

## Introduction to the tokamak operation (GOLEM specific) - Level 1

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on behalf of the tokamak GOLEM team  
for the National Research Nuclear University MEPhI, Moscow, Russia.

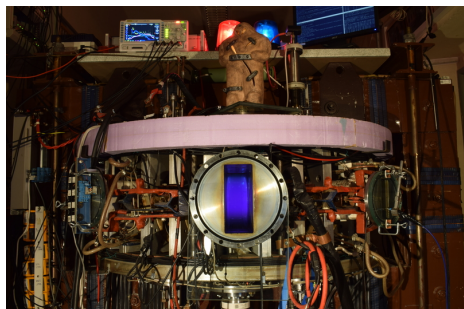
March 31, 2021

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- 2 The Tokamak (GOLEM)
- 3 The Tokamak GOLEM (remote) operation
- 4 Conclusion
- 5 Appendix

# 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

# Tokamak GOLEM @ Wikipedia ..

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## WIKIPEDIA

The Free Encyclopedia

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# Tokamak

From Wikipedia, the free encyclopedia

*This article is about the fusion reaction device. For other uses, see Tokamak (disambiguation).*

A **tokamak** (Russian: **токамак**) is a device that uses a powerful magnetic field to confine plasma in the shape of a torus. Achieving a stable plasma equilibrium requires magnetic field lines that move around the torus in a helical shape. Such a helical field can be generated by adding a toroidal field


it decays into a proton and electron with the emission of energy. When the time comes to actually try to make electricity from a tokamak-based reactor, some of the neutrons produced in the fusion process would be absorbed by a liquid metal blanket and their kinetic energy would be used in heat-transfer processes to ultimately turn a generator.

## Experimental tokamaks [ edit ]

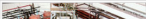
### Currently in operation [ edit ]

(in chronological order of start of operations)

- 1960s: TM1-MH (since 1977 Castor; since 2007 Golem<sup>[12]</sup>) in Prague, Czech Republic. In operation in Kurchatov Institute since early 1960s but renamed to Castor in 1977 and moved to IPP CAS,<sup>[13]</sup> Prague; in 2007 moved to FNSPE, Czech Technical University in Prague and renamed to Golem,<sup>[14]</sup>
- 1975: T-10, in Kurchatov Institute, Moscow, Russia (formerly Soviet Union); 2 MW
- 1983: Joint European Torus (JET), in Culham, United Kingdom
- 1985: JT-60, in Naka, Ibaraki Prefecture, Japan; (Currently undergoing upgrade to Super, Advanced model)
- 1987: STOR-M, University of Saskatchewan; Canada; first demonstration of alternating current in a tokamak.
- 1988: Tore Supra,<sup>[15]</sup> at the CEA, Cadarache, France
- 1989: Aditya, at Institute for Plasma Research (IPR) in Gujarat, India
- 1980s: DIII-D,<sup>[16]</sup> in San Diego, USA; operated by General Atomics since the late 1980s
- 1989: COMPASS,<sup>[13]</sup> in Prague, Czech Republic; in operation since 2008, previously operated from 1989 to 1999 in Culham, United Kingdom
- 1990: FTU, in Frascati, Italy
- 1991: Tokamak ISTOK,<sup>[17]</sup> at the Instituto de Plasmas e Fusão Nuclear, Lisbon, Portugal;
- 1991: ASDEX Upgrade, in Garching, Germany



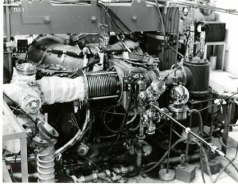
Alcator C-Mod





# The GOLEM tokamak for education - historical background

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



1974

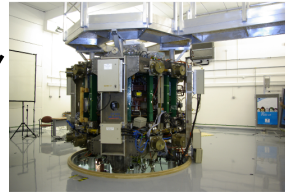


Institute of Plasma Physics  
Czech republic  
**CASTOR**      **COMPASS**

2006



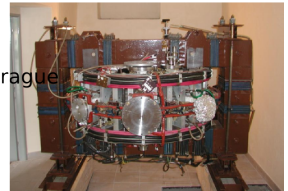
Culham Centre for Fusion Energy  
Great Britain  
1989: **COMPASS-D**



2008



Czech Technical University Prague  
Czech republic  
**GOLEM**



# GOLEM

... somewhere, in the ancient cellars of Prague,

*there is hidden indeed "infernal" power. Yet it is the very power of celestial stars themselves. Calmly dormant, awaiting mankind to discover the magic key, to use this power for their benefit...*

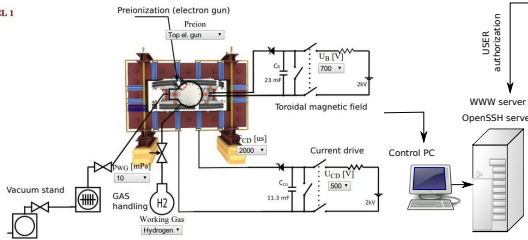


At the end of the 16th century, in the times when the Czech lands were ruled by Emperor Rudolf II, in Prague, there were Rabbi Judah Loew, well known alchemist, thinker, scholar, writer and inventor of the legendary GOLEM - a clay creature inspired with the Universe power that pursued his master's command after being brought to life with a shem, . 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. [1].

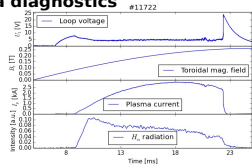
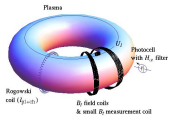
# The global schematic overview of the GOLEM experiment

LEVEL 1

## Tokamak technology setup



## Basic plasma diagnostics



internet

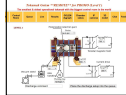
Virtual control room  
(remote participation)

WWW control interface

Data presentation

HTML & PHP scripts

HTML (www pages)



SSH control interface

WINDOWS via putty

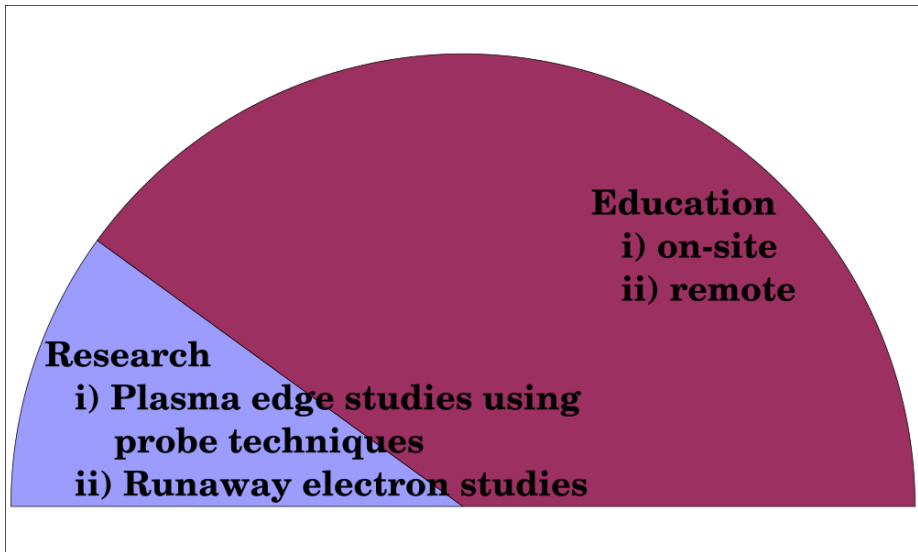
Data handling



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

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

# The GOLEM tokamak mission



## **Research**

- i) Plasma edge studies using probe techniques**
- ii) Runaway electron studies**

## **Education**

- i) on-site**
- ii) remote**

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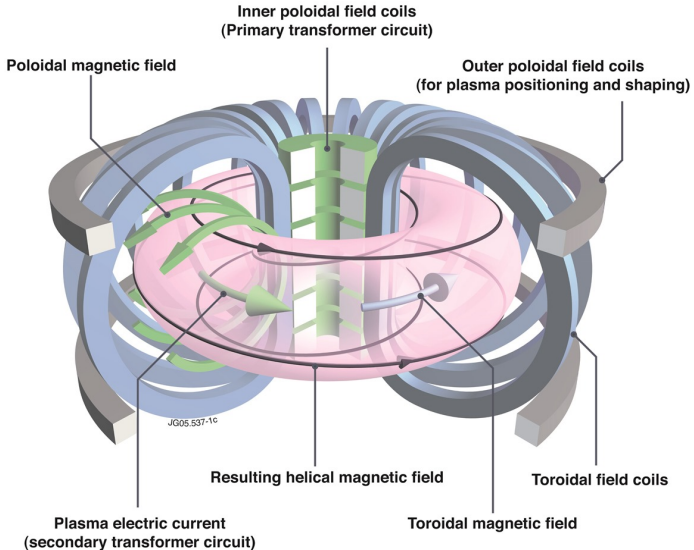
**2 The Tokamak (GOLEM)**

3 The Tokamak GOLEM (remote) operation

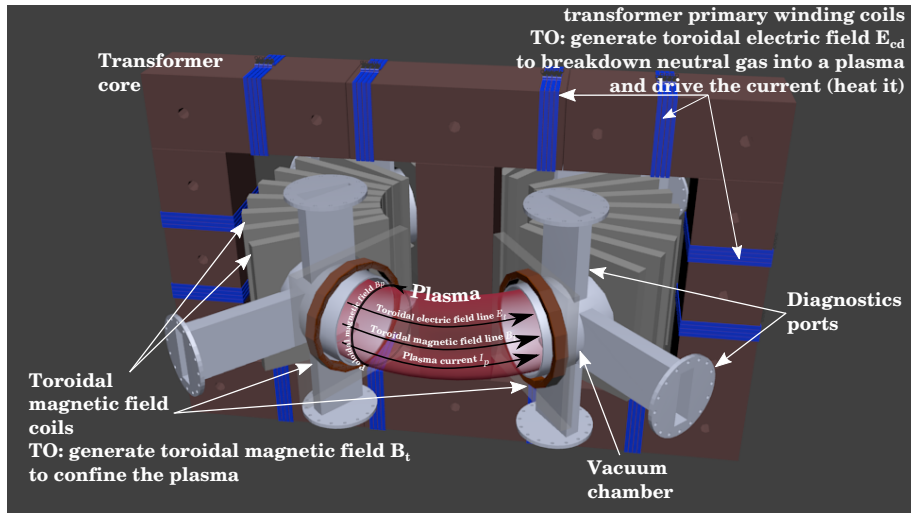
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# Tokamak magnetic confinement concept



# Tokamak (GOLEM) basic concept to confine and heat the plasma



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- The scenario to discharge virtually
- The GOLEM tokamak basic diagnostics
- The GOLEM tokamak - guide tour

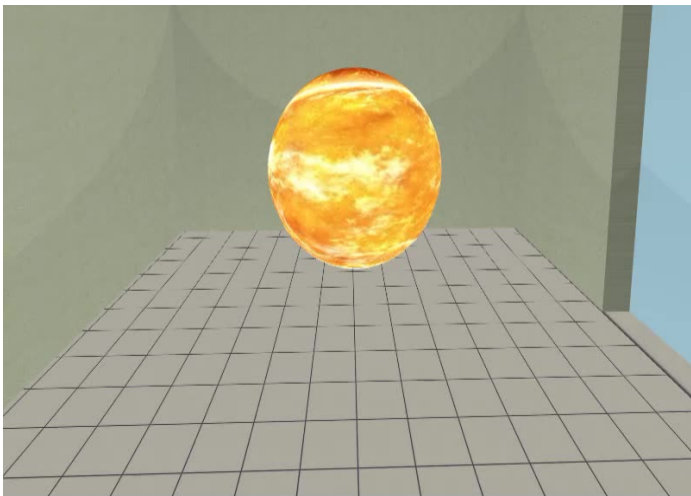
## 3 The Tokamak GOLEM (remote) operation

## 4 Conclusion

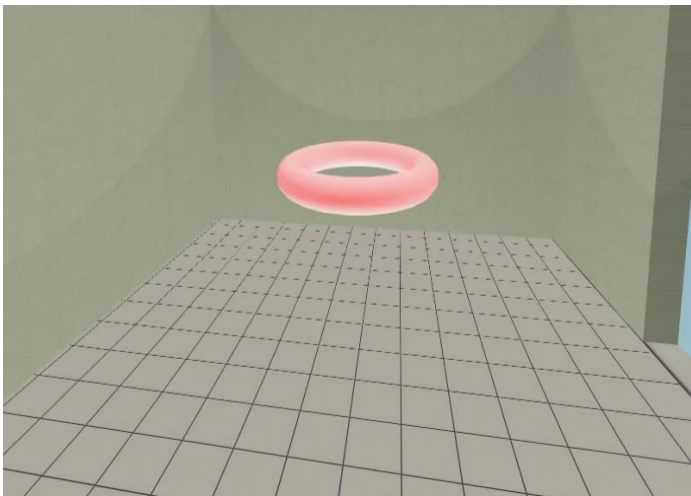
## 5 Appendix



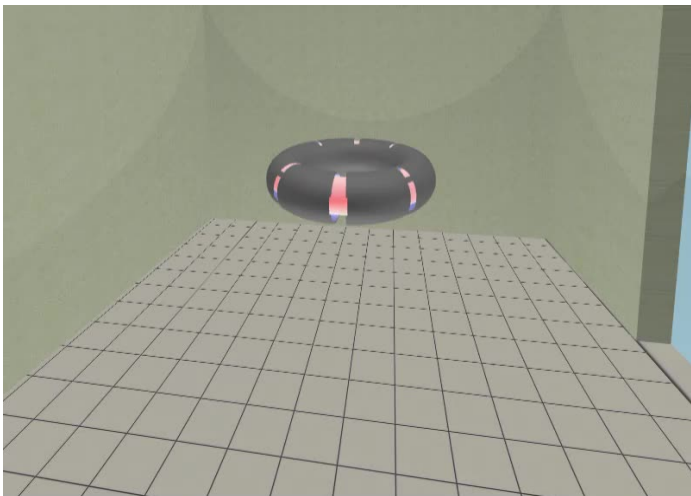
Our goal: the technology to create a  $\mu$ Sun on the Earth



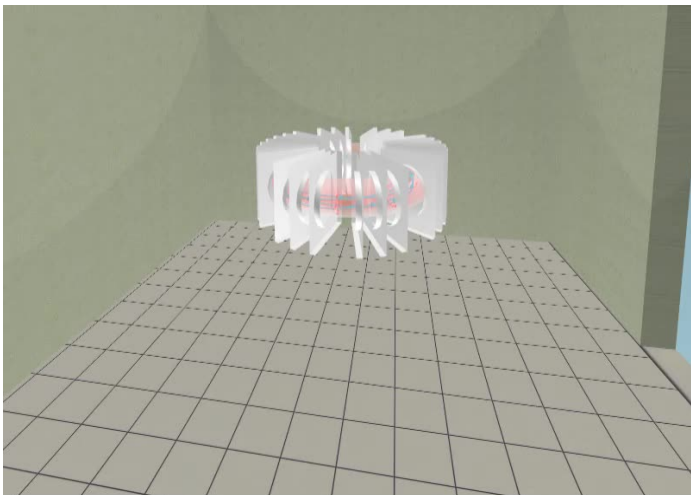
# Magnetic confinement requires toroidal geometry



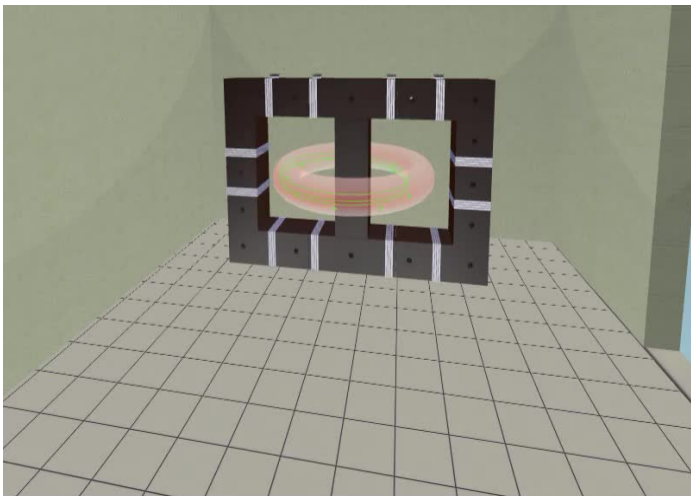
A chamber contains the thermonuclear reaction



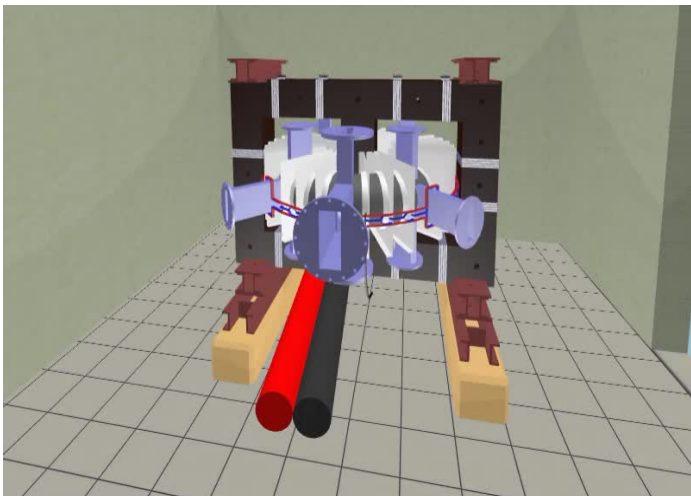
# Toroidal magnetic field coils confine the plasma



A transformer action creates and heats the plasma



# The final technology altogether



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## 3 The Tokamak GOLEM (remote) operation

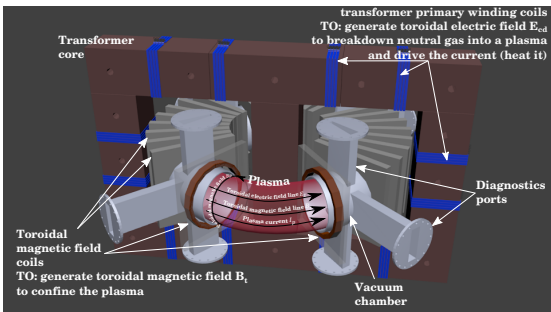
## 4 Conclusion

## 5 Appendix

# 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

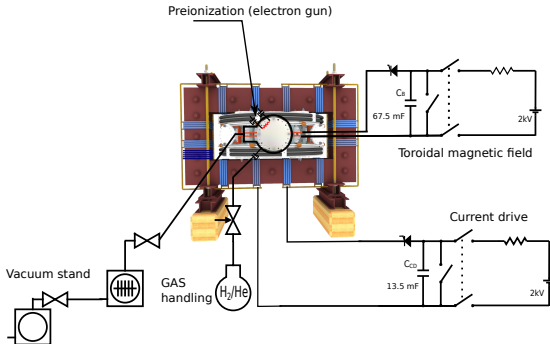




# Plasma in Tokamak (GOLEM) - the least to do

## To do:

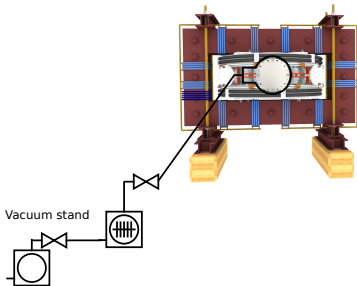
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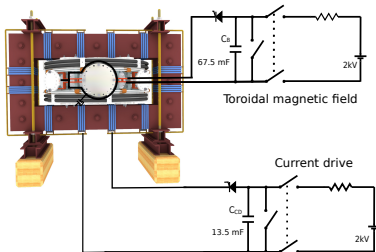
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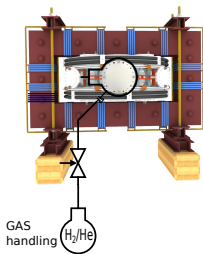
# Plasma in Tokamak (GOLEM) - the least to do



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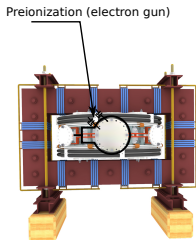
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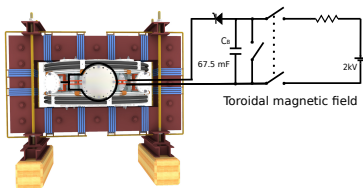
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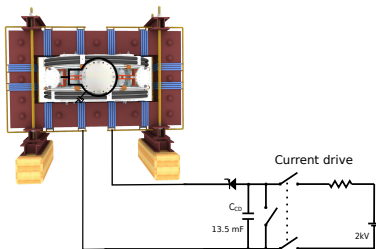
# Plasma in Tokamak (GOLEM) - the least to do



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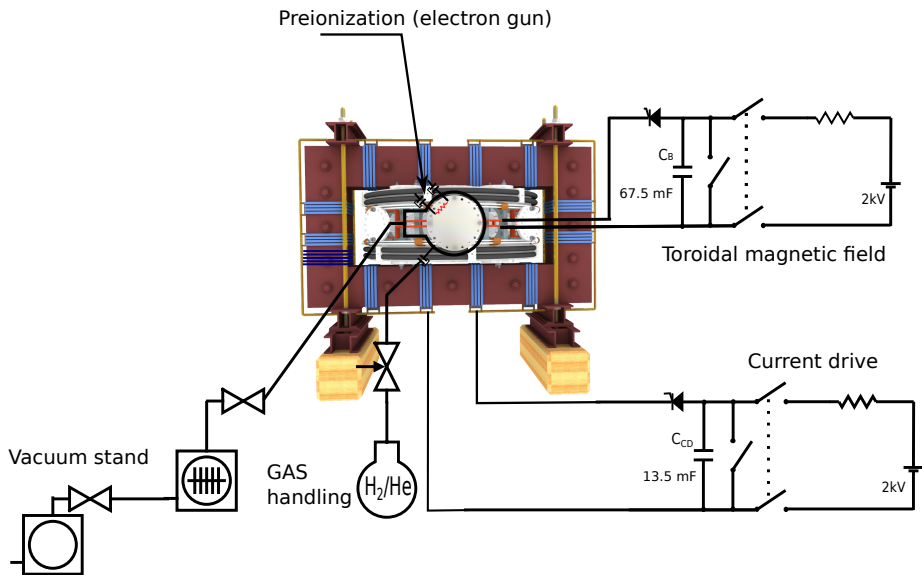
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# Tokamak GOLEM - schematic experimental setup





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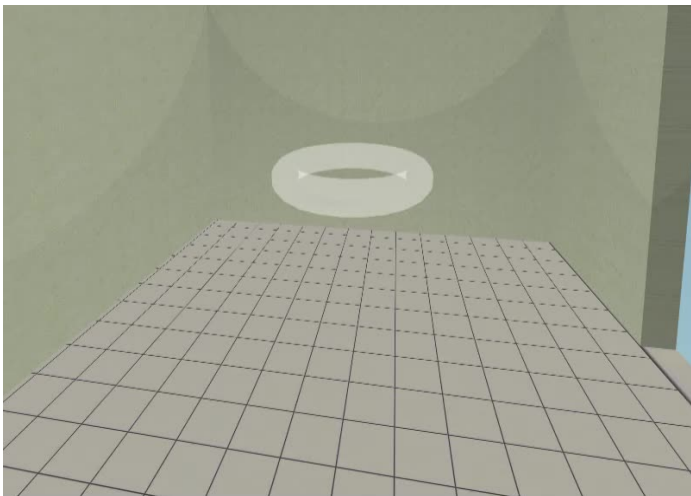
- The GOLEM tokamak concept
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## 3 The Tokamak GOLEM (remote) operation

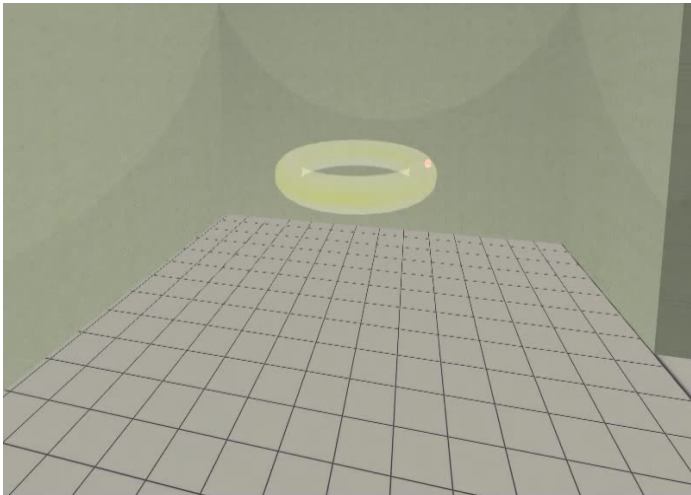
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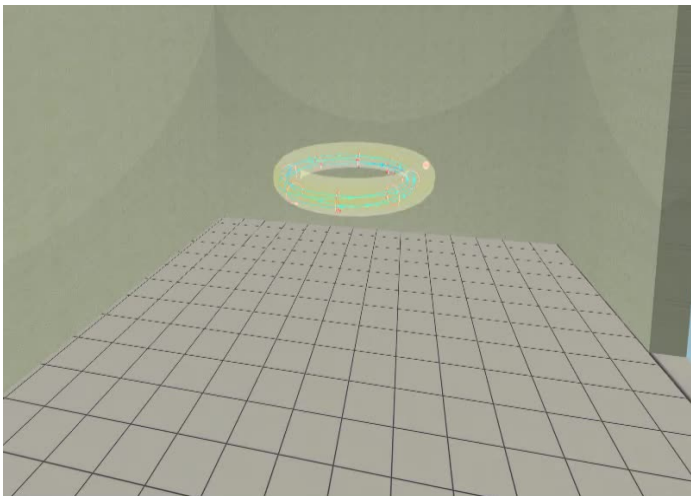
Introduce the working gas (Hydrogen x Helium)



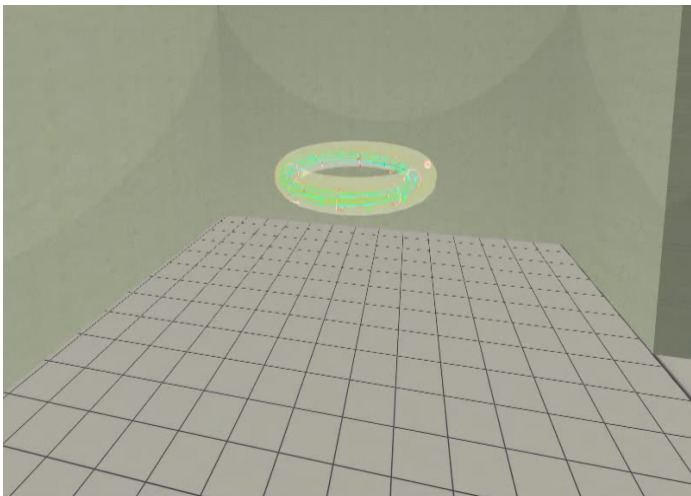
Switch on the preionization



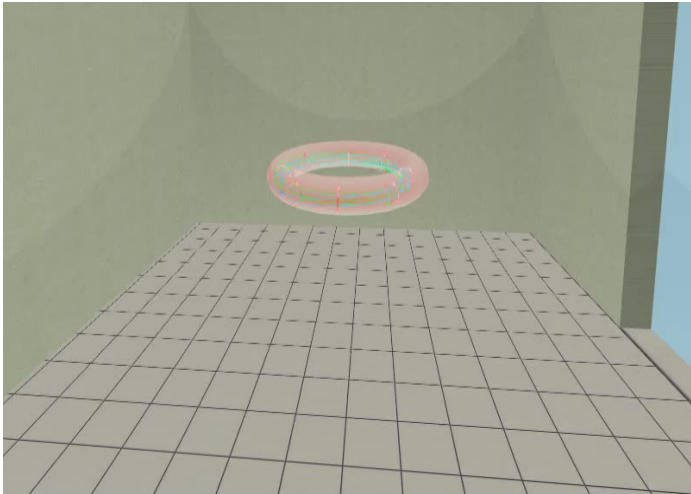
# Introduce the magnetic field



# Introduce the electric field



# Plasma ..



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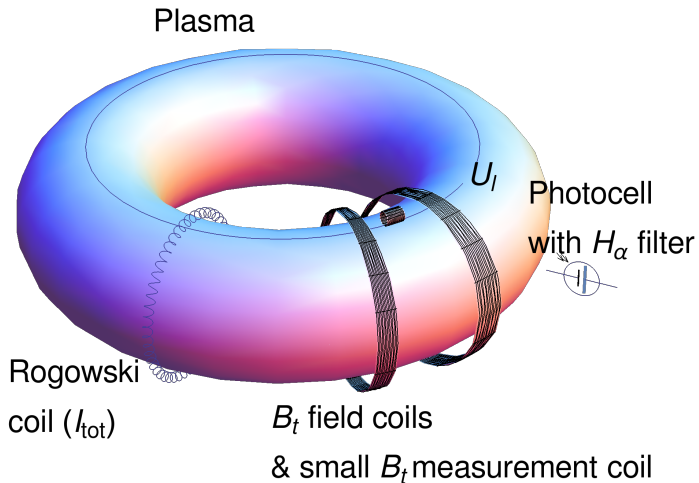
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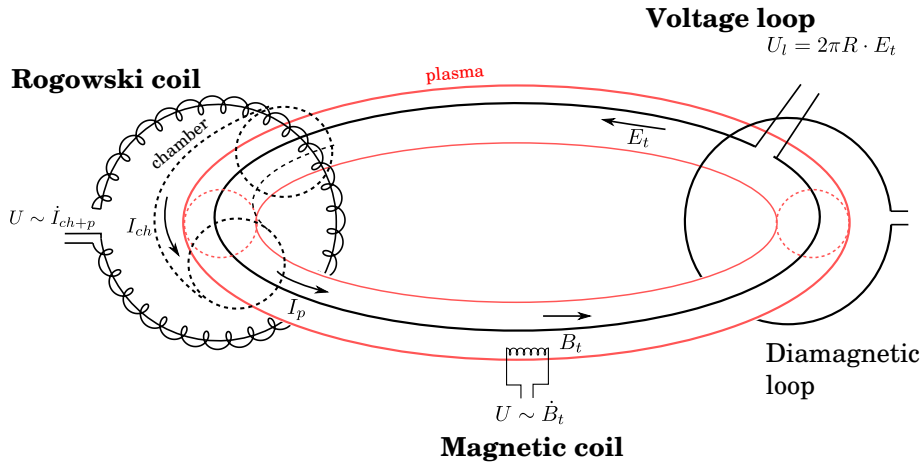
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# The GOLEM tokamak - basic diagnostics

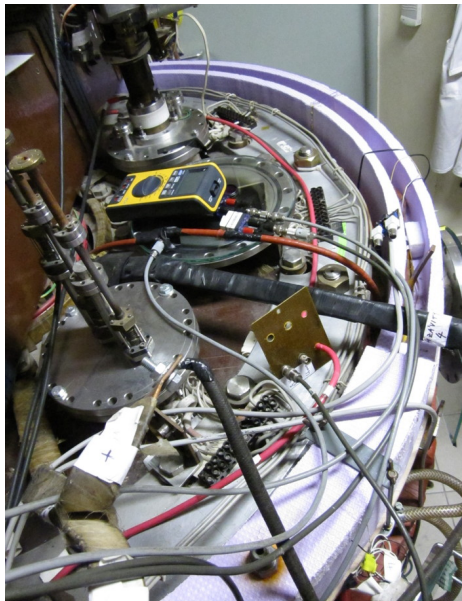
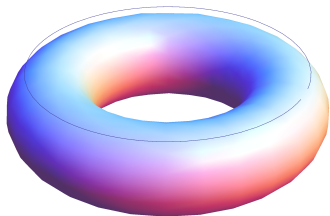




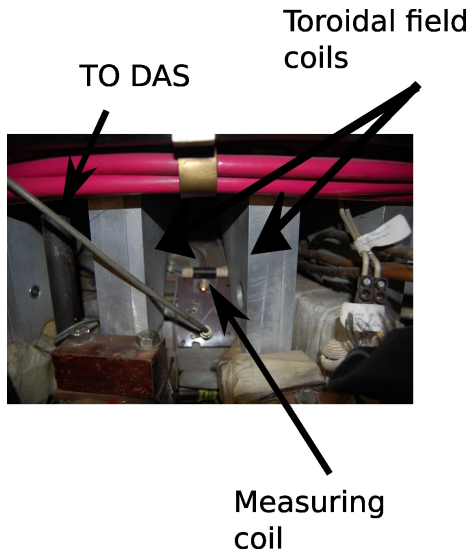
# Schematic of electromagnetic diagnostics



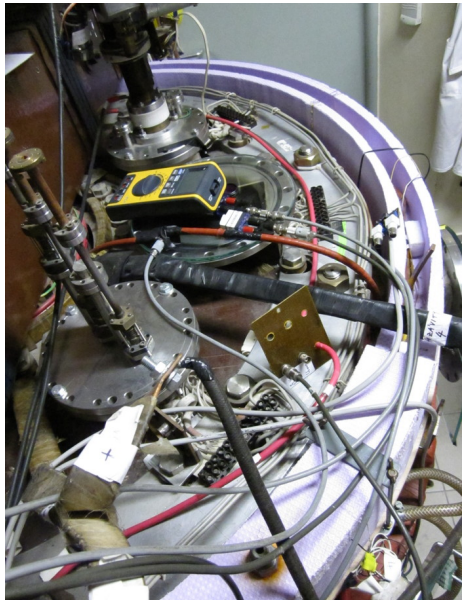
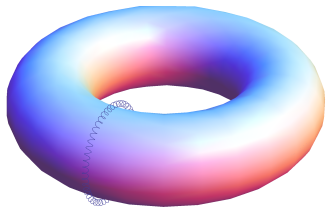
# Loop voltage $U_l$ @ the GOLEM tokamak



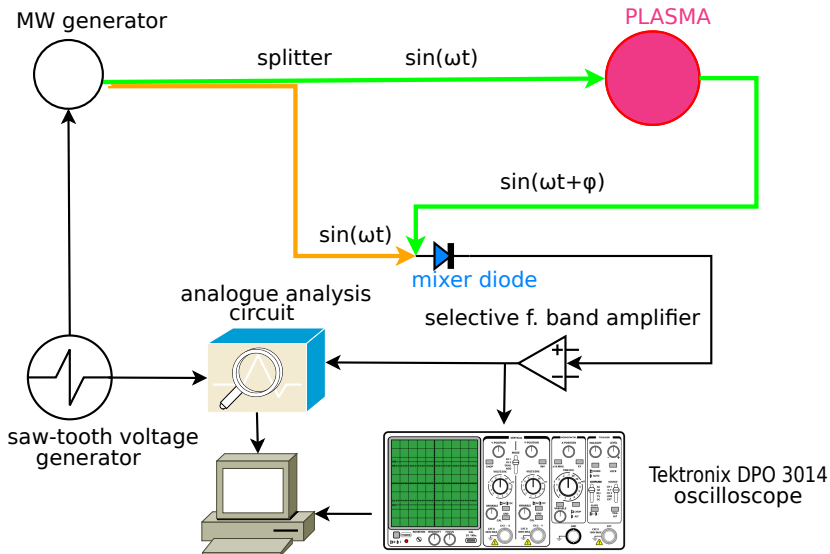
# Toroidal magnetic field $B_t$ @ the tokamak GOLEM



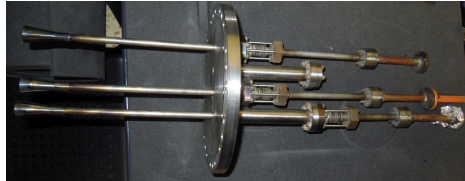
Total current  $I_{ch+p}$



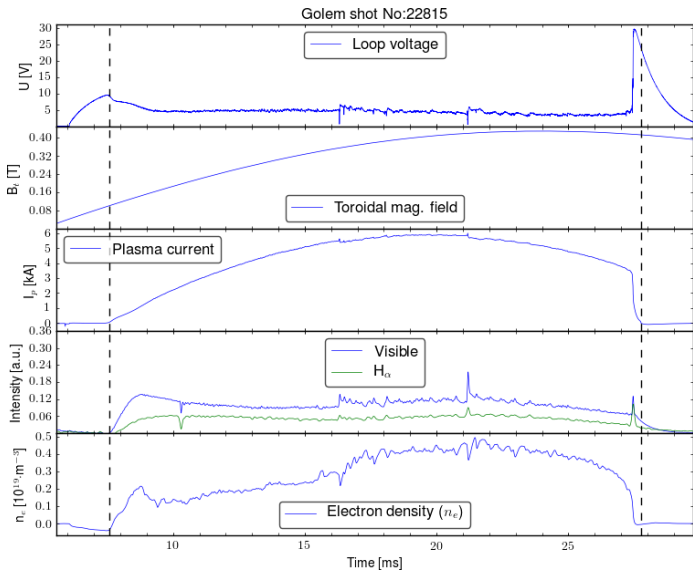
# Electron density $n_e$ interferometry measurement scheme



# The GOLEM tokamak interferometry HW



# "Typical", well executed discharge @ GOLEM



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# Infrastructure room (below tokamak) 10/16



# Infrastructure room (below tokamak) 10/16

Current drive CD field  
and toroidal magnetic Bt field  
circuits

To the tokamak  
GOLEM

Rotary  
pump

Vacuum  
control

Current drive CD  
capacitors

Plasma  
stabilization

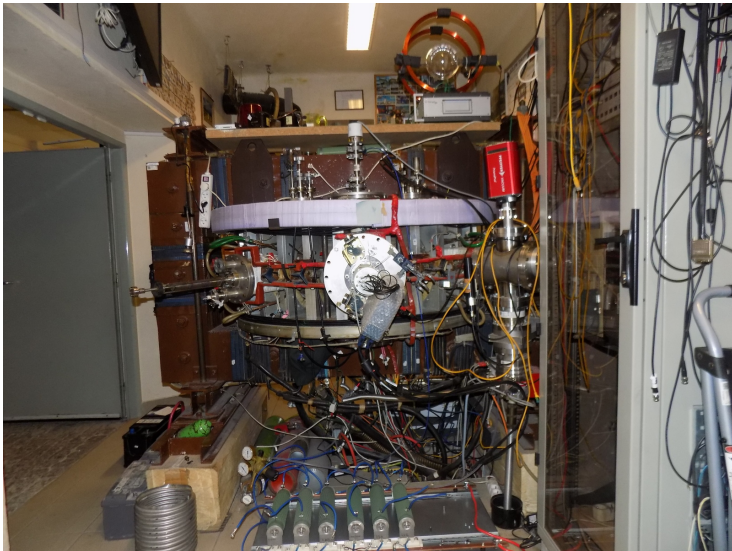
power  
supply  
2kV

Toroidal  
magnetic field B  
capacitors

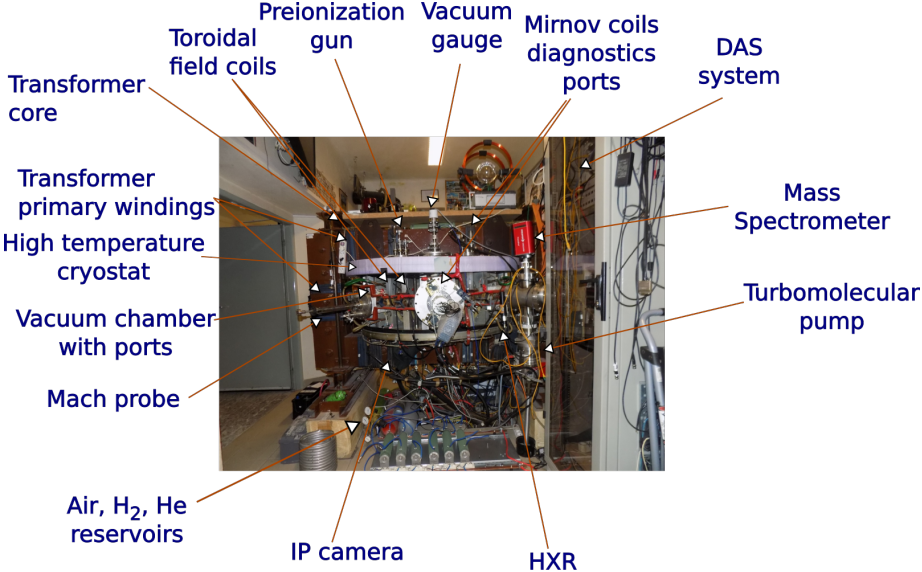
fire  
protection  
system



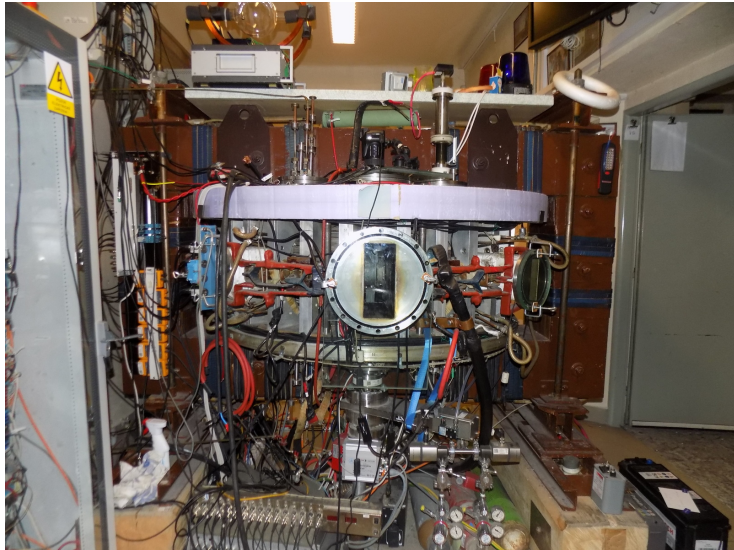
# Tokamak room (North) 10/16



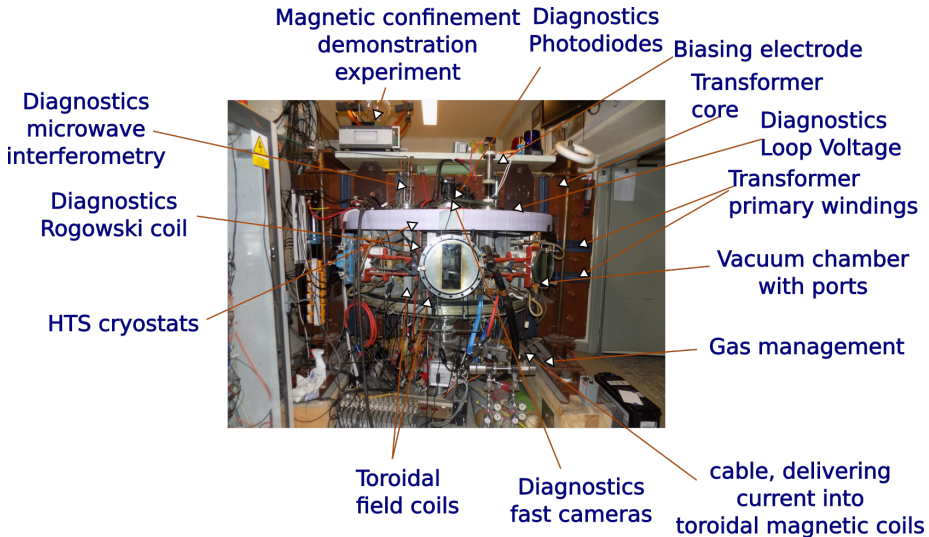
# Tokamak room (North) 10/16



# Tokamak room (South) 10/16



# Tokamak room (South) 10/16



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# Control room: Introduction

GOLEM remote Introduction **Control room** Live Results Prague Access: Level 1 Help

Introduction Working gas Preionization Magnetic field Current drive Submit

This web interface will walk you through the process of configuring a discharge in the GOLEM tokamak. All settable values are perfectly safe. Proceed through each step by setting the desired values and then clicking the [Next](#) button. You can always go to a specific step by clicking its tab.

**Preionization (electron gun)**

Vacuum stand

Preionization (electron gun)

Toroidal magnetic field

Current drive

GAS handling  $H_2/H_3$

[Next](#)

3D model rendering method: [Static image \(fast\)](#) [Interactive X3DOM \(slower\)](#)

# Control room: Working gas

GOLEM remote    Introduction    **Control room**    Live    Results

Introduction    **Working gas**    Preionization    Magnetic field    Electric field    Submit

Set the pressure and type of the working gas from which the plasma is formed. Pressure must be high enough for plasma to form, but low enough for gas breakdown to occur.

### Preionization (electron gun)

Vacuum stand

GAS handling  $H_2/Hg$

Toroidal magnetic field  $67.5 \text{ mF}$

Toroidal electric field  $13.5 \text{ mF}$

200V

200V

Gas type and pressure  $p_{\text{gas}} = 38 \text{ mPa}$

Hydrogen    Helium

Next    Set recommended value

3D model rendering method:    **Static image (fast)**    Interactive X3DOM (slower)

# Control room: Preionization

GOLEM remote    PREIONIZATION    Control room    Live    Results

Introduction    Working gas    **Preionization**    Magnetic field    Electric field    Submit

The neutral working gas must be first ionized in order to break down into a plasma. Using the electron gun will locally ionize the gas. Without any ionization, no plasma can form.

### Preionization (electron gun)

Vacuum stand

GAS handling

Toroidal magnetic field

Toroidal electric field

67.5 mF

13.5 mF

230V

230V

ionization method

Steady gas     No ionization

[Next](#)

3D model rendering method    [Static image \(fast\)](#)    [Interactive X3DOM \(slower\)](#)

# Control room: Magnetic field $B_t$

GOLEM interface: Introduction, Preionization, **Magnetic field**, Electric field, Submit

Press F11 to exit full screen  
3D model rendering method: **Static image (fast)** Interactive X3DOM (slower)

Set the voltage on the capacitors to be discharged into the toroidal field coils. The higher the voltage, the larger the magnetic field confining the plasma.

Preionization (electron gun)

Vacuum stand

67.5 mF

2kV

Toroidal magnetic field

Toroidal electric field

20V

13.5 mF

GAS handling

Capacitor voltage  $U_{C_1} = 600$  V

Next Set recommended value

# Control room: Current drive $E_{cd}$

GOLEM homepage    Introduction    Control room    Live    Results

the Torion Politecnico, Italy Group 1    Access: Level 2    Help

Introduction    Working gas    Preionization    Magnetic field    **Electric field**    Submit

Set the voltage on the capacitors to be discharged into the **primary transformer winding**. The higher the voltage, the larger the electric field creating and heating the plasma. The electric field capacitors are discharged after a configurable delay with respect to the magnetic field capacitors.

Preionization (electron gun)

Vacuum stand

Toroidal magnetic field

Toroidal electric field

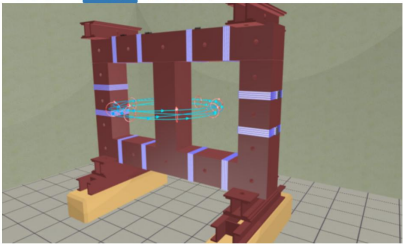
GAS handling

Time delay of electric field start after the magnetic field starts  $t_d$ : 0 micro seconds

Capacitor voltage  $U_c$ : 400 V

Next    Set recommended value

3D model rendering method:    **Static image (fast)**    Interactive X3DOM (slow)



The screenshot displays the control room interface for the GOLEM tokamak. The main window is titled 'Electric field' and contains a 3D model of the tokamak structure on the right and a schematic diagram on the left. The schematic diagram shows a vacuum stand with a central chamber, connected to a toroidal magnetic field and a toroidal electric field. It includes a capacitor labeled  $C_m$  with a value of 67.5 mF and a 2kV source. Another capacitor labeled  $C_e$  with a value of 13.5 mF is connected to a 2kV source. The interface also features a slider for the time delay  $t_d$  (set to 0 micro seconds) and a slider for the capacitor voltage  $U_c$  (set to 400 V). A 'Next' button and a 'Set recommended value' button are visible at the bottom. The top navigation bar includes 'Introduction', 'Working gas', 'Preionization', 'Magnetic field', 'Electric field', and 'Submit'. The top right corner shows the user 'the Torion Politecnico, Italy Group 1', 'Access: Level 2', and 'Help'.

# Control room: ... and Submit

The screenshot displays the Golem control room interface. At the top, a navigation bar includes 'Golem', 'Introduction', 'Control room', 'Live', and 'Results'. On the right, it shows the user 'The Torino Politecnico, Italy Group 1', 'Access: Level 2', and a 'Help' icon.

The main content area is divided into two sections:

- Submission Form:** Located on the left, it features a horizontal menu with tabs for 'Introduction', 'Working gas', 'Preionization', 'Magnetic field', 'Electric field', and 'Submit'. Below the menu, there is a text input field with the instruction: "Write a comment describing your discharge configuration, i.e. the scientific aim of your experiment. Or just leave a friendly message." A 'Submit' button is positioned to the right of the input field. Below this, a smaller instruction reads: "Click the Submit button to send your configuration into the queue." Further down, another instruction states: "After submission you can watch the discharge Live or go back to the Introduction tab and start again. Or you can go to specific control tabs and reconfigure the discharge and then submit another discharge request." At the bottom of this section are two buttons: 'Watch the discharge Live!' and 'Go back to Introduction'.
- 3D Model:** Located on the right, it shows a 3D rendering of the tokamak device. The model is primarily red and blue, with a central chamber containing a glowing orange-red plasma. Above the model, there are two tabs: 'Static image (left)' and 'Interactive X3DOM (right)'. The model is set against a simple grey background with a tiled floor.

# Shot homepage

GOLEM » Shot #22471 »



## Diagnostics

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

## Analysis

- ✓ ShotHomepage

## DAS

- ✓ TektronixDPO
- ✓ NIstandard
- ✓ Papouch\_St
- ✓ Papouch\_Ko
- ✓ Nloctopus

## Vacuum log

## Other

- Data
- References
- About
- Wiki
- Utilities

## Navigation

- Next
- Previous

## Tokamak GOLEM - Shot Database - 22471

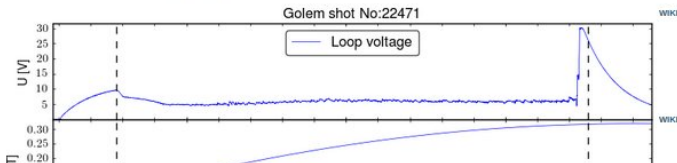
**Date:** 2016-09-29 - 14:33:57  
**Session:** TrainingCourses/Universities/Uni\_Belgrade.rs/2016/  
**Comment:** Standard discharge

### Basic parameters: (compare)

- Gas pressure  $p_{ch}$ : 0.42 → 20.39 mPa (request: 20 mPa) <sup>WIKI</sup>
- Working gas: H
- Preionization: Upper el. gun
- Chamber temperature: 27.20 C
- $C_B$  capacitors charged to: 800 V, triggered 5.0 ms <sup>WIKI</sup>
- $C_{BD}$  capacitors charged to: 0 V, triggered 5.0 ms <sup>WIKI</sup>
- $C_{CD}$  capacitors charged to: 400 V, triggered 6.0 ms <sup>WIKI</sup>
- $C_{ST}$  capacitors charged to: 0 V, triggered 5.0 ms <sup>WIKI</sup>
- Probability of breakdown: 85% <sup>WIKI</sup>
- 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 <sup>WIKI</sup>
- Mean plasma current: 3.60 kA <sup>WIKI</sup>
- Mean Uloop: 5.92 V <sup>WIKI</sup>
- Break down voltage: 9.6 V <sup>WIKI</sup>
- Ohmic heating power: 21.33 kW
- Q edge: 2.9 <sup>WIKI</sup>
- Electron temperature: 41.1 eV <sup>WIKI</sup>
- Line electron density: 5.52 [ $10^{17} m^{-2}$ ] <sup>WIKI</sup>



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- 1 Introduction
- 2 The Tokamak (GOLEM)
- 3 The Tokamak GOLEM (remote) operation**
  - Control room
  - Data handling @ the Tokamak GOLEM
- 4 Conclusion
- 5 Appendix



# GOLEM basic Data Acquisition System (DAS)

- $U_I, U_{B_t}, U_{I_{p+ch}}, I_{rad}$
- $\Delta t = 1\mu s / f = 1MHz$ .
- Integration time = 40 ms, thus DAS produces 6 columns x 40000 rows data file.
- Discharge is triggered at 5th millisecond after DAS to have a zero status identification.



Data file example, DAS  $\Delta t = 1\mu s / f = 1MHz$  (neutral gas into plasma breakdown focused)

$t$	$\approx U_I$	$\approx U_{\frac{dB_T}{dt}}$	$\approx U_{\frac{d(I_{p+ch})}{dt}}$	$\approx I_{rad}$
:	:	:	:	:
:	:	:	:	:
first	$\approx$	7405	lines ..	:
:	:	:	:	:
:	:	:	:	:
0.007383	1.53931	0.390015	0.048828	0.001831
0.007384	1.53686	0.395508	0.067749	0.00061
0.007385	1.54053	0.391235	0.079956	0.00061
0.007386	1.53686	0.38147	0.072632	0
0.007387	1.54297	0.397949	0.059204	0.00061
0.007388	1.54053	0.384521	0.05249	0.00061
0.007389	1.54053	0.39856	0.068359	0.001221
0.00739	1.54053	0.393677	0.082397	0.001221
0.007391	1.53809	0.38208	0.072632	0.001221
0.007392	1.54297	0.400391	0.056763	0.00061
0.007393	1.54419	0.383911	0.053101	0.00061
0.007394	1.53931	0.397339	0.068359	0.001221
0.007395	1.54297	0.391846	0.084229	0.00061
0.007396	1.54541	0.394897	0.074463	0.00061
0.007397	1.54297	0.388184	0.056763	0.001221
0.007398	1.54297	0.391846	0.056763	0.00061
0.007399	1.54297	0.394287	0.06897	0.00061
:	:	:	:	:
:	:	:	:	:
next	$\approx$	32500	lines ..	:
:	:	:	:	:
:	:	:	:	:

## Data access

All the recorded data and the settings for each discharge (shot) are available at the GOLEM website. The root directory for the files is:

```
http://golem.fjfi.cvut.cz/shots/<#ShotNo>/
```

The most recent discharge has the web page:

```
http://golem.fjfi.cvut.cz/shots/0
```

Particular data from DAS or specific diagnostics have the format:

```
http://golem.fjfi.cvut.cz/utills/data/<#ShotNo>/<identifier>
```

An overview of available data with identifiers, units, description, etc. for each discharge is at

```
http://golem.fjfi.cvut.cz/shots/<#ShotNo>/Data.php
```

# Matlab

```
1 ShotNo=33993
2 baseURL='http://golem.fjfi.cvut.cz/shots/';
3 diagnPATH='/DASs/StandardDAS/LoopVoltageCoil_raw.csv';
4 %Create a path to data
5 dataURL=strcat(baseURL,int2str(ShotNo),diagnPATH);
6 % Write data from GOLEM server to a local file
7 urlwrite(dataURL,'LoopVoltage');
8 % Load data
9 data = load('LoopVoltage', '\t');
10 % Plot and save the graph
11 f = figure('visible', 'off');
12 hold on
13 plot(data(:,1)*1000, data(:,2), '.');
14 xlabel('Time [ms]')
15 ylabel('U_1 [V]')
16 hold off
17 print -djpeg plot.jpg
18 close(f)
19 exit;
```

# Jupyter (python)

```
1 import numpy as np
2 import pandas as pd
3 import matplotlib.pyplot as plt
4 shot_no = 33993
5 data_URL = "http://golem.fjfi.cvut.cz/shots/{shot_no}/DASs/StandardDAS/{
    identifier}.csv"
6 ds = np.DataSource(destpath="/tmp")
7 def open_remote(shot_no, identifier, url_template):
8     return ds.open(url_template.format(shot_no=shot_no, identifier=
    identifier))
9 def read_signal(shot_no, identifier):
10     file = open_remote(shot_no, identifier, data_URL)
11     return pd.read_csv(file, names=["Time", identifier],
12                        index_col="Time", squeeze=True)
13 loop_voltage = read_signal(shot_no, "LoopVoltageCoil_raw")
14 ax = loop_voltage.plot(grid=True)
15 ax.set(xlabel="Time [s]", ylabel="$U_{l}$ [V]", title="Loop voltage $U_{l}$
    {}".format(shot_no));
16
17 plt.savefig("graph.jpg")
```

# Gnuplot

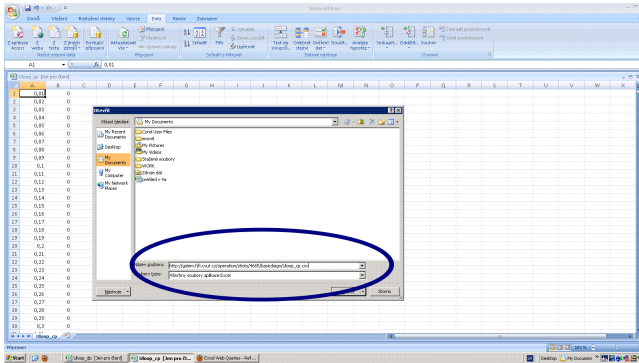
```
1 ShotNo=33993
2 gnuplot -e "set terminal jpeg;set datafile separator ',';set title '
  Uloop';plot '< wget -q -O - http://golem.fjfi.cvut.cz/shots/"$ShotNo
  "/DASs/StandardDAS/LoopVoltageCoil_raw.csv' u 1:2 w l t 'Uloop'" >
  plot.jpg
```

# GNU Wget

GNU Wget is a free software package for retrieving files using HTTP, HTTPS and FTP, the most widely-used Internet protocols. It is a non-interactive commandline tool, so it may easily be called from scripts, cron jobs, terminals without X-Windows support, etc.

- Runs on most UNIX-like operating systems as well as Microsoft Windows.
- Homepage: <http://www.gnu.org/software/wget/>
- Basic usage:
  - To get  $U_l$ : `wget http://golem.fjfi.cvut.cz/utis/data/<#ShotNo>/loop_voltage`
  - To get whole shot: `wget -r -nH -cut-dirs=3 -no-parent -l2 -Pshot http://golem.fjfi.cvut.cz/shots/<#ShotNo>`

# Excel



File→Open→

`http://golem.fjfi.cvut.cz/utis/data/<#ShotNo>/<identifier>`

Spreadsheets (Excel and others)

are not recommended, only tolerated.

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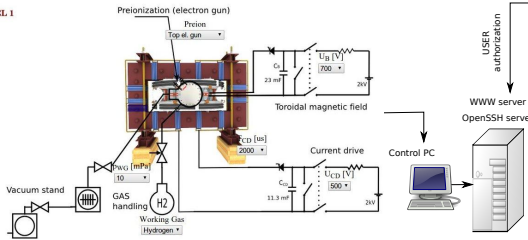
- 1 Introduction
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# The global schematic overview of the GOLEM experiment

LEVEL 1

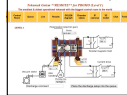
## Tokamak technology setup



**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

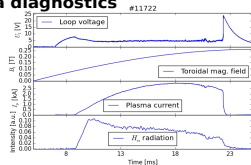
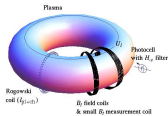
HTML (www pages)



Data handling

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

## Basic plasma diagnostics



# Fee: postcard from the venue of remote measurements



# Acknowledgement

## Financial support highly appreciated:

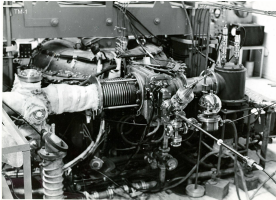
CTU RVO68407700, SGS 17/138/OHK4/2T/14, GAČR GA18-02482S, EU funds CZ.02.1.01/0.0/0.0/16\_019/0000778 and CZ.02.2.69/0.0/0.0/16\_027/0008465, IAEA F13019, FUSENET and EUROFUSION.

## Students, teachers, technicians (random order):

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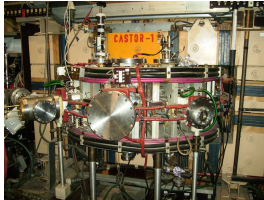
# Thank you for your attention

**Tokamak TM1**  
@Kurchatov Institute near Moscow  
~1960-1977



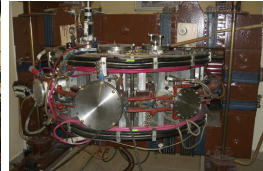
**SCIENCE**

**Tokamak CASTOR**  
@Institute of Plasma Physics, Prague  
1977-2007



**SCIENCE**  
& education

**Tokamak GOLEM**  
@Czech Technical University, Prague  
2007-



**EDUCATION**  
& science

... with the biggest  
control room  
in the world ..

**Tokamak Golem \*\*REMOTE\*\* for MASTER (Level 1)**  
The smallest & oldest operational tokamak with the biggest control room in the world

Home WB Control Room Queue Live Results GOLEM diagram Chamber status IP camera 3D model Chat Feedback Login

**LEVEL 1**

Preionization (electron gun)  
Press: 1

Toroidal magnetic field

Current drive

Vacuum stand  
GAS handling  
Working Gas

Discharge comment

Place the discharge setup into the queue

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# References I

- [1] Wikipedia contributors. Golem — Wikipedia, the free encyclopedia. <https://en.wikipedia.org/w/index.php?title=Golem>, 2020. [Online; accessed 29-March-2020].
- [2] J. Wesson. *Tokamaks*, volume 118 of *International Series of Monographs on Physics*. Oxford University Press Inc., New York, Third Edition, 2004.
- [3] V. Svoboda, B. Huang, J. Mlynar, G.I. Pokol, J. Stockel, and G Vondrasek. Multi-mode Remote Participation on the GOLEM Tokamak. *Fusion Engineering and Design*, 86(6-8):1310–1314, 2011.
- [4] Brotankova, J. *Study of high temperature plasma in tokamak-like experimental devices*. PhD thesis, 2009.
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