An ultra-fast electrical trigger for TAP using the OPCPA pre-amplifier

W Shaikh, C Hernandez-Gomez

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

J Milnes

Photek ltd, 26 Castleham Road, St Leonards on Sea, East Sussex, TN38 9NS, UK

Main contact email address: *w.shaikh@rl.ac.uk*

Introduction

Chirped pulse amplification has resulted in a dramatic reduction in amplified pulse lengths. To cope with the required improved temporal resolution for fast diagnostics such as streak cameras, improved (early) triggering requirements are required for a range of (fast) diagnostics. TAP required a low jitter early electrical trigger – this would preferably have to be generated using the 4.5 ns OPCPA pre-amplifier. Conversion to an appropriate electrical pulse would require a suitable OE (optical to electrical) converter. Overall desirable objectives included:-

1) a high voltage to optical light input ratio
2) a fast voltage risetime
3) insensitivity to slight optical mis-alignment

Both 1) and 2) required the building of an optical compressor for the 4.5 ns OPCPA beam to provide a sufficiently short optical pulse. An appropriate location for this compressor to enable the trigger to arrive in TAP as early possible was at the CW laser injection point just before the OPCPA oscillator is injected into the Silicate amplifiers.

Compressor Design

In any grating based compressor, the quadratic phase distortion which to first order determines a pulse width (linear chip) is given by [1] :-

$$T_2 = \frac{-N^2 \lambda^3 L}{2\pi c^2 \cos^2 \sigma}$$

where σ is the refracted grating angle, L the grating separation and N the number of groves per unit length. The parameters for the TAP compressor are well established[2]:- N = 1480 l/mm σ =54.7 deg L =13m (with only a 6.8^o angle between the input and diffracted angle) providing a linear dispersion of 300 ps nm^{-1}.

Space restrictions as well as OE detector response limitations meant that full compression to 500fs would not be required. A similar amount of linear chirp would be readily provided using higher dispersive 1740 l/mm gratings with σ = 74.6 deg and L = 2 m with a conveniently increased difference between the input and diffracted angles of 13.9 degrees. 75 cm wide gratings would provide an spectral throughput of ~ 2.3 nm, only ~18% of the full 13 nm OPCPA bandwidth for a double pass configuration but still sufficient to provide an optical pulse of <1ps[3]. For optimum T2 correction, the minimum pulse width at the output of the compressor would be determined by the nonlinear chip T3[1] due to a mismatch in the incidence angles and dispersion of the TAP compressor/stretcher and this compressor. This was calculated to be ~ 20ps – still substantially less than any possible OE detector response time.

Compressor Construction

Figure 1 shows a scale optical ray-trace of the optical compressor on a 450mm x 1200mm breadboard – Non optimal compression in air would be sufficient for relatively low energy OPCPA pulses. A simple convenient ray trace in ‘Optica’ computes a linear dispersion of 316ps nm^{-1}. The optical input (from the right) was provided using a 10% leakage mirror on the OPCPA beam. The double pass was provided by an AR coated 5 cm roof prism - 5 cm high gratings operating close to Littrow for maximum efficiency and dispersion provided suitable vertical displacement of the incoming and out coming beams. The 13.9^o angle between the input and diffracted angles enabled the positioning of two permanent reference alignment apertures > 1m apart on the optical input beam before the first grating. Optical paths/angles were calculated for 1055nm and temporary apertures used for grating alignment using CW beams - grating zero order retro-reflections were made to ensure grating groves were parallel before appropriate grating rotations were made. As a final grating alignment check, a far field monitor with 0.1mrad resolution was placed at the output of the compressor and the Vulcan 1053nm and 1047nm CW beams confirmed to be superimposed[4].

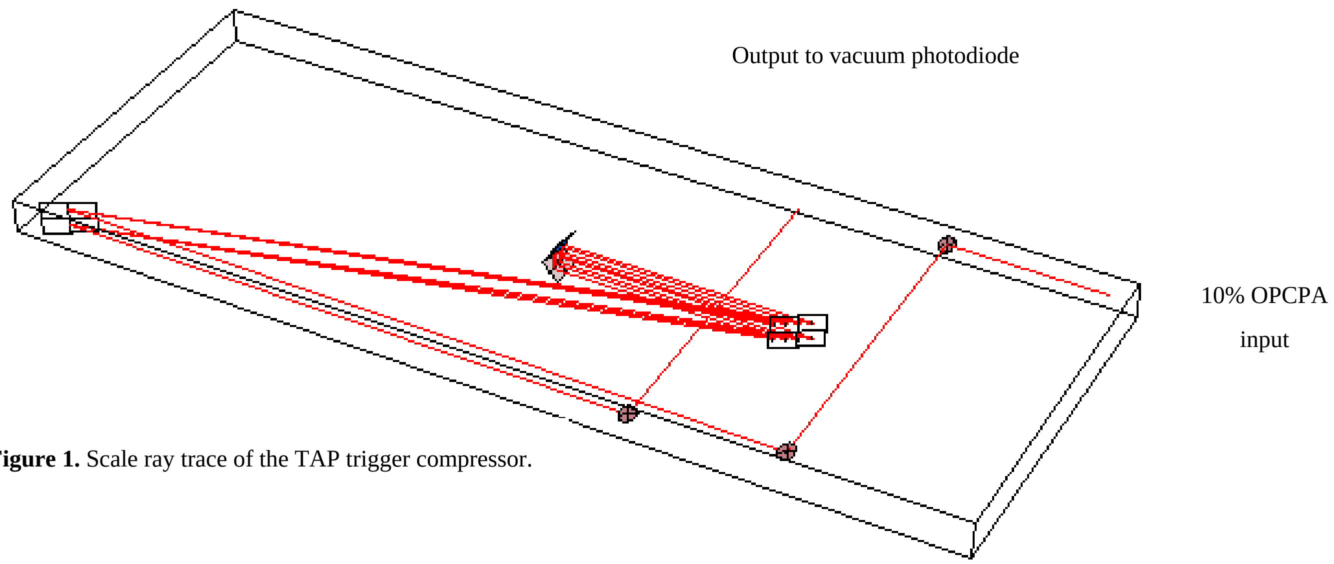

Figure 1. Scale ray trace of the TAP trigger compressor.

Optical to electrical conversion

An OPCPA energy of ~8 mJ, reflection and spectra losses of the compressor provided no more than a few 10's of µJ. PIN diodes that achieve sub 100ps response times have to overcome the problems of junction capacitance by using small active areas of ~ 30µm[5] – this inevitably leads to decreased throughput and sensitivity[6]. To provide both a fast and high voltage output, a vacuum photodiode with an optimized S1 IR photocathode and specified response time of < 100ps and >3GHz bandwidth was chosen as our OE converter – its 25mm active area would also ensure minimum sensitivity to OPCPA alignment changes[7] - for optimum photoelectron generation, the OPCPA compressor output was unfocussed onto the photocathode. Figure 2 shows the electrical output produced from the vacuum photodiode measured on a 1GHz oscilloscope – an output of ~ 18V into 50 ohm with a scope limited rise time of <350ps was typically achieved. It was used very successfully on a LLNL experiment to trigger a with 100% reliability a range of fast diagnostics with low jitter ~300ns before the Petawatt optical laser pulse in TAP. Further tests to increase the trigger voltage by frequency doubling the compressor output to 527nm where there is a >50 fold increase in photocathode sensitivity could be beneficial.

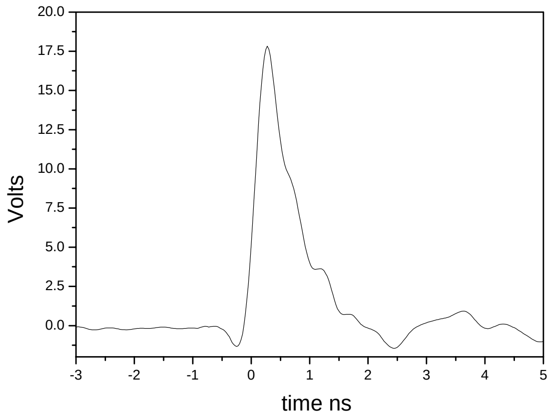

Figure 2. Trigger pulses -output of vacuum photodiode.

References

1. C Fiorini *et al.*, IEEE Journal of Quantum Electronics Vol 30 No 7 1994

2. J. Collier *et al.*, "CPA design considerations for The Vulcan Petawatt Upgrade ", CLF Annual Report 1999-2000, RAL-TR-2000-034, p 174

3. K. Sala *et al.*, "CW autocorrelation measurements of picosecond laser pulses", IEEE Journal of Quantum Electronics Vol QE-16 No 9 1980

4. J. Collier *et al.*, "Vulcan Petawatt – Compressor and system commissioning", CLF Annual Report 2002-2003, RAL-TR-2003-018 p 168

5. http;/www.newport.com

6. R.J. Clark *et al.*, " Ultrafast Optical Triggering for X-ray and Optical Femtosecond Streak Cameras", CLF Annual Report 1999-2000, RAL-TR-2000-034 p 213

7. Photek data sheet