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I. Jovanovic, C. Haefner, B. Wattellier, C. P. J. Barty

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Extreme prepulse contrast utilizing cascaded-optical parametric amplification

I. Jovanovic[1], C. Haefner[2], B. Wattellier[3], and C. P. J. Barty[1]

[1]Lawrence Livermore National Laboratory, 7000 East Ave., L-470, Livermore, CA 94550, USA
Phone: (925) 424-9773, FAX: (925)423-6195, email: jovanovic1@llnl.gov
[2]Nevada Terawatt Facility, University of Nevada, Reno, Nevada 89506
[3]Phasics, Campus de l'École Polytechnique, Bât. 404, 91128 Palaiseau Cedex, France

ABSTRACT

It has been shown recently that an optical parametric chirped-pulse amplifier can be easily reconfigured into a cascaded-optical parametric amplifier (COPA), enabling complete prepulse removal and optical switching with a window defined by the pump pulse duration. We have demonstrated instrument-limited measurement of the COPA prepulse contrast >$1.4\text{x}10^{11}$ using 30-mJ pulses. The COPA technique is applicable to all energy ranges and pulse durations. A convenient millijoule-scale implementation of this technique is presented using a single, large-aspect-ratio quasi-phase-matched nonlinear crystal.

It has been shown previously that the use of OPCPA amplifies only a single pulse out of the oscillator pulse train resulting in a prepulse contrast enhancement equal to the total saturated gain, provided that the pump pulse duration is sufficiently short and there is no overlap in time with preceding or subsequent pulses. Notwithstanding the significant prepulse contrast enhancement, OPCPA does not remove prepulses; it merely reduces their relative peak intensity, typically on the order of 10^8 in a large laser system. Here we report the measurement of the extreme contrast enhancement of a modified OPCPA technique, termed cascaded optical parametric amplification (COPA). [1] The technique is implemented by reconfiguration of a two-stage OPCPA into a phase-conjugated COPA system. Its feasibility has been described and recently demonstrated [2]. The method removes any pre- and post-pulses in the neighborhood of the main, amplified pulse. Instrument-limited experimental measurement of the prepulse contrast of $1.4\text{x}10^{11}$:1 is presented at a 30-mJ level using cascaded electro-optical modulators to protect the photodiode from damage by the main pulse.

Demonstration of a large prepulse contrast requires a high dynamic range prepulse measurement technique. We have chosen a relatively simple setup using a sensitive photodiode and a cascade of fast Pockels cells to protect the photodiode from damage by the main pulse. Pockels cells were operated such that the main pulse was rejected, while the prepulses were transmitted to the photodiode. The attenuation of the main pulse was $1.1\text{x}10^5$ and was sufficient to protect the diode from damage by the main pulse. We first determined the contrast ratio for the conventional OPCPA system. The prepulse contrast was $1.4\text{x}10^8$, which is approximately equivalent to the gain of the system. We reconfigured the OPCPA setup to the COPA configuration and we could not detect any prepulses within the noise level of our instrumentation. The baseline was measured with and without COPA turned on to correct for the noise level. The noise level was $6.2\pm0.05\text{x}10^{-3}$ on the normalized scale of Fig. 2. The main source of noise is digitizer and crosstalk effects in the oscilloscope. We determined the contrast ratio by comparing the pulse amplitude with the leading baseline ahead after subtracting the noise level, and obtained an instrument-limited contrast ratio of $1.4\text{x}10^{11}$. Fig. 1 shows the comparison between OPCPA and COPA contrast measurement. The measurement dynamics were limited by the maximum available energy determining the signal to noise ratio.

We have experimentally shown that the COPA technique indeed allows extreme prepulse contrast enhancement. In principle, infinite contrast enhancement is possible by the COPA technique and is only limited by the pump pulse time duration. Within this window the COPA contrast is limited by the usual parametric fluorescence. Simple modification of a multi-stage OPCPA system results in its operation in a COPA mode, particularly for systems operating near degeneracy. Since the COPA technique does not rely on the nonlinear effects on the pulse itself, it is extraordinarily versatile. COPA can be operated at any energy level, with either stretched or compressed pulses. A particularly attractive implementation of the scheme is to operate in conjunction with quasi-phase-matched OPA, (Fig. 2) where a simple low-energy contrast enhancement can be accomplished utilizing a single OPA crystal.

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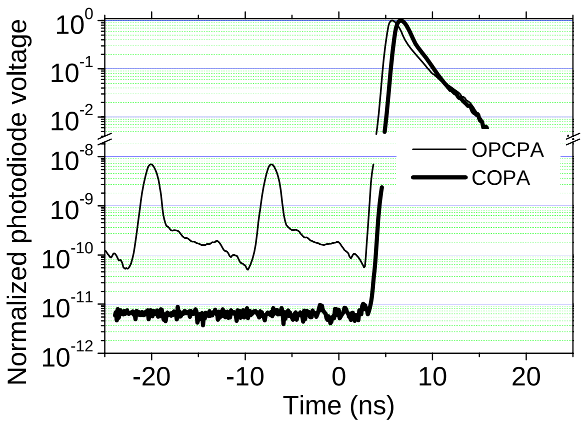

Fig. 1: (thin line) OPCPA amplifies an isolated oscillator pulse, but does not remove prepulses; (thick line) COPA removes all oscillator prepulses. The COPA pulse is shifted by 1 ns for better distinction.

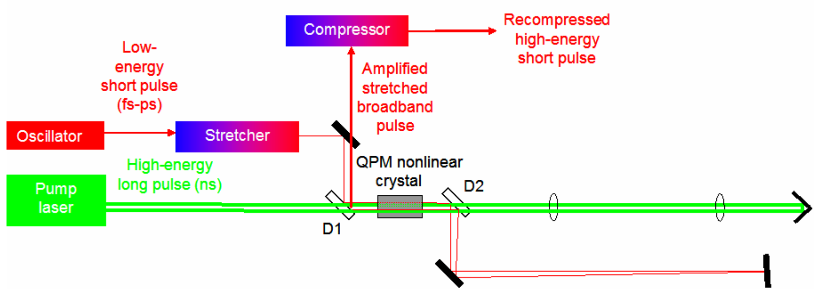

Fig. 2. Schematic for millijoule OPCPA/COPA in PPKTP. D – dichroic beamsplitter, Selection between OPCPA and COPA is accomplished by reflecting the idler instead of the signal into the second amplification pass.

References:

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[2] Jovanovic, I., C. Haefner, B. Wattellier, and C.P.J. Barty,"Optical switching and contrast enhancement in intense laser systems by cascaded optical parametric amplification," Opti. Lett..**31**, 787 (2006).