Reducing the Fast Carrier-Envelope Phase Jitter of Amplified Femtosecond Laser Pulses

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Abstract: Stabilizing the interference signal obtained from co-propagating a HeNe beam in the f-to-2f interferometer used for carrier-envelope phase stabilization of a femtosecond laser oscillator reduced the fast phase jitter of the amplified pulses by ~40%.

OCIS codes: (140.7090) Ultrafast Lasers; (320.7110) Ultrafast Nonlinear Optics; (120.5050) Phase Measurement

1. Introduction

Recently, carrier-envelope (CE) phase control and stabilization have become very important research topics. Strong-field processes, such as attosecond pulse generation and above-threshold ionization, are highly dependent on the CE phase of the laser pulses used [1].

Amplifying the CE phase stabilized pulses from a mode-locked femtosecond laser oscillator is integral for studying strong-field processes. The nJ pulses obtained from standard femtosecond oscillators are not energetic enough for studying strong-field physics. Thus, the pulses must be amplified up to the mJ energy level and the CE phase stabilization must be preserved. Effects such as beam-pointing instability and non-linear phase shifts can affect the CE phase of the pulses as they pass through the femtosecond laser amplifier. CE phase noise can also originate during the stabilization of the laser oscillator.

In this work, the influence of the drift of the f-to-2f interferometer used for stabilizing the CE phase of the Ti:Sapphire femtosecond laser oscillator used to seed a multi-pass Ti:Sapphire amplifier is studied. By adding a HeNe beam to the Mach-Zehnder interferometer used for CE phase stabilization and using the interference signal to feedback control a piezo-electronic mounted mirror, the interferometer phase noise was reduced to 60 mrad. Stabilizing the path length difference of the interferometer reduced the fast CE phase jitter of the amplified pulses from 79 mrad to 48 mrad [2].

2. Experiment and Discussion

The experiments were carried out at the Kansas Light Source (KLS) laser facility. The laser system and the f-to-2f interferometer used for the oscillator CE phase stabilization are shown in Figure 1. Half of the output from the Ti:Sapphire oscillator, ~200 mW, was focused into a photonic crystal fiber for spectral broadening and sent to a f-to-2f interferometer for detection of the carrier-envelope offset frequency. The offset frequency was locked to one quarter of the repetition rate of the laser and the timing of the amplifier was adjusted so that only pulses with the same CE phase were selected for amplification. Less than 1% of the amplifier output was then sent to a collinear f-to-2f for measuring the relative CE phase drift and for providing a slow drift feedback control to the oscillator locking electronics [1].

A HeNe beam co-propagated through the f-to-2f interferometer used for locking the CE phase of the oscillator. The resulting interference signal, due to variations in the path length in the interferometer, was used to feedback control a piezo-electronic mounted mirror in the long wavelength arm of the interferometer. This feedback control allowed the path length difference in the two arms to be held constant. Figure 2 shows the power spectral densities and the integrated phase error of the phase noise of the interferometer for both the locked and unlocked cases. As is shown, the phase error of the interferometer was reduced to the 60 mrad level by locking the path length difference.

Of course, any drift of the interferometer would be written onto the detected carrier-envelope phase offset frequency. In figure 3, the effect of locking the interferometer on the detected relative phase drift of the amplified pulses is shown. In figure 3a, it is shown that the RMS value of the detected CE phase drift did not change much when the interferometer was stabilized. However, by applying a >3 Hz high-pass filter to the measured CE phase signal, it is shown that the fast jitter was reduced from 79 mrad to 48 mrad.

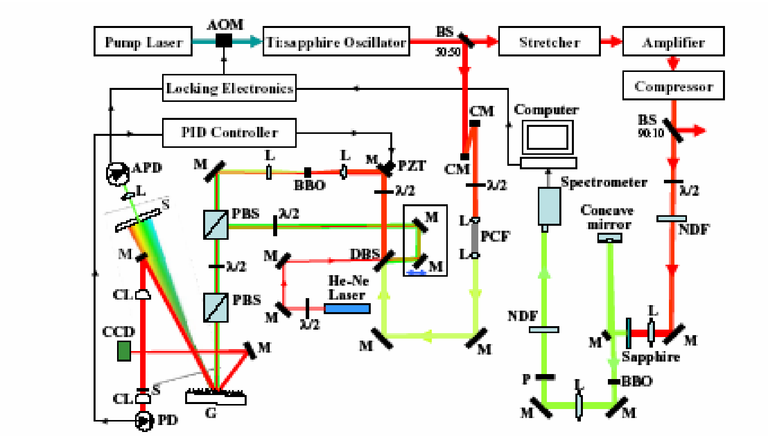

Fig 1. Experimental setup for stabilizing the CE phase of the oscillator and for interferometer stabilization. M: mirror, S: slit, BS: beam-splitter, PBS: polarizing beam-splitter, CM: chirped mirror, G: grating, CL: cylindrical lens, DBS: dichroic beam-splitter, PCF: photonic crystal fiber, NDF: neutral density filter, P: polarizer

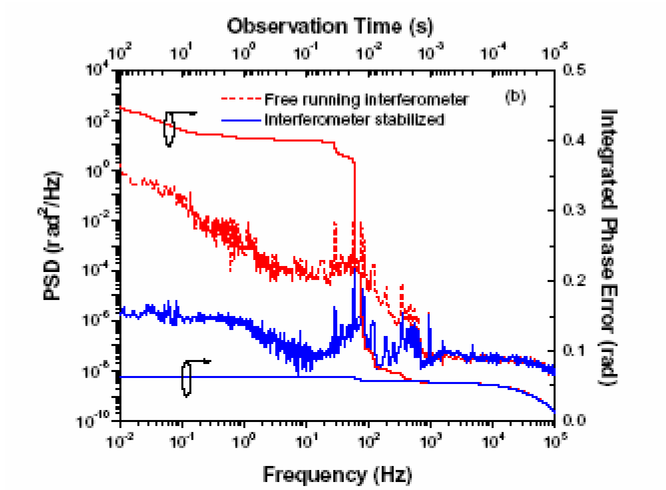

Fig. 2. Comparison of the phase noises of the stabilized and free running interferometers.

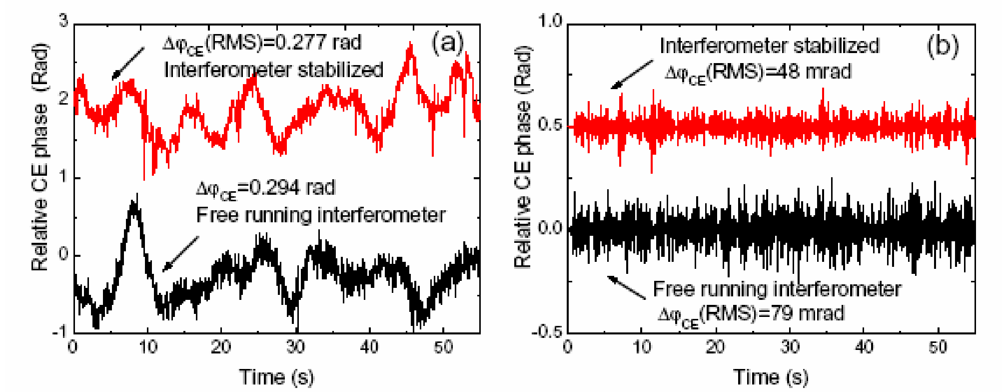

Fig. 3. Comparison of the CE phase noises of the amplified laser pulses between the free running and the stabilized f-to-2f interferometer. The slow drift of the CE phase in the amplifier was corrected by an additional feedback. a) the relative CE phase measured by the collinear f-to-2f interferometer. b) the fast jitter of the CE phase obtained by applying a high pass filter to the spectra in a).

References

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