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P4.1065 The concept of the compact ultra-low aspect ratio tokamak CULART

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Compact device with an Ultra-Low Aspect Ratio Tokamak plasma (CULART) is proposed. The major objective of CULART is twofold. First, to explore very high beta (VHB) limits (~ 1) via passive stabilization under relatively low toroidal field (TF). Secondly, as a proof-of-concept, to use these VHB plasmas as a target for applying the adiabatic compression (AC) technique aiming for 1MW of D-T fusion power with relatively high Q factor. The design must incorporate present day technology without necessarily using superconducting coils and with the advantage of using ohmic heating regimes exclusively.

Using the AC technique, CULART sets a pathway to study the potential for a high efficiency, ultra-compact, repeatedly-pulsed neutron source based on the spherical tokamak (ST) concept. CULART will serve as a benchmark for appropriate scaling towards a fusion reactor and related material studies, alongside broad areas of physical science beyond fusion energy.

The main characteristics of CULART plasmas prior to the use of the AC technique are: plasma major radius Ro = 0.51m, plasma minor radius a = 0.47m, aspect ratio of A = 1.1, plasma vertical elongation k = 2 (at A = 1.1), triangularity = 0.8, TF of BT(Ro) = 0.1T, plasma current of Ip = 0.5MA, central density of ne(0) = 1×1019m-3, central electron and ion temperatures of Te(0) = 300 and Ti(0) = 500eV, respectively, and discharge duration of = 100ms. These parameters should lead to toroidal beta limits around unity (100%), as scaled from an identical regime in the Pegasus experiments [1].

The vessel is a stainless-steel sphere that is insulated from the naturally diverted plasma by thin (~ 2cm) semi-circular tungsten limiters. No internal poloidal field coils or solenoid are envisioned. With the plasma conforming relatively closely to the vessel walls, wall stabilization is possible. Plasma protection and minor neutron shielding can be achieved using thin (~ 2-3mm) tungsten plates covering the copper central stack. All these features together make the whole design simple, compact, and cheap. The major source of initial heating is provided by Ip created primarily via the Local Helicity Injection (LHI) technique, as has been demonstrated by the Pegasus device in several regimes [1,2].

After a very high beta configuration is attained (that potentially is already operating in Hmode as all the scaling laws and ST experiments indicate), the AC technique is applied (a and R-compression) via raising BT(Ro) (< 1T) and the vertical equilibrium field. A simulation was performed using standard compression scaling laws [3] applied to a CULART VHB plasma target leading to the following parameters: Ro = 0.16m, a = 0.10m, A = 1.6, k = 1.6, = 0.2, BT(Ro) = 2.4T, Ip = 1.6MA, Te(0) = 4.6keV, Ti(0) = 8.0keV, and ne(0) = 1×1021m-3. These values produce 1MW of D-T fusion power with a neutron flux of 3.6×1017n/s.

Preliminary equilibrium and stability simulations prior to and after the use of the AC technique, basic engineering issues, and engineering constrains will be also presented.

[1] D J Schlossberg et al., Phys. Rev. Letters, 119, 035001 (2017). [2] J.M. Perry et al., Nucl. Fusion 58 096002 (2018). [3] H. P. Furth and S. Yoshikawa, Phys. of Fluids, 13, 2593 (1970).

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