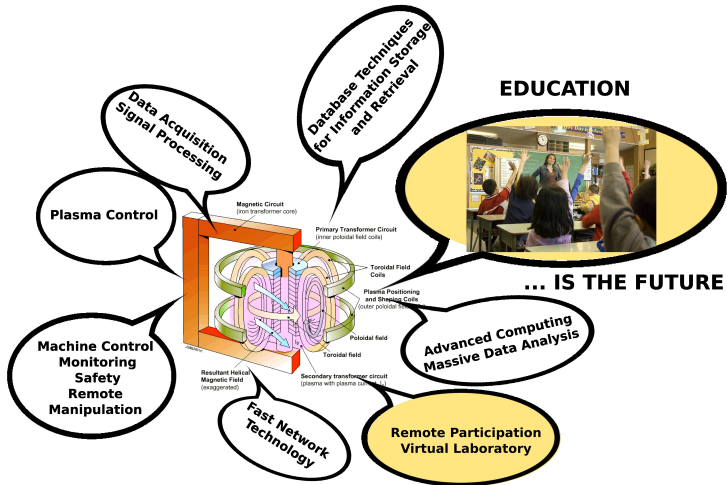


# Importance of education



The Golem tokamak remotely  
for education and training  
 $\approx$  5 years at service

Vojtěch Svoboda, et al. for TM IAEA 2015 @ Ahmedabad

April 22, 2015

# Outline

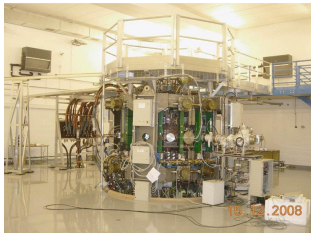
- 1 Introduction
- 2 Plan A - online (?Ahmedabad-Prague connectivity? ~ 5800 Km)
- 3 Plan B - offline
  - Engineering setup
  - Diagnostics
  - Remote control
  - Data access
- 4 Plan A & B cont.
  - Selected remote education events @ GOLEM tokamak
- 5 Plan A cont.
  - Tokamak GOLEM available for 10<sup>th</sup> IAEA TM@Ahmedabad
- 6 Closings

# Outline

- 1 Introduction
- 2 Plan A - online (?Ahmedabad-Prague connectivity? ~ 5800 Km)
- 3 Plan B - offline
  - Engineering setup
  - Diagnostics
  - Remote control
  - Data access
- 4 Plan A & B cont.
  - Selected remote education events @ GOLEM tokamak
- 5 Plan A cont.
  - Tokamak GOLEM available for 10<sup>th</sup> IAEA TM@Ahmedabad
- 6 Closings

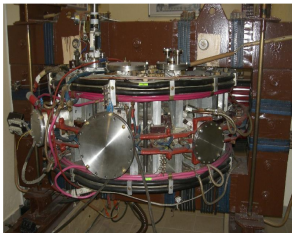
# Three tokamaks in Czech Republic in service

**Tokamak COMPASS**  
@Institute of Plasma Physics, Prague



**SCIENCE**  
& education

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



**EDUCATION**  
& science

**Music group Tokamak**  
Brno

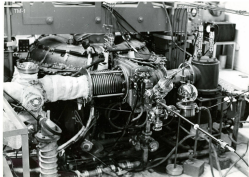


**ENTERTAINMENT**

# Three eras of the tokamak GOLEM

## The smallest & oldest tokamak...

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



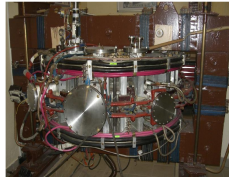
**SCIENCE**

**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 | Wiki | Control Room | Queue | Link | Results | GOLEM Diagram | Chamber status | IP cameras | 3D model | Chat | Feedback | Help |
|------|------|--------------|-------|------|---------|---------------|----------------|------------|----------|------|----------|------|

**LEVEL 1**

Preionization (electron gun)

Arise

Toroidal magnetic field

Current drive

Vacuum stand

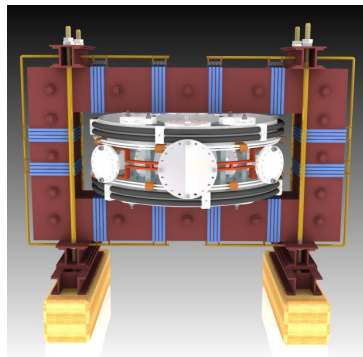
GAS handling

Working Gas (hydrogen)

Discharge comment

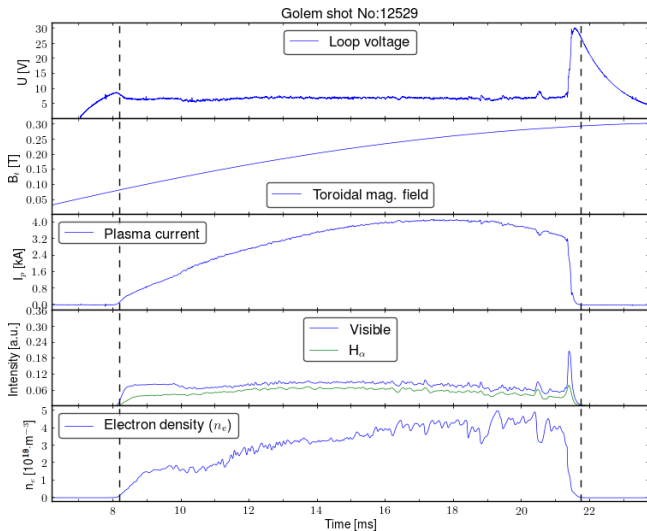
Place the discharge setup into the queue

# Tokamak GOLEM - basic parameters



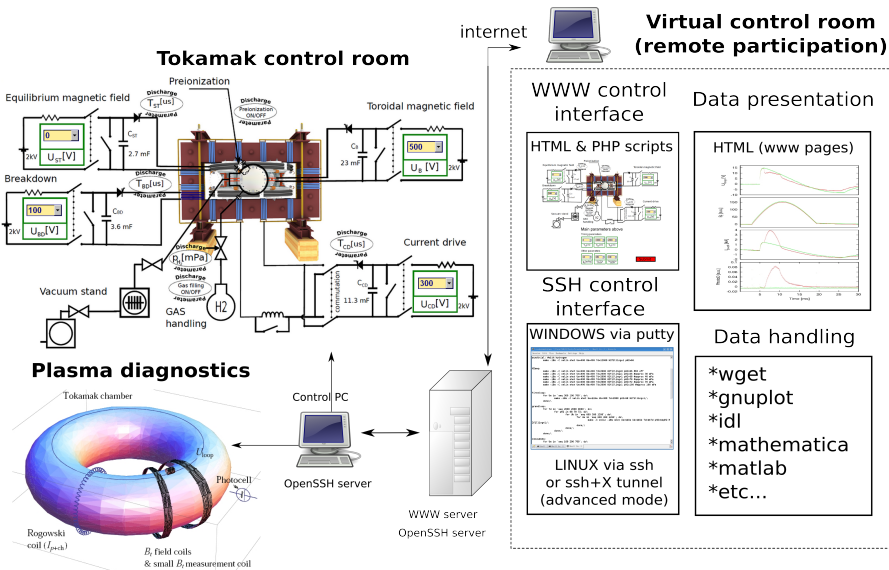
- major radius  $R = 0.4$  m
- plasma current  $I_p < 8$  kA
- toroidal magnetic field  $B_t < 0.5$  T
- electron temperature  $T_e(0) < 80$  eV
- minor radius  $a = 0.085$  m
- discharge duration  $\tau < 20$  ms
- plasma density  $n_e = 2 - 8 * 10^{18}/m^3$

# Typical well executed discharge #12529

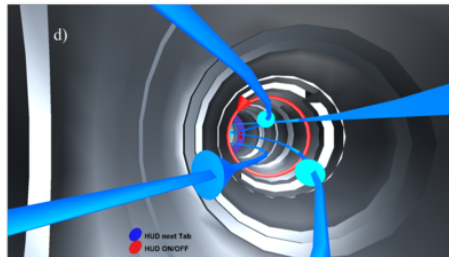
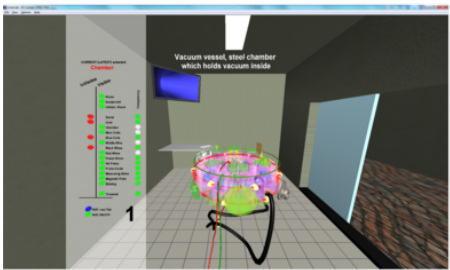
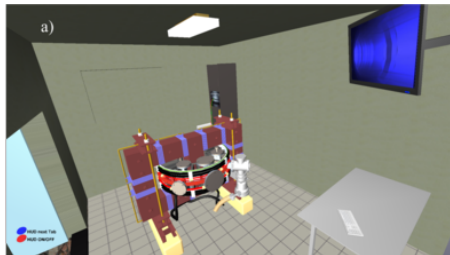




# The global overview of the tokamak GOLEM experiment



# Virtual Reality Modeling Language model version OP



# Outline

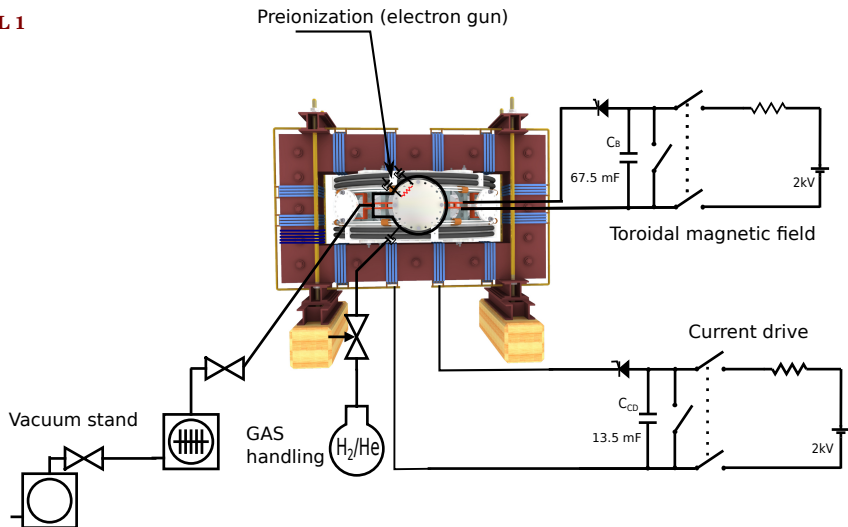
- 1 Introduction
- 2 Plan A - online (?Ahmedabad-Prague connectivity? ~ 5800 Km)
- 3 Plan B - offline
  - Engineering setup
  - Diagnostics
  - Remote control
  - Data access
- 4 Plan A & B cont.
  - Selected remote education events @ GOLEM tokamak
- 5 Plan A cont.
  - Tokamak GOLEM available for 10<sup>th</sup> IAEA TM@Ahmedabad
- 6 Closings

# Outline

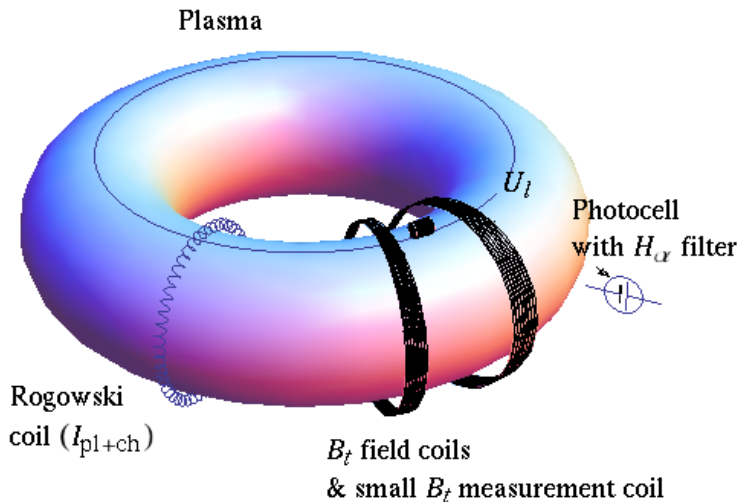
- 1 Introduction
- 2 Plan A - online (?Ahmedabad-Prague connectivity? ~ 5800 Km)
- 3 Plan B - offline**
  - Engineering setup
  - Diagnostics
  - Remote control
  - Data access
- 4 Plan A & B cont.
  - Selected remote education events @ GOLEM tokamak
- 5 Plan A cont.
  - Tokamak GOLEM available for 10<sup>th</sup> IAEA TM@Ahmedabad
- 6 Closings

# Tokamak GOLEM - engineering scheme

## LEVEL 1



# Tokamak GOLEM - Basic Diagnostics



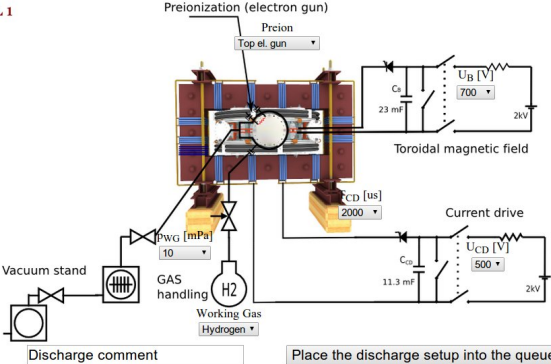
# Remote control

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

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

|      |      |              |       |      |         |               |                |            |          |      |          |         |
|------|------|--------------|-------|------|---------|---------------|----------------|------------|----------|------|----------|---------|
| Home | Wiki | Control Room | Queue | Live | Results | GOLEM dygraph | Chamber status | IP cameras | 3D model | Chat | Feedback | Level I |
|------|------|--------------|-------|------|---------|---------------|----------------|------------|----------|------|----------|---------|

LEVEL 1



# Shot homepage

GOLEM » Shot #11722 »

[previous](#) | [next](#) | [current](#)



## Diagnostics

- × PlasmaPosition
- × Interferometer
- × FastCamera
- × Spectrometer

## Analysis

- × AdvancedAnalysis
- × HistoricalAnalysis
- × ShotHomepage
- × MagFieldEvolution
- × Spectrograms
- × MultiCWT
- × Impurities

## DAS

- × Niturbo
- × TektronixDPO
- × Nistandard
- × Papouch

## Vacuum log

Charging log

## Other

- Data
- References
- About
- Wiki
- Utilities

## Navigation

- Next
- Previous
- Current

Go to shot

## Tokamak GOLEM - Shot Database - 11722

[\[Template source\]](#)  
[\[WebLog\]](#)

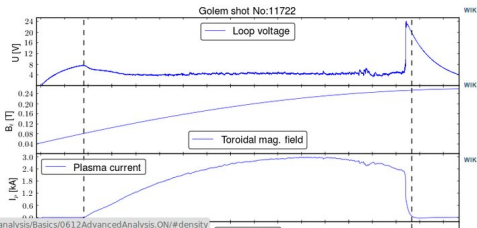
**Date:** 2013-04-10 - 10:27:18  
**Session:** TrainingCourses/0413GOMTRAC [new]  
**Comment:** NigGom - 3=95.7 UFL probe

### Basic parameters: [\(compare\)](#)

- Gas pressure  $p_{ch}$ : 1.61->10.00 mPa (request: 10 mPa) <sup>Wiki</sup>
- Working gas: N/A
- Preionization: ON
- Chamber temperature: N/A C
- $C_B$  capacitors changed to: 600 V, triggered 5.0 ms <sup>Wiki</sup>
- $C_{BD}$  capacitors changed to: 0 V, triggered 5.0 ms <sup>Wiki</sup>
- $C_{CD}$  capacitors changed to: 350 V, triggered 7.0 ms <sup>Wiki</sup>
- $C_{ST}$  capacitors changed to: 0 V, triggered 5.0 ms <sup>Wiki</sup>
- Probability of breakdown: 83% <sup>Wiki</sup>
- Time since session beginning: 2:10:44 h

### Plasma parameters:

- Plasma life time 13.9 [ms] (from 8.8 to 22.7)
- Mean toroidal magnetic field Bt: 0.19 T <sup>Wiki</sup>
- Mean plasma current: 2.59 kA <sup>Wiki</sup>
- Mean Uloop: 4.64 V <sup>Wiki</sup>
- Break down voltage: 7.7 V <sup>Wiki</sup>
- Ohmic heating power: 12.01 kW
- Q edge: 3.3 <sup>Wiki</sup>
- Electron temperature: 38.8 eV <sup>Wiki</sup>
- Line electron density: 3.59 [ $10^{17} m^{-2}$ ] <sup>Wiki</sup>

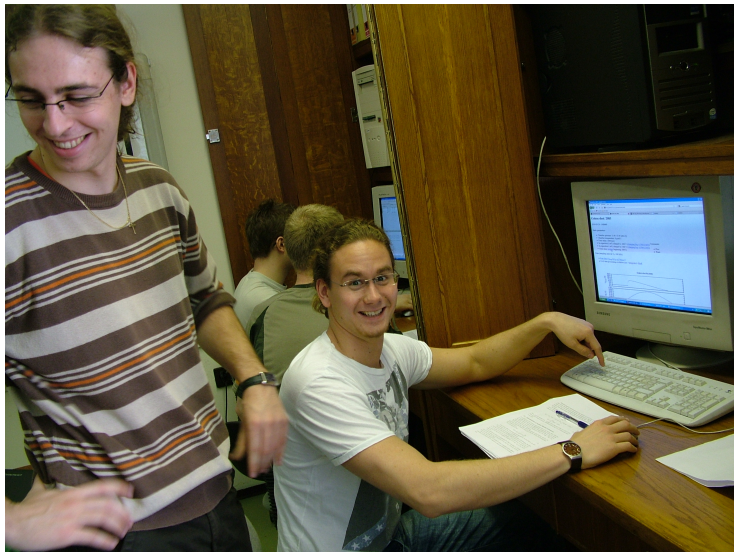




# Outline

- 1 Introduction
- 2 Plan A - online (?Ahmedabad-Prague connectivity? ~ 5800 Km)
- 3 Plan B - offline
  - Engineering setup
  - Diagnostics
  - Remote control
  - Data access
- 4 Plan A & B cont.
  - Selected remote education events @ GOLEM tokamak
- 5 Plan A cont.
  - Tokamak GOLEM available for 10<sup>th</sup> IAEA TM@Ahmedabad
- 6 Closings

# Remote training course for Hungarian university $\sim 440$ km



# 2014: Remote training course for Workshop@Bulgaria ~ 1400 km



**6<sup>th</sup> International Workshop  
&  
Summer School  
on Plasma Physics**

30 June - 6 July 2014  
Kiten, Bulgaria

**Topics:**

- \*Fusion Plasma and Materials
- \*Plasma Modelling and Fundamentals
- \*Plasma Sources, Diagnostics and Technology

**Organised by:**

**University of Sofia**

**Co-organisers:**

**PLASMER Foundation**

**Workshops:**

- \*Remote GOLEM operation  
Czech Technical University, Prague
- \*Plasmas for Sustainable Environment  
Institute of Plasmas and Nuclear Fusion, Lisbon, Portugal

IWSSPP.deo.uni-sofia.bg  
Email: IWSSPP@deo.uni-sofia.bg

# 2014: Remote training course for Erasmus students @ Cadarache ~ 800 km



## Remotely operated training courses, workshops, Summer schools, etc.

- Global Tokamak Experiment** (2010) in over 4 hours 38 participants from 10 different countries carried out 83 plasma discharges
- FUMTRAIC** (2012,13,14) Training course for Erasmus Mundus students from Cadarache@France
- HUNTRAIC** (2010,12,13,14) Training course for students from Budapest University@Hungary
- GOMTRAIC** (2012,13) The GOLEM Remote training course opened to the whole world (shots from India!)
- Remote lectures** Trieste@Italy (2012), Lemwig, Valaske Mezirici@CzechRep (2014), Kiten@Bulgaria (2012,14), Technical University@Denmark (2015)
- PhD sessions** Garching@Germany (2013,14), Padova@Italy (2015)

# Outline

- 1 Introduction
- 2 Plan A - online (?Ahmedabad-Prague connectivity? ~ 5800 Km)
- 3 Plan B - offline
  - Engineering setup
  - Diagnostics
  - Remote control
  - Data access
- 4 Plan A & B cont.
  - Selected remote education events @ GOLEM tokamak
- 5 Plan A cont.
  - Tokamak GOLEM available for 10<sup>th</sup> IAEA TM@Ahmedabad
- 6 Closings

# Control room now open ..

Go to <http://golem.fjfi.cvut.cz/ahm>

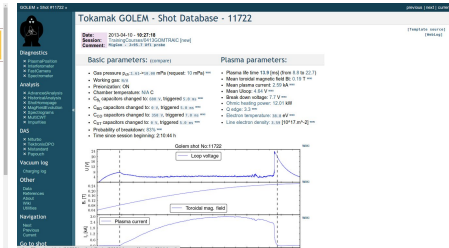
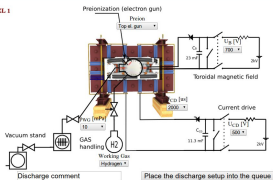
... and enjoy discharges from Ahmedabad ..

## Tokamak Golem \*\*REMOTE\*\* for PROMO (Level 1)

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



LEVEL 1



# Outline

- 1 Introduction
- 2 Plan A - online (?Ahmedabad-Prague connectivity? ~ 5800 Km)
- 3 Plan B - offline
  - Engineering setup
  - Diagnostics
  - Remote control
  - Data access
- 4 Plan A & B cont.
  - Selected remote education events @ GOLEM tokamak
- 5 Plan A cont.
  - Tokamak GOLEM available for 10<sup>th</sup> IAEA TM@Ahmedabad
- 6 Closings



# Acknowledgement

## Acknowledgement

The financial support by FUSENET@EU, Ministry of education@CzechRep, SGS15/164/OHK4/2T/14@CzechTechUniv, RVO68407700@NuclearFaculty, IAEA technical contract CRP F1.30.14 on Utilization of the Network of Small Magnetic Confinement Fusion Devices for Mainstream Fusion Research.

Special thanks to the GOLEM team (students, teachers, technicians)

Ondrej Grover, Jindrich Kocman, Lukas Matena, Michal Odstrcil, Tomas Odstrcil, Jan Stockel, Gabriel Vondrasek, Frantisek Zacek.

# Tokamak GOLEM for Fusion education

You are welcome to exploit this facility

- Lectures, demonstrations at universities
- Spring/Summer/Autumn/Winter schools
- Training courses
- ... etc.
- ... even remote Bachelor and/or Diploma thesis

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

mailto:[svoboda@fjfi.cvut.cz](mailto:svoboda@fjfi.cvut.cz)

Fee: postcard from the venue of remote measurements

# Control room now open ..

Go to <http://golem.fjfi.cvut.cz/ahm>

... and enjoy discharges from Ahmedabad ..

## Tokamak Golem \*\*REMOTE\*\* for PROMO (Level 1)

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



LEVEL 1

