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ITR/1-4Ra & FTP/1-3Rb: Development in Russia of Megawatt Power Gyrotrons for Fusion; Progress on the Development of High Power Long Pulse Gyrotron and Related Technologies

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ITR/1-4Ra: Development in Russia of Megawatt Power Gyrotrons for Fusion
During last years several new gyrotrons were designed and tested in Russia. Main efforts were spent for development 170GHz/1MW/50%/CW gyrotron for ITER and multifrequency gyrotrons. Additionally other new gyrotrons were shipped and installed at running plasma installations. The industrial production prototypes of the ITER gyrotron were tested at power 1.0 MW in 400···500 second pulses and 0.8-0.9 MW in 1000 second pulses. For 1 MW power regime the gyrotron efficiency is 55%. The last gyrotron versions operate in LHe-free magnet. It is important that two last gyrotrons (V-10 and V-11) demonstrate very similar output parameters. Time traces for the main gyrotron parameters are stable and confirm possibility of the gyrotron operation even in longer pulses. Detail analysis of the test results showed that a slightly modified ITER gyrotron prototype is capable to operate at power 1.2 MW. First tests of the modified tube are rather encouraging: microwave power 1.2 MW at MOU output was demonstrated in 100 second pulses with efficiency of 53%. Additionally two gyrotron models with TE28.12 operating mode were tested in short-pulse experiments.
The use of step-tunable gyrotrons can greatly enhance performance of ECRH/ECCD systems due to larger accessible radial range, possible replacement of steerable antennas, higher CD efficiency for NTM stabilization. The main problems in development of multifrequency gyrotrons are to provide: efficient gyrotron operation at different modes, efficient conversion of the modes into a Gaussian beam, reliable operation of broadband or tuneable window. Considering this three key problems one can say that first two of them are solved, but realization of a CVD diamond window for a megawatt power level multi-frequency gyrotron met real difficulties. Now a new tunable window concept is under consideration.

FTP/1-3Rb: Progress on the Development of High Power Long Pulse Gyrotron and Related Technologies
In the development of a higher power dual-frequency gyrotron, a high order mode gyrotron, which permits to select the oscillation at 170GHz or 137GHz, has been fabricated and tested. Short pulse experiments (0.5ms) were performed with 1.3MW power output at more than 30% of the oscillation efficiency for both frequencies. In long pulse experiments, 760 kW/46%/60 s at 170GHz and 540 kW/42%/20 s at 137 GHz are achieved. It is the first time long pulse experiments with the dual-frequency gyrotron/triode electron gun. Since the RF beam direction from the output window is designed to be almost the same for both frequencies, good power couplings to the transmission line, which are 96% for 170GHz and 94% for 137GHz, are obtained by using a pair of identical phase correcting mirrors. Pulse extension is underway aiming for >1MW at CW operation.
A 5kHz full power modulation experiment was performed using the 170 GHz gyrotron of TE31,8 mode oscillation. The 5kHz full power modulation was achieved with the full beam modulation by employing a fast voltage switching between the anode and cathode of the triode type electron gun. This satisfies the requirement of ITER. For further improvement, an advanced anode power supply system is proposed to reduce the oscillation period of adjacent mode at the start-up phase of each pulse.

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