Overview of the preliminary SPARC profile ECE diagnostic design and a novel method for thermal noise reduction in burning plasma measurements

C. Yoo[1], V. Nikolaeva[2], M. Kopanski[1], E.J. Kowalski[2], N.T. Howard[1], A. Hubbard[1], W. Burke[1], A. Rauschenberger[1], A.E. White[1], and the SPARC team

[1]*Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA*
[2]*Commonwealth Fusion Systems, Devens, Massachusetts 01434, USA*

Corresponding Author Email: cyoo@mit.edu

SPARC [1] is a high-field (12T), superconducting, D-T tokamak under development by Commonwealth Fusion Systems. SPARC aims to demonstrate a fusion gain (Q) > 1, with projections to reach Q ~ 11 in high-performance plasmas [1]. An electron cyclotron emission (ECE) radiometer will provide kinetic profile measurements important for thermal stored energy measurements and verifying fusion gain as well as for plasma control, including the detection of ELMs and disruption pre-cursors [2,3]. This presentation will provide an overview of the preliminary design of the SPARC profile ECE diagnostic, including calibration features under evaluation to support accurate and reliable electron temperature profile measurements up to 25 keV [4]. Preliminary design plans for the radiometer include multiple radio frequency (RF) and intermediate frequency (IF) sections for measurements of 1st harmonic, O-mode ECE across the frequency range 245 – 345 GHz in 12T SPARC plasmas, with possible capabilities for measurements at other magnetic fields. This presentation will also detail a novel signal analysis technique that enables the reduction of thermal noise in radiometer measurements [5]. Accurate measurements of turbulent electron temperature fluctuations using radiometers have until now required correlating pairs of separate radiometer channels in order to reduce thermal noise and improve the signal-to-noise ratio. The new analysis method enables thermal noise reduction using individual radiometer channels and opens up the possibility for cutting-edge turbulence measurements with profile ECE diagnostics. In addition, the new method could be applied to improve the signal-to-noise ratio in a variety of fusion diagnostics beyond radiometers. This presentation will discuss general design considerations relevant to the application of this method and the potential for the profile ECE diagnostic on SPARC to perform – in addition to electron temperature profile measurements – sensitive measurements of broadband, low-amplitude, transport-relevant electron temperature fluctuations across the plasma radius.

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