First Measurements of Electron Temperature and Density Profiles Using Thomson Scattering on the ST40 Spherical Tokamak

H.F.Lowe[1*], C. Colgan[1], T. Pyragius[1], D.V. Zakhar[1], H. Bohlin[1], H.V. Willett[1], M. Fontana[1], J. Wood[1], D. Osin[1], G. Tchilinguirian[2], M. de Haas[2], S. Trieu[2], K. Hammond[2], F. Janky[1], T. O'Gorman[1], M. Sertoli[1], R. Scannell[3], A. Diallo[2]. G. Naylor[1].

[1] Tokamak Energy Ltd, 173 Brook Drive. Milton, Abingdon, OX14 4SD, UK.
[2] Princeton Plasma Physics Laboratory, 100 Stellarator Road, Princeton, NJ 08540, USA.
[3] Culham Centre for Fusion Energy, Abingdon, OX14 3DB, UK.

ST40 is a high field low-aspect ratio spherical tokamak built and operated by Tokamak Energy Ltd in the UK [1] with typical operating parameters of $R_{geo} \approx 0.4$ - 0 .5 m, $A \approx 1.6$ - 1.9, $I_p \approx 0.4$ -0.8 MA and $B_T = 1.5$ - 2.2 T and a suite of more than 30 plasma diagnostics. In this presentation, we focus on the recent deployment of Thomson scattering on ST40 for the first time, providing real-time electron temperature and density profiles. Cross-validation of preliminary electron temperature and density results with spectroscopic [2] and interferometric measurements is underway and early results show encouraging correlations between instruments. In the next experimental campaign, we will perform a dedicated I_p/B_t parameter scan and an elongation factor scan to further verify system performance.

The Thomson scattering system is based on a 1 J, 9 ns, 100 Hz diode pumped Nd:YAG laser that transits through the ST40 midplane on a chord passing close to the centre column on a common path with an NIR interferometer and adjacent to radial rf interferometer views. The collection optics are located on the same midplane port as the laser flight tube utilising an oblique scattering angle of nominally 160° with a high numerical aperture, up to 0.16 (f/3) on the low field side (LFS). 16 duplexed 15 m and 25 m fused silica fibre bundles transport the scattered signal with a total throughput of >40% to 5 spectral channel polychromators [3]. The data is acquired by an 80 channel 250 MSPS data acquisition system provided by PPPL [4] that outputs 30 individual real-time temperature and density values to the ST40 Plasma Control System per laser pulse. This geometry provides electron temperature and density profiles consisting of 30 spatial points with a resolution of <10 mm on the LFS and an analytical error of <5% in the temperature range of 1 – 10 keV. The measured temperature and density profiles provided by the Thomson scattering system on ST40 will be essential for studying non-inductive current drive and optimising the fusion triple product paving the way to a first of a kind fusion reactor based on the spherical tokamak geometry.

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[1] S.A.M. McNamara *et al*, Nucl. Fusion **63** (2023) 054002.
[2] H.V. Willett *et al*, JINST **18** (2023) C03023.
[3] R. Scannell *et al*, Rev. Sci. Ins. **79** (2008) 10E730.
[4] R. Rozenblat *et al*, Fusion Sci. Technol. **75 (**2019) 835-840.

*Presenting author: Hazel.Lowe@tokamakenergy.co.uk