UPGRADE OF THE PERFORMANCE OF THE GOLEM TOKAMAK

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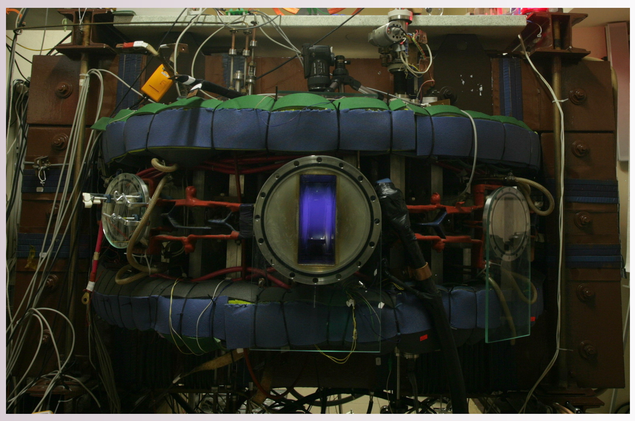
The GOLEM Tokamak



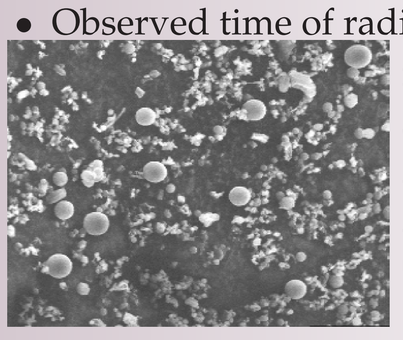
- An educational device for domestic as well as for foreign students via remote participation/handling.
- Operating routinely for nearly two years at a modest range of parameters $B_t < 0.5$ T, $I_p < 8$ kA, pulse length < 15 ms, and with a limited set of diagnostics.
- Wide range of tasks with varying levels of complexity covering tokamak physics, technology and operation can be studied by the future fusion specialists.

GOMTRAIC

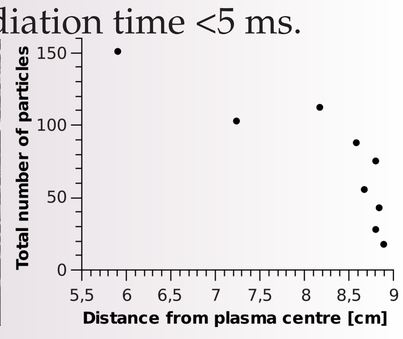
- Education and training course for University students
- in-situ part – one week in Prague, and getting experience with the tokamak, taking first measurements, and presenting first results
- remote part – performing discharges on-line
- Six topical groups
- 19 participants from 8 countries all over the world attended the remote part, 8 of them were present during the kick-off week.

Dust Studies

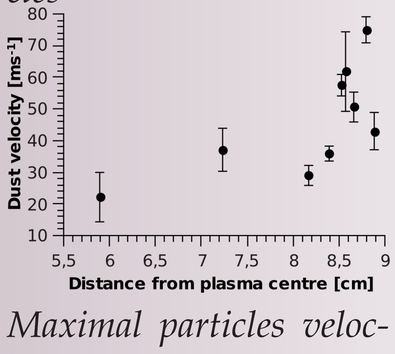
- $\approx 1\,\mu$m carbon dust was implanted to at different plasma radius
- The radiating dust positions were measured using a fast camera EX-F1 with 1/40 000 exposure time.
- Initial velocity is >50 m/s for plasma temperature roundly 10 eV
- Dust velocity is strongly dumped in all directions
- Observed time of radiation time <5 ms.



Used carbon dust particles



Number of generated particles



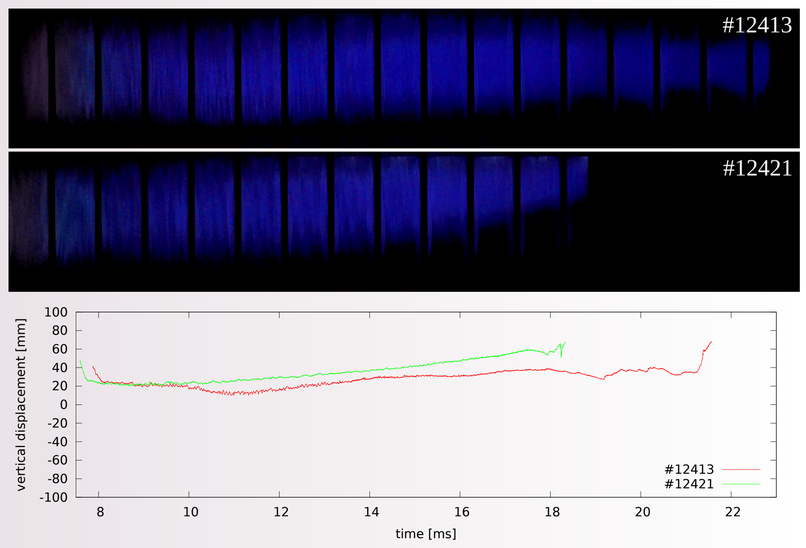
Maximal particles velocity

Plasma stabilisation

Feedback control system:

- 4 Mirnov coils at poloidal angles of $\theta = 0, \pi/2, \pi, 3\pi/2$.
- Computer with real-time OS for integratign signals and calculating the plasma position
- Program for determination of the vertical position of plasma is written in LabVIEW and counts with a frequency of 50 kHz
- Voltage source driven by the computer controls a current in a poloidal coils
- Poloidal coils affects the vertical plasma position

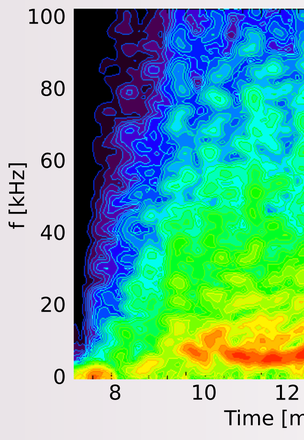
The average prolongation of the plasma life was over 2 ms. However, there are pending issues with Mirnov coil signal integration, which are planned to be solved in the future. Meanwhile, changes of plasma position are taken as more relevant, rather than absolute calculated position.



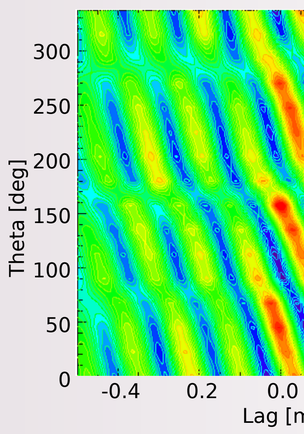
Evolution of the vertical displacement of plasma using fast camera. The upper image (#12413) is with the feedback stabilization, middle (#12421) is without. Bottom: comparison of their vertical displacements using Mirnov coils.

MHD studies

- Substantial improvement of the diagnostics means of B_θ perturbations (for detection of coherent MHD structures)
- Array of 16 Mirnov coils has been replaced with a new set with optimalized coil parameters [1].
- Additional set of 16 B_θ detection of the same parameters installed into the tokamak chamber (international collaboration with CICATA-IPN, Mexico)
- Use of detection coils of improved parameters enables clearer detection of magnetic islands present at low q regime of tokamak
- $m = 3$ magnetic island – shown by cross-correlation analysis of $14 - 15$ ms interval
- Qualitatively, the results and data processing are of virtually same character as on larger devices, which turns GOLEM into a suitable studenttraining tokamak



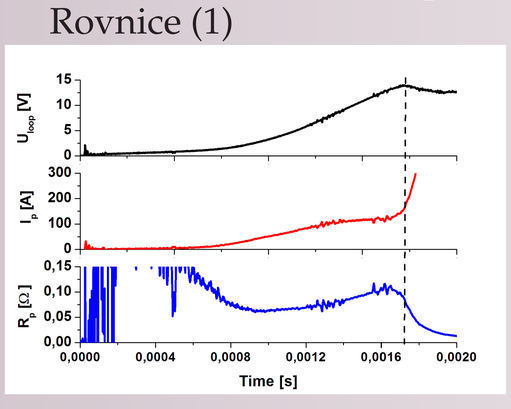
Spectrogram of B_θ perturbations detected by an improved-parameter Mirnov coil located on $\theta = \pi/2$



Cross-correlation coefficients of B_θ perturbation signal on an array of 16 Mirnov coils. Reference coil chosen on $\theta = \pi/2$

Avalanche phase at the plasma start-up

- Plasma resistance $R = U_{loop}/Ip$
- In cylindrical approximation, the plasma resistance is $R_p = \rho_{\epsilon_0} 2\pi R_0/\pi a^2$, where $R_0 = 0.4$ m is the major radius, $a = 0.085$ m is the minor radius.
- Weakly ionized plasmas: $\rho_{\epsilon_0} = 5.555 \cdot 10^3 \sqrt{E n_{H_2}/n_e}$ [Ωm,V/m, m^{-3}], where $E = U_{loop}/2\pi R_0$ is the toroidal electric field, n_{H_2} is the density of the working gas [2].
- Relation between the plasma resistivity and the plasma density on the GOLEM tokamak is Rovnice (1)



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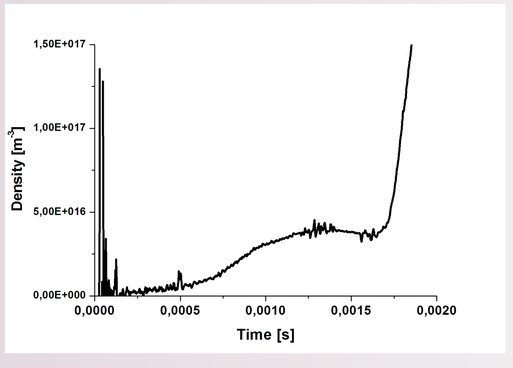

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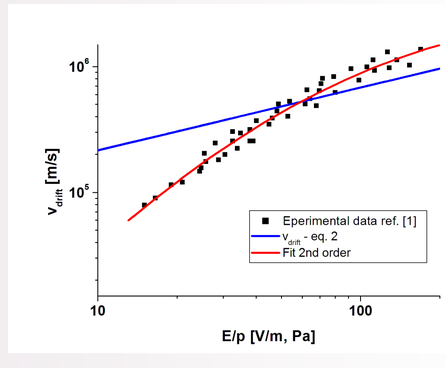

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Acknowledgment

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References

[1] T. Markovič, Master thesis, Dept. Of Phys., FNSPE CTU in Prague, 2013

[2] H. Prinzler et al, Czech J. Physics, B 34, 1984, p. 665

[3] V. A. Lisovski, Russian Physics Journal, No4, 1998, p. 394