Carrier-Envelop Offset Frequency Linewidth Narrowing Using an Intracavity Spatial Filter

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Synopsis: Significant carrier envelope offset frequency linewidth narrowing is observed in a self-referenced prism-based Cr:forsterite frequency comb when a knife edge is insert into the intracavity beam. The normally broad free-running linewidths (Δf_{ceo}) of ~1 MHz can be reduced by as much as an order of magnitude, and then further reduced after phase-locking to <100 Hz. A simple model has been used for comparison with the observed linewidths.

The linewidth of the carrier envelope offset frequency (Δf_{ceo}) of a stabilized frequency comb can be an indication of the total frequency noise present within the femtosecond laser. Broad linewidths indicate substantial noise and can limit the use of a frequency comb. Cr: forsterite frequency combs have been shown to possess broad linewidths. [1, 2] However because Cr:forsterite occupies a useful region of the near infrared spectrum (~1.25 μm) we have developed a self-referenced, prism-based Cr:forsterite frequency comb. During the course of its development significant Δf_{ceo} narrowing was observed when a knife edge was inserted into the intracavity beam as shown in Fig. 1. The inset in Fig. 1 shows a plot of the measured Δf_{ceo} with the comb stabilized for the case with (red) and without (black) the knife inserted.

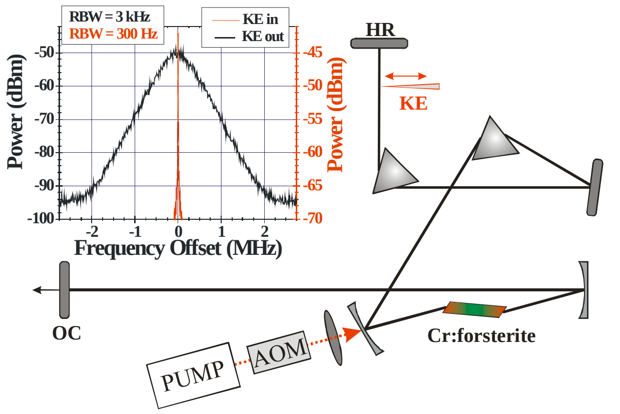

Fig. 1. Cr:forsterite cavity configuration showing the location of the knife edge (KE). HR: high reflector, OC: output coupler, AOM: acousto-optic modulator. The inset shows locked Δf_{ceo} with (red) and without (black) the knife edge inserted.

The introduction of the intracavity knife edge enabled the free-running Δf_{ceo} to be tuned through a minimum. If the comb is stabilized when Δf_{ceo} has been minimized then its locked Δf_{ceo} can be reduced to <100 Hz, implying the knife edge significantly reduces the frequency noise of the entire system.

To better understand the mechanism behind the noise reduction, a simple model for calculating Δf_{ceo} based on frequency noise was adopted [3], which is shown by Eq. 1.

$$\Delta f_{ceo} \sim \pi \left(\left(\mathrm{P} \frac{df_{ceo}}{d\mathrm{P}} \right)^2 \int_0^{f_{-3dB}} \mathrm{RIN}_l(\upsilon)\, d\upsilon \right)^{1/2} \quad (1)$$

P represents the pump laser power, df_{ceo}/dP the f_{ceo} response to pump power changes and RIN$_l$ (v) describes the relative intensity noise on the femtosecond laser.

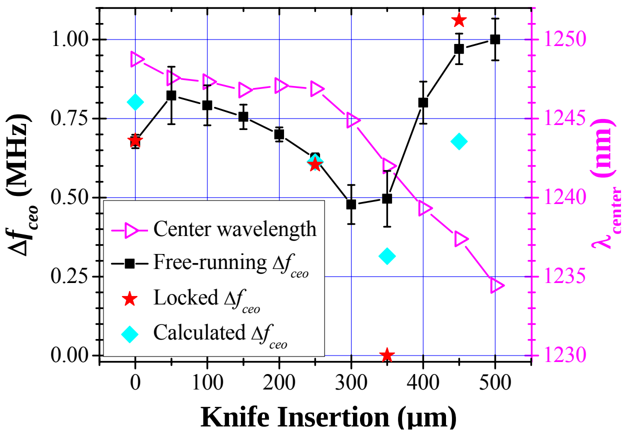

Fig. 2. Comparison between observed and calculated Δf_{ceo} plotted as a function of knife insertion

Figure 2 shows a comparison between the observed and calculated linewidths, where the free-running measurement is an upper limit and the calculated value is based on df_0/dP measured at low frequencies (~2 Hz). The locked width for the knife inserted by 350 μm represents the location of the minimum free-running linewidth and has a value of <100 Hz.

Further details will be presented including a study of the frequency dependence of df_{ceo}/dP. We believe the mechanism behind the noise reduction is related to intracavity dispersion changes caused by the knife acting as a spatial filter.

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References

[1] K. Kim, *et al*, Opt. Lett. **30**, 932 (2005).
[2] R. Thapa, *et al*, in *proceedings of CLEO,* CMKK7 (2007).
[3] J. J. McFerran, *et al*, Appl. Phys. B. **86**, 219 (2007).

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