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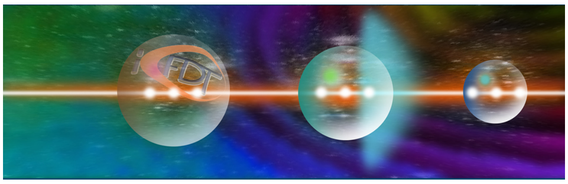

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Research on Frequency Feedback Control Method of Laser-aided Interferometer Based on Incremental Neural Network PID Algorithm

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Plasma electron density, as one of the core parameters of plasma characteristics, accurate and reliable measurement and real-time feedback control are indispensable foundations for ensuring stable operation of plasma and in-depth physical study. Specifically, online monitoring of electron density is an indispensable diagnostic method for every tokamak device. A Polarimeter/Interferometer (POINT)
is established based on the three-wave method, with its light source consisting of three optical pumping lasers. Stable intermediate frequency (IF) must be ensured between any two of these lasers to obtain low-noise phase information. An high-speed real-time IF stabilization system is specifically designed for POINT on EAST to address the issue of IF instability in electron density measurement. The system innovatively adopts active frequency stabilization technology based on neural networks, breaking through the limitations of traditional passive frequency stabilization, such as constant temperature control, vibration isolation[1]. By accurately monitoring frequency offset and adjusting the laser cavity length in real time, it can achieve fast and high precision frequency stabilization. Of particular note is that we have for the first time combined a back propagation (BP) neural network algorithm that combines incremental proportional integral derivative (PID) with the high-performance ZYNQ-7020 development board. This algorithm has been applied to POINT system on EAST. Compared to traditional digital PID, incremental PID enhances stability and anti-interference, and reduces the impact of the control variable on the PZT controller. The control variables output by the three-layer (4 input -5 hidden -3 output) structure of the neural network model[2] effectively eliminate a large number of overshoot phenomena that can cause damage to the PZT adjustment mechanism using a single incremental digital PID algorithm[3]. The AD/DA acquisition board connected to the PL side of ZYNQ performs fast Fourier transform on the collected laser IF signals, obtains the imaginary and real parts, and then calculates the effective IF frequency point. According to the Nyquist sampling theorem, the sampling frequency should be at least twice the original frequency[4]. To better apply it in engineering, a sampling frequency of 5~10 times the original frequency (approximately 4~8 MHz) is used. Then the amplitudes of each frequency point are compared to get the frequency point with the maximum amplitude. Then the current frequency value will be calculated according to the formula. GP interface is employed to complete communication between PL side and PS side of ZYNQ via Verilog HDL[5]. The BP neural network incremental PID algorithm, due to its large computational scale, puts the neural network algorithm model suitable for the dual-laser into the PS side for computation, and then the PZT controller obtains control rate after computation. Overall, through extensive statistics on algorithm completion time, the average calculation time for a single control rate can be better than 0.03 microseconds which can meet the control requirements. This innovative application utilizes ZYNQ-7020 platform as the hardware carrier and adopts the BP neural network as the algorithm for controlling variable output. When applied to the dual-laser IF stabilization system, it will enable the POINT diagnostic system to meet the requirements for long-term stable electron density measurement on EAST. The design and implementation of this system will provide design references for the IF stabilization of lasers in future Tokamak devices.

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