The GOLEM tokamak bibliography (IAEA CRP final report)

The tokamak GOLEM team

February 6, 2023

Official GOLEM Articles

Cerovsky et al.: Progress in HXR diagnostics at Golem and COMPASS tokamaks **CerovskyJINST22**

J. Cerovsky et al. "Progress in HXR diagnostics at Golem and COMPASS tokamaks". In: *Journal of Instrumentation* 17.01 (2022), p. C01033. DOI: 10.1088/1748-0221/17/01/c01033. URL: https://doi.org/10.1088/1748-0221/17/01/c01033.

Abstract: Scintillation detectors are widely used for hard X-ray spectroscopy and allow us to investigate the dynamics of runaway electrons in tokamaks. This diagnostic tool proved to be able to provide information about the energy or the number of runaway electrons. Presently it has been used for runaway studies at the Golem and the COMPASS tokamaks. The set of scintillation detectors used at both tokamaks was significantly extended and improved. Besides NaI(Tl) (2 x 2 inch) scintillation detectors, YAP(Ce) and CeBr3 were employed. The data acquisition system was accordingly improved and the data from scintillation detectors is collected with appropriate sampling rate (approx. 300 MHz) and sufficient bandwidth (approx. 100 MHz) to allow a pulse analysis. Up to five detectors can currently simultaneously monitor hard X-ray radiation at the Golem. The same scintillation detectors were also installed during the runaway electron campaign at the COMPASS tokamak. The aim of this contribution is to report progress in diagnostics of HXR radiation induced by runaway electrons at the Golem and the COMPASS tokamaks. The data collected during the 12th runaway electron campaign (2020) at COMPASS shows that count rates during typical low-density runaway electron discharges are in a range of hundreds of kHz and detected photon energies go up to 10 MeV (measured outside the tokamak hall). Acquired data from experimental campaigns from both machines will be discussed.

Kulkov et al.: Detection of runaway electrons at the COMPASS tokamak using a Timepix3-based semiconductor detector **KulkovJINST22**

S. Kulkov et al. "Detection of runaway electrons at the COMPASS tokamak using a Timepix3-based semiconductor detector". In: *Journal of Instrumentation* 17.02 (2022), P02030. DOI: 10.1088/1748-0221/17/02/p02030. URL: https://doi.org/10.1088/1748-0221/17/02/p02030.

Abstract: Runaway electrons are considered dangerous for the integrity of tokamak vacuum vessels. To secure the success of the future tokamak-based machines, reliable diagnostics and mitigation strategies are necessary. The COMPASS tokamak supported the research of runaway electron physics via regular experimental campaigns. During the last two experimental campaigns dedicated to runaway electrons, a semiconductor detector with a Timepix3 readout chip, Si sensor, and the SPIDR readout system was tested. Time evolution signals, energy measurements, and sensor snapshots collected with the Timepix3-based detector are presented.

Sarancha et al.: Magnetic turbulence and long-range correlation studies in the Golem tokamak **SaranchaJPCS21**

G Sarancha et al. "Magnetic turbulence and long-range correlation studies in the Golem tokamak". In: *Journal of Physics: Conference Series* 2055.1 (2021), p. 012003. DOI: 10.1088/1742-6596/2055/1/012003. URL: https://doi.org/10.1088/1742-6596/2055/1/012003.

Abstract: The small university-scale tokamak Golem equipped with the electric and magnetic probes becomes a test bench for studying the plasma turbulence and Zonal Flows, which are the essential processes affecting the plasma confinement. The broadband ($f_{BB} < 250$ kHz) magnetic turbulence was detected for the first time using the Mirnov probes. The two-dimensional (frequency–wavelength) Fourier power spectra $S(k, f)$ of the magnetic turbulence indicate the turbulence poloidal propagation. The long-range correlations (LRC) between the signals of magnetic and electric probes installed at different toroidal cross-sections were detected in the low-frequency range ($f_{LRC} < 60$ kHz), which is similar to the plasma potential LRC range observed in other devices.

Sarancha et al.: Hydrogen and helium discharges in the Golem tokamak **SaranchaPAST21**

G.A. Sarancha et al. "Hydrogen and helium discharges in the Golem tokamak". In: *Problems Of Atomic Science And Technology, Ser. Thermonuclear Fusion* 4 (2021), pp. 92–110. DOI: 10.21517/0202-3822-2021-44-4-92-110. URL: https://doi.org/10.21517/0202-3822-2021-44-4-92-110.

Abstract: The helium plasma properties and confinement remain an important area of research in modern fusion devices. This work is dedicated to the helium plasma initiation and control in a small-scale tokamak Golem compared to hydrogen plasma. Helium and hydrogen plasmas are comprehensively compared and the optimum operational conditions for the start-up are found. Long-range correlations between lowfrequency (¡50 kHz) electrostatic and magnetic oscillations are found, as well as broadband (< 250 kHz) magnetic oscillations resolved in frequency and wave vector in helium plasma.

Siusko et al.: Breakdown phase in the Golem tokamak and its impact on plasma performance **SiuskoUJP21**

Y. Siusko et al. "Breakdown phase in the Golem tokamak and its impact on plasma performance". In: *Ukrainian Journal of Physics* 66.3 (2021), pp. 231–239. URL: https://ujp.bitp.kiev.ua/index.php/ujp/article/view/2020180.

Abstract: The effect of the breakdown phase on subsequent plasma parameters was investigated remotely in Golem tokamak. The dependence of breakdown voltage and the breakdown time versus the time delay between the trigger of the toroidal magnetic field B t and the trigger of toroidal electric field E t for different groups of the pressure magnitudes is built. The performed ex- periments have shown that for Golem tokamak the shorter is temporal delay - the better mean plasma parameters are obtained. In addition, the breakdown phase was discussed more detailed. In the discussion the analysis of the avalanche phase of the breakdown was made. The dominant mechanism of particle loses during avalanche phase, future steps, tasks were discussed and set.

Gryaznevich et al.: Contribution of joint experiments on small tokamaks in the framework of IAEA coordinated research projects to mainstream fusion research **GryaznevichPST20**

M. Gryaznevich et al. "Contribution of joint experiments on small tokamaks in the framework of IAEA coordinated research projects to mainstream fusion research". In: *Plasma Science and Technology* 22.5 (2020), p. 055102. DOI: 10.1088/2058-6272/ab6d4d. URL: https://doi.org/10.1088%2F2058-6272%2Fab6d4d.

Abstract: Joint experiments (JEs) on small tokamaks have been regularly performed between 2005 and 2015 under the framework of the International Atomic Energy Agency (IAEA) coordinated research projects (CRPs). This paper describes the background and the rationale for these experiments, how they were organized and executed, main areas of research covered during these experiments, main results, contributions to mainstream fusion research, and discusses lessons learned and outcomes from these activities. We underline several of the most important scientific outputs and also specific outputs in the education of young scientists and scientists from developing countries and their importance.

Novotny et al.: Runaway electron diagnostics using silicon strip detector **NovotnyJINST20**

L. Novotny et al. "Runaway electron diagnostics using silicon strip detector". In: *Journal of Instrumentation* 15.07 (2020), pp. C07015–C07015. DOI: 10.1088/1748-0221/15/07/c07015. URL: https://doi.org/10.1088%2F1748-0221%2F15%2F07%2Fc07015.

Abstract: We present a proof-of-principle measurement of runaway electrons in a small tokamak using a silicon strip detector. The detector was placed inside the diagnostic port of the tokamak vessel and detected the runaway electron signal directly. The measured signal was compared to the signal provided by other tokamak diagnostics, especially the hard X-ray scintillation detector, which detects secondary photons created by interaction of accelerated electrons with tokamak walls (indirect detection of runaway electrons). The preliminary results show that when not saturated, direct detection with a segmented silicon strip detector provides promising new diagnostic information including spatial and temporal distribution of the runaway electron beam, and the measurement results are in good agreement with hard X-ray measurements with a scintillation detector.

Dhyani et al.: Study of Runaway Electrons in Golem Tokamak **DhyaniJINST19**

P. Dhyani et al. "Study of Runaway Electrons in Golem Tokamak". In: *Journal of Instrumentation* 14.09 (2019), pp. C09029–C09029. DOI: 10.1088/1748-0221/14/09/c09029. URL: https://doi.org/10.1088%2F1748-0221%2F14%2F09%2Fc09029.

Abstract: High loop voltage and low-density plasma discharges at the Golem tokamak present favorable conditions for the study of the runaway electrons (RE). A probe is being designed and developed for the spectral measurement of the RE energy inside the last closed flux surface of Golem tokamak plasma. Design of the probe is based on simulation results of the FLUKA code that estimates the energy absorbed by the scintillating crystals and filters of various densities. In the simulations, graphite, stainless steel and molybdenum were tested to filter the supra-thermal electrons. Since having different light yield, YSO (Y2SiO5:Ce), NaI(Tl) and plastic (EJ-200) scintillating crystals were chosen for the simulations.

Stockel et al.: Operational Domain in Hydrogen Plasmas on the Golem Tokamak **StockelJOFE19**

J. Stockel et al. "Operational Domain in Hydrogen Plasmas on the Golem Tokamak". In: *Journal of Fusion Energy* (2019). ISSN: 1572-9591. DOI: 10.1007/s10894-019-00215-7.

Abstract: A series of discharges in hydrogen were performed in two experimental sessions. The vessel was not conditioned before the first session, while inductive heating of the vessel and cleaning glow discharge were applied before the second session. Experimental results from both sessions are compared, and optimum operational conditions for the majority of key plasma parameters are determined. It is found that plasma performance with a properly conditioned vessel is significantly better, as expected. In particular, a noticeable increase of discharge duration, and of the electron temperature is observed.

Svihra et al.: Runaway electrons diagnostics using segmented semiconductor detectors **SvihraFUSENGDES18**

P. Svihra et al. "Runaway electrons diagnostics using segmented semiconductor detectors". In: *Fusion Engineering and Design* (2018). ISSN: 0920-3796. DOI: 10.1016/j.fusengdes.2018.12.054.

Abstract: A novel application of strip and pixel silicon radiation detectors for study and characterization of run-away electron events in tokamaks is presented. Main goal was to monitor runaway electrons both directly and indirectly. The strip detector was placed inside the tokamak vacuum chamber in order to monitor the run-away electrons directly. Whereas the pixel detector was placed outside the tokamak chamber behind a pin hole for monitoring the run-away electrons indirectly via radiation produce by interaction of the electrons with the plasma facing material. Results obtained using the silicon detectors are compared with already existing diagnostic methods consisting of scintillation devices detecting X-rays and photo-neutrons, providing the same results in the observable comparisons. Tests with the pixel detector proved that the pinhole camera is able to extract spatial information of interaction point (a place where the runaway electrons hit on the facing material) and the strip detectors indicate presence of additional signal from throughout the discharge. The performed experiments are innovative, illustrating possible development of new and easy to use diagnostic method.

Conference proceedings

Macha et al.: Self-induced transport barrier in the helium plasma on the tokamak Golem **MachaEPS22-a**

P. Macha et al. "Self-induced transport barrier in the helium plasma on the tokamak Golem". In: vol. July. Europhysics conference abstracts. 2022. URL: https://indico.fusenet.eu/event/28/contributions/64/attachments/78/1153/EPS_2022_article.pdf.

Abstract: Transport barriers and transmissions into different regimes of plasma confinement are currently very discussed topics. The lattes research showed a connection between transport barriers and E $\times$ B shear flows, which are able to suppress turbulent structures by tearing them apart. This process leads to better particle and also temperature confinement. Therefore, there is a significant effort for transport barrier studies. Usually, transport barriers are induced by an external electric field, which is used for plasma biasing. This method is useful, however, spontaneously formed transport barriers can provide more information about the processes taking place in a tokamak plasma. In this paper, the self-induced transport barrier in the helium plasma on the tokamak GOLEM is observed and analyzed.

Macha et al.: Tokamak Golem for fusion education - chapter 13 **MachaEPS22-b**

P. Macha et al. "Tokamak Golem for fusion education - chapter 13". In: vol. July. Europhysics conference abstracts. 2022. URL: https://indico.fusenet.eu/event/28/contributions/164/attachments/178/1152/EPS_2022_golem_article.pdf.

Abstract: The contribution is devoted to the description of several students projects, related mainly to edge plasma diagnostics, investigation of selected issues of tokamak physics and plasma performance on the GOLEM tokamak, particularly: i) Plasma stabilization, ii) A research on runaway electrons (RE) physics, iii) Plasma edge studies with electrostatic probes and iv) Tomography.

Macha et al.: Tokamak Golem for fusion education - chapter 12 **MachaEPS21**

P. Macha et al. "Tokamak Golem for fusion education - chapter 12". In: vol. July. Europhysics conference abstracts. 2021, P4.1028. ISBN: 979-10-96389-13-1. URL: http://ocs.ciemat.es/EPS2021PAP/pdf/P4.1028.pdf.

Abstract: The GOLEM tokamak is the oldest tokamak in the world. Currently, it serves mainly as an education device for students of tokamak physics. Remote control of the machine enables conducting experiments from all over the world. This contribution summarizes its main research topics of the last year.

Dhyani et al.: Design and development of probe for the measurements of runaway electrons inside the Golem tokamak plasma edge **DhyaniEPS19**

P. Dhyani et al. "Design and development of probe for the measurements of runaway electrons inside the Golem tokamak plasma edge". In: vol. July. Europhysics conference abstracts. 2019, P1.1016. ISBN: 979-10-96389-11-7. URL: http://ocs.ciemat.es/EPS2019PAP/pdf/P1.1016.pdf.

Abstract: FLUKA simulation results show that NaI(Tl) is a good candidate for the spectral measurement of the RE beam energy, since the amount of energy deposited by monoenergetic beam in the crystals is different as shown in figure 4. Further simulations will be carried out using GEANT4 and FLUKA codes, to interpret the signals obtained during the experiments. In GOLEM tokamak experiments, we measure HXR outside the machine that has S.S. (density 8.0 g/cm3) vacuum vessel of 0.2mm surrounded by a copper (density 8.96 g/cm3) donut shaped shield of thickness 10mm. Reported simulation results indicate that 2.5mm thin graphite (density 2.1 g/cm3) shield was able to absorb 1MeV beam effectively, indicating that the RE beam in the GOLEM tokamak has energy much higher than 1MeV, in general.

Grover et al.: Online experimentation at the Golem tokamak **GroverIEEE19-b**

O. Grover, V. Svoboda, and J. Stockel. "Online experimentation at the Golem tokamak". In: *2019 5th Experiment International*

Conference (exp.at'19). 2019, pp. 220–225. DOI: 10.1109/EXPAT.2019.8876482. URL: https://ieeexplore.ieee.org/document/8876482.

Abstract: The Golem tokamak offers students and other interested parties the opportunity to gain "hands-on" experience through online experimentation in the field of plasma physics and controlled thermonuclear fusion in tokamaks. A typical online experiment scenario is outlined. The new web application facilitating safe, easy and efficient online experimentation, including a live, real-time view of the experiment is described in detail. Simple access to the open and extensive database of experimental results is demonstrated. Finally, the wide range of possible experimental topics from past -and applicable to future-online experimentation sessions is reported.

Kulkov et al.: Tokamak Golem for fusion education - chapter 10 **MachaEPS19**

S. Kulkov et al. "Tokamak Golem for fusion education - chapter 10". In: vol. July. Europhysics conference abstracts. 2019, P1.1068. ISBN: 979-10-96389-11-7. URL: http://ocs.ciemat.es/EPS2019PAP/pdf/P1.1068.pdf.

Abstract: The GOLEM tokamak is the oldest tokamak in the world. Currently, it is located at the FNSPE CTU in Prague and it serves mainly as an education device for students of tokamak physics. Remote control of the machine enables conducting experiments from all over the world using an internet connection. This contribution summarizes main research topics of study of the last year.

O. Grover and V. Svoboda and J. Stockel: Remote demonstration of the Golem tokamak **GroverIEEE19-a**

O. Grover and V. Svoboda and J. Stockel. "Remote demonstration of the Golem tokamak". In: *2019 5th Experiment International Conference (exp.at'19)*. 2019, pp. 239–240. DOI: 10.1109/EXPAT.2019.8876584. URL: https://ieeexplore.ieee.org/document/8876584.

Abstract: The Golem tokamak serves as an educational device in the field of tokamak physics, technology, diagnostics and operation in the scope of the wider field of thermonuclear fusion. The typical scenario of a remote demonstration of the Golem tokamak is described. The new remote control and live status web interface in its mobile-ready form is presented.

Istokskaia et al.: Tokamak Golem for fusion education - Chapter 9 **IstokskaiaEPS18**

V. Istokskaia et al. "Tokamak Golem for fusion education - Chapter 9". In: vol. July. 2018, pp. 261–264. URL: http://golem.fjfi.cvut.cz/wiki/Presentations/Conferences/EPS/45th_Prague_2018/paper.pdf.

Abstract: The GOLEM tokamak, located at the FNSPE CTU in Prague, is the oldest tokamak in the world still operational. Its main mission is education and training of future fusion specialists in the Czech Republic. This contribution covers various student projects of the last year.

Linhart et al.: First Measurement of X-rays Generated by Runaway Electrons in Tokamaks Using a Timepix3 Device with 1 mm thick Silicon Sensor **LinhartIEEE18**

V. Linhart et al. "First Measurement of X-rays Generated by Runaway Electrons in Tokamaks Using a Timepix3 Device with 1 mm thick Silicon Sensor". In: *2018 IEEE Nuclear Science Symposium and Medical Imaging Conference Proceedings (NSS/MIC)*. 2018, pp. 1–9. DOI: 10.1109/NSSMIC.2018.8824534.

Abstract: An application study of modern pixel semiconductor detectors for characterization of runaway electron events in tokamaks is presented. Characterization techniques utilizing both spectroscopic measurements and monitoring of the intensity of secondary X-rays produced by the runaway electrons were used. Energy spectra of X-rays and time evolutions of their intensity on two tokamaks (Golem and Compass) were measured under different conditions and compared with results of standard runaway diagnostics. The energy spectra measured on both tokamaks have similar exponential shapes but with a significant variation in numbers of events per shot. The time evolutions of the X-ray intensity during several discharges on the tokamak Golem were measured using both the Timepix3 device and scintillation detectors (NaI:Tl and YAP:Ce). On a microsecond time scales, the signal time evolution measured by the TimePix3 device shows patterns in a form of unexpected or periodic-like increases of the intensity. We have also observed significant differences in number of events of the detected X-rays generated by the runaway electrons flying frontward and backward with respect to a limiter of the tokamak Golem. This fact declares that the runaway electrons have relativistic velocities. The experiments on the tokamak Compass provide similar results. Measurements in the immediate vicinity of tokamak Compass were impossible to perform because of a rapid change of the tokamak magnetic field. Measurements performed in the distance of at least 0.5 m from a diagnostic port of the tokamak Compass gave millions of correctly measured events per shot and an unknown number of events affected by pileups. The correctly measured events were used for construction of energy spectra and the time evolutions of the X-ray intensity.

Master thesis

M. Tunkl: Development of a new runaway electron diagnostics method based on strip semiconductor detectors **TunklMT22**

M. Tunkl. "Development of a new runaway electron diagnostics method based on strip semiconductor detectors". Master Thesis. 2022. URL: http://golem.fjfi.cvut.cz/wiki/Presentations/Students/MasterThesis/22TunklMarek.pdf.

Abstract: In this master's thesis, new diagnostics of runaway electrons on the GOLEM tokamak were developed. First, a simulation in the Geant4 toolkit was created to evaluate the effect of the backscattering of the runaway electrons from the limiter. Then, a silicon-based strip detector probe was designed and constructed with respect to the simulation result. Finally, the measured data were analyzed and compared to the relevant diagnostics and simulation results. Furthermore, a new scintillation detector was constructed from a silicon photomultiplier and a LYSO crystal. The signal from the silicon photomultiplier exhibited good characteristics. Even with multiple superimposed peaks, it was possible to reconstruct their original height and thus obtain the hard X-ray spectrum of the entire plasma discharge.

D. Cipciar: Ion and electron temperature study in the edge plasma of the tokamak device **CipciarMT21**

D. Cipciar. "Ion and electron temperature study in the edge plasma of the tokamak device". Master Thesis. 2021. URL: `http://golem.fjfi.cvut.cz/wiki/Presentations/Students/MasterThesis/21DarioCipciar.pdf`.

Abstract: This thesis reports on a systematic ion and electron temperature measurements in the scrapeoff layer (SOL) of two tokamak devices. Results are obtained using a fast swept ball-pen probe with unprecedented temporal resolution (10 jits). Moreover, an improved analysis technique is presented which increases the amount of relevant data obtained in comparison to previously published research. The results with high temporal resolution indicate non-Gaussian ion temperature histograms with a peak at low temperatures and a high temperature tail associated with blobs. The blobs are originating in the vicinity of last closed flux surface and propagate perpendicularly to the magnetic field lines through the SOL plasma. The resulting fast measurements are used to simulate the I-V characteristic of a slow swept (3 ms) retarding field analyzer (RFA). The exponential part of the RFA-like I-V characteristic also determines the ion temperature, but with low temporal resolution (3 ms). The ratios of the ion to electron temperatures are studied for different plasma densities. We observed that the ratio depends on the line-average plasma density and it is close to 1-2 in the vicinity of LCFS and 3-4 in the main SOL. A study of the ion temperature fluctuations shows an agreement with a stochastic model for intermittent turbulence in SOL.

P. Macha: Edge plasma studies in tokamaks by the mean of advanced electric probes. **MachaMT20**

P. Macha. "Edge plasma studies in tokamaks by the mean of advanced electric probes." Master Thesis. 2020. URL: `http://golem.fjfi.cvut.cz/wiki/Presentations/Students/MasterThesis/20MachaPetr.pdf`.

Abstract: This diploma thesis is dedicated to edge plasma studies in tokamaks by the means of advanced electric probes. After introduction of the theory and basic concepts of edge plasma physics, electric probes and numerical simulations, the analysis of probe data from COMPASS and Golem tokamaks is performed. Main focus is given to the fluctuations of plasma parameters and their respective profiles. A decrease of the level of relative fluctuations of plasma parameters in the velocity shear layer is observed and the impact of a quasicoherent mode on this decrease is discussed. The electron temperature is determined by the interpolation of measured tunnel probe current ratio in the scope of a wide parametric scan performed by numerical simulations, resulting in a high time resolution. This technique is cross-checked by a comparison with established electron temperature measurement methods. A good agreement between experiment and simulations on the electron side of the tunnel is observed.

Bachelor projects

J. Chlum: Implementation of tomographic inversion on the Golem tokamak. **ChlumBP22**

J. Chlum. "Implementation of tomographic inversion on the Golem tokamak." Bachelor project. 2022. URL: `http://golem.fjfi.cvut.cz/wiki/Presentations/Students/BachelorProjects/22ChlumJakub.pdf`.

Abstract: The topic of this bachelor's thesis is visible light tomography of tokamak plasma and its implementation on the GOLEM tokamak. The thesis includes a theoretical summary of radiation processes in tokamak plasmas in the visible spectrum. The thesis then summarises the principles of the tomography inversion task and its solution with emphasis on the minimum Fisher Tikhonov regularization algorithm used here. The practical part of the thesis includes the calibration of two fast cameras for the their use both on the tokamak and separately. The calibration was tested by the tomographic inversion of a known emissivity profile. Finally, the tomography was tested on experimental data from the GOLEM tokamak. Its limitations and errors were discussed and options for futher development were suggested.

J. Malinak: Electron temperature measurements using rail probe on the tokamak Golem. **MalinakBP21**

J. Malinak. "Electron temperature measurements using rail probe on the tokamak Golem." Bachelor project. 2021. URL: `http://golem.fjfi.cvut.cz/wiki/Presentations/Students/BachelorProjects/21MalinakJiri.pdf`.

Abstract: This bachelor thesis is devoted to the problem of measurement of edge plasma parameters with a new type of probe, the so-called rail probe. The advantage of this probe is that thanks to its design it can withstand extremely high heat fluxes and at the same time behaves as a proud Langmuir probe for a certain non-zero angle of incident field lines. The thesis summarises the fundamental physics of the Langmuir probe and sheath expansion. A manipulator was developed and constructed to allow tilting of the probe head, which includes a proud Langmuir probe and a ball-pen probe in addition to the rail probe. Comparative measurements of the electron temperature using all of these probes are presented and show conformity. The dependence of the obtained plasma parameters on the head tilt angle is also investigated. The measured data are compared with a 2D PIC simulation

performed for a Golem tokamak. These 2D PIC simulations will be an essential part of the rail probe's development for the COMPASS Upgrade tokamak.

F. Papousek: Impact of swept edge plasma potential biasing on turbulence in tokamaks. PapousekBP20

F. Papousek. "Impact of swept edge plasma potential biasing on turbulence in tokamaks." Bachelor project. 2020. URL: `http://golem.fjfi.cvut.cz/wiki/Presentations/Students/BachelorProjects/20PapousekFilip.pdf`.

Abstract: In the tokamak plasma the edge plasma is the barrier between the hot confined plasma centre and the cold tokamak vessel. One of the fastest mechanisms of energy and particle loss from the confined plasma is turbulent transport. One of the concepts to understand turbulence and its self–organization are zonal flows, further referred to as ZFs. ZFs have two branches, near-zero frequency flows and geodesic acoustic modes further referred to as GAMs with higher frequency(typically tens of kHz on most tokamaks of modest size and regular aspect ratio). The symmetry and stability of ZFs cause the energy of turbulence to flow out and thus, ZFs cause saturation of drift–wave turbulence.

P. Macha: Měření parametrů plazmatu pomocí kombinované ball-pen a langmuirovy sondy na tokamaku Golem. MachaBP18

P. Macha. "Měření parametrů plazmatu pomocí kombinované ball-pen a langmuirovy sondy na tokamaku Golem." Bachelor project. 2018. URL: `http://golem.fjfi.cvut.cz/wiki/Presentations/Students/BachelorProjects/18MachaPetr.pdf`.

Abstract: The bachelor thesis is dedicated to the edge plasma parameters measurements and ball-pen probe calibration at the Golem tokamak. The first part introduces the theory of plasma and the physics of tokamaks, focusing on the Golem tokamak. The next part presents basic diagnostics of the Golem tokamak. The second part covers the physical principles of both Langmuir and ball-pen probes and the theory important for planned meassurements. Finally, the description of experimental set-ups probes at the Golem tokamak and experimental set-ups are given. The third part describes the experimental results obtained in hydrogen and helium plasmas. Based on the data, ball-pen probe calibration is determined and basic plasma parameters are evaluated. These results are finally presented and compared for both working gases. The thesis is concluded with the overal discussion and summary of all the achieved results.

Unofficial articles (without GOLEM cooperation/authors)

Chandrasekaran et al.: Magnetohydrodynamic Mode Identification for Golem Mirnov Coil Signals Using Singular Value Decomposition and Multichannel Variational Mode Decomposition Method for Analyzing Time-Frequency ChandrasekarJFE22

J. Chandrasekaran and S. Jayaraman. "Magnetohydrodynamic Mode Identification for Golem Mirnov Coil Signals Using Singular Value Decomposition and Multichannel Variational Mode Decomposition Method for Analyzing Time-Frequency". In: *Journal of fusion energy* 41.2 (2022). ISSN: 0164-0313. DOI: `10.1007/s10894-022-00329-5`.

Abstract: In this paper, we have investigated the method to study non-stationary signal characteristics in plasma tokamak using the combination of Multichannel Variational Mode Decomposition (MVMD) and Singular Value Decomposition (SVD). We have applied this technique directly without any signal preprocessing techniques over the Mirnov coil signals to analyze the magnetic fluctuations produced by the rotating magnetic fields of the plasma in tokamaks. Extraction of Principal axes (PA) and Principal Components (PC) of multichannel Mirnov coil signals are through the singular value decomposition technique. The Multichannel variational mode decomposition technique is provided with a PC matrix to identify the dominant harmonics as K-modes. Finally, the Time-frequency analysis is carried out using Hilbert Transform (HT). The proposed technique handles multichannel Mirnov coil signals in parallel to frequency identification, and also to understand the poloidal structure during current perturbation. Artificially simulated data and Mirnov coil signals from Golem Tokamak aided in testing the proposed technique. In Golem data during the present rise phase, transition happens in the current perturbation from m = 4, poloidal structures to m = 3, and m = 2. The simulated data and Golem tokamak data generated the results of the proposed model. The article also compared this with other existing signal decomposition techniques.