Development in Russia of 170 GHz Gyrotron for ITER

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***Abstract*— During last years several new gyrotrons were designed and tested at IAP/GYCOM. Main development efforts were spent for development of 170GHz/1MW/50%/CW gyrotron for ITER and multi-frequency gyrotrons. The paper presents new results in development of gyrotrons for ITER.**

I. Introduction And Background

On the threshold of gyrotron delivery for ITER which will be started in the near future more and more attention is paid to reliability of gyrotron design. A detailed analysis of cathode assembly has shown that probability of arcing could be reduced further by improving of electrostatic field distribution due to correct shaping of electrodes in the vicinity of HV ceramic insulator. A test of gyrotron with modified cathode unit has been started in December 2007 and then prolonged in March 2008. In all other aspects gyrotron was produced following conventional GYCOM 170GHz/1MW/CW gyrotron design.

II. Results

At first 100-ms pulse duration operating regime was optimized. At operational beam voltage of 76.5kV output power of 1.2MW was attained with increasing of beam current to 54A as shown at Fig.1. Output power was measured by calorimetric load 30-cm distant from output window to absorb Gaussian beam power.

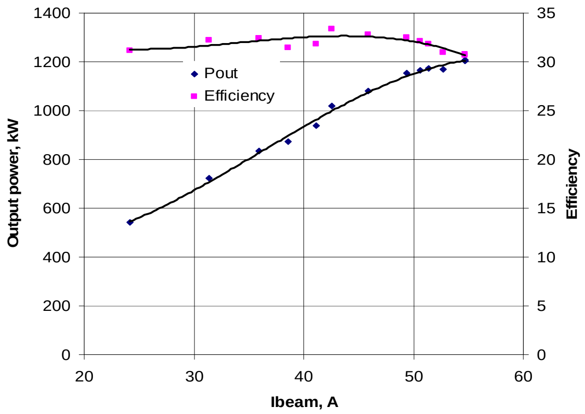

Fig.1 Output power & efficiency vs. beam current at beam voltage of 76.5kV.

In Fig. 2, gyrotron output power and efficiency are plotted as a function of retarding voltage. Total efficiency of 52% was reached at over 1MW output power.

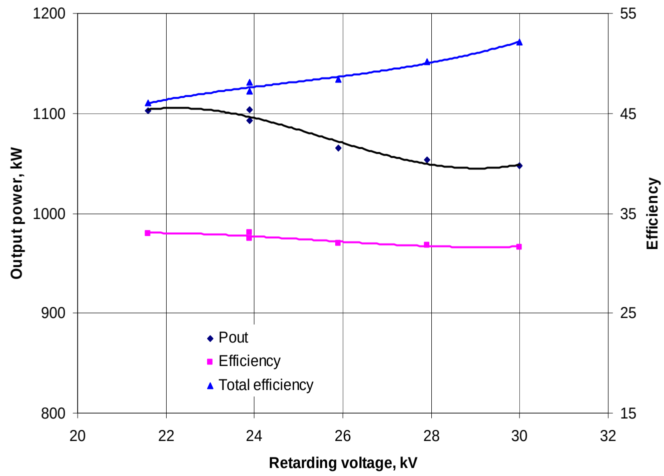

Fig.2 Output power & efficiency vs. retarding voltage at beam current of 46A

In long-pulse test gyrotron after some initial conditioning demonstrated very reliable operation with negligible amount of HV arcing verifying utility of made modification. Gyrotron output radiation formed finally by 2 mirrors of matching optics unit (MOU) was directed to the terminal load through the set of phase-correcting mirrors at atmospheric pressure. Small fraction of power was derived from the wave beam for monitoring of passing power to RF detector and to small calorimetric load. During test there was also measured fraction of stray radiation absorbed in MOU (~5%) and emanating through relief window (~3%). Diamond window losses were determined as ~0.1%.

Present test facility was upgraded several times to extend its testing possibilities and approach them to ITER specifications. High-voltage pulse as designed can lasts up to 5 min if voltage of main power supply does not exceed 50 kV and beam current is less than 50A. 5-min pulse duration was attained early for ~0.5MW output power at cathode voltage of 46kV and beam current of 25A [1]. 50kV/50A combination is nearly

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typical for gyrotron 1-MW regime but in the same time it is very close to the designed limit of the power supply. This limit was felt during long-pulse test as necessity of frequent retuning of power supply operational regime.

From the another side long-pulse gyrotron operation was found strongly limited by arcing of terminal load and overheating of metallic sheets shielded beam transporting channel especially with output power rise. Additional absorbers installed in beam channel enabled to extend pulse to 203sec at power of 830kW and to 116sec at power of 1020 kW. Signal traces corresponding to the longest pulse are shown in Fig.3.

As one can see all signals look pretty stable. Stability of beam current was provided by embedding of feedback to heater power source. Operational frequency showed good stability as well. Total frequency drift during the pulse is typically less than 100MHz. Change of vacion current indicating gyrotron internal pressure did not exceed 1-2μA.

Sometimes body current could deviate during a pulse between two stable values. Lower one was of 3-5mA while upper one was about 20mA higher. Deviation of body current led to minimum perceptible change of beam current and output power and has no another influence on gyrotron behavior.

Some of gyrotron pulses were terminated by oscillation cut-off happened after few tens of seconds from the pulse start which looked inexplicable against a background of stability of gyrotron voltage, current and internal pressure.

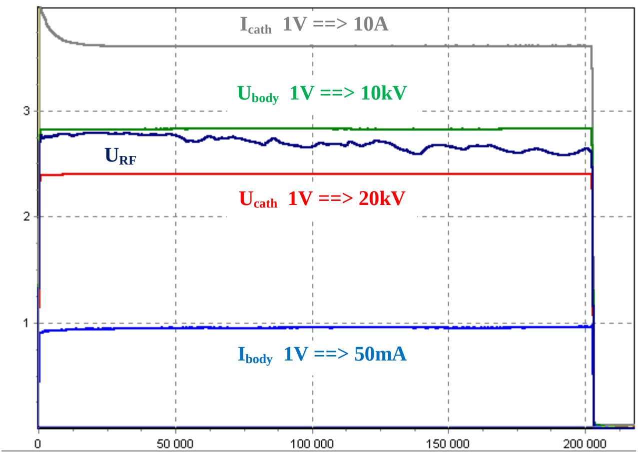

Fig3. Signal traces monitored in gyrotron 830kW/203sec pulse

Temperature rise of DC break ceramic insulator did not come to steady-state value but was noticeably reduced by forced air cooling. Air flow was rather weak and more intense air cooling or especially oil cooling will solve the problem. Possibility of oil cooling is envisaged in design of modified ITER gyrotron which will be ready to test to the end of this year.

After improvement of beam transporting channel arcing in MOU became main problem. It was caused by overheating of movable cylindrical part connecting MOU to gyrotron flange. Evidently switch to evacuated waveguide provided for ITER will thoroughly solve a problem of RF arcing. New power transmission line of this kind included evacuated wave guide and evacuated load has mounted in new testing facility which is under setting-up in Kurchatov Institute now. 80kV/50A main power supply of new test facility will provide gyrotron operation in CW regime. Considering 50-kV voltage of recuperation power supply total accelerating voltage up to 130 kV will be available. It may be useful for gyrotron with increased power level. New facility is expected to operate in full-scale regime in the end of this year.

III. CONCLUSIONS

In short-pulse test of 170GHz gyrotron over 1MW output power at total efficiency of 52% was attained according to ITER requirements. Up to now maximal pulse duration of 203sec at power over 0.8MW and of 116sec at power over 1MW was limited by arcing of terminal load and MOU operated under atmospheric pressure.

Testing of ITER gyrotron will be continued after debugging of new test facility in Kurchatov Institute having evacuated transmission line and power supplies capable to provide CW gyrotron operation.

New modified ITER gyrotron is manufacturing now and will be ready to test to the end of this year.

REFERENCES

[1] S.V.Usachev et. al. “New test results of 170GHz/ 1MW/ CW gyrotron for ITER” Conf. Digest of 32-th Int. Conf. on Infrared and Millimeter Waves and 15-th Int. Conf. on Terahertz Electronics, 2007, Sept.2-7,Cardiff, UK, p.44-45

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