ECR-heating experiments on L-2M stellarator with power density up to 3 MW*m^3

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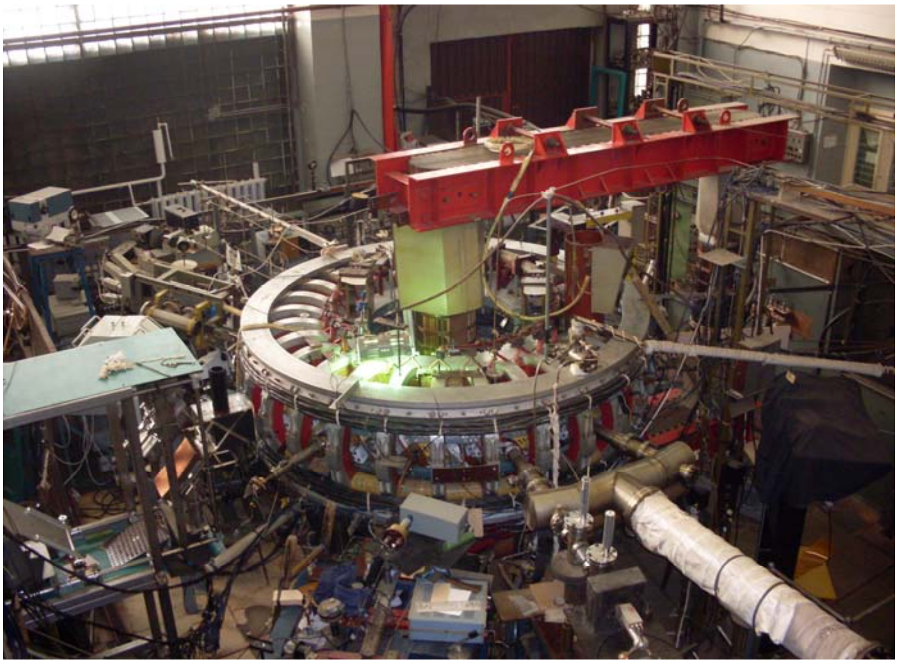
Experimental results from L-2M stellarator with electron cyclotron heating are presented. The heating system consists of two GYCOM/ IAP gyrotrons and is intended for ECR heating of plasma at the second harmonic of the electron gyrofrequency. Therefore, total ECRH power density in L-2M can reach a level above 3 MW/m^3. Measurements of global, profile and local plasma parameters were conducted for ECRH-plasmas at the condition of boronized chamber walls.

L-2M (fig.1) is a medium size high shear classical stellarator with the multipolarity l = 2, the total number of magnetic field periods N = 14 and the major radius R = 100 cm. So called "standard" (most frequently used) configuration has the rotational transform $\mu(0)$ = 0.18 at the vacuum magnetic axis and $\mu(a_p)$ = 0.78 at the vacuum separatrix with the average radius a_p = 11.5 cm. The vacuum magnetic field at the magnetic axis is $B_0 \approx 1.34$ T. The plasmas in these experiments were produced and heated by means of ECRH with a maximum power of 750 kW. The plasma



pressure was sufficiently small $\beta \leq 0.3$ % (β is the volume averaged ratio of the plasma pressure to the pressure of magnetic field). Small positive (i.e. increasing vacuum rotational transform) plasma currents with total current $I_p < 1$ kA (bootstrap current) cannot visibly change shear, modify equilibrium and be a driving force for instability [1].

L-2M gyrotron complex consists of two GYCOM/ IAP three-electrode gyrotrons with recovery of the energy of an electron beam and is intended for ECR heating of plasma at the second harmonic of the electron gyrofrequency. The first gyrotron has a power up to 800 kW and efficiency of 75% (frequency of 75 GHz). The second gyrotron has a power of 700 kW and efficiency of 60% and can operate at three fixed frequencies: 71.5, 74.8 and 78.2 GHz. Therefore, total ECRH power density in L-2M can reach a level above 5 MW/m^3. For an average plasma density of $2 \cdot 10^{19}$ m^{-3}, this value corresponds to a rate of heating of plasma electrons as high as 600 keV/s per electron [2].

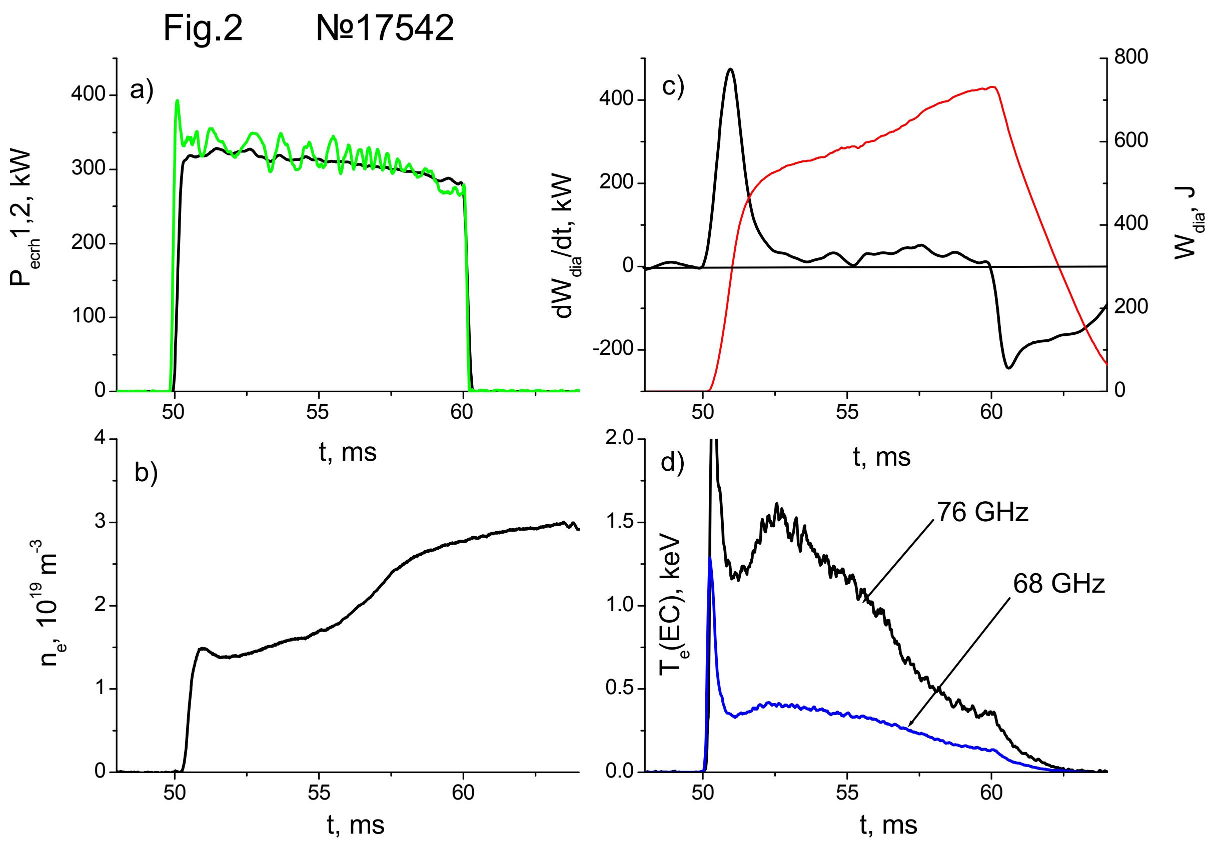


Figure 2. Plasma parameters versus time for pulse with plasma energy W_{dia} = 740 J (concurrent operation mode); a) ECRH power of two gyrotrons; b) line averaged plasma electron density; c) plasma energy and its time derivative; d) ECE plasma temperature, 76 and 68 GHz.

Figure 2 shows plasma pulse with heating power P ~ 600 kW. Line averaged electron density (b) and plasma energy (c) increase monotonously till the end of ECR heating pulse. Second harmonic ECE electron temperature at 76 GHz (plasma column centre) and 68 GHz ($0.6a_p$) decreases significantly during plasma pulse.

New 2-gyrotron complex can create concurrent operation mode or time modulations of ECR pulses. The record values of energy for L-2M stellarator were achieved in concurrent mode at frequencies 75 GHz (1^{st} gyroton) and 78.4 GHz (2^{nd} gyrotron).

The energy balance was performed on the basis of plasma diamagnetism and Pfirsch—Schlueter currents measurements. The ECRH power was varied from 100 to 750 kW, and the plasma density was varied from $1{\cdot}10^{19}m^{-3}$ до $3{\cdot}10^{19}m^{-3}$. Record value of plasma energy for L-2M stellarator is 800 J. The experimental results of energy confinement time τ_E = (1…3.5) ms in a wide range of parameters correspond to the LHD and ISS-95 Stellarator scalings.

Figure 3. Electron temperature measurements (soft x-ray spectrometers) show the increase of central temperature and flattening of temperature profile; heating power changes from 250 to 450 kW.

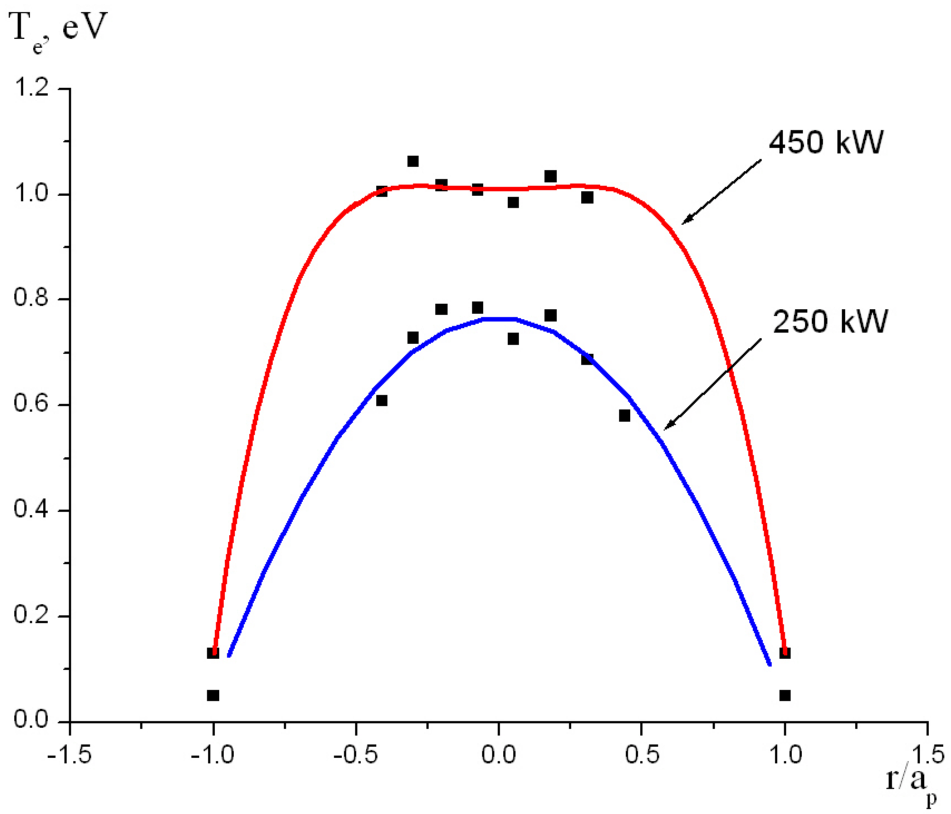
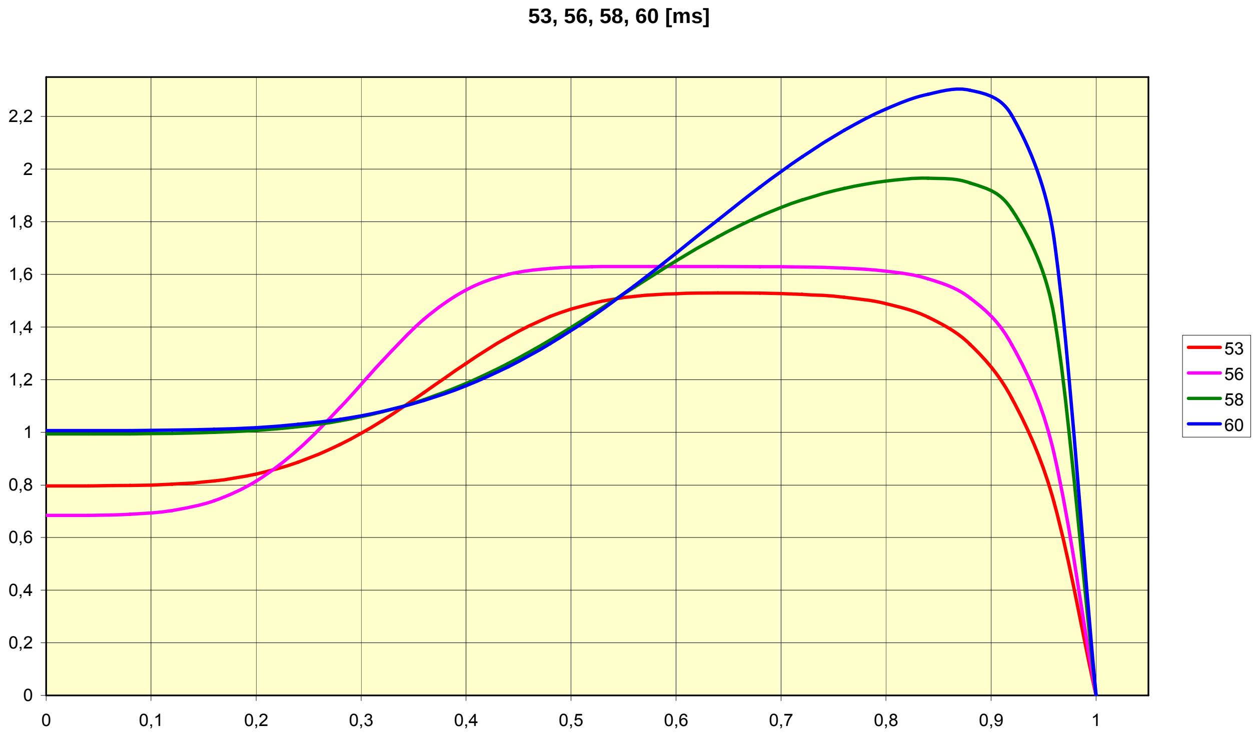


Figure 4. For all high-power experiments the strong pump-out effect can be seen on electron density profile measured by the laser interferometer. For smaller heating power values the density profile is high degree parabolic. Figure shows profiles corresponding to 4 different moments of ECR heating mode.



Method of gyrotron beam scattering measurements was developed and results for different experiment parameters, including high heating power experiments, are obtained (see P2.084 poster).

A detailed study of the received results is planned, including transport analysis of strong central density pump-out effect.

References

[1] S.V. Shchepetov et al. Plasma Phys. Control. Fusion. 2008. V.50. p.045001.

[2] N.K. Kharchev et al. 20th International Toki Conference “The Next Twenty Years in Plasma and Fusion Science”. 2010. Toki-city, Japan, paper P1-1.