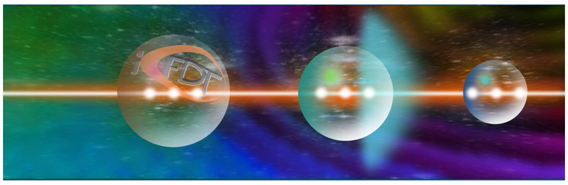

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Reconfigurable Architecture of Real-Time Data Processing for Laser-aided Electron Density Diagnostics on EAST Tokamak

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This paper presents a reconfigurable architecture designed for real-time data processing in tokamak diagnostics. Through the deployment and application on various laser-aided electron density diagnostics, including the HCN interferometer, POINT, solid-state source interferometer, and carbon dioxide dispersion interferometer, the architecture has been validated to meet the real-time data processing requirements of the diagnostic system on the EAST Tokamak.

A reconfigurable framework is a type of computing architecture that can adapt its hardware and software configurations to optimize performance for specific measurement tasks. In the realm of laser-aided density diagnostics on tokamaks, the data processing system is an indispensable part. Currently, different self-developed data processing systems are used in laser-aided density diagnostics on various tokamak devices, and some of these systems, after many years of use, face the risk of being unmaintainable and irreparable. Utilizing a reconfigurable architecture, not only can standard data acquisition (DAQ) and processing equipment be formed on the EAST to help rapidly build the diagnostic systems, but it can also provide a real-time data processing workflow and framework for other existing devices and future devices, offering effective reference for the design of the final data processing system.

A reconfigurable architecture mainly consists of three parts: the first is its main hardware platform, which serves as the carrier of algorithms and measurement data; the second is the algorithm component, which exists in the form of firmware cores and determines the boundaries of the modules through interfaces and functional divisions; the third is the software system, used for processing non-real-time data and relatively simple command data transmission. For the specific application of real-time data processing system for diagnostics, some key components need to be introduced detailly.

• FPGA-based development board
According to the different measurement principles, each diagnostic will have different data processing methods. Even for different laser-aided interferometers, different light sources, optical path designs, and detectors will also lead to different processing methods. Therefore, field-programmable devices must be present in the real-time data processing system to accommodate different parameters and different data processing methods. The main board's function is to provide field-programmable devices and their supporting chips, meeting the needs for algorithm carriers, low-ripple power supply, data buffering, and the ability to provide highly stable clock signals. As a versatile field-programmable device, the FPGA features high speed, multi-channel capabilities, and full digitalization, making it well-suited for subsequent data processing in coordination with front-end signals.

• FMC boards and interfaces
After the detector signal is output, it needs signal conditioning, followed by analog-to-digital conversion (ADC) before being sent to the FPGA. The ADC and its supporting circuitry are designed and implemented through FMC (FPGA Mezzanine Card) boards. Different FMC boards can be designed to meet various applications, enabling rapid system setup.

• Firmware cores
The firmware cores are the most important component for implementing data processing algorithms. By hardware-accelerating the phase information calculation algorithm, fringe jump counting algorithm, and

other general-purpose cores such as general digital signal processing, frequency stabilization, and triggering modules, this real-time processing diagnostic framework can ultimately realize the processing workflow and hardware structure from raw signals to density information.

By testing the mainboard and existing FMC boards in the laboratory, we have obtained electronic results that meet the experimental requirements. Through installation and application on the HCN interferometer, POINT, solid-state frequency-doubling interferometer, and carbon dioxide dispersion interferometer, the reconfigurable architecture has been validated and can meet the real-time data processing requirements of the diagnostic system on the EAST Tokamak.

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