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Review of Carrier-envelope Phase Stabilization via a Feed-forward Technique



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# Review of Carrier-envelope Phase Stabilization via a Feed-forward Technique

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**Abstract:**

Control and stabilization of the carrier-envelope phase (CEP) is highly needed for ultrafast laser. In this paper, we demonstrate a technique of measuring CEP and analyze the result of CEP and timing jitter.

**INTRODUCTION**

As laser pulses become shorter and shorter, how to accurately control and stabilize carrier envelope offset phase (CEP) continue to bother scientists. The CEP mostly comes from intracavity environmental conditions and optical power fluctuations. Besides, CEP will be shown in timing jitter in time-domain, which is a significant index for evaluating the stability of ultrafast lasers. To measure and decrease the timing jitter, some methods have been proposed. One of them will be present together with the whole system.

**METHODS**

In this paper, authors try to measure the shot-to-shot slippage of the CEP. At the same time, they need to decrease the timing jitter. To get the result, they build a setup to measure the frequency of carrier-envelope offset (CEO). Usually there are two methods: $f - 2f$ interferometry and forward feedback (FF). In this paper, authors choose FF because by employing this method, one can directly modify the comb and substitute $f_{CEO}$ with a constant frequency. This enables the stabilization along the beam line, irrespective of the optics of the cavity. The setup is shown in fig.1. The light is generated by SESAM soliton mode-locked Er:Yb:glass laser oscillator, whose power is 140 mW in175 fs pulses at a repetition rate of 204 MHz with a spectral bandwidth of 14.9 nm centered at 1.55 μm. And then the beam is spitted into two paths, one is in loop (IL) to get the feedback, which going through PPLN crystal, low-pass filter, bandpass filter, polarization-maintaining highly nonlinear fiber and amplifier part; the other one is out-of-loop (OOL) for frequency measurement, which go through an acousto-optic frequency shifter (AOFS). To make AOFS at the working condition, they need to give it 80MHz, which is provided by frequency of CEO and a local oscillator (LO). By measuring the frequency of OOL, the frequency of REP or CEO can be calculated by

$$f_{CEO} = \frac{\Delta\phi mod 2\pi}{2\pi} f_{REP} \tag{1}$$

$$f_{AOFS} = f_{CEO} + f_{LO} \tag{2}$$

$$f_{OOL} = n f_{REP} - f_{LO} \tag{3}$$

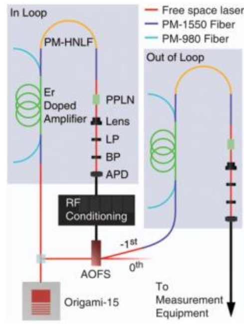


Fig. 1. Experimental setup with in-loop and out-of-loop beamlines [1].

## RESULTS AND INTERPRETATION

The study uses a figure to show the frequency of $f_{REP}$, $f_{REP} - f_{LO}$ and $f_{LO}$. Using this result, the authors can get the results of CEP. They also provide a figure which describes the integrated phase noise (IPN) and phase noise spectral density (PND). IPN can be calculated by integrating PND in math. The most important thing is that IPN is the biggest reason that affect the timing jitter. To achieve better ultrafast pulses, we want the CEP to be better controlled, which is related to the timing jitter. In the method that this paper demonstrates, we can measure the timing jitter and analyze the whole ultrafast laser system.

In 170B class, we have learned much related to the system in this paper. In the in-loop part, authors use nonlinear fiber like PM-HNLF. This kind of fibers are used to adjust the dispersion of ultrafast pulses. Unlike CW light, pulses are composed of light in different frequencies. So, light will get dispersed when propagating in medium. As mentioned in paper, solitons are required in this measuring system. By simulating and calculating, the authors add PM-HNLF to make the dispersion to be perfect. With the correct dispersion, power of pulses will be maximum. The bandwidth will also be broadened to get the shorter pulse in time-domain.

What’s more, in this paper, the writers also put the PM-HNLF at the last part after SHG process in PPLN crystal. It is definitely helpful to get better experiment results because there are many colors of light in the system, which will also cause different traveling speeds in fibers. Put the problem at last will help reduce errors.

## CONCLUSIONS

This paper introduces a simple and high-quality method to control and measure the CEP of ultrafast pulse lasers. The authors achieve an ultralow timing jitter of 2.9 as (1–3 MHz) and long-term stabilization over a duration of 8 h. The authors' approach has several advantages over traditional feedback methods. First, it is more robust to noise and perturbations. Second, it does not require any changes to the laser cavity. Third, it can be used to stabilize lasers with a wide range of repetition rates.

## REFERENCES

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