Temperature feedback control for long-term carrier-envelope phase locking

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Synopsis: We report a double feedback loop to improve the long-term carrier-envelope phase stabilization of a chirped mirror based oscillator. By combining the temperature control of the Ti: Sapphire crystal and conventional pump power modulation, the carrier-envelope offset frequency f_{ceo} can be locked for 34 hours, which is many times longer than the stabilization time using pump power modulation only.

The long term carrier-envelop phase (CEP) lock is required in the single attosecond experiments since such experiments usually take many hours to collect sufficient counts to suppress the statistical noise [1]. It is a common practice to obtain CEP stable pulses from the oscillator by modulating the pump power with an acousto-optic modulator (AOM). Due to the change of environmental conditions in laboratories, f_{CEO} may drift out of the AOM locking range, which limits the f_{CEO} stabilization time. We proposed and demonstrated a temperature feedback scheme to compensate the slow f_{CEO} drift and extend the CEP stabilization duration.

The long-term CEP locking setup is shown in Fig. 1. The temperature of the Ti:Sapphire crystal was modulated to compensate the slow f_{CEO} drift. The control range of the AOM signal was set to be ± 0.1 V. When the feedback signal is beyond the limits of this control range, the chiller temperature was changed 0.1° C every 400 s to compensate the slow drift of the f_{CEO} until the AOM driving voltage was returned to the control range. We calculated a f_{CEO} change rate of $df_{CEO}/dK=0.86$ *MHz* for the 2 mm Ti: Sapphire crystal used in the oscillator from a temperature dependent Sellmeier equation [2]. It is close to the measured value of 0.77 *MHz/K*. Given the temperature control range of 8 °C, the temperature feedback can compensate a f_{CEO} drift of 6 MHz, which is comparable to the AOM control range.

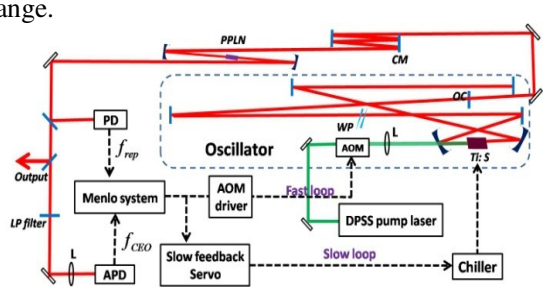

Fig. 1. Schematic of double feedback control for f_{CEO} locking.

As shown in Fig. 2, the CEP stabilization can reach 34 hours with the assistance of temperature control. On a daily basis, the CEP can be locked more than 12 hours using this scheme, about 3-4 times longer than the f_{CEO} locking time with AOM only in the same environment.

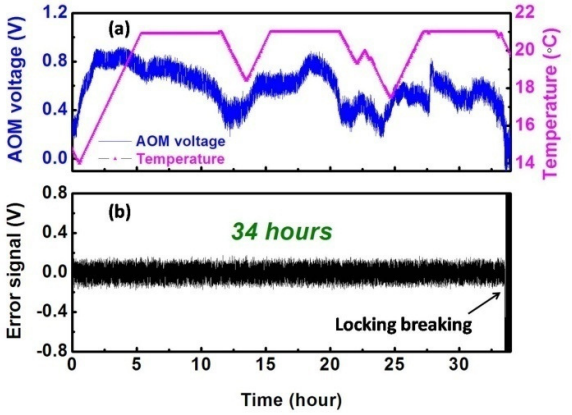

Fig. 2. (a) 34 hours CEP stabilization achieved by employing the double feedback loop; the blue curve shows the AOM driving voltage output; the pink curve shows the temperature of the crystal; (b) Error signal from locking electronics.

In conclusion, we improved the long-term CEP stability of a chirped mirror based oscillator by modulate the temperature of Ti:Sapphire crystal to assist the conventional AOM control. Without adding new optical elements or disturbing the operation of the oscillator, this scheme is compact, easy to operate, and economical.

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References

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