EPJ Web of Conferences **119**, 06003 (2016) DOI: 10.1051/epjconf/201611906003
ILRC 27

DITHER CAVITY LENGTH CONTROLLER WITH IODINE LOCKING

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ABSTRACT

A cavity length controller for a seeded Q-switched frequency doubled Nd:YAG laser is constructed. The cavity length controller uses a piezo-mirror dither voltage to find the optimum length for the seeded cavity. The piezo-mirror dither also dithers the optical frequency of the output pulse. [1]. This dither in optical frequency is then used to lock to an Iodine absorption line.

1. INTRODUCTION

Many lidar systems use seeded Q-switched lasers for their combination of pulse energy and narrow spectrum. Seeded Q-switched lasers generally need a controller to keep the main cavity modes locked to the exact frequency of the seed laser. We constructed a custom cavity length controller that uses end mirror dither to estimate the first derivative of the pulse build up time versus end mirror voltage. This first derivative estimate is then used to control the average end mirror voltage towards the optimum buildup time.

The optical pulse form the main cavity emerges with a frequency centered on the main cavity mode nearest to the seed laser frequency. [1] Thus the end mirror position dither also appears as a dither in output optical frequency. If a sample of the output optical pulse is then sent through a molecular absorption cell, the cavity length controller can also estimate the first derivative of the molecular absorption. The molecular absorption derivative is then used to lock the center frequency of the seed laser to the center of the chosen absorption line.

2. METHODOLOGY

A new cavity length controller (CLC) for a Photonics seeded Q-switched frequency doubled solid state laser was constructed. Figure 1 shows how the new CLC is connected to the laser and lidar control PC. It consists of a microcontroller board with inputs for the laser sync pulse, two energy monitors, and an optional input for the main cavity light pulse. For output it has an analog voltage for driving the piezo-mirror, and a logic output to signal the lidar data system if each laser pulse is good. The logic output is named Laser Pulse OK (LPOK). For PC communications it has a USB to serial connection that is used for data, commands, and firmware updates. See figure 1.

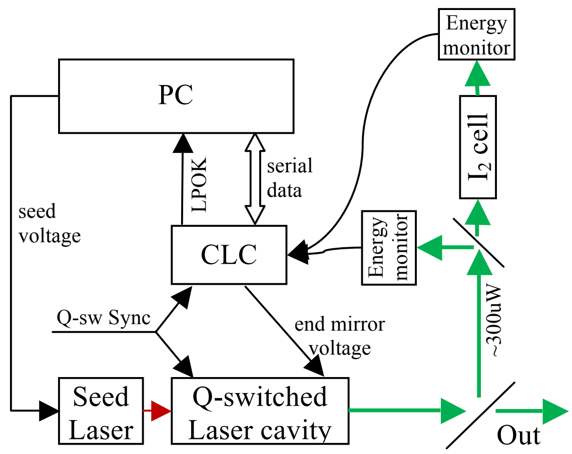

Figure 1: Block diagram of combined cavity length and Iodine locking controller.

The two energy monitors are configured to measure the absorption of a short Iodine cell. A small sample (<300uW average) of the output pulse is sent towards a beam splitter. One leg of the split beam is sent to the first energy monitor, while the second beam is passed through a short Iodine cell before detection by a second energy monitor.

Control of cavity length is done by minimizing the estimate of the first derivative of cavity build up time versus end mirror voltage. This derivative is estimated by adding a small (0.5-1V) dither voltage to the piezo end mirror voltage and averaging the difference between the cavity buildup time when the cavity is longer than average and shorter than average. An integral, double-integral controller is then used to adjust the average piezo end mirror voltage such that the buildup time is minimized.

The controller includes a laser pulse quality flagging function. (LPOK) The LPOK function improves lidar data-quality while also improving the robustness of the cavity length controller. The LPOK function rejects laser pulses that take too long to build up. The LPOK threshold is dynamically set. First minimum buildup time over 128 shots is recorded (the CLC lost-lock scan insures that there are always several seeded shots in this interval). This local minimum buildup time is then time averaged using a digital low-pass filter. Finally the LPOK threshold is set 50-100ns longer than the average of the minimum buildup time. The CLC directly uses the LPOK signal to detect when it has lost cavity length lock. When loss of cavity length lock is detected, the CLC starts a rapid scan for another seeded main cavity mode.

The cavity length controller is also linked to two energy monitors and a short Iodine cell configured to allow pulse by pulse measurement of Iodine absorption. Due to the end mirror position dither, the laser pulses also have an optical frequency dither [1]. This frequency dither in the pulses can be used with the Iodine cell to estimate the first derivative of the Iodine absorption.

Figure 2 shows the Iodine absorption and first derivative estimates during a frequency scan. Finally, the Iodine slope estimate is transmitted to the PC for use in a PID frequency locking loop.

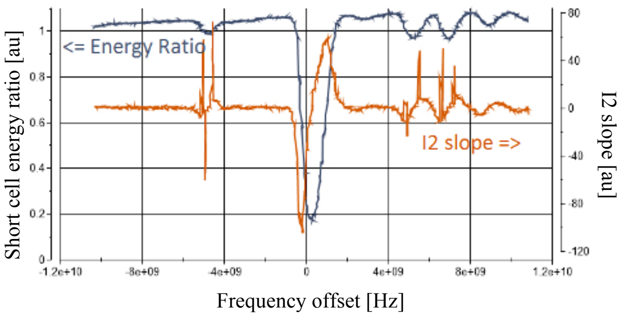

Figure 2: Transmission through the I2 cell and slope estimate versus frequency offset from I2 1109.

3. RESULTS

Figure 3 shows the ARM NSHSRL lidar system at Barrow Alaska recovering from several jumps in seed laser operating point. Recovery from the 500-600MHz jumps is prompt and well damped. (Note: the PC control is limiting how quickly the I_2 locking recovers) The controller will also recover from larger jumps in frequency as long as the jumps stay within the base of the Iodine 1109 line.

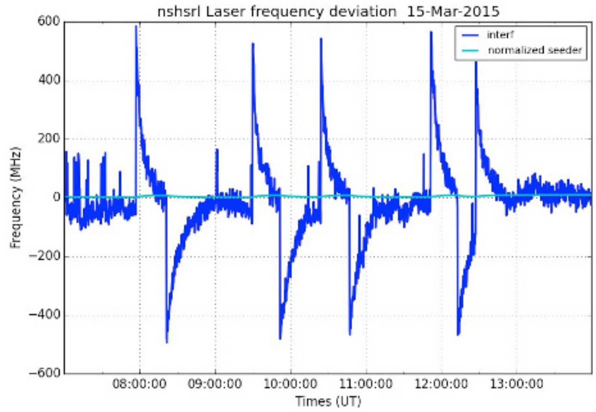

Figure 3: Slope estimate Iodine locking dealing with DPSS seed laser operating point jumps. (measured with a fiber interferometer)

Figure 4 shows the frequency locking error recorded by the ARM MF2 HSRL system while deployed on the NOAA Ship Ronald H. Brown during eight hours of typical operation in dock.

Frequency errors of the average slope estimate are 10 MHz peak to peak. The constant DC offset in frequency comes from the Iodine slope estimate calibration procedure (minimum and maximum represent the shot-shot variation in the Iodine slope estimate).

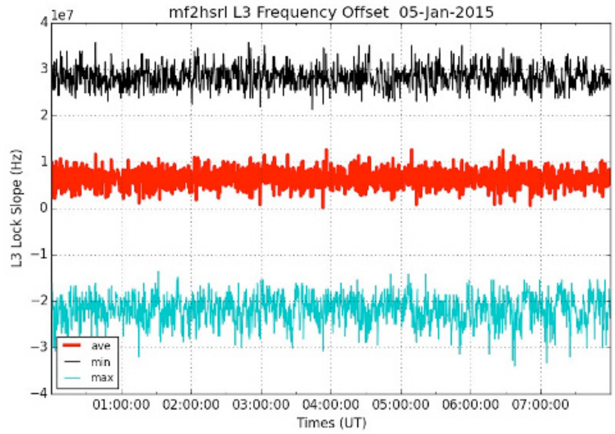

Figure 4: Frequency error over 8 hours with I_2 locking active. (calibrated I_2 slope)

This cavity length controller with I2 locking has been deployed to all five of the currently operating HSRLs built by the SSEC Lidar Group. The dither CLC replaced a Brillion shifted edgelocking Iodine locking system. [2] The dither CLC provides the same short term Iodine locking frequency error. The dither CLC also operates without periodic calibration, needs less optical power, and has less stringent alignment requirements.

4. CONCLUSIONS

With minimal additional hardware, a cavity length controller for a seeded laser can leverage the parasitic optical frequency modulation from dithering the piezoelectric end mirror to lock the average frequency of the laser to a molecular absorption filter or other frequency standard.

REFERENCES

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