

Scientific and Education Activities on the GOLEM Tokamak in the Framework of the IAEA CRP

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on behalf of the tokamak GOLEM team

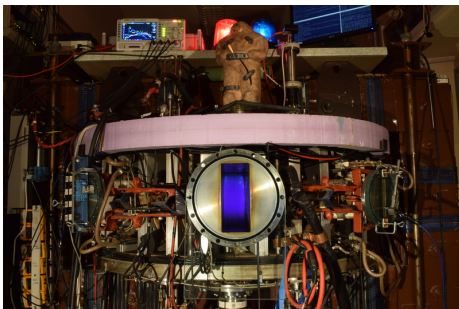
Prague, January 11, 2021

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- 2 Work actually done (selected examples)
- 3 Training events
- 4 Plan for the next period

The GOLEM tokamak basic characteristics

The grandfather of all tokamaks (ITER newslines 06/18)



- Vessel major radius: $R_0 = 0.4$ m
- Vessel minor radius: $r_0 = 0.1$ m
- Maximum plasma current:
 $I_p^{\max} < 8$ kA
- Maximum toroidal magnetic field: $B_t^{\max} < 0.5$ T
- Typical electron density:
 $\langle n_e \rangle \in (0.2, 3) \cdot 10^{19} \text{ m}^{-3}$
- Maximum electron temperature:
 $T_e^{\max} < 80$ eV
- Maximum discharge duration:
 $\tau_p^{\max} < 25$ ms

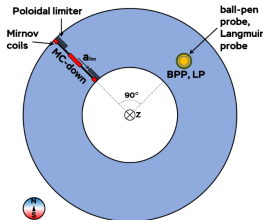
Objectives in the Framework of the IAEA CRP

- 2.2.14.1. Main research activities proposed:
 - Plasma edge studies using advanced probe techniques.
 - Developing diagnostics for runaway studies.
- 2.2.14.3. Education activities:
 - GOMTRAIC, a week of hands-on experiments at the GOLEM tokamak.
 - Set of remote participation training courses

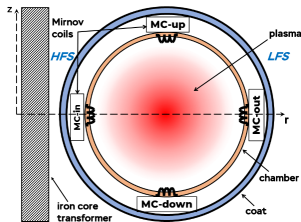
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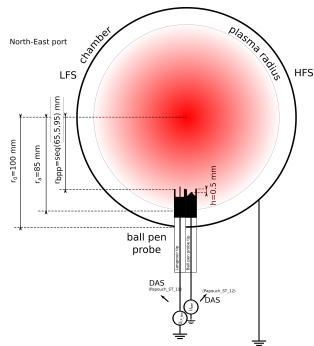
Hydrogen and Helium Plasmas in the GOLEM Tokamak



Experimental set-up

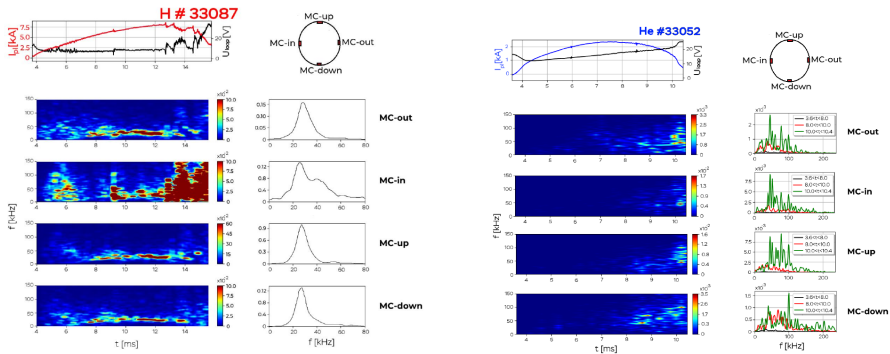


Mirnov coils to measure MHD activity



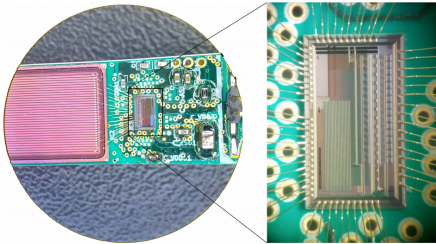
Ball-pen probe

H and He Plasmas in the GOLEM Tokamak: results

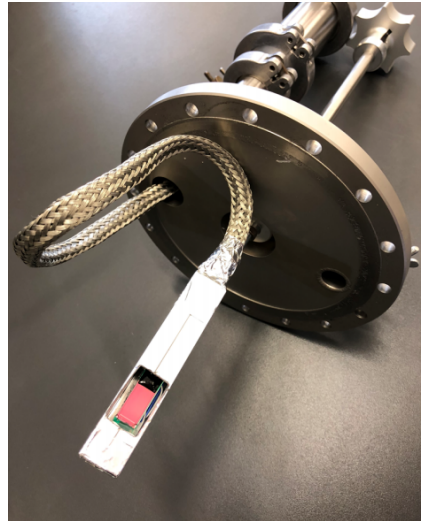


- Plasma scenarios in H and in He in the GOLEM are radically different.
- In hydrogen plasma magnetic instabilities usually occur near the maximum plasma current, that lead to the disruption.
- Helium plasma quietly extinguishes due to the exhaust of the magnetic flux in the primary winding of tokamak transformer.

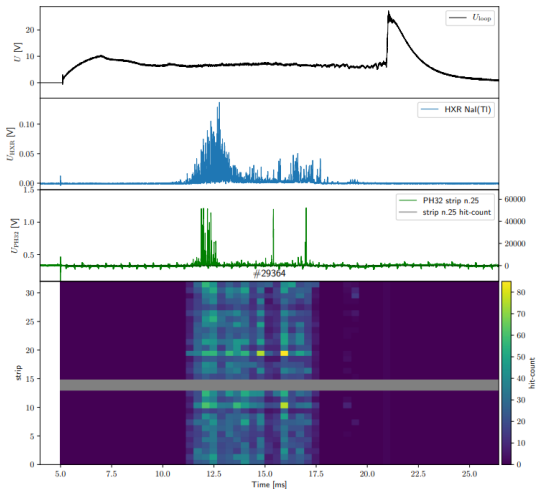
Runaway electron diagnostics using silicon strip detector



The silicon strip sensor connected to the PH32 readout chip by wire bonding.



Runaway electron diagnostics using silicon strip detector



- Loop voltage of plasma discharge.
- HXR scintillation,
- Analog signal voltage in the 25th strip
- Number of hits in all strips.

#29364, the PH32 detector in the LGM collected a number of hits,

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GOMTRAIC 2019: 5 -days mini-workshop (March, the 4th - 8th) at the GOLEM tokamak for ~ 15 foreign students.

■ Aim of the workshop:

- Hands-on experience of tokamak operation and learn its basic principles.
- Learn basic instrumentation of the tokamak operation and diagnostics.
- Provide working experience with an integrated tokamak facility.

■ Tasks for the workshop

- (All) Hands-On measurements of plasma basic parameters.
- (3 students) Study of runaway electrons in GOLEM tokamak.
- (3 students) Plasma position control by vertical stabilization.
- (3 students) Plasma Turbulence characterization with probes.
- (3 students) Temperature measurement by ball-pen probe.
- (3 students) Density measurements by microwave interferometer.

■ Programme:

- Mo: Introductory talks, the GOLEM tokamak visit.
- Tue: Basic hands-on experience with tokamak operation
- Wed: Tasks based experiments and data analysis
- Thu: The COMPASS tokamak visit. Preparation of presentation by participants.
- Fri: Presentations by participants.

GOMTRAIC: Friday - final photo (after presentations)



Students:

- 2x Russia
- 3x Ukraine
- 2x Portugal
- 2x USA
- 1x Hungary
- 1x Slovenia
- 1x Italy
- 1x Belgium
- 2x Serbia
- 1x Iran

Remote training courses 10/2018-01/2021 inventory



C#19 version (Budapest BUTE University, November 2020)

i) 8th IWSSPP workshop, Kiten, Bulgaria, 12 June 2018, ii) Budapest University of Economics and technology, Hungary 19th, November 2018, iii) Padova University, Italy 23rd, November 2018, iv) Eindhoven University, Netherlands 18th, December 2018, v) Torino University, Italy 20th, December 2018, vi) 5th ASEAN School on Plasma and Nuclear Fusion, 21-25 Jan 2019, Mahidol University, Thailand, vii) Fusion Master gathering in Cadarache, France 19th, February 2019, viii) Charkov University, Ukraine 13th, March 2019, ix) demo from ASDEX tokamak, Germany 25th, March 2019, x) Moscow University, Russia 9th, April 2019, xi) Budapest University of Economics and technology, Hungary, offline, xii) Eindhoven University, Netherlands 14th, January 2020, xiii) Torino University, Italy 15th, January 2020, xiv) 6th ASEAN School on Plasma and Nuclear Fusion, 30th, January 2020, Thailand, xv) Moscow University, Russia 27th, May 2020. xvi) Budapest University of Economics and technology, Hungary 24th, November 2020, xvii) 9th IWSSPP workshop, Kiten, Bulgaria, 3rd December 2020, xviii) MIPT Moscow University 15th December 2020, xix) Torino University, Italy 17th, December 2020, xx) Eindhoven Tecnical University, Netherlands 5th, January

Training courses - pandemic set-up

- Tokamak operator at the Golem tokamak
- Local student's tutors at their home/labs/offices.
- Students at their homes.
- + up to 3 czech PhD students (familiar with the GOLEM tokamak) ready to guide or assist with everything concerning tokamak GOLEM
- Students in a certain number of groups each having its own videoconference room and a tokamak controll room.



C#19 version (Torino Technical University, December 2020)

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Plans (adapted for remote regimes)

■ 2.2.14.1. Main research activities proposed:

- Plasma edge studies using advanced probe techniques.
 - Measurement with double rake electrostatic probe with the main goal to find the position of the velocity shear layer (VSL) and to find the dependence of this position on the discharge parameters.
 - Operational domains of the GOLEM tokamak.
 - Physics of the plasma edge column with a focus on determining and comparing the position of the plasma edge by electrostatic, magnetic and radiation measurement methods.
- Developing diagnostics for runaway studies.
 - Integral experiments focused on the behavior of runaway electrons, where a wide range of different types of HXR probes will be involved: scintillation, medipix, timepix, calorimetric and strip detectors.

■ 2.2.14.3. Education activities:

- GOMTRAIC, a week of hands-on experiments at the GOLEM tokamak (maybe remote version).
- Set of remote participation training courses (developing pandemic set-up)

Relevant References I

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