

Operation of the GOLEM tokamak at the PhD event

Adapted from Belgrade training course October 2015. Special acknowledge to Milos Vlainic, author of the original document.

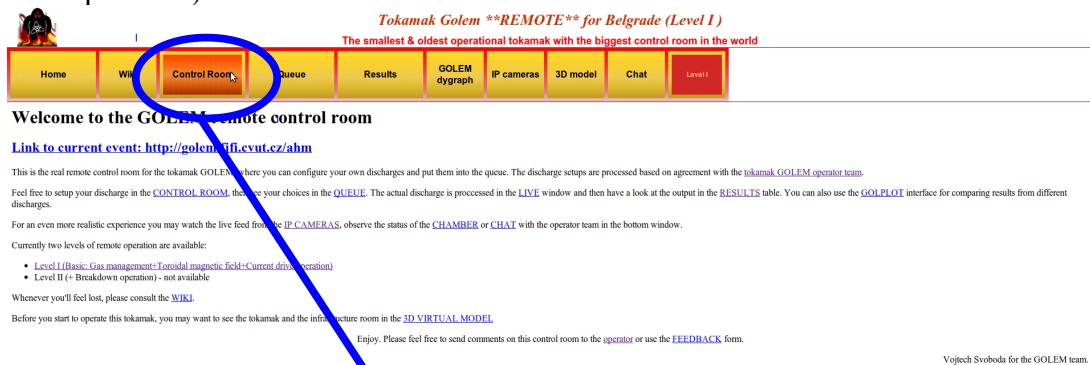
General Information:

Web of GOLEM: <http://golem.fjfi.cvut.cz>

Access to GOLEM database: <http://golem.fjfi.cvut.cz/shots/0/> (shows the last executed shot)

GOLEM Operation for Dummies:

Step 1: go to the link <http://golem.fjfi.cvut.cz/PhDevent>, now you get (note the burning GOLEM sign on the top left :D):



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

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Welcome to the GOLEM remote control room

Link to current event: <http://golem.fjfi.cvut.cz/ahm>

This is the real remote control room for the tokamak GOLEM, where you can configure your own discharges and put them into the queue. The discharge setups are processed based on agreement with the tokamak GOLEM operator team.

Feel free to setup your discharge in the CONTROL ROOM, then see your choices in the QUEUE. The actual discharge is processed in the LIVE window and then have a look at the output in the RESULTS table. You can also use the GOLPLOT interface for comparing results from different discharges.

For an even more realistic experience you may watch the live feed from the IP CAMERAS, observe the status of the CHAMBER or CHAT with the operator team in the bottom window.

Currently two levels of remote operation are available:

- Level I (Basic: Gas management+Toroidal magnetic field+Current drive operation)
- Level II (+ Breakdown operation) - not available

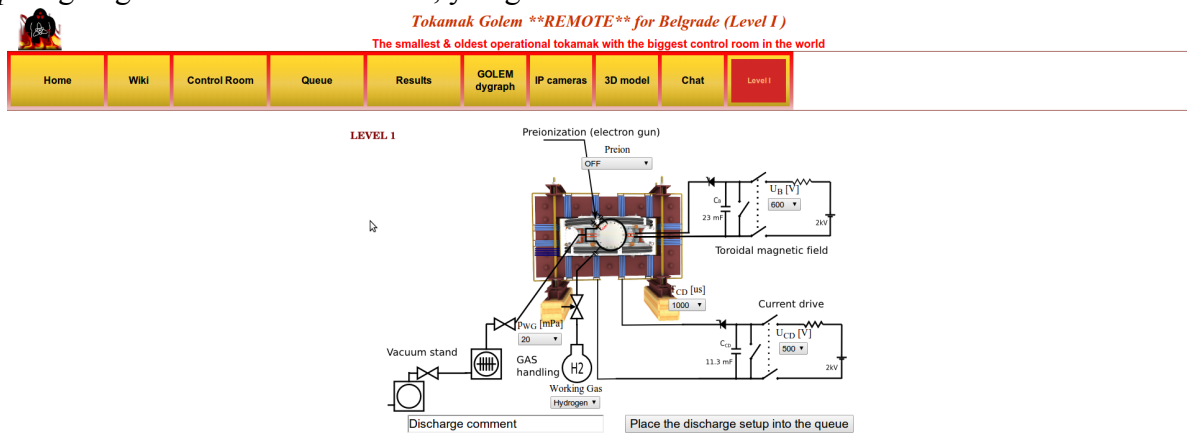
Whenever you'll feel lost, please consult the WIKI.

Before you start to operate this tokamak, you may want to see the tokamak and the infrastructure room in the 3D VIRTUAL MODEL.

Enjoy. Please feel free to send comments on this control room to the operator or use the FEEDBACK form.

Vojtech Svoboda for the GOLEM team.

Step 2: going to the 'Control Room', you get:



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LEVEL I

Preionization (electron gun)
Preion OFF

Toroidal magnetic field
 $U_B [V]$ 600 2kV
 C_B 23 mF

Current drive
 $U_{CD} [V]$ 500 2kV
 $C_{CD} [uS]$ 1000 11.3 mF

Vacuum stand
GAS handling
Working Gas Hydrogen
Discharge comment

Place the discharge setup into the queue

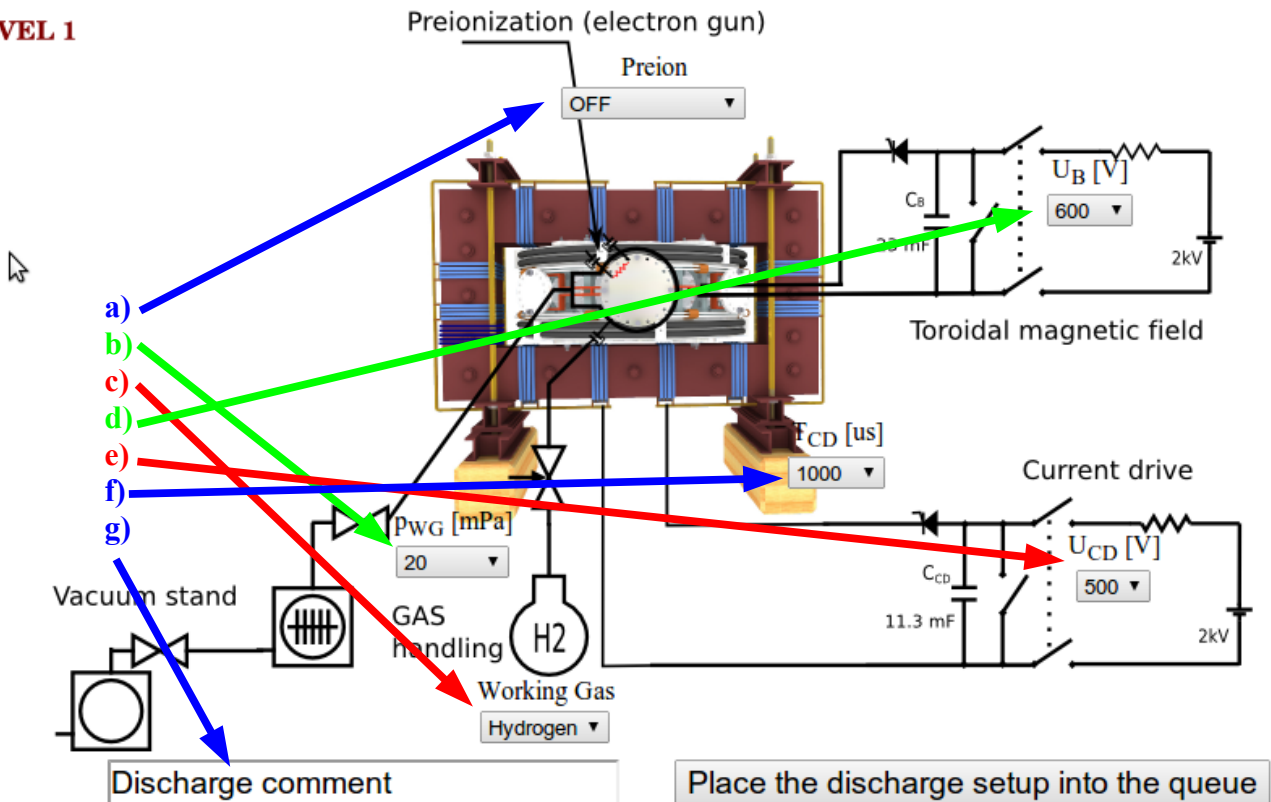
ZOOMED Control Room:

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LEVEL 1



Step 3: WHAT CAN BE MODIFIED (letters are connected with the ones on the figure above)?

a) Preion = Preionization → {OFF (default), Top el. gun, ECRH assisted}:

Choosing type of preionization. Even though Option 'OFF' is a default, use 'Top el. gun', as this one you assure that there will be breakdown to initiate ionization of gas for creating plasma! Option 'ECRH assisted' is not functioning at the moment! While it is possible to create plasma with 'OFF', it is a gambling and could be a waste of discharge – thus time!

b) p_{WG} [mPa] = Pressure in the vacuum vessel before the discharge → {from 1 to 100 with some steps, with 20 as default}:

Even though 20 mPa is default, pressure should be set to lower as possible. Unfortunately, there is some leak in GOLEM vessel those weeks, so there is background pressure of 11 mPa. Hence, putting under this value is nonsense. Anyway, there is plasma even with this relatively high pressure – which is enough for the current purposes! Moreover, real pressure is usually not 20 as requested, but something like 15-16 – thus better than requested ;)

c) Working Gas → {Hydrogen (default), Helium}:

Simply setting the the working gas – both are available, but maybe better to stay with the H due to the leakage...

d) U_B [V] = Voltage going through the capacitor charging the toroidal field (TF) coils → {from 50 to 1100 with step of 50 V, where 600 is default}:

This defines the strength of the toroidal magnetic field B_{tor} – higher U_B , higher B_{tor} .

e) U_{CD} [V] = Voltage going through the capacitor charging the central solenoid → {from 50 to 700 with step of 50 V, where 500 is default}:

This defines the strength of the plasma current I_p – higher U_{CD} , higher I_p .

f) T_{CD} [μ s] = Delay time of the central solenoid charging relative to TF coils charging → {from 500 to 20000 with step of 500, where 1000 is default}:

This defines delay time when the central solenoid will start to be charged relative to the starting time of charging the toroidal field coils (which is always 5 ms!!!). Higher this time, higher is the B_{tor} at the breakdown – to have maximum B_{tor} at the breakdown T_{CD} has to be set on 19000!

g) **DISCHARGE COMMENT:**

DO NOT FORGET ABOUT THIS ONE!!! It is very very important to write down why or what are you doing in this discharge!!! It is good for making difference after the experiments – so maybe write your name or something funny to make the discharge even more special ;)

Step 4: Give a discharge to a execution waiting list, by pressing the 'Place the discharge setup into the queue', after that you check is your discharge in the 'Queue':

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LEVEL 1

Discharge comment Place the discharge setup into the queue

One then gets this:

Where you should see all discharges in the queue and there statuses! Note that now there are none, as I did not do this PrintScreen when we really doing the experiments :D

Anyway, once you check that there is a discharge for you – you go to the '**IP cameras**', where the live streaming of the GOLEM tokamak hall is shown. There are two screens – one camera shows you the room with tokamak, where first blue rotating beacon light will sign the start of the discharge process and finally red rotating beacon light presents that there is only 10 seconds until the discharge and everybody (if anybody is still in the room) should leave the room immediately; second camera is inside the tokamak and you will see the 'Top electron gun' for preionization (if set ON) and after some time a strong flash is seen – which is the discharge!!!

After some time you can finally go to the '**Results**' and check what is there:

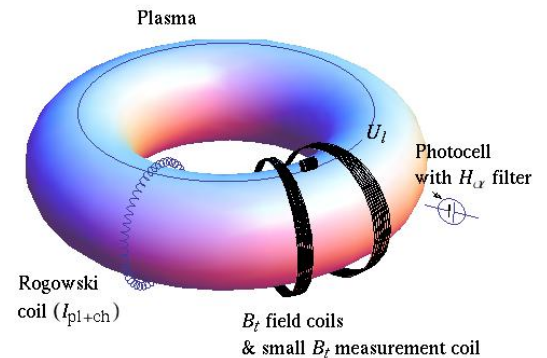
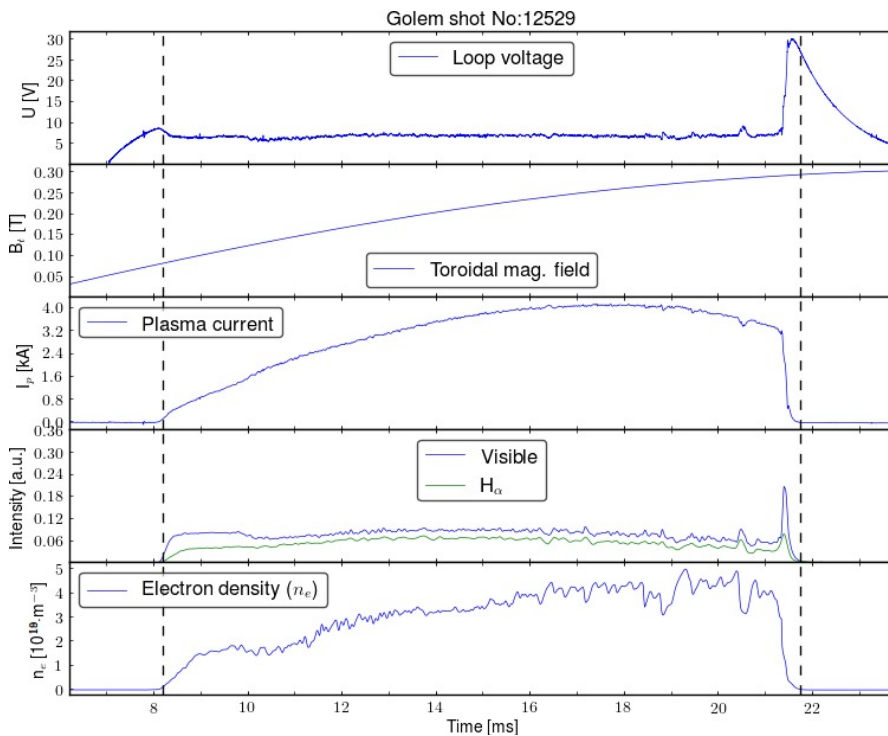
[Link to current session](#)

Identification	Submitted	U _B [V]	U _{cd} [V]	T _{cd} [us]	H ₂ [mPa]	Preion. [on/off]	Plasma [s]	Shot No	Global ShotNo	Comment
Belgrade	2015-10-01 18:08:34	1100	700	20000	->(20)	1		6777	19907	shot for Honza - all max
Belgrade	2015-10-01 18:04:32	600	650	20000	->(20)	1		6776	19906	Largest Btor with Large OH
Belgrade	2015-10-01 17:59:30	600	500	1000	->(20)	0		6775	19905	Tcd = 10ms / breakdown at max Btor
Belgrade	2015-10-01 17:58:55	600	500	10000	->(20)	1		6774	19904	Discharge comment
Belgrade	2015-10-01 17:50:52	600	600	0	->(20)	1		6773	19903	repeat previous for DAQ test
Belgrade	2015-10-01 17:41:43	600	600	0	->(20)	1		6772	19902	Zero delay - Tcd=0
Belgrade	2015-10-01 17:37:31	700	500	2000	->(20)	1		6771	19901	Higher Btor
Belgrade	2015-10-01 17:22:47	600	500	1000	->(20)	1		6770	19900	Milos playing with Honza

Actual time: Mon, 05 Oct 2015 08:49:39 +0200

Here you can click on the **discharge number ('Global ShotNo')** and see the data. You can see here the shots Stockel and Milos did.

After clicking on the **discharge number**, the new page is open with such graphs on the top (left figure):



The right figure serves as an illustration of the diagnostics that provides presented data on the left figure!

Now a little bit of physics, just to briefly explain from where does presented data comes from

- **Loop voltage U :** is practically the toroidal electric field, if U is divided by $2\pi R$ ($R=0.4\text{m}$). It introduces the charge separation (thus plasma creation) at the beginning of the discharge. It is measured with the single loop along the tokamak's toroidal direction (U_l in the right figure).
- **Toroidal mag. field B_t :** keeps plasma in the vessel. It is measured with the pick-up coils near toroidal field coils (*small B_t measurement coil* in the right figure).
- **Plasma current I_p :** induced current in plasma, as a secondary winding. It adds an poloidal component of the magnetic field. It is measured with the *Rogowski coil* (marked in the right figure) – spirally arranged loop in the poloidal direction. N.B. As the Rogowski coil is outside the vessel it measures both, plasma current and current going trough the vessel!!!
- **Visible & H_α :** radiation detected by the *photocells* (denoted in the right figure) – one without (*Visible*) and one with filter around 656nm (H_α).
- **Electron density n_e :** is measured with the *interferometer* (not in the right figure) – a device that measures phase change of the wave injected in the plasma. N.B. The measurement is integrated along the whole wave path through the plasma!