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A Full Digital Servo for Ultra-Stable Laser Frequency Stabilization

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The paper presents a fully digital servo designed for ultra-stability laser. To minimize laser frequency instability, the system requires high bandwidth and precision, low input and output noise, and minimal temperature drift. The laser system utilizes the Pound-Drever-Hall (PDH) method, employing an ultra-stable cavity to generate an error signal for servo input. This error signal is digitized by a high-speed and precision ADC and transmitted to Field Programmable Gate Arrays (FPGA). The FPGA accurately processes the signal at high-speed using IIR filters and a PID algorithm. The computed results are then converted into an analog signal through a high-speed DAC. The DAC output is then sent back to the laser, eventually stabilizing the laser. Due to the calculation process, the digital servo is inherently slower than its analog counterpart, often constraining the system's feedback bandwidth.

Nevertheless, a digital servo can still attain the same frequency stability goal with sufficiently low latency. A fully digitalized, high-performance servo can be applied in diverse experimental scenarios by making some feedback design modifications. Besides, High-order filters and automatic relocking features are more achievable in digital servo. This design is anticipated to possess sufficiently low latency to overcome the digital servo's bandwidth limitations while retaining maximum flexibility.

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