Overview of the Early Campaign Diagnostics for the SPARC Tokamak

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The SPARC tokamak [1] is a high-field, B_{t0} ~ 12 T, medium sized, R_0=1.85 m, tokamak that is presently under construction in Devens, MA, led by Commonwealth Fusion Systems. It will be used to de-risk the high-field tokamak path to a fusion pilot plant and demonstrate the commercial viability of fusion energy. SPARC's first campaign plan is to achieve $Q_{fus} > 1$ using an ICRF-heated, < 10 MW, high current, I_p ~ 8 MA, L-mode fueled by D-T gas injection, and its second campaign will investigate H-mode operations in D-D. To facilitate plasma control and scientific learning, a targeted set of ~50 plasma diagnostics are being designed and built for operation during these campaigns. While nearly all diagnostics are based on established techniques, the pace of deployment, relative to first plasma, and the harshness of the thermal, electromagnetic and radiation environment are unprecedented for medium-sized tokamaks. An overview of the SPARC diagnostic set is given, providing context to multiple posters presented by the SPARC team at this conference that will provide further system-specific details. The systems engineering philosophy for SPARC diagnostics is outlined and the design and engineering verification process for components inside and outside the primary vacuum boundary are described. Diagnostics are mounted directly to the vacuum vessel as well as housed within a series of 8 midplane and 24 off-midplane, replaceable port plugs. With limited exceptions, signal conditioning, digitization electronics and cameras as well as lasers and microwave sources are localized to a series of 5 diagnostic laboratory spaces, totaling 375 m^2, located >15 m from the center of the tokamak, on the other side of a 2.5 m concrete shielding wall. A series of 31 penetrations have been included in the SPARC tokamak hall to facilitate integration of early campaign diagnostics and to provide for upgradability. A vertically elongated slit couples to an 'aperture' in the port-based, boron carbide shielding to form a spatially resolving pinhole camera for neutron and gamma emission. Further optimization of the routing of light and electrical signals from tokamak hall to diagnostic hall is a particular design challenge, and examples of in-progress designs are provided. This overview of the design of SPARC diagnostics is timely to enable community involvement in tokamak science research on SPARC [2][3] and provide information for teams interested in designing diagnostics for future SPARC campaigns.

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[1] A.J. Creely, *et al*. J. Plasma Phys. **86** 865860502 (2020)
[2] A.J. Creely, *et al*. Phys. Plasmas **30** 090601 (2023)
[3] M.L. Reinke, *et al*. Phys. Plasmas. **30** 100603 (2023)