# Development Status of Gyrotron Setup for ITER ECW System

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***Abstract*— the paper presents development status of a gyrotron setup for ITER. Twenty four such setups are to be used for heating and current drive in ITER plasma. The setup includes a gyrotron in a superconducting magnet and several tens of other components. Recently the main required gyrotron parameters were demonstrated. In the last year tests confirmed 95% reliability of gyrotron operation. Now a prototype of complete gyrotron setup is assembled and it is under thorough testing.**

## I. GYROTRON TESTS

Several industrial production prototypes of the ITER gyrotron were tested at power 1.0 MW up to 1000 second pulse duration. For 1 MW power regime the gyrotron efficiency is 53%. Now the main activity on ITER gyrotron is to enhance its reliability. Recently run tests of the gyrotron were carried out and the tests confirmed high (95%) reliability of gyrotron operation (see Figure 1).

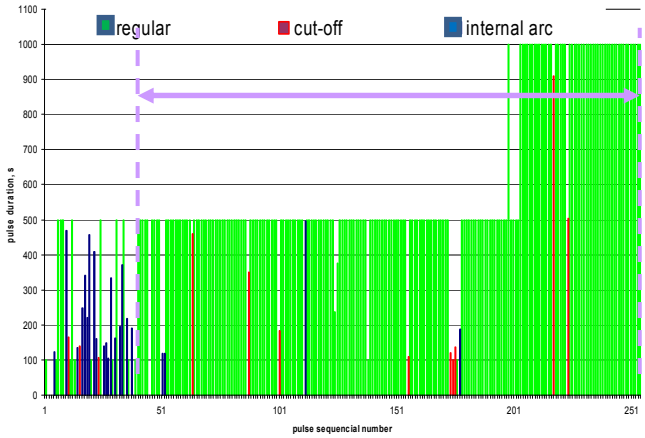


**Figure 1.** After conditioning gyrotron run test at 1MW output power with pulse duration 500s (160 pulses) and 1000s (55 pulses). Reliability is 95%.

## II. GYROTRON SETUP ASSEMBLING

The gyrotron setup for ITER for ITER includes many components . The main components are: gyrotron, gyrotron support (oil tank), superconducting magnet, microwave units, (MOU, relief load, waveguide), water cooling system, auxiliary power supplies, local controller, cubicles for apparatus. The gyrotron setup is presented by figures 2-4. Gyrotron local controller was developed in collaboration with Moscow company RTSoft and Russian ITER DA.

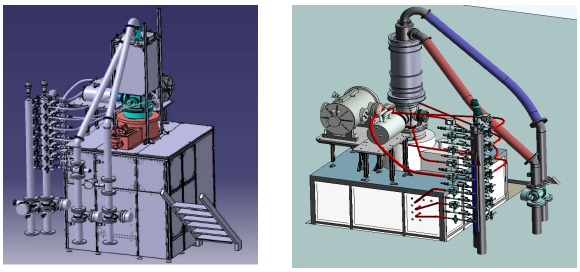

**Figure 2.** 3D view the main part of gyrotron setup. At the left picture a false flow is removed.

**Figure 3.** Part of gyrotron setup with water manifold and dummy load.

**Figure 4.** Control unit of the gyrotron setup.

## III. TESTS OF GYROTRON SETUP

ITER gyrotron setup construction was completed. Its testing was carried out on Factory site following RF source prototype FAT Program in presence of ITER organization (IO) representatives in May 2015. Some test results taken from the Acceptance Test Protocol are shown in the table below. The gyrotron system parameters satisfy to ITER requirements.

| Kind of test | Source of the technical requirements | Criteria | Result Pass/Fail |
|---|---|---|---|
| 1.Verification for the PRFS complement | Annex B to PA | compliant with PA requirement | |
| 2.Verification for compliance of the PRFS overall dimensions and its components' mutual position to the lay-out at ITER site | EC plant layout | Compliant with Drawing | |
| 3.Leakage check; temperature, flow rate and pressure measurement for CCWS-2a and CCWS-2d supply and return water cooling channels of the GS_RF. | | No leakages. Flow rate in the collector cooling circuit < 1200 l/min. Total flow rate in all other cooling circuits < 300l/min | Pass |
| 4.Test of the Local control unit parameters (functional check of the local controller of the gyrotron system prototype in the regime of actuation of the auxiliary equipment) | "Annex B to PA | Following systems are controlled by Local control unit: Auxiliary power supplies; Cooling water system; HVPSs. | pass . |
| 5.PRFS main output parameters measurement and verification for compliance for specified ones:<br>- operation frequency,<br>- power at the MOU output,<br>- generation efficiency<br>- $HE_{11}$ mode content at MOU output,<br>- pulse length,<br>- duty factor | "Annex B to PA", | <br><br><br>170±0.25 GHz<br>≥0.96 MW<br>≥50%<br>≥95%<br>≥1000s<br>≤1/4 | <br><br><br>170.07 GHz<br>0.96±5 %<br>58%<br>97±1%<br>1000s<br>1/4 |
| 6. Measurement of the gyrotron tube electrical parameters:<br>-cathode voltage,<br>-cathode current,<br>-body voltage,<br>-body current,<br>-cathode heater current,<br>-cathode heater voltage,<br>-SCM current,<br>-gun coil current,<br>-current of collector coil DC-section,<br>- Collector coil sweep-section current parameters<br>Sweep-current rise time,<br>Sweep-current fall time,<br>- ion pump current,<br>- correcting coils' current | <br>≤55 kV<br>≤55 A<br>≤35 kV<br>≤100 mA | <br>41kV±1kV<br>42 A±1A<br>30 kV<br>±0.5kV<br>10-15 mA<br>37 A<br>8 V<br>108.385 A<br>+ 0.5 A<br>- 10 A<br>22 A<br>40 ms<br>40 ms<br>10-15 μA<br>0 | |
| 7. Verification of the PRFS reliability in the operation regime with pulse repetition rate of 4:<br>– 1MW / 1000s, - 5 pulses<br>– 1MW / 500 s – 15 pulses | | | |

## REFERENCES


[1]. G.G.Denisov et all. "New Results and New Trends in Development of Gyrotrons for Fusion." Proceedings of 39th International Conference on Infrared, Millimeter, and Terahertz Waves, September 14-19, 2014 The University of Arizona, Tucson, USA.

[2]. A.Krasilnikov et al. "Progress with the ITER Project Activity in Russia". Proceedings of 25th IAEA Fusion Energy Conference. Saint Petersburg, Russia, October 13-18, 2014.