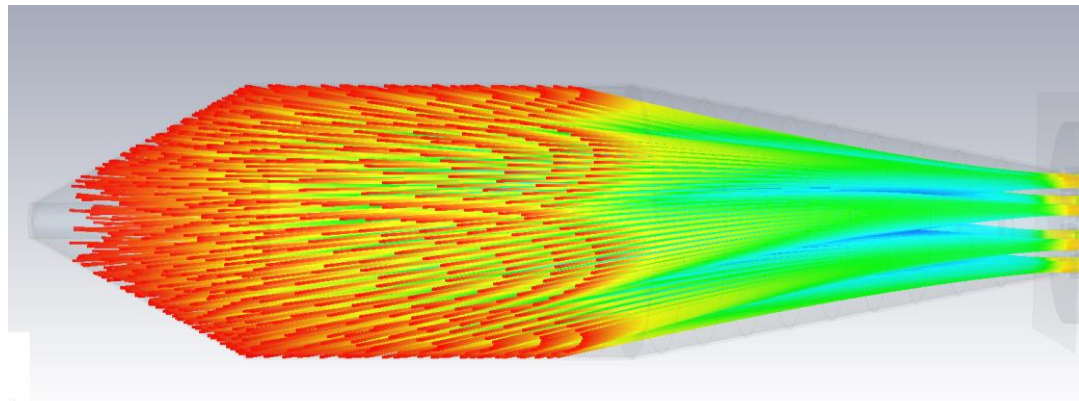
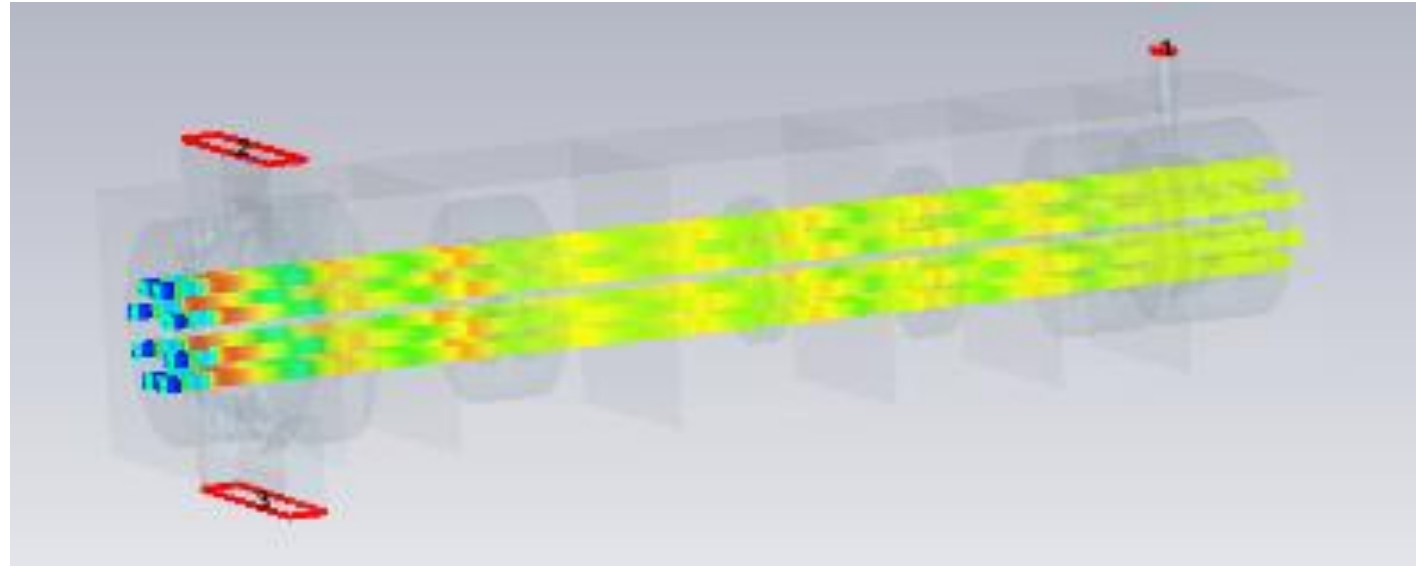
① High voltage klystron

- ① The design of high voltage klystron is completed with **77% efficiency** at CST 3D code this year.
- ② It's the world's **highest efficiency** 3D design on single beam klystron.
- ③ The high efficiency klystron prototype are being mechanical design and expected completed manufacture in the first half of next year.

② Multi-beam klystron

1) Design Parameters

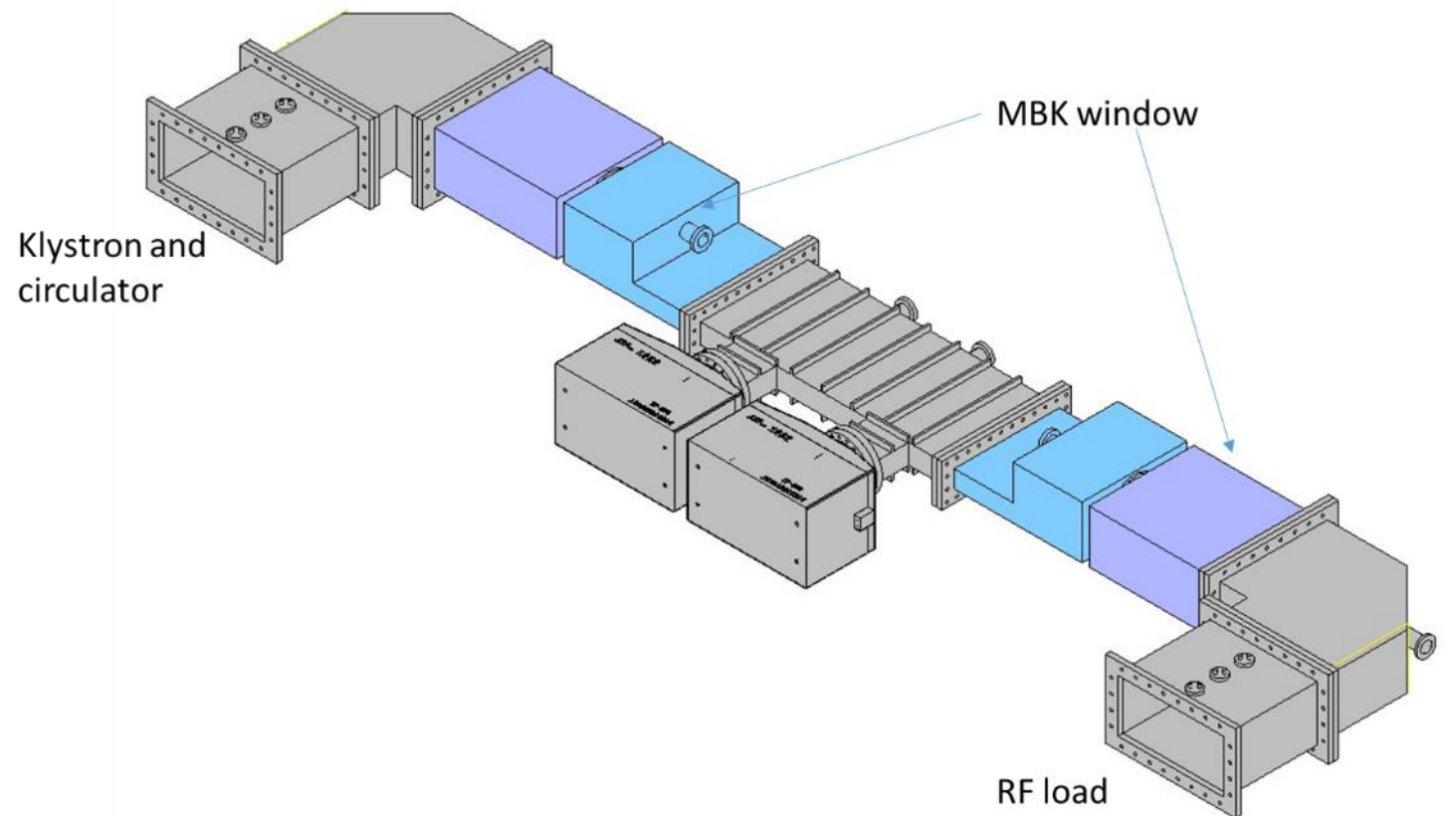
Parameters	Unit	Value
Gun Voltage	kV	54
Beam number		8
Beam perveance	μP	0.2
Output power	kW	800
1dB bandwidth (3-D simulation)	MHz	± 0.75
Efficiency(3-D simulation)	%	80.5



The major parts of MBK design are finished, including the interactive cavity, electron gun, focusing solenoid, window and collector.

② Multi-beam klystron

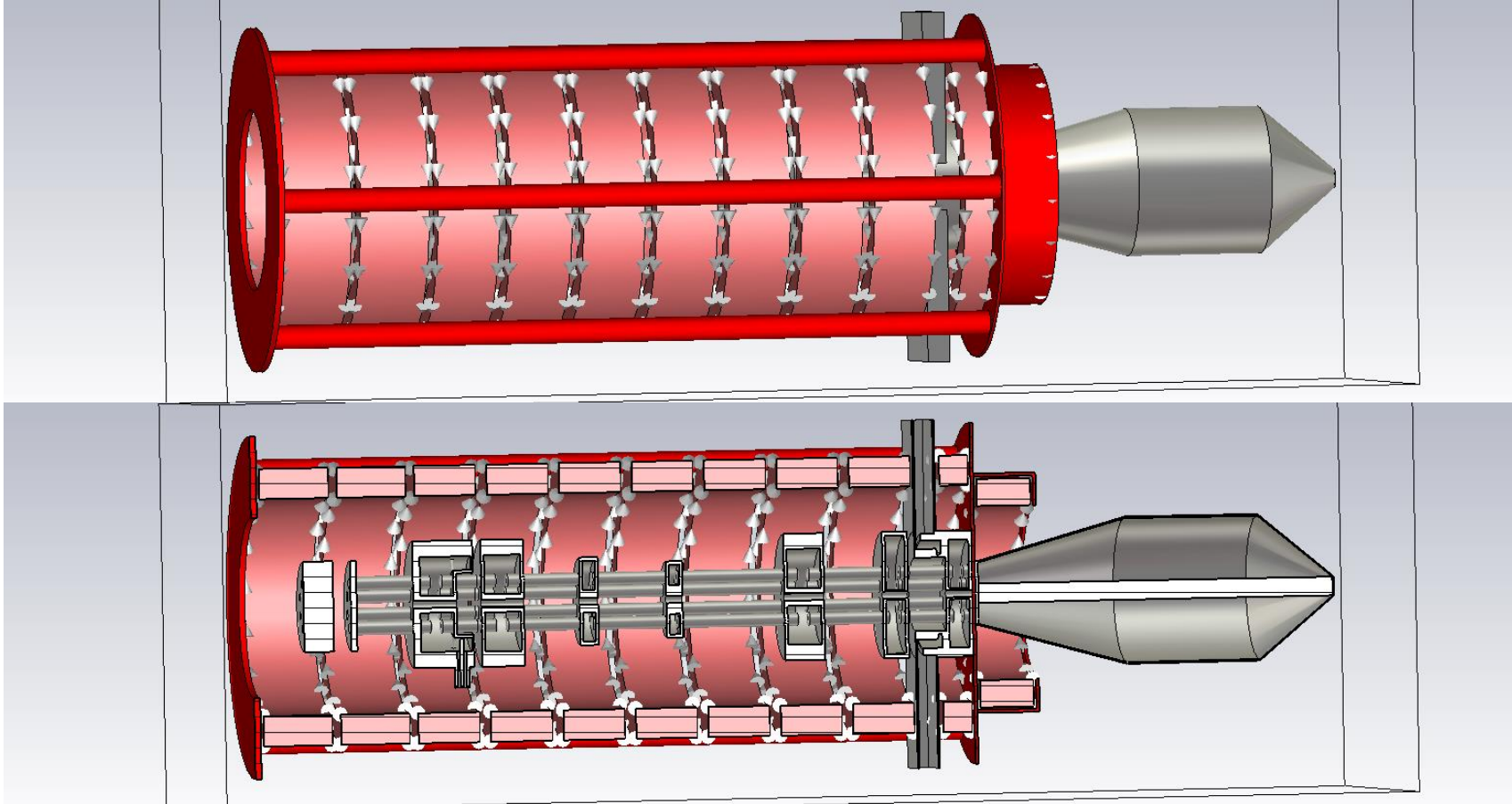
2) Design of MBK window prototype is finished and prototype manufactured is also processing.



Schematic diagram of MBK window test stand

② Multi-beam klystron

3) Mechanical design will start soon



MBK physical model

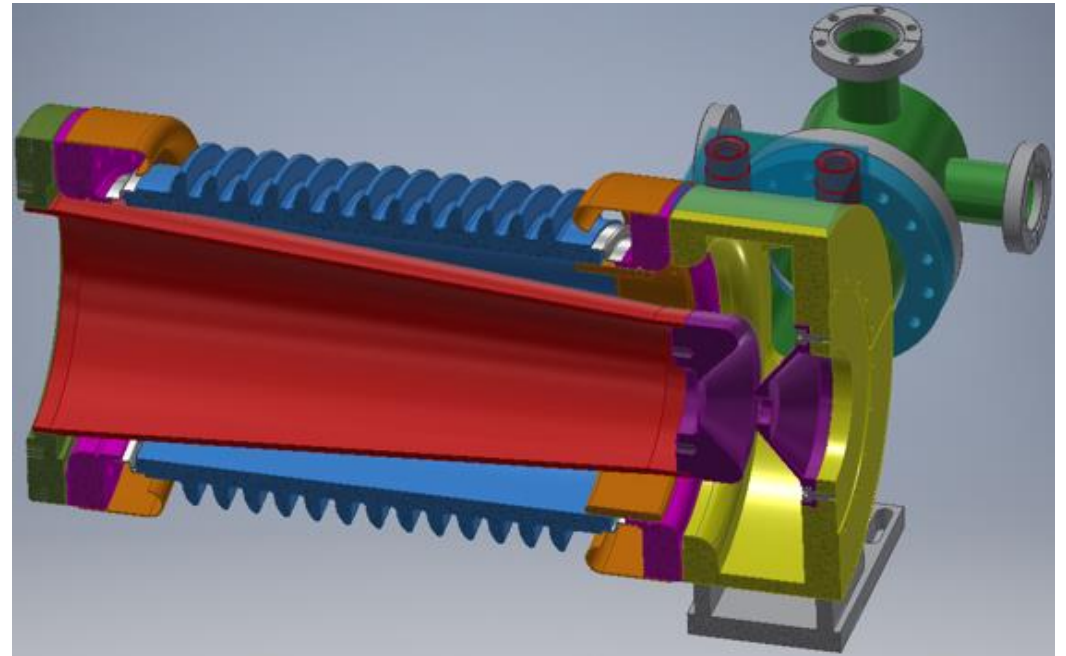
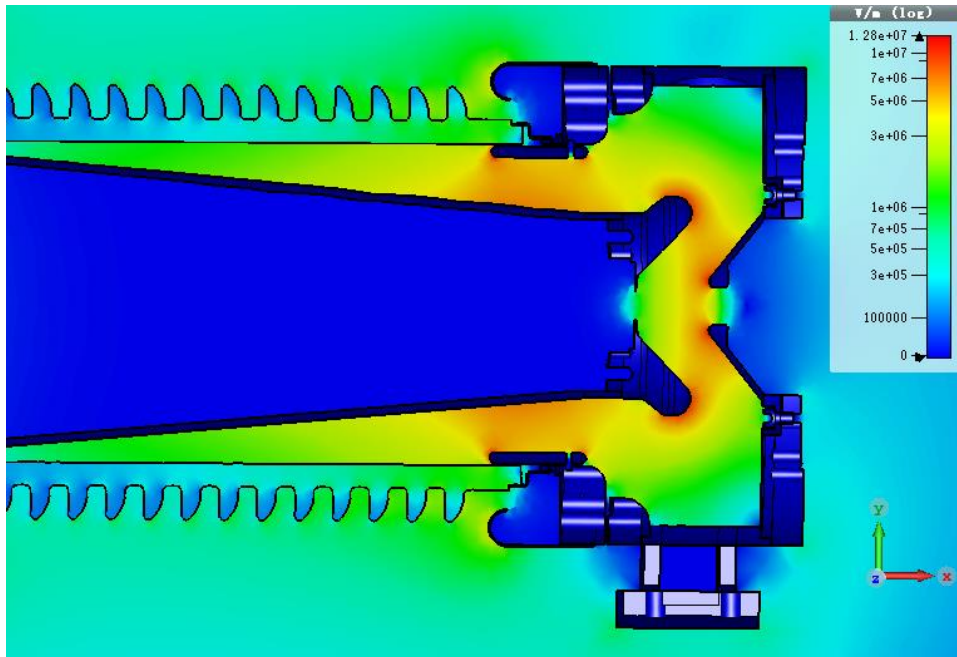
② Multi-beam klystron

- ① The design of multi-beam klystron is almost completed with **80.5% efficiency** at CST 3D code this year.
- ② It's the world's **highest efficiency** 3D design.
- ③ The MBK prototype are planning been completed manufacture at the end of next year.

Other work

HEPS electron gun

- ① The HEPS electron gun system are completed design and expert review this year.
- ② The gun body are being processed and will be completed manufactured at the end of this year.



BEPCII high power test stand update

- ① The S band 150MW high power test stand including S band 80MW klystron and modulator, the stand has been completed acceptance test last month.
- ② This is **highest pulsed power test stand** in China, it will be used for CEPC high gradient accelerate structure R&D and also for S band high efficiency klystron development.



Funding support

- **Yifang Wang's Science Studio of the Ten Thousand Talents Project**
 - Project name: CEPC RF power source system
 - My role: Project leader
 - Budget: Jan. 2018- Dec. 2022, 25,000,000 RMB
- **IHEP Innovation Grant**
 - Project name: Studies on large scale barium tungsten cathode for klystron development
 - My role: Project leader
 - Budget: Jan. 2019- Dec. 2021, 1,000,000 RMB
- **CAS Repair and Purchase project**
 - Project name: S band 150MW high power test stand
 - My role: Project leader
 - Budget: Jan. 2020- Dec. 2020, 5,000,000 RMB

Conference talk list

- ① **Zhou Z. S**, International Workshop on High Energy Circular Electron Positron Collider, Beijing, China, Nov. 2019
- ② **Zhou Z. S**, CEPC Day Meeting, Beijing, China, Dec. 2019
- ③ **Zhou Z. S**, Invited talk in IAS Program on High Energy Physics, HongKong, Jan. 2020
- ④ **Zhou Z. S**, CEPC Day Meeting, Beijing, China, Jul. 2020
- ⑤ **Zhou Z. S**, CEPC Day Meeting, Beijing, China, Oct. 2020
- ⑥ **Zhou Z. S**, International Workshop on High Energy Circular Electron Positron Collider, Shanghai, China, Oct. 2020

Publication list

- ① **Zhou Z. S** et al, Progress on CEPC 650MHz Klystron, white paper, IAS, Program on High Energy Physics, Hong Kong, Dec. 2020.
- ② **Xiao O. Z, Zhou Z. S** et al, Design of P band 800 kW CW klystron for CEPC, Chinese Physics B, will be published.
- ③ **Zaib Un Nisa, Zhou Z. S** et al, Evaluation of Thermal and Deformation properties of Electron gun used in Klystron, will be published.

Project management and coordination

Weekly regular meeting convener and formation of meeting minutes, coordination design, mechanical drawing and manufacture. (IE, Guoli, CSNS, IHEP)

中国科学院高能物理研究所 中国科学院高能物理研究所 中国科学院高能物理研究所 中国科学院高能物理研究所
新型高效率速调管研制会议纪要 新型高效率速调管研制会议纪要 新型高效率速调管研制会议纪要 新型高效率速调管研制会议纪要

2019 (第 34 期 总第 89 期)

2019 (第 42 期 总第 97 期)

2020 (第 14 期 总第 111 期)

2020 (第 38 期 总第 135 期)

时 间: 2019 年 10 月 9 日上午 9:00

地 点: 2#厅会议室

主 持: 周祖圣

出 席: 裴国玺、王建力、董东、肖欧正、王盛昌、福田茂树(skype)、
Munawar Iqbal、王少哲(昆山国力, 微信)、杨修东(电
子所, 微信)

本次会议主要内容如下:

周祖圣通报了 26-29 日福田茂树、董海义、裴国玺和周祖圣访
问国力相关情况并召开现场协调会, 电子所周健勇和廖云峰一并
参加:

排气台现状: 1) 过去两个月, 排气台完成清华样件 (2 次升
降温) 和模拟管样件 (150° 一次), 进行相关实验; 2) 排气管
道更换粗管道继续进行实验。

排气台目前存在问题: 1) 调试计划不明确, 目标不清晰, 华
创和国力协调效率有待提高; 2) 设备升级改造方案论证不充分。

下一步计划: 1) 继续调试排气台, 在离子泵和分子泵口增加
阀门; 2) 排气台改造完成后, 利用样件对其进行再调试, 确保

时 间: 2019 年 12 月 31 日上午 9:00

地 点: 2#厅会议室

主 持: 周祖圣

出 席: 裴国玺、董东、肖欧正、王盛昌、Munawar Iqbal、Abid
Aleem

本次会议主要内容如下:

1. 周祖圣通报了近期相关工作进展:

1) 12 月 23 日样管在国力装车完毕, 24 日上午 10:30 启运,
周祖圣和梅宏生押运运输车, 于 25 日 21:30 运抵高能所, 26 日
上午卸车完毕并顺利就位于 1#厅 2 楼测试现场; 2) 分析安装于
样管上震动仪数据显示运输过程平稳, 在高能所卸车和吊装过程
震动量较大; 3) 样管就位后速调管钛泵开启, 电流为 0。灯丝预
热至 10A 后, 钛泵电流 0.35 微安, 确认管内真空正常, 顺利完成
运输; 4) 测试现场条件准备: 冷却水管连接完毕、高压电缆插
头厂家准备中、流量计和温度探头及表头准备完毕、数据采集和
连锁准备中。

2. 肖欧正介绍样管不同枪压下束流包络和速调管输出特性,

时 间: 2020 年 5 月 14 日下午 14:00

地 点: 2#厅会议室 (视频会议)

主 持: 周祖圣

出 席: 裴国玺、福田茂树、董东、肖欧正、王盛昌、Munawar Iqbal、
Zaib Un-Nisa、周宁闯、张辉 (CSNS)、陆志军 (CSNS)、
王少哲 (昆山国力)

本次会议主要内容如下:

1. 王少哲介绍国力近期工作进展: 1) 完成第二腔的放电 3D
测绘及绘图; 2) 完成输出腔常导同轴转换情况下的冷测; 3) 测
量腔体内壁粗糙度小于 0.6um; 4) 完成速调管运行支架外形 3D
测绘的 90%工作量; 5) 完成速调管线圈外形 3D 测绘的 60%的工
作量; 6) 余下 5 个腔全部打包发往威视准备进一步 CT 拍摄。

2. Munawar 介绍了 324MHz 速调管电子枪和聚焦线圈设计
进展: 1) 计算理想磁场下的束流波数, 束流波数率低于 4%;
2) 根据理想磁场值设计线圈分布, 参照首支样管 pole piece 设计,
束流波数率大于 20%, 无法满足设计需要。福田教授建议继续优
化 pole piece 结构尺寸。

时 间: 2020 年 11 月 19 日下午 14:00

地 点: 2#厅会议室 (视频会议)

主 持: 周祖圣

记 录: 张湛东
出 席: 董东、王建力、肖欧正、王盛昌、Munawar Iqbal、Zaib un
Nisa、王少哲 (昆山国力)、张辉 (CSNS)、周宁闯、张湛
东

本次会议主要内容如下:

1. Munawar 利用 EGUN 对 325MHz ADS 速调管电子枪进行了
整体仿真复算并与 CST 和 DGUN 的仿真结果进行了比较, 电流
和阴极电流负载密度等数据均存在一定差异, 加入磁场后的束流
波动率差距也很大。建议待 Zaib 完成 MBK 高压陶瓷筒设计后进
行检查复算, 继续进行 324MHz 速调管电子枪的设计。

2. Zaib 介绍了多注速调管 (MBK) 高压陶瓷筒的设计进展并
与大家进行了讨论, 目前调研了 Toshiba 公司和 Thales 公司的两
种类型陶瓷筒设计, 目前设计工作正在进行, 但由于尺寸需要进
行调整, 将与福田教授和王盛昌进一步讨论。

Yifang Wang read all meeting minutes

Summary

- The highest CW power klystron in China are successfully developed and being used for test facility for RF components conditioning and commissioning.
- We are powerfully pushing manufacture of high efficiency prototype and hope it will be highest efficiency klystron in the world in the near future.
- The design and manufacture for MBK are also promoted and it will enable China to go a step further in klystron development technologies.

Thanks for your attention!