Development, commissioning and experimental delivery of full energy chosen shaped long pulse laser pulses at Vulcan

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Introduction

In previous years, we have reported on the development of a laser system providing shaped long pulse laser pulses[1]. This system is based on fibre optic modulators which can readily be driven by Arbitrary Waveform Generators (AWG) requiring small monopolar voltages over 300 samples separated by 100 ps. This system has the potential to considerably enhance the traditional capability provided by the Pockel cell switch-out of standalone SLM lasers which have provided long pulses on Vulcan for many years.

Production of mJ output from the regenerative amplifier and synchronization of the Shaped Long Pulse System with Vulcan

Excessive heat loading resulting in the thermal fracture of the YLF gain material in the regenerative amplifier required a change to a 10 Hz pulsed 1 ms duty cycle of the pump diodes[2] resulting in a maximum output from the regenerative amplifier of 2 mJ. For synchronisation with Vulcan, the timing scheme in Figure 1 provided operation of this new laser system synchronous with other oscillators within the jitter specification of the RF trigger re-synchronisers and AWG[3].

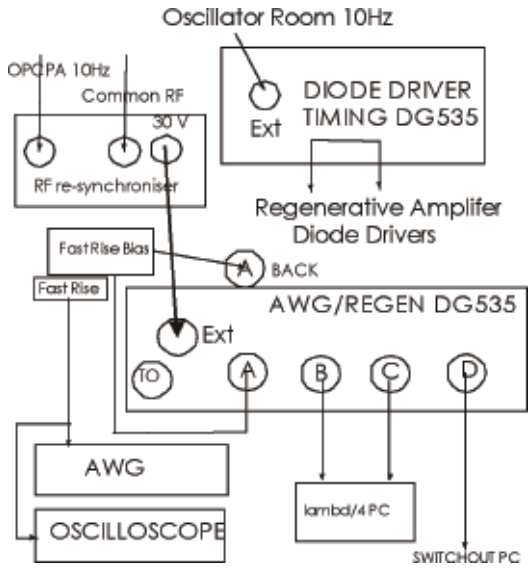

Figure 1. Timing scheme for the AWG and regenerative amplifer for Vulcan synchronization.

Commissioning in September 2007

The extra energy needed to provide joule level performance at the output of the rod amplifier chain of Vulcan[1] was achieved by establishing beam-lines from the Vulcan oscillator room and injecting the output of the regenerative amplifier, after suitable image relaying, through the inner Vulcan 9 mm rod amplifier used in double pass configuration. Suitable automated waveplate/polarizer selection allowed

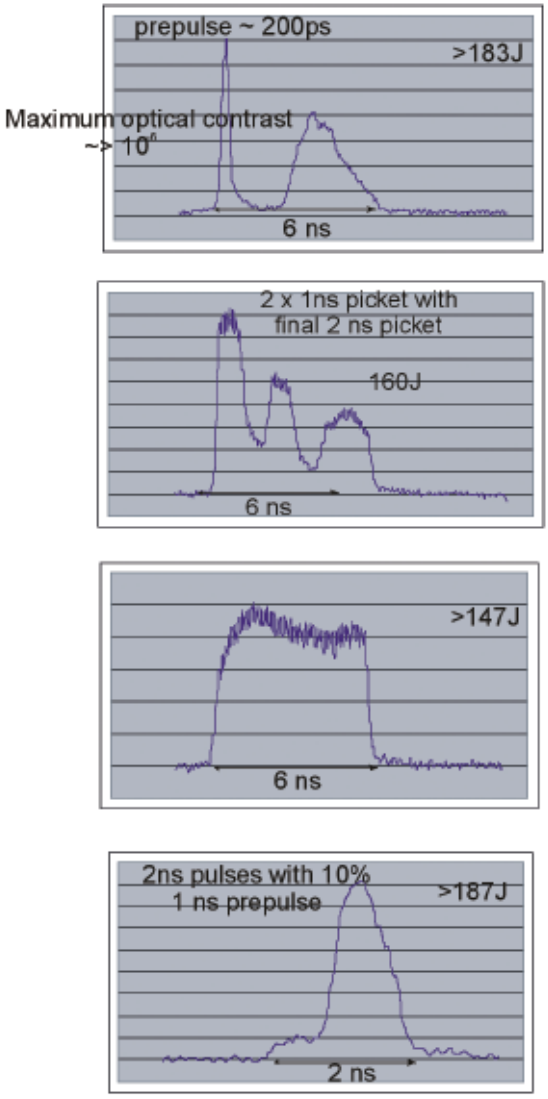

Figure 2. Examples of full energy shaped long pulses delivered on Beam 6 during commissioning work.

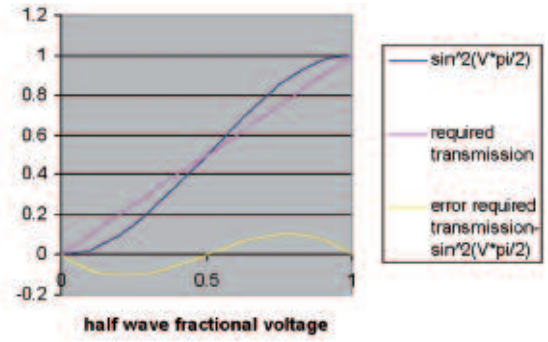

Figure 3. Fractional transmission error.

operation of the Shaped Long Pulse system on Vulcan in parallel with other oscillators. This arrangement provided in excess of 8 J at the output enabling full energy disc shots. During a period of 2 days in September 2007, amplification of a range of pulses shaped was demonstrated. By changing the text file loaded into the AWG, the following pulse profiles (Figure 2) with corresponding energies were readily generated after a single set of disc amplifiers (Beam 6). Severe modebeating effects from the temporary seed laser feeding the modulator and effecting the temporal profiles have been smoothed out. Partially because of these effects, no real attempt was made to compensate for Vulcan gain saturation.

A narrow band fiber laser source, a necessary requirement for stable and reliable seeding of the fibre based modulator and bias controller was successfully installed to seed the fibre modulator in October 2007 [4]. This enabled the modulator in conjunction with its bias controller to lock to its appropriate working point and provide stable shaped pulses of arbitrary shape.

Modification and development of arbitrary waveform generator text file

Further full energy tests revealed that a modification to the control software was required to provide with greater accuracy the required pulse profiles from the modulator e.g. those requiring linear ramps resulting in close to flat top profiles at full Vulcan energy. This is demonstrated in figure 3 which shows the deviation from a linear response that modulator voltages produce, resulting in a pulse shape error which produced rounded pulse profiles (in yellow). Further modifications could include single exponential component to compensate for gain saturation.

Using successive corrections of the error from a liner response and that provided by a sin^2 response, 3rd order corrections resulting in <1% error for the required and theoretical transmission and the corresponding voltages V for corresponding fractional full half wave modulator transmission T

$V=2\ Sin^{-1}\ (T^{1/2})/180$

and incorporated into a new Visual Basic text file generation programme. (Figure 4).

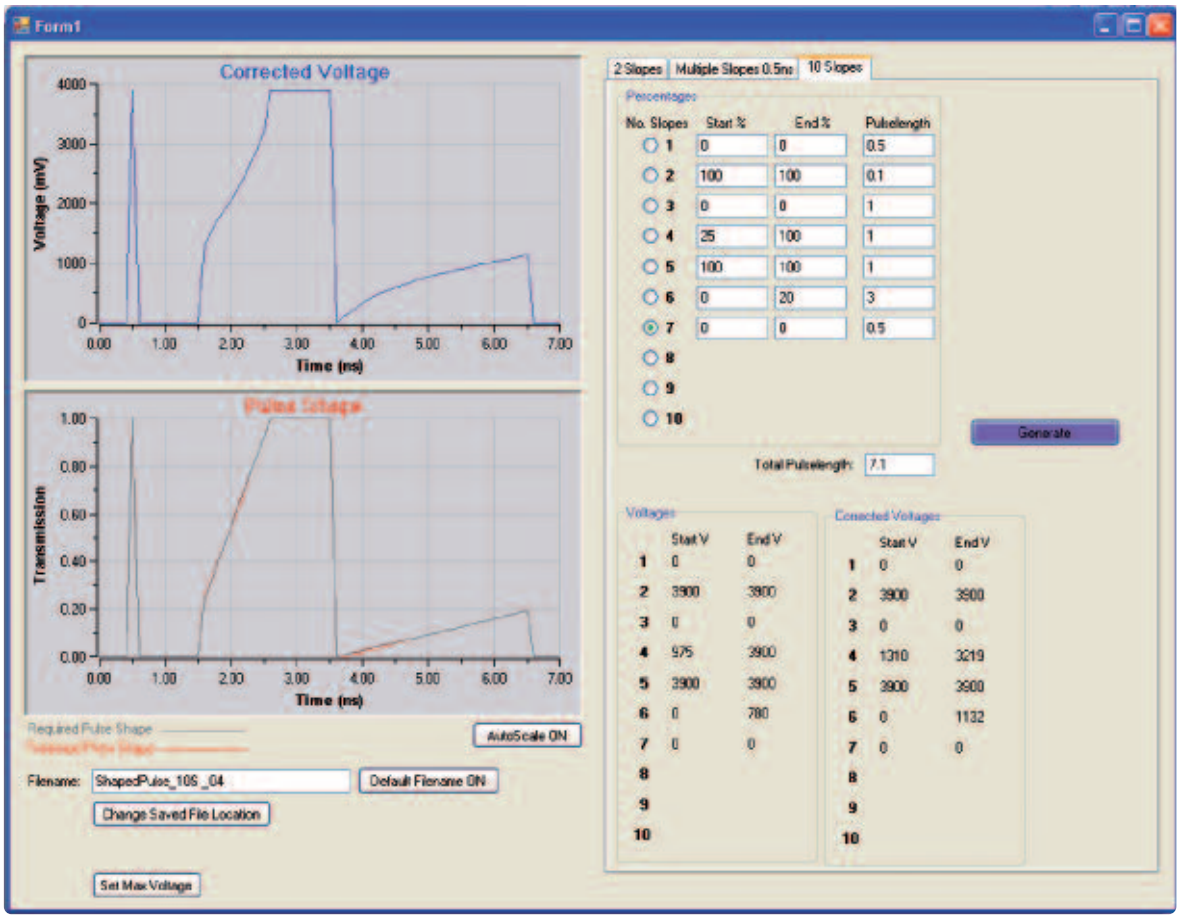

Figure 4. AWG text file generation programme for an example shape. Corrections for ramp outputs require 'close to parabolic' voltage corrections.

Figure 6. Transverse spatial profile of full energy shaped pulse.

Experimental delivery to Target Area East – May 2008

In May 2008, the requirement in Target Area East was flat top pulses of 4 ns duration. The output of the regenerative amplifier was injected into the outer track of Vulcan using a double pass of the outer 9 mm rod amplifier using another set of polarisers and waveplates to enable operation in conjunction with other oscillators. The new text file generation software was set to produce, linear 'ramps' of 30% to 100% pulses from the modulator – this resulted in near flat top pulses on beams 7 and 8. Figure 5 shows the temporal outputs achieved from the fibre modulator oscillator and Figure 8 that obtained on Beam 7 at an energy of 213 J.

References

1. W. Shaikh, '*Development of an amplified variable shape long pulse system for Vulcan*'. CLF Annual report 2005-2006, RAL TR. pp 199-201.
2. Highly stable, all-solid-state Nd:YLF regenerative amplifier. *Applied optics* Vol **43**, No 33, (2004).
3. www.kentech.ac.uk
4. Koheras Boostik Y10 Fiber Laser System. www.koheras.com

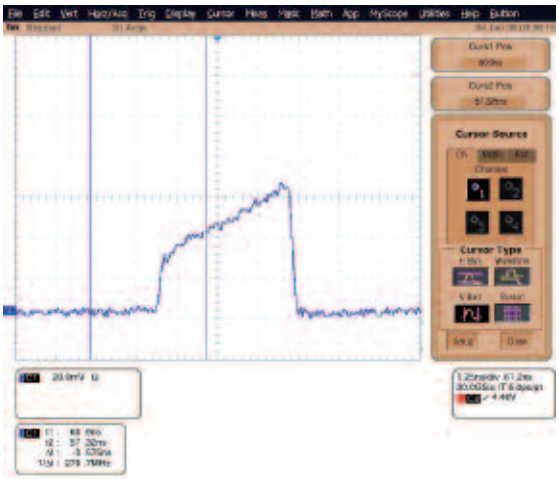

Figure 7. Corrected 4 ns linear optical ramp from oscillator.

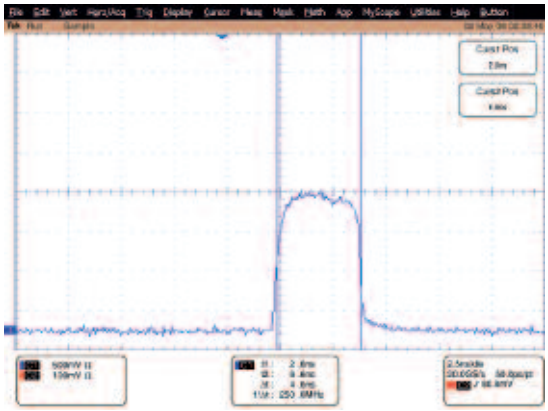

Figure 8. Corresponding 4 ns 213 J output on Beam 7 delivered to TAE.