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Development of ITER EC Launcher components
ITER ECランチャー要素機器の開発

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The ITER equatorial EC launcher is designed assuming the HE11 mode propagation and that the transmission efficiency of wave propagating in the launcher is 99.5 %. The launcher mock-up was fabricated based on the design and the high power experiments were carried out. The RF transmission was successfully demonstrated as designed and some stray RF radiation in the beam duct was however obtained. The torus window mock-up was fabricated based on the current design and the loss tangent of the diamond disk was evaluated to be 5.54 x 10^{-6}, based on the results of the high power experiment

1. Introduction

An electron cyclotron heating and current drive (EC H&CD) system is an indispensable tool to improve fusion plasma performance. The ITER EC H&CD system (Figure 1) consists of twenty-four(six) 170GHz, ≥1MW gyrotrons, a transmission line composed of twenty-four waveguide lines and five antennas injecting millimeter (mm) wave beam power into plasma. The gyrotrons are placed in the RF building and the launchers are installed in both equatorial (one) and upper port (four) of the vacuum vessel in the tokamak building. One side of the transmission line is connected to the gyrotrons and the other side is to the launchers. The torus diamond windows used to be installed at the interface between the launcher and the transmission line and it has been modified that the windows are installed in the port cell area, far back from the end of the launcher.

2. ITER equatorial EC launcher

The schematic picture of the ITER equatorial EC launcher (EL) is shown in figure 2. It shall be capable of injecting a 170GHz, 20MW millimeter (mm) wave beam into plasma. A toloidal steering of the beams (20º≤Θ_T≤40º) is also required. The launcher design has been modified to a partial quasi-optical (QO) layout consisting of the movable mirrors, the focusing mirrors and the dog-legged waveguide lines without changing the opening size of the blanket shield modules (BSMs) located in front, resulting some advantages such as a simpler configuration and a possible reduction of fabrication cost. The transmission efficiency of the mm wave beam on the QO layout is kept to be 99.5% [1]. This modification also derives the reduction of heat load on the steering mirror to be one-third of the reference design, which relaxes the thermal design of the mirrors [1-2].

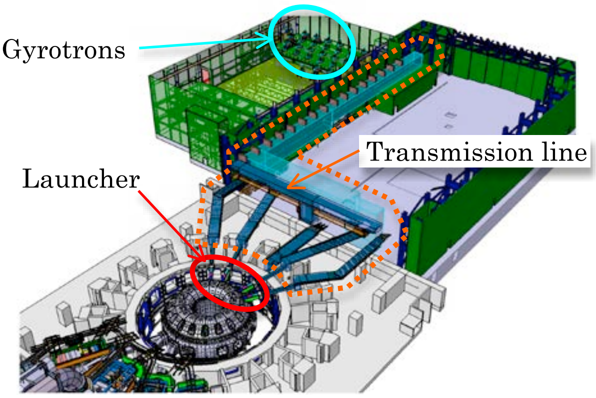

Fig. 1. ITER EC H&CD system : Gyrotrons and transimission line and launchers.

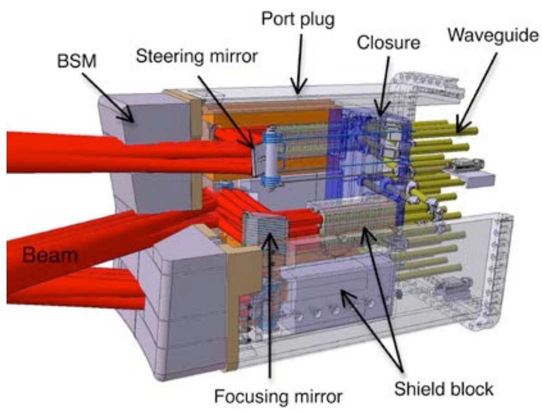

Fig. 2. Present design of ITER equatorial EC launcher : The 20MW power is provided by three beam bundles and one of them is injected for the evolution of counter current drive.

Based on this QO design, the full scale EL mock-up was fabricated. The mirrors are located in front of the waveguide structure composed by the waveguide lines. One of the line is authentic and mm wave can propagate in the line. Figure 3 shows the power distribution of the mm-wave beam at the mirrors and the outlet of the EL mock-up measured by using an IR camera. The measured pattern at the steering mirror agrees with the calculation. However, the measured pattern of the focusing mirror (M1) is inconsistent with the calculation. The high order modes other than HE11 could also be radiated from the waveguide outlet and the measured field patterns at M1 were possibly the mixture of those modes and HE11. This could be a reason of the inconsistency.

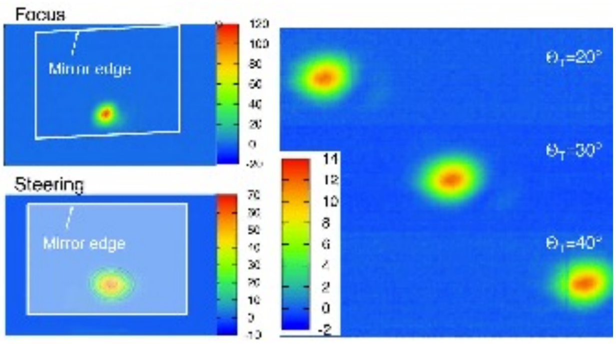

Fig. 3. Measured field pattern of radiated beam at the surface of M1 and M2 and the outlet of the EL mock-up.

3. Window development

Figure 4 shows the photograph of the torus window prototype fabricated on the current design basis. A pair of copper cylinder are brazed to both sides of the disk edge and they are welded to a stainless steel window housing that has a cooling water channel. The corrugated waveguides are inserted to both side of the window disk and welded to the window housing. The inner diameter of the waveguide is 63.5mm that is the same size of the ITER transmission line. The gap between the waveguide and the disk is 0.5mm. A thin copper layer (≤5μm) is coated onto the inner surface of the corrugation to minimize ohmic wall loss due to the high order modes propagation in the waveguides.

Transmission of both 430 kW and 740 kW was demonstrated and the successful pulse length was 100 sec on both cases. Temperature increase of cooling water was saturated to be 0.18 ºC in 25 sec at the transmitted power of 430kW. When the transmission power/pulse length of the propagated wave is 430kW/30sec, the deposited power into the window cooling water was measured to be 30W. Then, the loss tangent of the diamond disk was estimated to be 5.54 x 10^{-6}, which was the lowest value that had ever obtained. It should be noted that the deposited power includes the power (or heat) penetrated into the copper cylinder that are brazed to the window disk and the window housing. Therefore, it is expected that the loss tangent of the diamond disk itself is lower than the above.

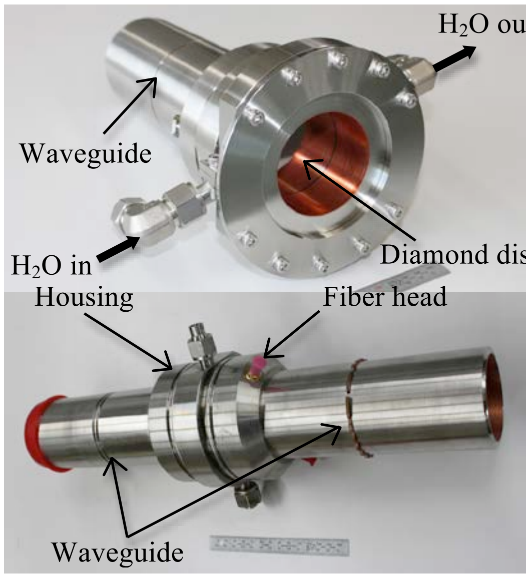

Fig. 4. Photograph of a torus diamond window prototype for ITER EC H&CD system.

4. Conclusion

The EL design to perform the high efficient transmission of mm waves power and to reduce the heat load on the mirrors is obtained assuming the HE11 mode propagation in the transmission line. The efficiency is 99.5 %. The EL mock-up was fabricated based on the design and the RF transmission experiments were carried out. Some stray RF radiation in the beam duct was qualitatively obtained. The torus window mock-up was fabricated based on the current design and the high power RF transmission experiment was carried out. The loss tangent of the diamond disk was evaluated to be 5.54 x 10^{-6}, which was the lowest value that had ever obtained.

References

[1] *Takahashi, K. et al.* Improved design of an ITER equatorial EC launcher // Nucl. Fusion 2008. V. 48, No. 5. P. 054014.

[2] *Kajiwara, K. et al.* Design of a high power millimeter wave launcher for EC H&CD system on ITER // Fusion Eng. Design 2009. V. 84. P. 72.

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