

Scientific and education activities on the GOLEM
tokamak in the framework of the IAEA CRP

Vojtěch Svoboda

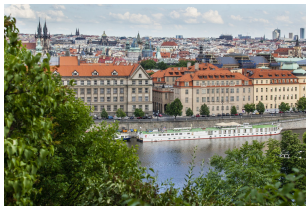
Czech Technical University in Prague

October 9, 2018

Outline

- 1 Introduction
- 2 The GOLEM tokamak research (recent issues)
 - Runaway studies
 - Edge plasma studies using probes
- 3 The GOLEM tokamak education activities
 - Hands on experiments
 - Remote experiments
- 4 The GOLEM tokamak for IAEA CRP

Faculty of Nuclear Sciences and Physical Engineering Czech Technical University in Prague



FNSPE main building in Prague



FNSPE insignia

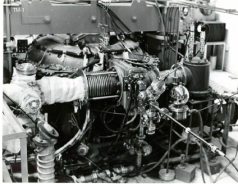


CTU ceremony hall

- CTU founded in 1707 by the emperor Joseph I.
- CTU approximately 2200 staff members, 15000 undergraduate students, 9000 graduate and PhD students. (\approx 2500 foreign students).
- FNSPE established in 1955 with the mission to train new experts for the emerging Czechoslovak nuclear programme.
- FNSPE currently a centre of education and research specialised in boundary fields between modern science and their applications in technologies, medicine, economy, biology, ecology, and other fields.

The GOLEM tokamak for education - historical background

Kurchatov Institute near Moscow,
Soviet Union
1960: **TM1-MH**



1974

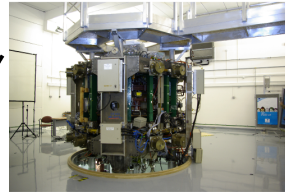


Institute of Plasma Physics
Czech republic
CASTOR **COMPASS**

2006



Culham Centre for Fusion Energy
Great Britain
1989: **COMPASS-D**



2008

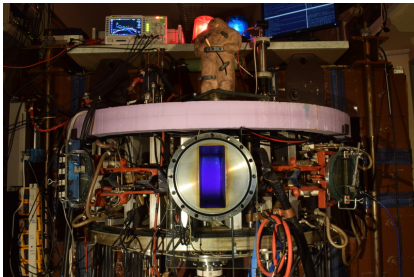


Czech Technical University Prague
Czech republic
GOLEM



The GOLEM tokamak basic characteristics

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

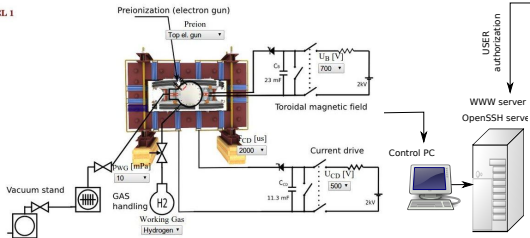


- Vessel major radius: $R_0 = 0.4$ m
- Vessel minor radius: $r_0 = 0.1$ m
- Plasma minor radius: $a \approx 0.06$ m
- Toroidal magnetic field: $B_t < 0.5$ T
- Plasma current: $I_p < 8$ kA
- Electron density:
 $n_e \approx 0.2 - 3 \times 10^{19} \text{ m}^{-3}$
- Effective ion charge: $Z_{eff} \approx 2.5$
- Electron temperature: $T_e < 100$ eV
- Ion temperature: $T_i < 50$ eV
- Discharge duration: $\tau_p < 25$ ms
- (Electron) energy confinement time:
 $\tau_e \approx 50$ us

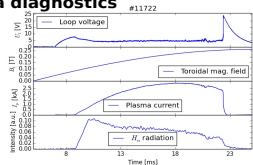
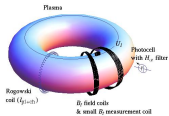
The global schematic overview of the GOLEM experiment

LEVEL 1

Tokamak technology setup



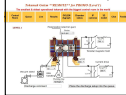
Basic plasma diagnostics



Virtual control room (remote participation)

WWW control interface

HTML & PHP scripts



SSH control interface

WINDOWS via putty



LINUX via ssh or ssh+X tunnel (advanced mode)

Data presentation

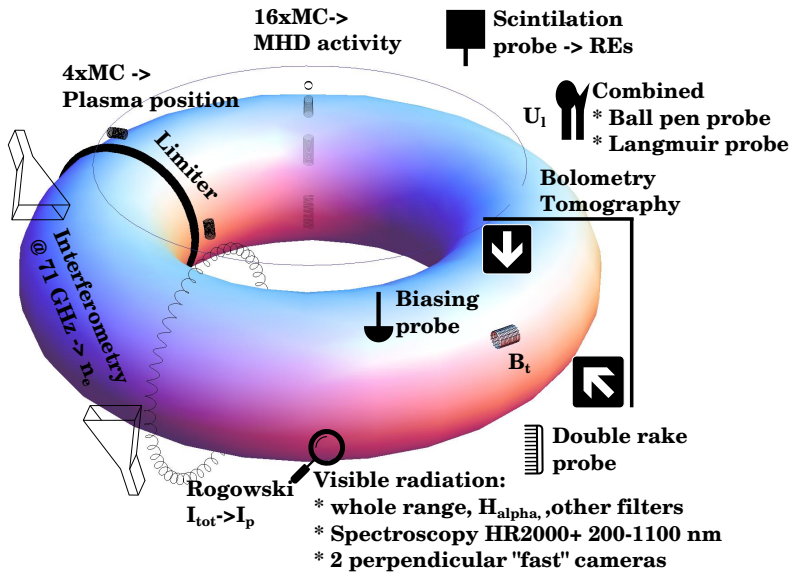
HTML (www pages)



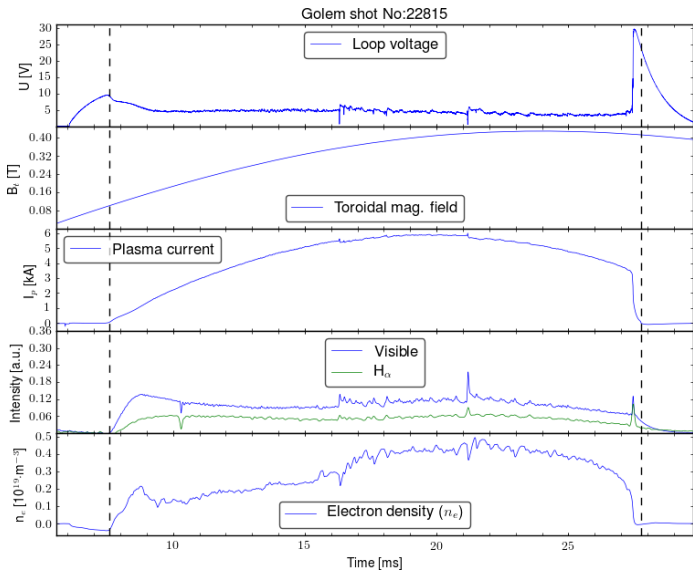
Data handling

- *wget
- *gnuplot
- *idl
- *mathematica
- *matlab
- *etc...

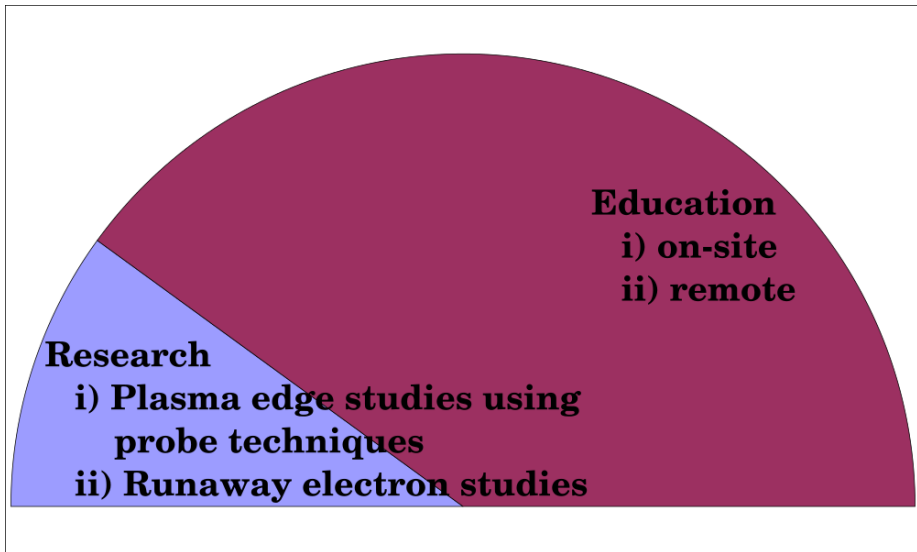
The GOLEM tokamak - standard diagnostics



"Typical", well executed discharge @ GOLEM



The GOLEM tokamak mission

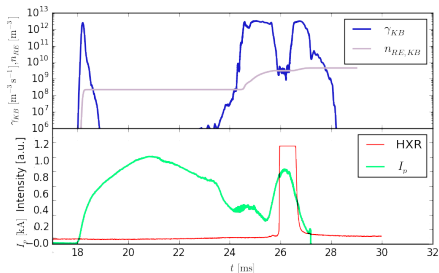
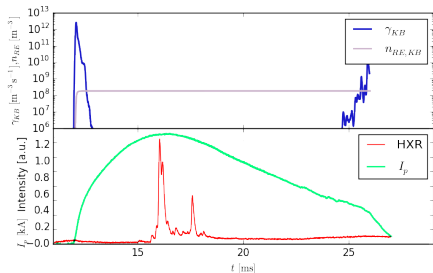


Outline

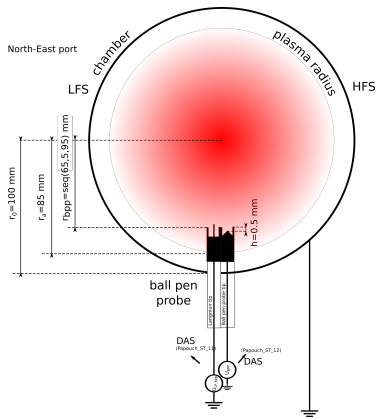
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REs@GOLEM: A basic observation

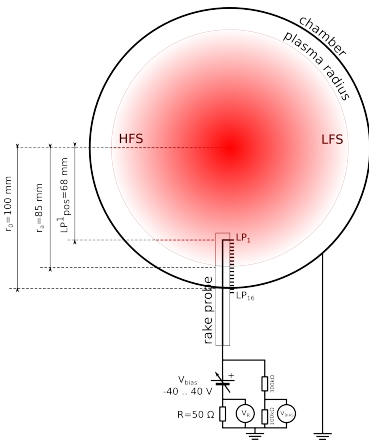
- A new NaI(Tl) scintillation detector with a photomultiplier tube was installed
- Kruskal-Bernstein criterion used for estimating the RE generation rate
- RE generation observed during the breakdown phase as well as during position instabilities
- Plasma recreation observed after the loss of RE (probably due to secondary electrons)



Electrostatic probes@GOLEM



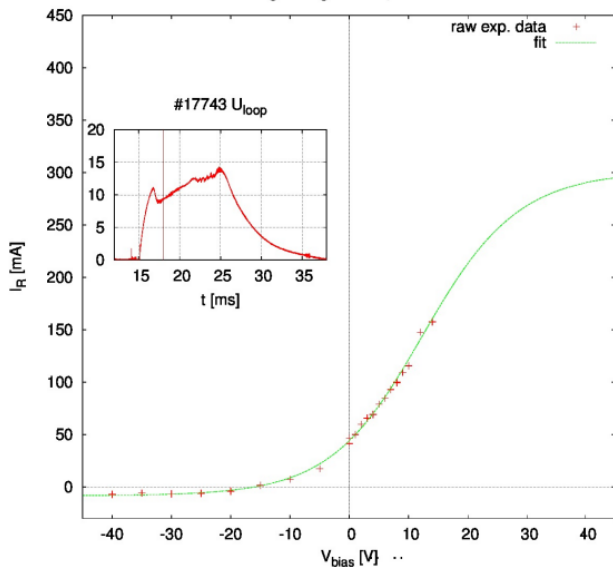
Combined Ball-pen probe and
Langmuir probe @
North-East-Down port



Double rake probe @
South-East-Down port

Probes@GOLEM: Empirical Parametrization of the GOLEM data on the shot-to-shot basis

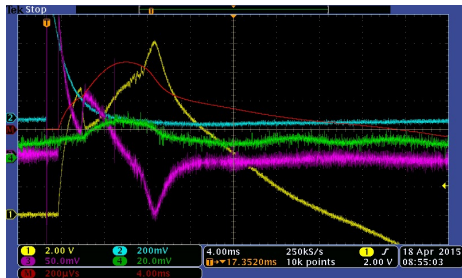
LP signal avg <18000,18010> us



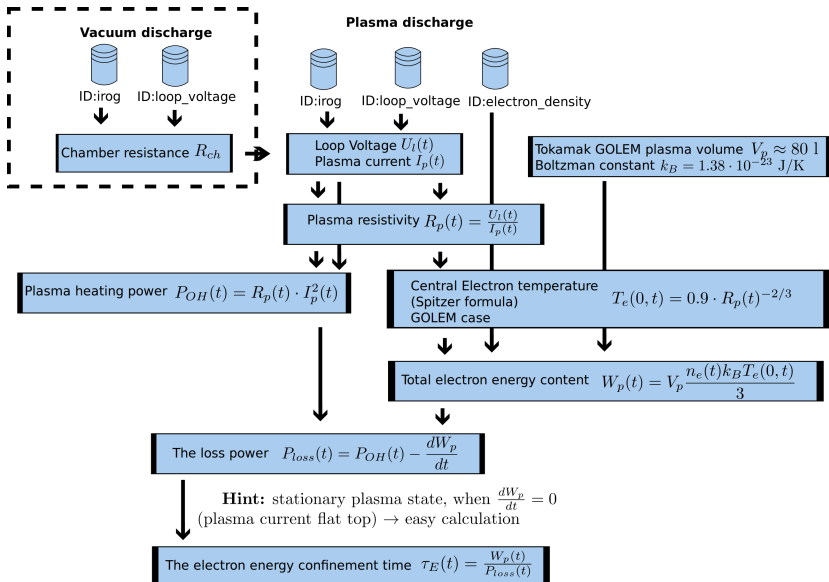
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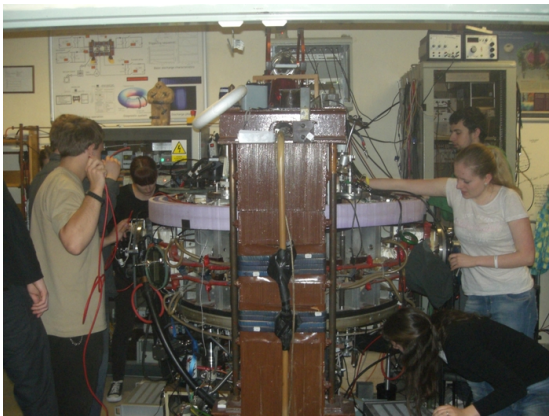
Hands on the GOLEM tokamak



Towards Electron energy confinement time τ_E



Hands on the GOLEM tokamak



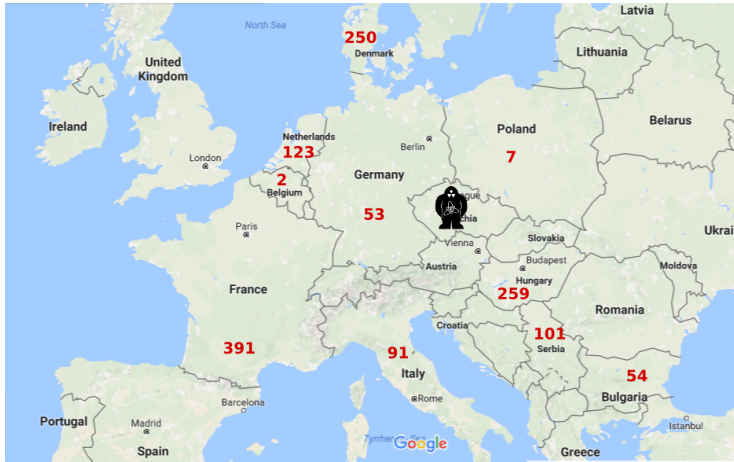
- Laboratory Practice for Basic course of Physics 15-18 (CT University Bachelor level).
- Advanced plasma training course 14-18 (CT University Master level).
- Week of scientists 13-18 (Czech republic High school level).
- Golem Training course 13 (Master and PhD level).

Remote control



- Demonstrations: Ghent University 09; Bochum University 13; Garching 13; Lemvig High School 14; Instituto Tecnologico Costa Rica 10; Armidale University 17.
- Training courses: French Training Course & EM 12-14,16-18; Bangkok 16-18; TU Eindhoven 11,15-18; TU Kobehaven 14,15; University of Belgrade 15-17; BUTE Budapest 10,12-18; University of Padova 14,16; TU Torino 16-18.
- Workshops Kiten: 14,16,18; Observatorium Valasske Mezirici 14; Islamabad 14.
- Miscellaneous: Global Tokamak Experiment 10.

Remote discharges over the Czech borders



+ IN ~ 10, + PK ~ 70, + OTHERS ~ 100

$\Sigma(09/12-02/17) \sim 1500$

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Research

	Tasks	Deliverables	Inputs needed / Remarks
Research	Edge plasma studies	Characterization of the influence of plasma species mass and edge biasing on edge plasma parameters and turbulence	* Remote/on site participation * Particular diagnostics share and development. 2 nd year: Joint event @ the GOLEM tokamak ?
	Runaway studies	Experimental test of various runaway detection techniques	

Education

	Tasks	Deliverables	Inputs needed / Remarks
Education	GOLEM on-site: GOLEM training course GOMTRAIC	On-site Training of graduate (and post-graduate students) for ~ 15 students. Feb-Apr.	The event advertisement
	GOLEM remote	Remote Training courses of graduate (and post-graduate students)	Experienced tutor on the remote side.

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

- Aim of the workshop is:
 - 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 (preliminary):
 - (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 and plasma control.
 - Wed: Tasks based experiments and data analysis
 - Thu: The COMPASS tokamak visit. Preparation of presentation by participants.

Summary and the tokamak GOLEM possible networking (on-site as well remotely)

- Research and Technology development
 - **Electrostatic probes** - Jan Stockel (Czech), Tsviatko Popov (Bulgaria)
- advanced diagnostics instrumentation, + ? biasing experiments (STOR-M) + isotopic studies ? + Pakistan, Slovenia
 - **Runaway studies** - Jan Stockel (Czech) + Pravesh Dhyani (India postdoc) + ?? Iran IR-T1 (runaway probe) ?? + ??
 - Preionization - Microwave (and ultraviolet welcome as well) preionization (Russia) + Plasma gun (China).
 - MHD activities - China + Juan I.M. Colepicolo from Costa Rica + ??
 - Liquid metal divertors tests - Jan Stockel (Czech) + (Horizon)
 - General collaboration on various scientific and technology issues with similar tokamaks.
- Education:
 - Remote training courses - IAEA CRP participants welcome.
 - **On-site training courses GOMTRAIC**- IAEA CRP priority (open for application).
- IAEA CRP JE ?? In principle yes. But ...

Acknowledgement

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