Fractional Instability of a Phase Stabilized Carbon Nanotube Fiber Laser Frequency Comb

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Synopsis: A 167 MHz repetition frequency fiber ring laser employing single walled carbon nanotubes mode-locker is phase-stabilized for the first time. The stability of the frequency comb generated by this laser has been measured by comparing it with a figure eight laser (F8L) and by beating it against a 1532 nm CW laser stabilized to a $\nu_1+\nu_3$ overtone transition of an acetylene-filled kagome photonic crystal fiber reference. The result shows the stability of comb to be ~10^{-11} in 1 s averaging time.

Phase-stabilized fiber-laser based frequency combs are indispensable tools for optical frequency metrology. The erbium doped fiber ring laser is passively mode-locked using single walled carbon nanotubes (SWCN) as a saturable absorber. The SWCN are optically attached to a fiber connector [1]. In this way the laser shows a substantial simplicity in its design and relatively high repetition frequency (f_{rep}). Our carbon nanotube fiber laser (CNFL) has a 167 MHz repetition frequency and produces 1 mW of average power at 40 mW of pump power. The pulse trains are injected into a parabolic pulse amplifier which allows high power pulse amplification, and then a supercontinuum (SC) spectrum is generated with a highly nonlinear fiber [2-4]. The offset frequency (f_0) is detected using the f-$2f$ self referencing method. The control of both f_0 and f_{rep} is accomplished in a similar manner as reported in prior work [5]. The f_{rep} was phase-locked using feedback control with piezo-electric transducer (PZT) fiber stretcher in the laser cavity. The f_0 was simultaneously phase-locked using feedback control of 980 nm pump power. The 10 MHz reference signal from a GPS disciplined Rb clock (Rb/GPS) referenced all synthesizers and frequency counters (Agilent 53132A). The CNFL comb was phase-locked over 4 hours while f_{rep} and f_0 were simultaneously counted and then their fractional instabilities were calculated. The f_{rep} dominates the stability of the optical frequency comb with ~0.4 mHz deviation at 1 s averaging time in the RF domain, corresponding to ~400 Hz in the optical frequency domain, similar to that of a F8L comb. The f_0 instability is negligible although the f_0 shows a wider linewidth and side peaks probably due to the lower operating pump power and phase noise. We beat the CNFL comb against a 1532 nm CW laser stabilized to a $\nu_1+\nu_3$ overtone transition of an acetylene-filled kagome photonic crystal fiber reference [6]. This measurement shows the instability of comb to be ~10^{-11} in 1 s averaging time limited by Rb/GPS (Fig. 1). At the longer averaging time, the stability is dominated by the acetylene reference.

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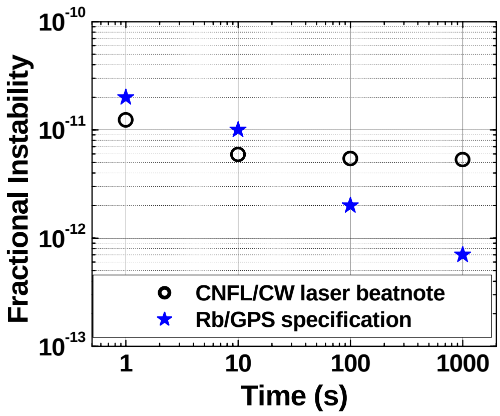

Fig. 1. The fractional instability of the beatnote between an acetylene stabilized CW laser and the CNFL frequency comb.

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References

[1] J. W. Nicholson et al, Opt. Express **15, 9176-9183** (2007).
[2] J. W. Nicholson and D. J. DiGiovanni, IEEE Photon. Technol. Lett. **20**, 2123-2125 (2008).
[3] J. W. Nicholson et al, Opt. Lett. **28**, 643-645 (2003).
[4] Y. Wang et al, in *Proceedings of Frontiers in Optics, FWF5* (2008)
[5] D. J. Jones et al, Science **288**, 635-9 (2000).
[6] K. Knabe et al, in *Proceedings of Conference on Lasers and Electro-optics (CLEO), JFA5* (2008).