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Measurement of Inter-Sweep Phase Stability of an FDML Laser with a 10 kHz Tunable Ring Laser

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Fourier Domain Mode Locking (FDML) lasers are light sources that generate a sequence of narrowband optical frequency sweeps at the fundamental or harmonic of the cavity repetition rate [1]. This frequency swept output can also be considered as a sequence of strongly chirped, long pulses. FDML lasers are mainly used in swept source optical coherence tomography (SS-OCT), a medical imaging technique. The coherence length of the source, i.e. the *intra-sweep phase* stability of an FDML sweep, is decisive for the image quality and performance of OCT imaging [2].

We present the first measurement of the *inter-sweep phase* of an FDML laser, i.e. the phase relation of consecutive sweeps. For this we measured the beating of an FDML laser with a ring laser having a line width of less than 10 kHz. The measurements strongly indicate a stable carrier envelope slip and only small amount of random phase noise.

For the measurement setup, shown in Figure 1, we use a tunable ring laser with a transmission grating as the wavelength selective element. The short term line width is smaller than 10 kHz and the tuning range is 150 nm at a central wavelength of 1300 nm. The FDML laser has a sweep repetition rate of 410 kHz at a duty cycle of 12.5 %. This results in a sweep duration of 304 ns for the 100 nm sweep at a central wavelength of 1300 nm.

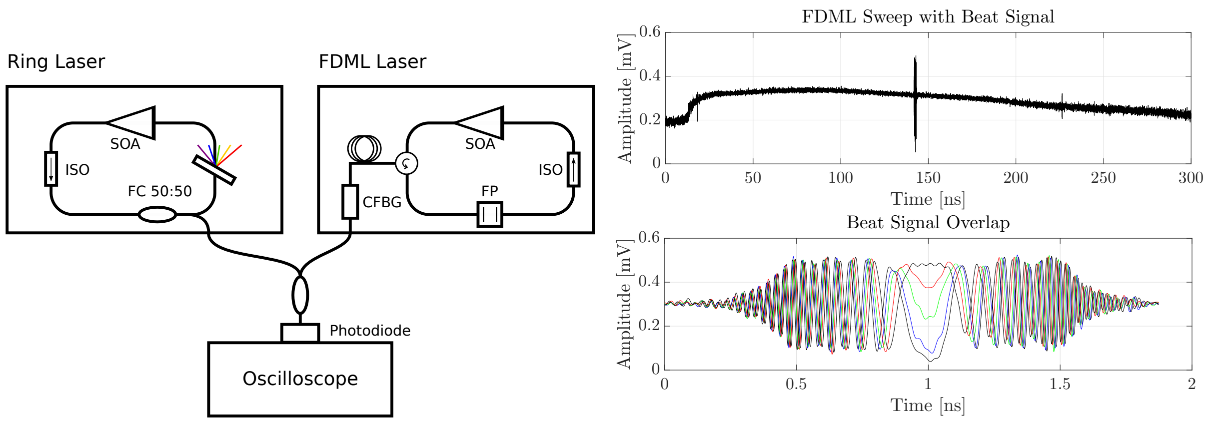

Fig. 1 Left: Schematic drawing of the measurement setup. Top right plot: single FDML-Sweep superimposed with cw ring laser. When the difference in optical frequencies between FDML and ring laser is less than ∼33 GHz (∼0.19 nm), a beat signal can be observed (in the plot at ∼140 ns). Bottom right plot: 5 superimposed beat signals of consecutive FDML sweeps.

The 10 kHz ring laser and the FDML laser are superimposed with a fiber coupler and the resulting beat signal is recorded by a fast photodiode. Each time the instantaneous optical frequency of the FDML sweep approaches that of the ring laser and the difference gets sufficiently small for our analog detection bandwidth of ∼33 GHz, an interference signal can be measured with the photodiode.

By analyzing the intensity of 5 consecutive beat signals at the time $t = 1.0$ ns, i.e. at the time when the FDML laser and the ring laser have the same frequency, we can detect the evolution of the inter-sweep phase. Our measurements show that the phase of successive FDML sweeps does not behave arbitrarily. We also analyzed more than 40 consecutive FDML sweeps, which corresponds to a time period of 100 µs, and observed that the phase follows a sinusoidal periodicity. This is evidence for a constant and stable carrier envelope phase slip with low arbitrary phase noise.

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