Testing of fiber based modulator systems for ‘shaped’ long pulse generation on Vulcan

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Introduction

High energy long pulse laser systems, as in Vulcan have traditionally used ‘standalone’ flashlamp pumped SLM lasers as their oscillators - appropriate variable length ‘square’ pulses are then ‘switched out’ using fast high voltage pockel cell systems. These flashlamp pumped systems, typically producing Gaussian shaped temporal pulses of 20ns, generally have poor stability in single longitudinal mode1) and cannot be easily shaped. Temporal pulse shaping, necessary for efficient conversion of the pump wave to the signal wave in OPCPA schemes2,3) and water Hugoniot equation of state studies4), can be performed using other bulk pockel cells to ‘carve’ shaped pulses from this longer Q-switched pulse (by changing the relative delays between the laser and pockel cell). However, the high voltage KV power supplies required for this shaping restricts the fidelity with which this can be done.

Fiber based modulators

In bulk transverse electrode Pockel cells, the half-wave voltage V $_{1/2}$ resulting in a π phase shift for total extinction can be given by 5)

$$V_{1/2} = \frac{\lambda d}{(electro - opticcoeff)n_0^{3} l}$$

where λ is the wavelength, d the beam cross-section, n$_o$ the ordinary wave refractive index and l the interaction length. In bulk pockel cell systems, these voltages are of ~ 6KV making high bandwidth shaping difficult. Lithium Niobate Mach Zender waveguide modulators reduce substantially the d/l ratio making the halfwave voltage requirement only a few volts. These intensity modulators consist of two parallel phase modulators operated with a DC Bias, the intensity control being performed by applying additional proportional amounts of the Vπ between these two modulators as an RF. The few volts ‘control voltage’ requirement can be readily delivered at high bandwidth using an Arbitrary Waveform Generators (AWG).

Vulcan plans to exploit two aspects of low power optical pulse generators – rapidly developing lithium niobate waveguide modulators and diode-pumped lasers. Several companies now market CW diode-pumped turnkey laser systems operating in single longitudinal mode with excellent frequency and power stability. Although lithium niobate integrated-optic devices represent a fairly mature technology at the optical communications wavelengths, >100mW power handling devices designed for 1053 nm have only recently become commercially available.

System description

The master oscillator shaping system constructed is shown schematically in Figure 1. It consists of three primary components - a fiber based laser source and a modulator, the later being ‘driven’ by the arbitrary waveform generator. The diode pumped solid state (DPSS) cw laser source is coupled with > 80% throughput efficiency into a single mode HB 980 fiber core integrated modulator using a double-aspheric lens. The spectral stability/output of the fiber laser source can be partially monitored (Figure 2) using a high resolution HR4000 fiber coupled spectrometer – the spectral resolution of this device with a 5µm slit being ~ 0.5nm, substantially less than the average SLM DPSS laser linewidth of < 1x10^{-5}nm. Where possible, fiber optic connections are FC/APC to eliminate sources of FM to AM conversion6). The modulator is designed to handle 100mW input power – to reduce the CW background on the shaped pulse, as well as to decrease the average power loading on the modulator, an AO modulator could be added modulator could be added between these two components. Shaping and synchronization of the optical pulse is performed

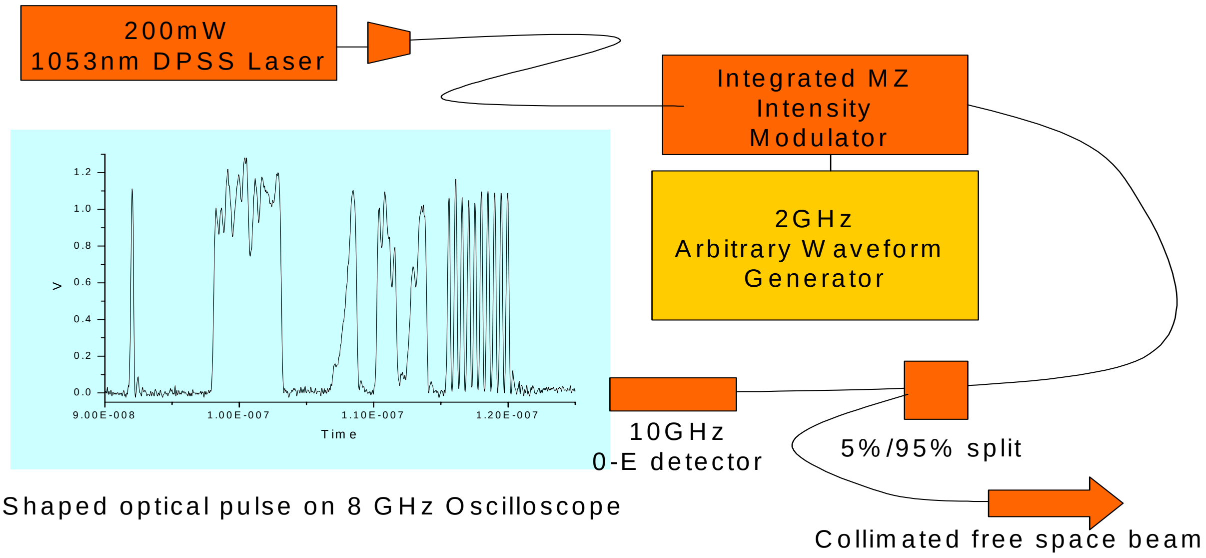

Figure 1. Schematic of optical pulse forming system.

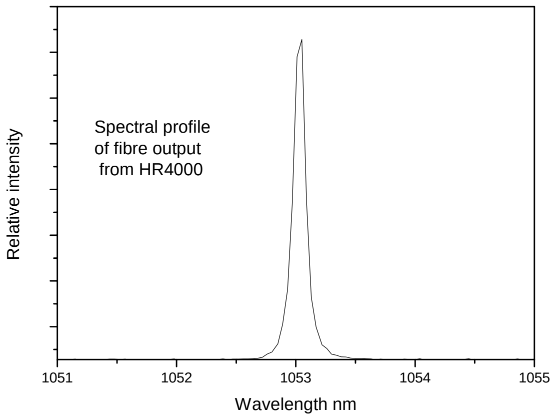

Figure 2. Output of HR4000 spectrometer.

using a Kentech7) AWG which can supply a 'semi programmable shape' to a voltage determined by the ½ wave requirement of the intensity modulator – shaping is achieved by setting time 'samples' separated by 100ps to the appropriate digital value – a smooth pulse is a result of these samples overlapping. The structure seen within the 5 ns square pulse in Figure 1 is due to the un-calibrated gains of the individual samples of this prototype AWG. However, the ability to produce a ramped optical 1ns pulse as used for OPCPA3) pumping is shown in the centre of the oscilloscope trace. For online monitoring of the shaped waveform, a 5% split using a fiber 'tap' feeds a fast 10GHz photodiode and oscilloscope – 95% of the shaped optical waveform can then be collimated back into free space using a lens based fiber collimator, reversing the laser launch process.

Shaping resolution

One criteria for evaluating the performance of any fiber based shaping system is its ability to produce a fine 'picket fence' structure, one of the waveforms needed for fusion experiments1). Figure 3 shows an expanded view of part of the pulse in Figure 1- it consists of 10 separate pulses in a 5ns macropulse, each pulse being < 230ps FWHM. The energy in the macro pulse is ~200pJ. External synchronization to enable this shaping to take place in conjunction with other Vulcan beams is important – measured jitter was < 50ps with respect to an external fast electrical trigger for all the shaped optical pulses.

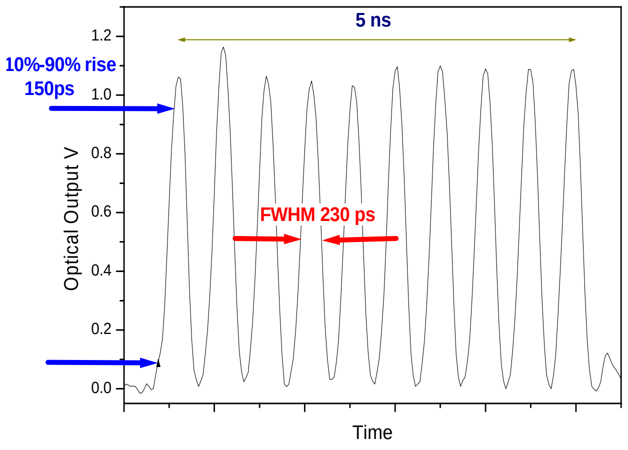

Figure 3. A 5ns optical picket fence.

Further amplification

The output from this master oscillator is suitable for further amplification – a large fraction of the transmitted light and the contrast will be improved before amplification using optical gates to apply a sharp rise and fall, thus removing pre and post energy1). Similar techniques have been implemented on Beamlet and Nova. We plan to incorporate these as part of a Regenerative Diode pumped regenerative amplifier8) to boost the output of the fiber modulator to the mJ level. The incorporation of phase modulation9) to produce spectral side-bands to enable smoothing by spectral dispersion (SSD)6) and to prevent SBS could be easily implemented using the experience gained.

Acknowledgements

The authors would like to thank Professor Marcus Roth of GSI and Dr Nick Hopps of AWE for useful discussions.

References

1. R.B.Wilcox, D.F.Browning,
   Oscillator and pulse forming systems for the Beamlet.

2. I.A.Begishev *et al.*,
   Sov. J. Quantum Electron 20 (9) Sep 1990.

3. W.Shaikh *et al.*,
   " Nanosecond pulse SPD correction (for large scale OPCPA trials)" CLF Annual Report 2003-2004 , RAL – TR-2004-025.

4. P M Celliers *et al.*,
   Physics of Plasmas, Vol 11, No 8 (2004)

5. W. Koechner,
   Solid State Laser Engineering 4th Edition pp 472

6. J.E.Rothenberg, D.F. Browning and R.B. Wilcox,
   The issue of FM to AM conversion on the National Ignition Facility. SPIE Vol 3492

7. http://www.kentech.co.uk/Arbitrary_waveform_gen.html

8. LLE Review Volume 91

9. S.N.Dixit,
   Numerical modeling of the suppression of stimulated Brillouin scattering due to finite laser bandwidth. SPIE Vol 1626