8.0 ns top hat pulse generation from Vulcan

S J Hawkes, C Hernandez-Gomez, I O Musgrave

Central Laser Facility, CCLRC Rutherford Appleton Laboratory, Chilton, Didcot, Oxon., OX11 0QX, UK

Main contact email address: *s.j.hawkes@rl.ac.uk*

Introduction

During the September-October TAE experiment there was a requirement for 8.0 nanosecond long top-hat pulses to be delivered from Vulcan. Vulcan long pulse duration ranges from 300ps to 4.0 ns, and is limited to 4.0ns by two factors. Firstly pinhole closure, this is caused by an expanding plasma created by the high spatial frequencies being filtered at the focus of the Vulcan Vacuum Spatial Filters (VSF). Secondly gain saturation effects in the glass amplifier chain will produce a decay of pulse energy towards the end of the 8.0 nanosecond pulse resulting in an irregular Trapezoidal pulse shape.

Gain saturation

The Miro optical propagation code was used to model 8.0 ns pulses being amplified by the Vulcan laser chain, see Figure 1.

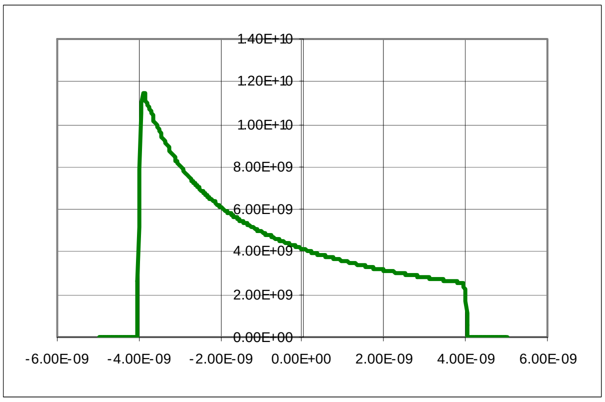

Figure 1. Miro code simulation of an amplified 8.0ns long pulse.

To confirm the results from the model measurements were made at the output of the Vulcan laser chain using a Newport photodiode and a 4GHz Techtronics oscilloscope. The measured pulse shape (Figure 2) compares very well with modeling. This also gives confidence for the use of the Miro code for different situations.

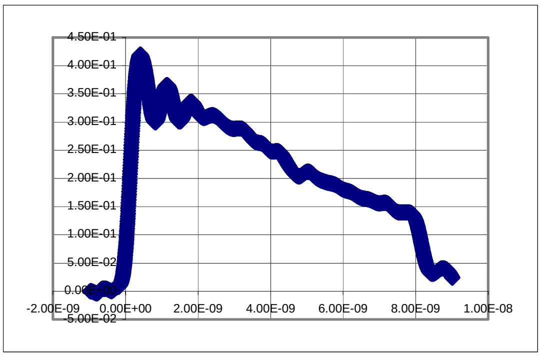

Figure 2. 8.0 ns long pulse with gain saturation effects.

Vulcan long pulses are produced by a Single Longitudinal Mode (SLM) oscillator, which produces a 20ns Gaussian pulse that is then sliced to the required pulse length using a 150ps rise time pockels cell. The normal operating mode for Vulcan is for the pulse slicing to be timed such that the middle of the Gaussian is selected for amplification in the glass amplifier chain (Figure 3). However if the slice is made on the rising edge of the Gaussian pulse then the shape of pulse injected into Vulcan is such that the sharp fall in gain that a long pulse sees through the amplifier chain and results in a 8.0 ns long top hat pulse see Figure 4. For more sophisticated pulse shaping techniques see[1].

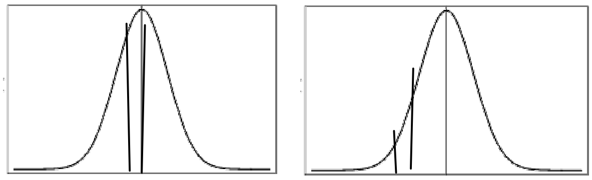

Figure 3. conventional slicing (left) and shaped slice (right).

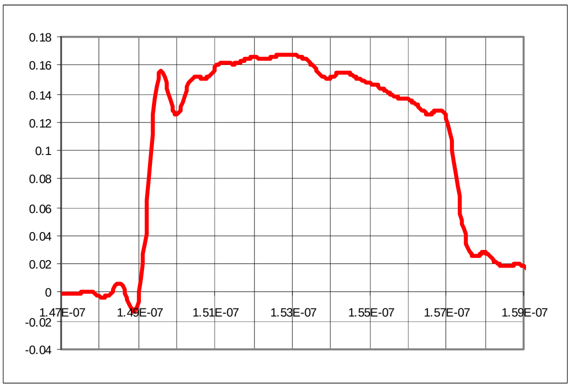

Figure 4. 8.0 ns long pulse, full 452 J Vulcan disc shot.

Pinhole closure

Pinhole closure can be a major issue when propagating longer pulse durations through Vacuum Spatial Filters; it can lead to the latter part of the pulse being cut off and even being retro-reflected back down the laser chain. This is a dangerous fault mode as the back propagating pulse will be amplified and can lead to damage in the pre-amplifiers and oscillator. Assuming a plasma expansion rate of 10^4 ms^{-1} calculations were made as to the minimum pinhole size required in the spatial filters, see Figure 5. The pinholes in the Vulcan spatial filter chain were changed such that the following requirements were met.

VSF	Energy	Focal spot dia	Power density	Min Pinhole dia
	(J)	(mm)	(W/cm^2)	(mm)
16 - 25	0.1	0.04447	8.04984E+11	1.689
25 - 45	1.5	0.04060	1.44891E+13	1.612
45 - 108	6	0.03817	6.5546E+13	1.563
108 - 150	120	0.10561	1.71268E+14	2.912
150 - 150	450	0.06756	1.56924E+15	2.151
150 - 208	450	0.05377	2.47804E+15	1.875

Figure 5. Calculated minimum pinhole sizes.

References

1. W.Shaikh. Testing of fiber based modulator systems for ‘shaped’ long pulse generation on Vulcan, CLF Annual Report 2004/05, p206