Prepulse removal at the PHELIX short-pulse facility

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Introduction

The temporal contrast of short-pulse laser systems is defined as the ratio of the peak-intensity and the intensity at a given time before the peak. With intensities exceeding 10^{20} W/cm^2 this parameter has become very critical for high-power laser systems like PHELIX [1]. Since the minimum for plasma generation is between 10^9 and 10^{12} W/cm^2 depending on the target properties a contrast of at least 9 orders of magnitude is mandatory to guarantee an undisturbed target at the arrival of the main pulse. Particularly for several lately proposed experiments such as probing new mechnisms for laser ion acceleration like BOA or RPA with thin targets in the sub µm range as well as experiments for surface high-harmonic generation which calls for a steep density gradient at the target surface high temporal-contrast is required.

Temporal-contrast at CPA systems

Several effects contribute to the imperfect temporal-contrast in a chirped-pulse amplification (CPA) system:

- Noise in the amplifiers due to amplified spontaneous emission (ASE) results in a pedestal that is typically 6 to 7 orders below the maximum and ranges over a few ns.
- Multiple reflections between parallel optical surfaces may generate postpulses which can be shifted to the front of the peak due to nonlinear effects in a CPA system. Furthermore compressed prepulses can arise due to the finite extinciton ratio of optical switches.
- Clipping of the spectrum in the stretcher or compressor as well as spectral phase noise due to imperfect surfaces of the gratings induce a slowly rising slope ranging over some tens of ps.

All these effects are independent from each other and therefore have to be treated separately.
The ASE-pedestal can be decreased by increasing the seeding energy of the amplifiers. For this purpose an ultrafast optical parametric amplifier (uOPA) has been developed and successfully implemented at PHELIX. This new module enables an ASE-contrast better than 10 orders of magnitude. For more detailed information about the uOPA see Ref. [2,3].

Prepulses at PHELIX

Parallel surfaces can generate postpulses which may become prepulses due to nonlinear effects. Therefore the temporal separation between the prepulse and the peak is defined by the optical path which enables to identify the element that is responsible for the prepulse by its thickness. By switching to wedged optical elements the particular prepulse can be removed.

Figure 1 shows the contrast improvement in the course of 2012. The measurement was performed with a scanning third-order cross correlator with high dynamic range (Sequoia, Amplitude Technology).

The main prepulse (no. 1) was attributed to a Pockels cell (PC) with parallel surfaces in a regenerative amplifier of the frontend. By switching to a PC with tilted surfaces the prepulse could be removed as shown in the measurement from August 2012. The prepulse 2 could also be eliminated by changing a PC (see measurement from January 2013). The remaining pulses (2, 3 and 4) should be removed in the beginning of 2013. The prepulse 3 is correlated with a one inch optical element. Furthermore there are four more PCs in the PHELIX frontend which could be responsible for the pulses 4 and 5 and which will be investigated in 2013.

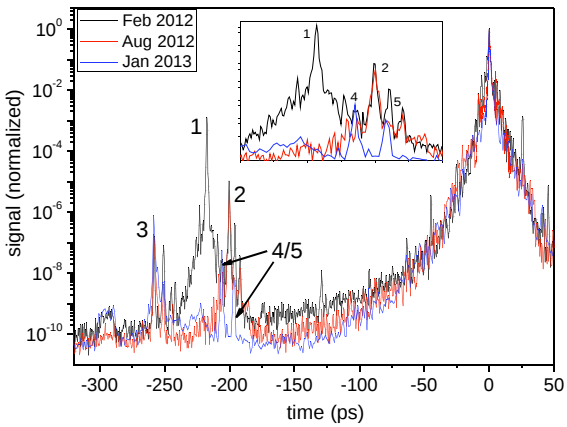

Figure 1: Contrast improvement at PHELIX in 2012

Conclusion and Outlook

The main prepulses of the PHELIX short-pulse beam were successfully removed. The remaining prepulses have been identified and will be investigated in 2013. Together with the new uOPA this enables a contrast level exceeding 10 orders of magnitude.

Reference

[1] V. Bagnoud et al., "Commissioning and early experiments of the PHELIX facility" Appl. Phys. B **100** 137–150 (2010).
[2] F. Wagner et al., "A compact temporal contrast-boosting module for petawatt-class lasers" submitted to Optics Express.
[3] C. P. João, F. Wagner et al., are preparing a manuscript to be called "Diode-pumped Yb:KYW regenerative amplifier for optical parametric amplifier pumping"