Controlling the Carrier-Envelope Phase of Single-Cycle Waveforms Synthesized from Raman Generated Frequency Combs

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Synopsis: We proposed and experimentally verified that the carrier-envelope phase of single-cycle waveforms synthesized from Raman generated frequency combs can be precisely set and controlled by generating the comb using an infrared laser tuned near a Raman resonance and the second harmonic of the laser to drive the Raman coherence.

In the interaction of single- to few-cycle pulses with matter it is essential that the carrier-envelope phase (CEP) of these pulses is stable since the electric field waveform of the pulses can vary substantially depending on the value of the CEP. The CEP of the pulses synthesized from frequency combs generated by CW mode-locked Ti:saphire lasers can be routinely controlled either actively [1] or passively [2] with high precision. However, while the Raman technique is very promising in the production of multi-octave spanning frequency combs [3] the CEP of waveforms constructed with these combs has varied randomly from one pulse to the next. In this report we demonstrate that by using the fundamental frequency and its second harmonic to drive a Raman coherence the carrier-envelope phase of the resulting waveform becomes fixed at all time.

The source of the problem of a random CEP in the Raman technique is that two driving pulses of vastly different frequencies are required to drive the Raman coherence. These two pulses normally come from different lasers that have a random phase difference between them, thus causing the CEP to vary greatly from one laser pulse to another. Our solution to this problem is to derive the two driving pulses from the same laser source. This way the two pulses will be phase-locked. It can then be shown that a comb generated from these two pulses will have a constant static phase that transforms into a constant CEP for the waveform at all time.

We experimentally verified the long-term inter-pulse phase locking and control of the static phase in a Raman comb whose components are generated by using an infrared laser tuned near a vibrational Raman resonance of the hydrogen molecule and the second harmonic of the laser to drive a H_2 vibrational Raman coherence. We allowed each Raman frequency component to beat with a beam formed from the summing of two lower order components to the same frequency. The resulting heterodyne signal is shown to be stable and the signal modulates as expected as a function of the relative phase between the two input driving beams. Consequently by setting the value of this relative phase we can control the CEP of waveforms synthesized from this Raman comb.

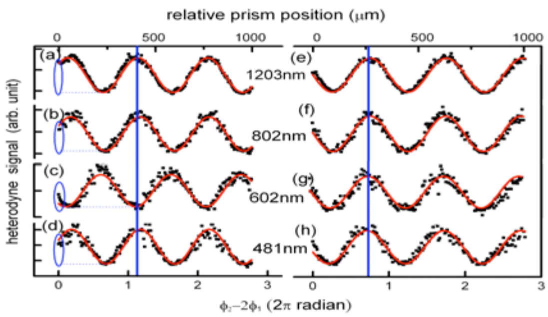

Figure 1. Heterodyne signals from several Raman components and the corresponding sum mixed frequncy in a BBO crystal as a function of the phase difference $\phi_2 - 2\phi_1$.

References:

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