Locking a RIO PLANEX Laser to the Vescent Photonics FFC-100 Fiber Frequency Comb

Vescent Photonics

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1 Introduction

The modern fiber frequency comb is a tool with incredible versatility, and a long list of applications both in the lab, and the field. One such application is the use of a comb to transfer the stability of one CW laser to another with a frequency difference which lies outside the bandwidth of typical photodetectors. To do this, the comb is locked to a stabilized CW laser at a convenient wavelength, and then a second laser is locked to the comb at a wavelength anywhere within its spectrum. In this application note, we will demonstrate the second part of this setup with the stable lock of a RIO PLANEX 1550nm narrow linewidth laser to the Vescent Photonics FFC-100 Fiber Frequency Comb using the Vescent Photonics D2-135 Offset Phase Lock Servo.

2 Experimental Setup

To generate a beatnote between the FFC-100's EDFA output and the RIO PLANEX CW laser, the two beams were overlapped in a fiber-optic 50:50 beam coupler and detected on a EOTech ET-3000A Amplified InGaAs photodetector. A fiber-optic channel 34 dense wavelength division multiplexer was used to select the region surrounding the beatnote and reduce the number of comb teeth in the signal before detection on the EOTech to improve SNR. Since the lower frequency limit of the D2-135's internal VCO is 385 MHz and the tooth spacing on the FFC-100 is only 100 MHz, it was necessary to generate this beatnote between the RIO and a tooth several repetitions away, as opposed to the nearest tooth. Directly after detection, a Texscan tunable RF band-pass filter was used to isolate f_{opt} at the operating frequency of 424 MHz. This signal was then amplified back up to within the D2-135's locking threshold of -10dBm in two stages using Mini-Circuits ZFL-500HLN 20dBm, and ZFL-1000LN 5dBm amplifiers separated by a Mini-Circuits VLF-1200+ low-pass filter. The servo feedback from the D2-135 was passed to the RIO's D2-105 Laser Controller for current control, and the beatnote ÷2 signal was used to manually tune the D2-135's internal VCO. Both the D2-105 and D2-135 were powered with a Vescent Phototonics D2-005 Linear Power supply.

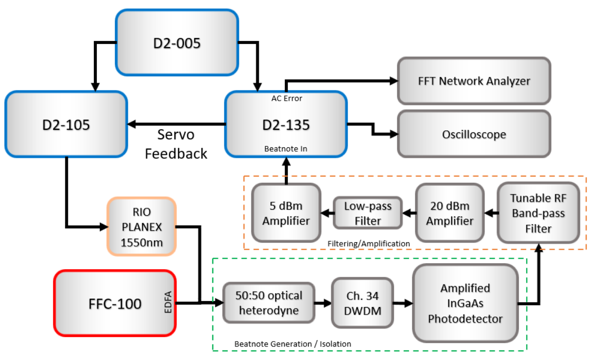

Figure 1: Block diagram of setup. To tune the D2-135's internal VCO an Agilent 8596E Spectrum Analyzer was connected to the Beatnote ÷2 output. PSD measurements were taken through the D2-135's AC Error output on a Stanford Research Systems Model SR770 FFT Network Analyzer (0-100kHz) and a RIGOL DSA710 Spectrum Analyzer (100kHz-1MHz).

Once the beatnote was found, the D2-135 was placed in "Ramp" mode and the VCO was tuned until the DC Error signal from the D2-135 showed a "Zero Crossing" (Fig 2. Left), at which point the D2-135 was switched to "Lock" mode to begin servoing the current to the D2-105 controlling the RIO (Fig 2. Right).

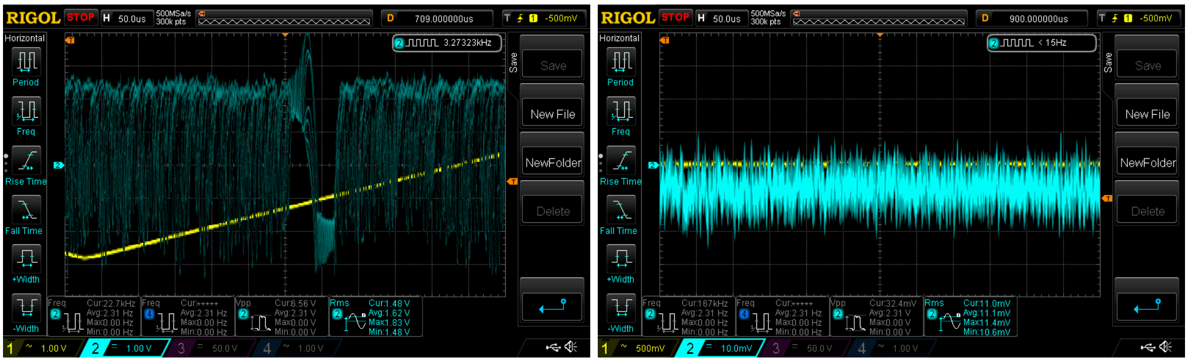

Figure 2: (Left) A zero crossing on the output of the D2-135's DC Error (teal line) corresponding to the VCO being tuned to the correct frequency for a lock. In the background, the D2-135's ramp signal can be seen in yellow. (Right) A steady DC error on the D2-135 corresponding to a lock between the RIO and FFC-100. Measurements were made with a Rigol DS1054 Z oscilloscope.

To achieve this lock, the PI and PD corners of the D2-135 were set to $f_I = 16$ kHz and $f_D = 250$ kHz respectively, while the high frequency option f_{HF} was left off. The D2-135 was set to operate in N=8 VCO Low mode, and the gain of the D2-135 was set to -6 dB with the "Fine Gain" knob turned to 2 o'clock.

3 Noise and PSD Measurement

When discussing noise in a system such as this one, it is often desirable to first convert from V_{RMS} noise to phase noise. This can be done using the conversion factor

$$\Theta_{noise} = N\frac{2\pi}{4}V_{noise}. \tag{1}$$

where 2π radians of phase noise per 4 volts of V_{RMS} noise comes from the phase detector used in the D2-135, and N is the factor by which the incoming beatnote is divided (in this case N=8).

To generate a power spectral density measurement for the locked system, data from a Stanford Research Systems Model SR770 FFT Network Analyzer (1 Hz - 100 kHz), and a Rigol DSA710 Spectrum Analyzer (100 kHz - 1 MHz) were stitched together after converting the spectrum analyzer data from dBm to $V/\sqrt{Hz}$ to match the FFT, and correcting for the difference in window functions used between the two machines (Hanning and Gaussian respectively). Finally, this PSD was converted into a Phase Noise PSD (Fig. 3) by multiplying by the factor given in Eq. 1 and converting from $V/\sqrt{Hz}$ to dBc/Hz.

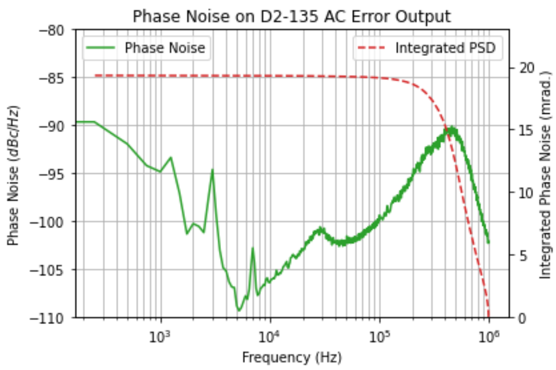

Figure 3: Phase noise power spectral density (green) and integrated phase noise from a RIO PLANEX CW laser locked to the Vescent FFC-100 Fiber Frequency Comb.

The integrated phase noise shown in Fig. 3 was calculated by taking the integral of the square of the power spectral density (in units of $V/\sqrt{Hz}$) from 1 MHz down to 1 Hz, then taking its square root as shown in Eq. 2.

$$Integrated\ Phase\ Noise = \sqrt{\int_{1MHz}^{1Hz} (Phase\ Noise\ PSD)^2\, d\nu} \tag{2}$$

The phase noise, and integrated phase noise on the D2-135's AC Error output were respectively measured to be -88.4 dBc/Hz at its maximum, and 19.31 mrad. integrated total between 1 MHz and 1 Hz.

4 Summary

A RIO PLANEX narrow linewidth 1550nm laser was locked to the Vescent Photonics FFC-100 Fiber Frequency Comb using a Vescent Photonics D2-135 Offset Phaselock Servo. The total integrated phase noise of this lock between 1 MHz and 1 Hz was measured to be 19.31 mrad., with a maximum phase noise of -88.4 dBc/Hz. One potential use for this type of lock is to bridge stability between two CW lasers with frequencies farther apart than the bandwidth of typical photodetectors would otherwise allow.

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