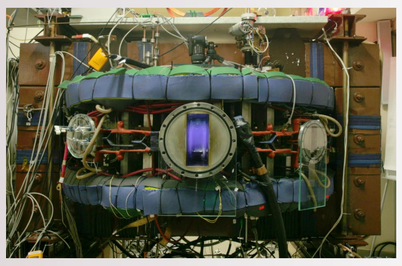
TOKAMAK GOLEM FOR FUSION EDUCATION - CHAPTER 11

P. Macha[1,2], K. Hromasova[1,2], D. Kropackova[1], M. Lauerova[3], A. Socha[4], J. Malinak[1], L. Lobko[1], D. Cipciar[5], J. Adamek[2], J. Cecrdle[1], V. Svoboda[1], J. Stockel[2]

[1] *Faculty of Nuclear Sciences and Physical Engineering CTU in Prague, Czech Rep.,* [2] *Institute of Plasma Physics AS CR, Prague, Czech Rep.,* [3] *Gymnazium Nad Aleji 1952, Praha, Czech Rep.,* [4] *Gymnazium a Střední odborna skola Cihelni 410, Frydek-Mistek, Czech Rep.,* [5] *Faculty of Science, Masaryk University, Brno, Czech Rep.*

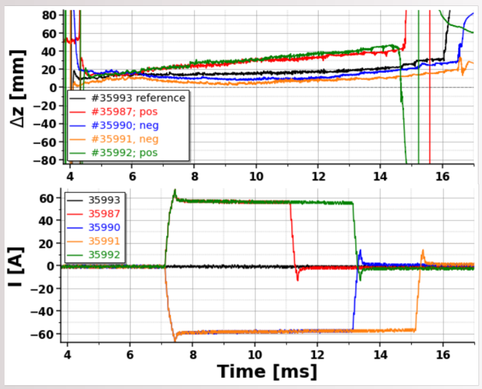
The GOLEM tokamak



- Parameters: $B_\mathrm{t} < 0.5$ T, $I_\mathrm{p} < 8$ kA, pulse length < 15 ms.
- An educational device for domestic as well as for foreign students via remote participation/handling [1].
- Students become familiar with probe measurements, data analysis and basic tokamak diagnostics.
- Subject of Bachelor's degree projects and Master's degree theses.

External plasma stabilization

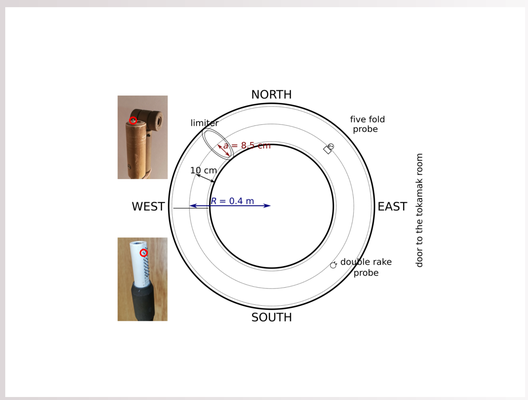
- 2 external windings generating predefined poloidal magnetic field used for plasma control (horizontal, vertical).
- Plasma position is determined by Mirnov coils.
- The influence of the horizontal mg. field on the discharge duration is shown.



Plasma vertical displacement for discharges with stabilization generating horizontal magnetic field.

Long-range correlations

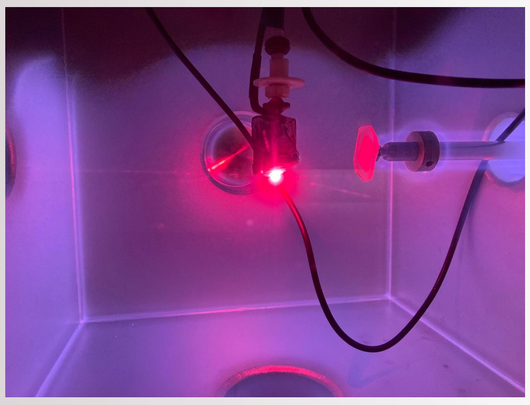
- Long-range correlations studies using 2 toroidaly separated Langmuir probes with focus on GAMs.
- The coherence for GAM confirmation was not reached yet.



Example of one of the long–range coherence in the edge plasma of GOLEM tokamak.

Lithization tests in vacuum tube

- Lithization setup tests performed in a small vacuum tube.
- Several critical problems need to be handled before usage in the tokamak wall - oxidation of the metallic lithium and potential melting of electrodes.
- A spectral line of neutral Li has been observed.



Snapshot of the glow discharge with the apparent red neutral lithium line.

References

[1] V. Svoboda, et al., Fus. Eng. and Des. 68, 1310-1314 (2011)

[2] J. Adamek et al 2021 Nucl. Fusion 61 036023 https://iopscience.iop.org/article/10.1088/1741-4326/abd41d

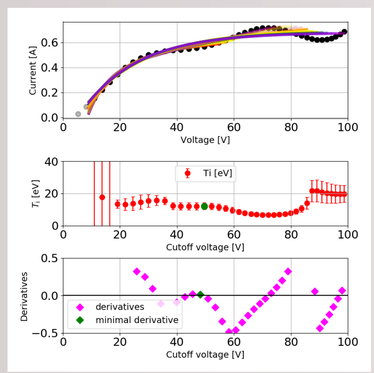
[3] J. Adamek et al., Czechoslovak Journal of Physics. (2004) 54, 95–99.

Contact us

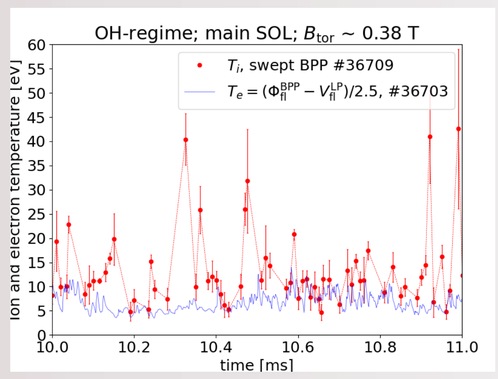
Tokamak GOLEM, Břehová 7, Prague, Czech Republic
golem.fjfi.cvut.cz
svoboda@fjfi.cvut.cz

Fast ion temperature measurement using swept ball-pen probe

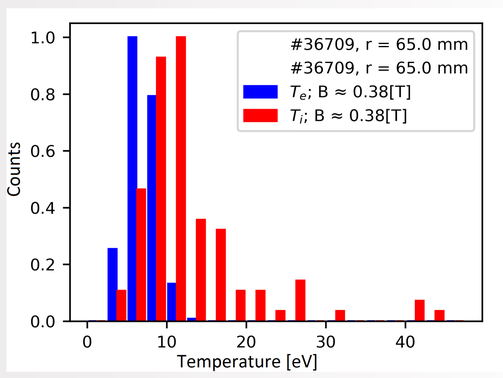
- Ion temperature is measured with 5 μs temporal resolution based on the measurements of the electron branch of a ball-pen probe (BPP) IV characteristics [2].
- The probe collector is biased with a voltage swept between -30V to +130 V at a frequency of 100 kHz.
- The T_i is obtained from $I(V) = I^+_\mathrm{sat} \cdot \left(\exp(\alpha_\mathrm{BPP}) \cdot [1 + K \cdot (V - \Phi)] - \exp\left(\frac{\Phi - V}{T_\mathrm{i}}\right)\right)$, $\alpha = \ln \frac{I^-_\mathrm{sat}}{I^+_\mathrm{sat}} = 0.25 \pm 0.09$ $(B_\mathrm{t} > 0.22$ T).
- Cut-off fitting technique is applied to all the IV characteristics.
- Fluctuations of the ion temperature ranging between 5 eV up to 40 eV reveal the turbulent behavior of the edge plasma.
- NON-Gaussian shaped histograms of T_e and T_e are observed with a peak at low temperature and a tail towards high temperatures.



Cut-of technique.



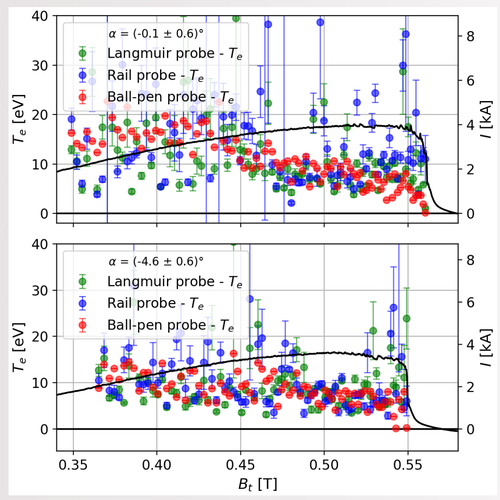
Temporal evolution of T_i and T_e.



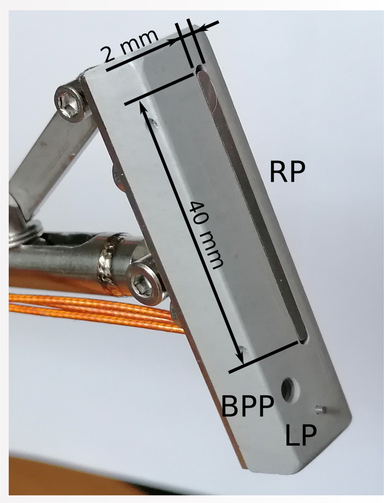
Histograms of T_i and T_e.

Electron temperature measurements using rail probe

- The rail probe concept can sustain exceptionally high heat flux and reduce the sheath expansion effect.
- A probe head consists of a rail probe (RP, length = 40 mm, wide = 2 mm), Langmuir probe (LP, length 1.5 mm, diameter 1 mm), and ball-pen probe (BPP) [3] has been designed
- Special manipulator with changable inclination to B_t within $\pm 10^\circ$ has been installed.
- Electron temperature is measured using a swept Langmuir and rail probe (f = 5 kHz) and a floating ball-pen probe.
- Capability of RP to reduce the sheath expansion effect was confirmed.
- Good agreement between LP, RP and BPP electron temperature measurements for large magnetic field.

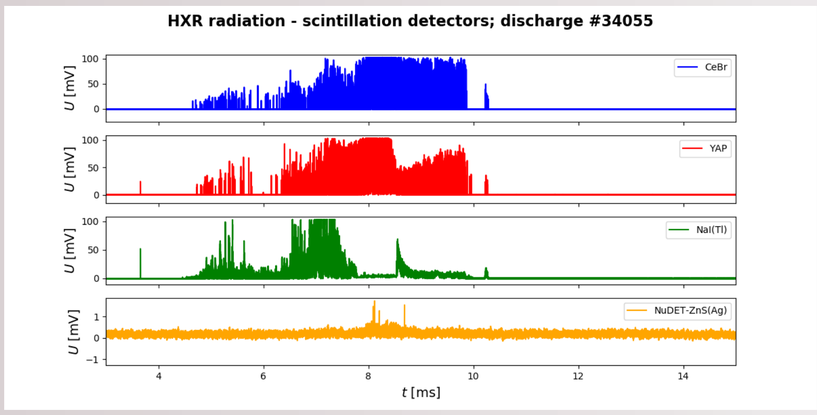


Left) Comparison of T_e measured by BPP, LP and RP. Right) Diagram of the combined probe head.

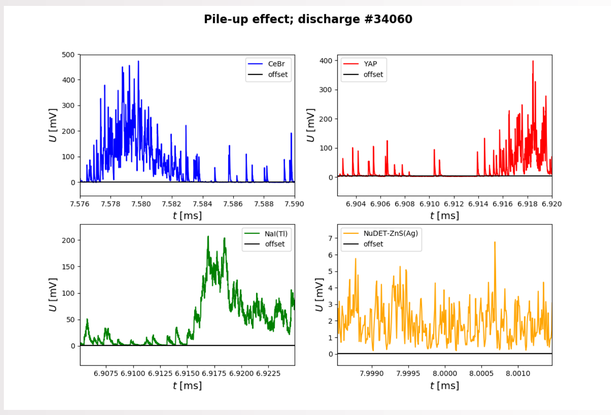


Measurements of HXR radiation

- Scintilation detectors were used for HXR spectromery.
- Electronics of standard photomultiplier tubes of scintillation detectors does not withstand too large HXR fluxes
- Two problems occured:
  - Standard photomultiplier tubes of scintilation detectors can not withstand high HXR (NaI(Tl) detector drops around 8 ms).
  - Pile-up areas and areas of individual peaks.
- Optimal setup must be found by ensuring sufficient lead shielding and the distance from tokamak.



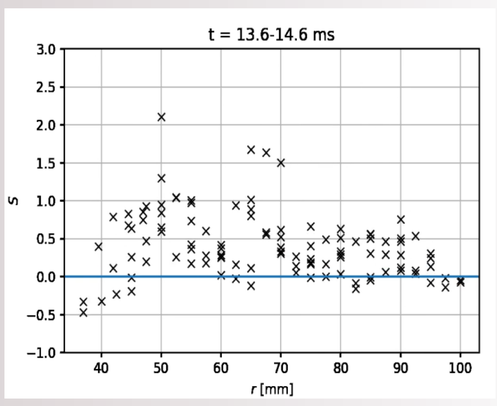
Comparison of HXR signals from 4 different scintillation detectors.



Comparison of piled-up signals and individual peaks.

Turbulent structures

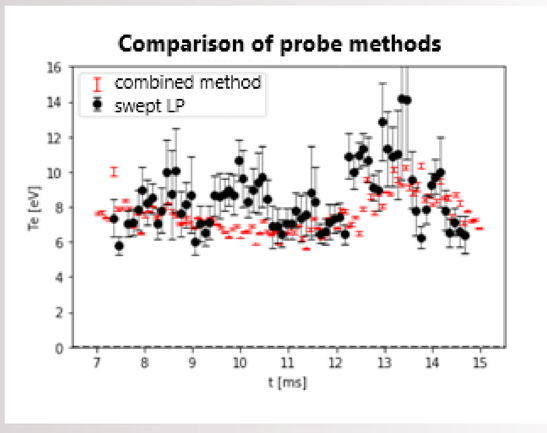
- Exchange turbulence (blob-hole pair generation and propagation) in the plasma edge enhances energy and particle losses.
- Double rake probe (tokamak bottom port) measured I_sat at $r = 37 - 90$ mm (limiter at $r = 85$ mm).
- I_sat histograms found asymmetric with positive skewness indicates the presence of blobs.
- Skewness seems to decrease to negative values at $r = 40$ mm, possible location of the blob birth zone.



Radial profile of ion saturated current skewness. Positive values indicate the presence of blobs throughout the investigated region.

Electron temperature measurements

- Swept Langmuir probe – verified but complicated and time-consuming.
- Combined method (floating ball-pen and Langmuir probe) – straightforward and high time resolution, but rather new.
- It was verified that both methods give the same results.
- We suggest that the combined method is suitable for measuring the edge plasma T_e.



Time evolution of T_e in two identical GOLEM discharges, showing good correspondence between the two methods.

Acknowledgment

This work was supported by the Grant Agency of the Czech Technical University in Prague, grant No. SGS19/180/OHK4/3T/14.