

Nanosecond pulse square pulse distortion (SPD) correction (for large-scale OPCPA trials)

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Introduction

Previous trials of large scale OPCPA experiments using Vulcan produced encouraging results but were hampered in producing the required amplified spectral profile – spectral narrowing of a potential bandwidth of 40 nm was shown to result from the far from ideal temporal shape¹⁾ of the beam-7 pump pulse on Vulcan. This pump pulse is generated by a long (~20ns) pulsed (SLM) laser and a nominal square pulse of tens of microjoules and nanosecond duration is ‘switched out’ for further amplification by the Vulcan long pulse switchout, VLPS. In this report we tried to address two aspects of this problem – a ‘double pulse transmission’ on the VLPS and more importantly, gain saturation in the Vulcan disc amplifiers that increased the leading edge intensity relative to the trailing edge.

Improved impedance matching

This first problem was addressed using appropriate 50 ohm matched URM 67 cables with HN connectors between the VPLS driver unit and its pockel cells - these had been changed on previous experiments in an attempt to try and shape the pulse profile.

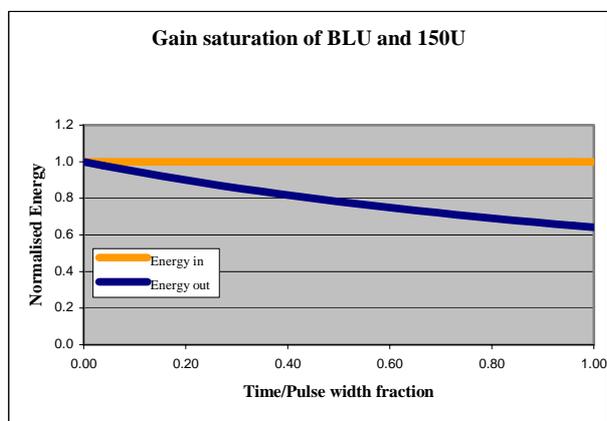


Figure 1(a). Modeling of SPD distortion due to gain saturation.

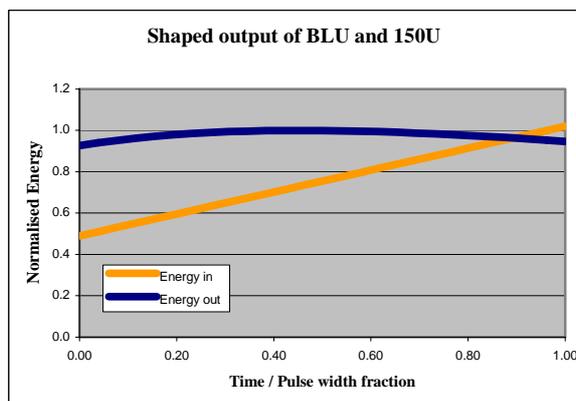


Figure 1(b). Near 100% SPD correction using a linear sloped input.

Modeling

Vulcan produces ‘corner’ energies after the rod amplifiers which do not show any saturation behaviour. We therefore modeled the saturation process in the disc amplifiers using some simple time slice modeling in Excel with the standard time independent Fanz-Nodvik²⁾ equation :-

$$E_{out} = E_{sat} \ln \left\{ 1 + \left[\exp \left(\frac{E_{out}}{E_{sat}} \right) - 1 \right] \exp(g_0 l) \right\}$$

where E_{sat} is that saturation fluence, E_{in} energy in and g_0 the small signal gain.

Using established saturation fluences of 4Jcm^{-2} for Nd doped phosphate glass and an effective diameter of 135 mm resulting in a saturation energy of 572J, time dependent ‘corner’ gains for the double pass BLU and the final 150 mm amplifier of beam-7 predicted square pulse distortion (SPD). Figure 1(a) shows the outputs achieved for a square input pulse – they were similar to those observed in the previous experiments. To try and correct for this distortion, the input pulse was then changed to a trial pulse with a linear slope. - Figure 1(b) shows that this would result in a substantial correction to the output profile, remaining distortions being only ~10%.

Fast Pockel cell and Driver

Figure 2 shows a typical temporal transmission profile of a fast pockel cell located between crossed polarisers – the output profile has the usual voltage dependent transmission $T = \sin^2(\pi V / 2)$ behaviour, V being the half-wave voltage, required to produce a half-wave rotation equivalent to a π phase-shift. This half-wave voltage is typically ~6KV for a dual cell pockel cell. It shows that a ‘linear ramp’ in the optical output of a fast pockel cell could be achieved at operation of 50% of half-wave voltage with only a factor of 0.5 in loss in throughput. The SLM lasers produce enough output to be able to cope with this attenuation. The requirement for SPD correction on beam-7 would need an optical ‘ramp’ from 0 to half-wave voltage during 1 ns matching that required as an input in Figure 1(b).

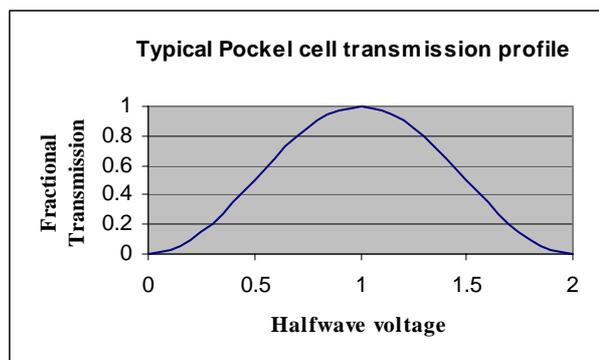


Figure 2. Transmission profile of a pockel cell system.

Fast shaping pockel cell installation and characterisation

An appropriate Kentech fast 6.4 KV driver and a Leysop 8 mm diameter aperture pockel cell system was incorporated to provide the necessary slope and synchronised to the VLPS on the outer track immediately after the SLM lasers. The arrangement is shown in Figure 3 where a horizontally polarized output is required to pass through the outer track polarizer - rotation of the wave-plate immediately before the pulse shaping pockel cell as well as the ability to turn of the driver enabled operation without the shaper if required.

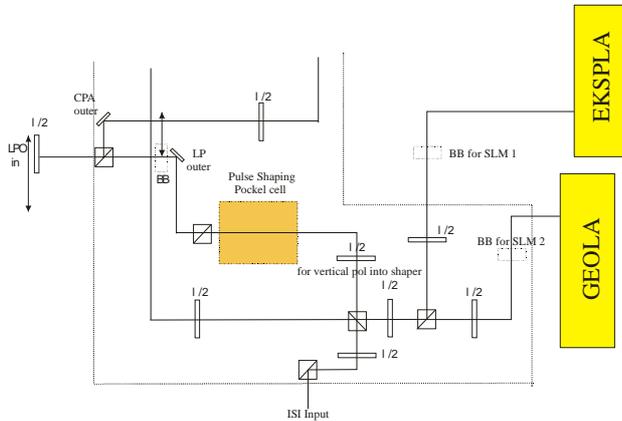


Figure 3. Arrangement on outer track of ‘shaping’ fast pockel cell.

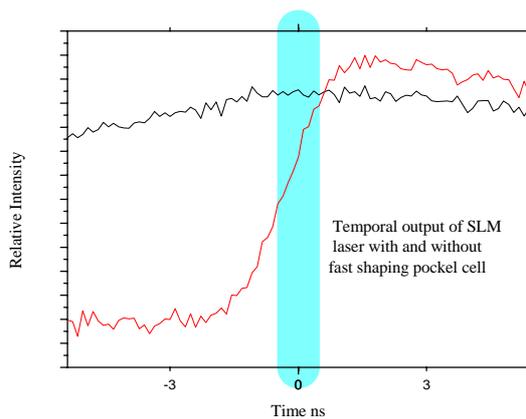


Figure 4. Temporal profile of square unshaped ~20ns SLM pulse and selected (shaded) shaped 1 ns pulse using the VLPS on the outer track.

Figure 4 shows the temporal profile of the normal SLM output and that achieved after the shaping fast pockel cell. These traces were obtained using a ~2GHz InGaAs PIN detector coupled to a 5 GHz scope. The shaded region of 1 ns duration, matches the slope required in Figure 1(b) to correct for the SPD on beam-7. The graph also illustrates the ability to change the slope and transmission of the shaped pulse through the VLPS by changing their relative delays. This relative delay was optimized during experimental runs using a dedicated DG535 pulse generator for triggering the fast shaping pockel cell. Enough energy from the SLM was available to run the shaper at lower transmission, with a dip in the linear rise if required.

Final amplified temporal profiles

Results obtained on beam 7 showed excellent SPD correction. Figure 5 shows streak camera profiles obtained at 300J and 150J using a 1 ns pulse from the VLPS - high pixel numbers corresponding to earlier times. The streaks, corrected for phosphor ‘degradation’ on both ends of the streak axis, show how gain saturation corrects for the slope imposed by the fast

shaping pockel cell on the SLM laser output. There was some evidence on high energy shots of a ‘dip’ in the temporal profile – this was attributed to some residual mismatch between the VLPS and its driver unit and was partially compensated for when a 0.8 ns pulse width was selected from the VLPS for optimum OPCPA pumping. The resultant amplified square temporal pulse profile enabled a broader amplified bandwidth and hence a shorter pulse after compression in the large-scale OPCPA experiments to be achieved.

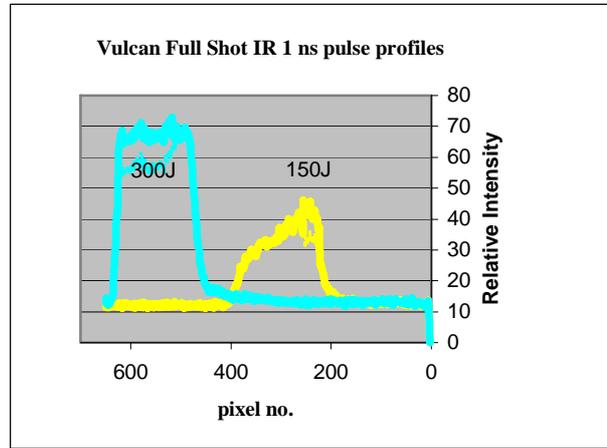


Figure 5. Streak camera temporal profiles of beam-7 outputs.

Conclusions

We have shown that suitable corrections for SPD can be made using a fast ‘shaping’ pockel cell. The optical ramp produced with these fast pockel cells can be sufficiently varied in conjunction with the VLPS to enable relatively easy optimization of the amplified output. Slower optical ramps could be produced by rotation of the waveplate before the shaper – faster ramps using the appropriate driver. Where finer pulse shaping is required, the suitability of fiber based modulator systems requiring lower drive voltages from Arbitrary Waveform Generators are currently being investigated.

References

1. I.N.Ross *et al.*, CLF Annual Report 2002/03, RAL-TR-2003-018,p190.
2. W.Koehner, Solid-State Laser Engineering, 4th Edition, p148.