

First measurements of SOL plasma filament properties with U-probe on the COMPASS tokamak

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Introduction

Elongated turbulent structures carrying electric current along the magnetic field lines in scrape-off layer (SOL), current filaments, were recently observed on RFX-mod [1, 2, 3]. The filaments carry out energy from plasma and deposit it unequally on the walls of the vacuum vessel. Therefore, large groups of filaments represent severe danger for the first wall and divertor components. This work is devoted to study of filamentary structures by the U-probe during H-mode discharges on the COMPASS tokamak [4].

Current filaments are characterized by electron density n_e , electron and ion temperature T_e and T_i , plasma potential Φ , vorticity ω , and parallel electric current density j_{par} . We measure the ion saturation current that is proportional to electron density $I_{sat} \sim n_e$ and the floating potential that is proportional to plasma potential and electron temperature $V_{fl} \sim \Phi, T_e$. The parallel electric current is calculated using Maxwell equation:

$$I_{//} = \frac{1}{\mu_0} \left(\frac{\Delta B_{pol}}{\Delta r} - \frac{\Delta B_{rad}}{\Delta p} \right) * S \quad (1)$$

where perpendicular components of the magnetic field B_{pol} and B_{rad} are measured by 3D magnetic coil sets embedded in the U-probe and surface S is given by area enclosed by the coils used for calculation $S = \Delta p * \Delta r / 2$, see Fig. 1.

U-probe

The U-probe [5] consists of two identical towers made of boron nitride and housing a triple probe, array of 6 Langmuir tips (rake probe) and 3 sets of 3D magnetic coils each. The probe is inserted in the SOL near separatrix by the manipulator located at outer side of the COMPASS vacuum vessel below the midplane, see Fig. 1. The manipulator allows radial and angular adjustment of the probe head position on the shot-to-shot basis.

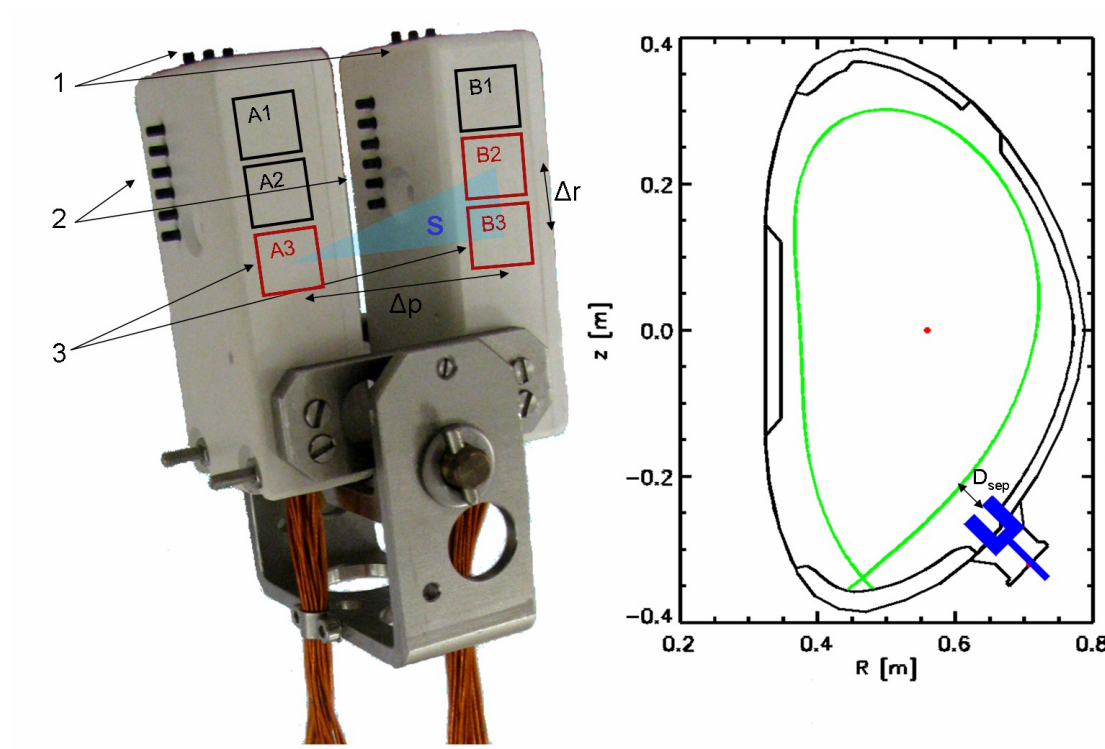


Figure 1. Left – photograph of the U-probe (1-triple probe, 2-rake probe, 3-coil sets), right – schematic view of U-probe position (blue) within the vacuum vessel (black) and with respect to the separatrix (green).

For calculation of I_{par} we use signals from coil sets A3, B2 and B3. The quantities required for I_{par} calculation according eq. 1 are defined as $\Delta B_{pol} = B_{pol}^{A3} - B_{pol}^{B3}$ and $\Delta B_{rad} = B_{rad}^{B2} - B_{rad}^{B3}$ and measured with the sampling rate of 5 MSps. The signals of V_{fl} and I_{sat} are measured with the sampling rate of 2 MSps.

Experimental results

Figure 2 shows temporal evolution of the discharge #7154 ($B_T=1.15$ T, $I_{pl}=300$ kA) with spontaneous transition to H-mode at time $t=1064$ ms, characterized as sudden drop of H_α radiation. The L-H transition is followed by several Type III-ELMs and ELM-free period with duration of 40 ms. We focus on detail analysis of two time intervals. The first contains one Type III-ELM at $t=1067.5$ ms and the second time interval corresponds to H-L transition at 1116.7 ms as noted by blue dotted lines in Fig. 2.

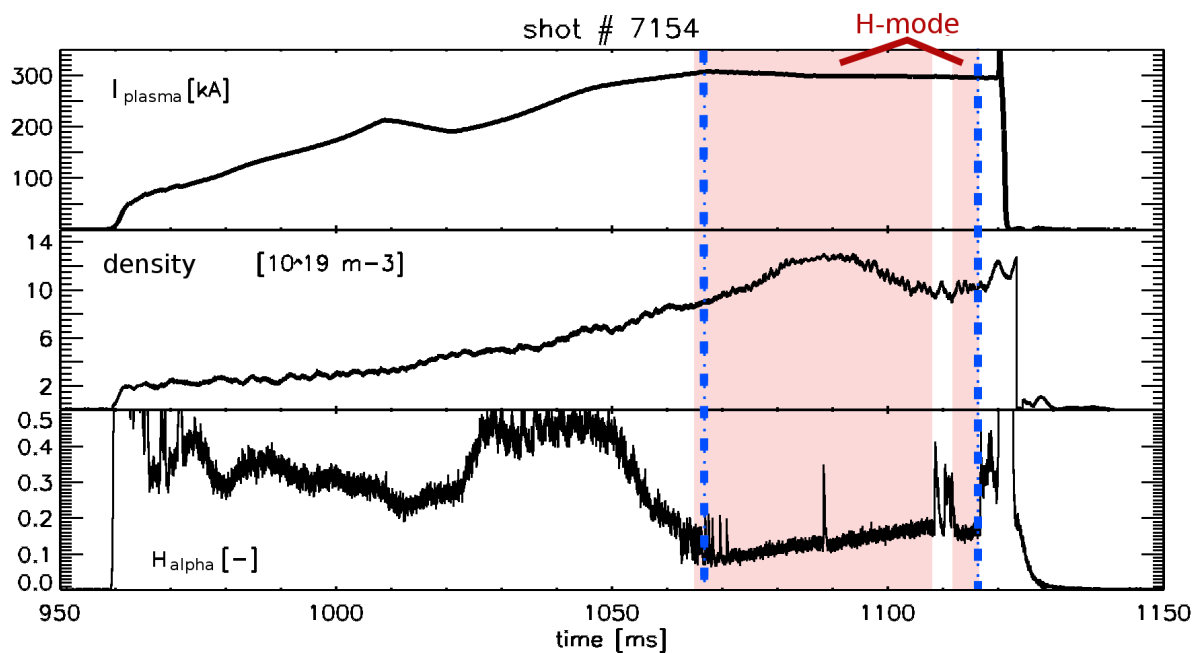


Figure 2. Temporal evolution of the discharge #7154. From top to bottom – plasma current I_{pl} , electron density n_e , and H_α radiation. Blue dotted lines highlight time intervals analyzed in detail.

Figure 3 show results obtained with the U-probe located at distance from the separatrix $D_{sep} = 33$ mm. The left panel plots evolutions of the probe signals during the single ELM (type III). The right panel represents the termination of the H-mode, i.e. the H–L transition and following L-mode phase.

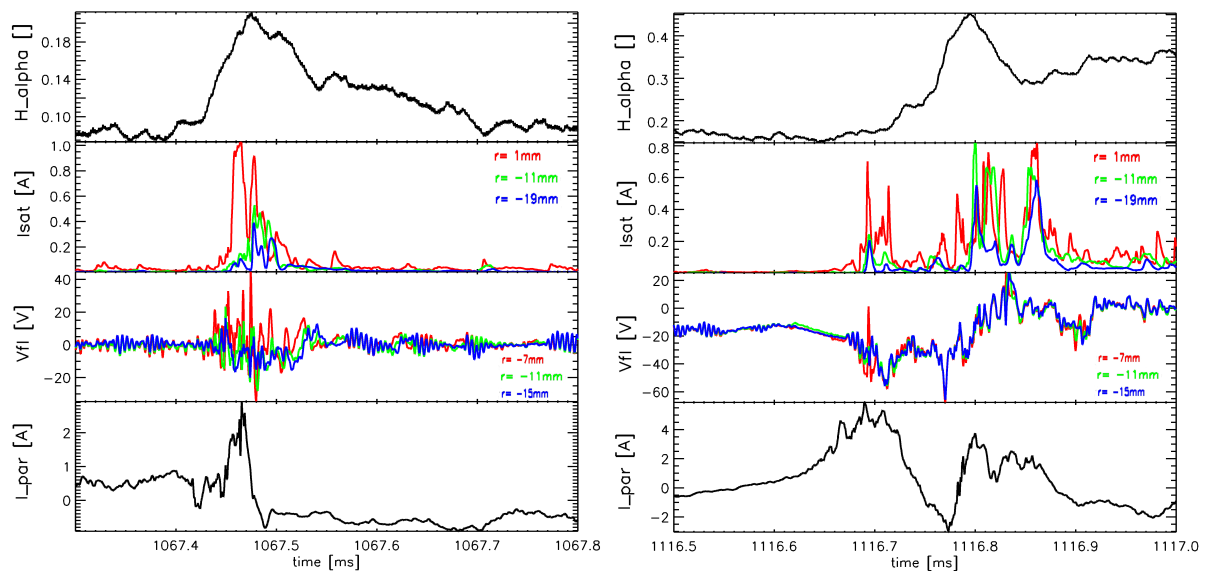


Figure 3. The temporal evolution of (from top to bottom) the H_α radiation, the ion saturation current I_{sat} at different radii, the floating potential V_{fi} at different radii, and the parallel electric current I_{par} during ELM (left) and the H-L transition (right).

The signals of H_α radiation (top graphs) show timing of the selected ELM and the H-L transition at which a clear I_{par} signal is observed. The second row of graphs from top compares

the evolution of the ion saturation current I_{sat} at different radial positions. As it is seen, the ion saturation current signal during ELM and the H-L transition is composed of several filamentary structures. However, the evolution of the floating potential during ELM and the H-L transition noticeably differs as seen from the third row of graphs in Fig. 3. The floating potential signals during ELM show the similar filamentary structure as I_{sat} signals again, while the V_{fl} signals suggest a single large potential structure seen simultaneously by all tips of the rake probe during the H-L transition.

The bottom graphs show the evolution of the parallel current calculated using eq. 1. The amplitude of the parallel current during ELM is $I_{par}^{ELM} = 4$ A. The duration of this current feature ($t_I = 40$ μ s) is shorter than duration of electrostatic probe signals ($t_E = 120$ μ s). On the other hand, the amplitude of the parallel current during the H-L transition, $I_{par}^{HL} = 9$ A, is higher and its duration is significantly longer.

Summary

We have investigated properties of the filamentary structures in the SOL of COMPASS tokamak using a novel probe diagnostic called U-probe. The ion saturation current, the floating potential and the parallel electric current in filamentary structures is measured during ELM and the H-L transition. Though electrostatic signals V_{fl} and I_{sat} show clear filamentary structure of ELM, there is no evidence of separate current filaments on I_{par} signal. We observe different evolution of the parallel currents during ELM and the H-L transition. Extensive statistical analysis is in progress.

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References

- [1] M. Spolaore et al., Direct measurements of current filament structures in magnetic-confinement fusion device, *Physical Review Letters* 102, 165001 (2009)
- [2] M. Spolaore et al., Magnetic and electrostatic structures measured in the edge region of the RFX-mod experiment, *Journal of Nuclear Materials* 390-391 (2009) 448-451
- [3] E. Martines et al., Current filaments in turbulent magnetized plasmas, *Plasma Phys. Control. Fusion* 51 (2009) 124053
- [4] Pánek R, Bilyková P, Fuchs V, Hron M, Chráska P, Pavlo P, Stockel J, Urban J, Weinzettl V, Zajac J and Zacek F: *Czechoslovak J. Phys.* 2006 56/2 B125–137
- [5] K. Kovařík et al, U-probe for the COMPASS tokamak, WDS'11 Proceedings of Contributed Papers: Part II - Physics of Plasmas and Ionized Media, Prague, pp. 227–232, 2011.