Recent results from GOLEM tokamak. 'Indeed, you can teach an old dog some new tricks.'

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GOLEM - 'an old dog' (former TM-1, TM-1-MH and CASTOR) is the second oldest tokamak device to be ever built and also the oldest one still operational. In its present configuration, it is a small, iron core, ohmically heated, limiter tokamak operated in a university environment. Although, it is not as significant as other devices with respect to its size and plasma performance, GOLEM (R = 0.4 m, a = 0.085 m, Bt < 0.5 T, Ip < 4 kA) is a viable platform for implementing a number R&D projects highly relevant to fusion.

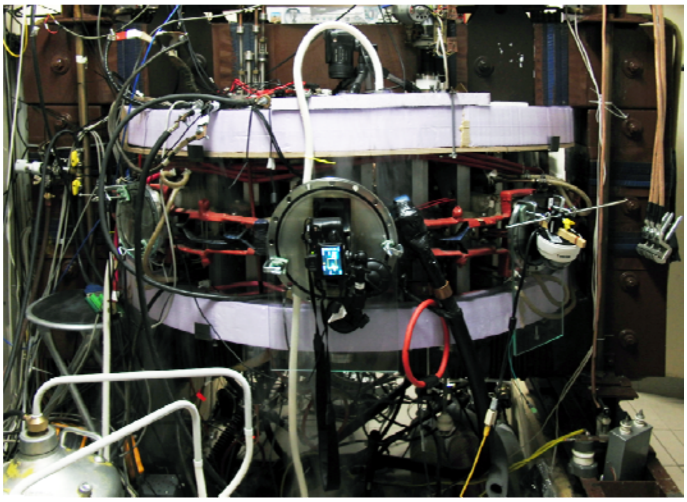
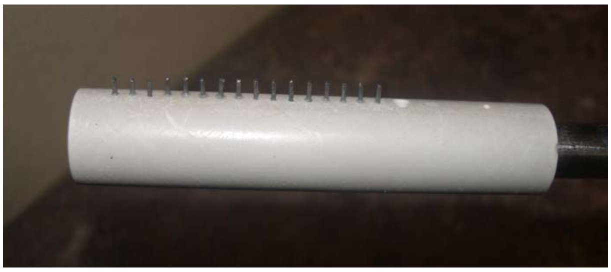


Figure 1: GOLEM tokamak with the visible cryostat housing the pair of high temperature superconducting poloidal field coils.

The essential element of the present GOLEM operation is its capability to be controlled almost fully remotely via the Internet. This is allowed by a set of hardware and software tools which together with a tokamak operation simulator and a virtual model of the device massively increase its educational and training outreach [1]. These tools were extensively used recently during the **GO**lem re**M**ote **TRAI**ning **C**ourse (**GOMTRAIC**) - an educational and training course in basics of experimental tokamak physics via remote experiments on GOLEM. GOMTRAIC participants formed a number of research groups around 11 scientific topics, familiarized themselves with the experimental set-up using the virtual reality model of GOLEM, got a flavor of tokamak GOLEM operation using GOLEM discharge simulator, and proposed and conducted remotely real experiments under supervision of GOLEM experts available on-site. This truly global event was attended by 49 participants from 17 countries spread over 3 continents. There are also number of research activities going on at GOLEM which are of interest to wider plasma physics and tokamak community. Recently, first performance tests of a tokamak magnet, winded from the new generation of high temperature superconductors (Re)BCO, have been conducted on GOLEM [2]. A simplified equilibrium reconstruction code (based on ref. [3]), has been developed in order to obtain a better estimation of plasma position. As the GOLEM transformer core is made of iron, it was also necessary to develop an appropriate model for its ferromagnetic core. Good correlation between the theoretical model and magnetic measurements has been achieved. Advanced algorithms for plasma breakdown prediction using support vector learning machines approach were developed and tested. Spatial and temporal characteristics of magnetic turbulence were investigated on GOLEM using a new full poloidal in-vessel ring housing 16 equidistantly spaced pick-up coils. Cross-correlation and spatial Fourier transform analysis revealed a clear MHD activity occurring during most of the GOLEM discharges with typical poloidal mode number m=3. First tests of the high temperature resistant (<300°C) Hall sensors in a tokamak environment are being prepared on GOLEM. These sensors are one of the candidate solutions for measurement of stationary magnetic fields in fusion reactors. Energy distribution of HXR photons was measured at several discharge conditions on GOLEM using NaI(Ta) scintillator detector. Measured HXR photons spectrum ranges up to 1.5 MeV and peaks typically at 300 keV. We assume the measured energy spectrum of HXR photons correspond to the energy distribution of runaway electrons. Finally, the spatial and temporal characteristics of electrostatic turbulence in GOLEM edge plasmas were studied using the radial array of 16 Langmuir probes. Comparison of turbulence properties between standard hydrogen and helium discharges was done. These experiments are discussed in more detail within the rest of this contribution. It is widely recognized that electric probes are important tools for studying edge plasma physics in tokamaks, because the required space resolution (in the range of several ion Larmor radii) and a high temporal resolution (of about 1 μs or even better) can be easily achieved. The GOLEM tokamak is equipped by the array of Langmuir tips which measure signals at 16 different positions from the center of the tokamak vessel, see Figure 2 - top panel. This probe array, called the rake probe, is inserted in the tokamak from bottom, as it is seen in Fig. 2 - bottom panel. The probe head can be moved in vertical direction on the shot-to shot basis. It is also viewed by the fast camera through the corresponding vertical port equipped by a glass window. Such arrangement allows seeing the interaction of the probe with plasma with the temporal resolution 0.8 ms. The probe head is composed of 16 tips spaced radially by 2.5 mm. The tips are made of Molybdenum wire of thickness 0.7 mm. The length of each tip is 2 mm. The orientation of tips with respect to the magnetic field lines can be changed on the shot-to-shot basis. In the current experiments, the tips are perpendicular to the magnetic field lines and turned towards the low-field side of the torus. The individual tips measure the floating potential in the described experimental campaign. Signals of the probe tips are digitized using the sampling frequency 1 MHz. The frequency band of the measuring circuit has upper limit of 150 kHz. The floating potential U_{fl} is related to the plasma potential according the formula $U_{fl} = \Phi - \alpha T_e$, where T_e is the electron temperature and the coefficient α is around 3 in hydrogen plasmas. The gradient of the floating potential is linked to the radial electric field at the plasma edge as grad $U_{fl} = E_{rad} - \alpha$ grad T_e. The electron temperature of the edge plasma on GOLEM is typically ~ 16 – 20 eV and its radial profile is rather flat. Therefore, grad $T_e \sim 0$ is a reasonable assumption for the edge region of the GOLEM tokamak. Therefore, the gradient of the floating potential can be considered as indicative of the radial electric field E_{rad} = grad U_{fl}. The radial electric field causes poloidal rotation of the plasma due to the E×B drift. The poloidal velocity can be easily calculated as $v_{pol} = E_{rad}/B_T$, where B_T is the toroidal magnetic field, which is routinely measured during every GOLEM discharge. Radial profile of v_{pol} was measured for two similar discharges: #9022 in H_2 and #9038 in He, see Figure 3. Generally,



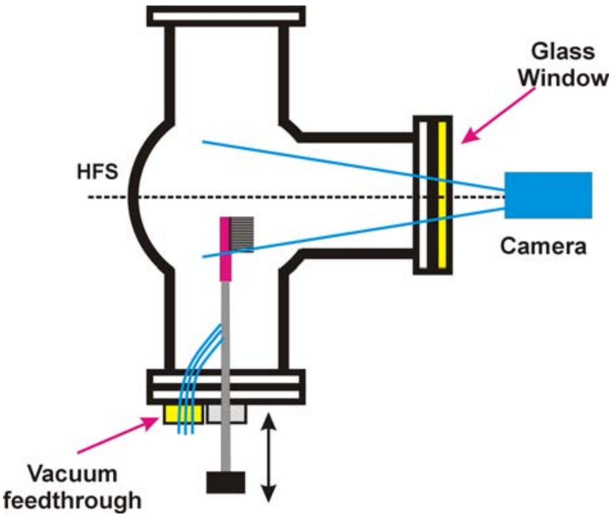


Figure 2: Top panel - probe head containing radial array of 16 Langmuir probes. Bottom panel - schematic layout of experiments with the rake probe on GOLEM tokamak.

significantly lower magnitude of poloidal rotation and particularly of its shear in radial direction is observed in helium discharge (v_{pol} < 1 km/s) compared to the discharge in hydrogen (v_{pol} < 9 km/s). This picture is consistent with results obtained from correlation analysis of floating potential fluctuations, see Figure 4. Here, significantly longer radial correlation length is observed for helium discharge ~ 10 mm compared to the hydrogen discharge where it is ~ 3 mm. Also, autocorrelation time of U_{fl} turbulent structures is noticeably longer in helium discharges. These initial findings motivate

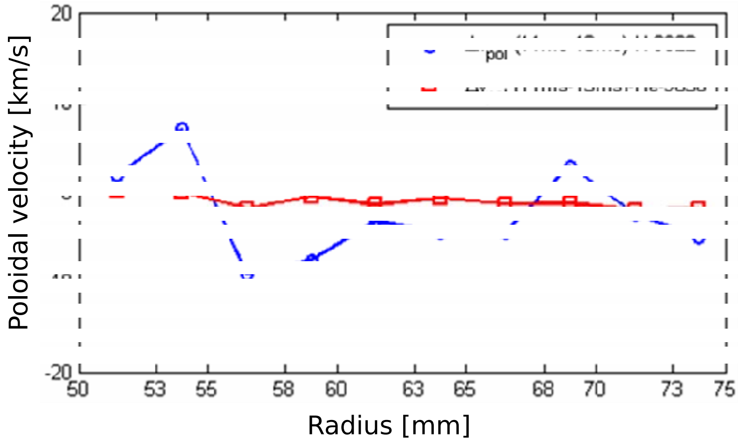


Figure 3: Radial profile of poloidal plasma rotational velocity measured in discharge with working gas hydrogen (blue trace) and in helium discharge (red trace).

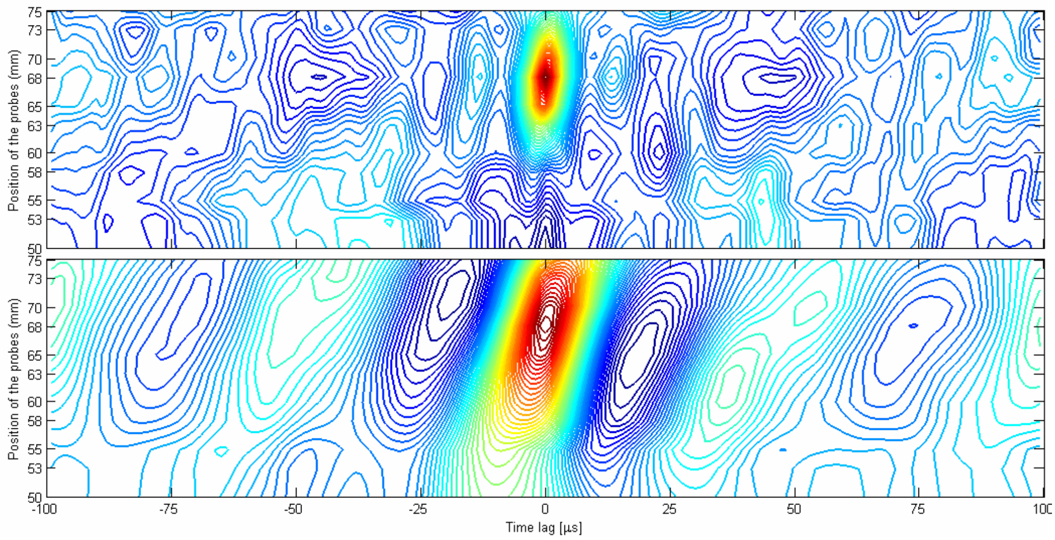


Figure 4: Top panel - cross-correlation functions of U_{fl} fluctuations in hydrogen plasmas, discharge #9022. Bottom panel - cross-correlation functions of U_{fl} fluctuations in hydrogen plasmas, discharge #9038.

further investigation of impact of working gas on electrostatic turbulence properties and particularly on resulting anomalous transport on GOLEM tokamak.

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