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Design of reciprocating probes and material-testing manipulator for tokamak COMPASS Upgrade

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Three new in-vessel manipulators are designed and built for the new tokamak COMPASS Upgrade [1] with uniquely high vessel temperature (250-500^{o}C) and heat loads (perpendicular to divertor surface $q_{\perp}$~80 MW/m^2 and $q_{||}$~GW/m^2 at separatrix), which challenges the edge diagnostics [2]. Here we show their detailed engineering designs supported by heat conduction and mechanical models.
Deep reciprocation of electrostatic probes near the separatrix should be possible by optimizing older concepts [3] in a) the head and probe geometry [4], b) strongly increasing the deceleration upto 100x gravity by springs and strengthening the manipulator mechanical structure. One reciprocates at the region of edge plasma influx (the outer midplane), the other at the plasma sink (between the outer divertor strike point and X-point), for studying the plasma divertor (impurity-seeded [5]) detachment and liquid metal vapor transport. Both probe heads are equipped with a set of ball-pen and Langmuir probes, measuring reliably extremely fast (10^{-6} s) and local (1 mm) plasma potential, density, electron temperature and heat flux [4] and even ion temperature with 10^{-5} s resolution [6].
The divertor manipulator (without reciprocation) will place various material test targets at the outer divertor. Unique will be its capability to increase 20x the surface heat flux with respect to the surrounding tungsten tiles just by controllable surface inclination of the test targets. We plan to test liquid metal targets [7] where such inclined surface was found [8] critical to achieve the desired mode with lithium vapor shielding. Even in the conservative expected performance of COMPASS Upgrade, we predict [9] to reach and survive the EU DEMO relevant heat fluxes.

References

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