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Review of Carrier-envelope phase stabilization of an Er: Yb: glass laser via feed-forward technique

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Abstract:

Carrier-envelope phase stabilization is essential in ultrafast laser systems. The system described can stabilize this phase using a feed forward technique showing low timing jitter over 8 hours.

INTRODUCTION

Ultra-fast laser systems in the attosecond and femtosecond speed are essential in timing, communication, and quantum measurement areas. For example, to study quantum effects such as measuring the state of an electron in an atom, it would require a very precise pulse of energy. This pulse would need to have its peak electric field when the peak in time is, so that the interaction happens when its expected. To go with it, the timing mechanisms must also have the peak electric field stabilized to the expected time peak so that the timing of this phenomena is correct as well.

METHODS

The system detailed in [1] applies a feed forward (FF) f-2f interferometer technique onto an Er:Yb:glass mode locked laser (MML) to accomplish a low 3.5mrad (1Hz – 3MHz) carrier-envelope offset (CEO) over 8 hours.

MMLs are phenomena that are not fully understood, and thus their output is filled with shot-to-shot slippage; meaning the phase velocity and group velocity for a single shot or pulse will be different depending on pumping conditions and intracavity conditions. Due to this, the CEO will be different at every pulse, thus a system must be used to stabilize it. As noted in [1], there are two kinds of architectures to fix this: feedback and FF.

They focus on FF, since feedback methods are more demanding in the electronics used to maintain low CEO. The FF method acts on the MML output instead of the direct cavity pulses; so that the stabilization is not impacted by the MML shot noise. The MML's amplified signal at 60fs pulses, 204MHz repetition rate and 250mW average power are fed into a highly nonlinear fiber (HNLF) to broaden out the frequency spectrum. It is then fed through a frequency doubler (PPLNs) to generate a 1024nm harmonic, and passed through a bandpass filter at 1024, and an avalanche photo diode (APD). Then it is split into 2 paths, one in loop for a feedback measurement and one out of loop through an acousto-optic frequency shifter (AOFS). The out of loop structure is identical to the in-loop section, just without a AOFS split at the end and instead going to measurement equipment.

In summary, the system makes use of the PPLNS to self-interfere and discover the CEO. Please see [1] for more explicit details on the derivation. CEO is then measured, where in the pump power and AOFS are adjusted so that the out of loop CEO is low. This yielded the result stated above, a CEO of 3.5mrad (1Hz – 3MHz) over 8 hours of operation. This doesn't require any changes to the initial cavity length, thus this kind of stabilization can be easily done to other Er:Yb:glass systems. All that had to be adjusted is the gain of the fiber, so that when frequency doubled by the PPLN, there is enough energy in the second harmonic to make the f-2f interference work.

RESULTS AND INTERPRETATION

The main results are that FF techniques are shown to stabilize CEO to very low values. For reference, they reported the lowest CEO from another paper, [2] which is at 120mrad (0.01Hz-1MHz). This was much higher because they suspected that there was not enough amplification in the design. To this, I was hoping that they would report the CEO in the same frequency range to exemplify this point, but such result was not provided.

To delve deeper into one section of the design, I would like to focus on the HNLF, and its use in the system. The HNLF is used for spectral broadening for f-2f interferometry in the system. The amplification before this stage is very important that the required octave is generated from broadening. If this system is implemented so onto an existing mode locked laser, how finely tuned will this HNLF need to be, and how much amplification is needed to meet the octave requirement?

They only briefly mention the fact that the amplification needs to be at a mean average of 250mW, increased from the 140mW; while instead a ratio between maybe Watts to repetition rate or pulse length may be more useful in replicating this design with a laser at a lower/higher power. However, it is known that most mechanisms behind mode locked lasers are still a mystery to us, this ratio may be in this category; or this may just be a limitation of the HNLF that is being used, and that is why 250mW of power is needed. Thus, can a HNLF be customized to broaden with a lower power, so that this extra amplification is not needed, and so that the system can just be readily attached without an amplification step before?

Toward the end of the paper detailing the results, they also mentioned a section on future work being a proportional, integral, derivative (PID) controller to adjust the pump power and the AOFS. Their results shown over the 8 hours were maintained by manual adjustment every half hour, so it is good to know that adjustments don't need to be happening very often, and that they have already identified the solution to it. This would make continuous use of this MML system possible, so that all the timing/measurement/communication applications are realizable.

CONCLUSIONS

In conclusion, this paper showed promising findings in stabilizing CEP in a SESAM mode locked Er:Yb:glass laser system with a FF and f-2f method. As noted in [1], for the future a PID controller will be needed to make the system autonomous. It requires no change in the MML cavity and thus is free of the associated noise. The author's work is a big accomplishment toward low CEO in ultrafast laser systems.

REFERENCES

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