New front-end for the Astra Gemini Project

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Introduction

The concepts behind a new front-end for the Astra laser were described in detail in last year's CLF Annual Report [1]. The primary aims of the development implemented this year were as follows:

- To enhance the contrast of Astra by installing a pre-amplifier providing high-contrast pulses.
- To implement a unique double-pass stretcher scheme to provide chirped pulses of different durations (on-demand). The 10Hz beam lines in experiment areas 1 and 2 with their existing grating compressors require a pulse duration of 0.5 ns. The Gemini upgrade with its additional, 4th titanium sapphire (Ti:Sa) amplification stage requires a pulse duration of 1 ns to avoid problems associated with high B-integral.
- The provision of kHz pulses for experimenters in Astra's low energy experiment area.

The work carried out this year is shown schematically in Figure 1. A commercial oscillator and kHz Ti:Sa pre-amplifier (Femtopower Compact Pro, Femtolasers) was installed to provide high-contrast pulses for further amplification in the Astra laser. kHz pulses can also be directed for experiments in Astra's low energy experiment area TA1. A double-pass stretcher scheme was required to provide pulses chirped (stretched) either to 0.5 ns for use in the 10Hz beam lines with their existing grating compressors or with additional stretch to 1 ns for amplification in the 4th amplifiers as part of the Astra Gemini project. A new multi-pass first amplifier was also constructed to amplify pulses prior to Astra's existing 2nd and 3rd amplifiers.

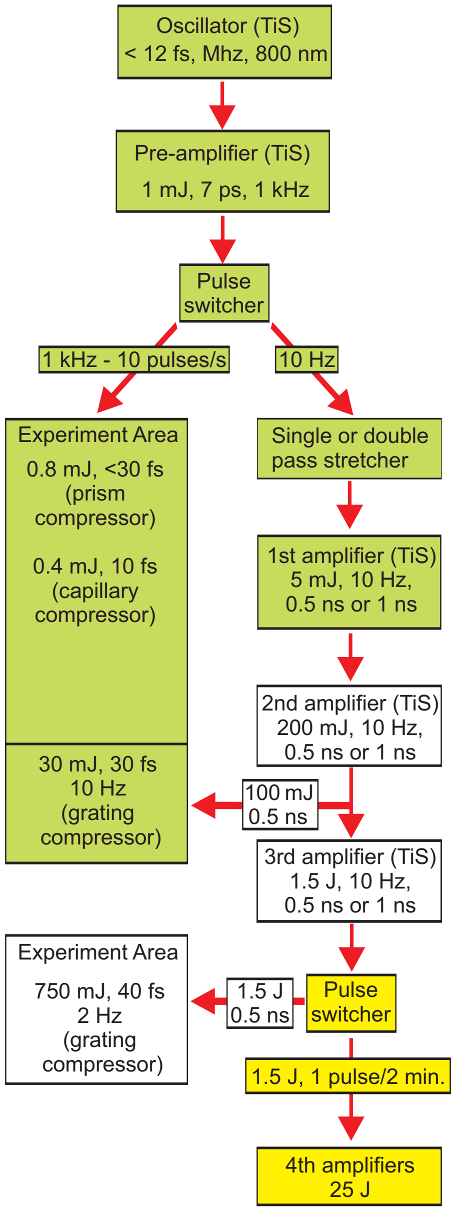

Figure 1. Schematic layout of Astra. Newly completed front-end sections are shaded green. Astra Gemini sections under development are shaded yellow. Unchanged sections are shaded white.

Contrast Measurements

Figure 2 shows a contrast measurement of the kHz pulses after compression to 30 fs in a Femtolasers prism compressor. This trace was obtained with a commercial third-order correlator (Sequoia, Amplitude Technologies). The pre-pulse background was measured to be at the $5*10^{-10}$ level.

Pulse switching using an ultrafast Pockels cell

A pulse picker is required to select pulses at a repetition rate of 10 Hz for amplification in Astra. A suitably fast Pockels cell was chosen to suppress pre-pulses some 200 ps from the main pulse as observed in the third-order scan above. However, the speed at which a Pockels cell opens is compromised by the size of the KDP crystal: the larger the crystal - the slower the cell. To maximise the speed of the Pockels cell, whilst also minimising contributions to B-integral, a special ultrafast Pockels cell was commissioned from Leysop with an aperture of 8 mm. A photograph of this device is shown in Figure 3. The output beam diameter of the Compact Pro was set at 5 mm ($1/e^2$).

The performance of the ultrafast Pockels cell is shown in figure 4. The rise-time in Pockels cell transmission is ~190 ps and will adequately suppress pulses 200 ps (and more) ahead of the main pulse. The Pockels cell open time can be reduced to ~ 400 ps.

The double-pass stretcher scheme

The double-pass stretcher scheme was implemented as described in detail in last year's CLF Annual Report [1]. The stretcher now forms part of a stable cavity into which the laser pulse is injected by means of a Pockels cell, shown in Figure 5. The same Pockels cell is used to switch the pulse

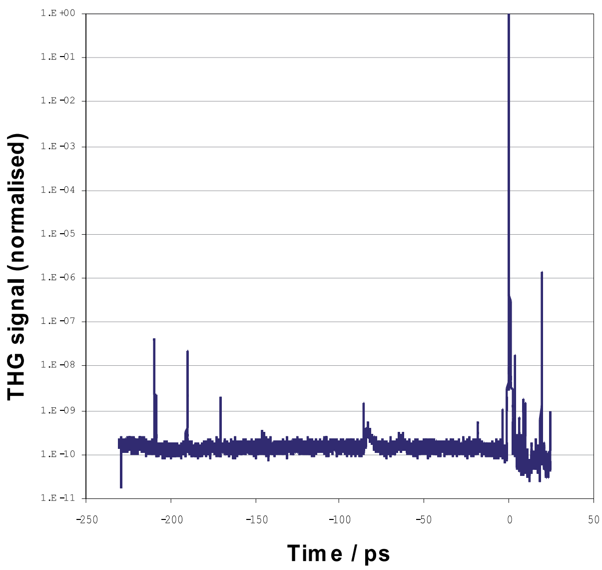

Figure 2. Contrast measurement for the 1 kHz output pulses.

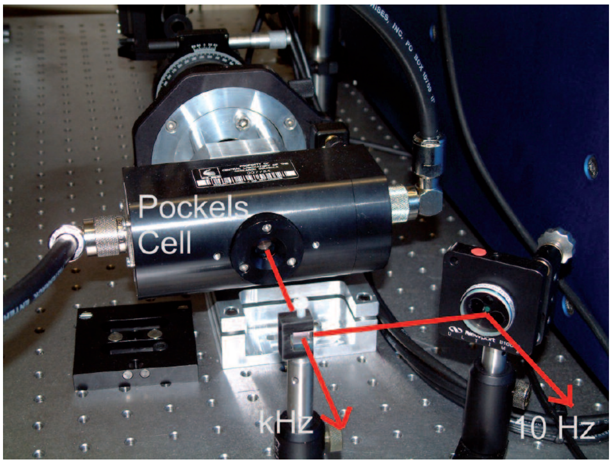

Figure 3. Fast Pockels cell.

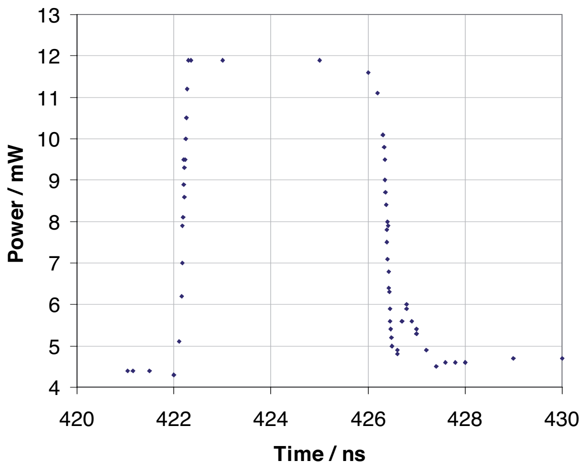

Figure 4. Rise time measurement for the fast Pockels cell.

out of the cavity after a certain number of round trips. If the pulse remains inside the cavity for one pass through the stretcher (one round trip), it is stretched to a duration of 0.5 ns, if it passes the stretcher twice (two round trips), its duration will be 1 ns. The round trip time for this cavity is 40 ns.

The practical issues connected to this are timing and pulse energy. If double stretch is selected, the pulse will emerge 40 ns later from the stretcher cavity and with a considerably lower energy than for single stretch. Hence the timing sequence for all following pump lasers and Pockels cells is triggered by a “master pulse” which is tied to the pulse that controls the switching-out of the laser pulse from the stretcher cavity. This also ensures that the prepulses that results from optical leakage at the stretcher Pockels cell experience no gain in the following amplifier stages and are properly suppressed by the Pockels cell situated before the second amplifier stage. To compensate for the difference in energy between singly and doubly stretched pulses, the pump energy for the first amplifier (see below) is adjusted by changing the flashlamp timing. The timing changes necessary for switching from single stretch to double stretch and vice versa can be effected electronically on a shot-to-shot basis.

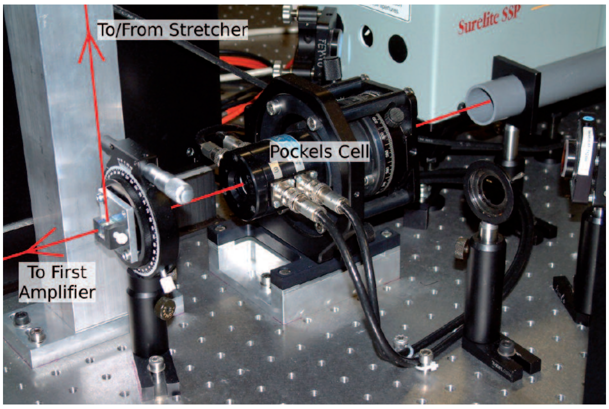

Figure 5. Photograph of part of the double-pass stretcher scheme showing the Pockels cell that directs the pulses into the stretcher.

It could be demonstrated that the multipass scheme works in practice; however, the single pass mode is used routinely for regular Astra operations when delivering 10Hz pulses to target areas one and two. The functioning of double pass stretching was also demonstrated, and in a preliminary experiment it was shown that doubly stretched pulses can be re-compressed to the same pulse duration as singly stretched pulses. An in-depth characterisation of the double stretch operation mode however was prevented by a malfunction of the Pockels cell driver which could not be repaired during ongoing user experiments.

The First Amplifier

The purpose of the new first amplifier is to boost the stretched pulses to the few-mJ level so that they are suitable for amplification in the existing further amplifier stages of the Astra system. The amplifier was mostly implemented in the way described in last year’s CLF Annual Report [1]. The only changes made were a more compact layout, a bigger pump spot diameter and the addition of fixed apertures.

The new layout is shown in Figure 6. The turning mirrors were moved as close to the crystal as possible in order to decrease the effect of beam divergence and keep the beam diameter as small as possible for all of the three passes. Fixed apertures with a 3mm diameter were installed close to the turning mirrors on either end of the amplifier. These act as alignment aids and provide some suppression of ASE.

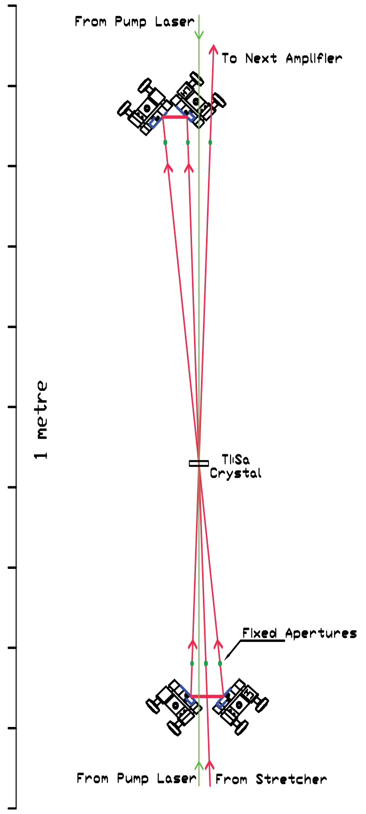

Figure 6. Layout of first amplifier.

When characterising the pump beam diameter in the plane of the Ti:Sa amplifier crystal, it was found that the generation of a clean top-hat profile with steep edges was not possible and that the central flat plateau of the intensity distribution extended only over about 50% of the total diameter. Therefore the originally projected pump spot diameter was increased by changing the image relay setup in order to achieve a homogeneously pumped region of 1.2 mm in diameter. An image of the pump spot profile that was finally chosen is shown in Figure 7. It was recorded with a CCD camera (Marlin F-033B, Allied Vision Technologies).

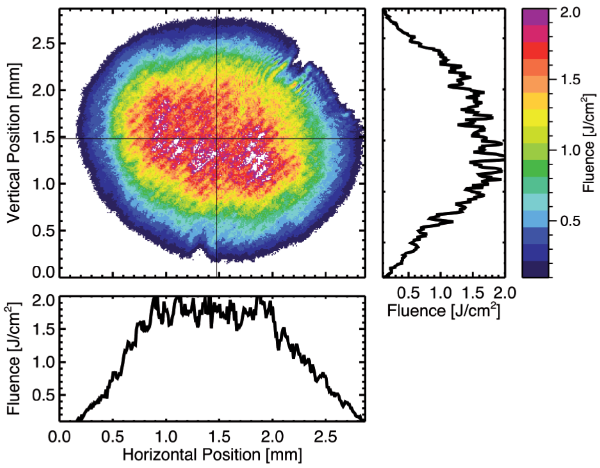

Figure 7. Beam profile of one of the pump beams in the Ti:Sa crystal plane of the 3 pass amplifier. The pulse energy in this arm was 50 mJ.

The output energy from the new amplifier as a function of pump energy is shown in Figure 8. The measurements were carried out at an input energy of 110 μJ, typical for a single pass stretch. To achieve the required output energy of 5 mJ, the amplifier needed to be pumped at a total energy of 53 mJ.

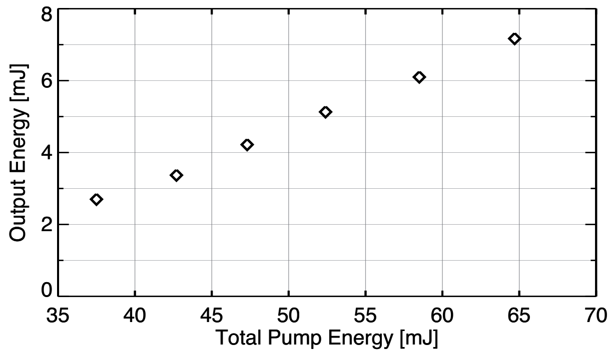

Figure 8. Output energy of the 3 pass amplifier as a function of pump energy. The input energy was 0.11 mJ.

Although an in-depth characterisation was not possible again, it could be shown that, by increasing the pump energy, a sufficiently high output energy could also be reached for doubly stretched pulses.

References

1. A. J. Langley, K. Ertel, E. J. Divall, J. M. Smith, C. J. Hooker and J. L. Collier, *CLF Annual Report*, RAL-TR-2005-025, 214, (2005)