25D01

High Mode Purity Excitation of HE11 mode in Circular Corrugated Waveguides

円形コルゲート導波管における高純度HE11モード励起

Hiroshi Idei[1)], Masatsugu Sakaguchi[2)], Michael Shapiro[3)], Richard Temkin[3)] and Walter Kasparek[4)]
出射　浩, 坂口政嗣 Michael Shapiro, Richard Temkin and Walter Kasparek

[1)]*Research Institute for Applied Mechanics , Kyushu University, 6-1, Kasuga-koen, Kasuga, 816-8580, Japan*
[2)]*Interdisciplinary Grad. School of Eng. Sci., 6-1 Kasuga-koen, Kyushu University., Kasuga, 816-8580, Japan*
[3)]*Plasma Science and Fusion Center, Massachusetts Institute of Technology, Cambridge, MA 02139, USA*
[4)]*Institut für Plasmaforschung, Universitat Stuttgart, Pfaffenwaldring 31, D-70569 Stuttgart, Germany*
[1)]九州大学応用力学研究所　〒816-8580　春日市春日公園６－１
[2)]九州大学総合理工学府　〒816-8580　春日市春日公園６－１

A new HE11-mode exciter system using overlapped 2 Gaussian beams is designed and proposed, instead of a traditional Gaussian system. The system is composed of a scalar horn antenna, a beam splitter and combiner, and quasi-optical mirrors. The amplitude distribution of a HE11 mode has smaller kurtosis, compared to a Gaussian beam, and the field can become zero at the waveguide wall. The amplitude distribution is controlled by interference of the 2 Gaussian beams. The phase profile is flat at the waveguide aperture. The optimum HE11 mode purity excited in this system is 99.98%.

1. Introduction

Electron Cyclotron Heating (ECH) using high power millimeter waves is an attractive method for plasma production, auxiliary heating, and current drive in a nuclear fusion research. In planned fusion experiments at the ITER, the injected total power is 20 MW for ECH. An output beam from high power gyrotron oscillators is coupled into the oversized circular corrugated (CC) waveguide transmission lines as a main transmitted HE11 mode. The higher order modes are excited in the oversized condition due to miss-alignment of the coupled beam or due to manufacturing error of the components. These cause undesirable arcing events and/or overheating in the transmission line. In the ITER-ECH transmission line, the total loss including unwanted mode excitation is evaluated as 2% [0.088dB] at each miter bend section. A precise understanding of the mode contents transmitted in the CC waveguides is one of most important issues in the ITER-ECH transmission. In order to study the unwanted higher mode excitation experimentally, a pure HE11 mode should be first excited in the CC waveguides. In this paper, the high HE11 mode purity excitation is described in quasi-optical (QO) systems.

The Gaussian beam was widely used to excite the HE11 mode at the CC waveguide aperture in the QO system. The Gaussian beam can be converted into the HE11 mode with an efficiency of 98%. The field distribution of the HE11 mode has a smaller kurtosis, indicating a strong flatness, compared to a Gaussian beam distribution, and the HE11 mode field should be zero at the waveguide wall. In order to obtain the broad amplitude profile of the HE11 mode with zero amplitude at the waveguide wall, an amplitude control is needed. A new HE11-mode exciter system is designed and proposed here. In this system, 2 Gaussian beams are overlapped with a phase matching to control the amplitude distribution.

2. Conceptual Design

The HE11 mode of the CC waveguide has a broad amplitude and flat phase profiles. Here, a new QO HE11 mode exciter using overlapped 2 Gaussian beams is proposed. Figure 1 shows 2 Gaussian parabolic phase profiles with phase curvatures of +/- R, indicating one is expanding and the other is focusing. The diameter of CC waveguide is 63.5mm, and the frequency is 170 GHz. A flat phase profile is obtained, resulting in the interference of 2 beams. The amplitude profile stemming from the interference is a cosine with an argument of the parabolic phase profile. The cosine

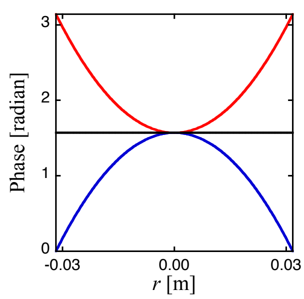

Fig.1 : Gaussian parabolic phase profiles of overlapped 2 Gaussian beams.

distribution by the interference has a smallest kurtosis of 2.2 without taking Gaussian amplitude profiles into consideration. The kurtosis of the HE11 mode and Gaussian beams are 2.7 and 3, respectively. The small kurtosis (2.7) of the HE11 mode can be obtained by the interfered cosine dependence and Gaussian distributions. The field at the waveguide can become zero, provided that [0,π] phasing is given there, as shown in Fig.1.

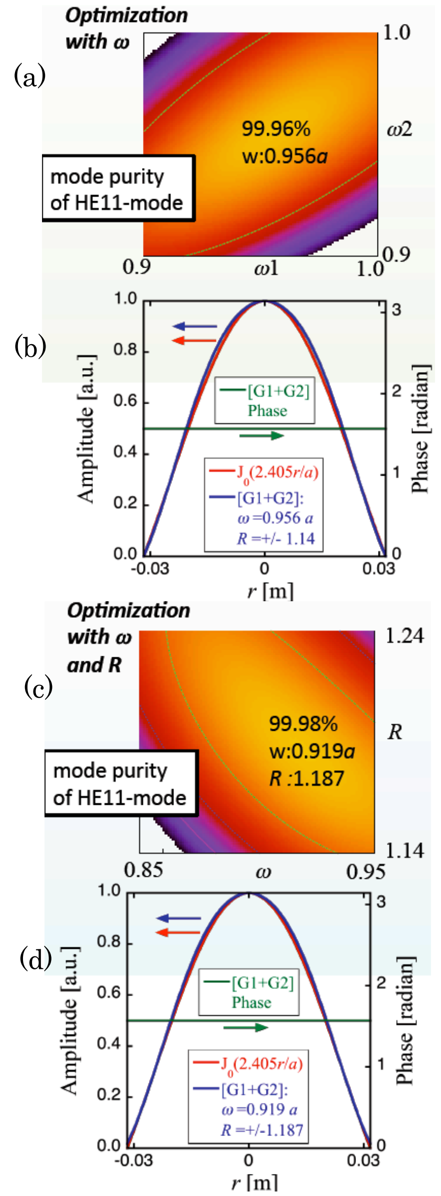

Fig.2 (a): Contour plot of HE11 mode purity for given beam sizes ($\omega 1$, $\omega 2$), and (b): amplitude and phase profiles in the optimized ($\omega 1$, $\omega 2$). (c): Contour plot of HE11 mode purity for given beam size ω and phase curvature R, and (d): amplitude and phase profiles in the optimized (ω, R).

Figures 2 show contour plots of the HE11 mode purity for beam sizes ($\omega 1$, $\omega 2$) and phase curvature R of the 2 overlapped Gaussian beams. The amplitude and phase profiles in the optimized beam parameters are shown in the figures. The high HE11 mode purities of 99.96% and 99.98% can be excited in the optimization of the beam parameters ($\omega 1$, $\omega 2$) and (ω, R), respectively. In the optimization of ($\omega 1$, $\omega 2$), the phase curvature R is taken to obtain zero amplitude at the waveguide wall with the [0,π] phasing. The inferred amplitude profile matched for the HE11 mode profile and flat phase profile can be excited using a 2 phase-matched Gaussian system.

3. System Schematic

Figure 1 shows a schematic of the phase-matched Gaussian system. In the phase-matched Gaussian system, expanding and focusing Gaussian beams should be injected to the CC waveguide. The scalar horn antenna and a QO mirror are used to excite a Gaussian beam, and wire grid polarizers are used a combiner and a splitter. Some QO mirrors are used to obtain the 2 phased-matched Gaussian beams.

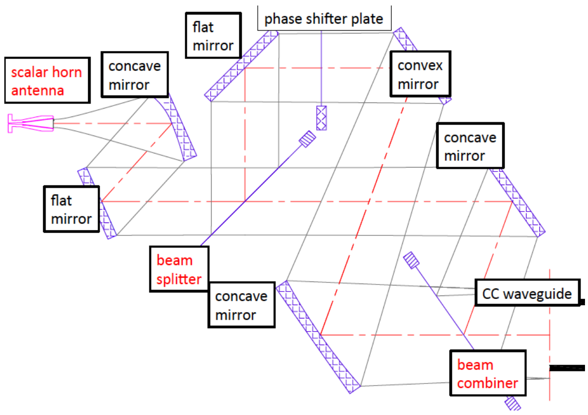

Fig.3: Schematic of phased-matched Gaussian system.

4. Component Design

The scalar horn antenna is designed for broadband operation of 110-140GHz using a moment method simulator. The radiated amplitude and phase profiles are measured in low power test facilities. The measured Gaussian-like amplitude profile coincided within more than 15dB dynamic-range to the designed profile, and the measured phase is exactly the same to the designed one. However, the beam propagation cannot be explained with Gaussian optics. The Kirchhoff integral code is developed to design the QO mirror surface, instead of the moment method simulator, to obtain a Gaussian beam. The wire grid polarizer is also designed using the moment method simulator. The beam can be split without significant influence by the wire grid, depending on the polarization. The design of this 2 phase-matched Gaussian beam system is finished and is going to fabricate and be tested soon.