

The tokamak GOLEM ...for fusion education
The global introduction

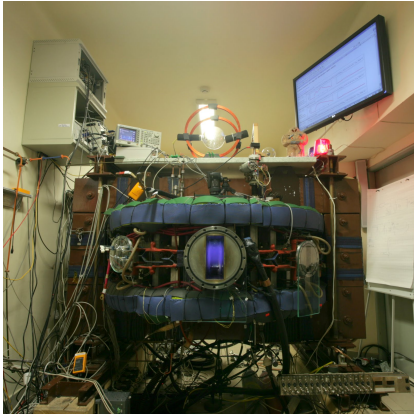
Vojtěch Svoboda
on behalf of the tokamak GOLEM team

July 29, 2017

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- 2 The tokamak GOLEM - schematic experimental setup
- 3 The tokamak GOLEM - operation
- 4 Tokamak GOLEM for fusion education

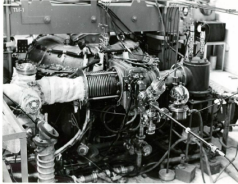
Tokamak GOLEM basic characteristics



- Vessel major radius: $R_0 = 0.4$ m
- Vessel minor radius: $r_0 = 0.1$ m
- Plasma minor radius: $a = 0.06$ m
- Toroidal magnetic field: $B_t < 0.5$ T
- Plasma Current: $I_p = 8$ kA
- Electron density:
 $n_e \approx 0.2 - 3 \times 10^{19} \text{ m}^{-3}$
- Electron temperature: $T_e = 100$ eV
- Ion temperature: $T_i = 50$ eV
- Discharge length: $\tau_p = 25$ ms

Tokamak GOLEM for education - historical background

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



1974

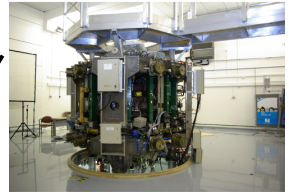
Institute of Plasma Physics
Czech republic
CASTOR



2008

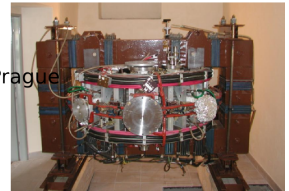
Czech Technical University Prague
Czech republic
GOLEM

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



2006

COMPASS



GOLEM

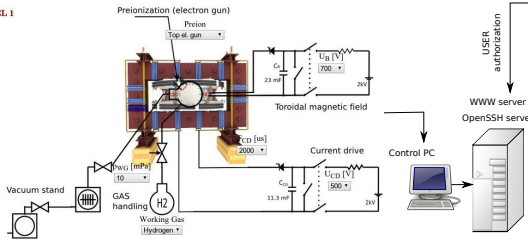


The new location of the tokamak is just next to the old Prague Jewish cemetery where Rabi Loew (Golem builder) is buried, and that is why it was renamed GOLEM (and also for the symbol of potential power you get if you know the magic). Interestingly, here in Prague, where the Golem legend originated, Golem is not perceived as a symbol of evil, but rather as a symbol of power which might be useful but is very challenging to handle. To learn more of the Golem legend, see e.g. [wikipedia](https://en.wikipedia.org/wiki/Golem).

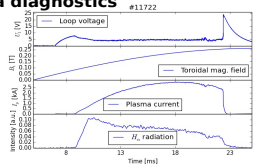
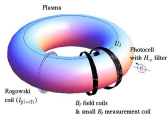
The global schematic overview of the GOLEM experiment

LEVEL 1

Tokamak technology setup



Basic plasma diagnostics



internet

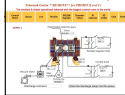
**Virtual control room
(remote participation)**

WWW control interface

Data presentation

HTML & PHP scripts

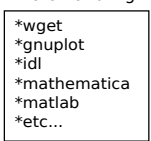
HTML (www pages)



SSH control interface

WINDOWS via putty

Data handling



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

OpenSSH server

WWW server
OpenSSH server

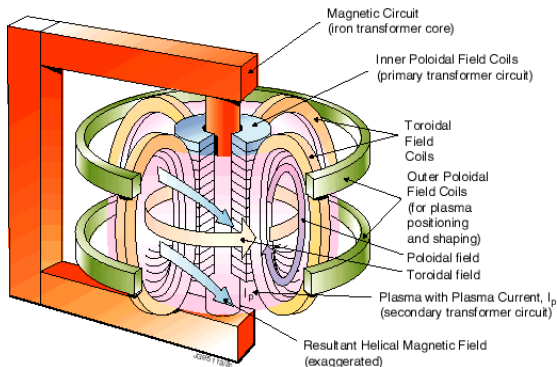


Control PC

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Plasma in Tokamak (GOLEM) - the least to do



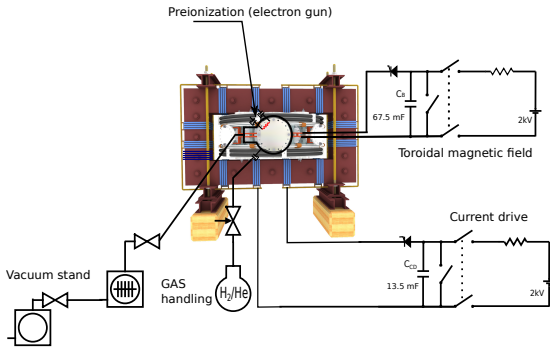
To do:

- session start phase:
 - Evacuate the chamber
- pre-discharge phase
 - Charge the capacitors
 - Fill in the working gas
 - Preionization
- discharge phase
 - Toroidal magnetic field to confine plasma
 - Toroidal electric field to breakdown neutral gas into plasma
 - Toroidal electric field to heat the plasma
 - Plasma positioning
 - Diagnostics
- post-discharge phase

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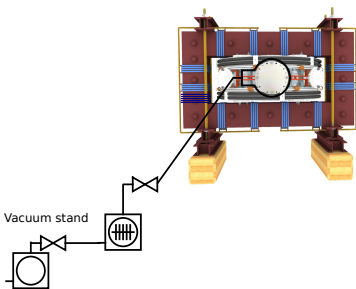
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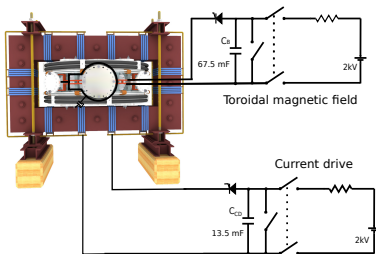
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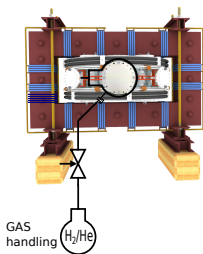
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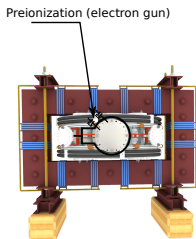
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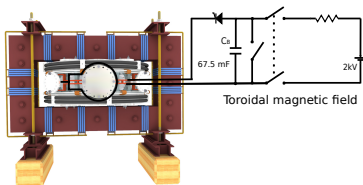
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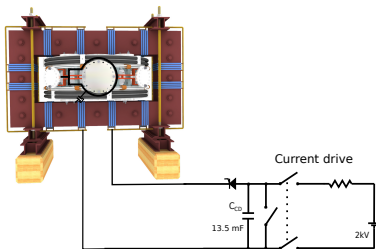
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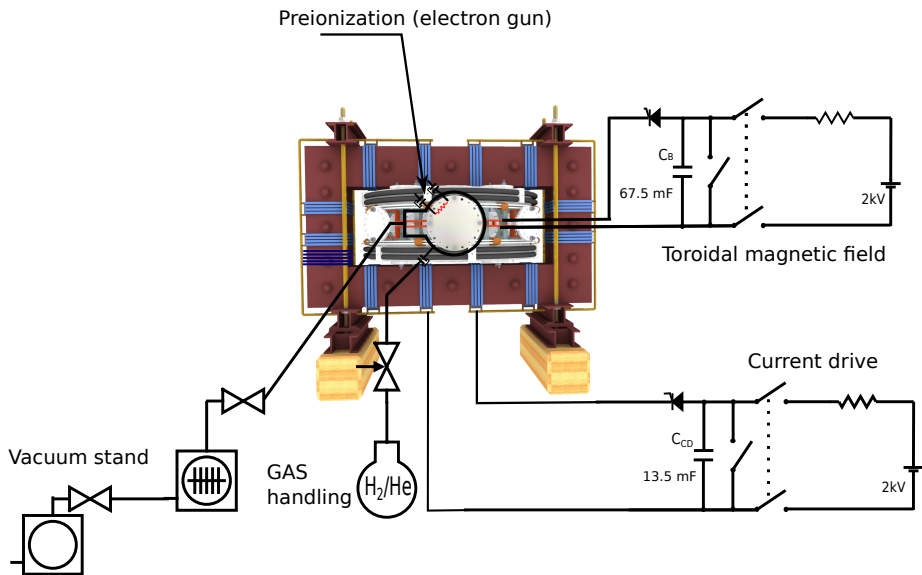
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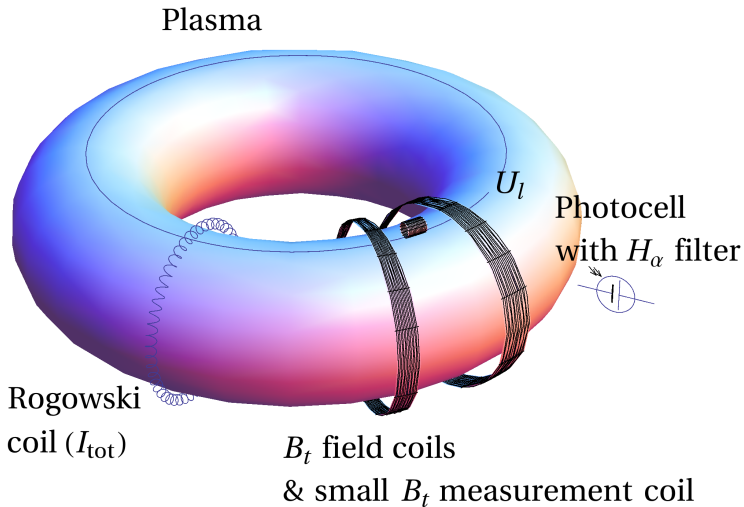
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Tokamak GOLEM - schematic experimental setup



Tokamak GOLEM - basic diagnostics



"Typical", well executed discharge @ GOLEM

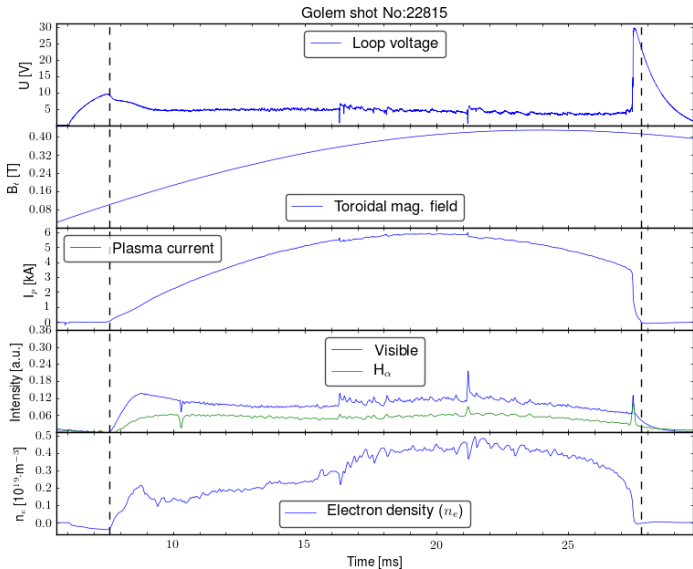


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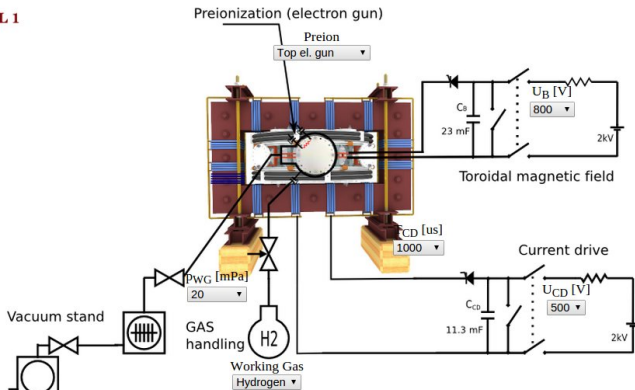
Remote operation

Tokamak Golem ****REMOTE**** for PROMO (Level I)

The smallest & oldest operational tokamak with the biggest control room in the world



LEVEL 1



Default discharge setup

Place the discharge setup into the queue

Note: We use cookies to record last set parameters in your browser to simplify parameter scans.



Diagnostics

- ✓ Interferometer
- ✓ Spectrometer
- ✗ FastCamera
- ✓ HXR

Analysis

- ✓ ShotHomepage

DAS

- ✓ TektronixDPO
- ✓ Nlstandard
- ✓ Papouch_St
- ✓ Papouch_Ko
- ✓ Nloctopus

Vacuum log

Other

- Data
- References
- About
- Wiki
- Utilities

Navigation

- Next
- Previous
- Current

Tokamak GOLEM - Shot Database - 22471

Date: 2016-09-29 - 14:33:57
Session: TrainingCourses/Universities/Uni_Belgrade.rs/2016/
Comment: Standard discharge

Basic parameters: (compare)

- Gas pressure p_{ch} : 0.42 → 20.39 mPa (request: 20 mPa) [WIKI](#)
- Working gas: H
- Preionization: Upper el. gun
- Chamber temperature: 27.20 C
- C_B capacitors charged to: 800 V, triggered 5.0 ms [WIKI](#)
- C_{BD} capacitors charged to: 0 V, triggered 5.0 ms [WIKI](#)
- C_{CD} capacitors charged to: 400 V, triggered 6.0 ms [WIKI](#)
- C_{ST} capacitors charged to: 0 V, triggered 5.0 ms [WIKI](#)
- Probability of breakdown: 85% [WIKI](#)
- Time since session beginning: 0:07:50 h

Plasma parameters:

- Plasma life time 14.8 [ms] (from 7.8 to 22.6)
- Mean toroidal magnetic field B_t : 0.23 T [WIKI](#)
- Mean plasma current: 3.60 kA [WIKI](#)
- Mean Uloop: 5.92 V [WIKI](#)
- Break down voltage: 9.6 V [WIKI](#)
- Ohmic heating power: 21.33 kW
- Q edge: 2.9 [WIKI](#)
- Electron temperature: 41.1 eV [WIKI](#)
- Line electron density: 5.52 [10^{17}m^{-2}] [WIKI](#)

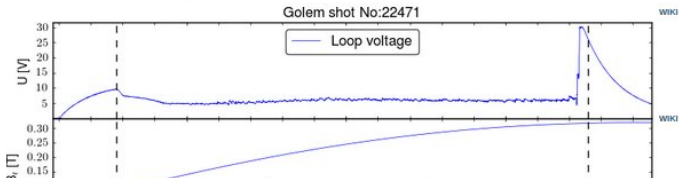
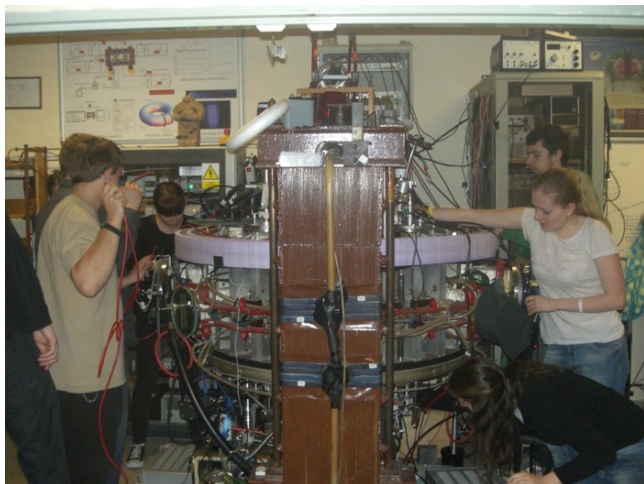


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Hands on tokamak



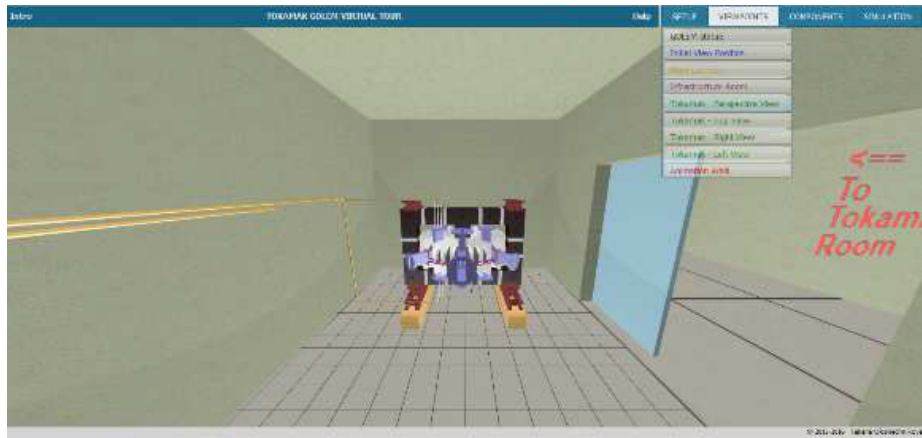
- Laboratory Practice for Basic course of Physics 15,16,17
- Golem Training course 13

Remote controll - inventory



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

TO: Tokamak GOLEM - virtual model



2010 Tokamak GOLEM

