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Deliverable 33.4

Final report on OPA system with 12 cm aperture: Improved repetition rate of the 12 cm aperture beam line

Lead Beneficiary: GSI

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Deliverable Nature	
R = Report, P = Prototype, D = Demonstrator, O = Other	R
Dissemination Level	
PU = Public PP = Restricted to other programme participants (incl. the Commission Services) RE = Restricted to a group specified by the consortium (incl. the Commission Services) CO = Confidential, only for members of the consortium (incl. the Commission Services)	PU

A. Abstract / Executive Summary

The continuing development and application results of the high-temporal contrast, ultrafast OPA-based front-end (uOPA) are described. Additionally, we report on the development and test of all critical components of an improved preamplifier system with increased repetition rate at the 7 cm aperture level. This can be seen as the test bed for a possible future upgrade of the 12 cm system which has not been pursued up to now due to resource shortage.

B. Deliverable Report

1 Introduction

This report follows up on the document filed as Deliverable 33.2 and describes the recent progress in the further development of the uOPA system as a means to pushing the temporal contrast of the compressed PHELIX pulse to the 10^{-12} level. The reproducible delivery of such a high contrast level is an important prerequisite for the investigation of novel particle acceleration mechanisms which rely on thin (few-100nm) targets. Such targets could not be used with the typical contrast level of 10^{-6} available without the uOPA system because the light intensity before the actual laser pulse would be high enough to already destroy the target.

2 Objectives

To increase the attractiveness and versatility of the PHELIX laser system for experiments, a high and furthermore tunable contrast level is a very desirable feature. Even more important is the proof that this contrast, usually measured at the few-mJ front-end level can also be delivered onto the target after the amplification and re-compression to the 250 J / 500 fs regime.

The second objective which greatly improves the range of experiments which can be carried out (e.g. x-ray laser development requiring a high number of shots [1]) is the increase of the laser system's shot repetition rate. At the PHELIX main amplifier level, this rate is currently limited to one shot per 90 min due to the cool-down time necessary to avoid thermally induced wave front deformations. In order to achieve this objective, a new pre-amplifier scheme for the few-J, 7 cm aperture level has been developed.

3 Work performed / results / description

As has been described in the previous report, the uOPA system has been implemented in the PHELIX front-end already in 2013 and has since then been available as an option for user experiments requiring high contrast [2]. To verify that this contrast is maintained after the amplification in the PHELIX pre- and main amplifiers and the re-compression in the PW compressor, a series of shots has been carried out which allowed for the characterization of the pre-plasma on the target surface before the arrival of the actual laser pulse. This was achieved by using a leakage of the compressed pulse through a turning mirror shortly before the focussing parabola to generate a probe pulse passing along the target surface. Since this probe pulse was frequency doubled and could be precisely timed with respect to the main pulse with a calibrated delay stage (see figure 1), it could be used to image the shadow caused by the (pre-)plasma at the target surface with a temporal resolution of about 30 ps.

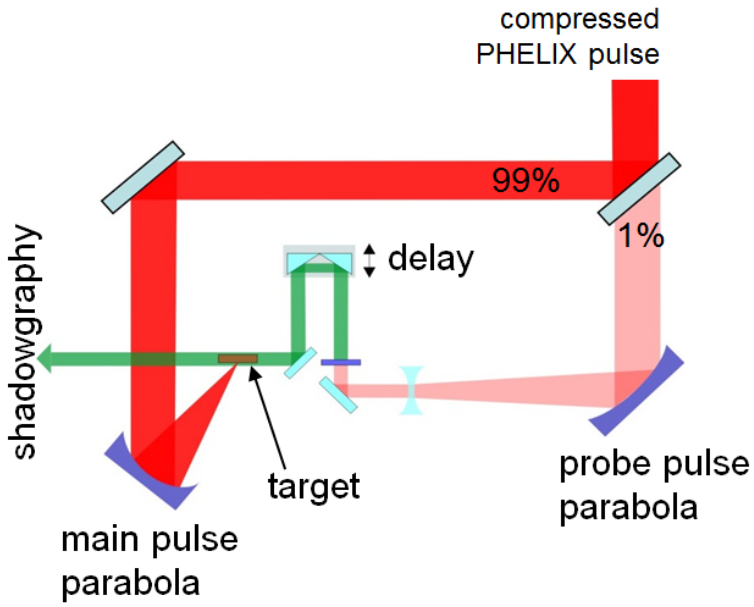

Fig. 1: Setup to generate a precisely timed probe pulse to image the plasma at the target surface.

The shot series has shown that, in accordance with the expectation, the size or indeed the appearance of the pre-plasma was strongly reduced with the improvement of the contrast level (see figure 2). The different contrast levels (high/intermediate/low) were achieved by changing the gain level in the uOPA system.

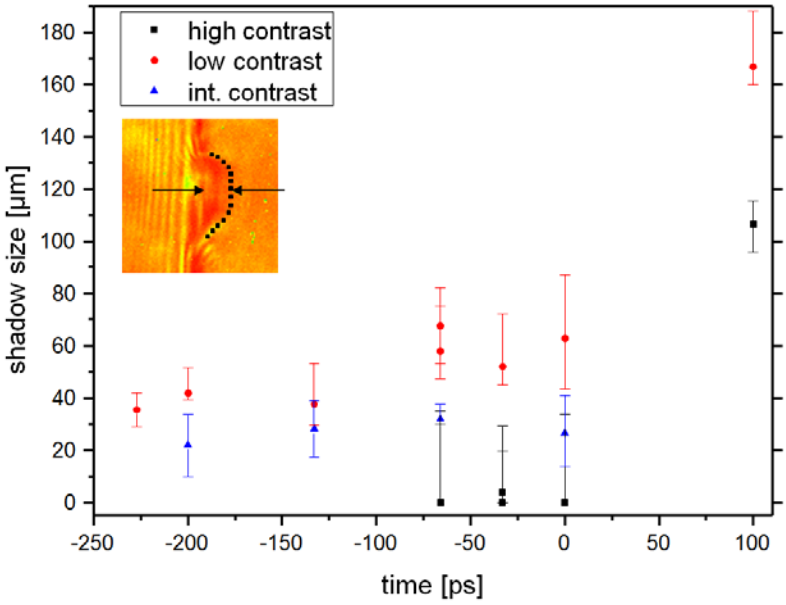

Fig. 2: Results of the measurements of the pre-plasma shadow at different times before the main pulse (at 0 ps) for different contrast levels

Concerning the second objective, we report here on the development of an upgrade of the current PHELIX preamplifier system to meet the need for higher repetition rates which currently is limited to one shot per 2 min at the few-J level.

The original plan was to develop an amplifier head of an intermediate size between the PHELIX 45 mm rod preamplifier and the 315 mm disc main amplifiers to increase the repetition rate of the 12 cm sub-aperture (100 TW) installation at PHELIX used for ion acceleration experiments [3]. However, due to the problem of the birefringence effects arising from thermal gradients in glass rods pumped beyond the limit of a quasi-homogeneous temperature distribution, this plan was changed in favor of high-repetition rate 19 mm and 45 mm rod amplifier designs which allow for a continuous sequence of one shot every 20 s at the few-J level and which might also be extended to larger beam apertures.

This layout (see fig. 3) has been demonstrated in a test setup which uses a conventional Faraday rotator to pass the thermally loaded Nd:glass rod in a double-pass configuration

which, by rotating the polarization between the two passes, allows for a highly effective compensation of the birefringence effect (see fig. 4).

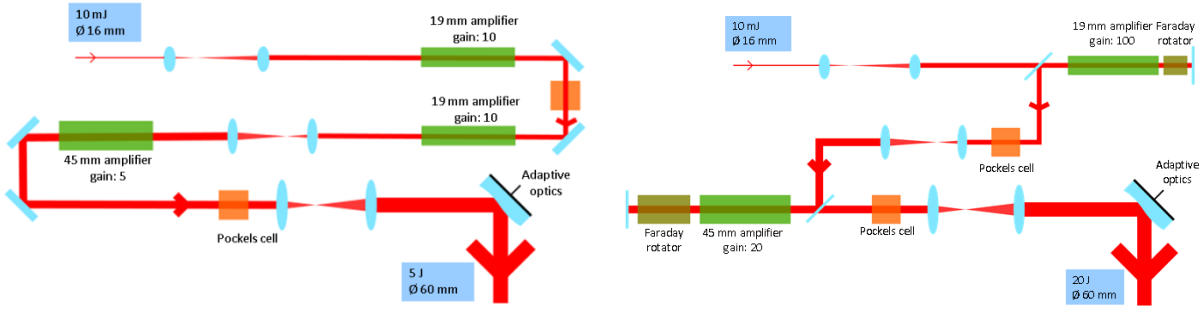

Fig. 3: Schematic layout of the PHELIX preamplifier current state (left) and upgrade (right)

In addition to this design change, the current flash lamp power supply of the 45 mm amplifier head, based on a single 15 kV capacitor as well as an Ignitron switch to pump the twelve flash lamps which are connected in two series, a new commercial power supply was acquired. Now, the flash lamps are driven separately with independent 2 kV channels of the supply unit which improves maintainability as well as safety due to the modern, semiconductor based high voltage switches.

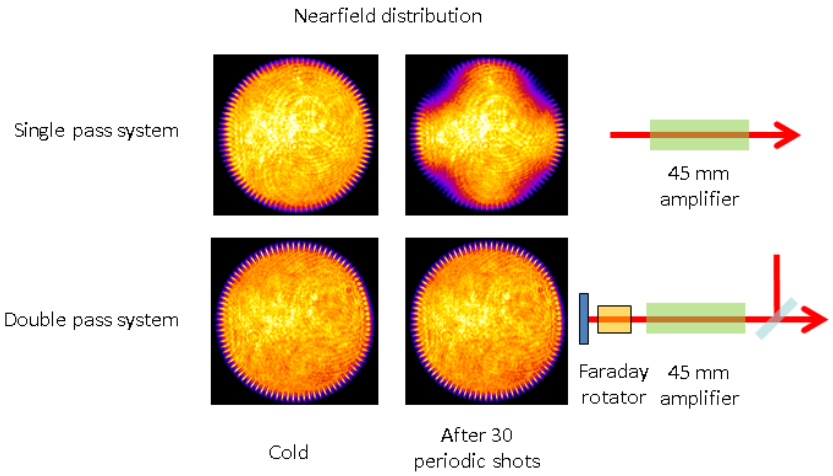

Fig. 4: Effect of the birefringence compensation by double-passing the thermally loaded glass rod

4 Conclusions

The uOPA system at PHELIX as become a serviceable tool to meet the users' requirements for high and furthermore tunable temporal pulse contrast. In addition, the proof of principle and preparation of the upgrade of the PHELIX preamplifier system allows to use this contrast at the few-J, 7 cm aperture level which is an important step towards the increasing the full-system repetition rate.

5 References/Publications

[1] C. P. Joao et al, *A 10-mJ-level compact CPA system based on Yb :KGW for ultrafast optical parametric amplifier pumping,* Appl. Phys. B, DOI 10.1007/s00340-015-6003-6 (open access: will be granted 12 months after publication)

[2] Report on INREX objective 8 within this initiative

Citation of publication outside Laserlab program:

[3] S. Busold et al., *Shaping laser accelerated ions for future applications – The LIGHT collaboration,* Nuclear Instruments and Methods A, 740, 11.03.2014, pp 94-98, http://dx.doi.org/10.1016/j.nima.2013.10.025 (open access: yes)

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