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Comparison of the RF power coupling efficiency for 1.0 and 1.7 MHz at BATMAN Upgrade

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In the negative Ion-Based Neutral Beam Injector (NNBI) sources for ITER, hydrogen/deuterium plasma is generated by inductive coupling of RF power at 1 MHz. Experiments on the BATMAN upgrade (BUG) prototype source revealed a significant power loss (over 40%) within the RF network and driver assembly, prompting the necessity to seek source performance improvements to avoid increasing input power. Zielke et al. predicted that increasing the driving frequency could enhance plasma coupling using a self-consistent fluid model [1]. This prediction motivated the modification of the RF generator at the BUG, an initiative by ITER IO in collaboration with Consorzio RFX under a bilateral framework agreement to experimentally investigate the effect on power coupling at higher RF frequency. The current RF generator allows for an increase in RF frequency to 1.7 MHz with slight modifications to the oscillator amplifier setup. However, modifications caused severe RF disturbances, which affected many sub-systems of BUG since the whole setup was previously optimized to 1.0 MHz.

After several optimization steps, an experimental study has been performed comparing power coupling at 1 MHz and 1.7 MHz. Losses in the RF network and power coupling efficiency are evaluated from measured input RF power and coil current [2]. Langmuir probe and Optical Emission Spectroscopy (OES) were used to diagnose the driver plasma. The experimental results showed a higher power coupling efficiency up to 15% at 1.7 MHz across all tested power levels. This increased efficiency was also reflected in higher plasma density values measured by the probe and OES. When comparing the same power coupled to the plasma, the density values at 1.0 and 1.7 MHz are comparable, pointing out that the different frequency impacts only the coupling efficiency.

1. S. Briefi et al., Rev. Sci. Instrum. 93 (2022) 023501.
2. Hopwood, J. PSST 3.4 (1994): 460.

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