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First results from the Wisconsin HTS Axisymmetric Mirror (WHAM)

C.B. Forest[1], N, J. Anderson[1], O. Anderson[1], M, Brown[5], E. Claveau[1], M. Clark[1], D. Endrizzi[1,2], M. Ialovega[1], J. Kirch[1], G. Kristofek[3], J. Lohr[4], B. Mumgaard[3], E. Penne[1]1, J. Pizzo[1], S. Oliva[1], T. Qian[1], K. Sanwalka[1], B. Terranova[1], J. Viola[2], J. Wallace[1], D. Yakovlev[1], M. Yu[1]
[1]University of Wisconsin, Madison,
[2]Realta Fusion,
[3]Commonwealth Fusion Systems,
[4]General Atomics,
[5]Swarthmore College
e-mail (speaker): cbforest@wisc.edu

The WHAM project [1] is a public-private partnership between the University of Wisconsin, Realta Fusion, and Commonwealth Fusion Systems (CFS), initially funded for construction by ARPA-E with the objective of applying new generation HTS magnets to compact magnetic mirror systems. With start of operations and first plasmas in July, 2024, WHAM has set a new world record for steady applied magnetic field applied to a magnetic confinement fusion experiment from two 17 T, 55 mm diameter bore HTS magnets supplied by CFS. The WHAM device is now operating with an array of high-power heating and control systems, including a 500 kW, 110 GHz gyrotron, a 1 MW, 25 kV neutral beam injection system, and multi-megawatt radially controlled plasma biasing actuator for stirring the plasma to provide vortex stabilization of MHD interchange.

The goals of the experiment are to demonstrate reactor relevant techniques for stabilizing MHD interchange modes (including vortex confinement) in the weakly collisional rather than the gas dynamic regime, and to provide a technology development and risk reduction platform for a breakeven class simple mirror on a path to a tandem mirror reactor [2], and to provide data for validating modern numerical models of confinement in magnetic mirror systems. Additionally, efficient neutral particle handling and control of first-wall plasma/material interactions are crucial for optimizing machine performance.

In the first experimental campaign the vacuum field was entirely due to the two HTS magnets corresponding to a mirror ratio of 70. One major accomplishment of the first campaign was to demonstrate robust operation of the heating systems and diagnostic set in the presence of the high magnetic field. The base-line diagnostic set includes a 1 mm wave interferometer for density, diamagnetic flux loops for stored energy, visible and X-ray spectroscopy uv tomography, an array of NBI shine-through detectors to infer density profiles, bolometry, end-loss analyzers, and fusion product measurements.

The application of up to 400 kW of ECH, limited to 10 ms pulse lengths, demonstrated robust target plasma formation achieving average line densities $\sim 3 \cdot 10^{19} m^{-3}$, very clear evidence of both a cold high density plasma and a low density but hot electron plasma (with hard x-rays of energy > 100 keV observed) that appear to modify MHD stability (both positively and negatively). Preliminary data analysis indicates high m-number flute modes with real frequencies in the 40-60 kHz range suggestive of hot electron interchange in low ion temperature plasmas. Biasing of the tungsten limiter modifies MHD activity and by optimizing the bias has led to an increased plasma stored energy by 50% (and can also be used to drive MHD and make confinement worse). Neutral beam injection has successfully been used to fuel the plasma by injecting into ECH target plasmas, but at present the lack of wall conditioning in this first campaign indicates that charge exchange of the fast ions on residual and recycled neutral particles is limiting the build-up of fast ion pressure and controlling the overall confinement.

Near-term next steps will include the implementation of a novel non-evaporable getter technology[3] for reducing neutral pressure, installation of a Thomson scattering system, commissioning of the rf heating system, and the addition of a midplane magnet to bring the central field to ~1 T.

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References

[1] Endrizzi, D. et al. *Physics basis for the Wisconsin HTS Axisymmetric Mirror (WHAM)*. J. Plasma Phys. **89**, 975890501 (2023).
[2] Forest, C. B. et al. *Prospects for a high-field, compact break-even axisymmetric mirror (BEAM) and applications*. J. Plasma Phys. **90,** 975900101 (2024).
[3] 1.Ialovega, M. et al. *Initial study on thermal stability of cold spray tantalum coating irradiated with deuterium for fusion applications*. Phys. Scr. **98**, 115611 (2023).