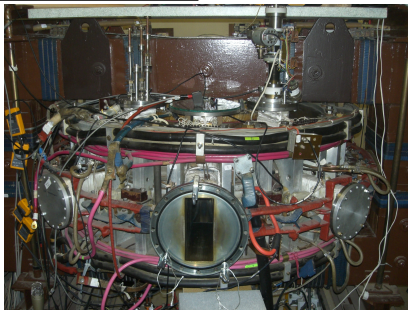


Golem tokamak for education and training

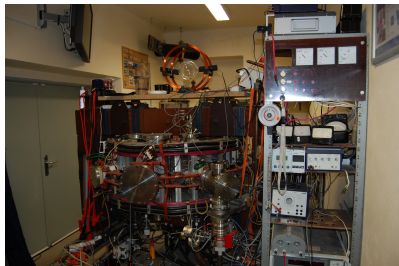
Vojtěch Svoboda, et al. for IBA 2012



Content

- 1 The GOLEM tokamak
- 2 Forecast 2011
- 3 Educational projects
- 4 Student's Scientific projects
- 5 Forecast 2013

The Golem tokamak - the oldest tokamak in operation



Scientific eras:

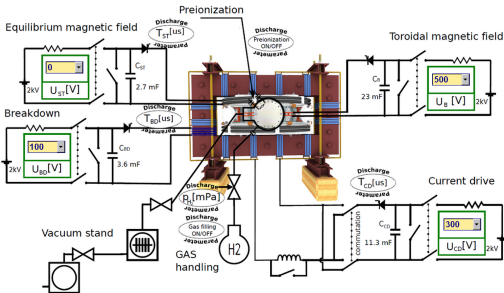
- 1960-1974 **TM1-MH**
USSR: Kurchatov institut near Moscow.
- 1977-2007 **CASTOR**
CSSR/CSFR/CR: Inst. of Plasma Physics, Prague.

Educational era:

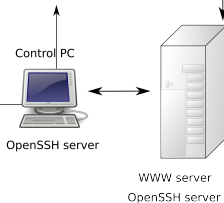
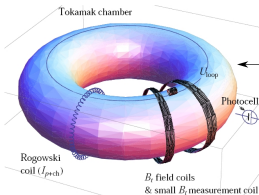
- 2009- **GOLEM** CR: Czech technical University, Prague

Unique remote operation capability

Tokamak control room



Plasma diagnostics



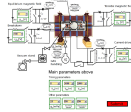
internet



Virtual control room (remote participation)

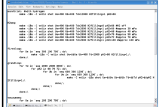
WWW control interface

HTML & PHP scripts



SSH control interface

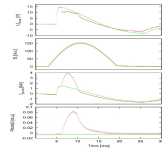
WINDOWS via putty



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

Data presentation

HTML (www pages)



Data handling

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

The GOLEM tokamak real Control Room

Location Edit View Bookmarks Tools Settings Help

http://golem.fjfi.cvut.cz/roperation/tasks/PROMO/1212GOLEM/Level_1/exp.php

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

Home Control Room Queue Live Results Manual

LEVEL 1

Preionization (electron gun)

Preion ON

Vacuum stand

GAS handling

P_{H_2} [mPa] 20

H_2

Toroidal magnetic field

C_b 23 mF

U_B [V] 600 2kV

Current drive

C_{cd} 11.3 mF

U_{CD} [V] 500 2kV

I_{CD} [us] 1000

The result webpage

previous | next | current

Tokamak GOLEM - Shot Database - 9694

[Template source]
[WebLog]

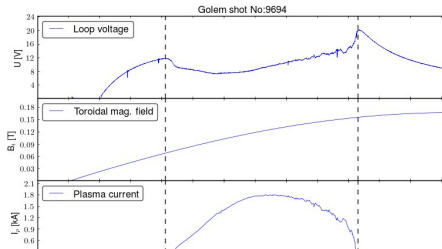
Date: 2012-09-07 - 121544
Session: Technological/Software/Debugging/0912Optimization
Comment: USER A - three

Basic parameters:

- Chamber pressure p_{chamber} : 1.27-> 19.28 mPa (request: 20 mPa)
- Working gas: N/A
- Chamber temperature: N/A C
- C_B capacitors (23.0 mF) charged to: 600 V, triggered 5.0 ms
- C_{BD} capacitors (3.6 mF) charged to: 0 V, triggered 5.0 ms
- C_{CD} capacitors (11.2 mF) charged to: 500 V, triggered 6.0 ms
- C_{ST} capacitors (2.7 mF) charged to: 0 V, triggered 5.0 ms
- Max saturation of iron core transformer: 47%
- Time since session beginning: 0:51:47 h

Plasma parameters:

- Plasma life time **6.2** [ms] (from 8.1 to 14.3)
- Mean toroidal magnetic field B_t : 0.12 T
- Mean plasma current: 1.43 kA
- Mean Uloop: 9.71 V
- Break down voltage: 11.9 V
- Ohmic heating power: 13.87 kW
- Q edge: 7.6
- Central electron temperature: 25.3 eV



GOLEM » Shot #9694 »



Diagnostics

- × PlasmaPosition
- ✓ Flukes
- × MirnovCoils
- ✓ HXR
- ✓ FastCamera
- × Spectrometer

Analysis

- ✓ AdvancedAnalysis
- ✓ ShotHomepage
- × MagFieldEvolution
- × MultiCVT
- × MHD

DAS

- ✓ Niturbo
- ✓ Nistandard
- × Papouch
- ✓ Nilbasic
- × Papouch

Vacuum + Energetics

Log

Other

- Data
- References
- About

Navigation

- Next
- Previous
- Current

Go to shot

9694

The GOLEM tokamak **virtual** Control Room - level I

Location Edit View Bookmarks Tools Settings Help

http://golem.fjfi.cvut.cz/voperation/tasks/PROMO/1212GOLEM/Level_I/exp.php

Tokamak Golem ****VIRTUAL**** for GOLEM (Level I)

Home Control Room Queue Live Results Manual

LEVEL 1

Preionization (electron gun)

Preion

U_B [V] 600 2kV

23 mF

Toroidal magnetic field

t_{CD} [us] 1000

Current drive

U_{CD} [V] 500 2kV

11.3 mF

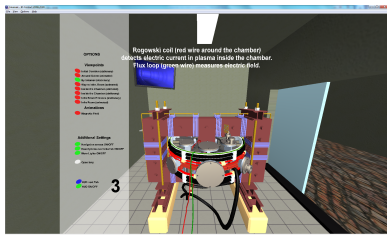
P_{H_2} [mPa] 20

Vacuum stand

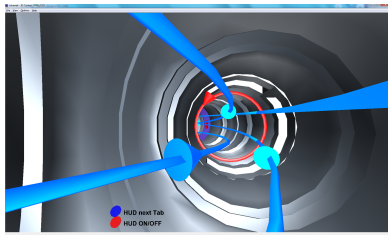
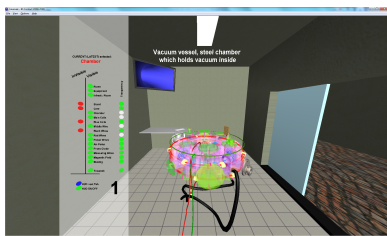
GAS handling

H₂

The GOLEM tokamak virtual model



Tokamak Room & Infrastructure Room



Inner view & Inside chamber

Remote sessions from Europe



Content

- 1 The GOLEM tokamak
- 2 Forecast 2011**
- 3 Educational projects
- 4 Student's Scientific projects
- 5 Forecast 2013

Forecast IBA, October 2011

- Path to Science - cont. (**finished, Ondrej Grover cont.**)
- Bachelor and Diploma Thesis - cont. (+)
- Excursions - cont. (**OK**)
- University of third age - cont. (**OK**)
- The week of science - cont 2012. (+)
- SUMTRAIC - cont 2012. (+)
- Automated Virtual Guide of the Tokamak. (**0**)
- Winter Remote Tokamak Physics School GOMTRAIC 2012. (+/-)

Scientific projects?

HTS ..

Content

- 1 The GOLEM tokamak
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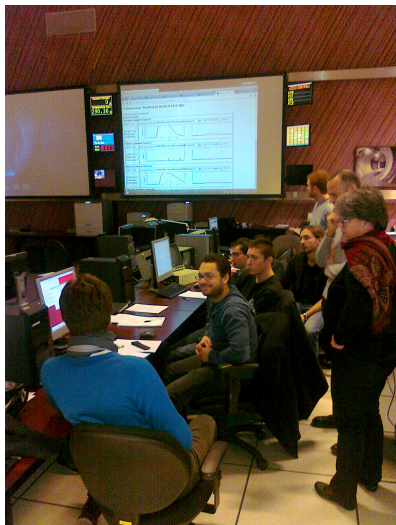
Regular (Czech) activities .. cont.

- 06/12 The week of science - 4 groups (≈ 70 shots) :
 - Spectroscopy studies at the tokamak GOLEM.
 - Plasma position studies at the tokamak GOLEM via magnetic diagnostics.
 - Plasma position studies at the tokamak GOLEM with the help of fast cameras
 - HXR studies at the tokamak GOLEM.
- 10/11-06/12 University of third age (Introductory HXR, HTS, Langmuir probe and magnetic studies).
- Excursions (≈ 20)

Bachelor & Diploma thesis

- Jindrich Kocman: Plasma position studies, HTS.
- Lenka Kocmanova: HXR studies.
- Tomas Markovic: Magnetic studies.
- Michal Odstrcil: Breakdown studies.
- Tomas Odstrcil: Spectroscopic studies.
- Ondrej Grover: Interferometry - density measurements.

02/12 French master meeting "FUMTRAIC" 2012



≈ 100 shots

Quotation

... It is fascinating to be able to work on such a device, and we're really enjoying the possibility to make our very first discharges...

- **GO**lem re**M**ote **TRAI**ning **C**ourse.
- Course oriented on basic understanding of experimental tokamak physics and control.
- The basis of GOMTRAIC is remote operation of the GOLEM tokamak operated at the Czech Technical University in Prague.
- Organized for undergraduate and postgraduate students interested in experimental tokamak physics.
- Participants do not need to leave their country to get experienced in tokamak operation. They can participate even from their home. No fee.

Tasks

- Breakdown studies:
- Radial profile of floating potential and plasma density (determination of radial electric field and poloidal plasma velocity)
- Determination of plasma resistivity and electron temperature, variation with different discharge regimes
- Plasma position studies with Mirnov coils diagnostics.
- Role of vertical magnetic field on plasma performance.
- Spectroscopy studies
- First wall conditioning (baking of the vessel and glow discharge) on plasma performance.
- Comparison of tokamak discharges in H and He working gases.
- Generation of runaway electrons at different discharge regimes by means of hard X ray radiation.

GOMTRAIC 2012



Quotation

... It was wonderful experience for me to do experiment under your guidance. I thank you, the GOLEM team again for yesterday's rack probe experiments. We will thoroughly analyse the shots. ...

06/12 5th International Workshop & Summer School on Plasma Physics Kiten 2012.

**5th International Workshop
&
Summer School
on Plasma Physics**

25 - 30 June 2012
Kiten, Bulgaria

Topics:

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

Organised by:
University of Sofia

Co-organisers:
TCPA Foundation
Bulgarian Academy of Sciences
Association EURATOM/INRNE BG

Workshops:

- *Remote GOLEM operation
Czech Technical University, Prague
- *Plasmas for Environmental Issues
Institute of Plasmas and Nuclear Fusion, Lisbon

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

≈ 50 shots

Quotation

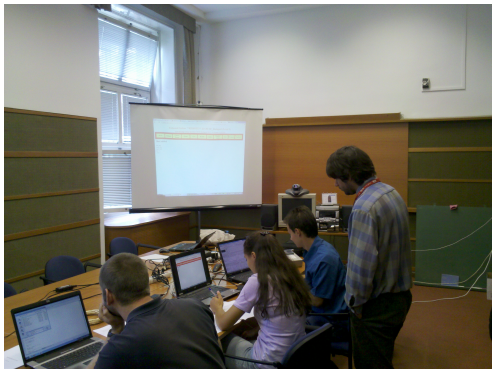
I have been present at a remote participation on GOLEM, and I can confirm that the students are very enthusiastic about this.
Jean-Marie Noterdaeme

08/12 SUMTRAIC 2012 at GOLEM

≈ 100 shots



Remote practica (Budapest September 2012) control room in ≈ 443 km distance



≈ 50 shots

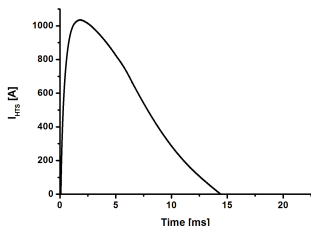
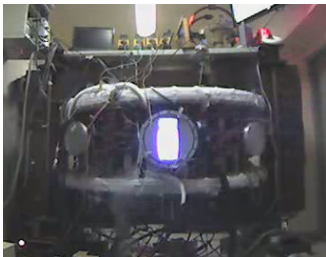
Quotation

Thanks for the operation! The lab exercise went perfectly well, and the students were really enjoying it. Gergo Pokol (teacher)

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- 1 The GOLEM tokamak
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High Temperature Superconductors first ever used on tokamak

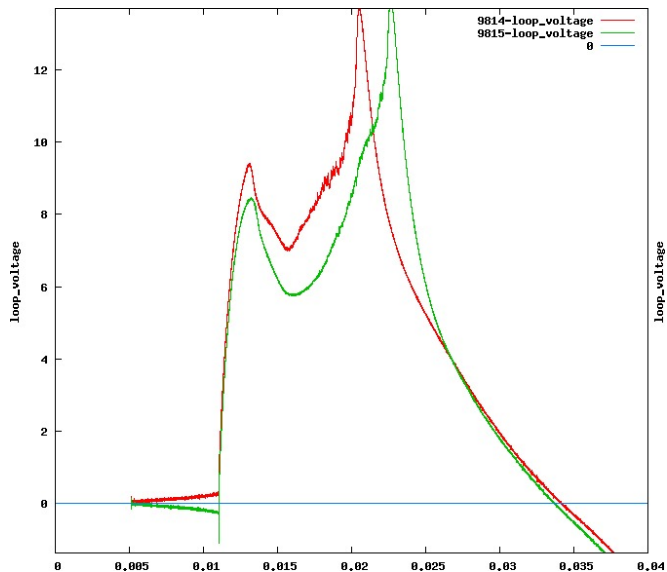


- 6 turns of the 2nd generation HTS (Re)BCO tape SCS12050-AP.
- Current ramp-up speed of up to ≈ 0.6 MA/s .
- Current through the tape ≈ 1 kA.
- Little "quench" effects observed for perpendicular magnetic field up to 0.5T

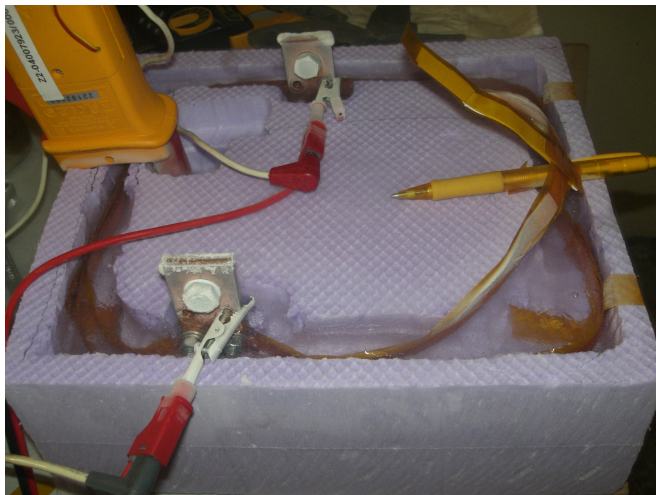
video

HTS used as a equilibrium field:

Plasma & $I_{HTS} = 85A$ (discharge 2 ms prolongation)

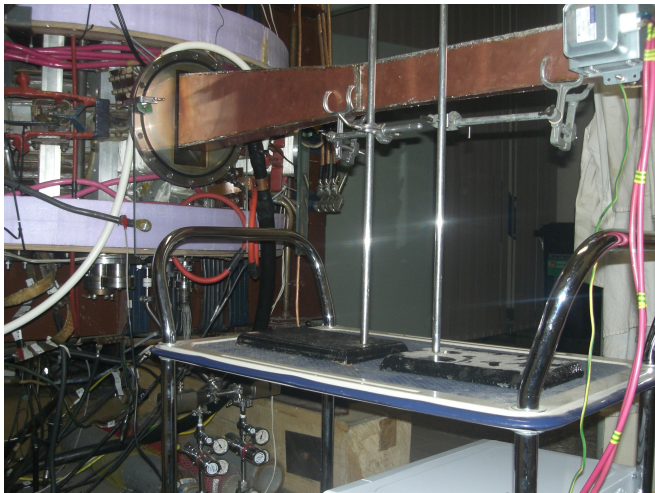


HTS switch step I: Table Top Experiment

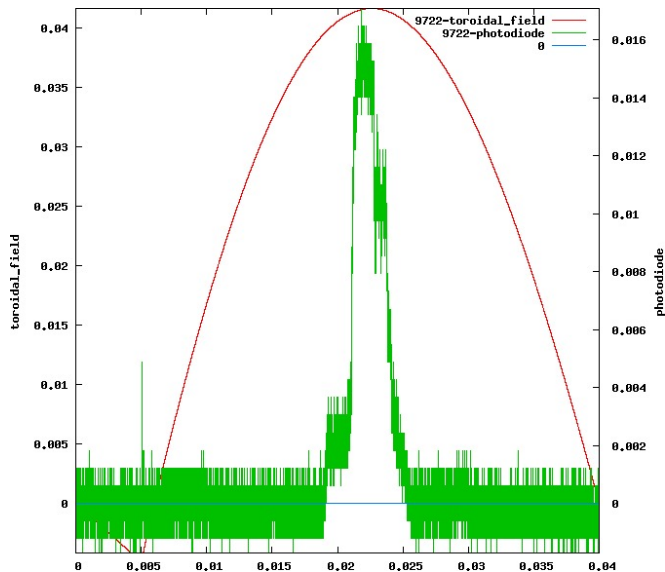


Extremely low inductance (and lack of time) - no results

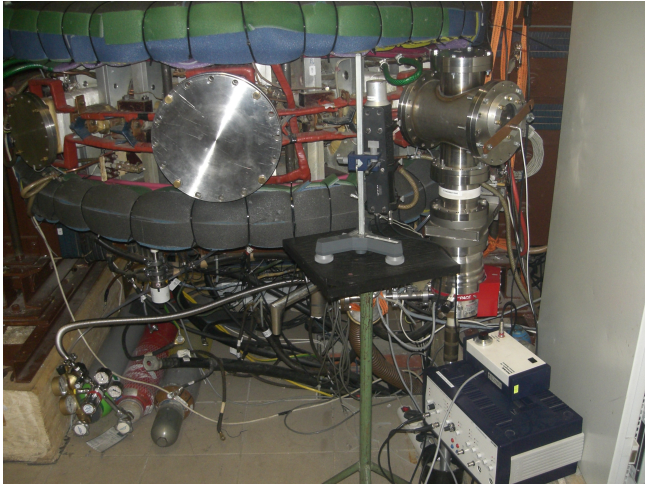
RF preionization

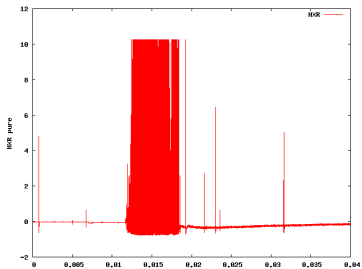
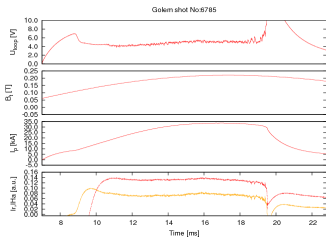
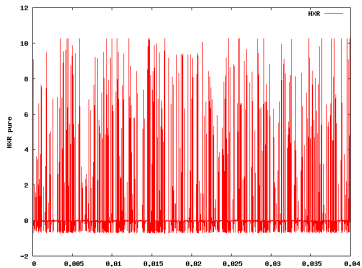
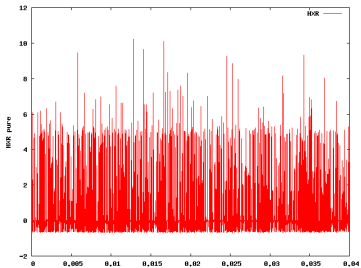


Results (B_t & H_2) ... one hit

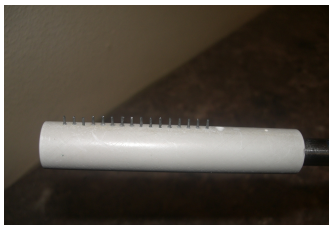
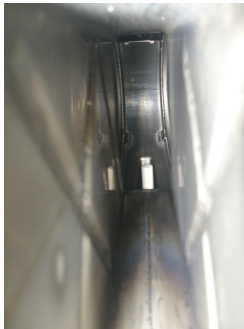
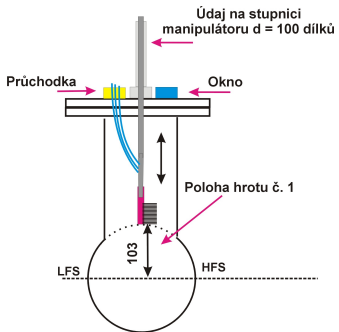


HXR

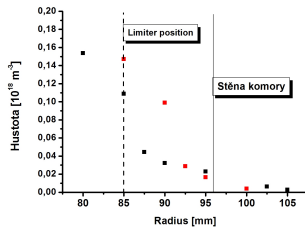
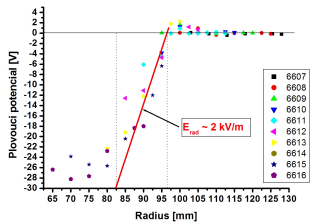
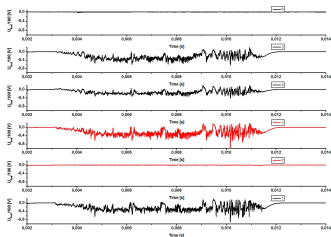




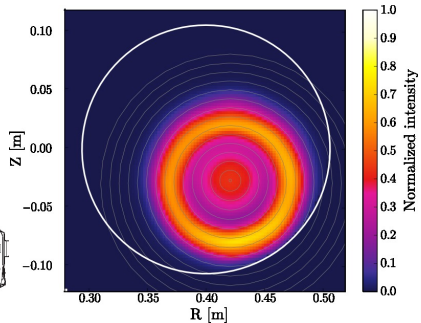
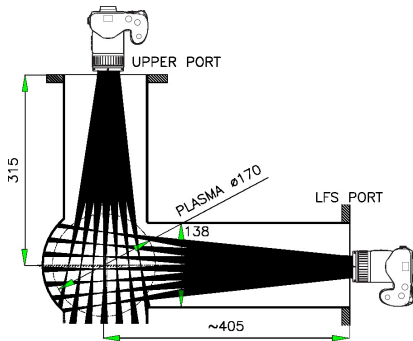
Rake probe (2012)



Rake probe (2012) - results

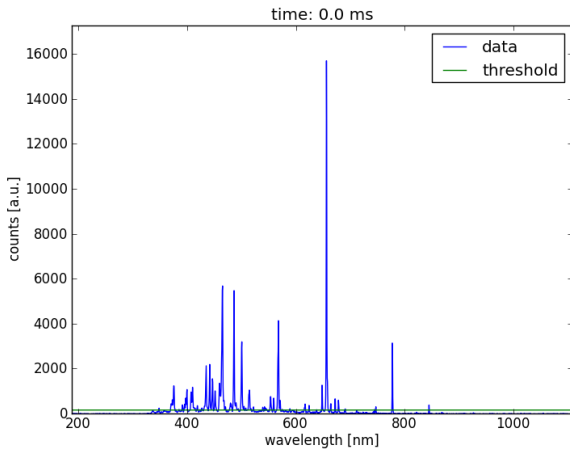


Low Cost Alternative of High Speed Visible Light Camera for Tokamak Experiments)



(HTPD conference Monterey + RSI 2012)

Spectra



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Forecast IBA, October 2013

- 10/12 Remote practica from Budapest II.
- 10/12 Remote demonstration from Trieste IAEA workshop.
- Bachelor and Diploma Thesis - cont.
- Excursions - cont.
- University of third age - cont.
- The week of science - cont.
- GOMTRAIC II - spring 2013.
- SUMTRAIC 2013- cont.
- FUMTRAIC II - Feb. 2013.
- Remote practica.
- HTS, RF preionization, magnetic phenomena, probes measurements.

Acknowledgement

Acknowledgement

The financial support by FUSENET, MSM 6840770039, MSM 6840770014 and A1581, SGS SGS11/131/OHK4/2T/14 is acknowledged.

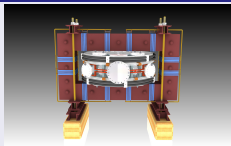
Special thanks to the GOLEM team (students, teachers, technicians)

Edita Bromova, Zdenek Cespiro, Ivan Duran, Vladimir Fuchs, Ondrej Grover, Pavel Hacek, Billy Huang, Igor Jex, Michal Kazda, Jindrich Kocman, Martin Kubic, Ondrej Kudlacek, Petr Liska, Tomas Markovic, Jan Mlynar, Michal Odstrcil, Tomas Odstrcil, Ondrej Pluhar, Gergo Pokol, Ondrej Sebek, Adam Sindlery, Michal Smid, Gabriel Vondrasek, Frantisek Zacek, and Jiri Zara.

Winter school of Plasma Physics - Marianska 2011 (Tokamak, probably COMPASS, with NBI)



Thank you for your attention



<http://golem.fjfi.cvut.cz>,
you and your students are welcome

References I

-  Tokamak GOLEM at the Czech Technical University in Prague.
<http://golem.fjfi.cvut.cz>, 2007.
-  ITER news.
Launch of the world's first global tokamak experiment.
<http://www.iter.org/newsline/156/512>, 2010.
-  V. Svoboda, B. Huang, J. Mlynar, G.I. Pokol, J. Stockel, and G Vondrasek.
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Computer Graphics Forum, 25(1):(105–112), 2006.