

Title

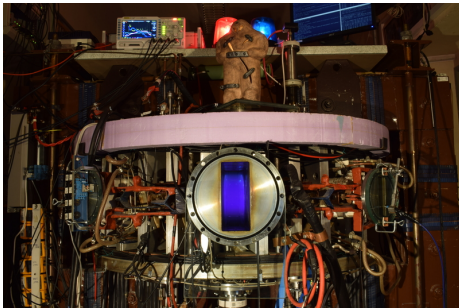
The GOLEM tokamak for Fusion Education

Vojtěch Svoboda
on behalf of the GOLEM tokamak team

Promo

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

The GOLEM tokamak for education - historical background

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



1974

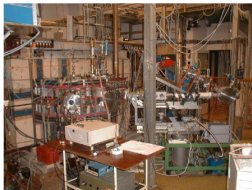
Institute of Plasma Physics
Czech republic

CASTOR

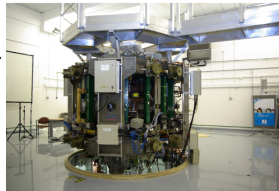
COMPASS

2008

Czech Technical University Prague
Czech republic
GOLEM



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



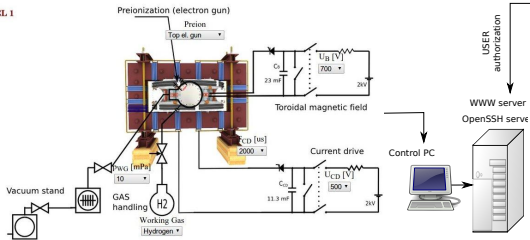
2006



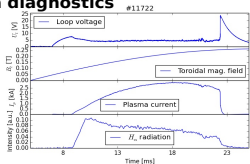
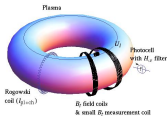
The global schematic overview of the GOLEM experiment

LEVEL 1

Tokamak technology setup



Basic plasma diagnostics



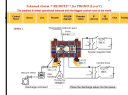
internet



**Virtual control room
(remote participation)**

WWW control interface

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...

WWW server
OpenSSH server

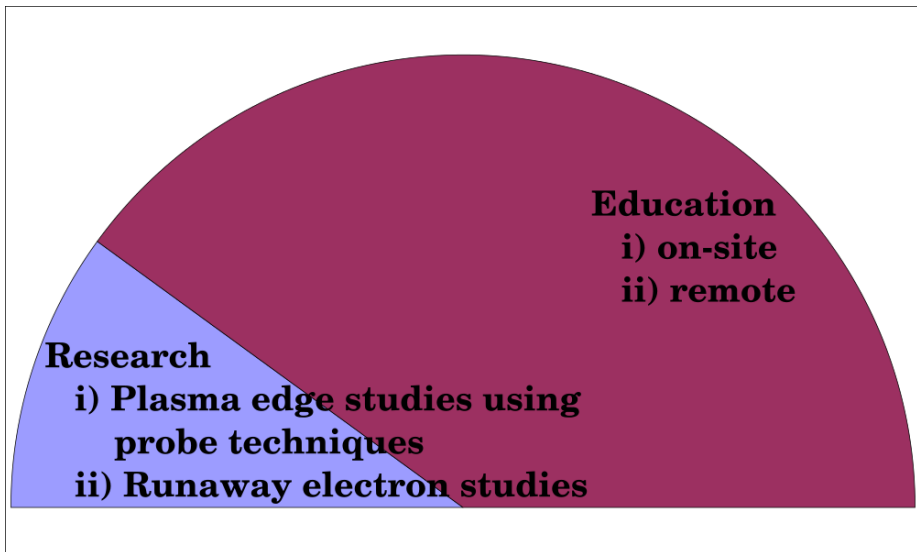


OpenSSH server



Control PC

The GOLEM tokamak mission



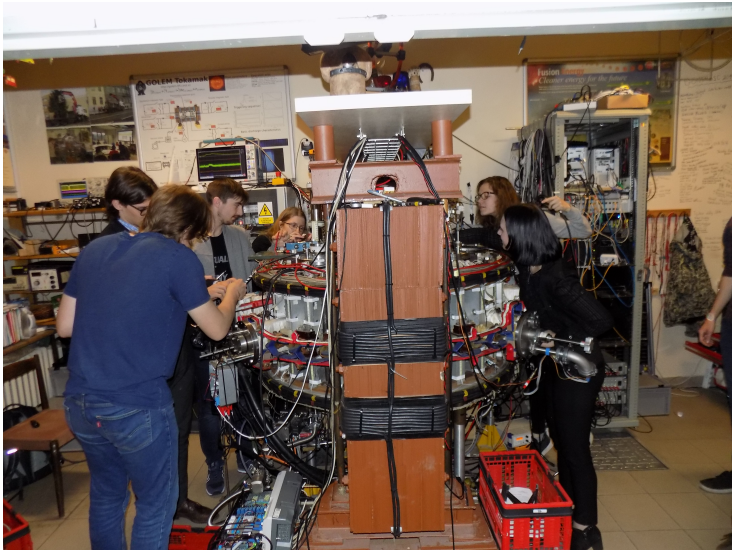
Research

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

Education

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

On site education - basic laboratory training (Hands on tokamak experiment)



Remote education: CEA France & Czech Technical University for Chiang Mai university on February, 2018)

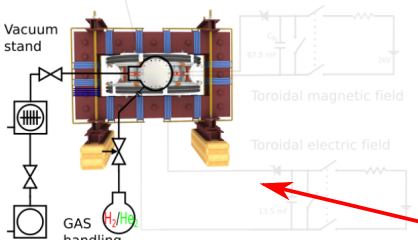


Remote control interface of the GOLEM tokamak

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/He

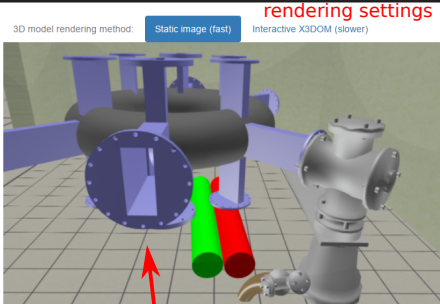
Toroidal magnetic field

Toroidal electric field

Gas type and pressure $p_{WG} = 16 \text{ mPa}$

Hydrogen Helium

Next Set recommended value



3D model rendering


engineering scheme

sliders and checkboxes

workflow buttons

Shot homepage (≈ 2 minutes after discharge execution)

GOLEM # Shot #40631
autoreload



Diagnostics

BasicDiagnostics
DontUseRakeProbe
Interferometry
LimiterMicroCoils
ScribbleRakeProbes

Other

View
Showroom

Navigation

Next
Previous
Current

Go to shot
40631

Golem utils

Home
Plot data
Shot manual plot
Manipulators control

Database operations

Shots listing
Shots filtering

Tokamak GOLEM - Shot Database - #40631

The date of discharge execution 23-02-07 17:23:54

The session mission 1Final -> Dringit service

The session ID 40605

The discharge comment Rake probe 50mm

Discharge command jDringit.sh --discharge --UBt 800 --Tbt 0 --Utd 450 --Tod 500 --preionization 1 --gas H --pre issue 15 --diagnostics.limitermicrocoils.vacuum_shot=40615F --discharge.preionization "m air_switch=on;powsup_heater=80;powsup_accel=100" --infrastructure.position_stabilization "main_switch=on;radial_switch=on;vertical_waveform=1000,0.8000,-20,10000,-25,12000,-10,30000,0;vertical_switch=on;radial_waveform=2000,0.3000,0.7000,-20,9500,-25,10000,-20,30000,2,25000,0" --ScanDefinition 40625 40629F --comment "Rake probe 50mm"

[Shot Logbook]

Technological parameters

- Working Gas: $P_{discharge, before} = 2.46$ mPa; $P_{discharge, pre} = 5.04$ mPa ($P_{WG}^{response} = 15$ mPa @ $\Delta_{WG}^{response} = 4$)
- Toroidal magnetic field: $U_{B_t}^{response} = 800$ V @ $B_t^{response} = 0.0$ us
- Current drive field: $U_{Ecd}^{response} = 450$ V @ $I_{cd}^{response} = 500.0$ us













Plasma:

- Plasma: yes or no:
- Time parameters: $\Delta T_p = 10.88$ ms ($t_{onset} = 2.67$ ms, $t_{end} = 13.54$ ms)


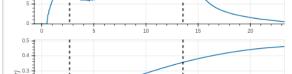
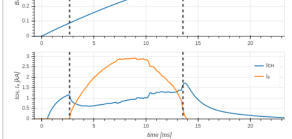
Plasma parameters:

- Loop voltage: $\bar{U}_{loop} = 6.82$ V; $max_{T_{inj}}(I_{discharge}) U_{loop} = 16.17$ V; $U_{loop, end} = 0.00$ V
- Toroidal magnetic field: $B_t = 0.24$ T; $max_{T_{inj}}(I_{discharge}) B_t = 0.36$ T
- Plasma current: $I_p = 2.28$ kA; $max_{T_{inj}}(I_{discharge}) I_p = 2.92$ kA; $t_p^{max} = 0.00$ ms

On stage diagnostics

Data flow	measurement	digitization	Raw data	analysis	Analysis results
Name	Experiment setup	Data acquisition system	Raw data	Analysis results	Analysis results
<p>Basic Diagnostics</p> 					
<p>Double rake probe</p> 				<p>Without Analysis</p> 	

Basic Diagnostics

Remote education: Presentations the day after ..



Tokamak GOLEM for Fusion education

You are welcome to exploit this facility

- **Remote** lectures, demonstrations at universities.
- Spring/Summer/Autumn/Winter schools.
- **On-site/remote** training courses.
- ... etc.
- ... even on-site/remote Bachelor projects or Diploma thesis.

web:<http://golem.fjfi.cvut.cz>

contact:vojtech.svoboda@fjfi.cvut.cz