Experiment on the TOKAMAK GOLEM

Wednesday, November 25, 2015

GOLEM is a small-sized tokamak located in Prague (Czech Republic). This device is mainly used for educational purposes. Indeed GOLEM from a first tokamak "castor" which has been operated for 30 years at the IPP Prague and which was moved to the Czech Technical University in Prague. A remote participation can be performed and enables students from all around the world to work on this tokamak and to discover how it works.
An online session was organized under the supervision of Pr. Peysson (CEA, INSTN) as part of the master of students from the engineering school Phelma in Grenoble (France) and Pr. Svoboda who performed the experiments.

Acknowledgements

The Phelma students who participated to these experiments would like to warmly thank their professor, Pr. Peysson, for bringing the idea of this activity, for organizing it and for making the experiments so lively and interesting.
Special thanks go to Pr. Svoboda who provided us with deeper explanations of the tokamak technology and functioning, and who made the good progress of the experiments possible.

The Tokamak GOLEM

Various studies are made by modifying different parameters of the Tokamak in order to see the impact on the plasma. To make these changes more visual and easier to understand, a sketch of the GOLEM tokamak is shown (figure 1), representing the parameters which can be changed.

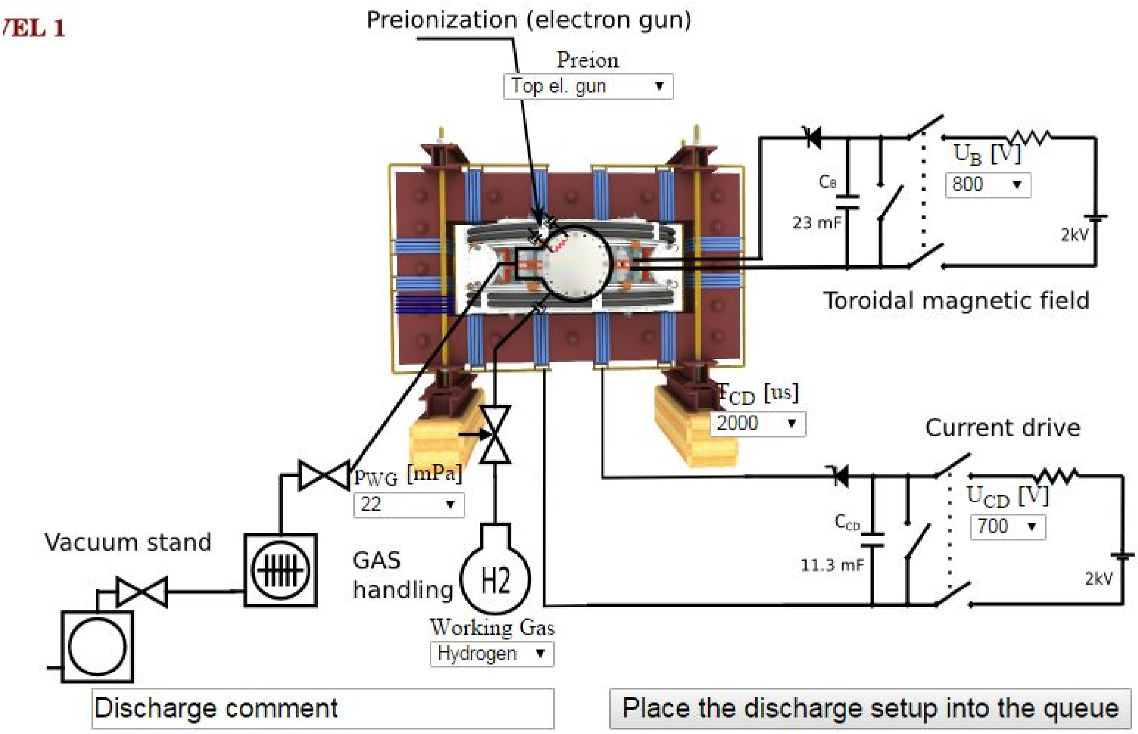


Figure 1: Schema of the Tokamak [1]

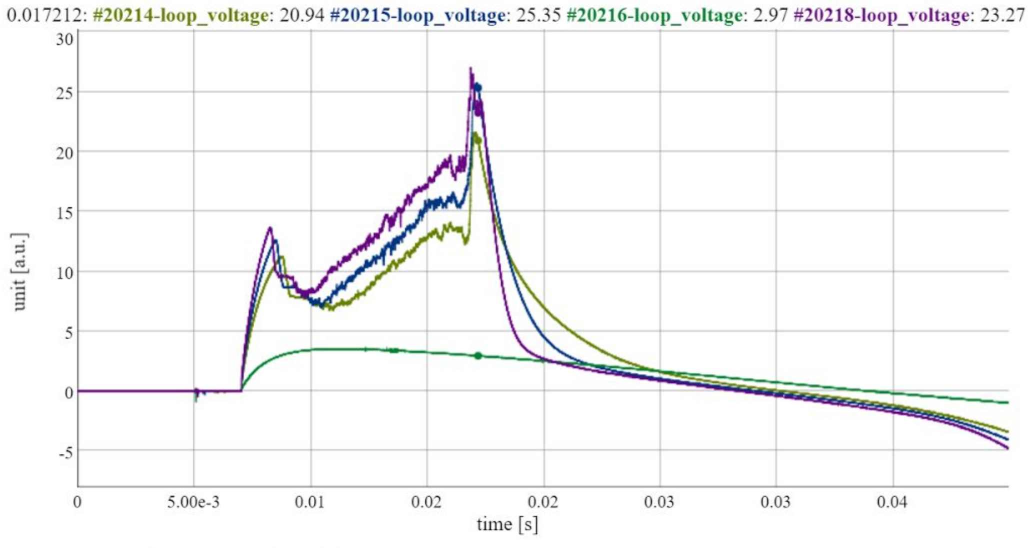
1-**Preion** = Preionization. We will use the option 'Top el. gun', as this one assures that there will be breakdown to initiate ionization of gas for creating plasma. This preionization is performed by an electron gun, based on a heated filament.
2- **pWG [mPa]:** Pressure in the vacuum vessel before the discharge.
3-**Ub [V]:** Voltage going through the capacitor charging the toroidal field (TF) coils. This parameter defines the strength of the toroidal magnetic field "Btor". The higher Ub, the higher Btor is.
4- **Ucd [V]**: Voltage going through the capacitor charging the central solenoid. This parameter defines the strength of the plasma current "Ip". The higher UCD, the higher Ip is.
5-**Tcd [µs]:** Delay time of the central solenoid charging relative to TF coils. This delay is the time between the central solenoid beginning of charging and the starting time of charging the toroidal field coils. The higher this time, the higher the Btor is at the breakdown.

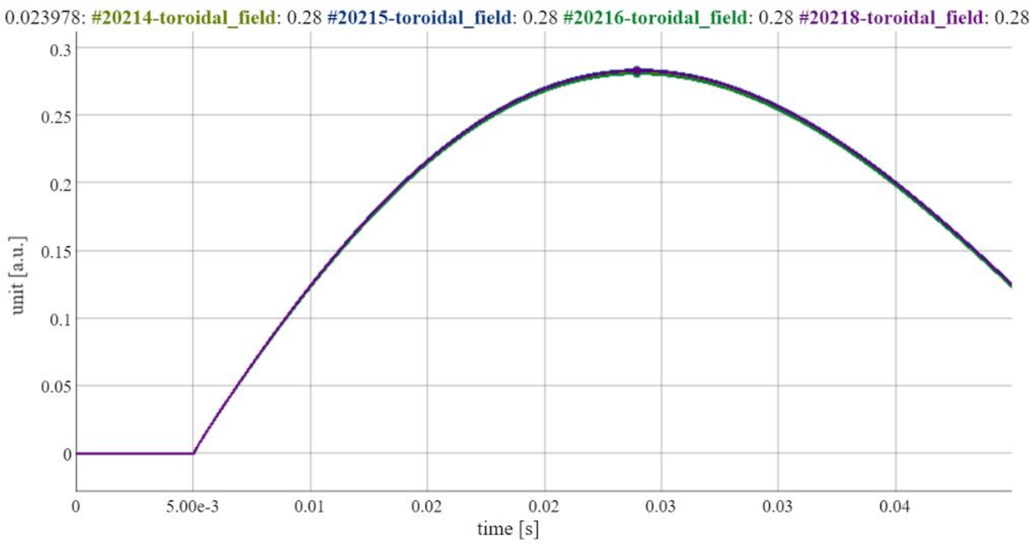
EXPERIMENTAL ANALYSIS

For each discharge, the gas can be chosen and is either hydrogen or helium. However, due to the need to perform several discharges before the possibility to use helium, only hydrogen was used in the following experiments. The gas is taken up by the walls, so to change we must make several gas discharges to clean and have a homogeneous plasma. In addition we always preionized to improve the gas discharge.

1- <u>Variation of Ucd</u>

The first analysis focused on the importance of the voltage going through the capacitor charging the central solenoid. The other parameters, namely pWG, Ub, Tcd were fixed to the following values : pWG= 6mPa Tcd=2000µs, Ub=700V, and Ucd was made vary according to the following program : 100, 500, 600 & 700 V. The results were then compared to each other. Despite pre ionization 100V was no plasma. So we spent 500 for the threshold and discharge.





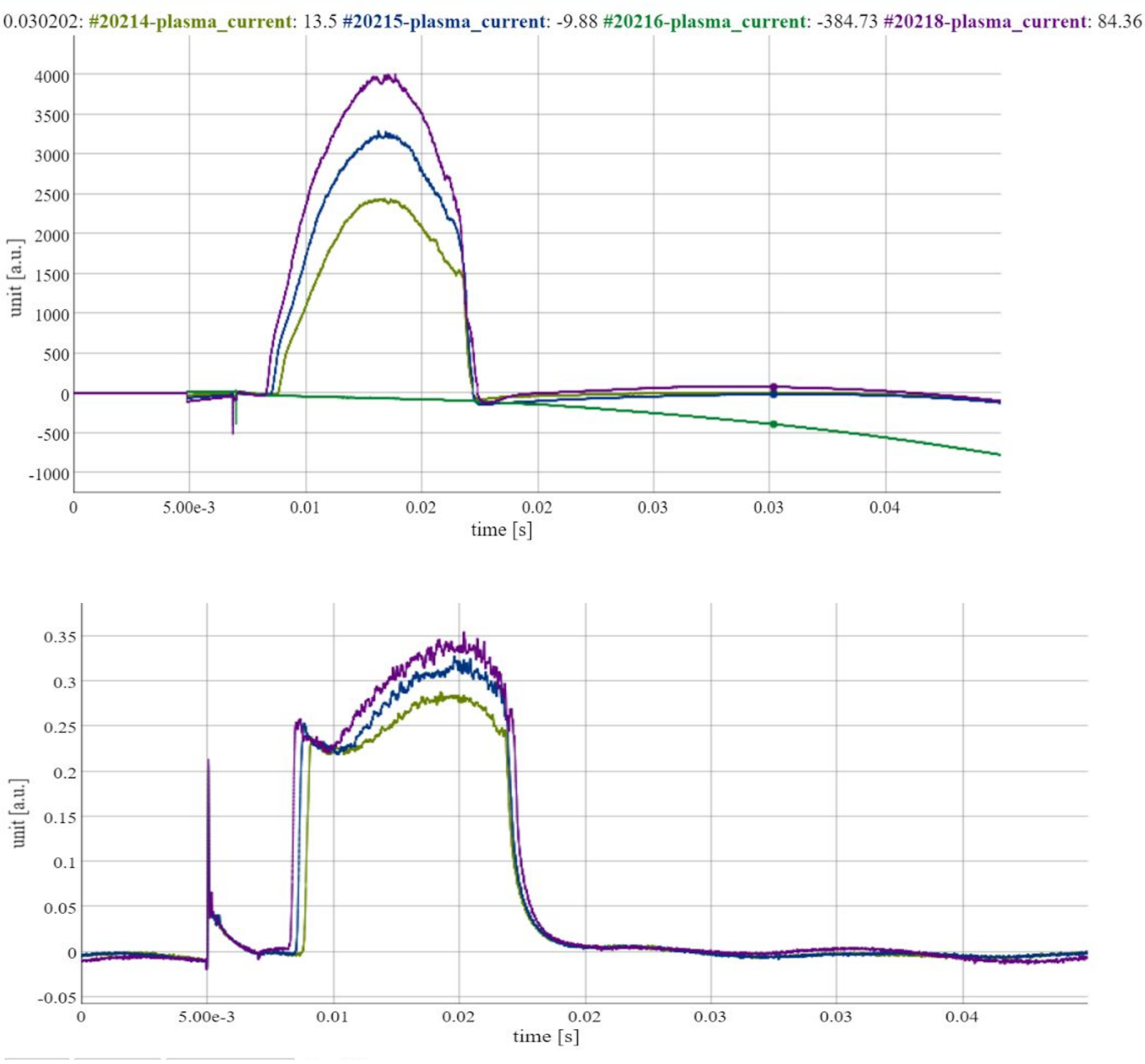


Figure 2: Development in time of some plasma parameters for the runs 20214, 20215, 20216, 20218

Firstly, it could be verified that the higher Ucd, the higher Ip and the loop voltage are. Another interesting fact is that there is no discharge when the Ucd voltage is very low (100V).

The toroidal field is not modified with a variation of Ucd. The radiation increases most certainly causes impurities.

2- <u>Variation of Ub</u>

In this analysis, only Ub was made vary and the other parameters were held to the following values : Ucd= 700V pWG= 6mPa Tcd=2000µs. And different values of Ub (600, 700, 1000 V) were respectively used for the runs 20217, 20218, 20219.

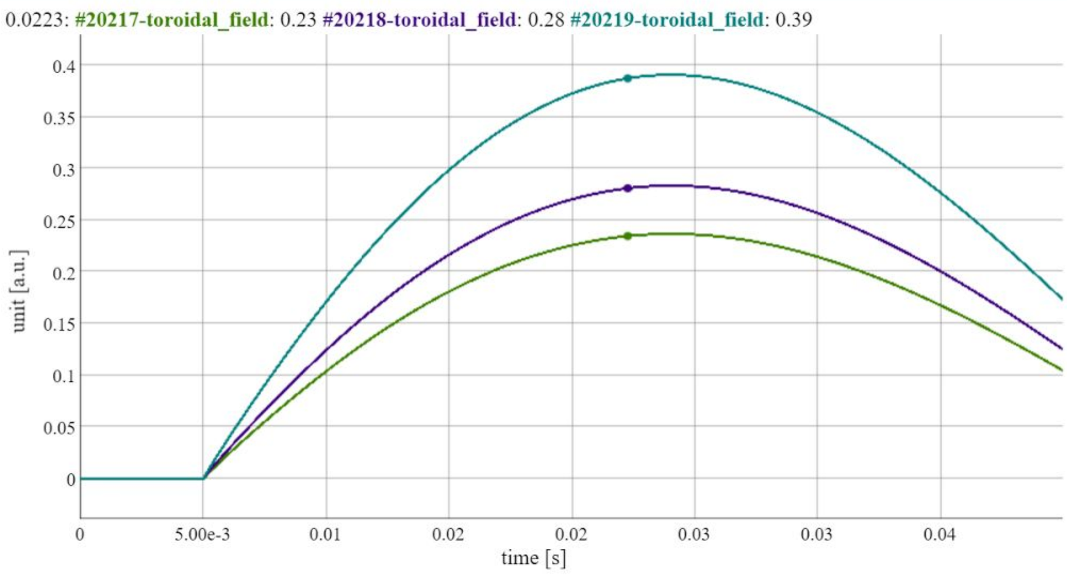


Figure 3: Development in time of Btoroidal for the runs 20217, 20218, 20219

Ub fait varier le courant dans les bobines toroidales

It can be seen on figure 3 that effectively the evolution of the magnetic field follows a similar behavior, and it gets larger when UB is increased.

However if we check the evolution of Ip current with these parameters [Figure 4], it appears that it is lower when UB increases. It maybe the signature of confinment issues because changing the magnetic field it's changing the equilibrium.

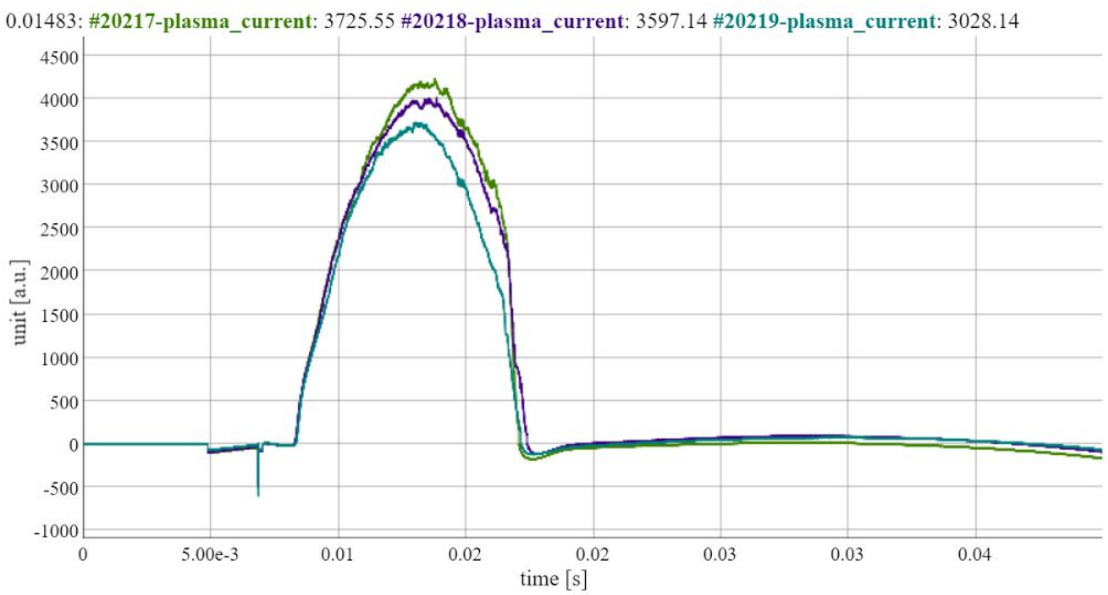


Figure 4: Development in time of I plasma for the runs 20217, 20218, 20219.

3- Variation of Pwg (mPa)

In this study the pressure was modified, using 10, 20 and 30 mPa. The other parameters were held to the following values : Ub=Ucd=700V and Tcd=2000µs.

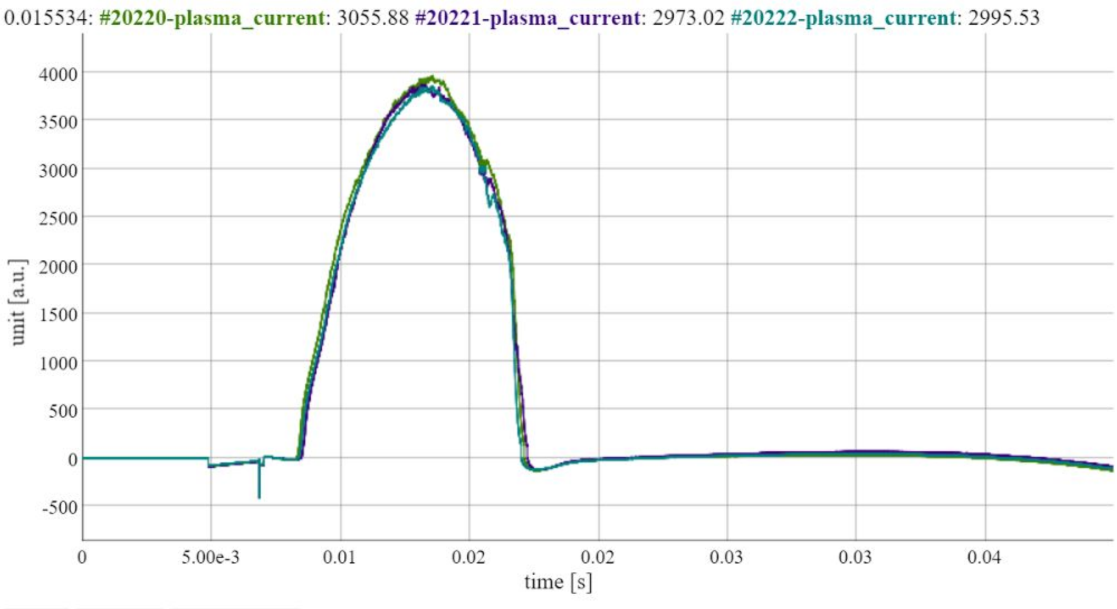


Figure 5: Development in time of I plasma for the runs 20220, 20221, 20222

In this case the results for the Ip current are much closer to each other than in the previous studies. With an increase in pressure, there was increase in the density thus for the same induction of the toroidal current there was more collisions.But if we pay attention, it can be seen that the plasma current diminishes by increasing the pressure, i.e. by increasing plasma density. This is due to the fact that U is constant, and we are increasing the internal resistance of the system, so the current falls a bit. Note that we have U = RI with constant U or R increases, so I decreases.

4- Variation of Tcd

Finally we modified the delay time, Tcd, and chose the following values : 1000, 2000, 4000 µs. The other parameters were, as usual, Ub=Ucd=700V and a pressure of 6mPa.

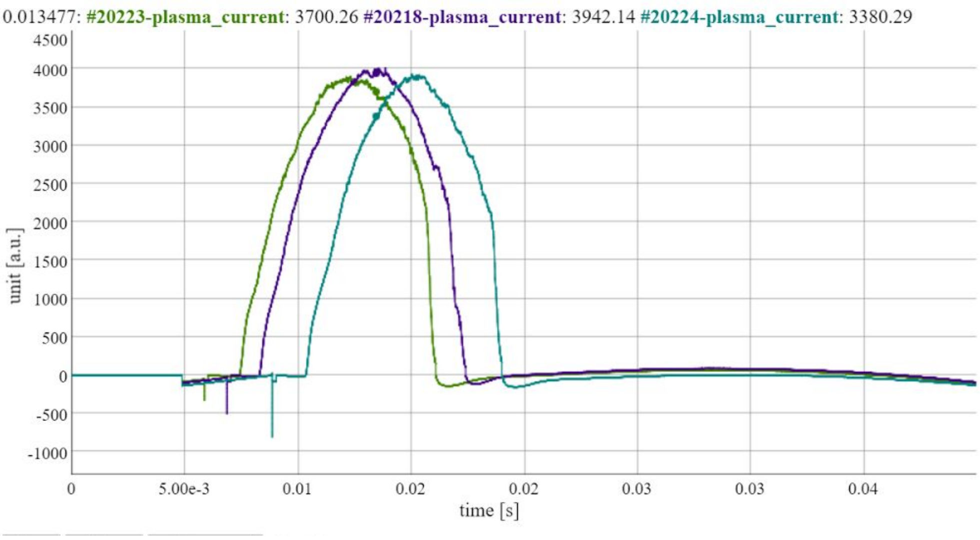


Figure 6: Development in time of I plasma for the runs 20223, 20218, 20224

The influence of the delay time can be seen on figure 6. Plasma properties are the same, except the time shift between the toroidal field and the current, which increases when Tcd increases. The only difference is the Hα in the photodiode which is a bit lower in the case of Tcd = 4000µs. But the reason is not clear and it would be necessary to carry out a deeper analysis.

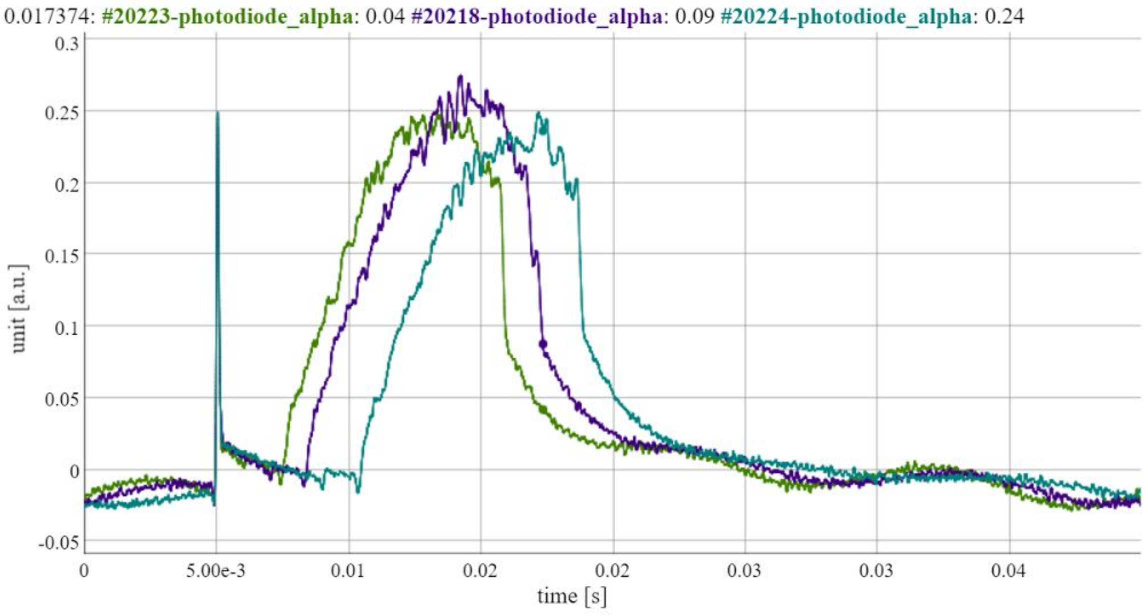


Figure 7: Development in time of Hα for the runs 20223, 20218, 20224

Conclusion

The control in real time of a tokamak as well as the subsequent analysis of the experiments is a unique experience for students, that makes them feel the atmosphere, the spirit of such experiments and that raises their interest and motivation in understanding the principles of plasma control. Therefore the experiments on the GOLEM tokamak have a tremendous importance in plasma science education and will certainly remain very useful in the future

<u>Réferencies</u>

[1] http://golem.fjfi.cvut.cz/roperation/tasks/XXYYGUESTS/Level_I/index.php