RECENT EXPERIMENTS AND DEVELOPMENT OF LHCD SYSTEM ON HL-3

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1. LHCD SYSTEM OF HL-3

HL-3 (used name HL-2M) is a tokamak with a major radius 1.78m and minor radius 0.65m [1]. 1MA plasma current was realized at the end of 2021 after one year device upgraded to divertor configuration since the first plasma at the end of 2020 [2]. There is a plan that HL-3 will run in D-T phase, 4MW LHCD system will be developed then. Up to now, half of the system has been installed and demonstrated. Four TH2103C1 klystrons are located in the heating hall of HL-3 as the wave source with all of the auxiliary equipments. There are 4 transmission lines in the system, about 40 m length each. The antenna is designed in FAM structure and the peak parallel refractive index $N_{//0}$ is 2.25. TE10 to TE30 mode converters are used in the antenna to divide the power in three parts equally in ploidal direction. As a result, There are 192 active grills (6×32) facing to the plasma, with passive ones at each side [3], as shown in Fig. 1.



Fig. 1 Photo of the FAM launcher in HL-3. A gas puffing system with tree poloidal injections are located at the left of the launcher mouth (as viewed from the plasma). A set of Langmuir probes is located to the right.

2. LHCD EXPERIMENT ON HL-3

The LHCD system was demonstrated in 2023 for the first time. The coupled power has reached 800kW with coupling coefficient 95% since 2024, where 360kW maximum power was delivered in a WR284 wave guide transmission line. The loss of the transmission lines are quite high, 20% - 40% efficiency of the four lines, respectively. The coupling optimization experiments were also carried out. Gas injection next to the antenna was applied not only for density control, but also for the coupling optimization, which is effective in the experiments. Full non-inductive current drive phenomenon was also obtained in the experiments, which is shown as Fig. 2. 300 kA plasma current was driven by 800kW coupled LH power. The CD efficiency was estimated when loop voltage became zero, which is $0.87 \times 10^{19} \,\mathrm{AW}^{-1}\mathrm{m}^{-2}$ in the density of $n_c = 1.3 \times 10^{19} \,\mathrm{m}^{-3}$.



Fig. 2 Full non-inductive current drive shot. From top to bottom are plasma current (in kA), control signal of gas injection valve for LHW coupling optimization (in V), loop voltage (in V), CS coil current (in kA), coupled LH power (in kW), ECRH power (in kW), electron density (in m^{-3}) and stored energy (in kJ), respectively.

3. UPGRADING PLAN FOR LHCD SYSTEM OF HL-3

For D-T phase, the ability of HL-3 LHCD system will be upgrade to 4MW. 4 more klystrons will be installed and new mode converters will be applied in the transmission lines to avoid high insertion loss on the long transmission lines. Two new antennas has been designed with the peak parallel refractive indexes $N_{//0}$ around 2.0 until now, which will be manufactured soon.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support of the HL-3 Team at SWIP, in particular the Vacuum & Gas puffing group, the Probe diagnostic group and also the plasma operation group. This work is supported by the Natural Science Foundation of China (NSFC) project (No. 12105083), funded by NSFC and the domestic important research and development project of China (No. 2022YFE03020002, 2022YFE03010004), funded by Ministry of Science and Technology (MOST).

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