Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 12-13, 2016

Experimental measurements of Helicon wave coupling in KSTAR plasmas

H. J. Kim [a*], H. H. Wi [a], S. J. Wang [a], S. Y. Park [a], J. H. Jeong [a], J. W. Han [a], J. G. Kwak [a], Y. K. Oh [a], M. H. Chun [b], I. H. Yu [b]

[a]*National Fusion Research Institute, 113 Gwahangno, Yuseong-gu, Daejeon, 34133, Korea*
[b]*Pohang Accelerator Laboratory, 80 Jigokro-127, Nam-gu, Pohang, Gyeongbuk, 37673, Korea*
[*]*Corresponding author: haejin@nfri.re.kr*

1. Introduction

Helicon wave coupling for efficient off-axis current drive using a traveling wave antenna has been proposed [1]. It was found that helicon wave can drive plasma current in the mid-radius of high electron beta plasmas in medium and large size tokamak due to moderate optical thickness and wave alignment nature of helicon wave in helical magnetic field. KSTAR tokamak can be a good platform to test this current drive concept because it has adequate machine parameters. Furthermore, KSTAR will have high electron beta plasmas in near future with additional ECH power. In 2015 KSTAR experiments, low-power traveling wave antenna has been designed, fabricated and installed for helicon wave coupling tests in KSTAT plasmas [2, 3]. In 2016 KSTAR campaign, 200 kW klystron power will be combined using three coaxial hybrid couplers and three dummy loads [4]. High power RF will be fed into the traveling wave antenna with two coaxial feeders through two dual disk windows and 6 inch coaxial transmission line system [5]. Current status and plan for high power helicon wave current drive system in KSTAR will be presented. Also, design and rf test results of key components such as traveling wave antenna, hybrid combiners and dual disk window will be presented.

2. Helicon wave couplings in KSTAR plasmas

2.1 Coupling measurements using a mock-up traveling wave antenna in 2015 KSTAR plasmas experiments

In 2015 KSTAR experiments, mock-up traveling wave antenna (TWA) has been designed using electromagnetic 3D HFSS. Mock-up TWA was fabricated and tested by using a vector network analyzer (VNA). Figure 1 shows mock-up TWA installed during 2015 KSTAR plasmas experiments. After the TWA installation at the KSTAR in 2015, wave couplings were investigated by measuring and analyzing reflection and insertion losses at ports 1 and 2 of the TWA using VNA. As shown in Fig. 2, preliminary results of couplings between plasmas and the TWA were obtained in both L- and H-mode plasmas, respectively. The coupling of 70~80% could be controlled by changing radial outer gap, the distance between last closed flux surface and poloidal limiter at outer mid-plane, without severe degradation of plasma confinement.

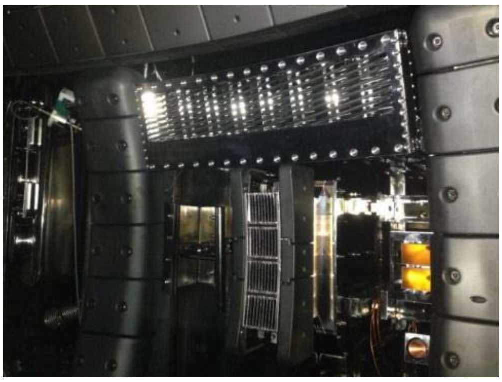
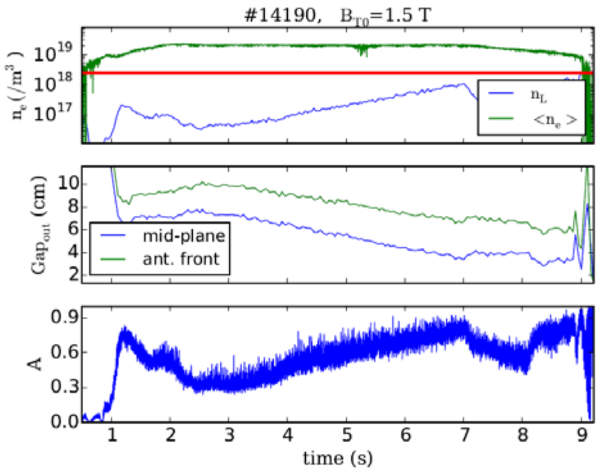
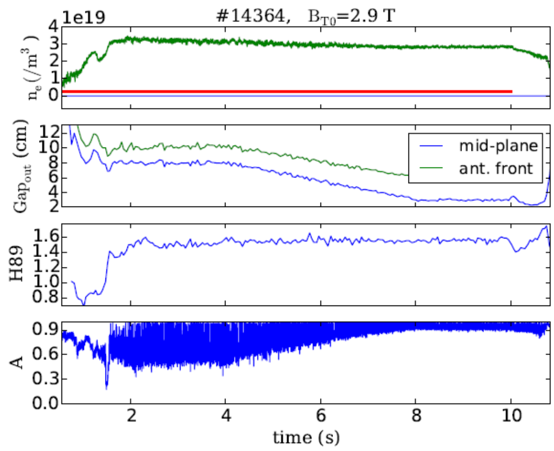


Fig. 1. Photograph of a mock-up traveling wave antenna installed at KSTAR.



(a)



(b)

Fig. 2. Preliminary results of wave coupling in (a) L-mode and (b) H-mode plasmas.

2.2 High power helicon wave current drive system for 2016 KSTAR plasmas experiments

In order to investigate the effects of off-axis current drive we loaned four klystrons, high power dummy loads and 6-1/8 inch coaxial transmission line components from Pohang Accelerator Laboratory (PAL) in 2015. Each klystron was operated at the frequency of 500 MHz with an output power of 60 kW at PAL for 10 years. Figure 3 shows the layout of high power helicon wave current drive system for 2016 KSTAR plasmas experiments. As shown in Fig. 3, RF power from 4 klystrons generating 60 kW at 500 MHz will be combined using three 6-1/8 inch coaxial hybrid couplers and transmitted through coaxial transmission line of 10 m long. Finally, 500 MHz, 200 kW RF power will be fed into the prototype TWA connected to 5 inch coaxial feeders through dual alumina disk windows. Figure 4 depicts prototype TWA installation at P-port above LHCD launcher. Preliminary experimental measurements using the prototype TWA for high power helicon wave coupling in KSTAR plasmas will be discussed.

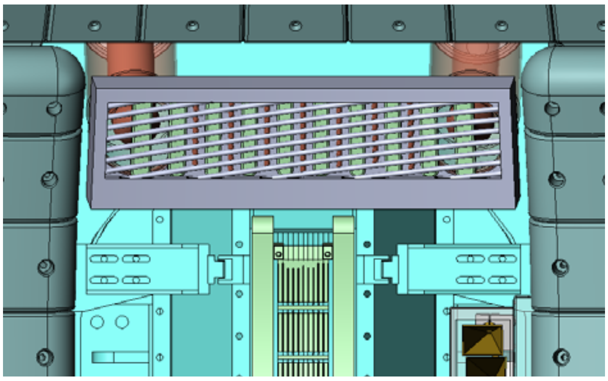


Fig. 3. Prototype traveling wave antenna for high power application in 2016 KSTAR plasmas experiments.

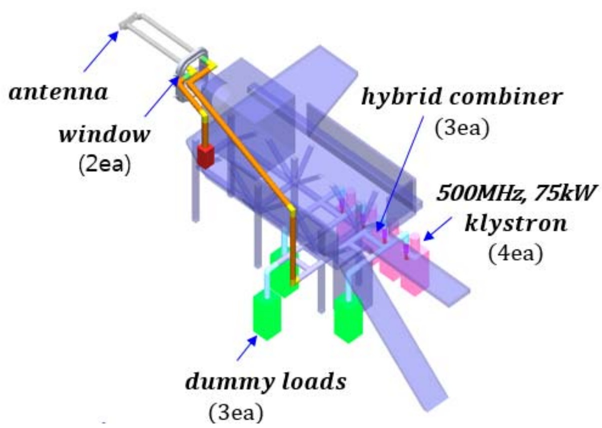


Fig. 4. Layout of high power helicon wave current drive system using 4 klystrons at 500 MHz.

Figure 5 (a) and (b) show the simulation results of prototype TWA for high power injection. As shown in Fig. 5(a) the operating frequency and bandwidth of prototype TWA are 500 MHz and 40 MHz, respectively. Peak parallel refractive index of the prototype TWA is 3 as depicted in Fig. 5(b).

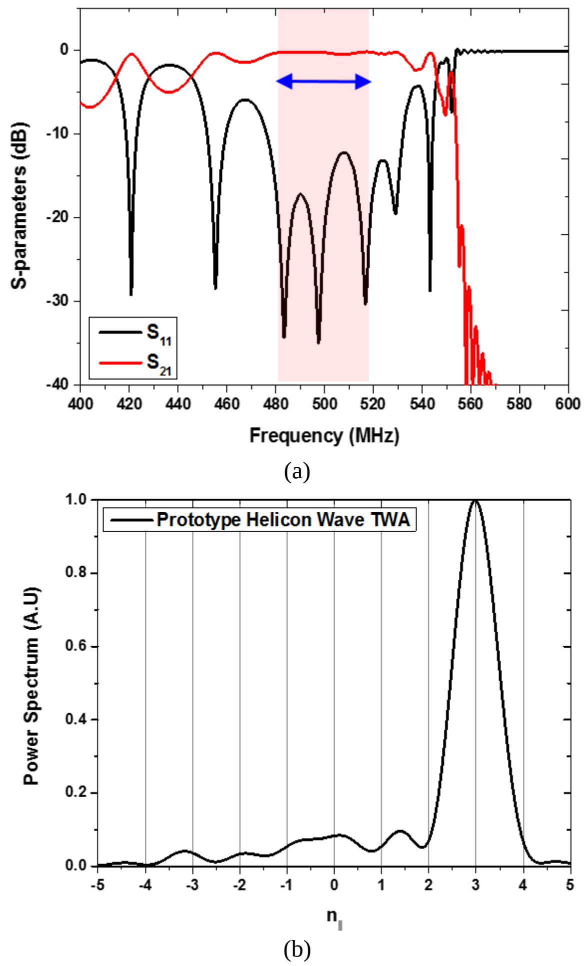


Fig. 5. Simulation results of prototype TWA operating at 500 MHz for helicon wave current drive in 2016 KSTAR experiments.

3. Conclusions

We have designed, fabricated, and tested two TWA antennas. Mock-up TWA antenna installed at the KSTAR reveals high couplings in both L- and H-mode plasmas. The coupling can be easily controlled by radial outer gap without degradation of plasma confinement or local gas puffing with slight decrease of plasma confinement.

Acknowledgements

This work was supported by the KSTAR research project funded by the Ministry of Science, ICT and Future Planning of the Republic of Korea.

REFERENCES

[1] V. Vdovin, E. Azizov et al., Helicons current drive system in tokamak T-15, Fusion Energy Conference FIP/P5-5 (2014).
[2] H. J. Kim, S. J. Wang, H. H. Wi et al., Draft design of Helicon wave current drive system in KSTAR, KSTAR Conference (2015).
[3] S. J. Wang et al., Measurement of helicon wave coupling for current drive and anticipated role for high beta KSTAR plasmas, 57th Annual Meeting of the APS Division of Plasma Physics (2015).
[4] H. J. Kim, S. J. Wang, B. H. Wang, J. G. Kwak, J. J. Choi, RF design and tests on a broadband, high-power coaxial quadrature hybrid applicable to ITER ICRF transmission line system for load-resilient operations, Fusion Eng. Design, vol. 96-97, pp.498-502 (2015)
[5] H. J. Kim, H. H. Wi, S. J. Wang, et al., High power helicon wave current drive system in KSTAR, KSTAR Conference (2016)..