

# Installation Status of Transmission Line and Alignment for KSTAR 84-GHz ECH System\*

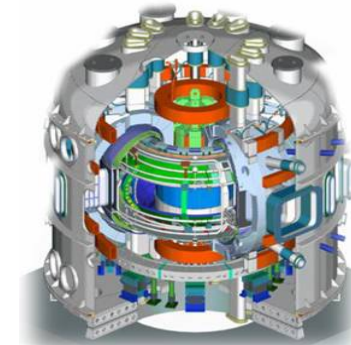
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POSTECH, <sup>1</sup>National Fusion Research Center

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# Abstract

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The KSTAR electron cyclotron heating (ECH) system is consisted of a millimeter-wave source (a gyrotron), a transmission line system, and a launcher. The high-power millimeter-wave of 500 kW at 84-GHz is transmitted from the gyrotron to the launcher through circular corrugated waveguides of the 31.75-mm inner diameter. In the corrugated waveguide, the dominant propagation mode of the HE<sub>11</sub> mode can be easily converted to the other higher modes by misalignments, such as tilts and offsets of the waveguide axis, and therefore, the power loss occurs. The vacuum at 0.1 mTorr is also required for preventing RF breakdowns. In this paper, we present the installation status of transmission lines: the alignment method aiming at the 90% transmission efficiency and the vacuum system.

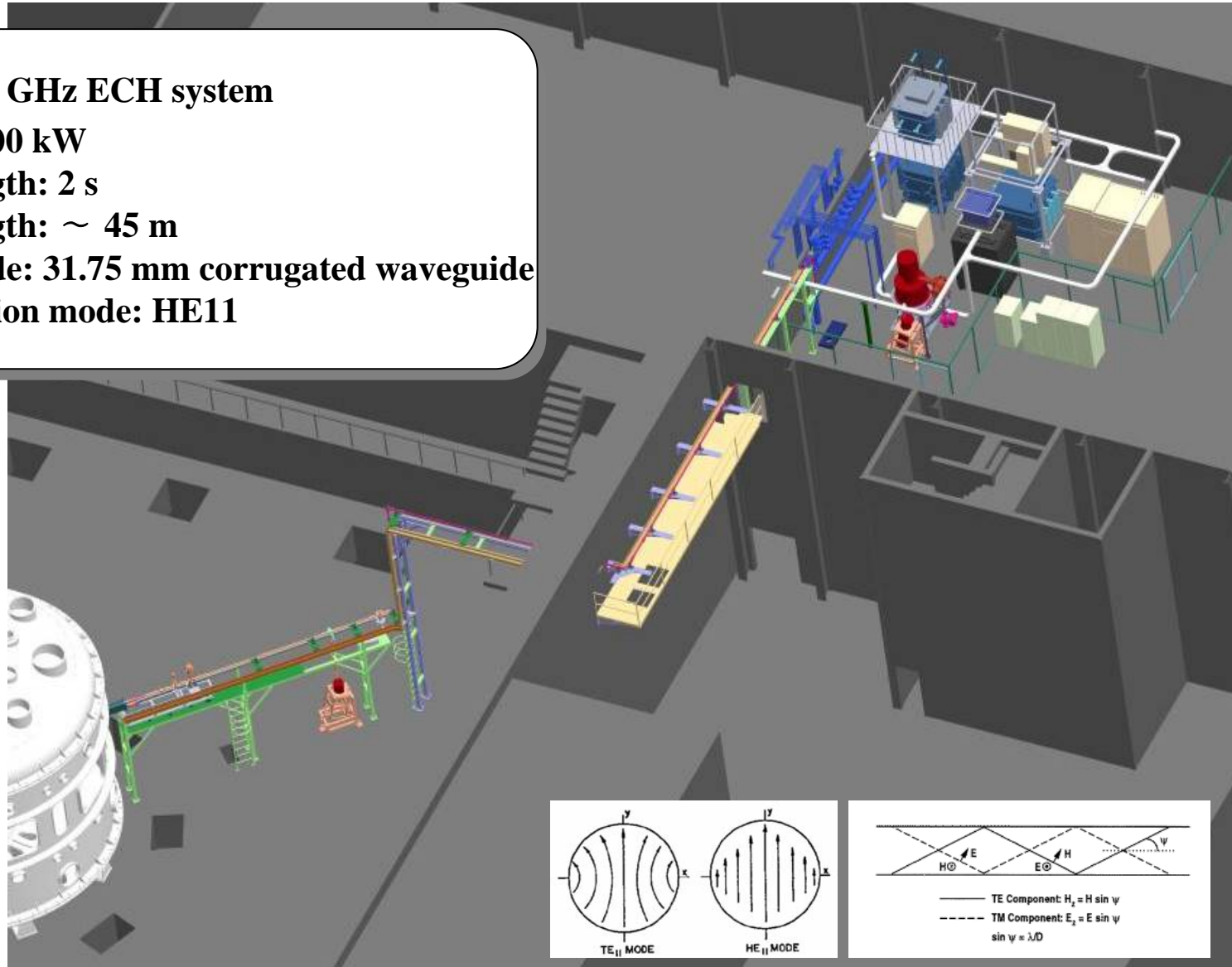


# KSTAR 84 GHz ECH System

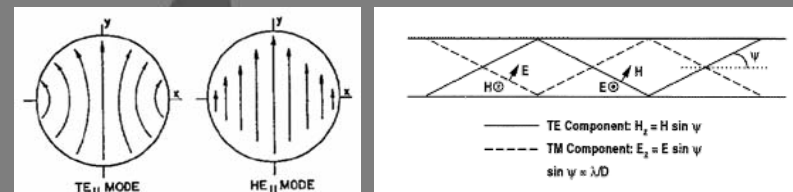
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## KSTAR 84 GHz ECH system

- Power: 500 kW
- Pulse length: 2 s
- Total length: ~ 45 m
- Waveguide: 31.75 mm corrugated waveguide
- Propagation mode: HE<sub>11</sub>



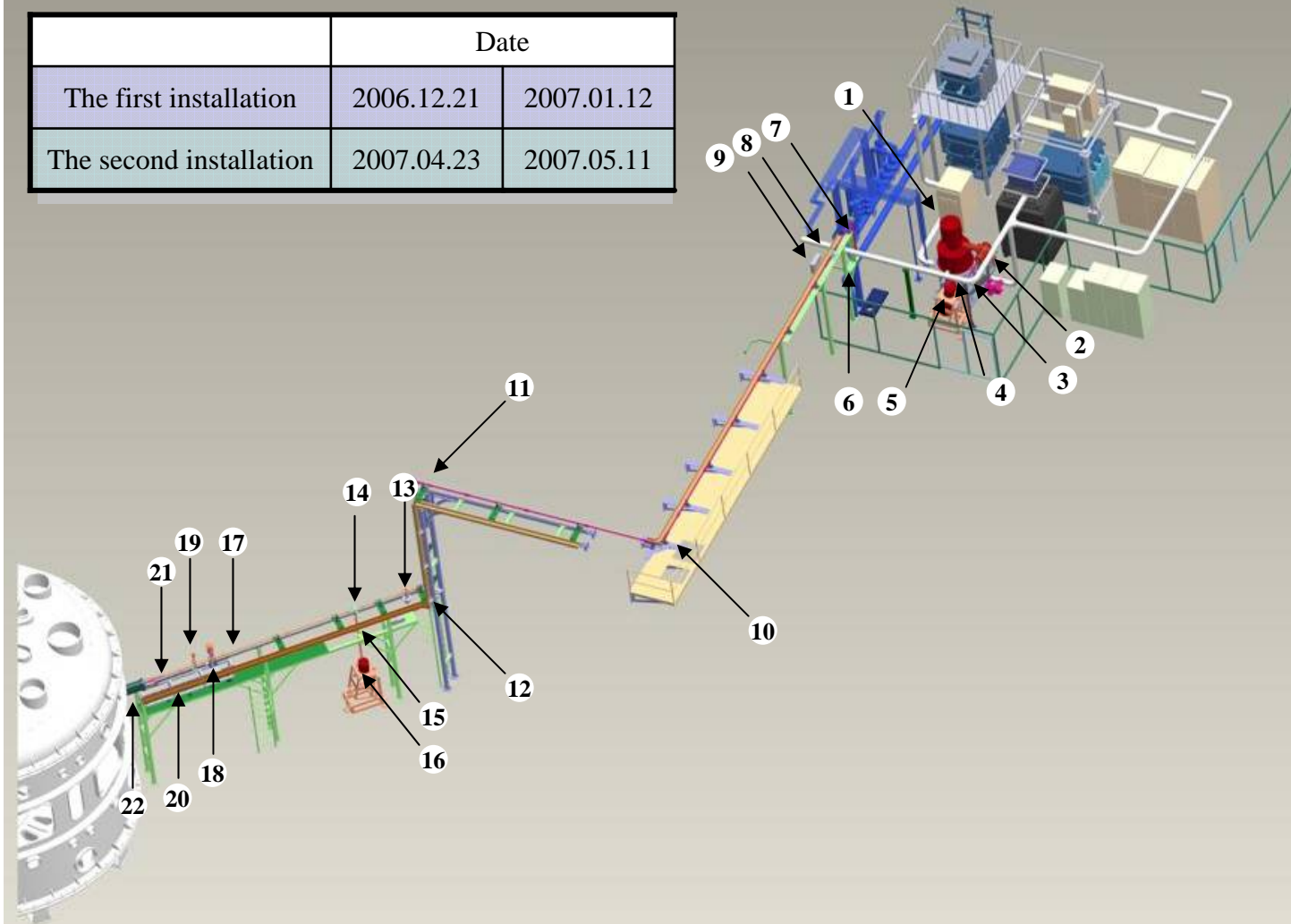
Plasma Sheath Lab



# 84 GHz ECH T/L System

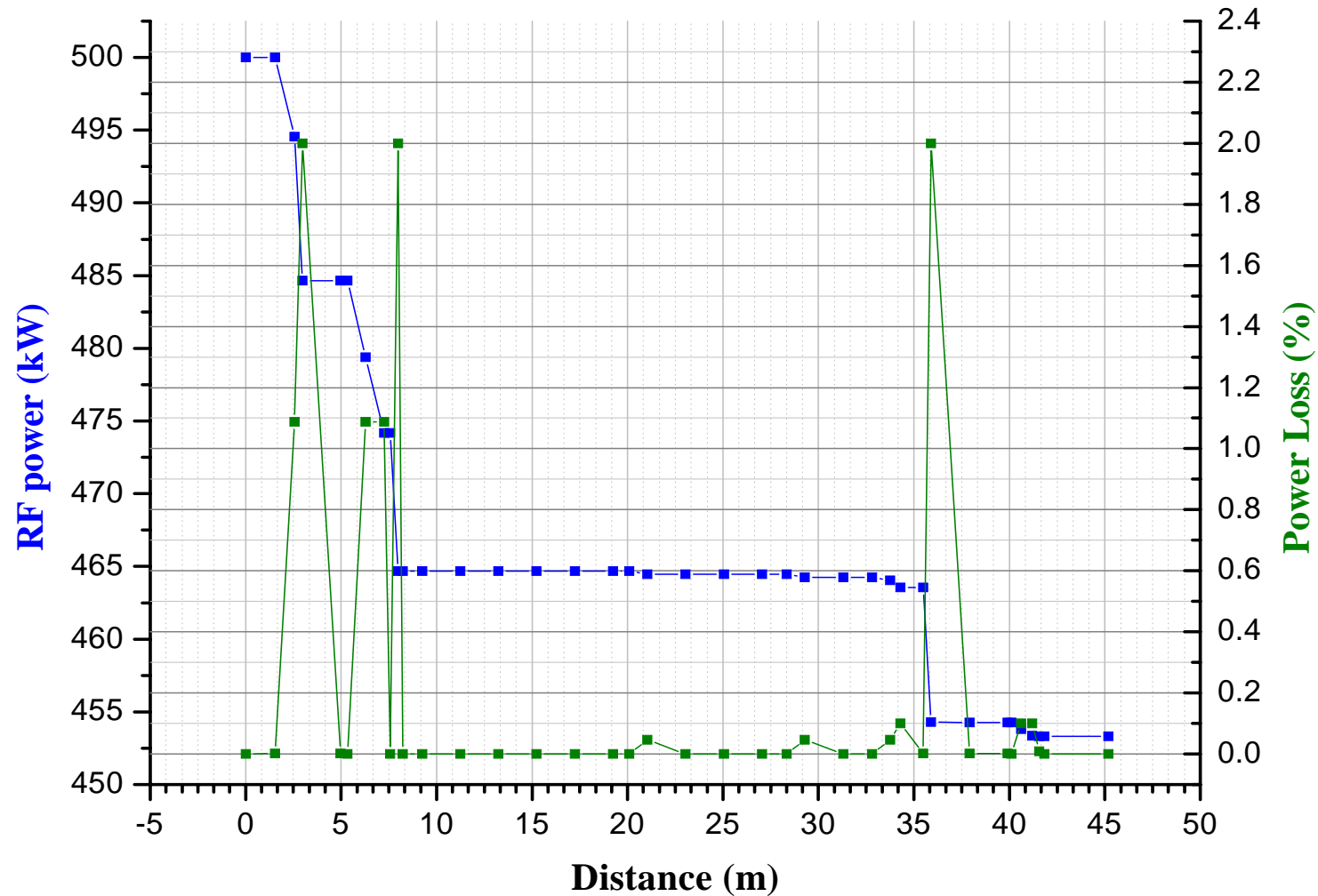
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	Date	
The first installation	2006.12.21	2007.01.12
The second installation	2007.04.23	2007.05.11



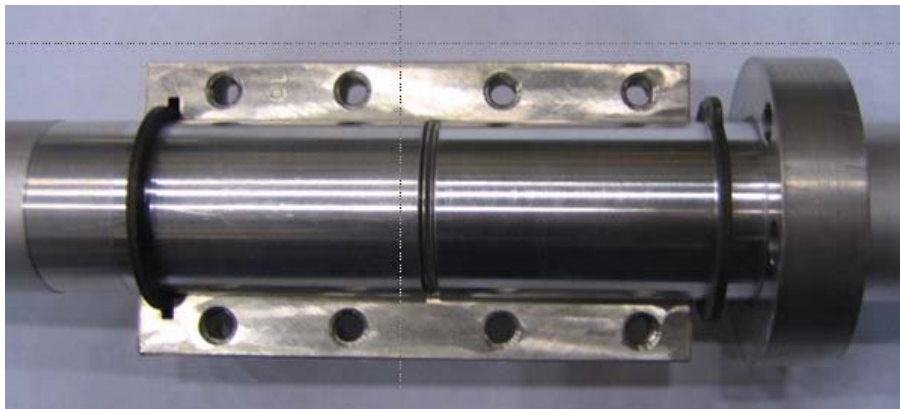
No.	Description
1	Gyrotron
2	L-Box
3	M/B (power monitoring)
4	W/G switch
5	Al tank dummy load
6	M/B (polarizer)
7	M/B (polarizer)
8	W/G switch
9	Bellows
10	M/B (Regular)
11	M/B (arc detector)
12	M/B (power monitoring)
13	Pumpout tee
14	W/G switch
15	Waveguide load
16	Al tank load
17	Diamond window
18	Pumpout tee
19	RF gate valve
20	DC break
21	Bellows
22	ECH launcher

# RF Power & Power loss\*



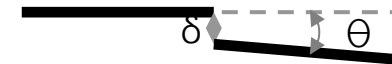
# W/G Misalignment

		Formula [dB]	Power loss (%)	Remarks
Mode conversion loss by misalignment	Diameter change, $\Delta D$	$1.2(\lambda/D)^{3/2}$	$9.9e-5$	$\Delta D = 0.06$ mm
	Axial offset, $\delta$	$2.7(\delta /D)^2$	$6.2e-4$	$\delta = 0.1$ mm
	Tilts, $\theta$	$2(0.73D\theta/\lambda)^2$ [ $\theta$ in radians]	$7.8e-3$	$\Delta\theta < 2$ mrad ( $0.115^\circ$ )



31.75 mm corrugated waveguide coupling

- No. of Coupling: 36 ea
- Power loss (%): 0.00848 %/ea
- Calculated power loss by the misalignment: 0.31 %



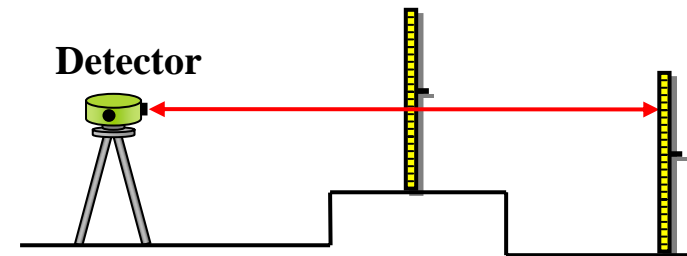
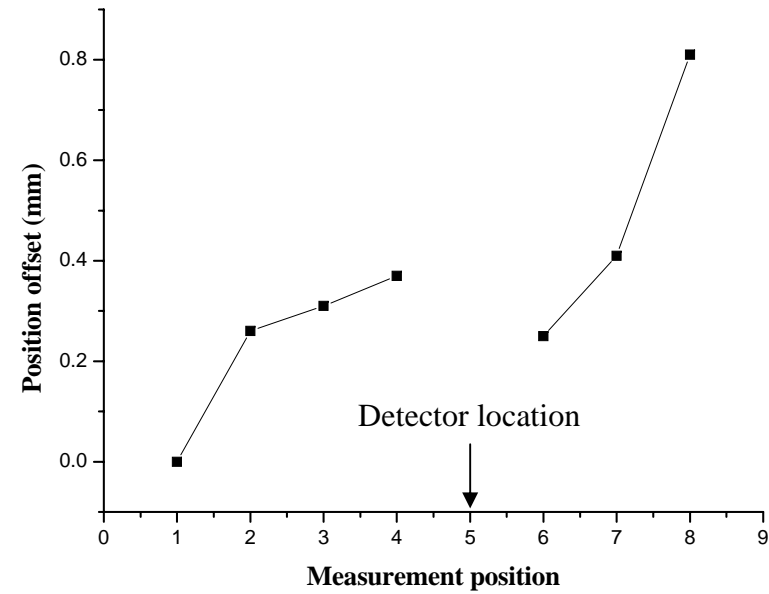
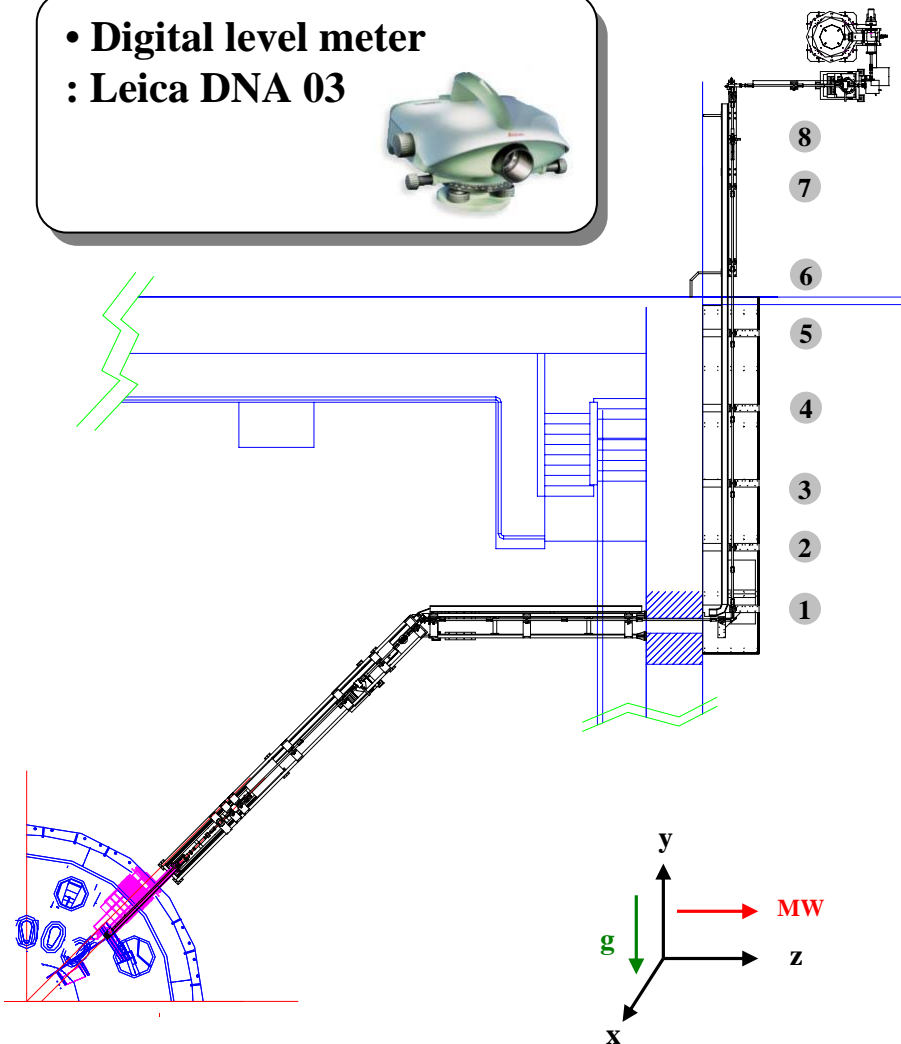
Total power loss without misalignment: 9.72 %

# Waveguide Alignment 1

## - Digital level meter -

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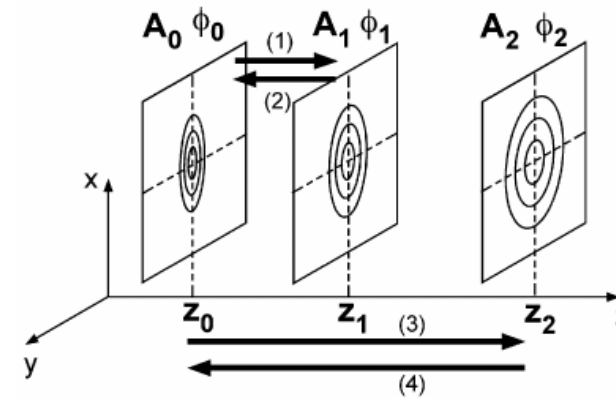
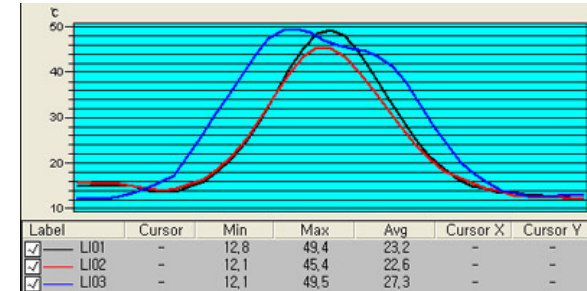
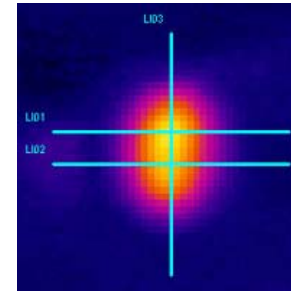
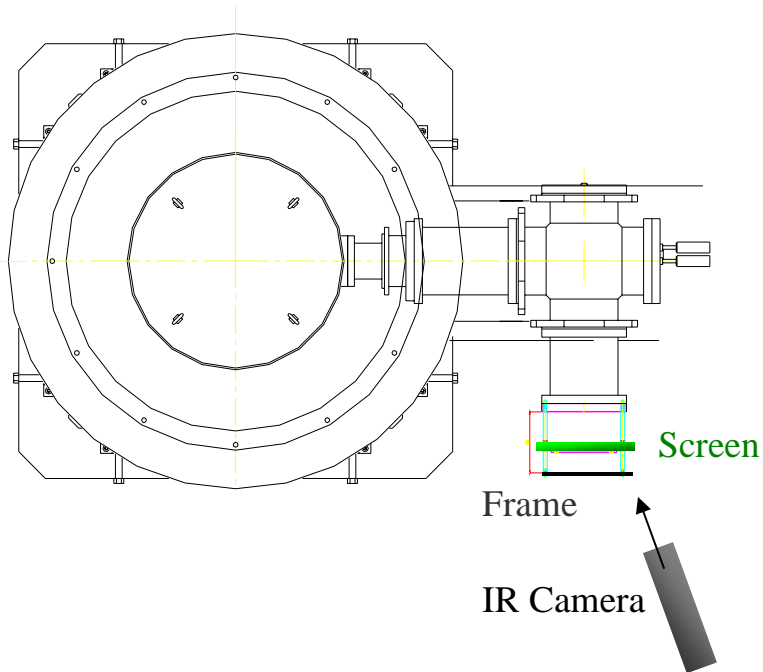
- Digital level meter
- : Leica DNA 03



# Waveguide Alignment 2

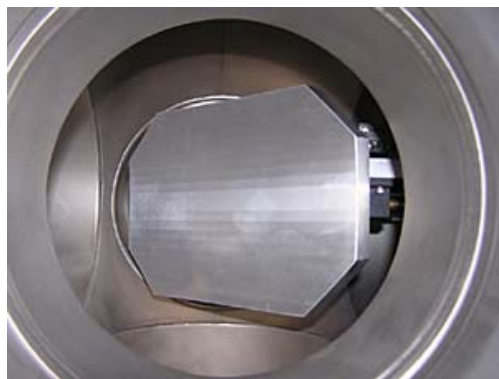
## - IR image -

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S. Takashi, et al., Alignment method of ECH transmission lines based on the moment and phase retrieval method using IR images. J. Plasma Fusion Res. Vol.81 No.3 191 (2005)

**The L-Box is designed to match the output beam of the 84 GHz gyrotron, into a 31.75-mm corrugated waveguide.**



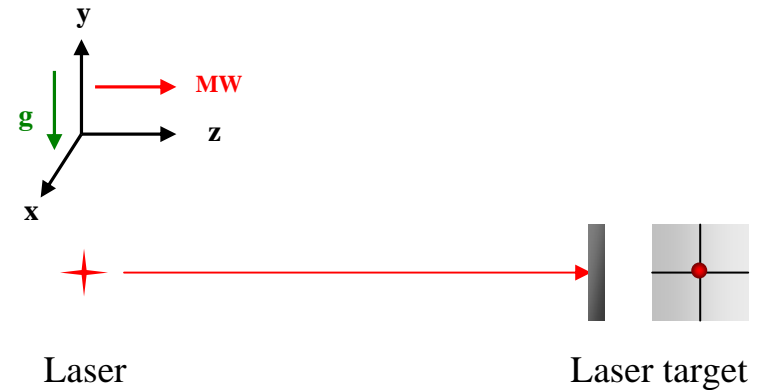


# Waveguide Alignment 3

## - Laser system -

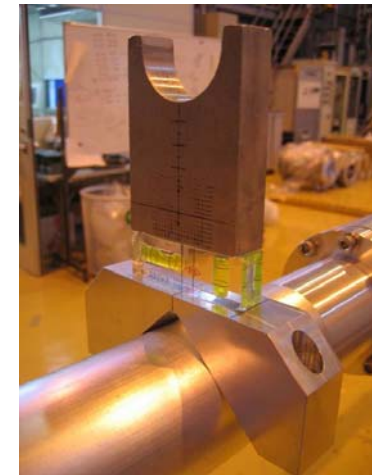
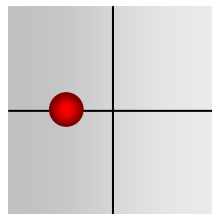
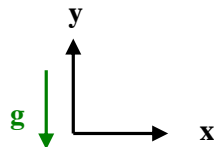
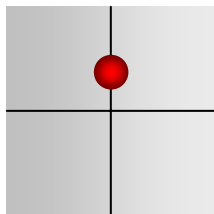
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- Waveguide Alignment
  - y-direction alignment (along the gravity direction)
  - x-direction alignment (transverse direction)



y-direction alignment

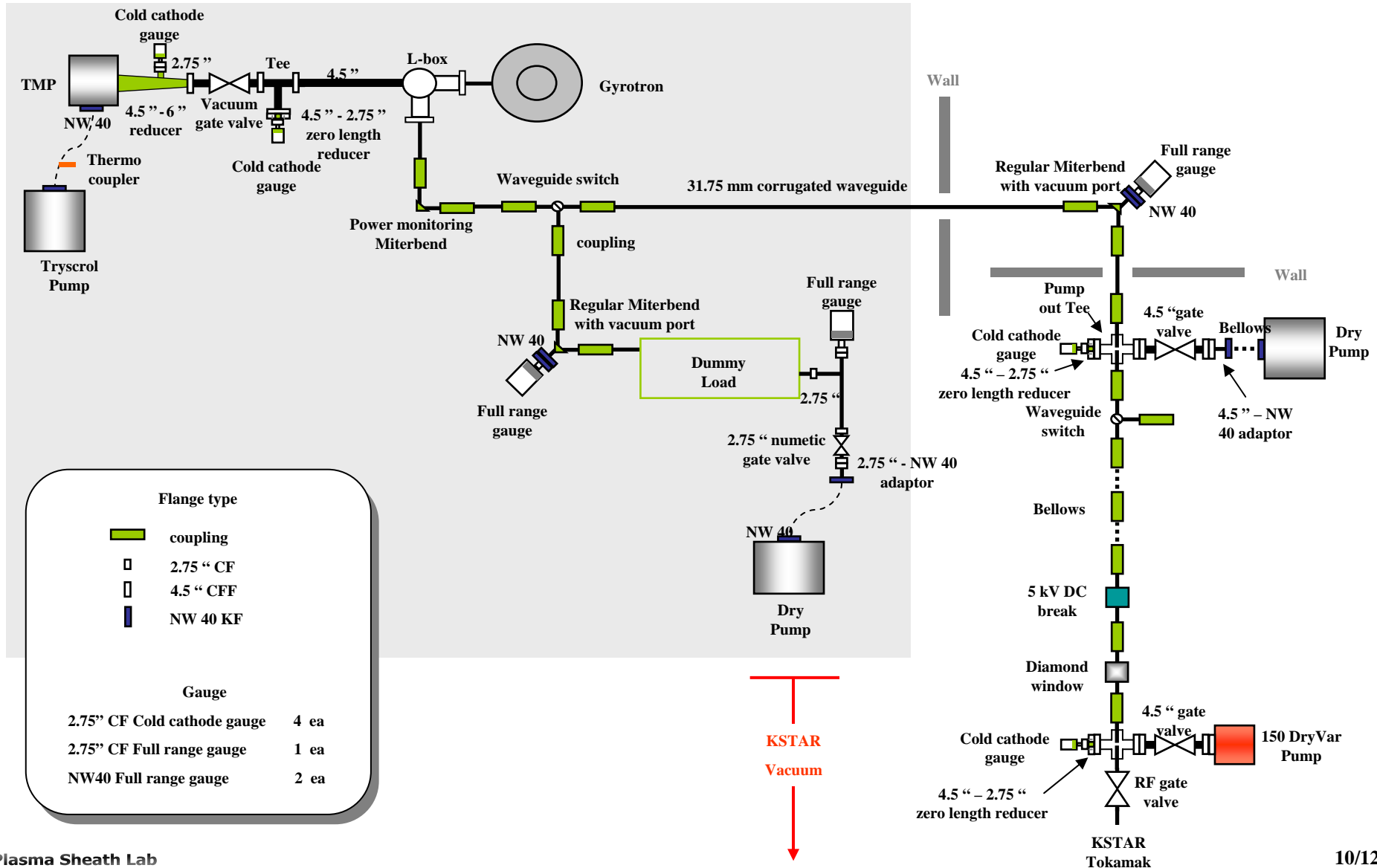
x-direction alignment



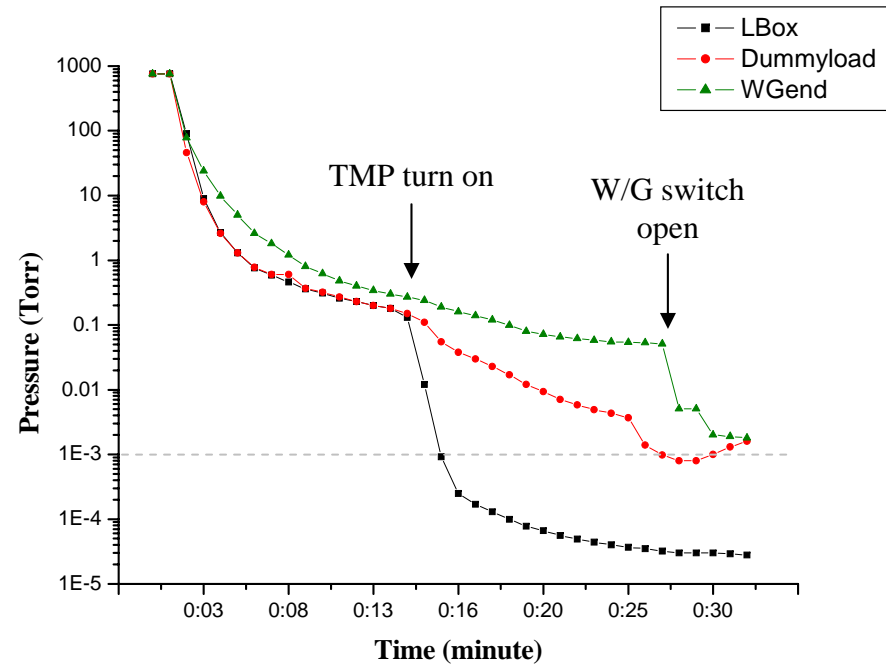
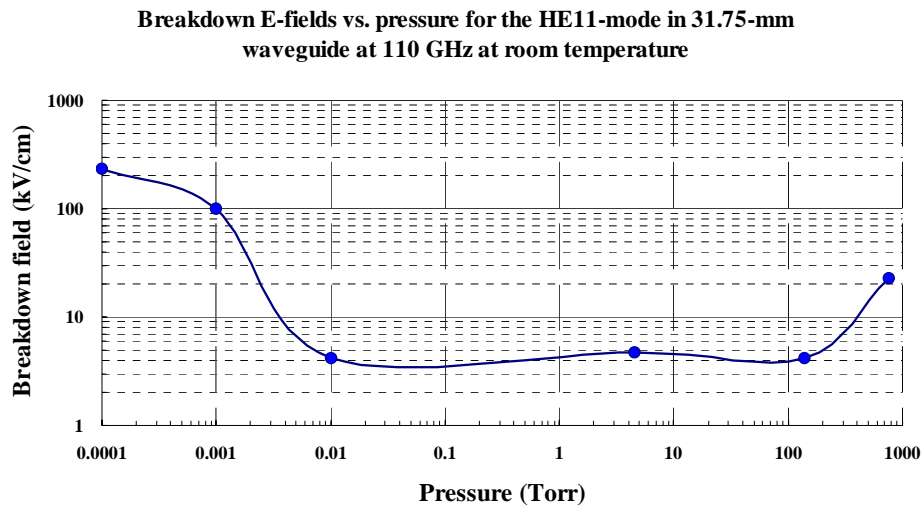
Alignment setup of 170 GHz gyrotron in JAEA, Japan

# 84 GHz ECH T/L Vacuum System

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# Microwave Breakdown and Vacuum Pressure



• This calculation seems to indicate that any pressure under about 0.01 torr is operation condition without breakdown.

D. Anderson et al, "Microwave Breakdown in Resonators and Filters", IEEE Transactions on Microwave Theory and Techniques, Vol. 47, 2547 (1999)

# Summary

- Next week, the second installation of the KSTAR 84 GHz ECH transmission line system will start at NFRC.
- RF power loss without misalignment is 9.72 %. And power loss by misalignment is 0.31 %. ( $\Delta D = 0.06$  mm,  $\delta = 0.1$  mm,  $\Delta\theta < 2$  mrad)
- To minimize power loss, we align the corrugated waveguide and the mirror in L-box using IR image and laser system.
- Any pressure under about 0.01 torr is operation condition without breakdown.