Design and Preparation of RF System for the Lower Hybrid Fast Wave Heating and Current Drive Research on VEST

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1. Introduction

Continuous current drive is one of the key issues for tokamak to be a commercial fusion reactor[1]. As a part of new and efficient current drive concept research by using a Lower Hybrid Fast Wave (LHFW), the experimental study is planned on Versatile Experiment Spherical Torus (VEST) and a RF system is being developed in collaboration with Kwang Woon University (KWU), Korea Accelerator Plasma Research Association (KAPRA) and Seoul National University (SNU)[3]. The LHFW RF system includes UHF band klystron, inter-digital antenna, RF diagnostics and power transmission sub components such as circulator, DC breaker, vacuum feed-thru. The design and preparation status of the RF system will be presented in the meeting in detail.

2. Design and Preparation of LHFW RF system

2.1 Design of RF system including diagnostic

The overall design is shown in Fig.1. It is based on old 10kW UHF broadcasting klystron.

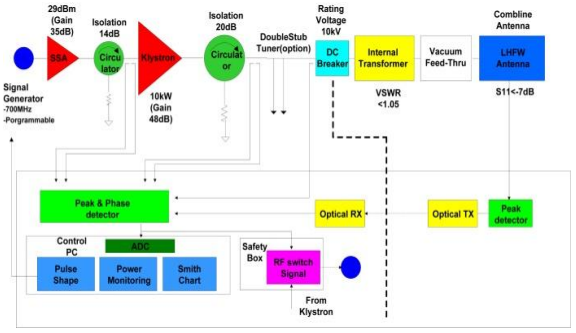

Fig. 1. Output current of the SiC detector for three particles

A signal from generator is amplified in two steps through 39 dB solid sate amplifier and 48 dB klystron. And the amplified RF power of 10 kW is transmitted to inter-digital antenna to launch LHFW in plasmas through 3-1/8" coaxial transmission line, 10kV rating DC breaker, matching internal transformer with VSWR < 1.05 in wide band, and high vacuum compatible feed-thru. The parameters for main components of RF system are summarized in Table I.

Table I : Specification of LHFW RF system components

Components	Values
Signal generator	500kHz~1.3GHz(13dBm)
Solid state amplifier	35dB (max 29 dBm)
Circulator(SSA)	14dB isolation, 75 W
Klystron	10 kW UHF Harris system for broadcasting
Circulator(Klystron)	20 dB isolation, 15 kW
DC breaker	Rating 10kV, VSWR<1.05
Internal transformer	VSWR<1.05,for matching
Vacuum feed-thru	High vacuum< 10^{-7} mbar
Power line	3-1/8" EIA coaxial
Inter-digital antenna	$N_{\parallel}$: 3~5, VSWR < 3

The RF diagnostics are consisted of directional coupler for the forward-reflected power measurements in front of amplifiers and voltage probes for the arcing detection at the transmission line and antenna. The power and voltage signals are digitized through peak-phase detector and ADC, which are processed and used for the monitoring of input power level and safety measures.

2.2 UHF Klystron

The klystron is prepared by refurbishing an old Harris UHF broadcasting system which has been hold by SNU. The maximum RF power is 30 kW, and the frequency ranges from 470 to 700 MHz. The beam voltage and current are 19.5 kV and 5.4A. More specification of the klystron is summarized in Table. II. The vacuum soundness of the klystron is tested and confirmed through the vacuum current measurement. Since the beam power for the klystron in Harris system is absent, it is lent from KAPRA and the refurbishing is now completed. The repair of magnet and filament power in the old klystron system is currently under progress.

The whole klystron system will be tested in near future after the completion of filament and magnet power repair.

Table II : Specification of klystron

Parameters	Values
Frequency	470~700 MHz
Output power	37.5 kW
Gain	48 dB
Beam voltage	19.5 kV
Beam current	5.4 A
Electrode voltage	19.5 kV
Heater voltage	7 V
Heater current	17 A
Body current	50 mA
Magnet voltage	145 V
Magnet current	32 A
Collector cooling	Water 2.0 gal/min
Body cooling	Water 1.5 gal/min
Magnet cooling	Water 2.0 gal/min
Gun cooling	Forced air 50 ft^3/min

2.3 RF Antenna

The LHFW antenna is being developed in inter-digital type through collaboration with KNU. The preliminary design of curved inter-digital antenna is shown in Fig. 2.

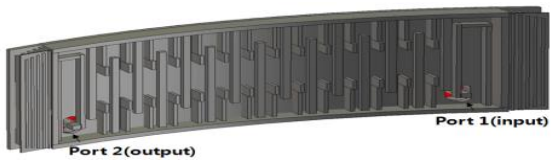

Fig. 2. Curved inter-digital antenna designed for LHFW RF system on VEST

It is simulated with HFSS commercial code for antenna characteristic parameters evaluation and the result is in Fig.3. In 480~496 MHz frequency range, the parallel refractive index is between 3.5 and 4.5 and the S-parameters S_{11} and S_{12} are less than -10 dB. It satisfies the requirement for LHFW experiment on VEST and more specific design and optimization will be carried out considering the plasma density profile in front of antenna in next step.

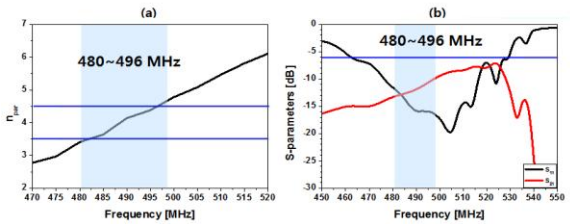

Fig. 3. Parallel refractive index spectrum (a) and S-parameters (b) of curved inter-digital antenna designed.

2.4 RF sub components and diagnostic

The RF sub component such as DC breaker, internal transformer, and vacuum feed-thru and the diagnostic systems are under detail design and it will be presented in the conference.

3. Summary

A RF system has been designed and prepared for the experimental study of efficient current drive by using Lower Hybrid Fast Wave. Overall LHFW RF system including diagnostics is designed to deliver about 10 kW in UHF band. And the key hardware components including klystron and antenna are being prepared and designed through the collaboration with KWU, KAPRA and SNU.

REFERENCES

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[2] S. H. Kim, S. H. Jeong, H. W. Lee, B. J. Lee, J. G. Jo, H. Y. Lee, and Y. S. Hwang, Heating and current drive by fast wave in lower hybrid resonance frequency on VEST, Proceedings of International Symposium on Fusion Nuclear Technology (ISFNT-12), Sep. 14-18, Jeju.