Electron cyclotron heating (ECH) system (2020~)

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1. Objectives

- Optimization and improvement in heating efficiency
- Generation of high temperature and high performance plasmas
- Controlling profiles of electron temperature, power deposition, plasma pressure, and driven current
- Sustainment of steady state plasmas
- Study of particle and heat transports
- Development of advanced heating scenarios such as Bernstein wave and high harmonic heatings
- Measurement of ion energy distribution function by Collective Thomson Scattering (CTS) scheme

2. Apparatus

2.1. Gyrotrons

- two 77GHz (1.2MW/2s, 0.3MW/CW, Canon Electron Tubes & Devices Co., Ltd.)
- two 154GHz (1MW/2s, 0.5MW/CW, CETD)
- one 154/116GHz Dual Frequency (1MW/2s, 0.5MW/CW, CETD)
- one 56GHz (0.5MW/1s, GYCOM)

2.2. Transmission Lines

- transmission efficiency of about 80~90%
- 6 evacuated 88.9mm inner diameter corrugated waveguide transmission lines
- ~100m total length with ~15 miterbends for each transmission line
- total water cooling for 5 transmission lines not only for miterbend mirrors, for long pulse operations

2.3. Power injection antennas

- 6 antenna systems with four horizontal port antennas (2-OUR (77GHz), 2-OLL (154GHz), 2-OUL (154GHz) and 2-OLR (154/116GHz)) and two top port antennas (5.5-Uout (77GHz) and 1.5-U (56GHz))

2-OUR antenna
connected gyrotron: 77GHz#2
mirrors: 1 convex, 1 focusing, and 1 steering plane mirrors
1/e beam electric field waist size on the R=3.9m plane: 65mm circular Gaussian

focal point scan range on the R=3.9m plane: −0.75m < Tf < 0.85m, −0.55m < Zf < 0.35m

2-OLR antenna
connected gyrotron: 154/116GHz dual frequency
mirrors: 1 focusing and 1 steering plane mirrors
1/e beam electric field waist size on the R=3.9m plane:
focal point scan range on the R=3.9m plane: −0.65m < Tf < 0.75m, −0.6m < Zf < 0.75m

2-OLL antenna
connected gyrotron: 154GHz#4
mirrors: 1 focusing and 1 steering plane mirrors
1/e beam electric field waist size on the R=3.9m plane: 30mm circular Gaussian
focal point scan range on the R=3.9m plane: −0.55m < Tf < 1.0m, −0.55m < Zf < 0.55m

2-OUL antenna
connected gyrotron: 154GHz#5
mirrors: 1 focusing and 1 steering plane mirrors
1/e beam electric field waist size on the R=3.8m plane: 33.7mm circular Gaussian
focal point scan range on the R=3.9m plane: −0.8m < Tf < 0.85m, −0.55m < Zf < 0.55m

5.5-Uout antenna
connected gyrotron: 77GHz#3
mirrors: 3 focusing and 1 steering plane mirrors
1/e beam electric field waist size on the equatorial plane: 15 mm radial, 50 mm toroidal elliptical Gaussian
focal point scan range on the equatorial plane: 3.4m < Rf < 3.8m, −0.2m < Tf < 0.2m

1.5-U antenna
connected gyrotron: 56GHz
mirrors: 3 focusing and 1 steering plane mirrors
1/e beam electric field waist size on the equatorial plane:
focal point scan range on the equatorial plane:

3. Data

echpw: Injection power and timing of each gyrotron.

LHDGAUSS_DEPROF: Power absorption profile of each ECH beam and at each timing of TS measurement, calculated with the ray-tracing/power absorption calculation code LHDGauss.
* To know more about LHDGauss, please refer to

https://www-lhd.nifs.ac.jp/LHD/pdf/LHD_Guide/Numerical_Codes/LHDGauss.pdf

LHDGAUSS2_DEPROF: Power absorption profile of each ECH beam calculated with the upgraded code, LHDGauss2 which takes the oblique propagation effect in power absorption calculation. The calculation will be done on demand.

Travis: Power absorption and EC-driven current profiles of each ECH beam calculated with the TRAVIS code (N.B. Marushchenko *et al.*, Phys. Plasmas **18**, 032501 (2011)). The calculation will be done on demand.

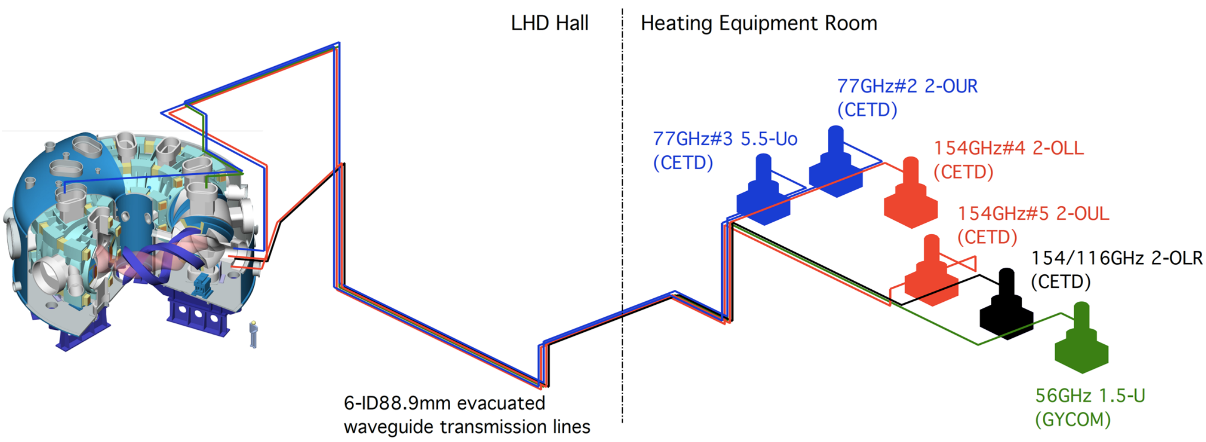

Fig. 1. Schematic view of ECH system in the LHD hall and heating equipment room (2020~).

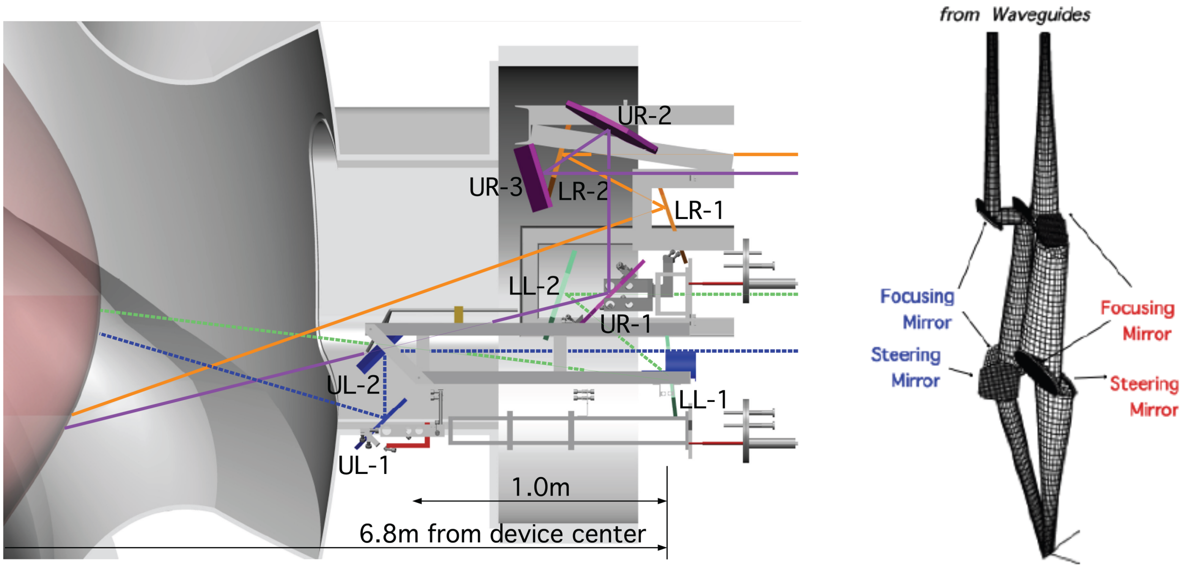

Fig. 2. Schematic views of EC-wave injection antenna systems in the 2-O port (left) and 5.5-U port (right).

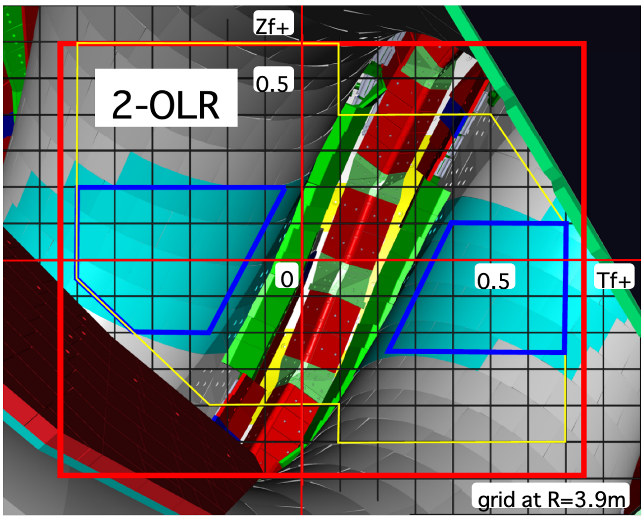

Fig. 3. Map of available EC-wave beam focal point scan ranges for 2-OLR antenna as an example. The beam direction setting parameters Tf and Zf are defined on a virtual vertical plane set at R=3.9m. Protecting tiles made of molybdenum are colored in light blue, and the areas closed with blue lines have no-limitation in beam injection. Aiming at the area between the blue lines and yellow lines is available, but with limitation. The area outside the red (yellow) lines is inhibited by hard (soft) limit. Each beam line has its own ranges of available injection.

References

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