Recent Experimental Results on the 170 GHz, 2 MW Coaxial Cavity Pre-Prototype Gyrotron for ITER*

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Abstract— **The development of a 2 MW, CW, 170 GHz coaxial cavity gyrotron at Forschungszentrum Karlsruhe (FZK) is in progress in cooperation with several European research institutions. The gyrotron is foreseen as a source for heating, current drive and plasma stabilization in the International Thermonuclear Experimental Reactor (ITER). The design of critical components, especially the electron gun, cavity and quasi-optical RF output system are verified at FZK in tests with a short pulse gyrotron.**

I. Introduction And Background

First experimental results obtained with the 2 MW, 170 GHz coaxial cavity pre-prototype gyrotron at short pulse operation have already been presented in [1]. At that time the gyrotron operation was strongly limited due to the excitation of parasitic LF-oscillations with very high amplitude mainly around 265 MHz. The oscillations have been successfully suppressed due to small modification of the geometry of the coaxial insert. In recent experiments another parasitic oscillation around 160 GHz appears simultaneously with the desired gyrotron working mode. This parasitic oscillation belongs to a multi-moding scenario observed at operating parameters near the nominal values. The reason for this behavior is currently under investigation.

The performance of the quasi-optical (q.o.) RF-output system was experimentally tested at low power. The measured pattern at the window position has shown some discrepancies in comparison with the calculations. In particular, the fundamental Gaussian mode content of the RF-beam at the window position evaluated from the experimental values was only 77 %, whereas from design calculations a value of 86 % is expected. Recent activities towards the improvement of the gyrotron operation will be presented and discussed.

II. Experimental Results

When starting the experiments the gyrotron operation was strongly limited due to the excitation of parasitic LF oscillations with very high amplitude mainly around 265 MHz. The reason of the LF oscillations has been studied and a mechanism has been proposed [2]. Based on the suggested hypothesis the geometry of the coaxial insert on the cathode side of the gyrotron cavity has been modified. Due to these modifications, a significant reduction of the level of the LF oscillations has been found in measurements. In particular, the corresponding starting currents increased by a factor of about 3. Recent measurements have been performed with the electron gun previously used in the coaxial gyrotron at 165 GHz. The anode has been modified for operation at 170 GHz in the $TE_{34,19}$ mode. In the operation with this gun no LF oscillations have been observed. This confirms the observations at the 165 GHz gyrotron and indicates a great sensitivity of such parasitic oscillations on the overall geometry.

The anode of the electron gun previously used in the 165 GHz coaxial cavity gyrotron has been adjusted for a velocity ratio of 1.3 at $U_C = 80$ kV and $I_B = 75$ A and a beam radius $R_b = 10$ mm in order to be able to perform experiments in the $TE_{34,19}$ mode at 170 GHz. The magnetic field in the cavity is limited to 6.72 T. As maximum output power P_{out} a value around 1.3 MW with an efficiency of ~23 % has been obtained in non-depressed collector operation. Fig.1 shows the measured microwave power in the different modes as well as the microwave power calculated with a single and a multi-mode self-consistent code. The experimental values are in reasonably good agreement with results of simulations for U_C<73 kV.

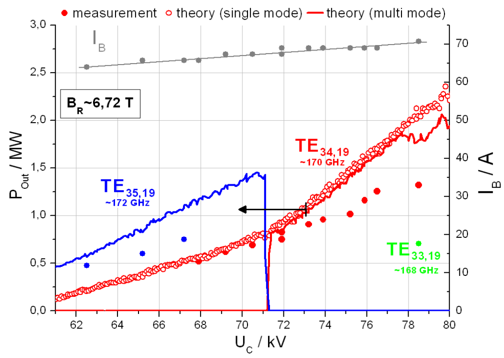

Fig. 1. RF output power vs. cathode voltage - the experimental values are compared with self consistent calculations (single and multi-mode).

During the experiments it has been found that at U_C>74 kV and I_B>57 A another oscillation around 160 GHz was excited simultaneously with the nominal $TE_{34,19}$-mode at 170 GHz. This coincides with reduction of the generated power in comparison with calculations in this region (Fig. 1). There are some indications that the oscillation around 160 GHz could be generated inside the beam tunnel between cathode and cavity. Above U_C~78 kV severe "multimode"-operation has been observed. Investigations concerning parasitic oscillations in the beam tunnel are in progress.

III. Quasi-Optical RF Output System

General task of the q. o. system is to convert the RF-power generated in the $TE_{34,19}$-cavity mode into a free-space beam with a high content of the fundamental Gaussian mode. The quasi optical RF output system has already been presented in detail in [3]. It consists of a launcher antenna and three mirrors. To

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obtain a better focusing of the RF power radiated from the launcher antenna only an azimuthal perturbation and 3rd order instead of a combination of the 2nd and 3rd orders has been taken together with the 1st order deformation [3]. The "new" launcher was installed inside the old mirror system. Although the phase correcting mirror was not optimized for the "new" launcher the expected Gaussian beam content calculated at the window position was about 86%. The schematic arrangement of the RF output system is shown in shown in Fig.2.

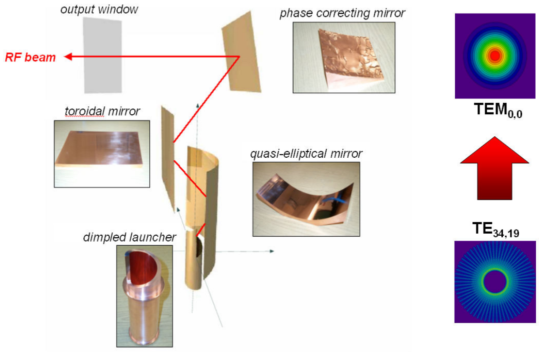

Fig. 2. Arrangement of the RF output system.

The q.o. RF-system has been fabricated and tested at low power ("cold"). First measurements at the window position have shown relatively strong disagreement with theory. According the calculations with the OSSI code, which is currently used at FZK, a Gaussian mode content of 86 % at the window plane was expected. However, the analysis of "cold" measurements in the window plane resulted only in 77 % Gaussian mode content. To prove the OSSI code and to find the reason for the disagreement, calculations with the SURF3D code [4] have been performed. The results obtained using SURF3D were in very good agreement with calculations with results of the OSSI code (Fig.3). In following a special attention was paid to the alignment of the components of the output system. A small discrepancy of about 0.3 mm to the theoretical position of the 2nd mirror has been found to cause a shift of about 5 mm from the optimal position at the phase correcting mirror. As a consequence the phase correction with 3rd non-quadratic mirror did not work properly. After a new adjustment of the mirrors, measurements at low power were repeated and results were in a good agreement with calculations (Fig.3). However, the Gaussian content evaluated from the low power measurements is still about 5% below the theoretically expected value. The reason for this is probably related to the evaluation of the calculation of Gaussian content out of the experimental values. In particular, the algorithm of the code used for calculation of the Gaussian content is quite sensitive to parasitic effects observed usually in the measurements. Such effects may result from interferences with stray radiation. Further studies are going on.

The first way to improve the efficiency of the current mode converter is by optimization of a new phase correcting mirror for the RF pattern of the launcher with only 3rd order azimuthal perturbation. The calculations have shown that with a new non-quadratic mirror a Gaussian beam content of about 88 % can be achieved. The calculated field distribution at the window plane is shown in Fig.4.

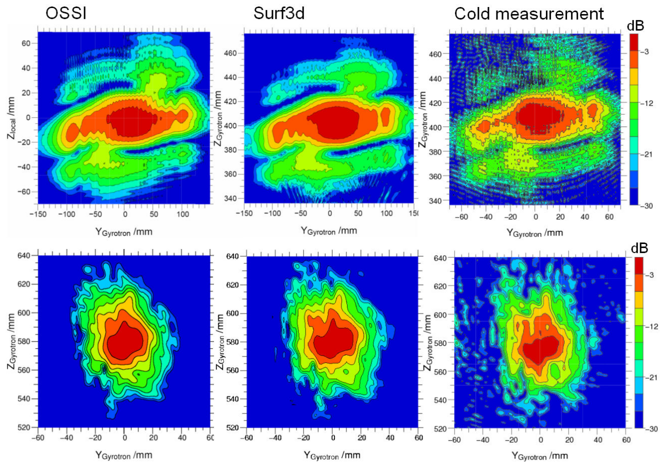

Fig. 3. Measured field patterns (right) vs. calculations: OSSI (left) and SURF3D (middle), at the 2nd mirror position (upper row) and on the gyrotron window (bottom row).

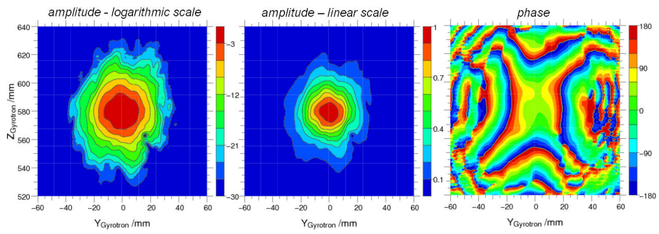

Fig. 4. Results of the optimization of the 3rd phase correcting mirror (field distribution at gyrotron window).

However, to achieve a conversion efficiency of the $TE_{34,19}$ mode into the Gaussian beam by the q.o. system of around 95%, the launcher antenna has to be improved. The development of a new code which uses another optimization method is in progress [5].

IV. Conclusion And Outlook

The performance of the 170 GHz coaxial cavity gyrotron was improved by using an electron gun used previously in the 165 GHz gyrotron. With this gun no parasitic LF oscillations at 265 MHz have been observed. During the experiments a high frequency parasitic oscillation at 160 GHz was observed which is suspected to be excited in the beam tunnel of the gyrotron. The work on the q.o. system going on by: (1) optimization of the new phase correcting mirror as well (2) development of an improved launcher code.

References

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