Progress of the Methods for Optimum of Quasi-Optical Mode Converters at KIT

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***Abstract*—The paper reports the progress of the methods for the synthesis of Quasi-Optical (QO) mode converters at KIT in the period from 2018 until today. Typically, the QO mode converter consists a waveguide launcher and a mirror system. The first progress done is the development of the spectrum reconstruction method for smoothing the launcher wall. The second is the improvement of the method for the design of quasi-parabolic mirrors. The third progress considers the synthesis of a Denisov-type launcher for the conversion of co- and counter-rotating modes.**

I. INTRODUCTION

A Quasi-Optical (QO) mode converter of a megawatt-class gyrotron for nuclear fusion plasma heating consists of an oversized launcher and a set of mirrors. Two types of launchers have been developed at KIT, (i) the mirror-line launcher and (ii) so-called hybrid-type launcher. Both launchers are synthesized from numerical optimization and have complex shaped surface contours. For manufacturing, a smoothing of the surfaces of the numerically optimized launcher walls is required.

Quasi-parabolic mirrors with caustic radii corresponding to the launcher are usually employed to reflect the RF beams radiated from QO launchers. Recently, the method for the design of quasi-parabolic mirrors has been improved at KIT by using flexible caustic radii to match up-tapered launchers.

For the injection-locking operation in high power gyrotrons, a new type of launcher has been proposed for the conversion of co- and counter-rotating modes in the same design [1]. By expanding the in-house computer code for launcher design, we also successfully designed such kind of launcher.

II. PROGRESS OF SYNTHESIS METHODS FOR QO SYSTEM

A spectrum reconstruction method has been developed to smoothen the launcher wall [2]. The key point of this method is to perform a Fourier transform on the surface contour function, then select the main frequency components and delete all the parts of amplitude less than the desired threshold A_0. As an example, Fig.1(a) shows the amplitude distribution A of the spectrum function generated with the wall profile of the mirror-line launcher operated in the $TE_{34,19}$ mode at 170 GHz. The radius of the launcher is 32.5 mm. the minimum curvature radii in azimuthal direction (R_φ) and in longitudinal direction (R_z) are estimated as 1.8 mm and 10 mm, respectively. The simulation results show the Gaussian mode content of the RF beam at the launcher aperture is 96.26 % and the stray radiation in the gyrotron is estimated as 7 %. In the iterative procedure for optimization of the launcher wall, the spectrum reconstruction method is used to further smoothen the perturbed launcher wall. The amplitude distribution is shown in Fig. 1(b), where the threshold is $A_0 = 0.1$. The curvature radii R_φ and R_z increase to 29 mm and 107.8 mm, respectively. The Gaussian mode content of the RF output beam is slightly decreased to 96 %, whereas the measured stray radiation is reduced to about 4 %.

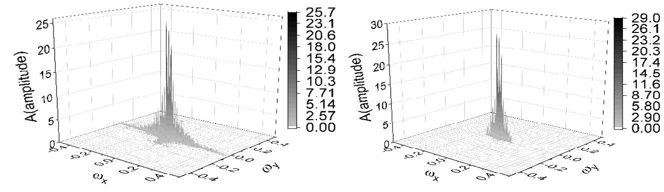

Fig. 1 Spectrum of the wall profile of the mirror-line launcher: without (a) and with (b) spectrum reconstruction.

For an up-tapered launcher, the radius at the launcher aperture is not constant. Conventionally, the average value $\bar{R}$ of the radius defined on the launcher aperture is used for the design of quasi-parabolic mirrors. In order to match the up-tapered launcher, the radius $R(z)=R_0+\tau z$ is used in the design of the present improved flexible quasi-parabolic mirrors, R_0 is the radius at the beginning of launcher, τ and z are the slope of the radius taper and the z coordinate, respectively. The flexible quasi-parabolic mirror is used in the QO system operating with the $TE_{28,10}$ mode at 140 GHz developed for the upgrade W7-X gyrotrons, the Gaussian mode content could be increased from 97.43 % to 97.89 % with this new advanced quasi-parabolic mirror instead of the conventional quasi-parabolic mirror.

Based on the Denisov-type launcher [3], a launcher has been designed for the conversion of co- and counter-rotating modes in the same launcher. Fig. 2 shows the field distributions on the launcher wall, where the operating modes are the co- and counter-rotating $TE_{32,9}$ and $TE_{-32,9}$ mode at 170 GHz. The Gaussian mode contents are 96.65 % at the launcher aperture.

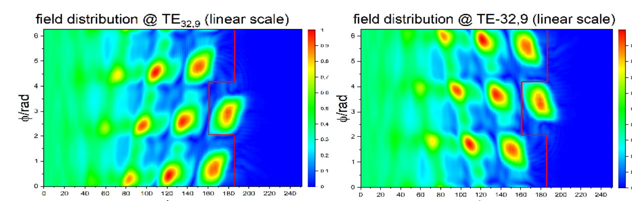

Fig. 2 Field distributions on launcher wall (left) $TE_{32,9}$ (right) $TE_{-32,9}$.

III. SUMMARY

The development of novel methods for the synthesis of QO mode converters improves the conversion efficiency, reduces the stray radiation and reduces the sensitivity to tolerances. In addition, the design of a new type of launcher for co- and counter-rotating modes is presented.

REFERENCES

[1]. A.V. Chirkov, et al., "Perspective gyrotron with mode converter for co- and counter-rotation operating modes," *Applied Physics Letters 106, 263501 (2015); doi: 10.1063/1.4923269*

[2]. J. Jin, et al., "Improved Simulation of Quasi-Optical Launchers for High Power Gyrotrons with Smoothing Algorithm," *EC20, May, 2018, doi: 10.1051/epjconf/201920304008.*

[3]. G. G. Denisov, et al., "110 GHz gyrotron with built-in high-efficiency converter," *J. Electron.*, vol. 72, pp. 1079–1091, 1992.