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Multi-octave Parametric Amplification for Ultrashort Laser Pulses

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Optical parametric amplifiers deliver intense ultrashort pulses with broadly tuneable frequencies, useful for strong field physics, high harmonic generation, and attosecond experiments. Currently, this nonlinear amplification scheme relies on the second order nonlinearity, $\chi^{(2)}$,which is made possible only by crystals without centro-symmetry. More recently, investigations into a non-collinear setup show an increase in the phase matching bandwidth, leading to the creation even shorter pulses [1]. In this presentation, we discuss our research involving non-collinear parametric amplification of ultrashort pulses using wide bandgap materials with centrosymmetry, previously reported as Kerr instability amplification (KIA) [2].

We find that by using these crystals that exploit the next order nonlinearity, $\chi^{(3)}$,we can choose our amplifying medium from a more general class of crystals and still can generate gain factors of g = 50 /mm, or amplification factors of > 10^{12} [3]. Without the constraint of centrosymmetry, we have a greater selection by varying the bandgap, thermal properties, and linear and nonlinear indices of refraction. We developed pulse propagation models to optimize the critical parameters for amplification, and we find that the amplified pulse duration is much shorter than the pump and can be independent of the seed. We test several high bandgap dielectrics to optimize our scheme. We experimentally demonstrate the octave spanning amplification, showing that KIA is closely linked to degenerate four-wave mixing. We also spectrally and temporally characterize the amplified pulses to show the agreement with theory.

References

[1] H. Fattahi et al, Third-generation femtosecond technology, Optica 1 45-63 (2014)

[2] G. Vampa, TJ Hammond et al, Kerr instability amplification, Science 359 673-675 (2018)

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Author: HAMMOND, TJ (University of Windsor)

Presenter: HAMMOND, TJ (University of Windsor)

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