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Application of microwave imaging system for density fluctuation measurements on Large Helical Device

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INTRODUCTION

After decades of fusion research, plasma transport remains an outstanding issue. The problem of anomalous transport in magnetically confined plasmas and relation of this phenomenon to microturbulence of small amplitude continues to be of critical importance. Understanding the mechanism of this transport requires the use of sophisticated diagnostic tools for the measurement of turbulent fluctuations. Diagnostic systems for fluctuation measurements in plasmas have evolved from basic 1-D systems to multi-dimensional systems due to the complexity of plasma turbulence physics illustrated by advanced numerical simulations.

Using the significant advancements in millimeter wave imaging technology, Microwave Imaging Reflectometry (MIR) and Electron Cyclotron Emission Imaging (ECEI), capable of simultaneously measuring density and temperature fluctuations are under development in National Institute for Fusion Science (JAPAN). Since both systems require same collection optics for the reflected waves from the “cut-off layer” in the MIR system and vertically (poloidally) extended emissions in ECEI system and since both systems operate in a close microwave range (the MIR frequency range is 60~80 GHz and ECEI ranges from 70 to 180 GHz for LHD), it is feasible to combine the two systems. The one of the clear advantages will be to combine the detection part, which utilize state-of-the-art millimeter-wave planar imaging arrays positioned at the focal point of the detection system to form an image.

The presented work emphasizes the developing of the microwave imaging reflectometry part of this diagnostic for spatially resolved plasma density fluctuations.

GENERAL DESCRIPTION OF THE MIR SYSTEM FOR LHD

Large Helical Device (LHD) is a superconducting heliotron type device (Fig.1) with $m/l = 2/10$ continuous helical coils and three pairs of poloidal coils. The major and minor radii of the plasma are 3.6 - 3.9 m and 0.6 - 0.65 m, respectively. The main plasma parameters (which were obtained with different experiment conditions) are: (a) maximum electron temperature $T_e(0) = 10$ keV; (b) maximum ion temperature $T_i(0) = 7$ keV; (c) maximum confinement time: $\tau_E = 0.36$ s; (d) maximum stored energy $W_p^{dia} = 1.3$ MJ; (e) maximum beta $\beta = 2.4\%$ at 1.3 T, $\beta = 3.2\%$ at 0.5 T (those are the highest β values for helical devices plasma experiments).

Based on LHD plasma parameters the proposed MIR part of the system will utilize V-band (50–75 GHz) of microwaves for the probing at

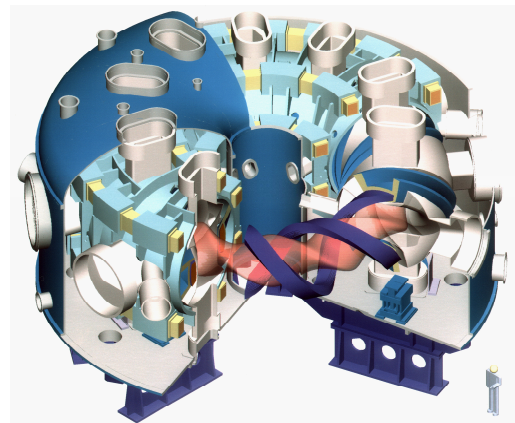


Fig.1. LHD, CAD model

frequencies 66 and 69 GHz with X-mode polarized radiation. The basic schematic view of the combined ECEI/MIR and reflectometer part of the system is depicted in the Fig.2.

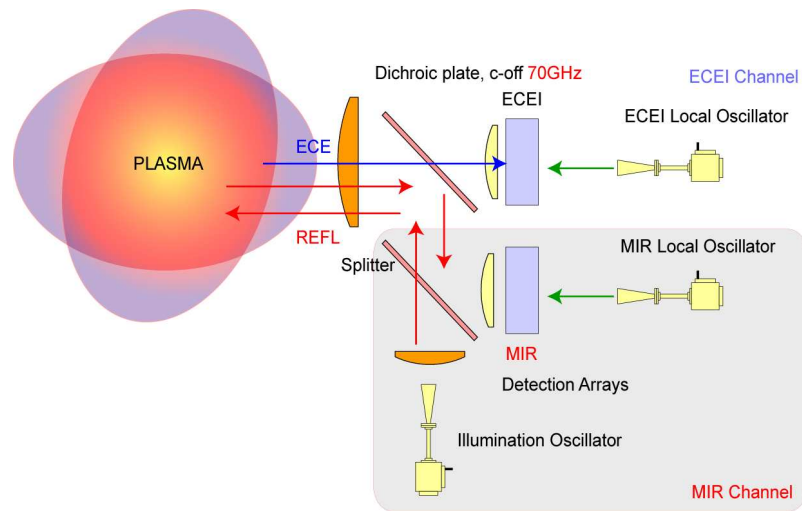


Fig.2. Schematic view of the combined ECEI/MIR system.

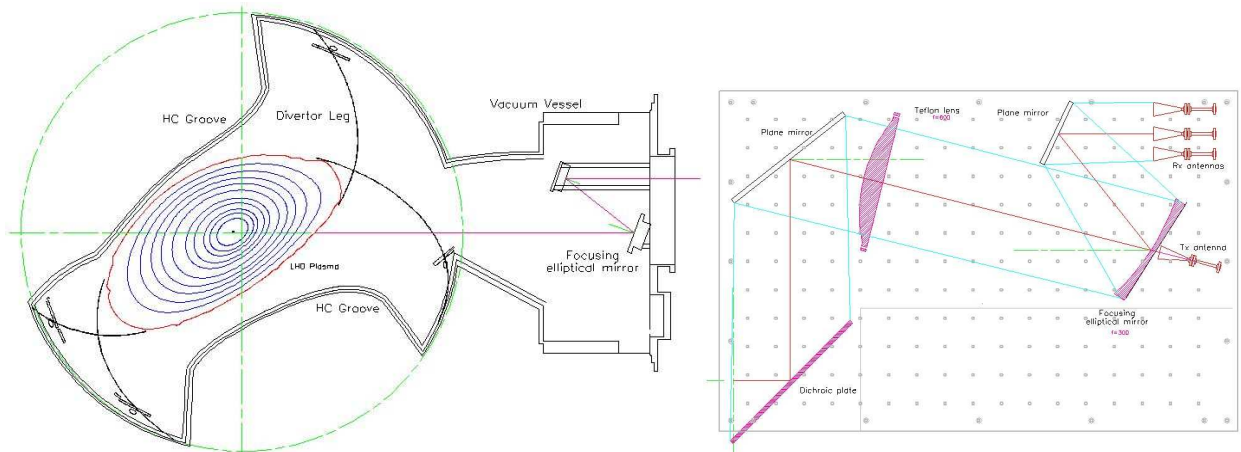


Fig.3. Focusing mirrors inside (left) and outside (right) LHD vacuum chamber, the red line indicate the direction of the probing beam.

The focusing elements of the microwave imaging system are consisting of main focusing elliptical mirror and one plane reflector. Both mirrors are located inside the LHD vacuum chamber. For the test run the MIR system was fully occupied the LHD diagnostic port. The view of the system assembled inside LHD vacuum chamber is shown in the Figure 3.

The combined system has to utilize the diagnostic port for the both reflectometer and ECE parts (Figure 4). For this purposes the dichroic plate has to be used in order to separate the two frequency bands: below (for the reflectometer) and above (for ECE) the 70 GHz.