THE TOKAMAK GOLEM FOR FUSION EDUCATION

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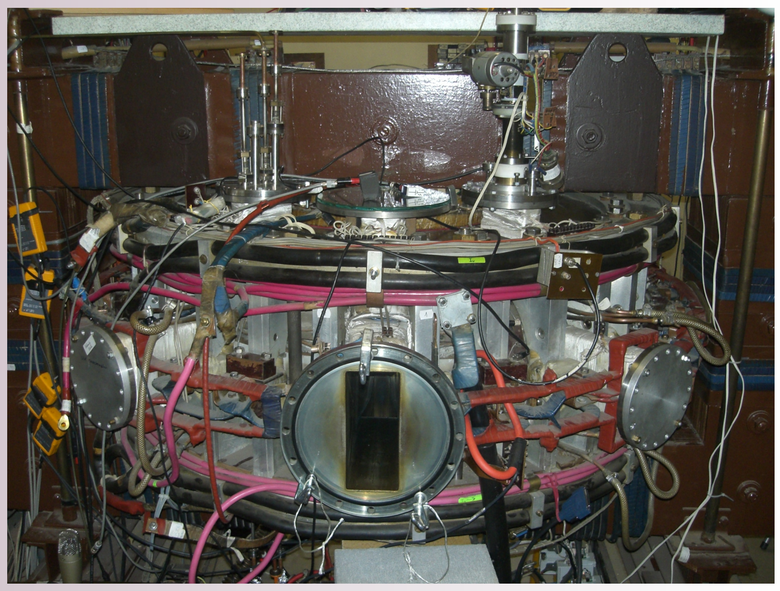
The GOLEM Tokamak



- An educational device for domestic as well as for foreign students via remote participation/handling.
- Operating routinely for nearly two years at a modest range of parameters $B_t < 0.5$ T, $I_p < 8$ kA, pulse length < 15 ms, and with a limited set of diagnostics.
- Wide range of tasks with varying levels of complexity covering tokamak physics, technology and operation can be studied by the future fusion specialists.

Interactive Virtual Model

In order to present the GOLEM tokamak via the Internet to distant users, an interactive 3D virtual model has been created.
It consists of several connected parts:

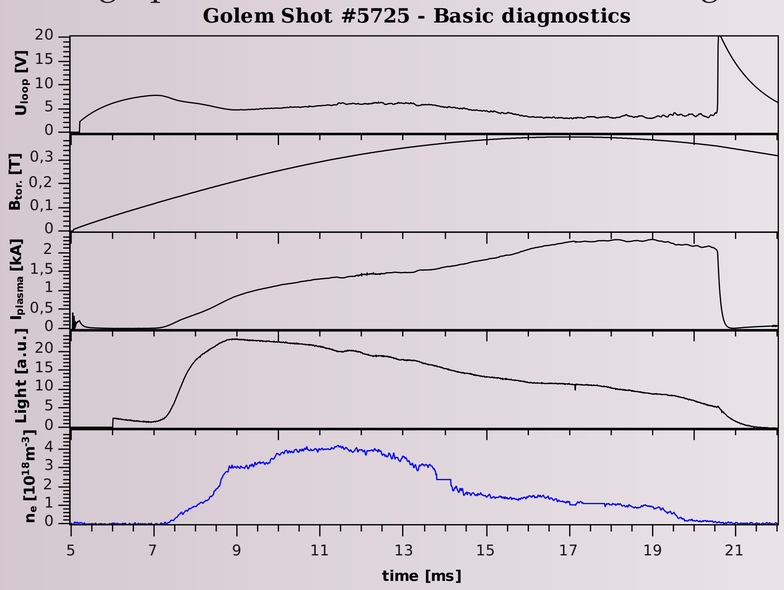
- the tokamak itself,
- power supply infrastructure,
- rooms and access paths.

In addition to the real-world environment, various virtual objects have been added to ease interaction/control and to provide extended information via textual legend and animations.

Recent Diagnostics Enrichment - Students' Contribution

Electron Density Measurement

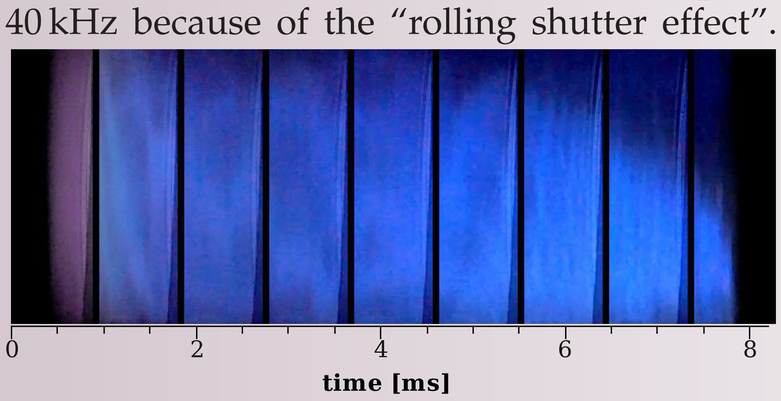
The oldest and most widespread MW diagnostics is now implemented at the GOLEM tokamak. A generated MW interacts with the magnetized plasma which results in a change of the MW's phase. Interferometry evaluates the MW signal that has passed through plasma relative to the reference signal.



Evolution of a typical Golem discharge. The loop voltage, toroidal magnetic field, plasma current, signal of a photodiode, and newly the electron density measurement.

High Speed VIS Cameras

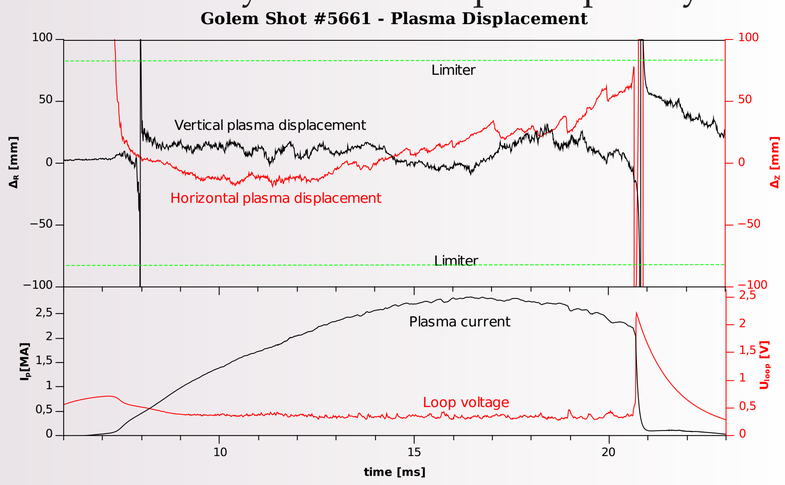
Two cameras Casio EX-F1 have been installed in ports at one poloidal cross-section perpendicular to the plasma column. This configuration is suitable for VIS tomography. The camera can achieve frame rate up to 1200 fps, however the real time resolution is up to 40 kHz because of the "rolling shutter effect".



Plasma column observed from the horizontal port during shot #3754, exposure time 50 μs

Determination and Control of the Plasma Displacement

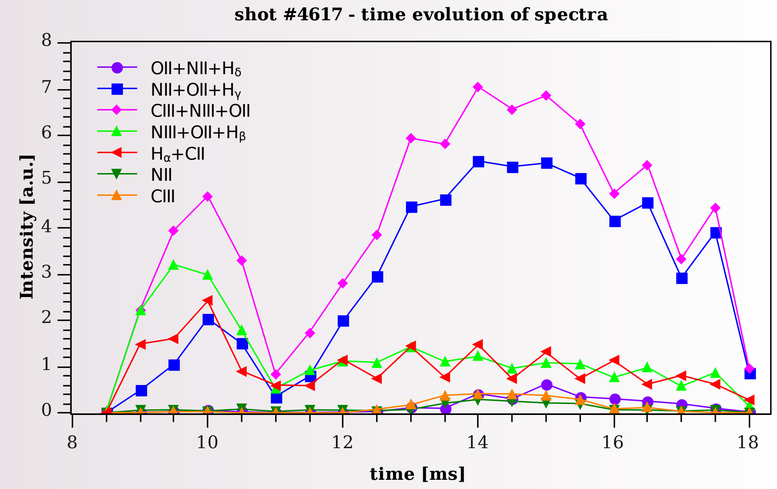
For the determination of the plasma displacement the poloidal and the vertical magnetic field are used. The poloidal field is measured by the set of Mirnov coils and the vertical filed is measured by the former quadrupole system



Horizontal and vertical plasma position, stabilization current and plasma current showing stabilization incidence on plasma behaviour.

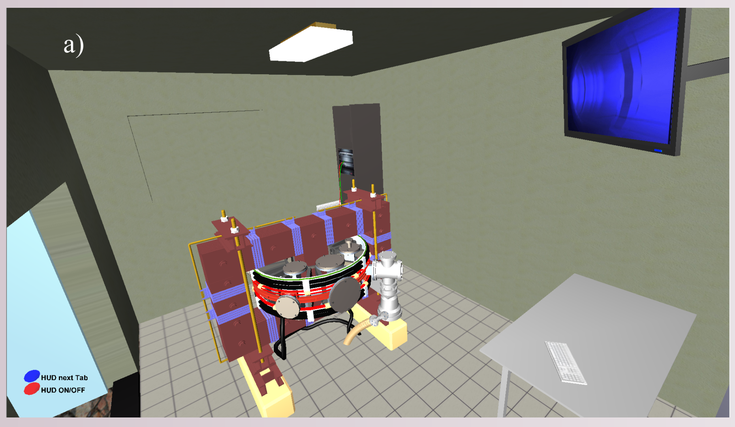
Visible Light Spectrometer

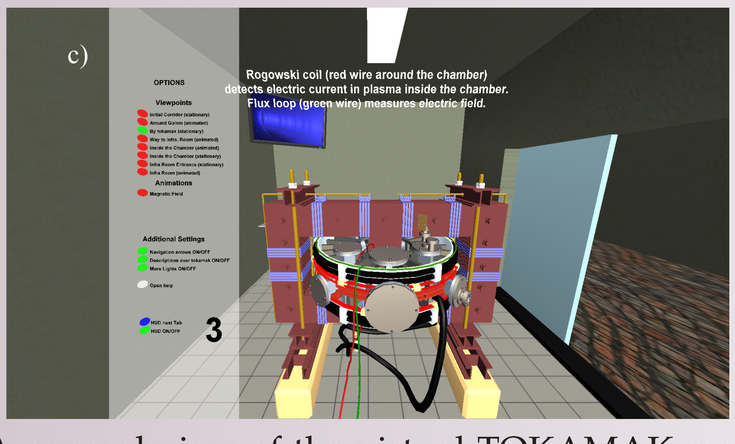
Temporary gratings spectrometer based on the HS camera has been installed at the GOLEM tokamak. In the final configuration it will be capable of achieving time resolution of 0.1 ms and resolving power ($\Delta\lambda/\lambda$) of up to 300.

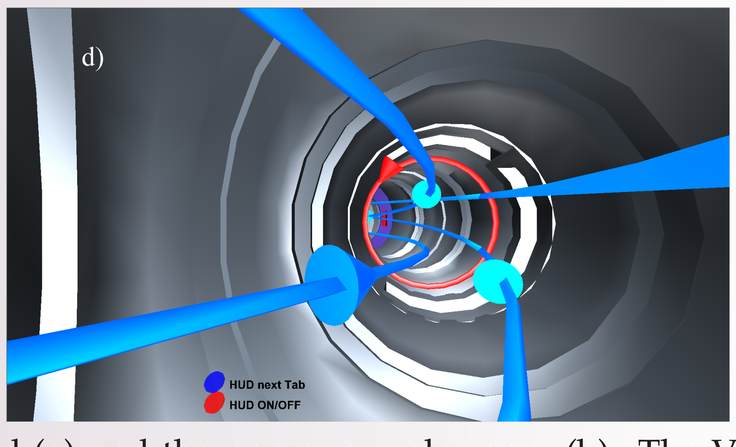


Time evolution of the acquired spectra by the simple spectrometer with a time resolution of 0.5 ms.

Presentation of the Virtual Model







A general view of the virtual TOKAMAK model (a) and the power supply room (b). The Virtual HUD panel allows to control the visual, navigation, and simulation features (c) and visualization of the magnetic fields inside the chamber (d).

Summary

- The present status of the GOLEM tokamak from the engineering as well as plasma performance point of view is presented.
- The research and educational opportunities are offered to the fusion community.

Acknowledgment

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References

[1] 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*, ():(Accepted for publication), 2011.

[2] Zara, J. Virtual Reality Course - A Natural Enrichment of Computer Graphics Classes. *Computer Graphics Forum*, 25(1):(105–112), 2006.