The MAST Upgrade:
How to tackle the exhaust challenge

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Abstract

The MAST device is 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 presently undergoing a substantial staged upgrade [1, 2] aimed to make major contributions to some of the most challenging problems on the path to a viable fusion power plant.

A key aspect of the upgrade are the two closed, pumped divertors allowing a wide variety of divertor configurations. These include concepts with radially extended outer legs, such as the Super-X configuration [3], or configurations with large flux expansion around the X-point, such as the snowflake configuration [4]. The physics understanding gained in these divertors will help to tackle the challenge of exhausting an order of magnitude more power under reactor relevant conditions than in present day devices.

The MAST upgrade will also greatly extend the burning plasma studies using the super Alvénic fast ion distribution created by neutral beams. This fast-ion distribution with $\beta/\beta_{\text{fast}} \lesssim 60\%$ mimics important aspects of α particles leading to highly non-linear mode bahviour that can lead to a strong redistribution of the fast-ions. Operation at low density ($n_e/n_G \gtrsim 0.2$) facilitated by the cryogenically pumped divertor should also allow plasmas with $I_p > 1$ MA fully non-inductively driven during the flat-top phase. The flexible beam set-up with on- and off-axis beams allows to taylor the fast-ion distribution and the q-profile. Upgrades of the centre column, the polidal field coils and power supplies give access to advanced scenarios with elevated q-profiles high elongation $\kappa \leq 2.5$ and up-to 5s flat tops.

During the first major upgrade between 2013 and 2015 the full load assembly is implemented as well as power supply upgrades and jacking of one of the two neutral beams to an off-axis position. In the subsequent years MAST will be upgraded to the stage 1 introduced here with divertor cryo-pumping and 3 neutral beams. Later stages currently in planning would include 2 MW of EBW heating at 19 GHz for current drive and heating, one additional counter current neutral beam for fine q-profile and rotation control and a high frequency pellet injector for ELM mitigation and reactor relevant shallow pellet fuelling.

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