High-contrast 10-fs OPCPA-based Front-End for the Apollon-10PW laser (Orale)

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Abstract: We present a high-contrast 10-fs Front-End for Ti:sapphire PW-lasers within the Apollon-10PW project. This injector uses OPCPA pumped at 100 Hz by Yb-based CPA chain. Combination of OPCPA and XPW permits a $>10^{12}$ contrast ratio.
OCIS codes: (140.7090) Ultrafast lasers; (190.7110) Ultrafast nonlinear optics, (190.4410) Nonlinear optics, parametric processes

1. The Apollon 10 PW laser

In the framework of the Apollon 10-PW French laser program, we develop a front-end delivering ultrashort pulses around 800 nm with a very-high temporal contrast to be used as seeder for high energy Ti:Sapphire amplifiers. Indeed, in the development of PW laser chains, the contrast is one of the key issues. For high-field physics applications, laser pulses are only useful with nice contrast *id est* with a ns-ps piedestal under 10^{12} W/cm^2. That leads, for 10 PW systems delivering 10^{23} W/cm^2, a contrast of at least of 10^{11}. Moreover, to reach the 10 PW the gain narrowing in Ti:Sapphire systems is also an issue and the use of spectral filtering together with a 10 fs input pulse is the solution to reach the peak power with manageable energy (150 J). Finally, the repetition rate of this injector (typically 100 Hz) is also important to actively control the stability of the complete laser chain even if it operates below, *e.g.* 0.1 Hz.

In this paper, we are presenting the status of the Apollon 10-PW research status by exposing the results on this particular Front-End. The system is described and the results are analyzed in the context of PW laser facilities.

2. Architecture of the high-contrast short-pulse Front-End

The Front-End of the Apollon system is based on optically-synchronous OPCPA. An ultrashort-pulsed Ti:Sa oscillator (7 fs) produces a very broad spectrum that is split into two outputs : the part centered at 800 nm is sent to a commercial Ti:Sa multipass amplifier that generates 1 mJ, 25 fs pulse at 1 kHz, and the part >1020 nm is used to inject a Yb-based system that will be used to pump the OPCPA (fig. 1).

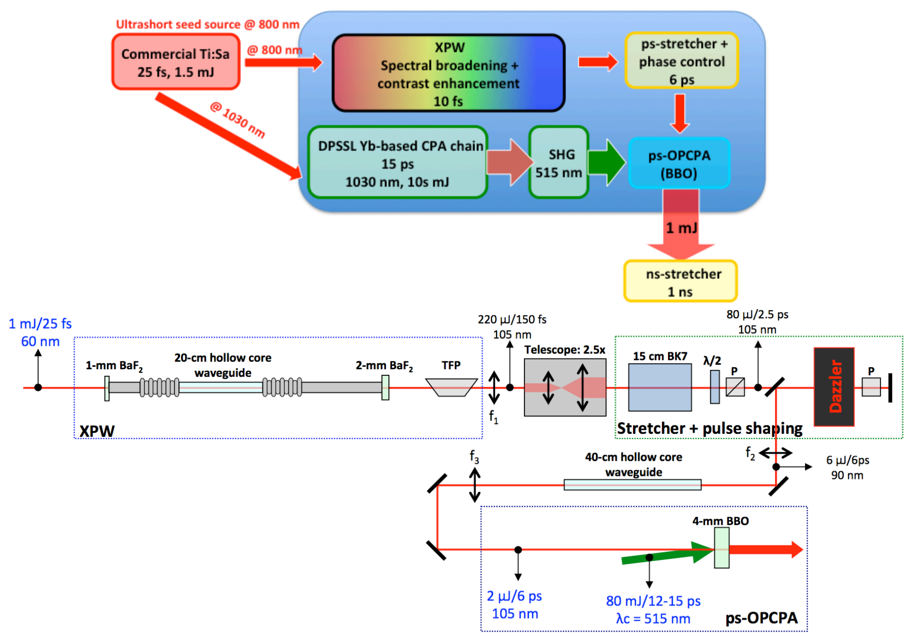

Figure 1 : Apollon Front-End simplified schematic (top); and close up on the OPCPA signal formatting (buttom).

The generation of the OPCPA signal is based on a specific XPW configuration providing the following characteristics: 10-fs-pulse bandwidth and contrast better than 10^{10} [1,2]. The signal is then stretched to 6 ps and goes to a spectral phase controller (double-pass Dazzler) that will compensate the spectral phase distortion of the entire chain. The 1030 nm part of the oscillator spectrum is amplified in an YDFA (from Keopsys), stretched to 1.5 ns, amplified to 2 mJ in a Yb:KYW regenerative amplifier (from Amplitude Systemes), amplified in a Yb:YAG thin-disk regenerative amplifier to 150 mJ [3] and compressed down to 15 ps. The 1030 nm pulses are then frequency-double in a type-I LBO crystal producing approximately 12 ps pulses at 515 nm with energy in the 10s of mJ.

3. OPCPA

The approach for setting up the OPCPA stage is mainly experimental. The beam size of the pump is varied with the use of several lens combinations for the telescope and the target is to obtain a stage which when pumped with 10 mJ, will deliver a stable pre-amplified seed, with an energy around 1 mJ and bandwidth for 10-fs pulses. This best result is obtained for a pump diameter of 3 mm. The behavior of this OPCPA stage is investigated with respect to the pump beam energy, which leads to intensities ranging from 3.8 – 15.1 GW/cm^2. Regarding the input signal, it has an almost perfect Gaussian form with a 1/e^2 diameter of 5 mm. The choice of using a larger seed beam is a precaution based on a method to suppress superfluorescence implemented in [4], where the larger signal beam allows the selection of the part of the signal beam with the highest signal to noise ratio and cleanest wavefront. The results are summarized in Figure 2. Under perfect phase matching conditions, the amplified seed pulse is broadened and approaches a square-shaped spectrum at 10 mJ. The optimal efficiency –chosen in order to avoid the excessive backconversion and the superfluorescence- is 9 %, which leads to a signal energy of 0.9 mJ.

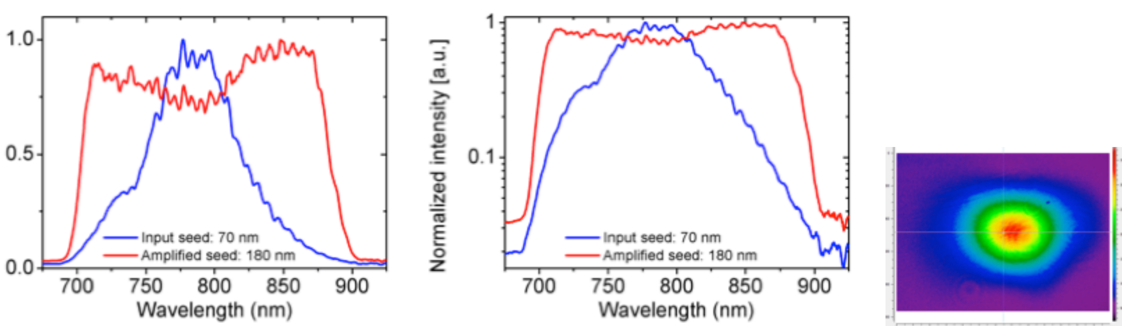

figure 2 : spectrum (linear and log scale) and beam profile of the OPCPA.

In order to evaluate the compressibility of the ultra-broadband generated pulses. The pulses are recompressed using a grating compressor set in an Offner configuration (close to the zero dispersion setting). The pulses are analyzed and optimized with a Wizzler/Dazzler loop. This allowed the validation of the compressibility of the amplified pulses in sub-10 fs level with a measurement of 9.5 fs to be compared to 8.1 fs FT limit (fig. 3). The residual phase is restricted to an acceptable level resulting only in minimal issues on the coherent contrast.

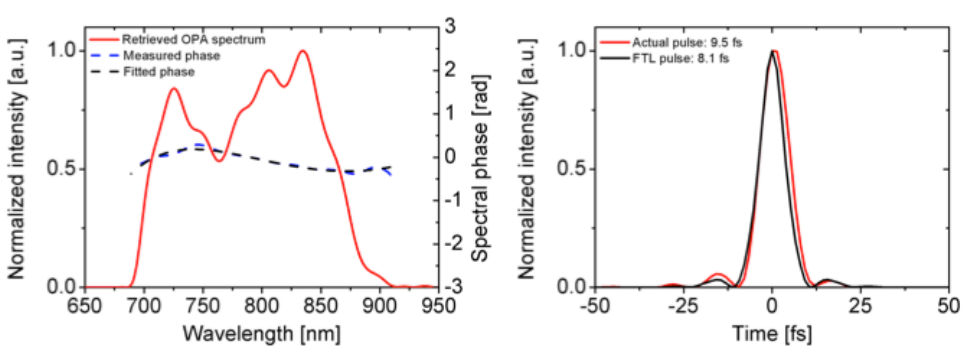

Figure 3 : characterization of the compressed pulses.

After compression a contrast measurement is performed using a high-dynamic third order autocorrelator. A contrast ratio of 10^{12} is measured, and taking into account the limit in bandwidth of our autocerrelator, we can even estimate confidently a real contraste measurement of 10^{13}.

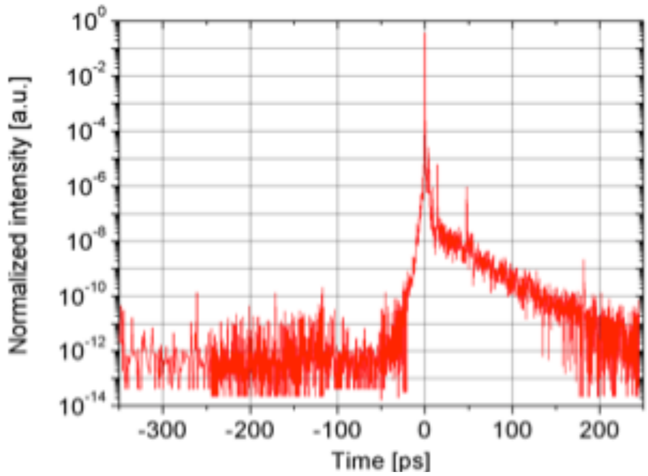

Figure 4 : Contrast measurement.

3. Conclusion

We have presented, within the Apollon 10PW project, a high-contrast Front-End for Ti:sapphire high-energy amplifiers. A 10^{13} contrast is obtained combining the XPW and OPCPA techniques. This injector demonstrated several advantages in the framework of multi-PW laser: First ultra-braodband amplification is demonstrated with a quasi-square shape compressible down to 9.5 fs. Moreover, the OPCPA efficiency is handled such as the beam profile stay of very good quality, and the contrast preserved against superfluorescence. Finally, the pump of the OPCPA is based on DPSSL Yb-based technology[3,5], which allows the 100 Hz operation. This repetition rate will be used advantageously to drive the servo-loops of the system between high energy shoots.

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