Microwave current drive for STEP and MAST Upgrade

S.J. Freethy[1], L. Figini[2], M. Henderson[1], H. El-Haroun[1], S. Gibson[1], K.K. Kirov[1], A Köhn-Seeman[3], I. Konoplev[1], S. Saarelma[1], R. Sharma[1], D. Speirs[4], R.G.L. Vann[5], H. Webster[1], T. Wilson[1] and the STEP team[1]

[1] UKAEA, Culham Science Centre, Abingdon, OX14 3DB, United Kindgom

[2] Istituto per la Scienza e Tecnologia dei Plasmi, Consiglio Nazionale delle Ricerche, 20125 Milano, Italia[3] University of Stuttgart, IGVP, Pfaffenwaldring 31, 70569 Stuttgart, Germany

[4] University of Strathclyde, 16 Richmond St, Glasgow, G1 1XQ, United Kingdom

[5] University of York, York, YO10 5DD, United Kingdom

The UK's Spherical Tokamak for Energy Production (STEP) reactor design program has recently taken the decision to use exclusively microwave-based heating and current drive (HCD) actuators for its reactor concepts. This is based on a detailed assessment considering all viable HCD concepts, covering the grid to plasma efficiency (η_{grid}), physics applications, technology maturity, integration, maintenance, and costs. Of the two microwave techniques: Electron Cyclotron (EC) and Electron Bernstein Wave (EBW), EC was deemed the lowest risk and EBW is maintained due to its exceptional CD efficiency. To assess the ECCD efficiency, the GRAY beam tracing code was employed to perform detailed scans of the launcher position, toroidal and poloidal launch angle, and frequency over the first 3 cyclotron harmonics. It was found that normalized efficiencies, ζ_{CD}, of 0.45 could be achieved reliably, with $\zeta_{\mathrm{CD}} \simeq 0.9$ for far off-axis Ohkawa current drive. For EBW, GENRAY/CQL3D were used to estimate the CD efficiency. Efficiencies of $\zeta_{\mathrm{CD}} > 0.9$ were found over 1/3 of the plasma radius, peaking more than a factor of 2 greater than ECCD in this range. EBW-CD is not as widely used or as mature as ECCD. To reduce the physics uncertainties in present models for EBW coupling and current drive, MAST Upgrade will install 2 x dual frequency (28, 34.8 GHz), 900kW, 5s gyrotrons from Kyoto Fusioneering, as part of the MAST Upgrade enhancements package. This will be accompanied by a flexible 2D steering launcher system to allow midplane co- and counter-CD and above midplane launch for co-direction off-axis CD. Coupling efficiency is quantified by measuring the heating induced by reflected (i.e. non-coupled) power to a plate inserted in the reflected beam path. The experiments will also include EBW driven solenoid-free start-up, increasing power and pulse length by a factor of 10 on MAST experiments. This presentation will discuss the STEP microwave studies and the MAST Upgrade physics design and capabilities.