Automatic optimization of the temporal duration of a 21 fs, 4 mJ CPA laser system with high B-integral

L. Canova*, X. Chen, B. Mercier, O. Albert, R. Lopez Martens
Laboratoire d'Optique Appliquée, Ensta-Paritech – Ecole Polytechnique – Centre National de la Recherche Scientifique, 91761 Palaiseau Cedex, France
N. Forget and T. Oksenhendler
Fastlite, Centre scientifique d'Orsay - Bât.503, Plateau du Moulon - BP 45, 91401 Orsay France
**lorenzo.canova@ensta.fr*

Introduction and results

Long-term stabilization of carrier-envelope phase (CEP) at the multi-mJ level imposes new constraints on the design of few-cycle laser systems based on chirped pulse amplification [1]. In particular, dispersion fluctuations must be avoided as much as possible. One option is to choose small pulse stretching factors and compress with compact components with limited amount of dispersion. The counter part of this choice is the resulting high B-integral induced by the high intensity level in the amplification stages and in the compression stage. Therefore the spectral phase of the amplified pulse becomes a function of the output pulse energy, which calls for an adaptive spectral phase compensator. In this presentation we demonstrate how an acousto-optic dispersive filter (AOPDF) [2] can be used not only to pre-compensate spectral narrowing but also to measure (DazScope software from Fastlite) the spectral phase induced by SPM and then compensate for the measured phase distortion.

The laser source is a commercial 1 kHz, Femtopower Compact Pro CEP front-end system from Femtolasers GmbH followed by a home made three-pass amplifier and a hybrid compressor (prism + chirped mirrors). The AOPDF pulse shaper is situated inside the Femtopower amplifier (between passes 4 and 5). For the pulse measurement, a small fraction of the output energy (<1 μJ) is selected with a beam splitter and focused with a f=500 mm focal length lens into a 50 μm type-I BBO crystal. The generated SHG is separated from the fundamental and collected with a commercial spectrometer (AvaSpec-3648 from Avantes). The optimized pulse duration measured with a home-made SPIDER is 21 fs. The residual phase measured after optimization is less then 0.5 rad which corresponds to the typical measurement precision of SPIDER or FROG devices. In the measurement mode, the AOPDF is set to add a sequence of pure quadratic phase (pure chirp) to the pulse [3] and the input spectral phase is extracted from the successive SHG spectra. This Local Spectral Compression (LSC) algorithm is commercialized under the name DazScope^{TM}. Figure 2a, 2b, 2c and 2d show the SHG spectra versus chirp traces together with the extracted local chirp function for four states: initial state at low energy (2a), coarsely optimized pulse at low energy (2b), pulse at high energy with the same phase settings (2c), finely optimized pulse at high energy (2d). Figure 2c clearly indicates that the change in energy dramatically changes the spectral phase of the amplified pulses. Simulations of the amplification in the laser chain with the software MIRO corroborate this result.

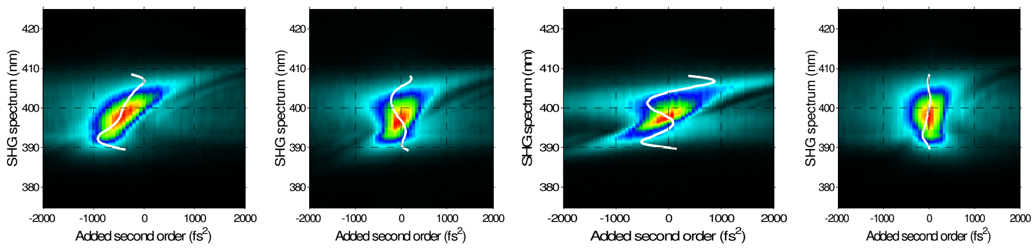

Fig.2. Traces corresponding to the following states: (a) initial state, low energy seed, (b) after optimization of second, third and fourth orders; (c) high energy seed (d) high energy seed after optimization of the polynomial phase and pre-compensation of self phase modulation in the CPA laser (d).

References

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