Coupling between Energy and Carrier-Envelope Phase in Hollow-Core Fiber based *f*-to-2*f* Interferometers

He Wang, Michael Chini, Eric Moon, Hiroki Mashiko, and Zenghu Chang[1]

JRM Laboratory, Kansas State University, Manhattan, KS, 66506-2604, USA

Synopsis: The coupling coefficient between carrier-envelope phase and laser pulse energy is measured for white-light generation from a hollow-core fiber. It is determined that 1% fluctuation in laser energy gives a phase shift of 128 mrad.

For high power few-cycle laser pulse applications, the carrier-envelope (CE) phase plays a critical role. To produce such few-cycle pulses, spectral broadening in hollow-core fiber is typically followed by pulse compression. Previous work has suggested that the hollow-core fiber may introduce significant CE phase noise [1, 2]. However, it was unclear whether the measured CE phase instability was caused by the fiber itself or by measurement error caused by power instability. Here, we demonstrate a measurement of the coupling coefficient between laser pulse energy and CE phase drift for a hollow-core fiber without the ambiguity introduced by measurement based on white-light generation in sapphire.

The experiment was performed using the Kansas Light Source laser system. The 2 mJ, 35 fs pulses centered at 790 nm from the chirped pulse amplifier (CPA) were coupled to a 0.9 m long hollow-core fiber filled with neon gas. The output power and the CE phase of the CPA were locked [3, 4].

The effect of input laser energy fluctuations on the CE phase of the output pulses from a hollow-core fiber was studied using two *f*-to-2*f* interferometers. A variable neutral density (ND) filter was placed in front of the fiber entrance to modulate the input power. By rotating the ND filter periodically within a range of 5 degrees, the power was modulated within 10%. The in-loop hollow-core fiber based *f*-to-2*f* interferometer was used to stabilize the CE phase after the fiber, whereas the out-of-loop sapphire-based *f*-to-2*f* interferometer was used to simultaneously measure the CE phase of the unmodulated beam.

The in-loop CE phase shows a fluctuation of 107 mrad in Fig. 1(a), which is similar to the case without power modulation. Fig. 1(b) shows the anti-correlation between the in-loop power modulations and out-of-loop CE phase measurement. We assume that the out-of-loop CE phase drift is caused only by the modulation of the in-loop pulse energy in order to simplify the analysis. A linear least-squares fit of the data shows that a 1% change in input pulse energy introduced a CE phase drift of 128 mrad in Fig. 1(c).

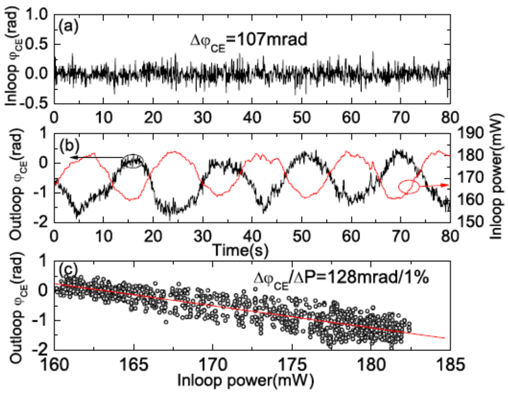

Fig. 1. (a) In-loop CE phase locked by a hollow-core fiber based *f*-to-2*f* interferometer; (b) Out-of-loop CE phase measured by a sapphire plate based *f*-to-2*f* interferometer and the in-loop power modulation; (c) CE phase change to laser power coupling coefficient by a least-square fitting.

In conclusion, we found that the hollow-core fiber based *f*-to-2*f* interferometer provided a higher accuracy of CE phase measurement. Understanding the CE phase properties of such fibers is crucial for attosecond pulse generation, ATI and other experiments at the frontiers of ultrafast science. This material is supported by the U. S. Army Research Office under Grant No. W911NF-07-1-0475, and by the Chemical Sciences, Geosciences, and Biosciences Division, U.S. Department of Energy.

References

[1] H. Mashiko *et al.*, *Appl. Phys. Lett.* **90**, 161114 (2007).
[2] C. Li *et al.*, *Opt. Lett.* **32**, 796 (2007).
[3] H. Wang *et al.*, *Appl. Phys. B* **89**, 275 (2007)
[4] C. Li *et al.*, *Opt. Lett.* 31, 3113 (2006)

E-mail: chang@phys.ksu.edu