Real-time capabilities of laser aided plasma diagnostics at TCV

B. Vincent[1*], C. Galperti[1], P. Blanchard[1], Y. Andrebe[1], F. Felici[1]

[1]*École Polytechnique Fédérale de Lausanne (EPFL), Swiss Plasma Center (SPC), CH-1015 Lausanne, Vaud, Switzerland*

The Tokamak à Configuration Variable (TCV) employs a flexible digital control system for the exploration of multiple control solutions [1]. Accurate real-time measurements are crucial in identifying the plasma confinement state to better constrain real-time predictive models. Two real-time available laser-aided plasma diagnostics at TCV provide information on the electrons' properties: an incoherent Thomson Scattering (TS) diagnostic and the Far-InfraRed interferometer (FIR).

Incoherent Thomson Scattering diagnostics use the elastic scattering process of photons by free electrons. In the limit of probing length scale smaller than the Debye screening length scale, scattered photons are imprinted by the thermal properties of the electrons. At TCV, three Nd:YAG Q-switch lasers deliver 60Hz repetition rate pulses at 1064nm to induce TS. Scattered photons spectra is analyzed by 4 or 5-channel polychromators, the electron temperature is estimated by the ratios between spectral channels and assuming a Maxwell-Boltzmann (thermal) velocity distribution. The electron density is then obtained from the measured signal intensities. TCV's TS diagnostic has undergone several upgrades to improve spatial coverage [2] and extend sensitivity to electron temperatures down to ~1eV [3]. A recent upgrade introduced 10 low-temperature polychromators to complete the vertical spatial coverage within the TCV vacuum chamber. Additionally, a real-time acquisition system has been commissioned, and real-time TS analysis has been improved to provide electron temperature/density estimations in less than 1ms after data arrival. This real-time analysis was validated by the legacy post-shot analysis.

The FIR interferometry diagnostics estimate the line-integrated electron density from the phase shift induced by passage of electromagnetic light-waves through the plasma. At TCV, an optically pumped CH2F2 laser in a Mach-Zehnder heterodyne configuration probes the plasma along a radial array of 14 vertical chords. A real-time compatible acquisition system has been commissioned to acquire the sine-cosine decomposition of the phase shifts, enabling digital fringe counting algorithms. Digital fringe counting generally exhibits increased robustness to fringe jumps compared to legacy analog trigonometric function conversion.

By employing these laser-aided plasma diagnostics in real-time at TCV, accurate and timely measurements of plasma properties are now available, that are essential for plasma control and modeling advances.

[1] Reimerdes, H., et al. Nucl. Fusion (2022): 62 042018

[2] Hawke, J., et al. Journal of Instrumentation (2017): C12005

[3] Arnichand, H., et al. Journal of Instrumentation (2019): C09013

[4] Barry, S. *PhD Thesis at National University of Ireland, Cork* (1999)

[*]Presenting author: benjamin.vincent@epfl.ch