An Upgrade to MAST

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Abstract

The MAST device one of the two largest spherical tokamaks in the world. The poloidal cross section of MAST is similar to mid-size conventional tokamaks such as ASDEX Upgrade (Germany) or DIII-D (US). The device is currently undergoing a substantial upgrade [1] aimed to make major contributions to some of the most challenging problems on the path to a viable fusion power plant.

The power that needs to be exhausted under reactor relevant conditions will increase by at least an order of magnitude compared to present day devices. Most of this power needs to be radiated away before the plasma interacts with material surfaces, but even then it is likely that the conventional poloidal divertor solutions of present day tokamaks will not work under those conditions. The MAST upgrade will therefore test novel closed divertor solutions with radially extended outer divertor legs to mitigate the power density at the target plates. The unique flexible design for both the upper and lower divertor allow a wide variety of configurations including the so called Super-X configuration [2] in order to optimise the flux expansion and parallel connection length.

In a burning plasma the α particles are born with velocities well above the resonant Alfvén velocity. The interaction of a slowing down fast-ion population with the thermal plasma is different from that of a bump-on high energy tail distribution as currently accessible an many tokamaks by RF heating. In MAST neutral beam heating ions are born well above the Alvén velocity, due to the low toroidal magnetic field in the spherical tokamak. Furthermore, high normalised fast ion pressures β_{fast} can be easily achieved. This mimics important properties of the α particle physics. The driven fast particle instabilities can also be very detrimental to non solenoidal current drive schemas such as neutral beam current drive that are crucial to a steady state fusion reactor based on the tokamak principle. The upgrade will have on- and off-axis neutral beam sources to shape the current profile and the fast-ion distribution. Operation at relatively low density will allow access to plasmas with dominant fast particle pressure $\beta/\beta_{\text{fast}} \lesssim 60\%$. Also regimes with elevated q-profiles with q_{min} well above 1 to avoid low order rational surfaces and the associated MHD should be accessible. Furthermore, scaled transport calculations suggest that fully non-inductive current drive with $I_{\text{p}} \leq 1$ MA during the flat-top should be possible.

The upgrade will also have a 50% higher toroidal field, and almost a factor of two more solenoid flux than the existing device. Three new high field side coils, 14 divertor coils and passive vertical stabilising plates allow access to higher elongation $\kappa \lesssim 2.5$ whilst keeping good control over the divertor configuration. The longer flux swing together with the high fraction of non-inductive current drive should give access to 4s to 5s current flat tops. The physics of this exciting new major facility and some highlights of recent physics studies on MAST will be discussed.

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[1] STORK, D. et al., The upgrade to the Mega Amp Spherical Tokamak, in *Proceedings to the 23rd IAEA Fusion Energy Conference, 11-16 October 2010, Daejon, Korea Rep. of*, 2010, ICC/P5-06.

[2] VALANJU, P. M. et al., Physics of Plasmas **16** (2009) 056110.