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Conceptual Design of High Resolution and Reliable Density Measurement System on Helical Reactor FFHR-d1 and Demonstration on LHD

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This paper describes a conceptual design of the density measurement system on the helical reactor FFHR-d1 based on its quantitative operation scenario.
One of the important plasma parameters which is used for plasma control is the line averaged electron density on FFHR-d1. This is because the startup and the steady state plasma will be mainly operated by feedback control of the line averaged electron density. From recent quantitative investigations of operation scenario in FFHR-d1, the density resolution of the order of 10^17 m^-3 with a response time less than 10 ms is required. In addition to that, the density measurement has to meet the reactor design. As for the interferometer, the vibration isolation system, which is necessary for the usual interferometer, cannot be installed on FFHR-d1.
A possible system which can satisfy the requirements is a combination of a dispersion interferometer (DI) and a polarimeter. The DI is a special interferometer which can cancel the vibration components by itself. Hence the DI meets the reactor design and the immunity to the vibrations can also improve the density resolution. The DI can suppress failures of fringe counting "fringe jump", which lead to uncontrollability of the density, by fast sampling which reduces the phase shift less than one fringe between sampling intervals. Even when the fringe jump occurs, a polarimeter, which measures the Faraday rotation, can correct the fringe number of the DI. Although the density resolution of the polarimeter is not enough, there is no fringe jump. Hence the combination can increase the reliability of the density measurement. The appropriate wavelength of the laser source, vacuum windows, deposition mitigation for first mirrors are also investigated.
A prototype of the dispersion interferometer is installed on LHD, which can realize a demo relevant density plasma. The achieved density resolution is 2×10^17 m^-3 with a response time of 30 microsecond. While the fringe jump occurs in the existing FIR interferometer in the case of repetitive pellet injected discharges, the DI can successfully measure without any jumps. In this way, the DI on LHD demonstrates the feasibility of the density measurement with the dispersion interferometer, which satisfies the requirements from FFHR-d1. This system is applicable not only to FFHR-d1 but also to other demo reactor designs.

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