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Temporal contrast enhanced to 10^{-10} for femtosecond lasers by nonlinear filtering

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Abstract. We present a new third-order non-linear solid-state cleaner for temporal femtosecond pulses. This filter is based on cross-polarized wave generation in non-linear crystals. The contrast reaches 10^{-10} for millijoule input pulse. The method is reliable enough to solve the contrast issue for Petawatt class lasers.

1. INTRODUCTION

One of the main bottlenecks for future Petawatt class ultra-short lasers and applications in high-field physics is the temporal contrast of the pulses. In classical femtosecond laser chains, a nanosecond pedestal of amplified spontaneous emission (ASE) and some parasitic pulses are generated at the same time as the femtosecond pulse. The intensity ratio between ASE or parasite pulses and the main femtosecond pulse is called incoherent pulse contrast. One way to improve temporal contrast by several orders of magnitude is to clean the pulse after the pre-amplification, with a non linear filtering device [1, 2], before further amplification, in a double CPA setup [3].

We present a new technique for non linear filtering, based on cross-polarized wave (XPW) generation in non linear crystals [4].

2. NON LINEAR FILTER BASED ON CROSS-POLARIZED WAVE GENERATION

XPW generation is a four-wave mixing process governed by the anisotropy of the real part of the crystal third-order nonlinearity tensor. XPW generated signal presents a cubic dependence on intensity with the input pulse and consequently has significant interest for contrast applications. The process presents also perfect group velocity matching between the two orthogonally polarized waves. A 2 mm-long BaF_2 crystal is used. This solid-state method is not wavelength dependant (visible and near-infrared) and is adaptable to various energy levels by geometrical tuning, since the efficiency of the XPW generation is determined by the peak power intensity of the laser. The filter was tested on three different femtosecond laser systems (200 μJ at 620 nm, 1,2 mJ at 800 nm, 1 mJ at 1064 nm) with equal efficiency. The energy converted from the input pulse to the XPW signal is about 15%.

Characterizations are presented for the 42 fs, 1.2 mJ, 800 nm laser [5]. The cleaned pulse has an energy of more than 100 μJ.

The significant contrast enhancement is illustrated by Fig. 1, where temporal profiles of the pulse before and after filtering are measured using a high-dynamic range third order cross-correlator. The cleaning efficiency is only limited by the extinction ratio of the polarizing elements (5.10^{-5}). Consequently, the ASE pedestal is reduced to 10^{-10}.

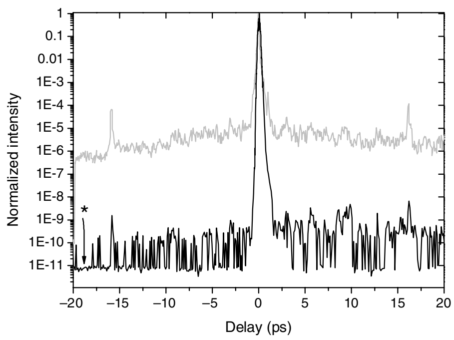

Figure 1. Third order correlation curves before (grey curve) and after (black curve) filtering. The correlator noise is 10-11.

No spectral modification, no phase distortion were observed. The device also acts as an efficient spatial filter.

3. CONCLUSION

All these performances demonstrate that this technique is relevant and reliable enough to obtain high contrast Petawatt peak power pulses.

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