Current status of ECE system on EAST tokamak

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OUTLINE

- **ECE diagnostic introduction**
- **EAST ECE Current status**
- **Future plan**
- **Summary**

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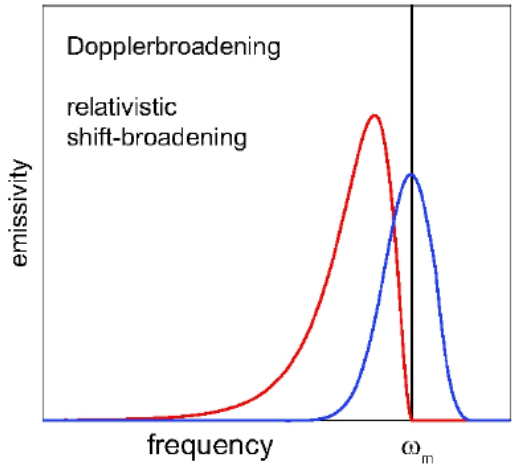
ECE diagnostic introduction

- **ECE frequency:**

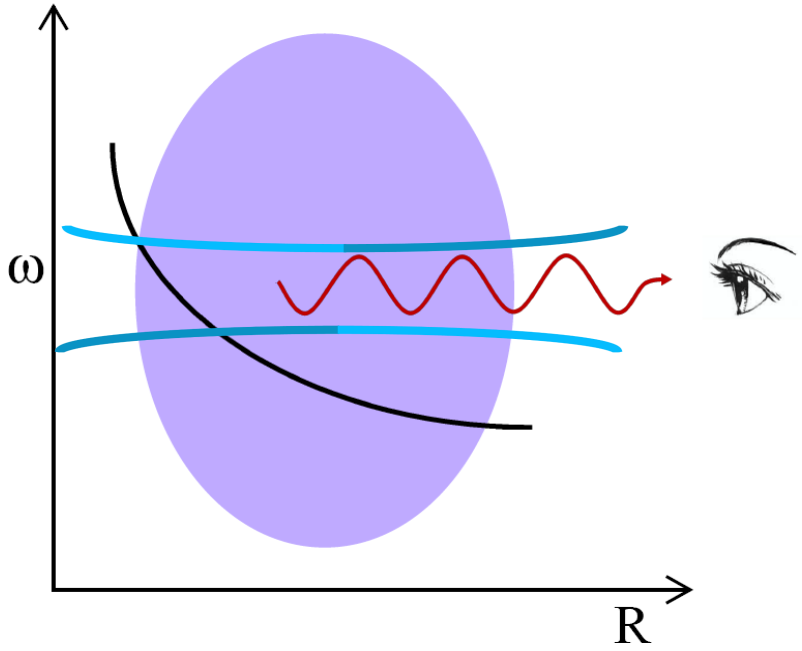
$$\omega = n\frac{eB}{m_{e0}}\sqrt{1-\beta^2} + k_{//}v_{//} = n\frac{eB}{m_{e0}}\frac{\sqrt{1-\beta^2}}{1-\beta_{//}cos\theta}$$

- **Horizontal Measurement:**
  - $\theta \neq 90°$: **Oblique ECE**
  - $\theta = 90°$: **Conventional ECE**



- **When plasma is optical thick and thermal equilibrium, ECE intensity can be regarded as blackbody radiation**

$$I_B(\omega, T) \simeq \frac{\omega^2 T}{8\pi^3 c^2}$$



- **From ECE spectrum, Te profile can be obtained.**

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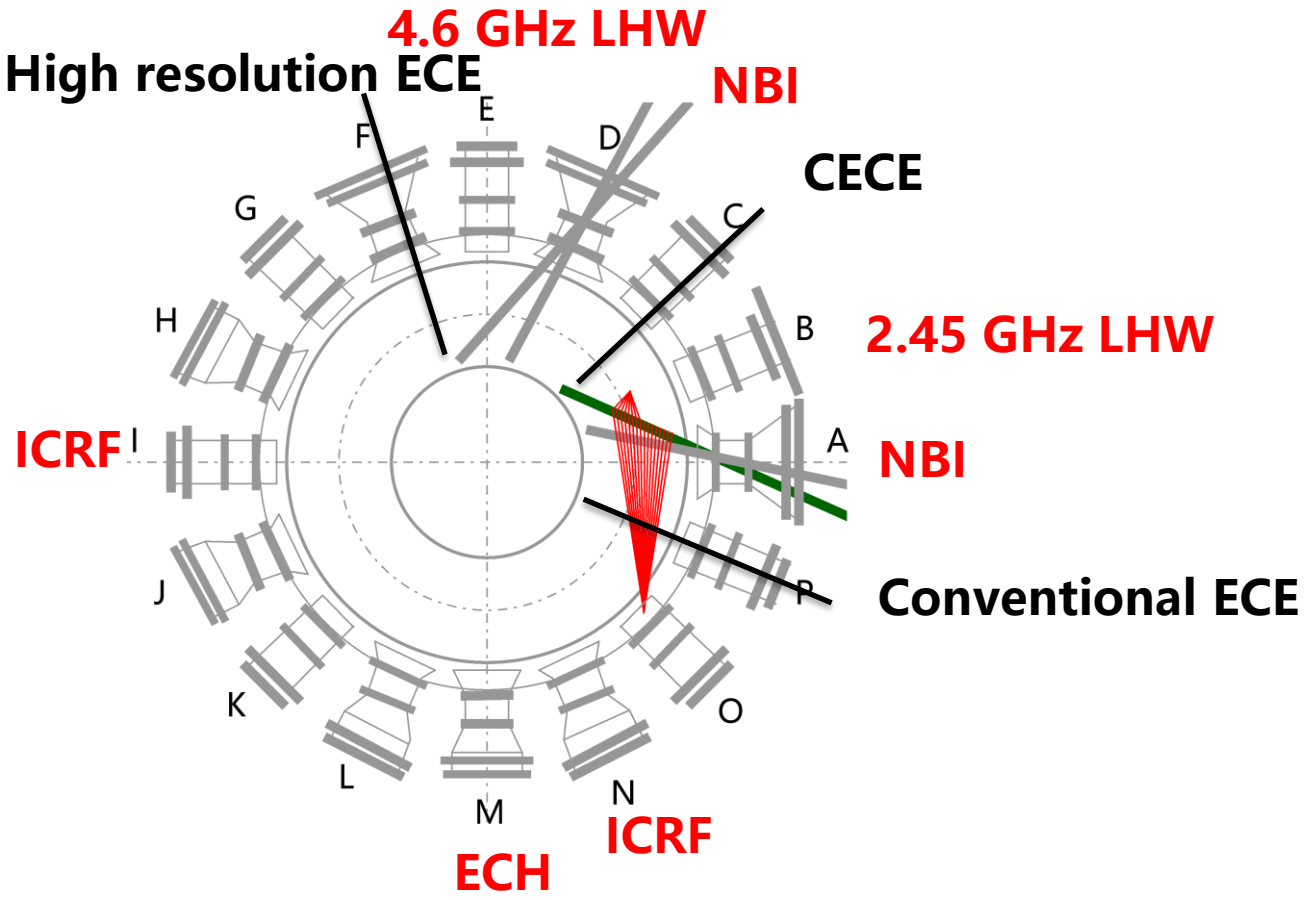
EAST ECE system overview

✓ Conventional ECE system （port P）：
◆ Te profile measurement，including
56 channel Heterodyne radiometer
Michelson Interferometer

✓ Correlation ECE（CECE）system（Port C）
◆ Small scale Te fluctuation measurement

✓ High resolution ECE system （Port F）
◆ Magnetic island precise positioning



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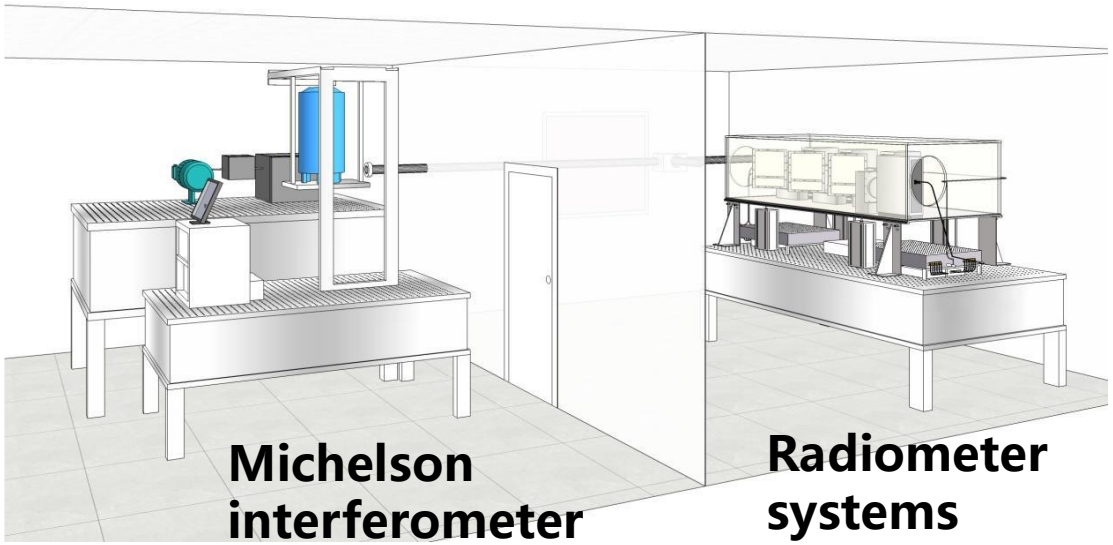
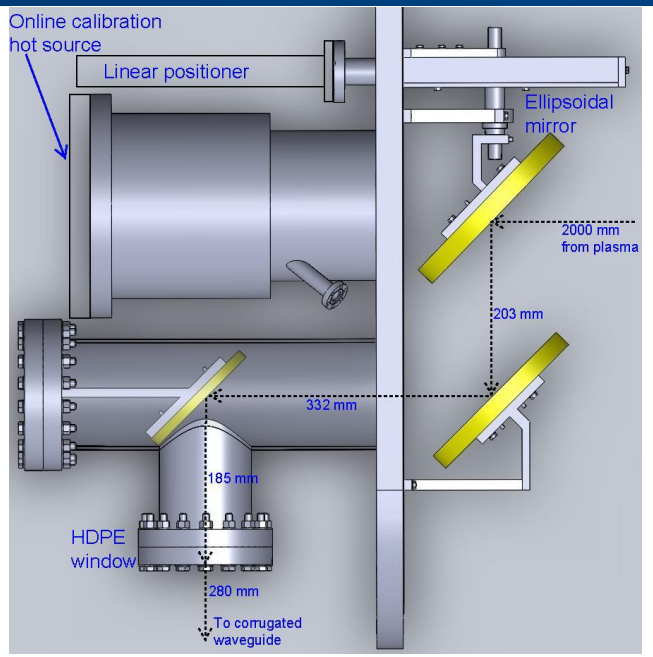
Conventional ECE system in 2020

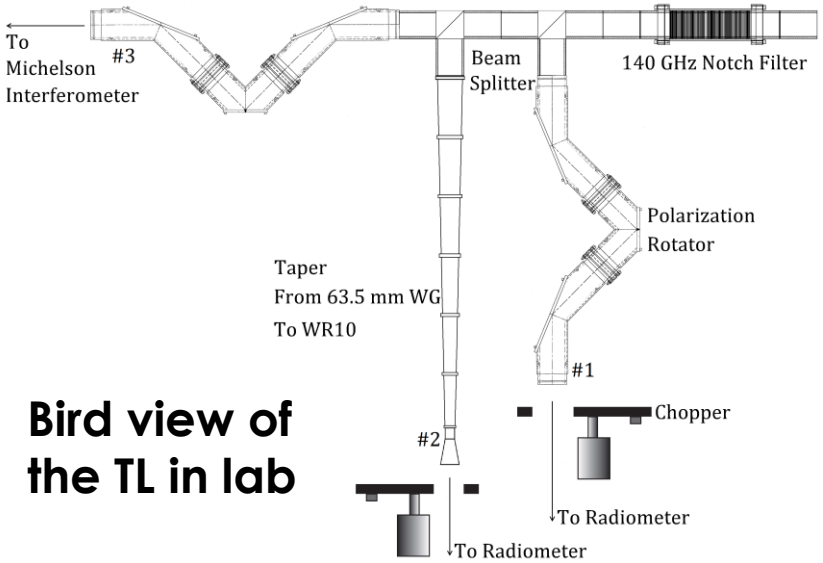
- ✓ **Common quasi-optical antenna and transmission line (TL) (~45 m)**
- ✓ **Independent in-situ absolute intensity calibration**

	Frequency Coverage (GHz)	Spectral resolution (GHz)	Temporal resolution
Michelson interferometer	80-500	2.8	30 ms
56-channel Radiometer	97-168	0.2/0.5	2.5 μs



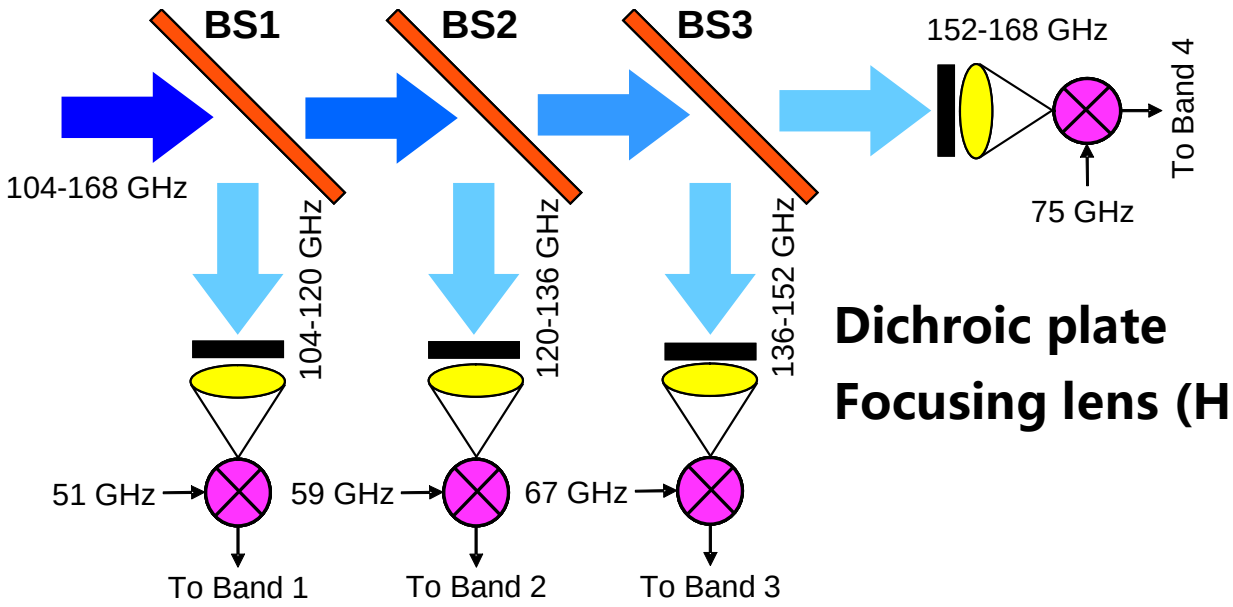


Port P



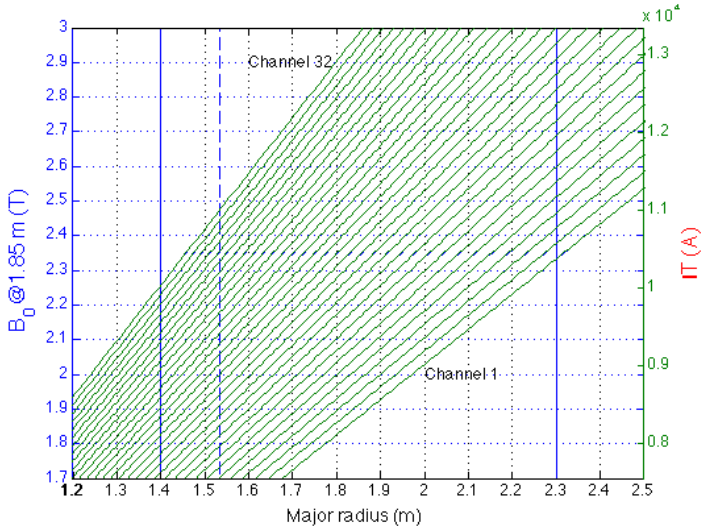
Bird view of the TL in lab

32 channel Heterodyne Radiometer system



Dichroic plate

Focusing lens (HDPE)



Designed for 2.3 to 2.5 T (High toroidal field)

In collaboration with UC Davis

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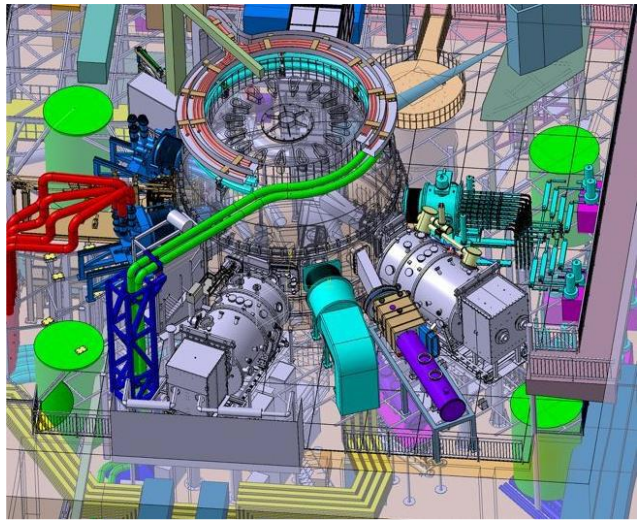
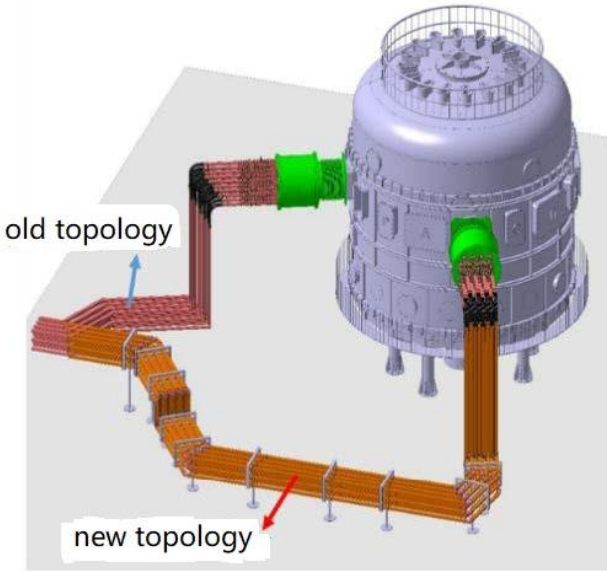
EAST heating upgrade in 2021

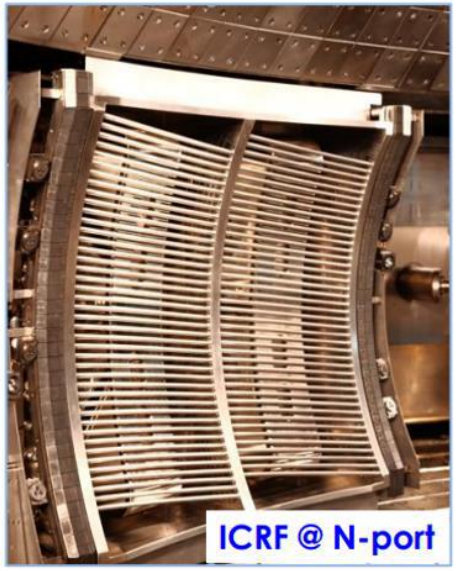
- **NBI：counter-current to co-current，one moved from port F to port D, total beam power ~5 MW.**
- **LHW：new 2.45 GHz PAM antenna, moved from port N to port B，6 MW (2.45 GHz and 4.6 GHz).**
- **ICRF：one moved from port B to port N, in total 3 MW.**
- **ECH：3 gyrotrons, 140 GHz, in total 1.75 MW.**



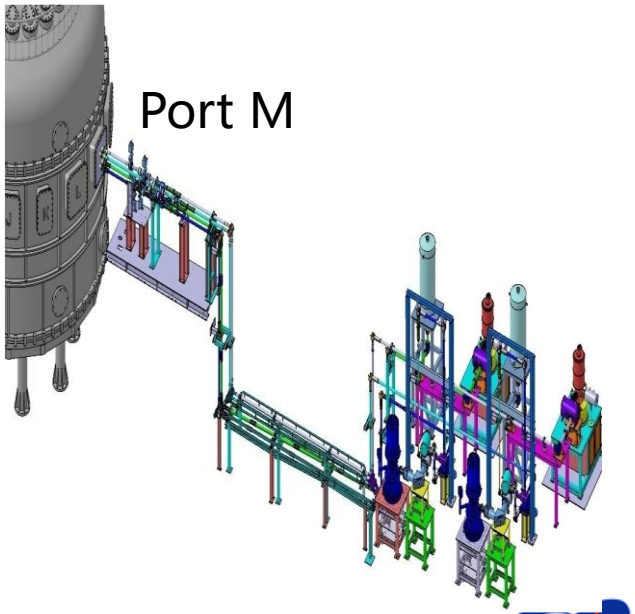
NBI system



LHW system



ICRF system



ECH system

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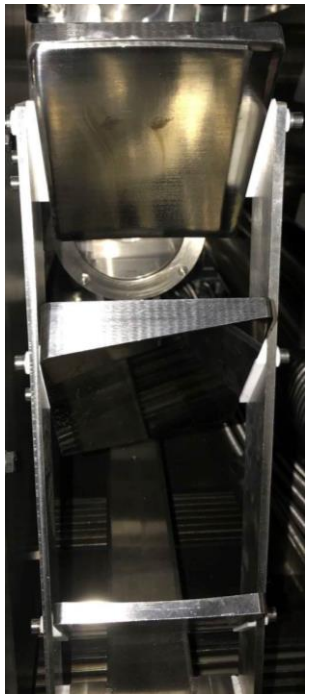
ECE QO redesigned in 2021

- Redesigned two QO systems, for ECE and future oblique ECE.
- The added oblique ECE QO can be used for future studies of high-energy electron characteristics generated by LHW.
- The transmission waveguide rearranges the direction.

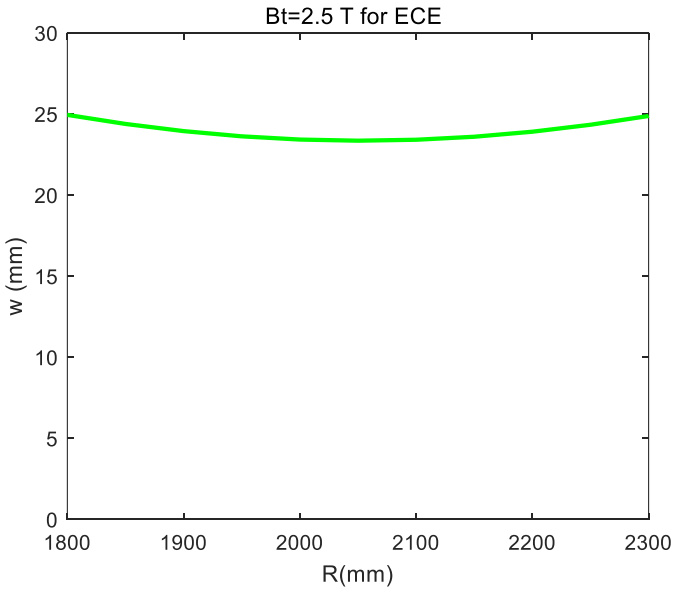
two QO systems



QO front view

Conventional ECE

Oblique ECE



The beam waist in EAST

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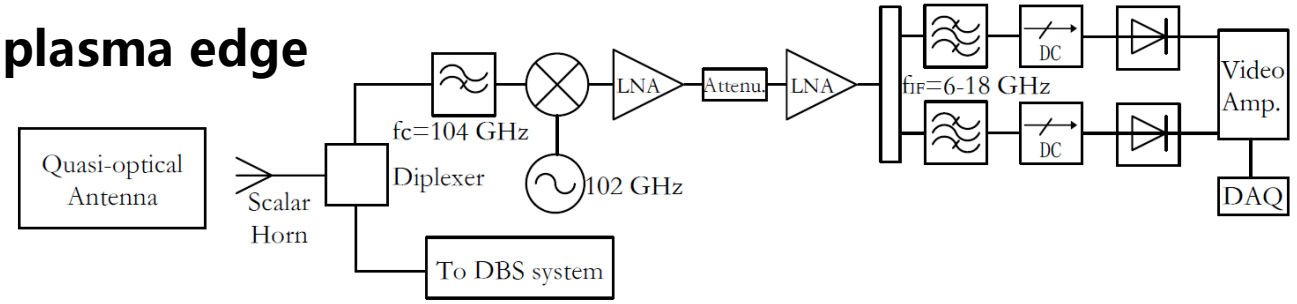
CECE upgraded to 16 channels

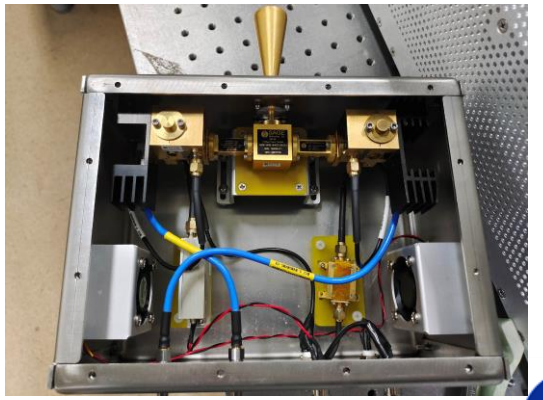
- **Moved From Port G to port C**
- **A 8-channel CECE radiometer system operated routinely since 2018.**
- **Integrated QO with DBS system, 8 YIG filters.**
- **In 2021, add another RF band and another 8 channels with fixed frequency bandpass filters.**
- **The system now covers 106 GHz to 132 GHz, so can work in wide B_T range.**

~ 25 cm to plasma edge



Ellipsoidal mirror
Flat Mirror
Focusing lens (HDPE)

102 GHz LO **114 GHz LO**



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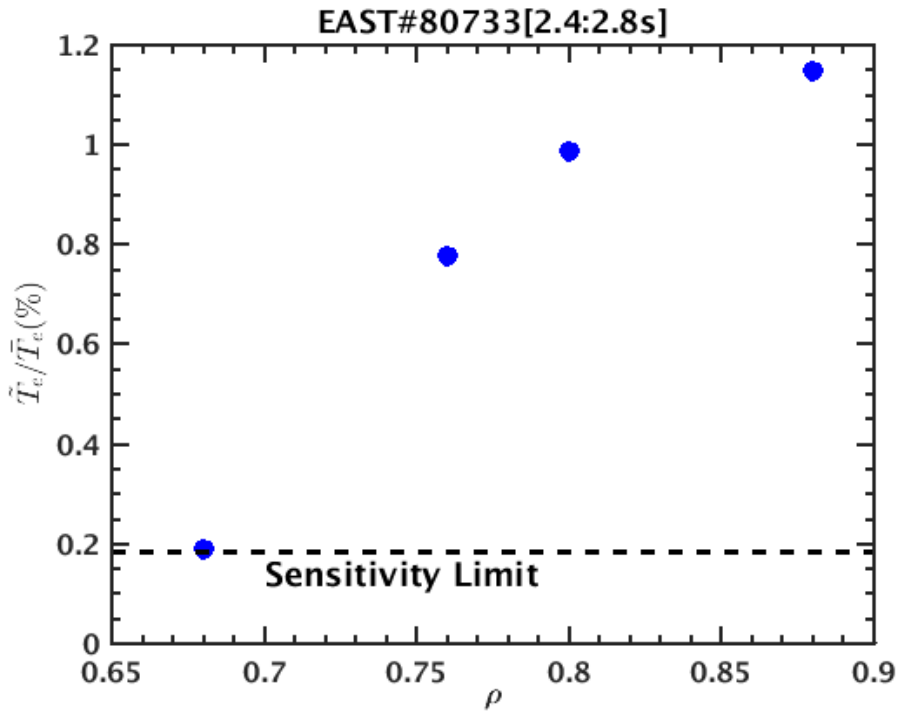
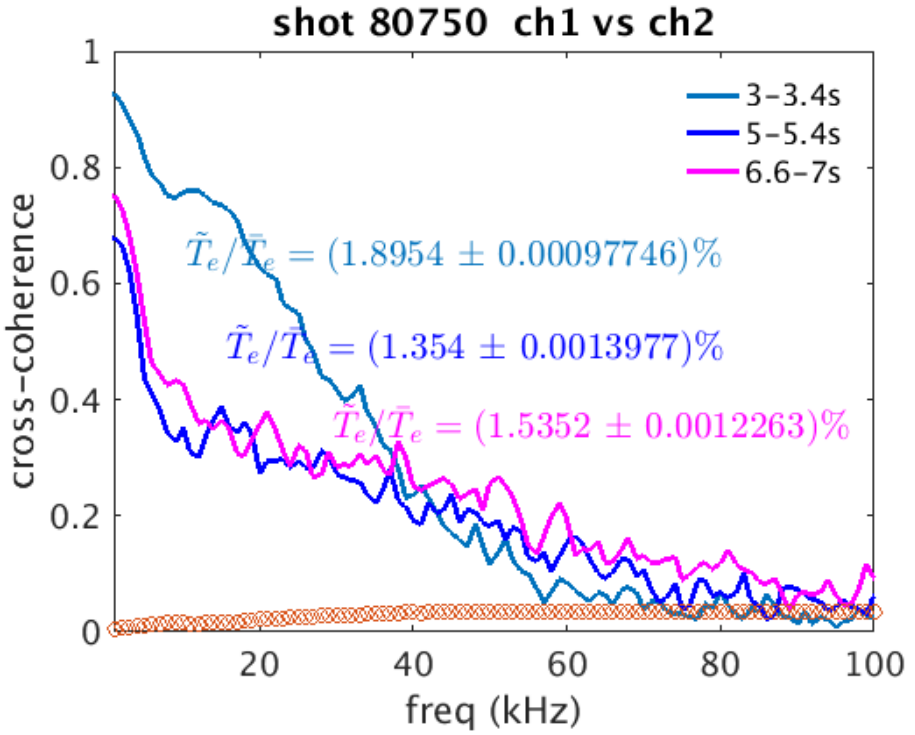
CECE system

- **Flexible radial coverage & radial separation**
- **k_θ<1.85 cm^{-1}, k_r <4.19 cm^{-1}**
- **Interesting phenomenon have been observed**

$$\left(\frac{\tilde{T}_e}{T_e}\right)_{ECE} = \sqrt{\frac{2\Delta f_{video}}{f_{IF}}}$$

$$\left(\frac{\tilde{T}_e}{T_e}\right)_{CECE} = \sqrt{\frac{1}{\sqrt{N_s}}\frac{2\Delta f_{video}}{f_{IF}}}$$





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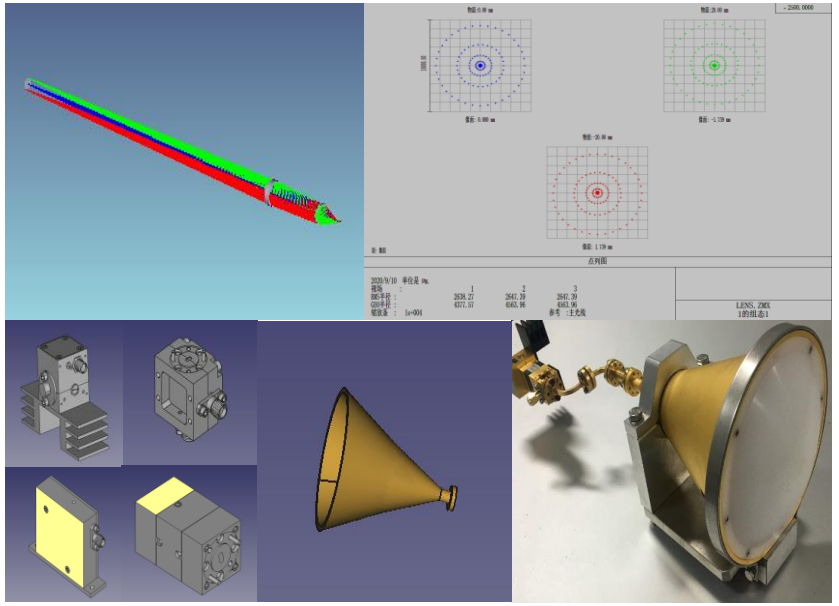
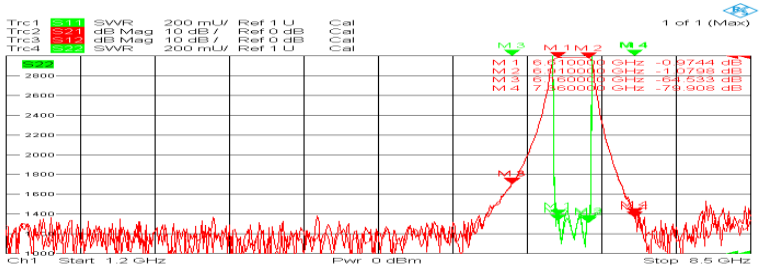
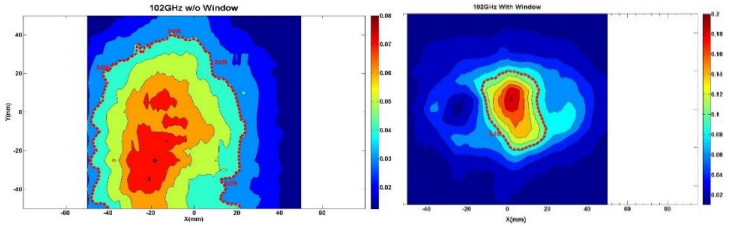
High resolution ECE radiometer in port F

- LO and IF filter Frequency is selected according to typical 3/2,2/1 mode position.
- Curvature window and lens antenna are designed to improve the poloidal optical collection capability (poloidal resolution ~ 4 cm)
- Narrow band IF filter is used to reduce radial measurement region and channel spacing. (Bandwidth~200 MHz /Interval~600 MHz)







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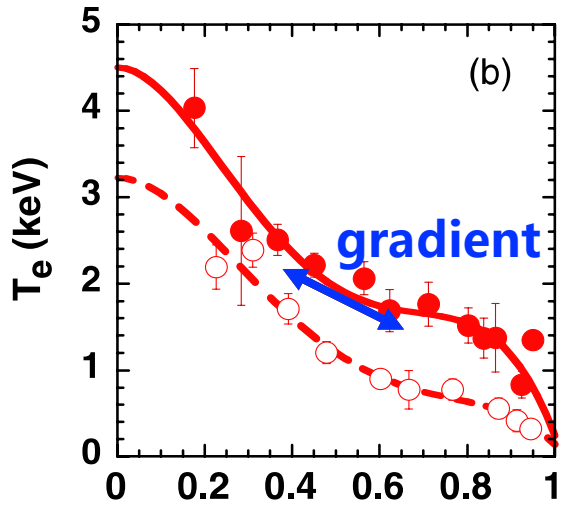
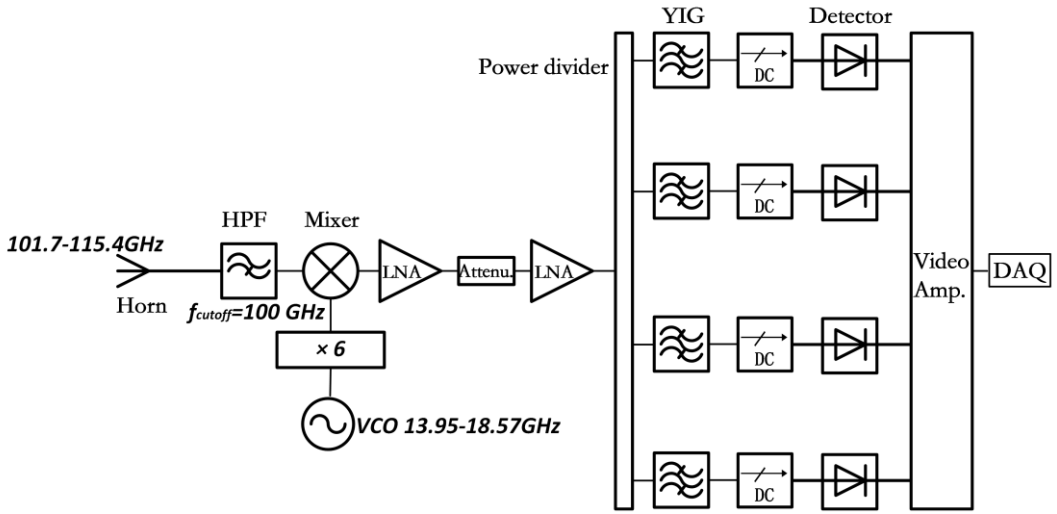
L_{Te} measurement system in the pedestal region

- **Conventional method: fit T_e profile to get L_{Te}**
- **The L_{Te} measurement system:**
  - $\nabla T = \frac{\Delta T}{\Delta R}$, $I_{ECE} = C \times T, \Delta T \propto \Delta I_{ECE}, \Delta R \propto -\Delta f$
  - **Change frequency a little, ECE intensity change can derive L_{Te}.**
  - **Not rely on system absolute calibration.**



- **Scan LO frequency to measure L_{Te} directly**
- **Change IF YIG filter frequency to change the position.**
  - **Time resolution: ~ 10 ms**
  - **Radial Position: r/a = 0.8 – 0.95**



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ECE diagnostic for low B_T

- Low B_T is an attractive regime for low q95,high β_N.
- Now ECE on EAST can not measure T_e profile for B_T smaller than 1.8 T.
- Plan to build a 16 channel ECE heterodyne system
  - Frequency range 81 to 96 GHz, 1 GHz separation per channel.

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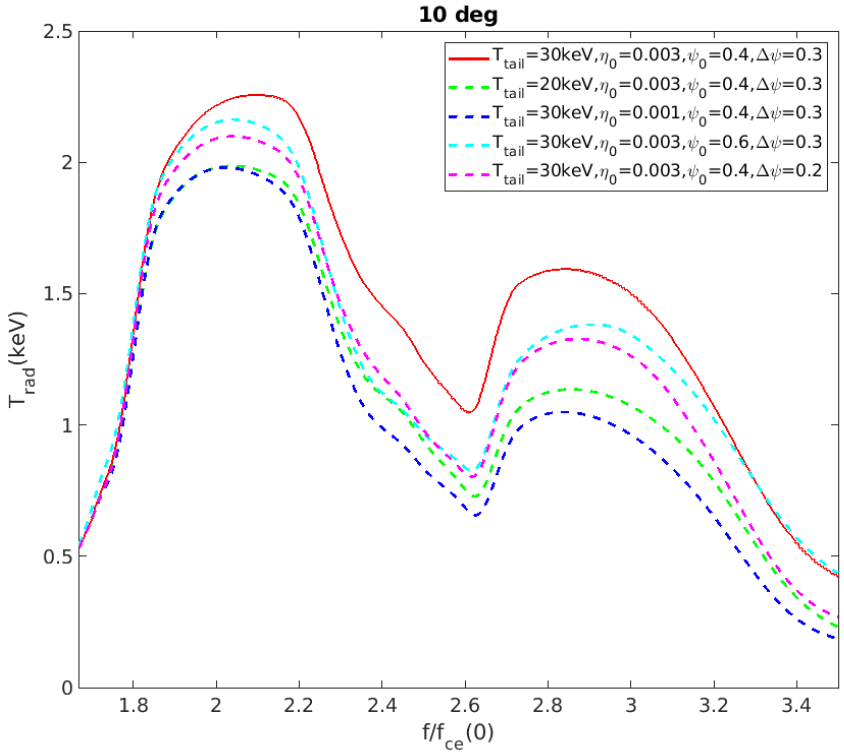
Oblique ECE

- **The capability of oblique ECE diagnostic is evaluated by using synthetic diagnostic technique.**
  - **Including high energy electron fraction, position, width, energy et al.**



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Summary

- ✓ A series of conventional ECE heterodyne radiometer systems has been routinely operated on EAST, which can provide Te profile measurement and MHD analysis.
- ✓ CECE system has been upgraded to 16 channels and the frequency range can cover wider B_T regime.
- ✓ High resolution ECE is still on its way to precise position the MHD modes.

- ☐ Pedestal L_{Te} measurement system will be available next year.
- ☐ A 16 channel radiometer is planned for low filed measurement.

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Thank you for your attention!!