



Recent developments of **ECE radiometer** and **ECEI** for low magnetic field strength operation on **LHD**

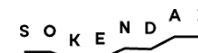
Tokihiko Tokuzawa^{1,2}

Y. Goto¹, D. Kuwahara³, M. Nishiura¹, R. Yanai¹, and LHD Experiment Group

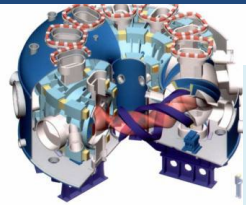
¹ *National Institute for Fusion Science*, ² *The Graduate University for Advanced Studies*, ³ *Chubu University*

Acknowledgments

This work was partially supported in part by KAKENHI (Nos. 19H01880 and 21H04973), by a budgetary Grant-in-Aid from the NIFS LHD project under the auspices of the NIFS Collaboration Research Program (ULPP051 and KBAP065).



ECE for low magnetic field experiments in LHD



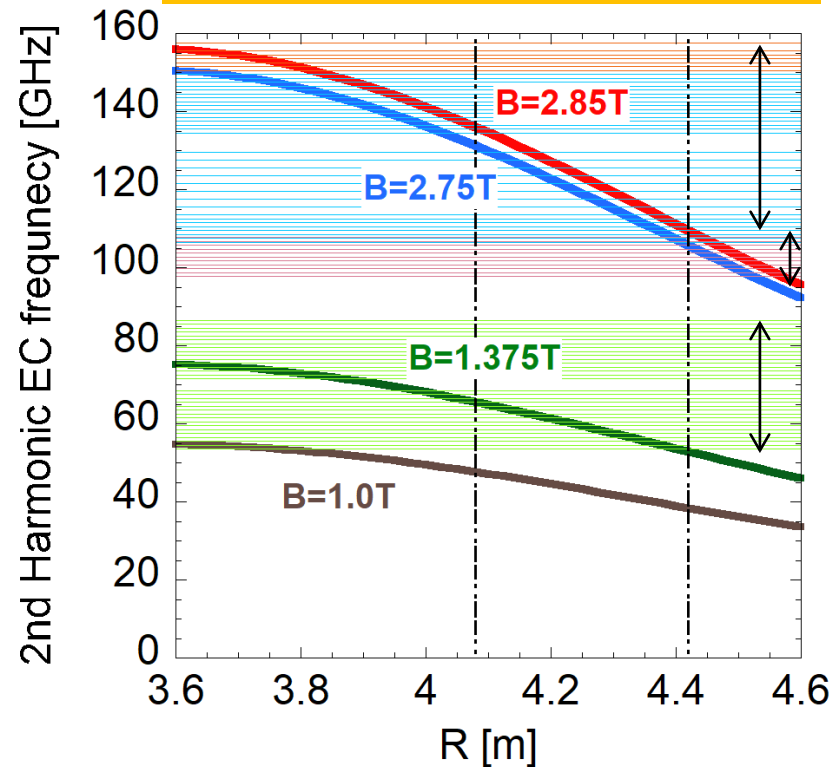
Bt:

- Normal: 2.75T
- High : 2.85T
- Half : 1.375T
- Very-low (High- β) : 0.5T
- **Low : ~ 1.0 T**

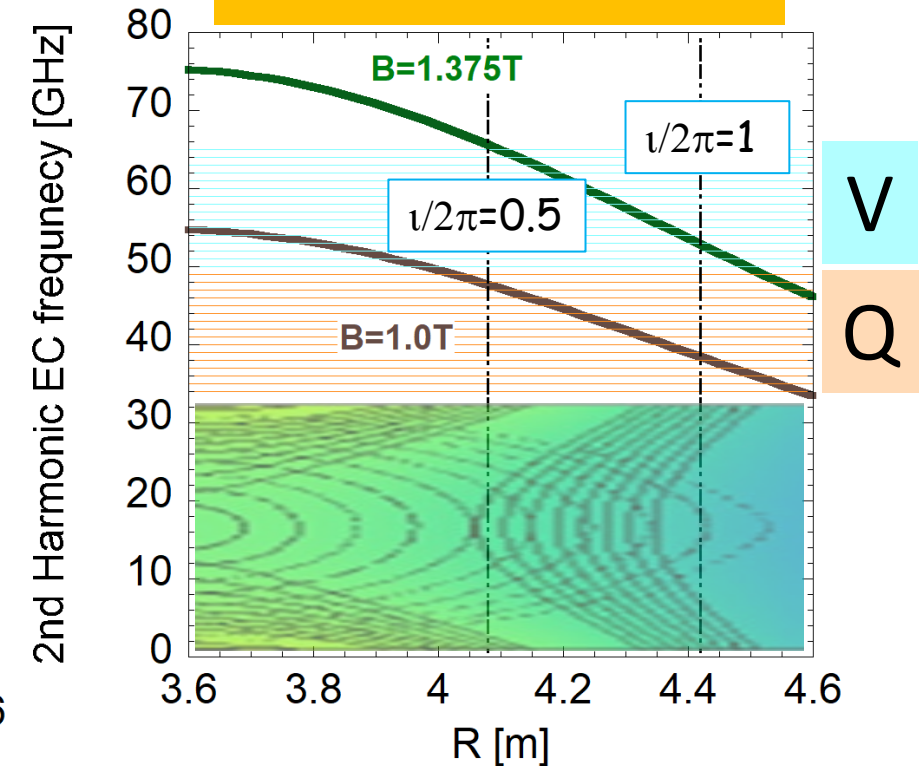
Gyrotron:

- 154 GHz
- 77 GHz
- **56 GHz**

Existing ECE radiometer



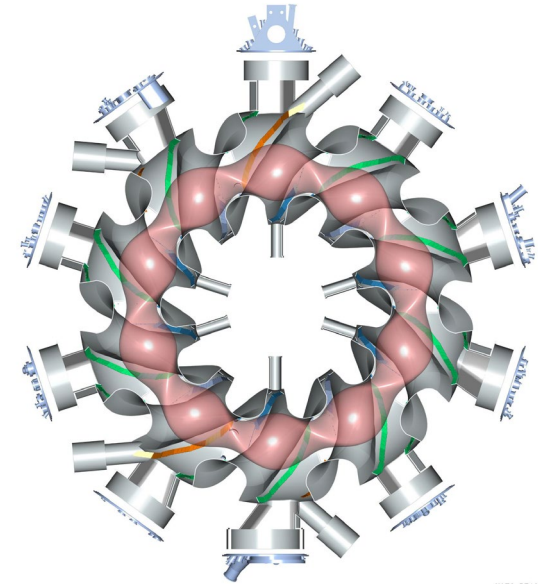
new ECE radiometer



- 88ch radiometer (3 system) has been working more than 20 years.
- Needs to study MHD events etc. in low magnetic field experiments. → new system

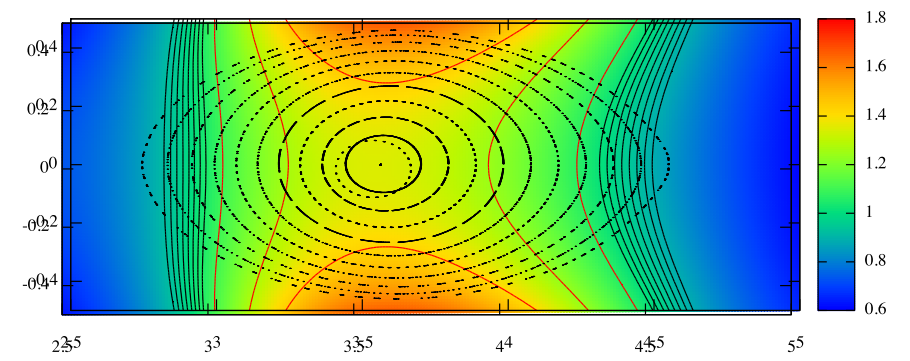
Contents

- New Q/V-band Radiometer
- ECE Imaging system
- Summary

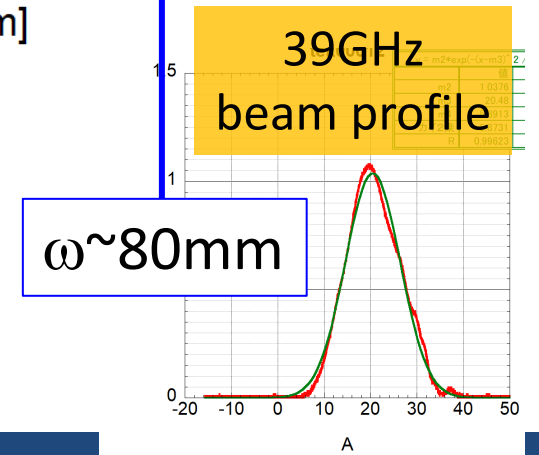
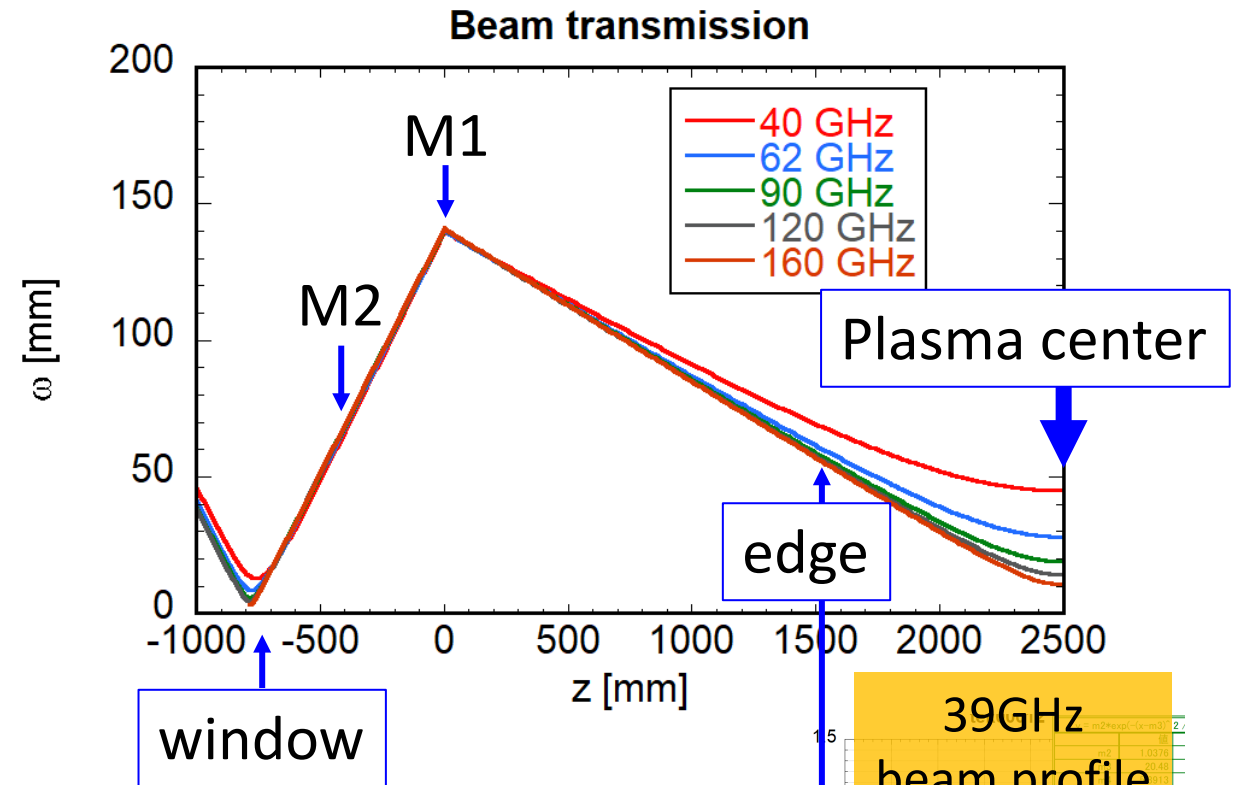
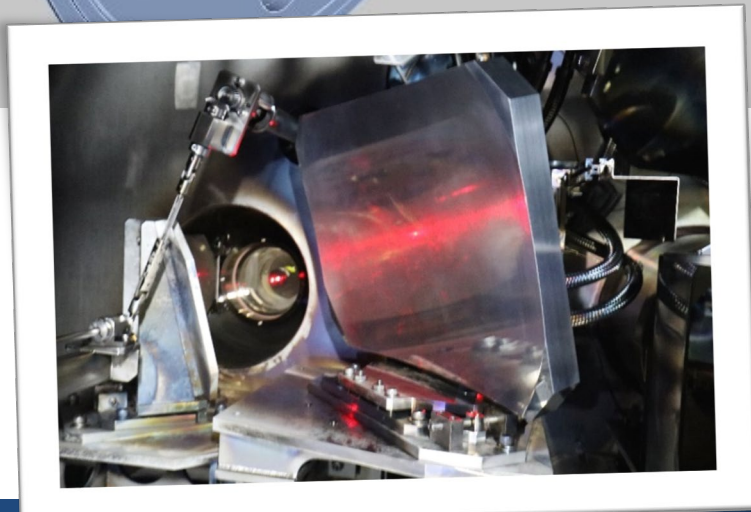
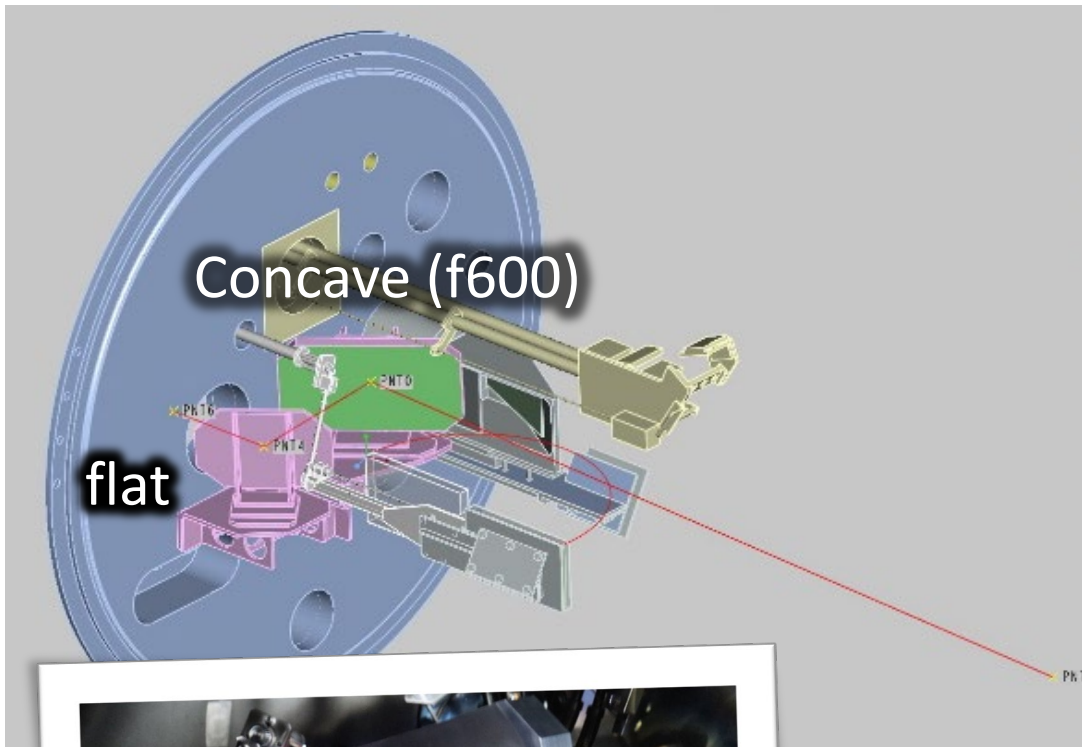


NIFS-PE1089

RRx3.60MB-1.375T

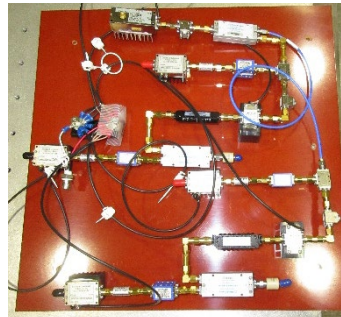
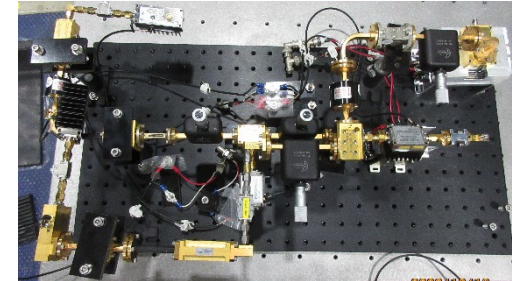
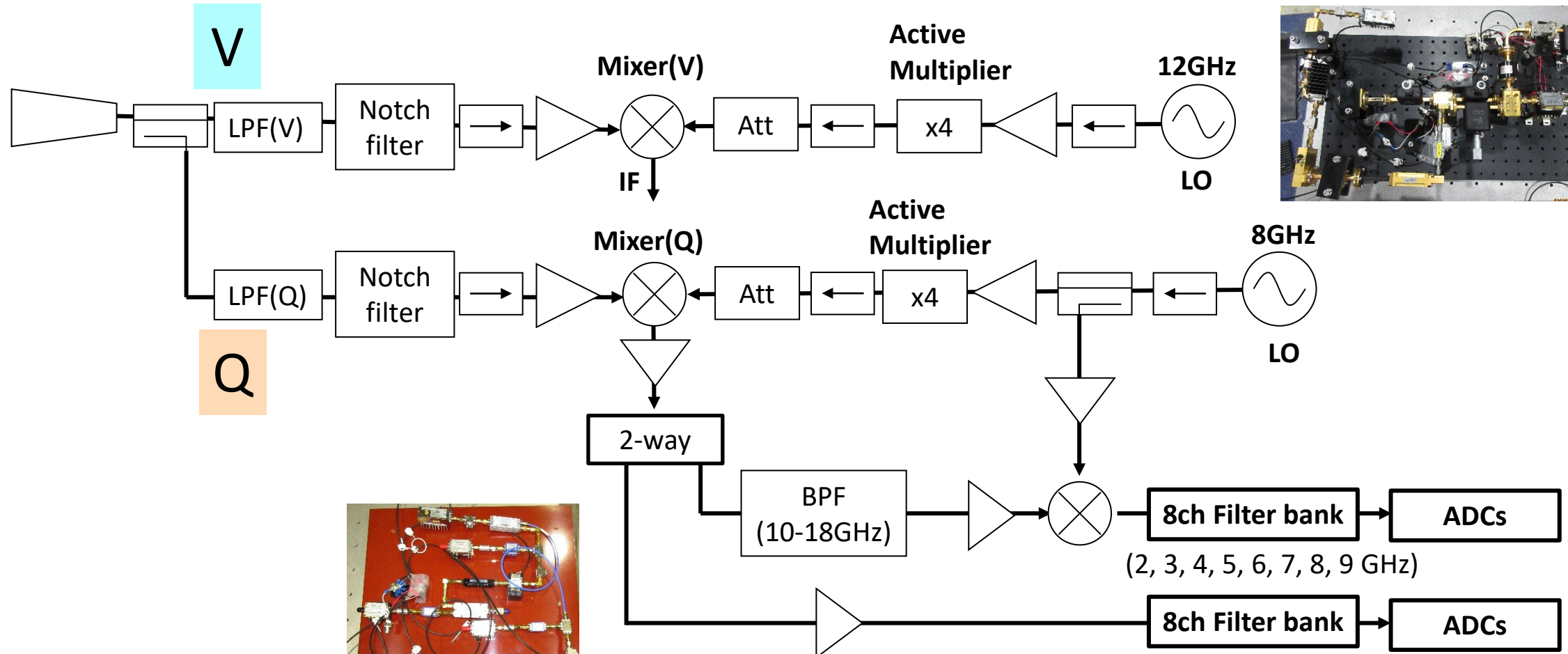


In vessel focusing optics for new ECE radiometer



- Gaussian beam propagation with two mirrors applied in VV.

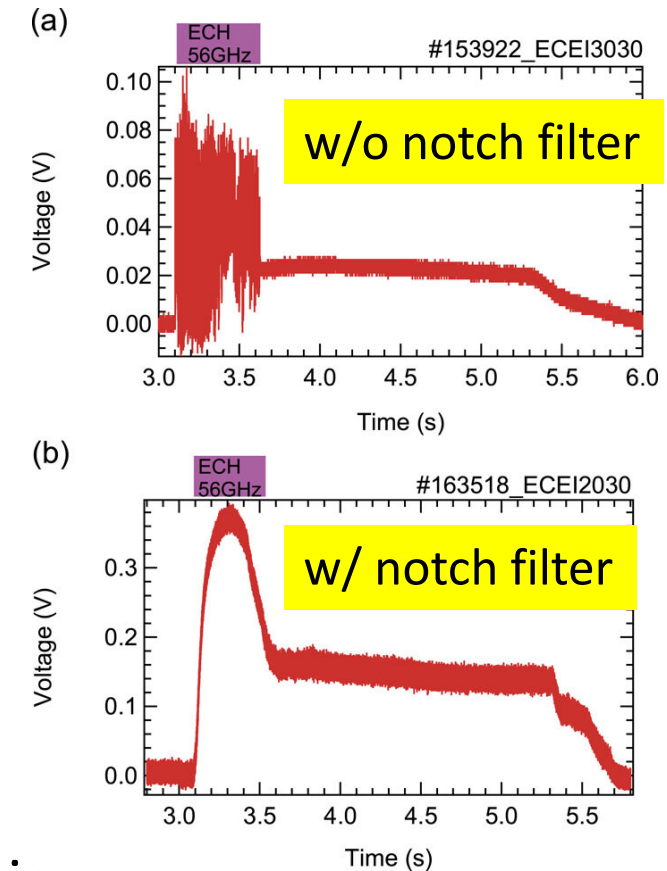
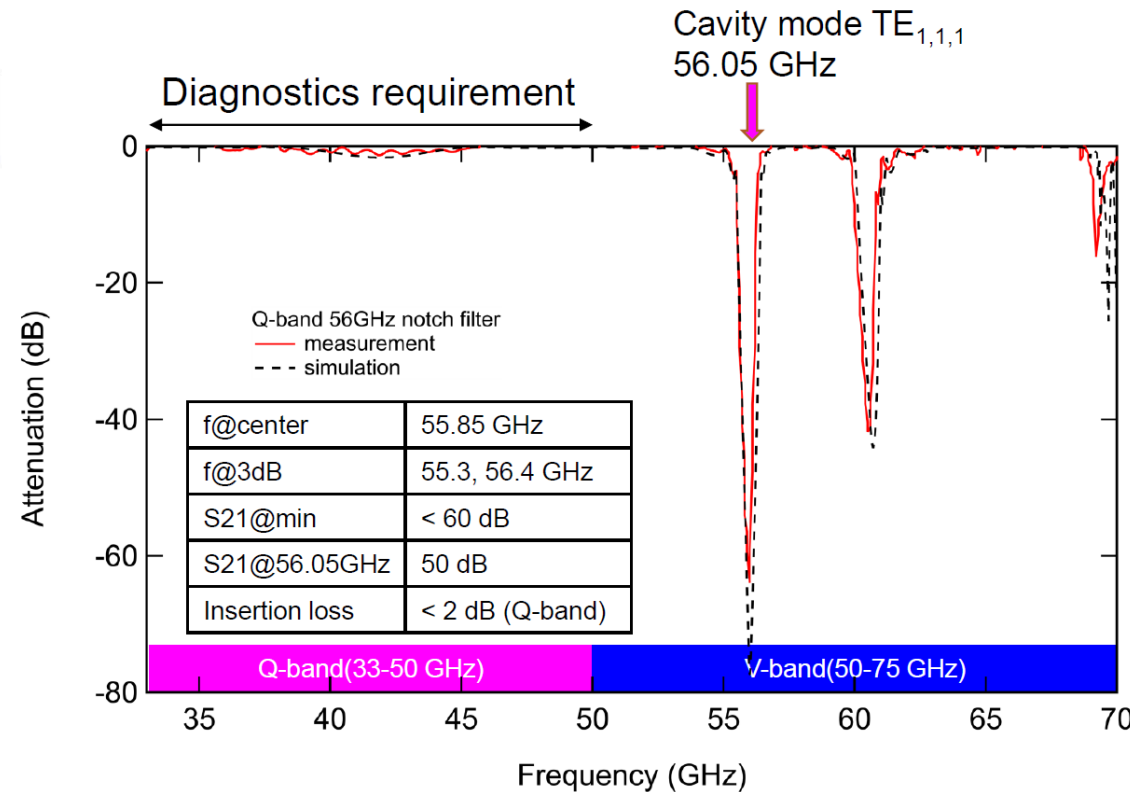
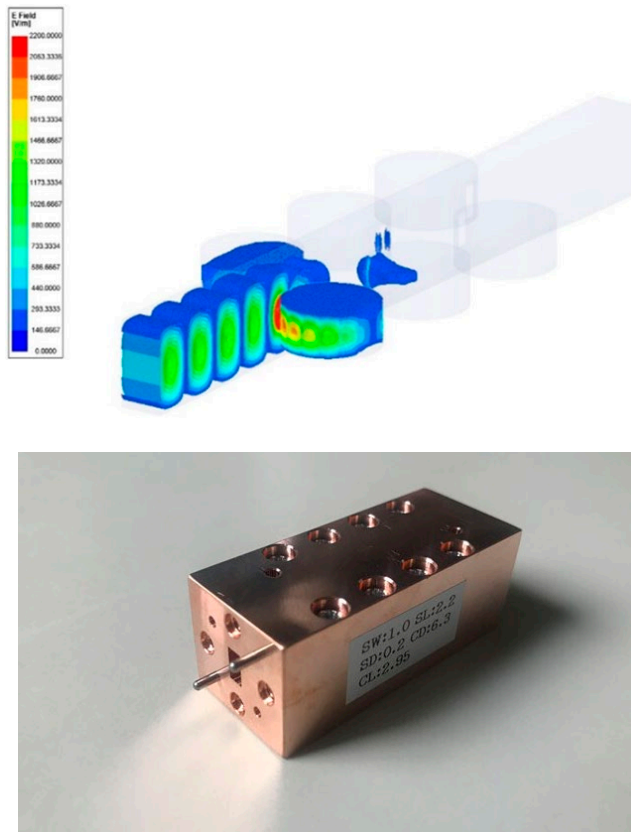
Q/V-band Radiometer circuits



“Oversized” Notch Filter

Need to reject stray light from 56 & 77 GHz gyrores in Q band.

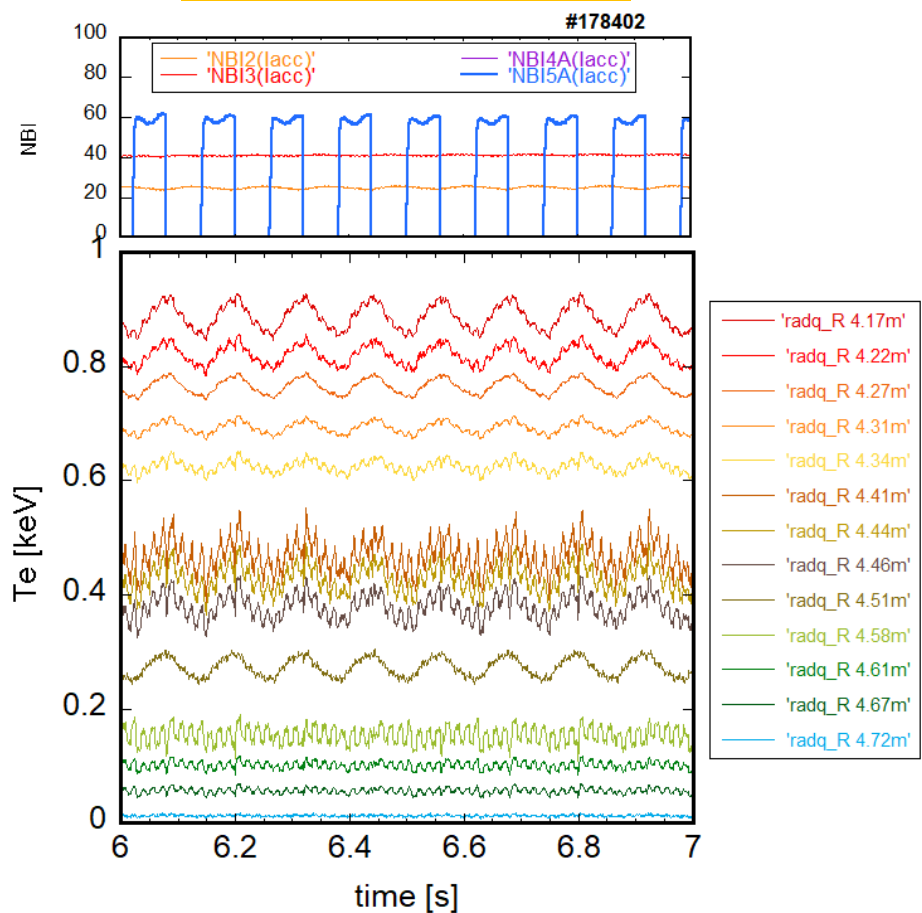
M. Nishiura RSI(2021)



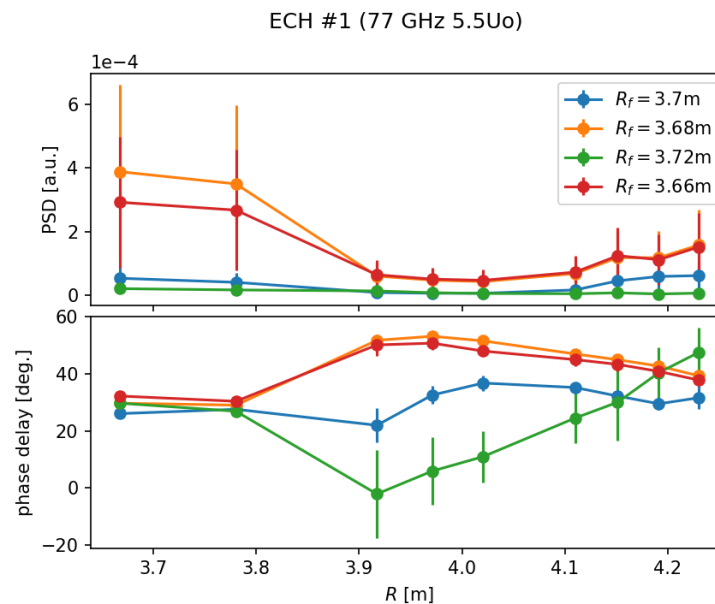
- The designed notch frequency agrees well with the HFSS simulation
- >60dB attenuation is achieved.

Observation examples

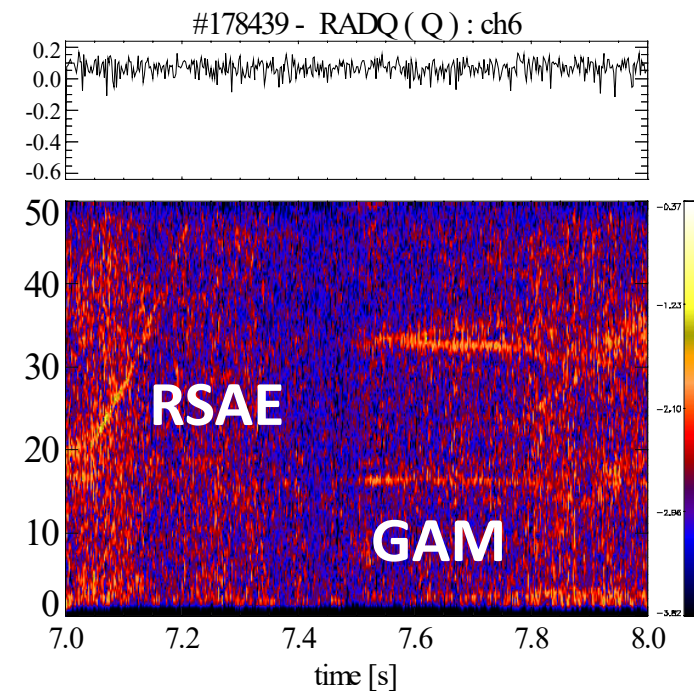
NBI modulation



ECH Rf-scan (Power deposition)



Fluctuation



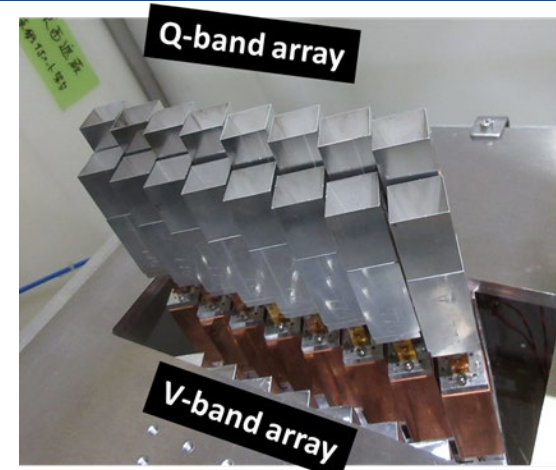
Contents

■ New Q/V-band Radiometer

■ ECE Imaging system

● Q-band ECEI : 8ch (radial) x 8 antenna (vertical) = 64ch

● V-band ECEI : 8ch (radial) x 8 antenna (vertical) = 64ch

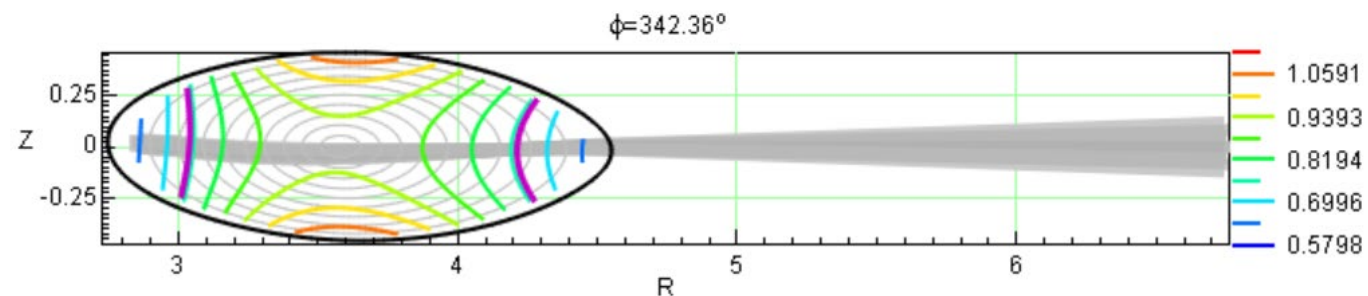


➤ Focusing optics

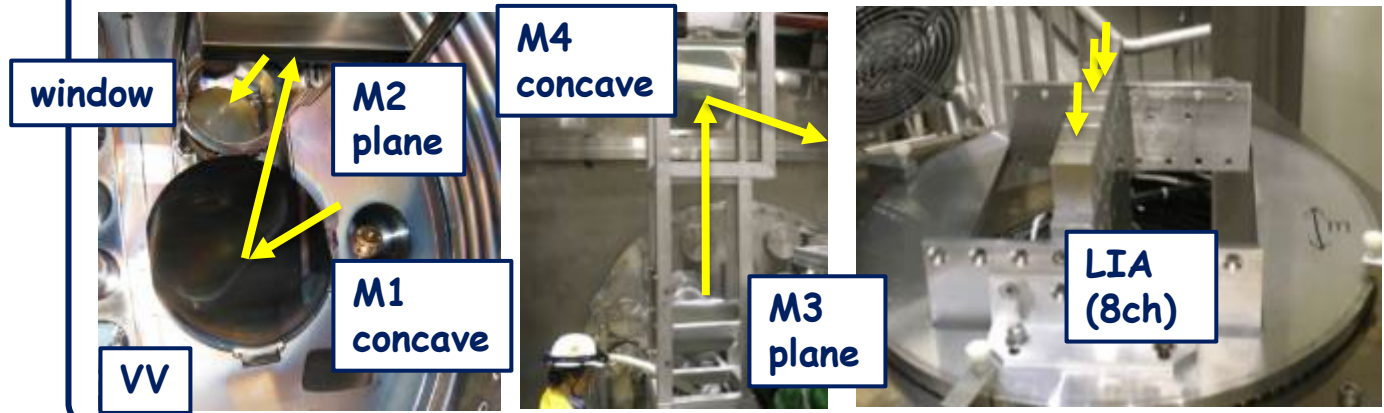
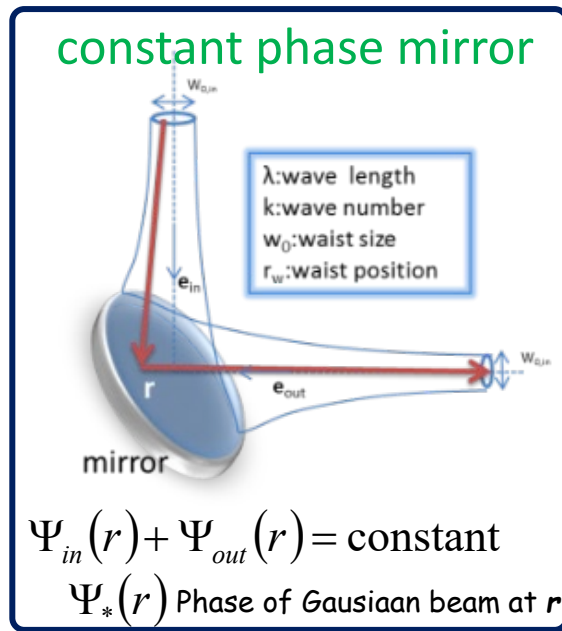
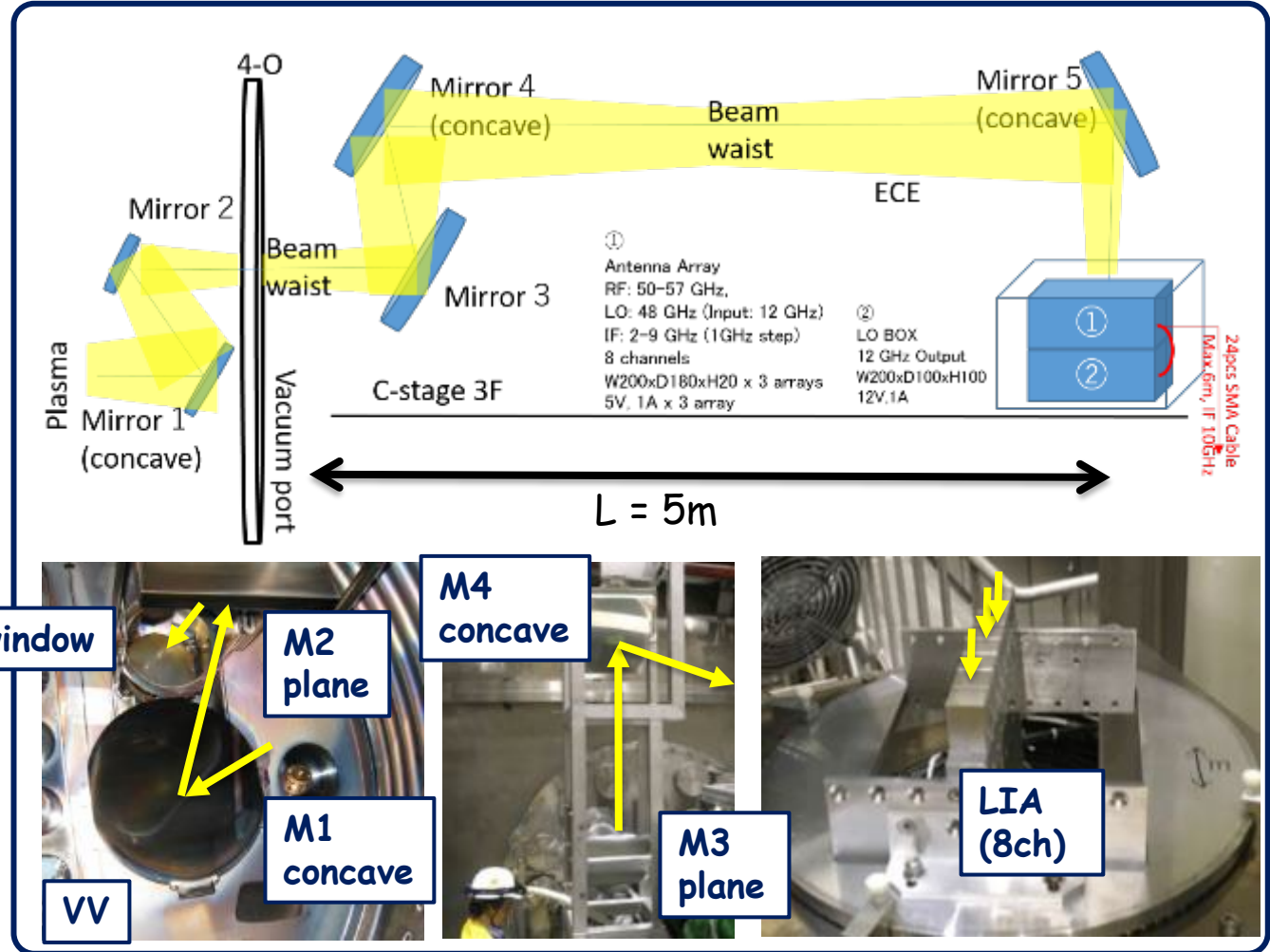
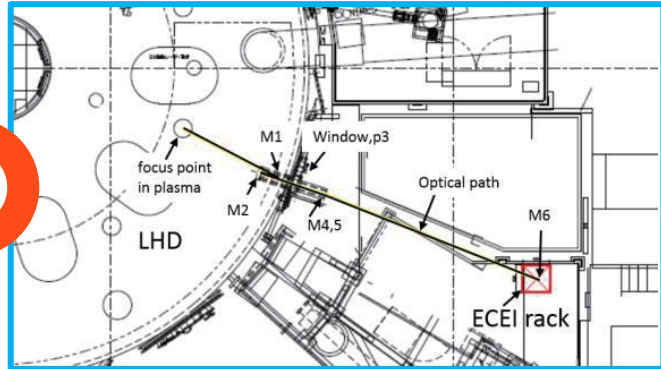
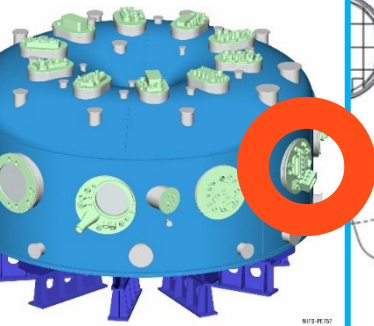
➤ Receiver array (LIA)

➤ Improvements of signal detection (LOG detector, heterodyne circuits)

➤ Observation examples of LHD plasmas



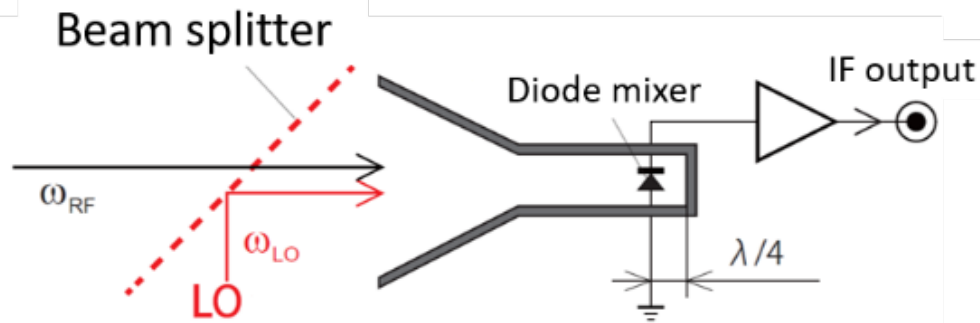
Imaging optics



H. Tsuchiya, PFR, 3402063(2018)

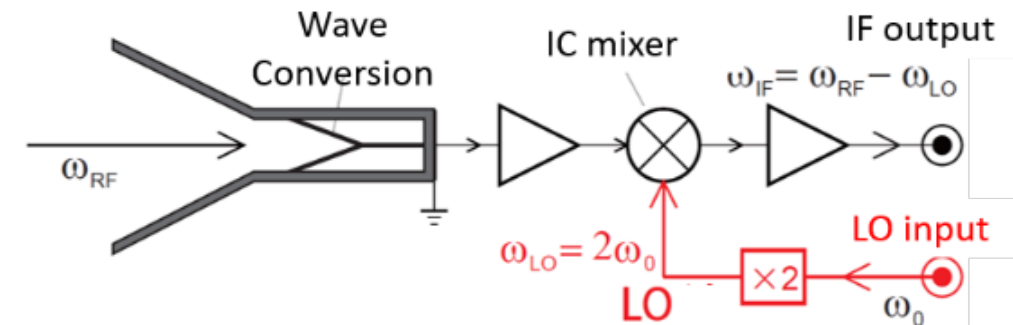
Receiver Improvements

HMA : Horn Antenna Mixer Array



- ✘ High power/expensive source for LO
- ✘ Power Loss by Beam Splitter
- ✘ Non-Uniformity of LO beam Profile

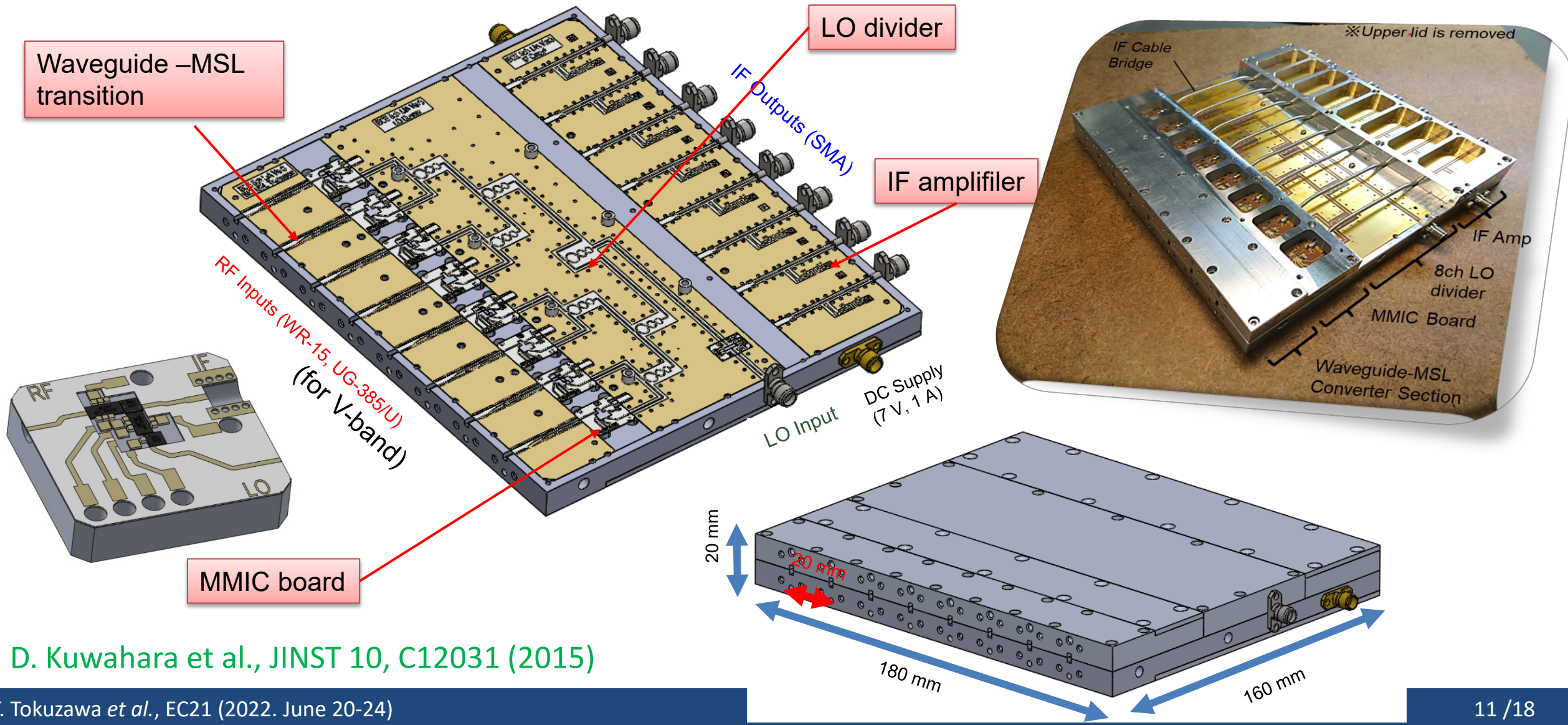
LIA : Local Integrated Antenna array



- Applied **MMIC** Doubler / Mixer.
- Increasing conversion ratio of Mixer
- Improving Uniformity of sensitivity

40dB!! Gain up

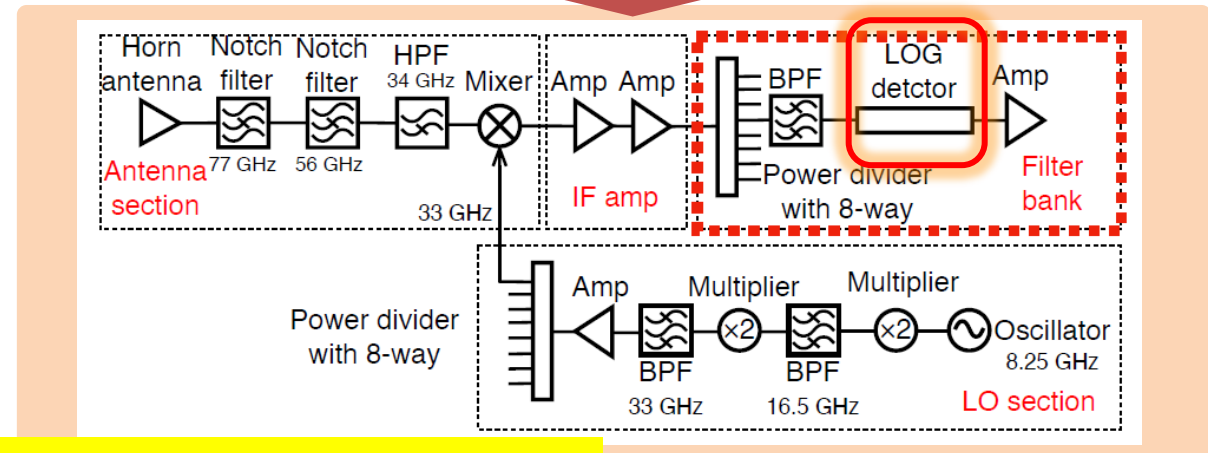
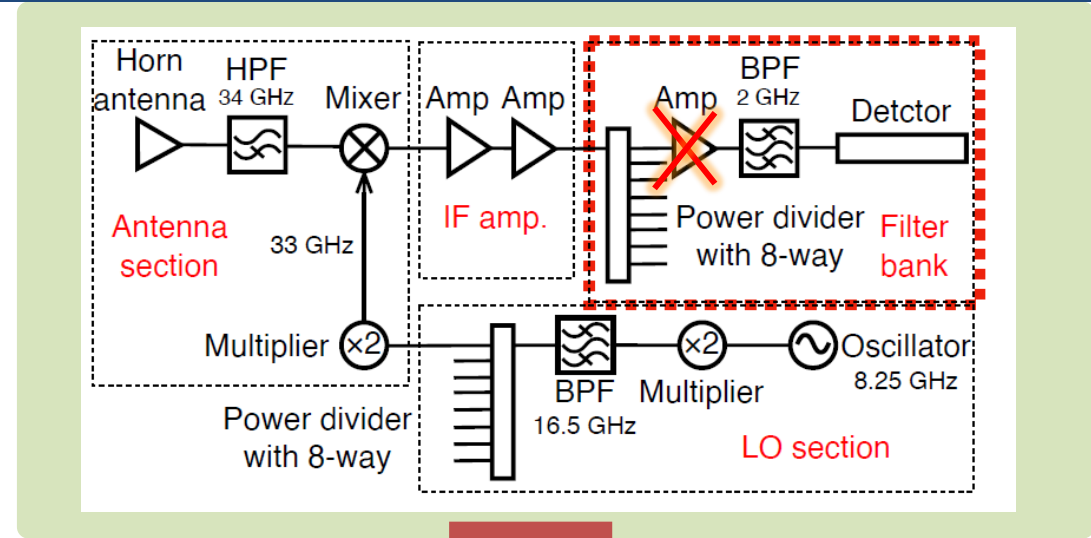
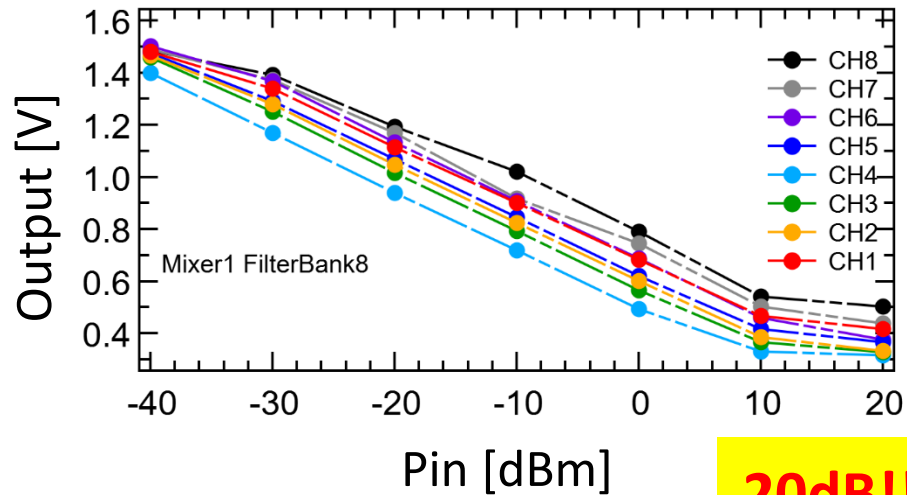
8 channel LIA (Local Oscillator Integrated Antenna) array



D. Kuwahara et al., JINST 10, C12031 (2015)

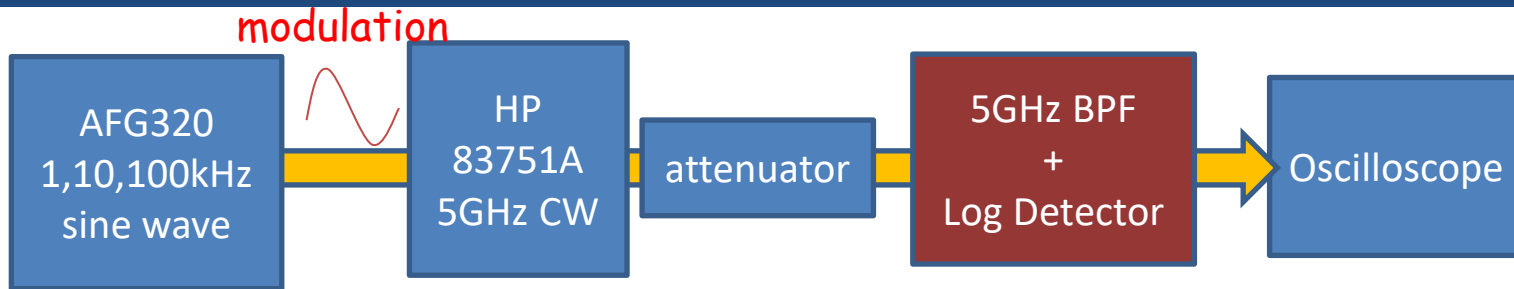
LOG detector is applied

- ✓ When the weak signal is focused on, amplifier saturates due to dramatic plasma fluctuation
- ✓ Remove the amplifier from filter bank, then replace into **LOG detector** for expanding the measurement scale.

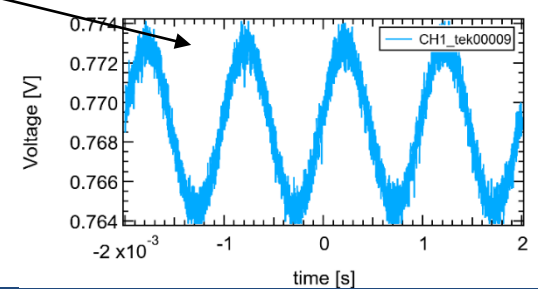
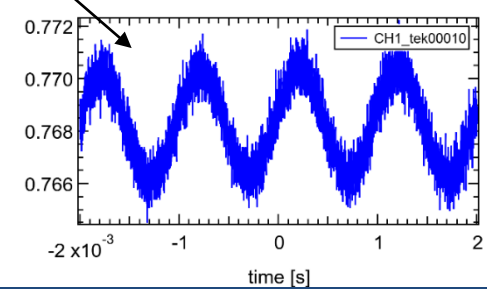
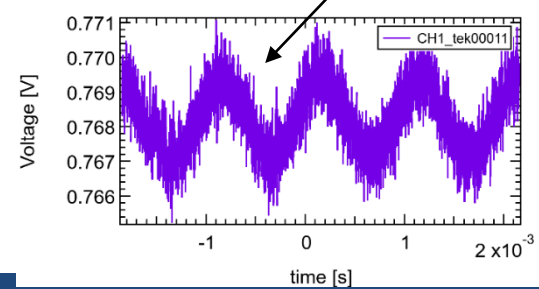
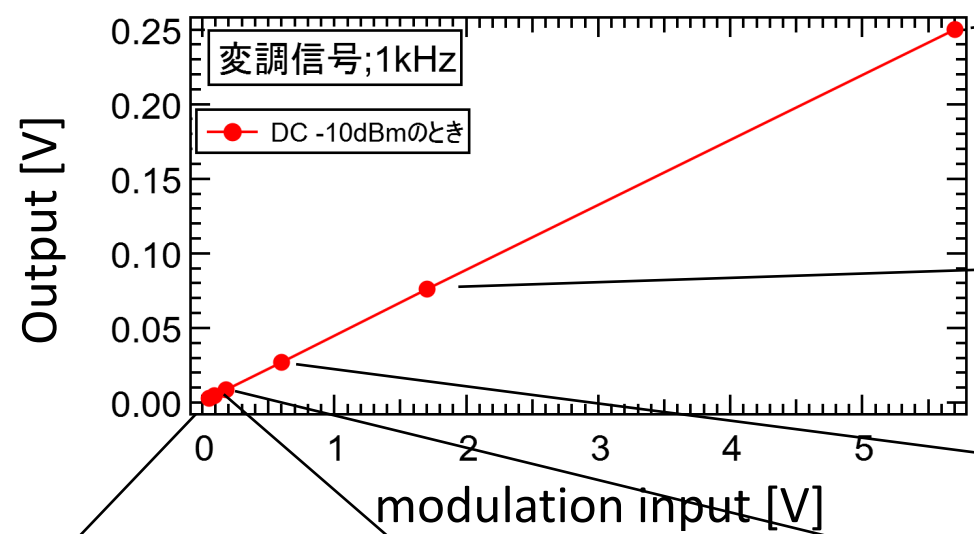
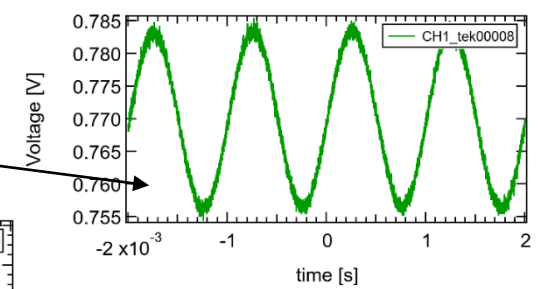
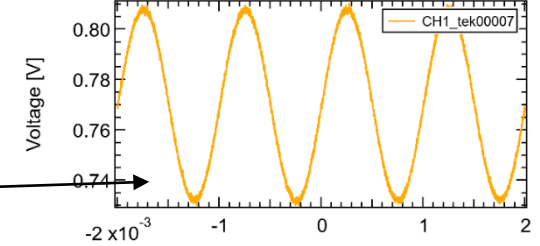
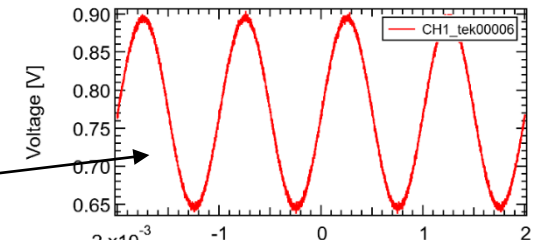


20dB!! Dynamic range expansion

Responsiveness of LOG detection



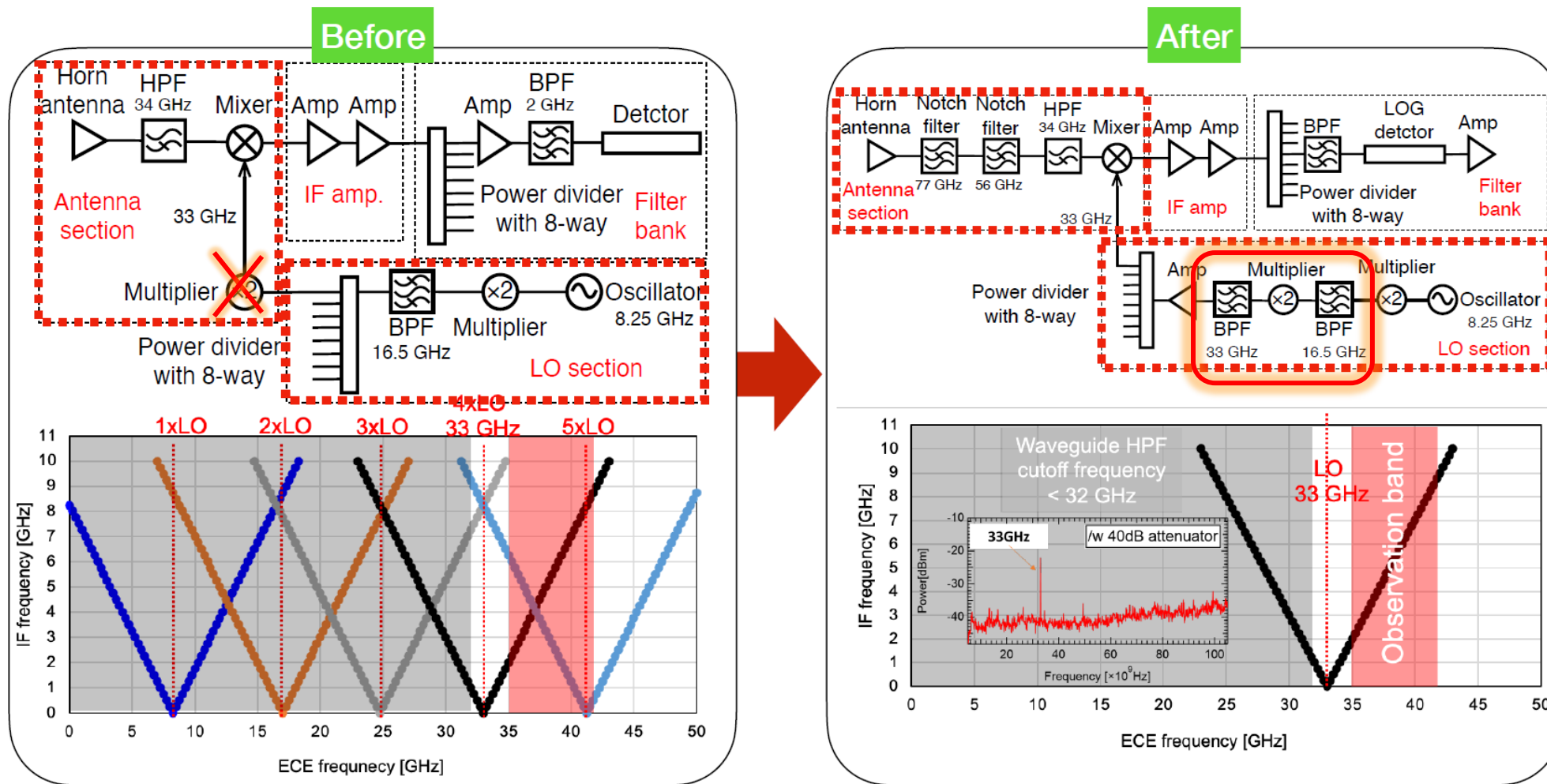
LOG detector output



✓ Oscillating input exhibits smooth waveform response.

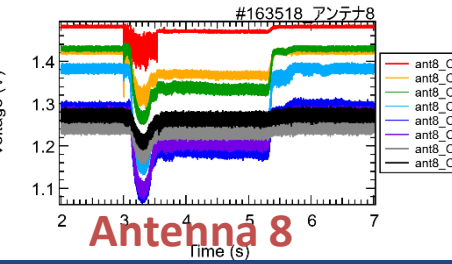
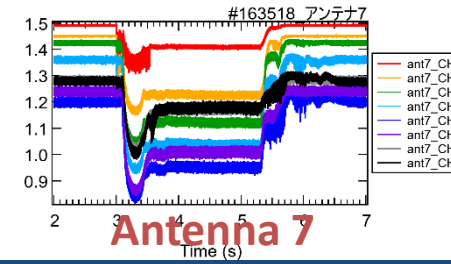
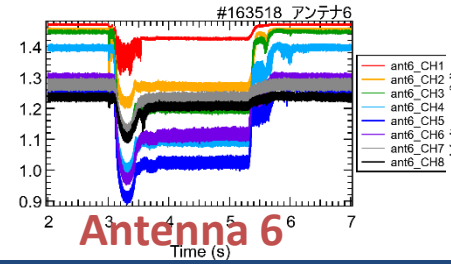
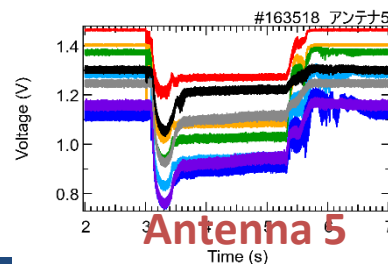
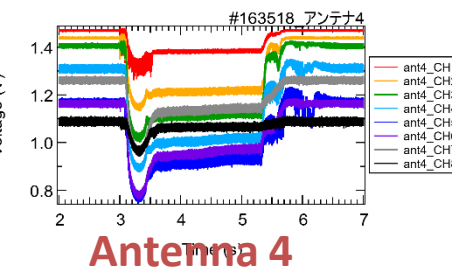
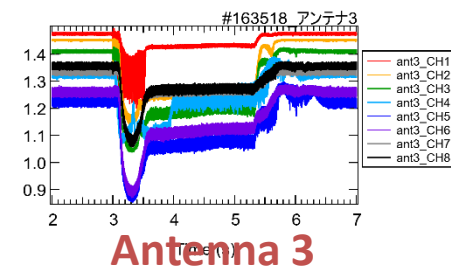
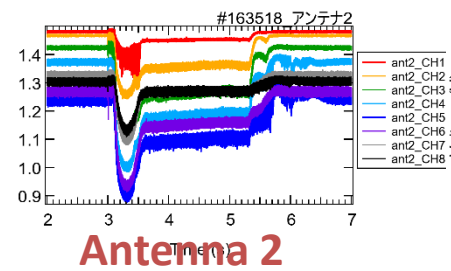
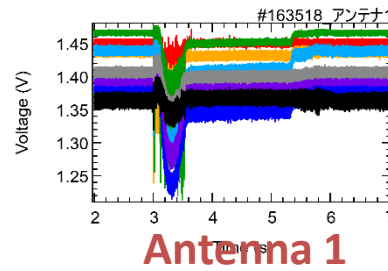
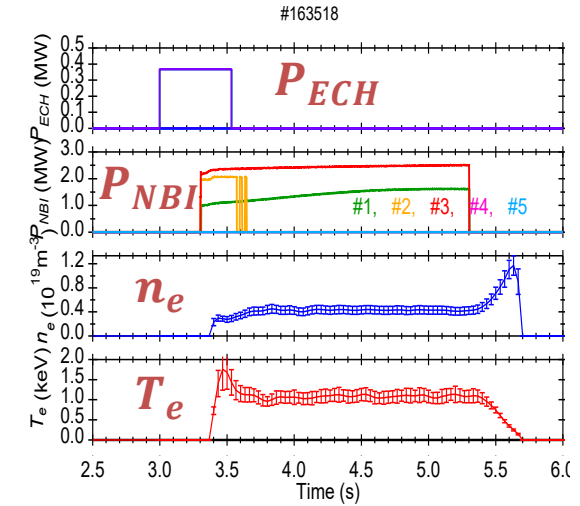
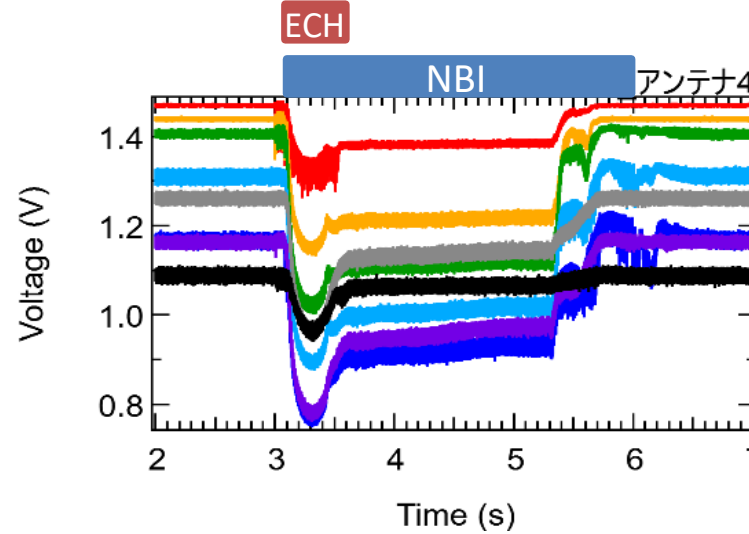
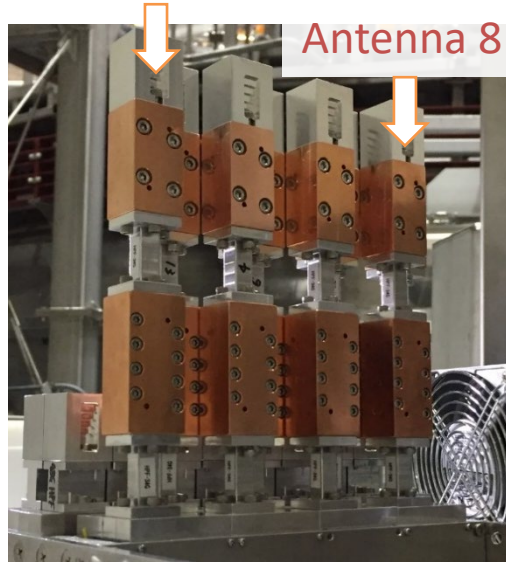
Reduction of harmonic components of LO

- ✓ Harmonics components in LID receiver were getting mixed in and disturbing the measurement.

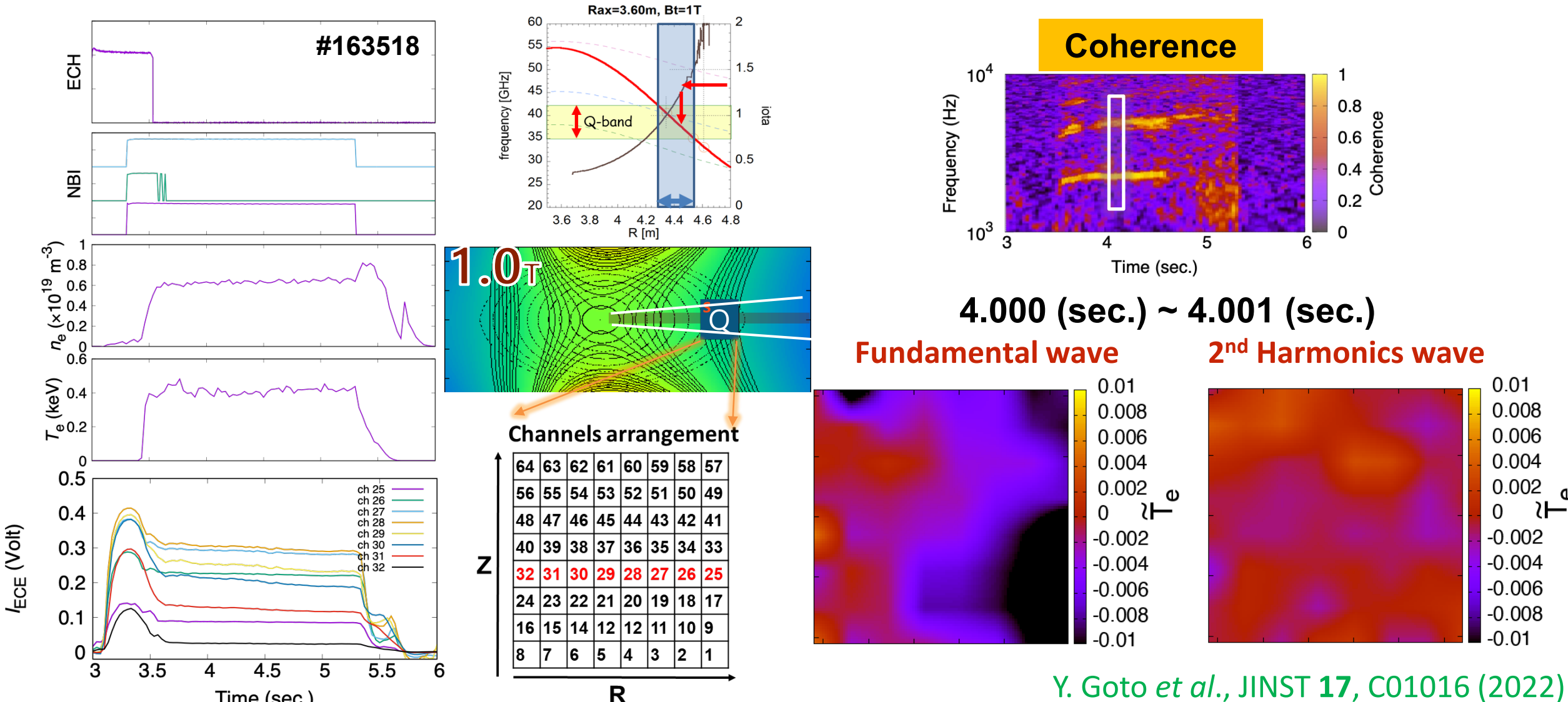


ECE radiation was successfully observed on 64 channels.

Antenna 1

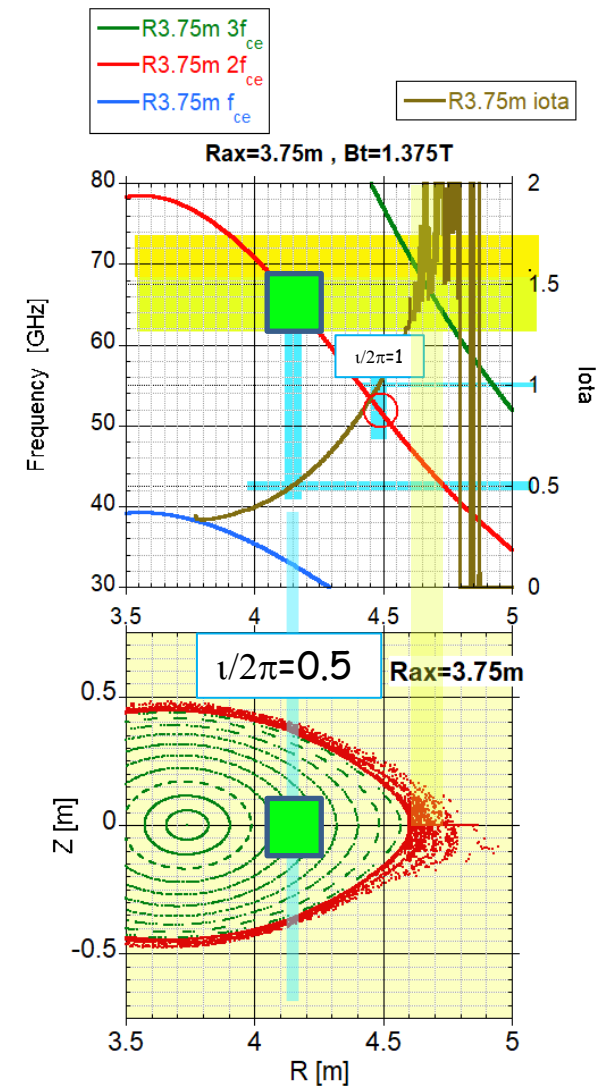
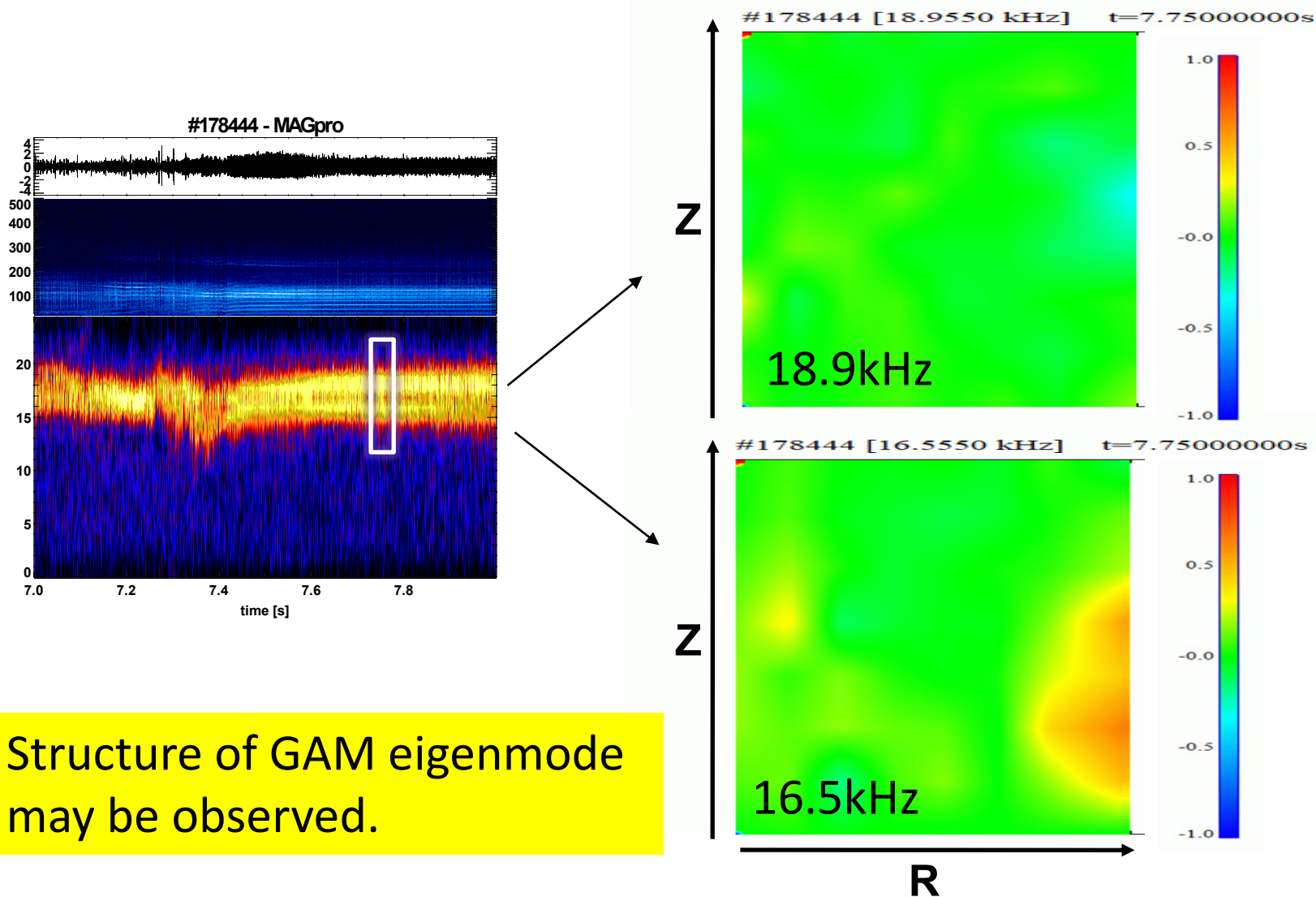


Edge Te Fluctuation (MHD: m/n=3/4)



Y. Goto *et al.*, JINST 17, C01016 (2022)

Core GAM oscillation



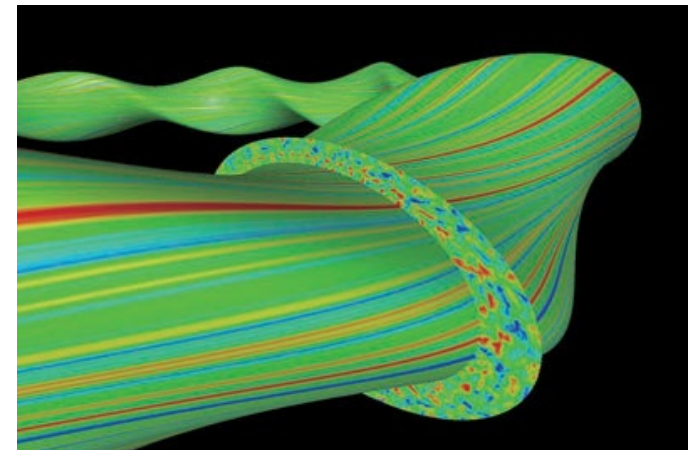
✓ Structure of GAM eigenmode may be observed.

Summary

For $B_t \sim 1\text{T}$ (low magnetic field strength experiments),
32 channel Q/V-band ECE radiometer &
Q/V-band ECEI (8x8x2 =128ch) have been developed with

- Gaussian beam propagation using quasi-optical mirrors
- Oversized notch filter
- LOG detector
- Frequency separator
- etc.

Now, ready for physics study



Thank you for your attention

Proposals for LHD experiments are welcome!

https://www-lhd.nifs.ac.jp/pub/Collaboration2_en.html



National Institute for Fusion Science

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Large Helical Device Project

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Research Proposals for the LHD experiment

Welcome to the LHD experiment!

The submission website for research proposals for the 24th LHD experiment campaign is now open. If you are already a member of the LHD experiment group, please submit your research proposals through the [Proposal submission page](#) (Collaborator's website). The proposal submission will be due on **30 June 2022**. You should need to [set your password](#) at the first login in the new campaign.

Deadline is June 30