ASIPP

Improvements of the Tungsten Guard Limiter of 4.6GHz Lower Hybrid Wave Antenna of the EAST and its Service Status under Operations

by

L. Yin[1*]

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Outline

1 Review of the GL with Graphite tiles

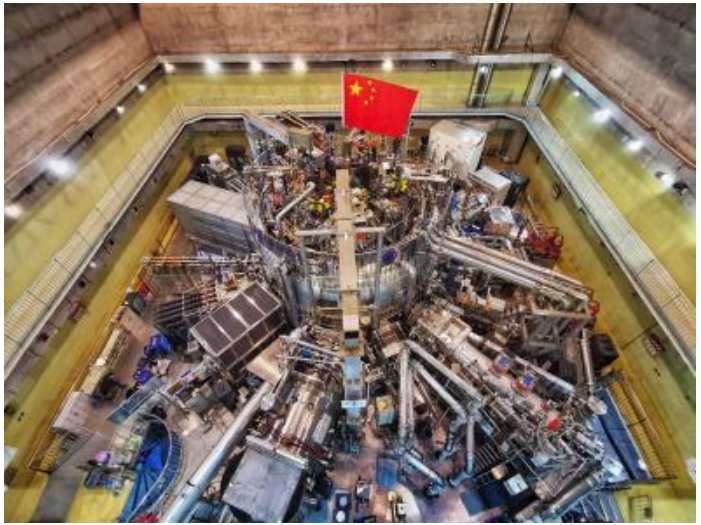
2 Review of the obsolete Tunsgten Guide Limiter

3 Improvement of the Tunsgten Guide Limiter

4 Service Status under the EAST Operations

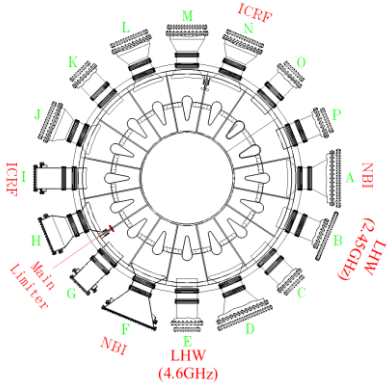
5 Summary

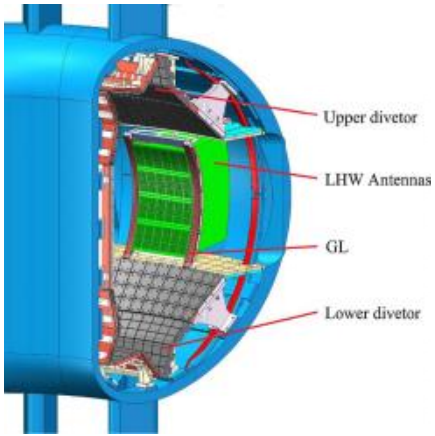
Brief Introduction of the EAST

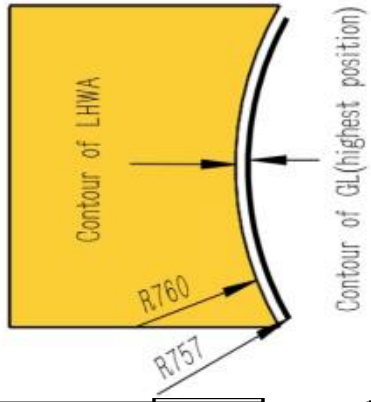


- **Feature:**
  1. non-cricular cross-section
  2. fully superconducting magnets
  3. fully actively water cooled plasma facing componets
- **Mission:**
  conducting ITER-like steady-state advanced plasma research

Overview of the EAST LHCD and GL





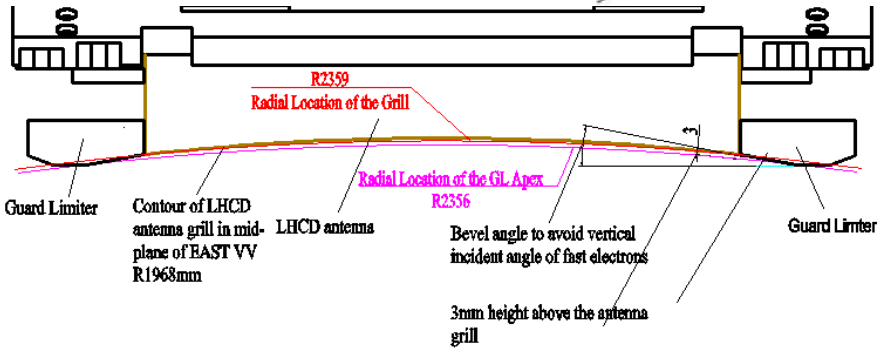


Main Parameter of 4.6GHz LHCD

- Maximum 6MW
- Long-pulse (>1000 s)
- FAM launcher with actively water cooling

Design Requirements of the GL

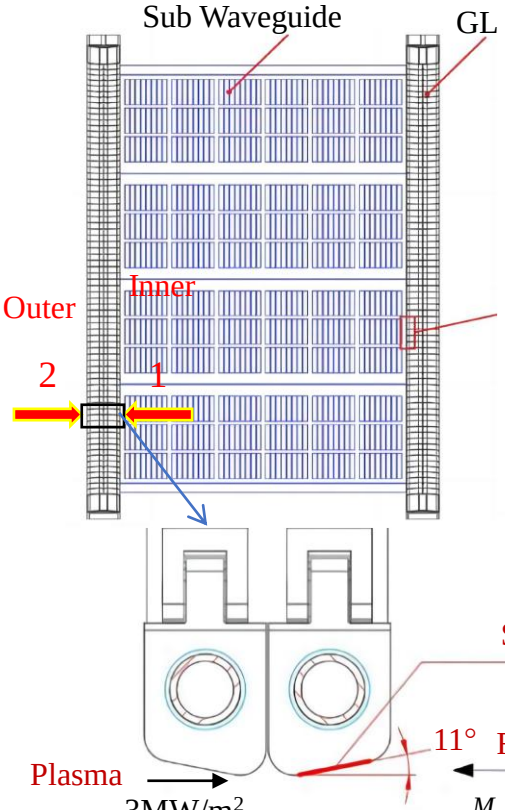
1. GL 3mm higher than the LHWA grill in mid-plane, located at R2356mm .
2. GL should be 3mm higher thanthe LHWA grill in the poloidal cross section, R757mm .



[1] C.L. Liu er al. IEEE T. PLASMA SCI. 50（2022）990
[2] C.L. Liu er al. Fusion Eng. Des. 2017
[3] L.L. Zhang er al. Fusion Eng. Des. 2018

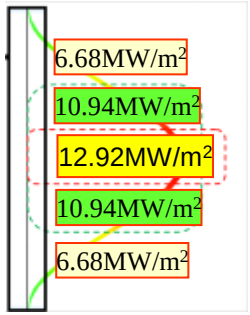
Review of the Obsolete Designs

High Heat Flux Componet for the GL



1. Heat from fast electrons

LHW Power: 4MW



2. Heat flux from plasma

3MW/m²

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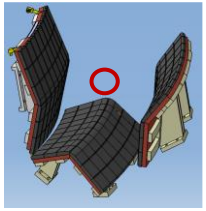
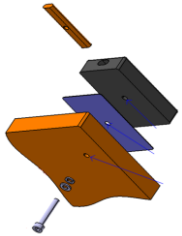
Require

High Heat Flux Componet avaliable in EAST

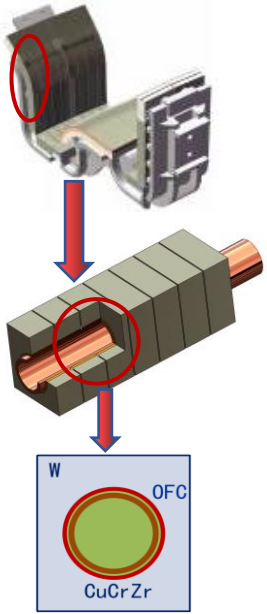
Graphite Tiles





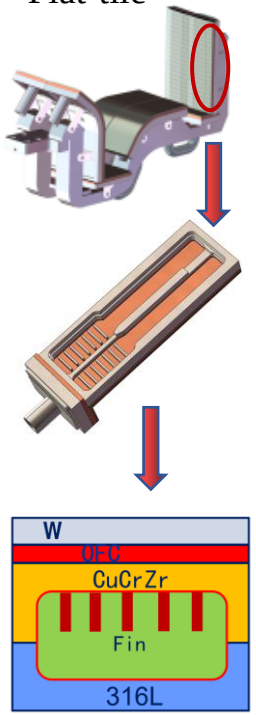
steady state :
2MW/m²

Monoblock



steady state :
10MW/m²

Flat-tile

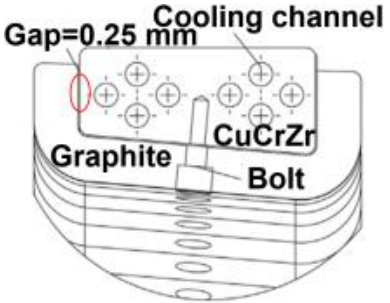


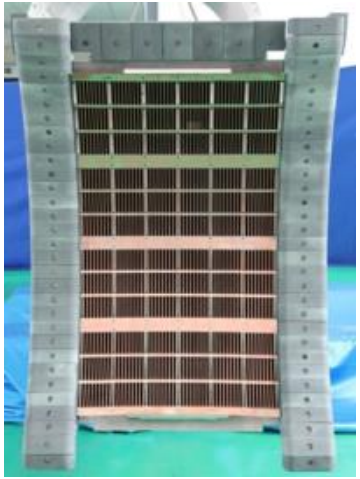
steady state :
20MW/m²

L. Lei er al. Plasma Sci. Technol. 23(2021) 095601

Obsolete GL consisting of Graphite tiles

Overall Limiter structure





- **Graphite tiles coated with SiC, CuCrZr heat sink with stainless support frame.**
- **low thermal conduction due to poor contact**
- **Design target ~ 2.0 MW/m^2.**

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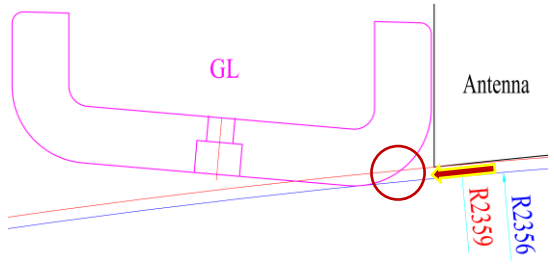
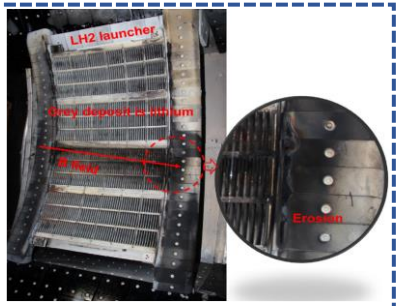
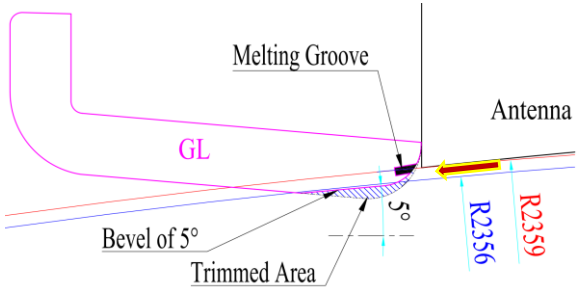
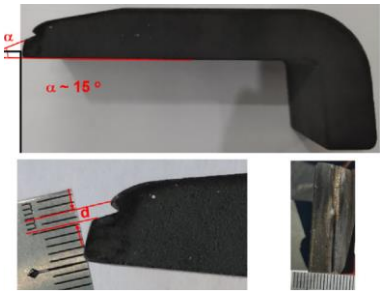




2014





2015

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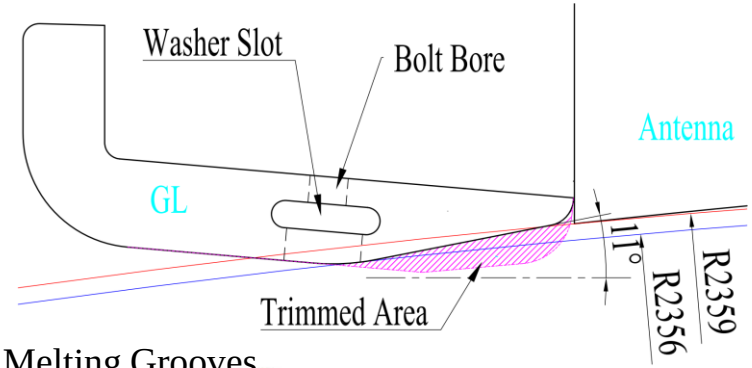
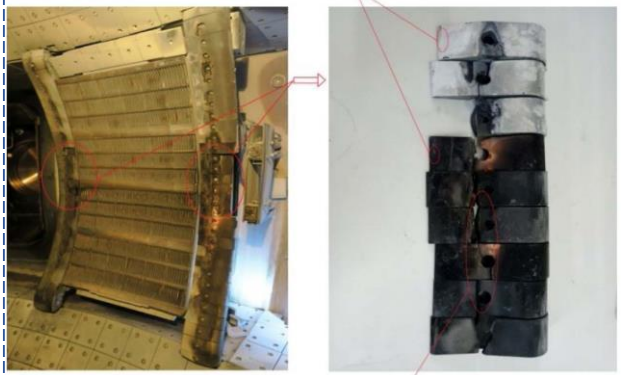
Assumption:

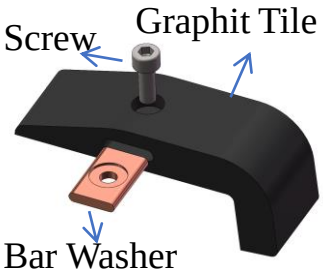
- A layer of fast electrons exsit adjacent to the grill
- Heat load of fast electrons goes approximately toroidally

Obsolete GL consisting of Graphite tiles



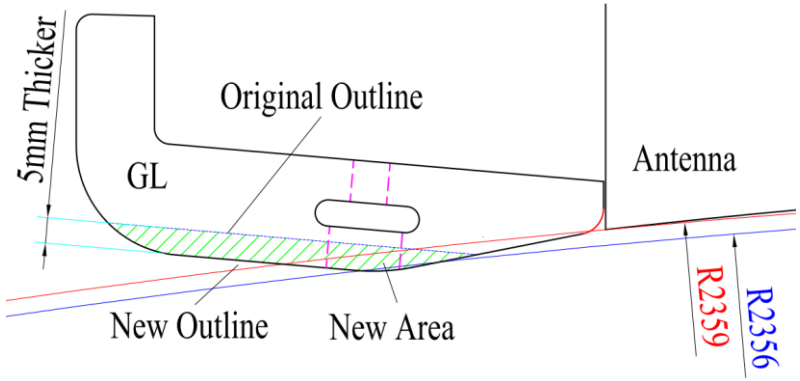
No Melting Grooves

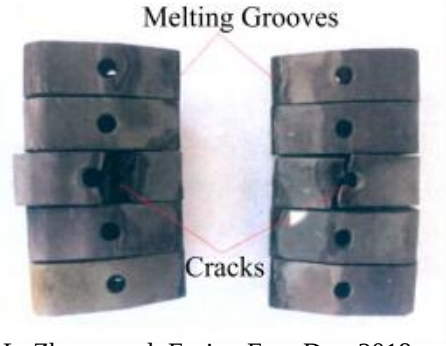




Cracks

2016 C.L. Liu er al. Fusion Eng. Des. 2017





2017 L.L. Zhang er al. Fusion Eng. Des. 2018

Outline

1 Review of the GL with Graphite tiles

2 **Review of the obsolete Tunsgten Guide Limiter**

3 Improvement of the Tunsgten Guide Limiter

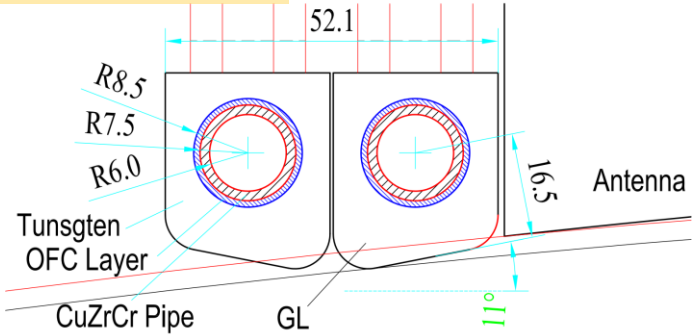
4 Service Status under the EAST Operations

5 Summary

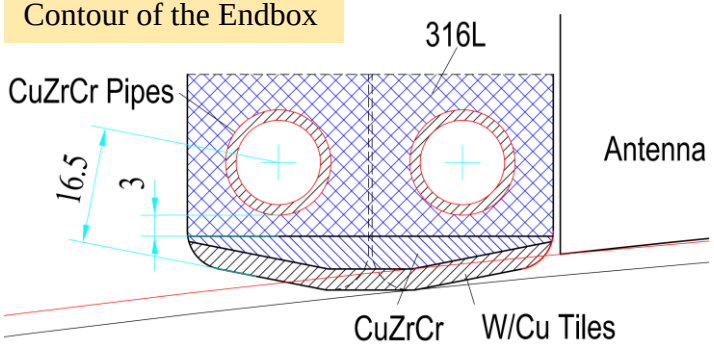
Obsolete Tungsten GL

设计及工艺

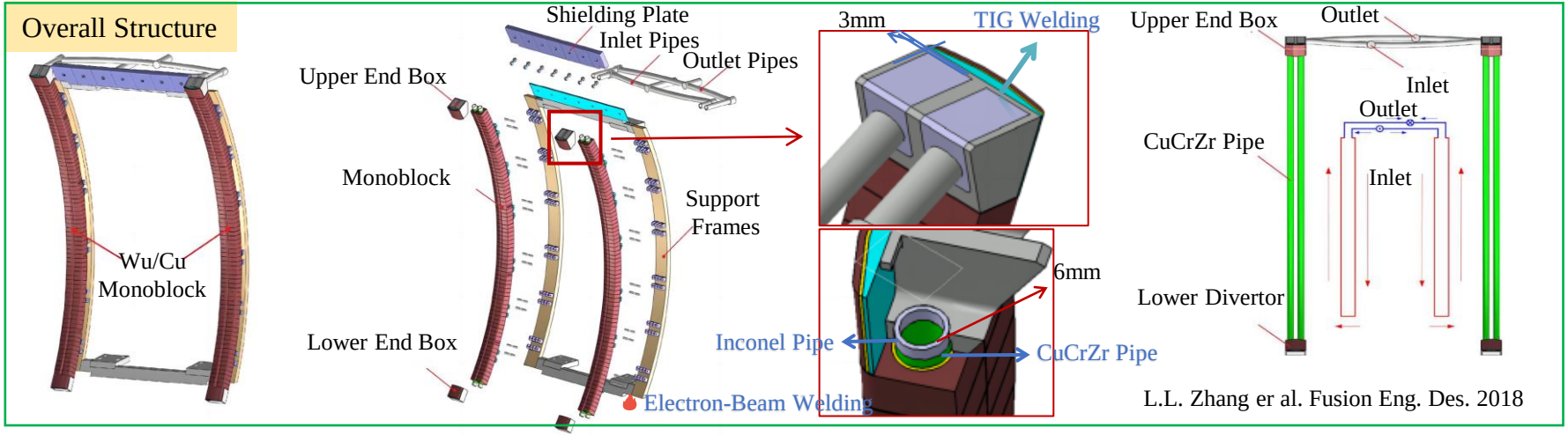
Contour of the Monoblock



Contour of the Endbox



Overall Structure



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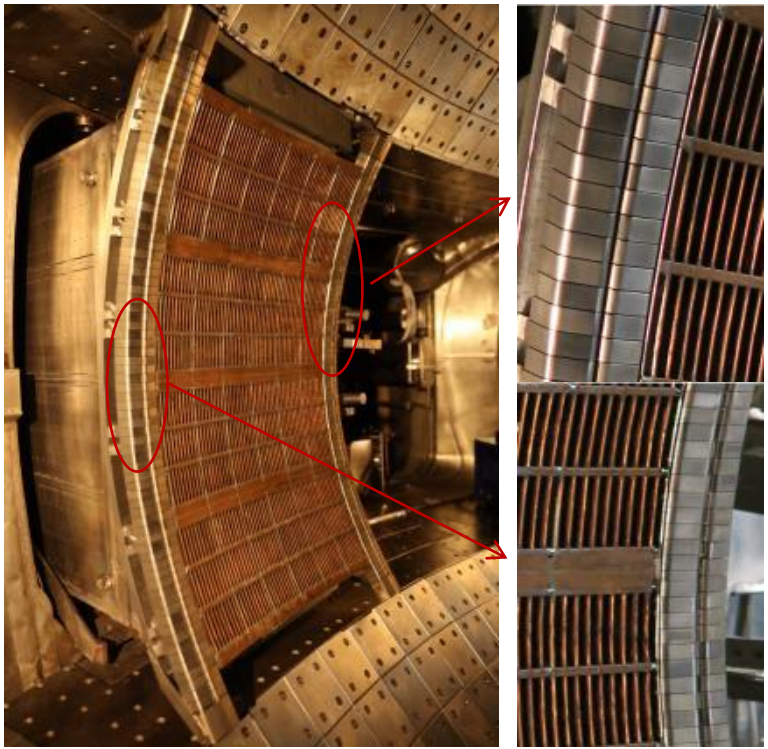
Service History of the Obsolete Tungsten GL



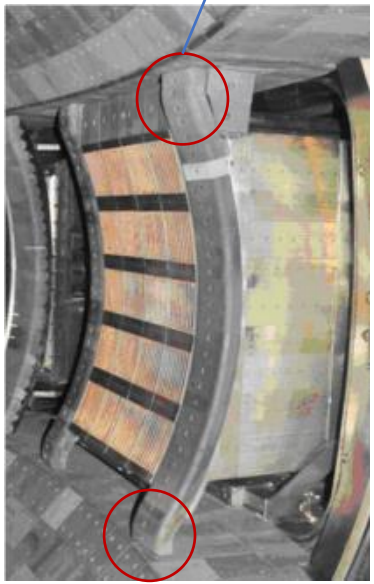
2017.11 First installation

1. Melt on the end boxes
2. Melt on the inner corners of the monoblocks

First Modication of the Obsolete Tungsten GL

Reason for the Ablition of the End Box

Bend

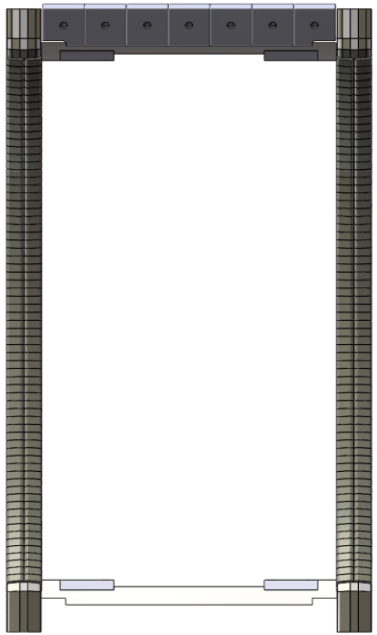


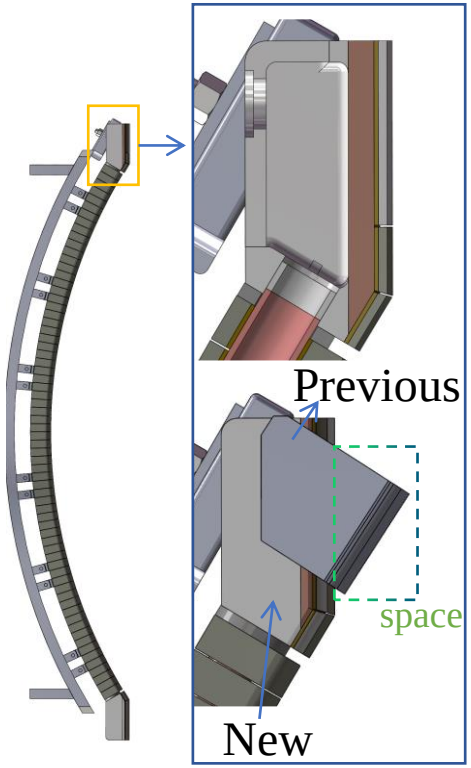
previous graphite tils GL

No Bend

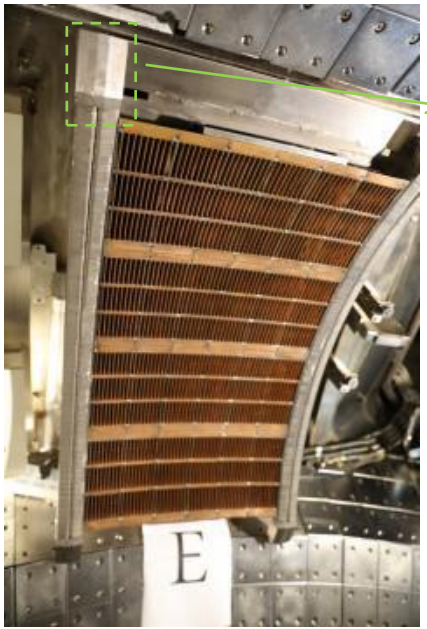
new Tungsten GL

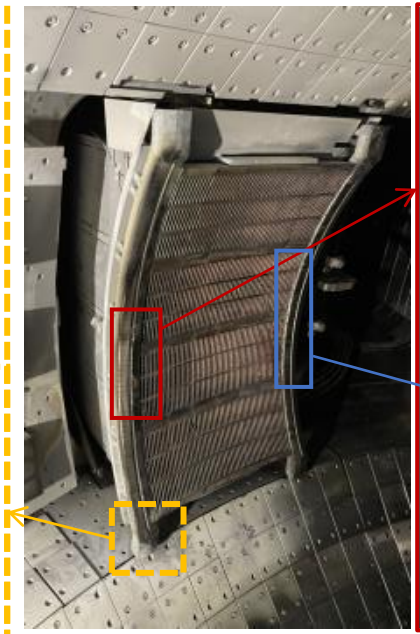
New Design





Service History of the Obsolete Tungsten GL



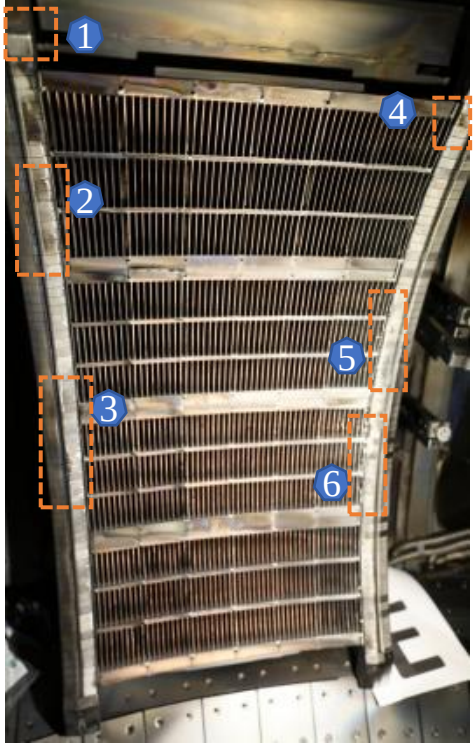


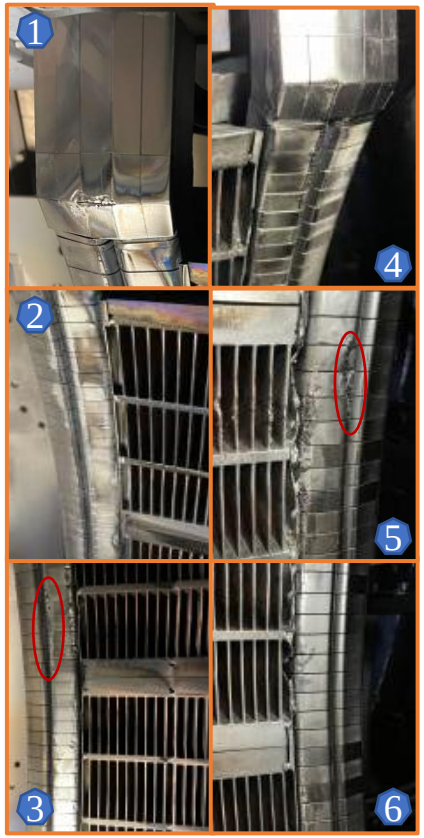
2020.8-2021.4 upgrade

After 2021 Spring Campaign

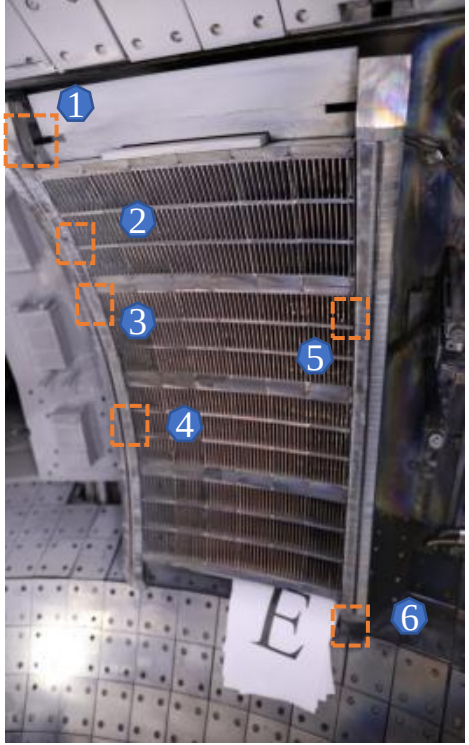
Service History of the Obsolete Tungsten GL

After 2021 Autumn Campaign





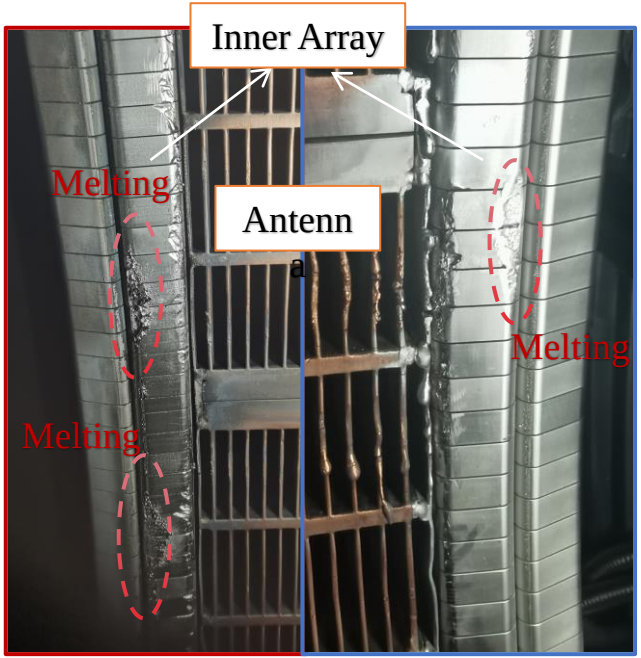
After 2022 Spring Campaign

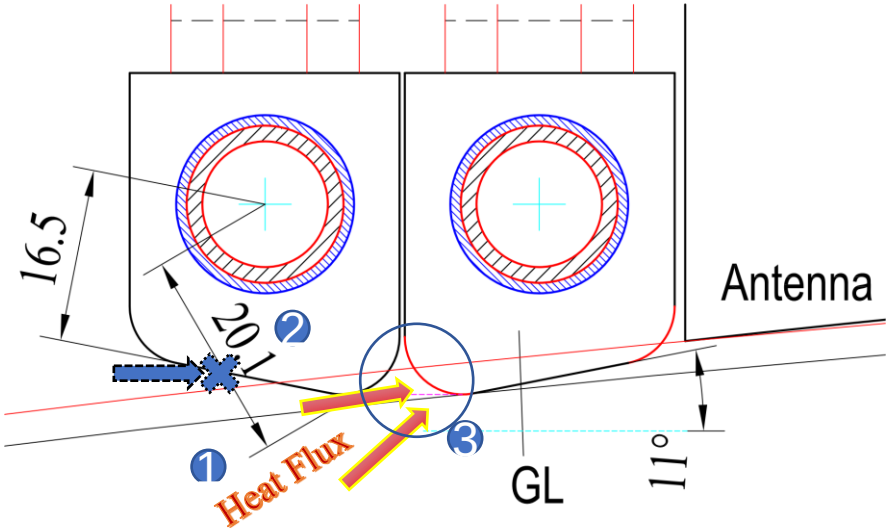


Modificaiton and Rectificaiton

Cause Analysis for Damage:

1. Melting on the top





Possible Reason:

① Incident heat flux on the corner
② Low heat exhaust ability of the top
③ Potential assemble misalignment

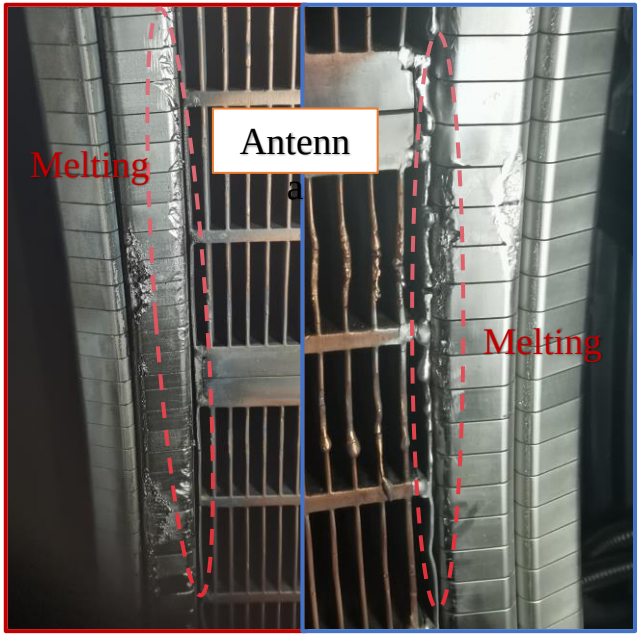
Suggestion:

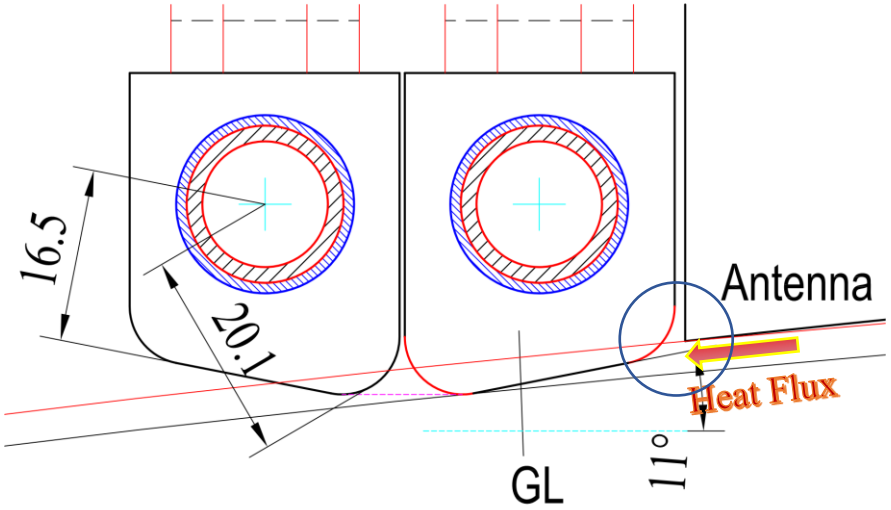
① Top of the GL should be on one monoblock

Modificaiton and Rectificaiton

Cause Analysis for Damage:

2. Melting on the Inner Fillet





Possible Reason:

① Incident heat flux on the Fillet
② Fast Electron Layer close to the grill
③ Potential assemble misalignment

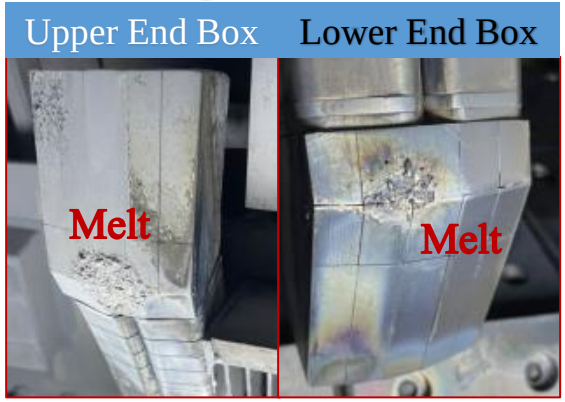
Suggestion:

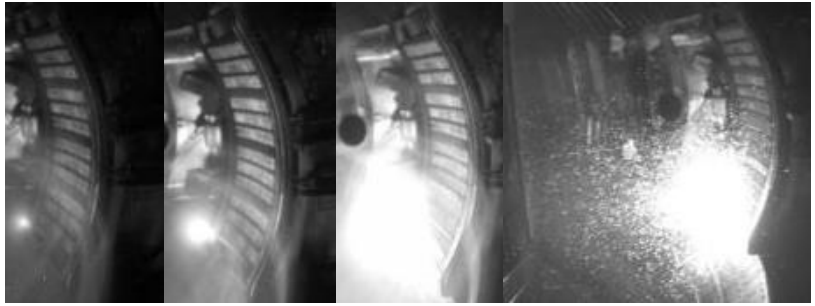
① Set the inner cornor below the grill(considering misalignment)

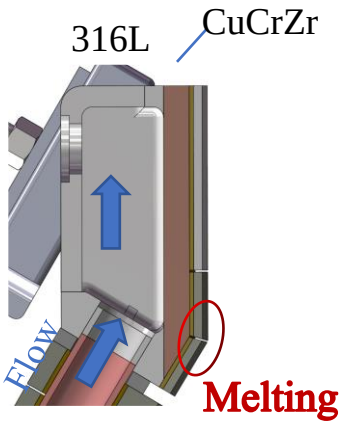
Modificaiton and Rectificaiton

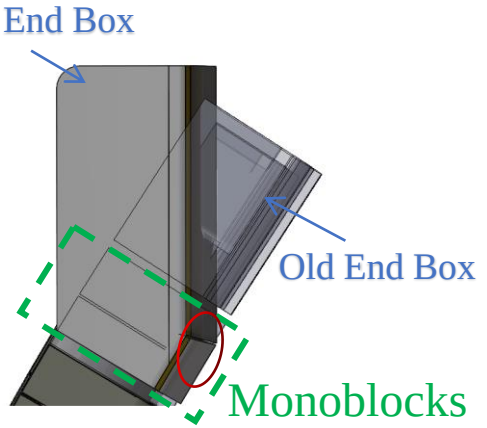
Cause Analysis for Damage:

3. Melting on the End Box









Possible Reason:

① Poor local heat exhaust ability

② Closet location to the plasma

Suggestion:

① Elongate the monoblock components

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3 **Improvement of the Tunsgten Guide Limiter**

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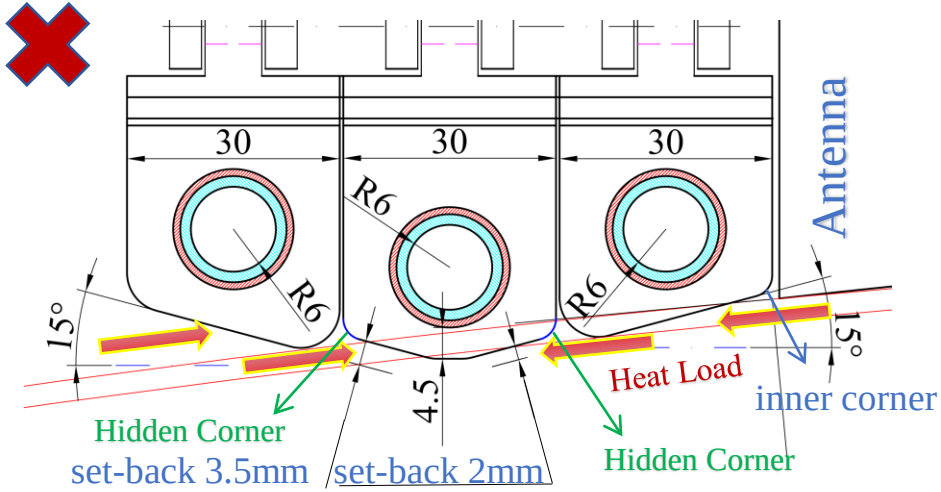
5 Summary

Modificaiton and Rectificaiton

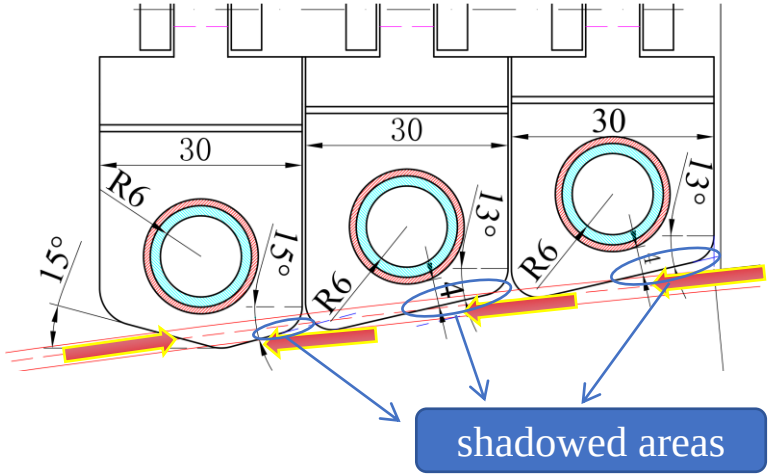
Modificaition:

1. Contour of the GL: *Plan A*



- Inner corner hidden behind the grill
- All corners shadowed to avoid leading edge
- Bevel angles incresing from 11° to 15°
- Thicnkess of Tunsgten reduced to 4.5mm

1. Contour of the GL: *Plan B*

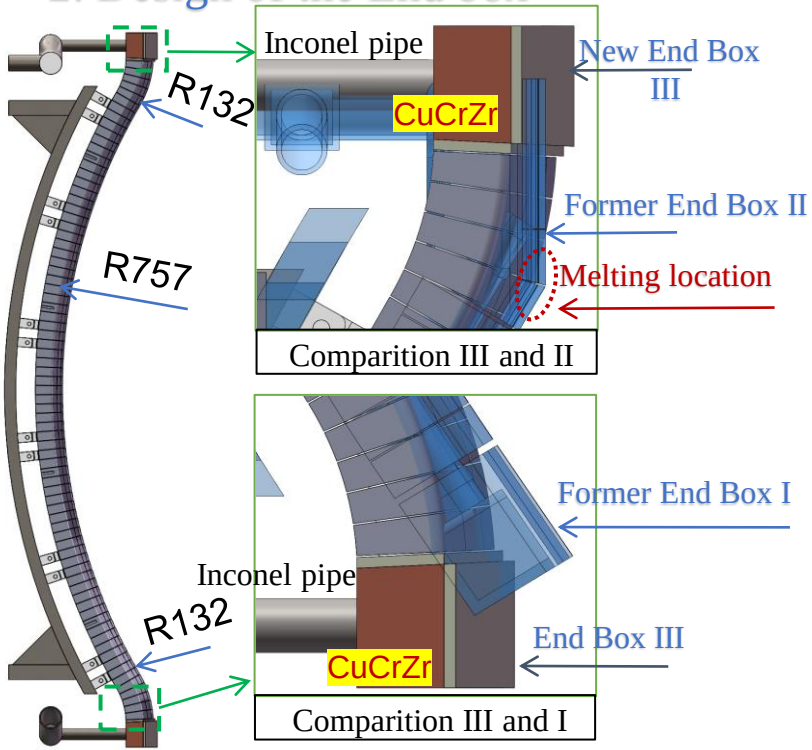


- Inner corner being hidden behind the grill
- All corners being shadowed to avoid leading edge
- Bevel angles（inner） incresing from 11° to 13°
- Thicnkess of Tunsgten reduced to 4.5mm

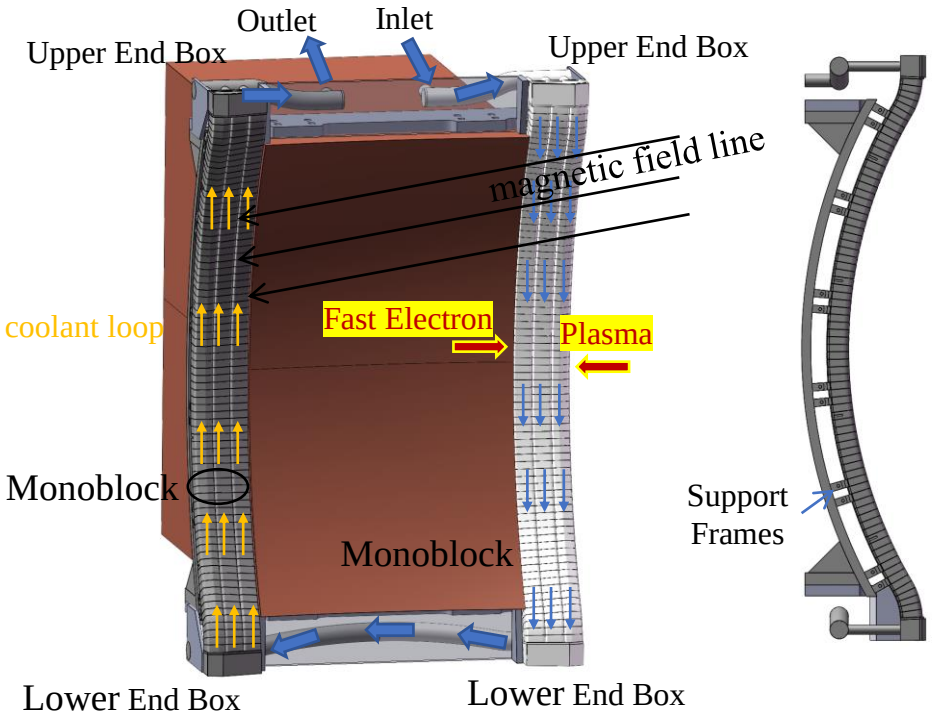
Modificaiton and Rectificaiton

Modificaition:

2. Design of the End box

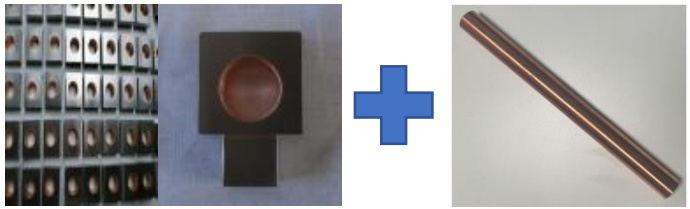


3. Overall Structure



Modificaiton and Rectification

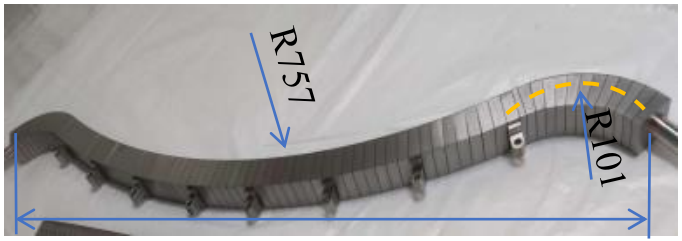
Processing procedure



Monoblock

CuCrZr

HIP:600℃ 100MPa



Monoblock component: welded by HIP

Supplied by Advanced Technology & Materials Co., Ltd

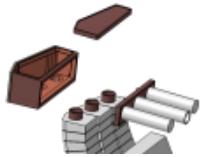
Assemble Requirment

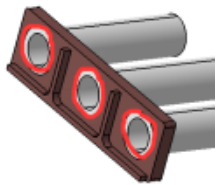
Profile tolerance:±0.5mm

Misaligment: 0.5mm

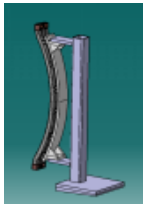
by Hefei Keye manufacturing Co., Ltd

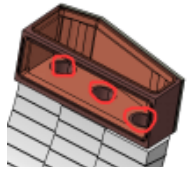
componets

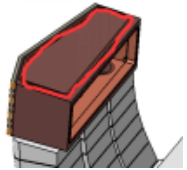




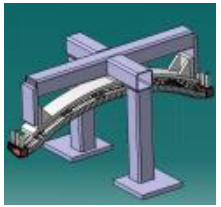
post 1

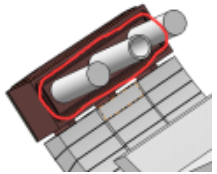






post 2

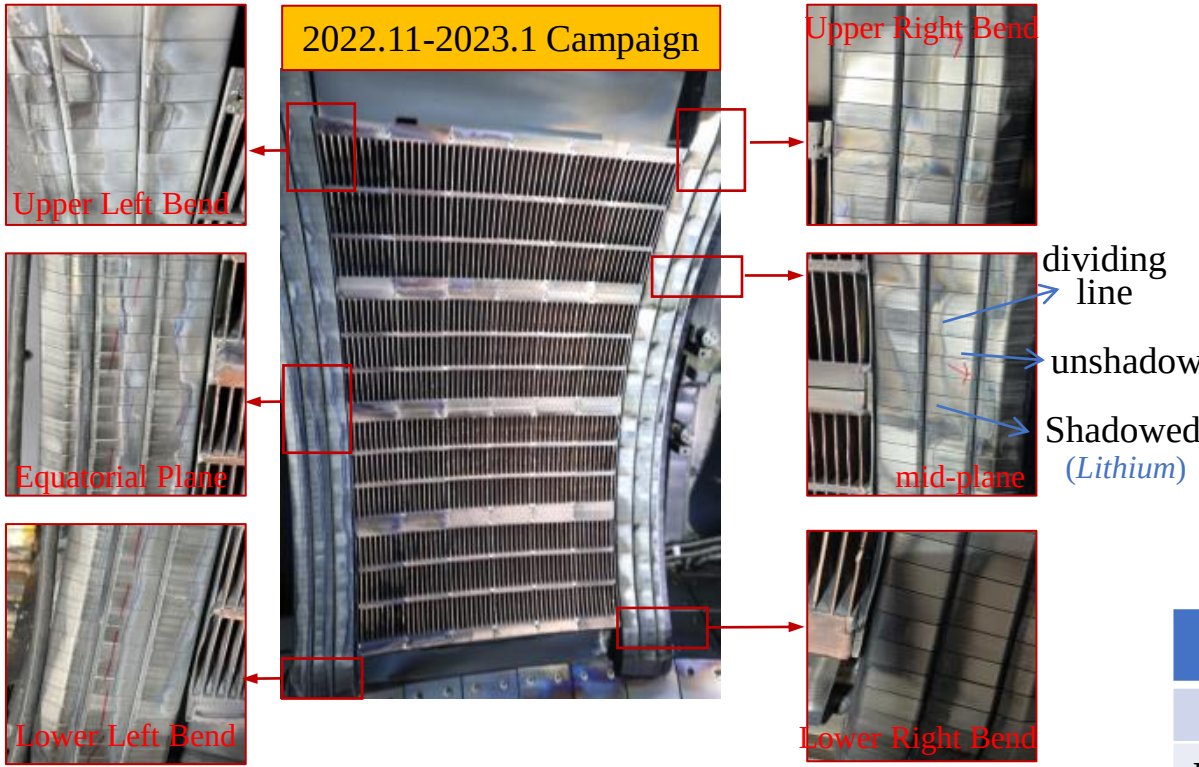


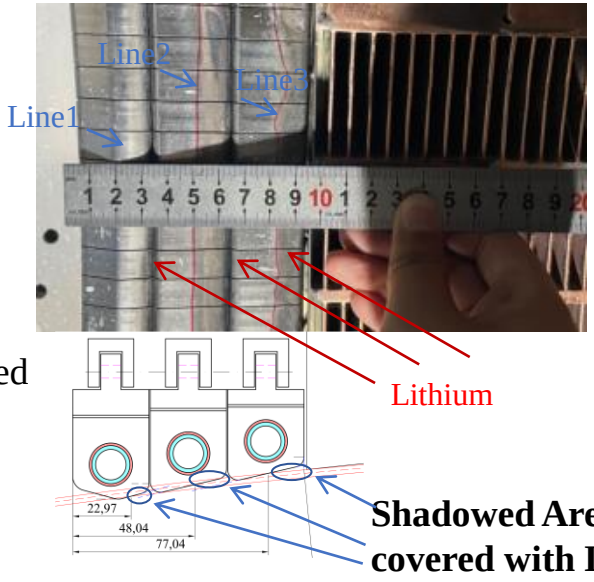


installation

implemented by Hefei Juneng Electron Physics High-tech Development Co., Ltd

Service under the EAST experimental operation

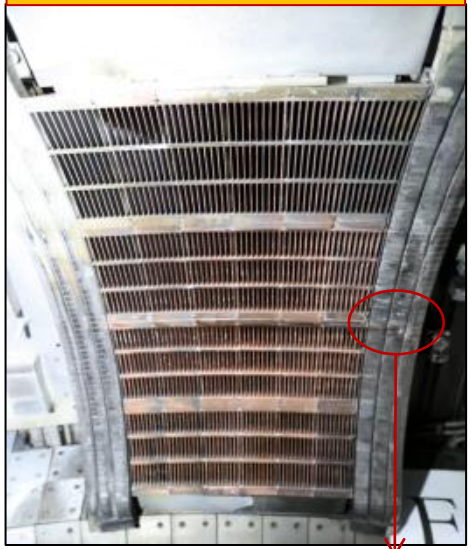


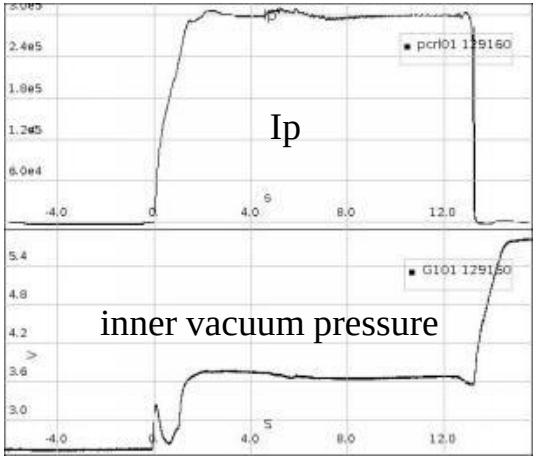


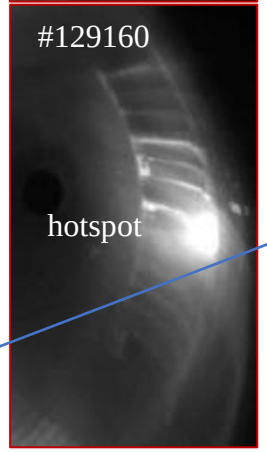
	Line 1	Line 2	Line 3
Design Value	23	48	77
Measured Value	24	56	83

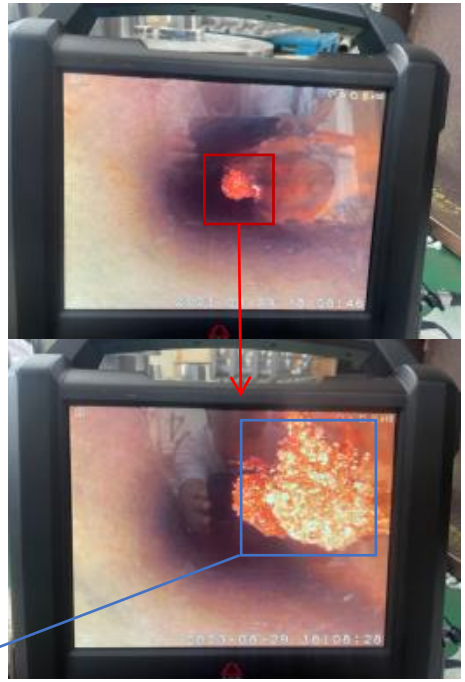
- No visible Damage found on the surface of the GL
- A dividing line found between the shadowed and unshadowed area

2023.03-2023.08 Campaign

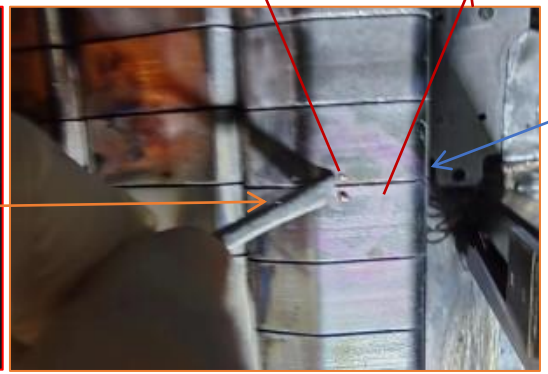








copper leakage location



Lasting 3.8s

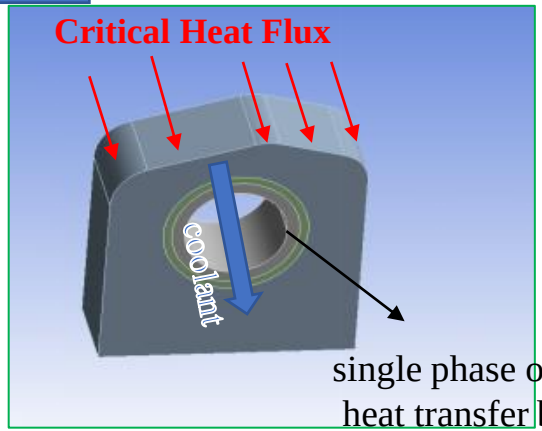
Over CHF?

#Shot129160 :

Ip310KA,13.2s, ne~4.5
LH2~2.3MW
EC~2MW
IC~2.5MW
NBI_1L~50kV
NBI_1R~55kV
NBI_2R~55kV

Estimation CHF

Original



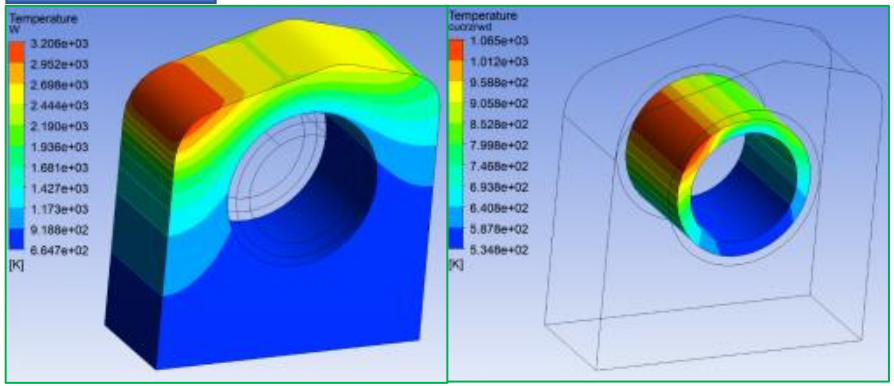
single phase or boiling
heat transfer boundry

coolant pressure: 0.6MPa
coolant temperature:27^{o}C

Using Tong-75

Flow speed (m/s)	Coolant temperature (^{o}C)	CHF (MW/m^2)
5	27	~29.8
6	27	~32.2
7	27	~34.4
8	27	~36.5
9	27	~38.3
10	27	~40.1

Improved



coolant pressure: 2MPa
coolant temperature:27oC
coolant speed : 7.4m/s

Using Tong-75

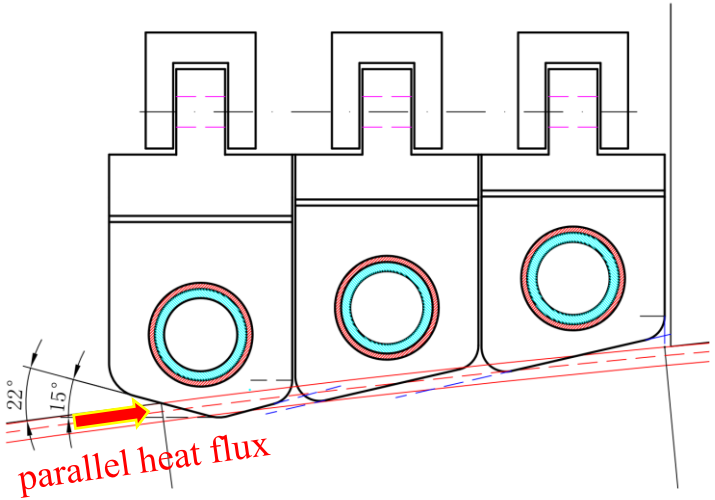
critical warning temperature

CHF(MW/m^2)	41
Max. allowable heat flux (MW/m^2)	29
Max. temperature(Wu) /^{o}C	2933
Max. temperature(CuCrZr Pipe)/^{o}C	954
melting point(CuCrZr)/^{o}C	1080

by L. Han, ASSIP

mitigate

Original



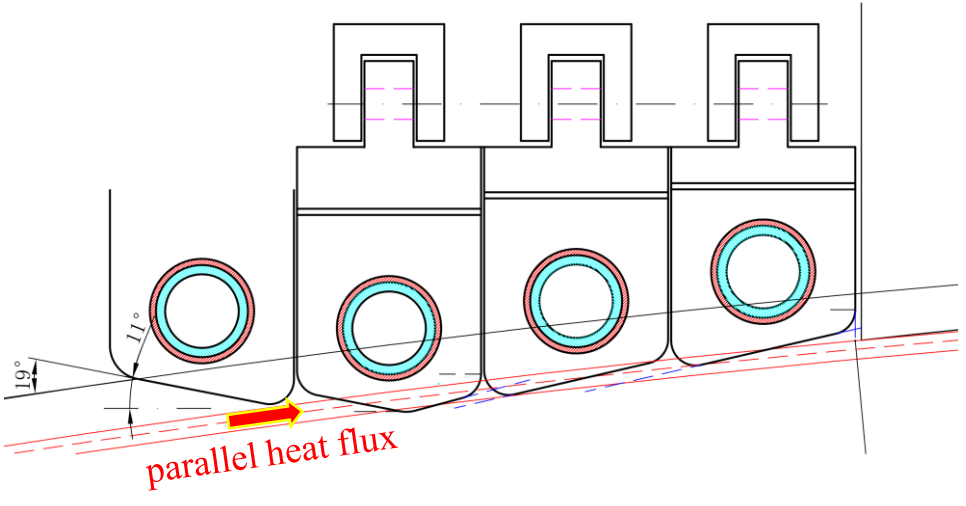
PHF(parallel heat flux)

CHF≥34.4MW/m^2

CHF=PHF*sin22°

➡ PHF=91.7MW/m^2

Improved



VHF(vertical heat flux)

VHF=PHF*sin22°

PHF=91.7MW/m^2

➡ VHF=29.8MW/m^2

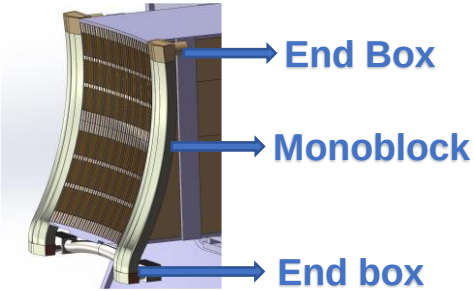
Decreased by 13.3%

Summary and Prospect

- **In order to mitigate the cracks,melting or ablations on the GL of the 4.6GHz LH atenna, efforts have been made:**
  - **Upgrading the guard limiters from graphite tiles to tunsgten monoblock limiter**
  - **Ablation on the inner corner eliminated, by moving the corner behind antenna**
  - **Ablation on the top of the GL eliminated, by move the top of GL to one monoblock**
  - **Ablation on the bend of the GL miligated, by moving back of the bend from the plasma.**
- **The leakage in the last shot#129160:**
  - **High possibly caused by the CHF event, according to observation**

Summary and Prospect

- **To Solve the CHF events**
  - To increasing CHF of the GL as much as possible.
  - To ease vertical heat flux on the GL.
  - To get reliable heat flux data .
- **Design of the new GL of 4.6GHz PAM LHWA in port B**
  - End box with low heat exaust ability locating near the mid-plane where heat flux is extremly high



Thank You

The authors acknowledge the financial support from the National MCF Energy R&D Program (2018YFE0312300)