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Progress on Burning Plasma Diagnostic Design for CFEDR

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The Chinese Fusion Engineering Demonstration Reactor (CFEDR), proposed in the 2020 edition of China's Magnetic Confinement Fusion Development Roadmap, is currently undergoing conceptual design and is planned to start construction in 2030s. As a DEMOnstration power plant (DEMO), CFEDR's primary objectives are to demonstrate steady-state operation with high fusion power and tritium self-sufficiency. The main parameters of CFEDR include a major radius of R=7.8 m, a minor radius of a=2.5 m, and a toroidal magnetic field of BT=6.5 T. These dimensions are larger than those of the Chinese Fusion Engineering Testing Reactor (CFETR), which has a major radius of R=7.2 meters and a minor radius of a=2.2 meters [1, 2]. CFEDR is designed to produce up to 2-3 GW of fusion power to address the scientific and technological challenges associated with fusion power plants. More detailed information on the CFEDR program and its baseline scenario can be found in [3].

This talk presents the progress in the conceptual design of the diagnostic system tailored for the CFEDR. Different from present diagnostics, new requirements and challenges arising from burning plasma for CFEDR diagnostics have been investigated first. These specifications facilitate establishing criteria for measurement identification and technique selection. A comprehensive workflow is then outlined to clarify the design steps. Given the harsh environment and limited port resources, a compact and robust diagnostic system is envisioned. The measurements for nuclear safety, machine protection, plasma operation control, and fusion physics understanding are proposed, and 21 candidate techniques are selected for CFEDR. Key R&D challenges, such as the high neutron radiation environment and advanced diagnostic port integration, are identified. Additionally, the development of new diagnostic techniques and synthetic diagnostics is discussed.

The conceptual design of CFEDR is progressing smoothly. New requirements and challenges of diagnostic systems for CFEDR have been specified, including the expanded range of target parameters, long pulse length, high neutron and gamma radiation environment, alpha particle confinement, etc. A comprehensive workflow for the diagnostic design of CFEDR has been established, as shown in Figure 1. To meet the scientific objectives and operational requirements of CFEDR, we have proposed a compact set of measurements and candidate techniques. These are designed to ensure the needs of nuclear safety, machine protection, plasma operation control, and to advance our understanding of fusion physics. However, as the conceptual and engineering design of CFEDR advances, and as diagnostic techniques evolve and new technologies are integrated, it is likely that the proposed measurements and selected technologies will undergo adjustments. Furthermore, we have identified several common issues for the CFEDR diagnostic system, particularly the challenge posed by the high neutron radiation environment. The development of new diagnostic techniques and the Integrated Modelling Analysis Suite (IMAS) platform also require ongoing attention and investment.

Next, we will make full use of the technologies developed by domestic programs such as EAST, and the experience gained from participation in ITER construction and extensive international collaborations, to improve CFEDR's diagnostic design and address outstanding issues. In the near future, domestic and international expert groups will be established to focus on the internal components (such as the first mirror), nuclear electronics, advanced port integration strategy and synthetic diagnostics development

References

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Figure 1. Workflow of CFEDR diagnostic design