Improved Quasi-Optical Launcher for Coaxial Cavity ITER Gyrotron

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Abstract— **A 2MW, 170GHz coaxial cavity gyrotron is under development for ITER at Forschungszentrum Karlsruhe (FZK), Germany. A quasi-optical (q.o.) mode converter integrated in the pre-prototype gyrotron is investigated, and measurements revealed that the mode converter could only provide a corrected wave beam with low fundamental Gaussian mode content in the output window plane. In order to improve the performance of the launcher, a numerical method is used to iteratively optimize the launcher wall surface to pre-shape the wave beam with high Gaussian mode content. Simulation results show that a vector power correlation coefficient of 93% of the outgoing wave beam to an ideal Gaussian-like distribution can be achieved at the aperture of the improved launcher. With the new launcher, both the Gaussian mode content and the power transmission of the outgoing wave beam in the window plane are expected to be larger than 95%.**

I. Introduction And Background

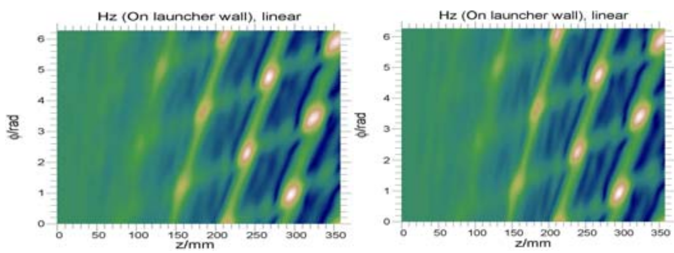
A $TE_{34,19}$-mode, 2 MW, CW, 170 GHz coaxial cavity gyrotron is under development for ITER at FZK. For gyrotrons operated in such a high order mode, it is necessary to employ a quasi-optical mode converter to transform the cavity mode into a fundamental Gaussian wave beam. A quasi-optical (q.o.) mode converter has been investigated in this gyrotron. Low power measurements revealed a low fundamental Gaussian mode content in the output window plane[1]. Our analyses show that the outgoing wave beam cannot be well pre-shaped with a high Gaussian mode content in a conventional helically deformed launcher with an acceptable length. The Gaussian mode content of the field distribution radiated from the launcher is low and it makes the synthesis and fabrication of the adapted phase correction mirrors very difficult[2]. In order to improve the performance of the launcher, a numerical method has been developed and used to iteratively optimize the launcher wall surface.

II. Analysis of Field on Launcher Wall

In a highly oversized waveguide, if the deformations are shallow and smooth, the field remains paraxial. This allows us to calculate the field in the launcher by taking use of the scalar diffraction integral equation. Based on the scalar diffraction integral equation, a computer code has been developed for the analysis of the field on the launcher wall surface with arbitrarily shaped deformations. As an example, the field on the helically corrugated launcher wall surface used in the pre-prototype coaxial cavity gyrotron is calculated with the new code. The simulation results reveal a very high vector power correlation coefficient of 99.1% of the field (see Fig.1b) in comparison with the field distribution calculated using the coupled mode method (see Fig.1a). The vector power correlation coefficient is defined as:

$$\eta = \frac{\left|\int_S u_1^* \bullet u_2 ds\right|^2}{\int_S |u_1|^2 ds \bullet \int_S |u_2|^2 ds} \tag{1}$$

The superscript "*" represents the conjugate of a complex function.



(a) (b)

Fig.1. Field distribution on launcher wall surface calculated by taking use of: a) the coupled mode method, b) the new method.

III. Target Function

For the synthesis of a specified field distribution on launcher wall surfaces, we make a theoretical model of the generation of an ideal Gaussian field distribution which can be used as a target function in the iterative optimization of launcher wall profiles. Table I shows a set of TE modes used to artificially generate a Gaussian-like field distribution in a launcher. As shown in Fig. 2, the initial phases, the phase of each mode at the beginning of launcher, are chosen to make the phase differences among these modes to be zero at the launcher aperture, therefore the field distribution at the launcher aperture has a high fundamental Gaussian mode content (>99%). The ideal field distribution are shown in Fig. 3a and Fig. 4a.

IV. Synthesis of Launcher Wall Surface

Combined with the computer code for the analysis of the field in launchers, a new method has been developed for the synthesis of the launcher wall surface to achieve a wave beam with high Gaussian mode content. The main idea of the new method is to find the maximum of the vector correlation coefficient leading to the necessary condition:

$$\nabla \eta = 0 \tag{2}$$

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Table I Set of TE modes to generate a Gaussian-like field distribution (relative power).

$TE_{m-2,n+1}$ (1/36)	$TE_{m+1,n}$ (1/9)	$TE_{m+4,n-1}$ (1/36)
$TE_{m-3,n+1}$ (1/9)	$TE_{m,n}$ (4/9)	$TE_{m+3,n-1}$ (1/9)
$TE_{m-4,n+1}$ (1/36)	$TE_{m-1,n}$ (1/9)	$TE_{m+2,n-1}$ (1/36)

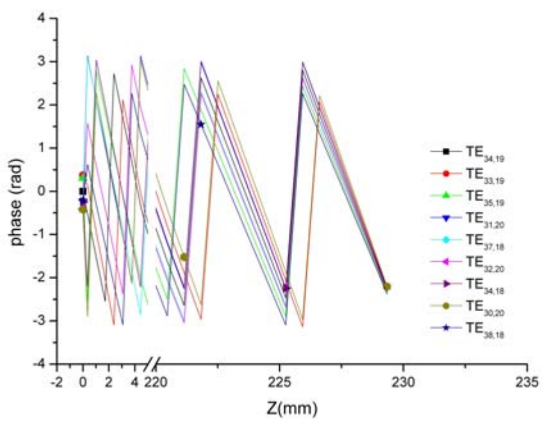
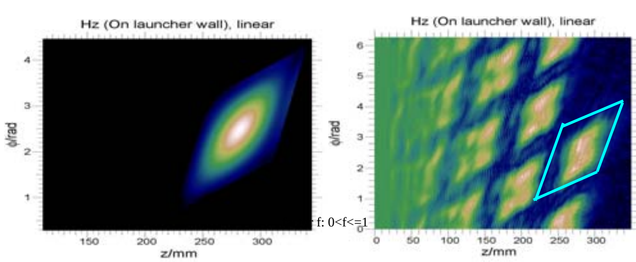


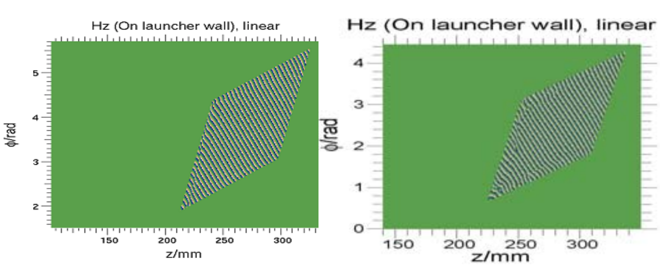
Fig. 2 Phases along z-axis.

The numerical results are shown in Fig.3 and Fig. 4, the vector power correlation coefficient of the optimized field (Fig.3b and Fig.4b) to the ideal Gaussian-like field distribution (Fig. 3a and Fig.4a) is as high as 93% at the aperture of the launcher.



(a) (b)

Fig.3. a) Ideal Gaussian-like distribution, b) numerically optimized field distribution.



(a) (b)

Fig.4. Phase patterns at the launcher aperture, a) ideal Gaussian-like distribution, b) numerically optimized field.

ACKNOWLEDGEMENT

This work, supported by the European Communities under the contract of Association between EURATOM and Forschungszentrum Karlsruhe, was carried out within the framework of the European Fusion Devolopment Agreement. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

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