ST Path to Fusion: First Results from ST40

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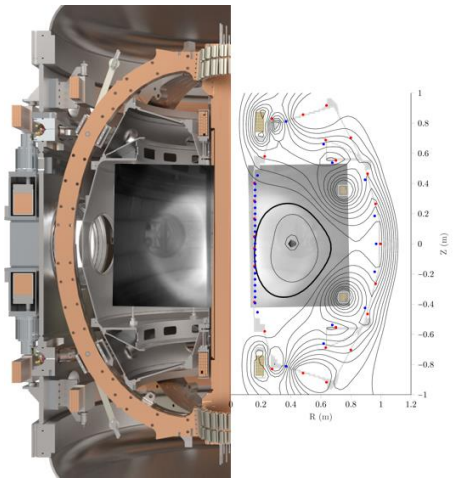
Spherical Tokamak (ST) path to Fusion has been proposed by R Stambaugh [1] and experiments on STs since then demonstrated feasibility of this approach. Advances in the high temperature superconductor technology [2] allows significant increase in the toroidal field which was found to improve confinement in STs. The combination of the high β, which has been achieved in STs [3], and the high TF that can be produced by HTS TF magnets, opens a path to lower-volume fusion reactors, in accordance with the fusion power scaling proportional to $\beta^2 B_t^4 V$. Feasibility of a low-power compact ST reactor and physics and engineering challenges of the ST path to Fusion Power will be discussed. Several devices have been built by Tokamak Energy on the development of this path. A small tokamak ST25 (R/a=0.25/0.125m, I_{pl}<10kA, B_t<0.2T, τ_{pulse} up to 30sec, circular and D-shaped vessels) is operational since 2012, testing EBW pre-ionisation and current drive. 29h discharge has been demonstrated in a similar small tokamak, but with all-HTS magnets [4], Results from these STs will be overviewed.

High field spherical tokamak ST40 (R=0.4-0.6m, R/a=1.6-1.8, I_{pl}=2MA, B_t=3T, k=2.5, τ_{pulse}~1-10sec, 2MW NBI, DD and DT operations) is now operating. Plasma current of 300kA has been already achieved at B_t=0.72T during first weeks of operations. The Figure shows magnetic reconstruction and visible light image of the plasma obtained using merging-compression plasma formation, as used on START and MAST tokamaks [7].

Results of numerical simulations on the energy, fast ions and alpha particle confinement, stability and equilibrium [5,6] will be discussed. According to simulations, due to low collisionality, high field and low ion neoclassical transport, a hot ion mode with T_i ~ 10-15keV may be achieved in ST40 even with moderate confinement. We will undertake experiments on ST40 to demonstrate the performance of high field ST in burning plasma regimes and to support designs of next step devices on the ST path to Fusion. Details of engineering design and experimental plans will also be presented.



[1] R Stambaugh et al, Fus. Tech. 33 (1998) 1; [2] M Gryaznevich et al, Fus. Eng. & Design 88 (2013) 1593; [3] M Gryaznevich et al, Phys Rev Lett 50 (1998) 3972; [4] M Gryaznevich et al, Nucl. Fus. 55 (2015) 104019; [5] A Salmi et al, Fus. Eng. & Design 117 (2017) 14; [6] A Dnestrovskij, J W Connor and M Gryaznevich, submitted to NF (2017); [7] M Gryaznevich, A Sykes, NF 57 (2017) 072003.