A High Performance OPCPA Front End for the Orion Laser Facility

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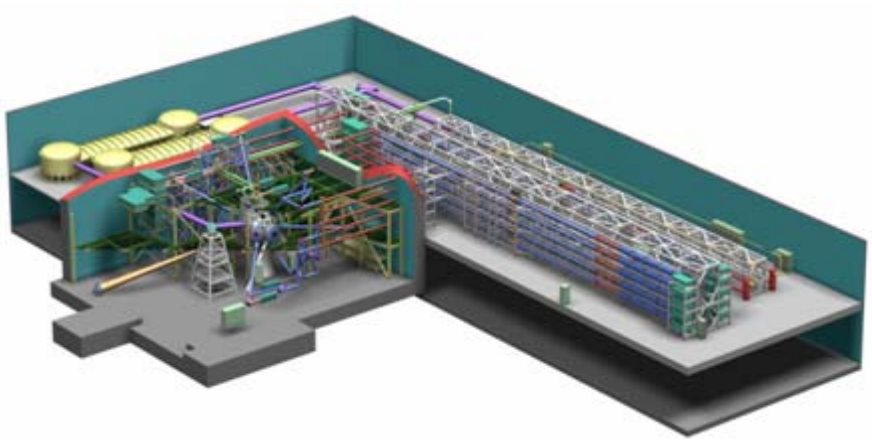
Introduction

Orion is designed as an entirely new laser facility for AWE for studying high energy density physics.

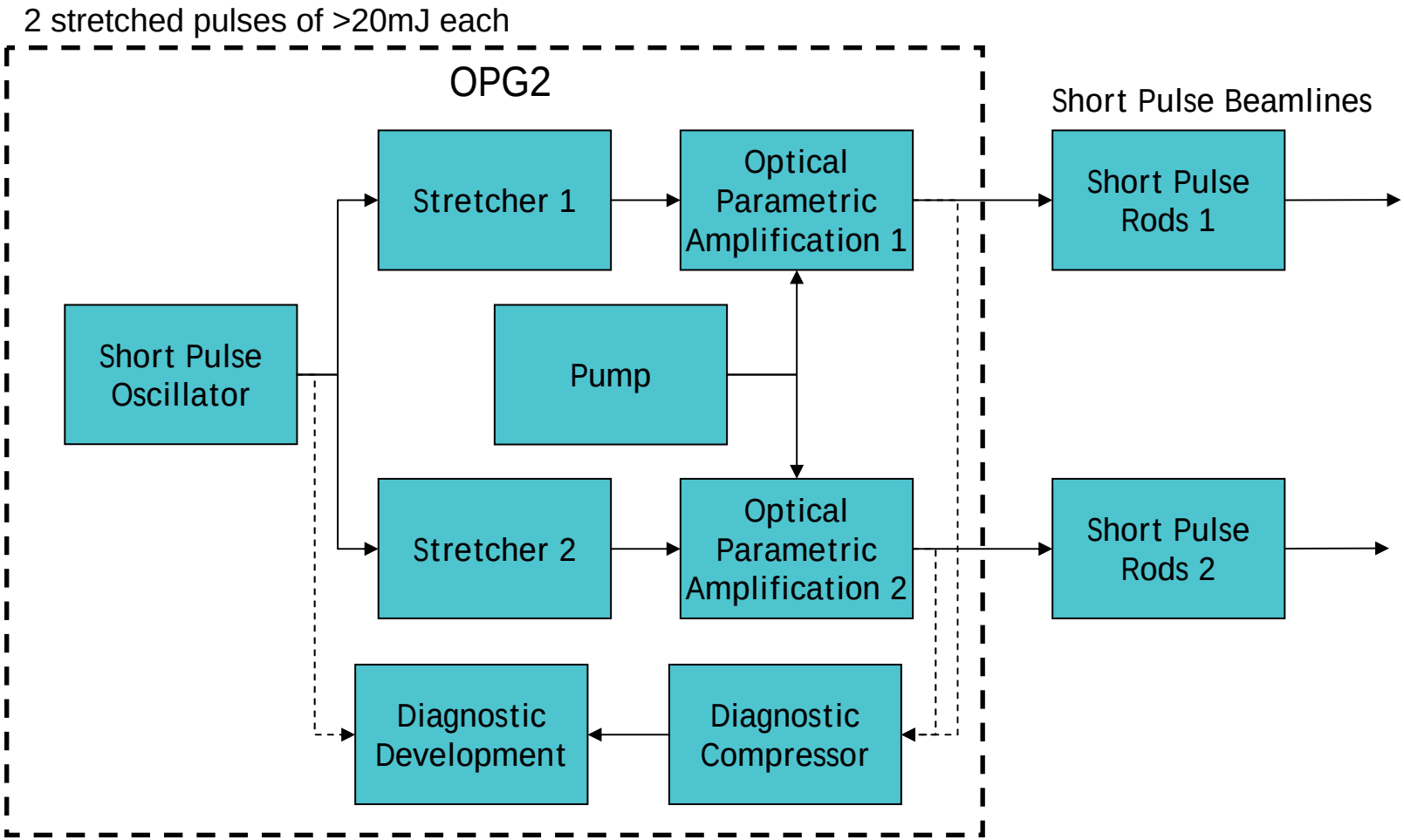
Orion combines ten laser beams operating in the nanosecond regime with two operating below 1 picosecond.



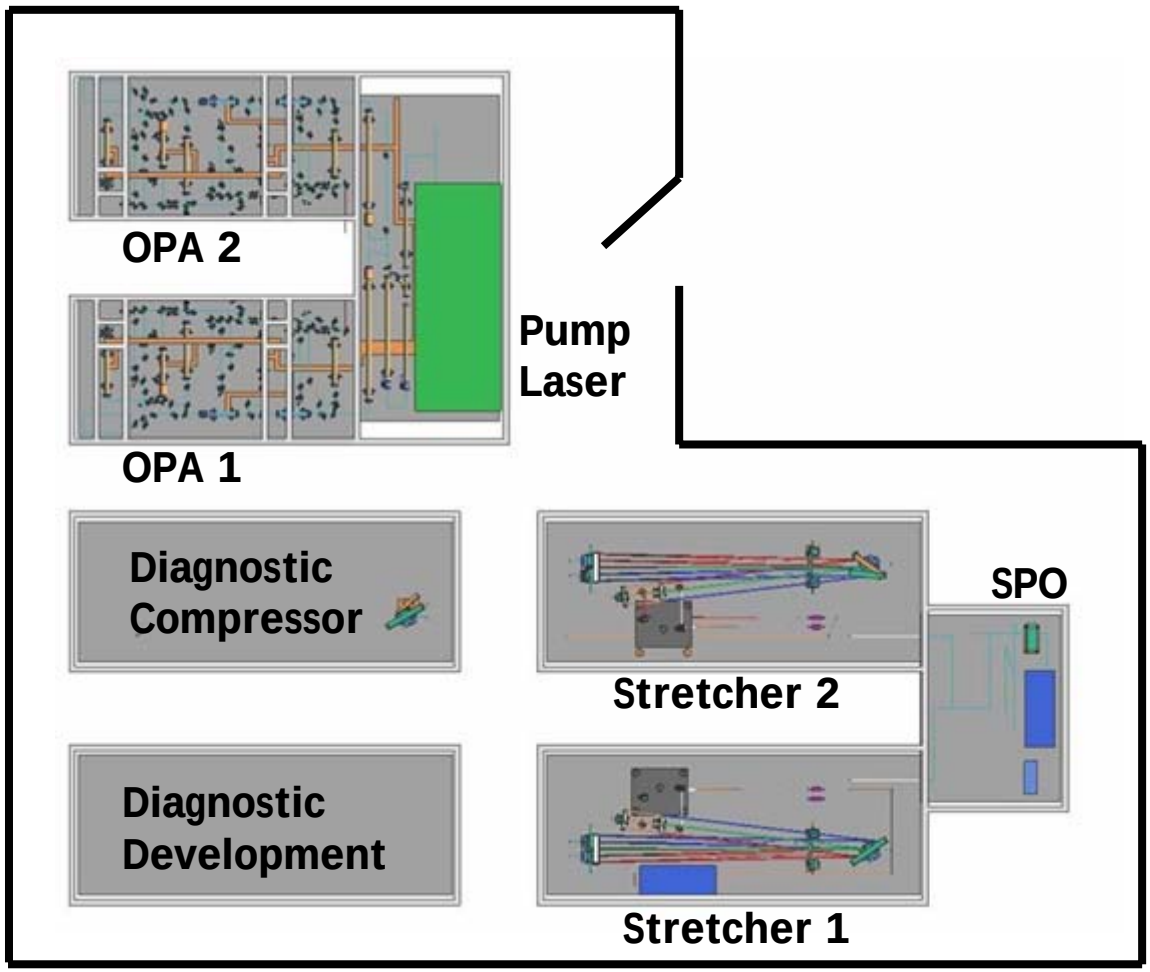
LP performance:
500J per beam @ 351nm in 1ns pulse
90% of energy in 100um spot

SP performance:
500J per beam @ 1054nm in 0.5ps pulse
Near-diffraction limited f/3 focussing
$>10^{21}Wcm^{-2}$ per beam

OPG2 overview

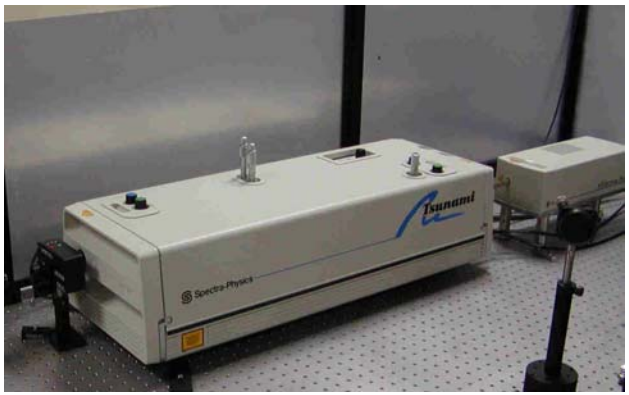


OPG2 – Orion Installation

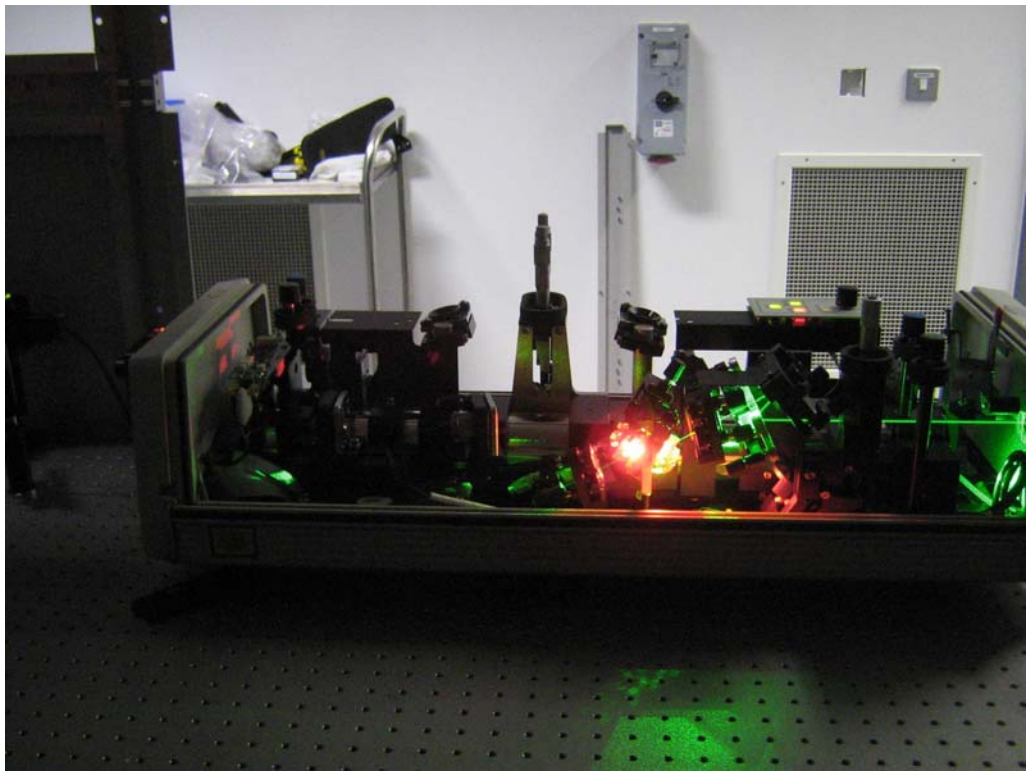


- SPO, Stretcher 1, Stretcher 2 successfully installed, tested and commissioned Jan 09
- Pump Laser and OPA2 currently operational and seeding one short pulse beamline
- Diagnostic compressor functional and initial results obtained
- Full OPG2 subsystem to be commissioned by Oct 10

Short Pulse Oscillator (SPO) – Pulse Generation

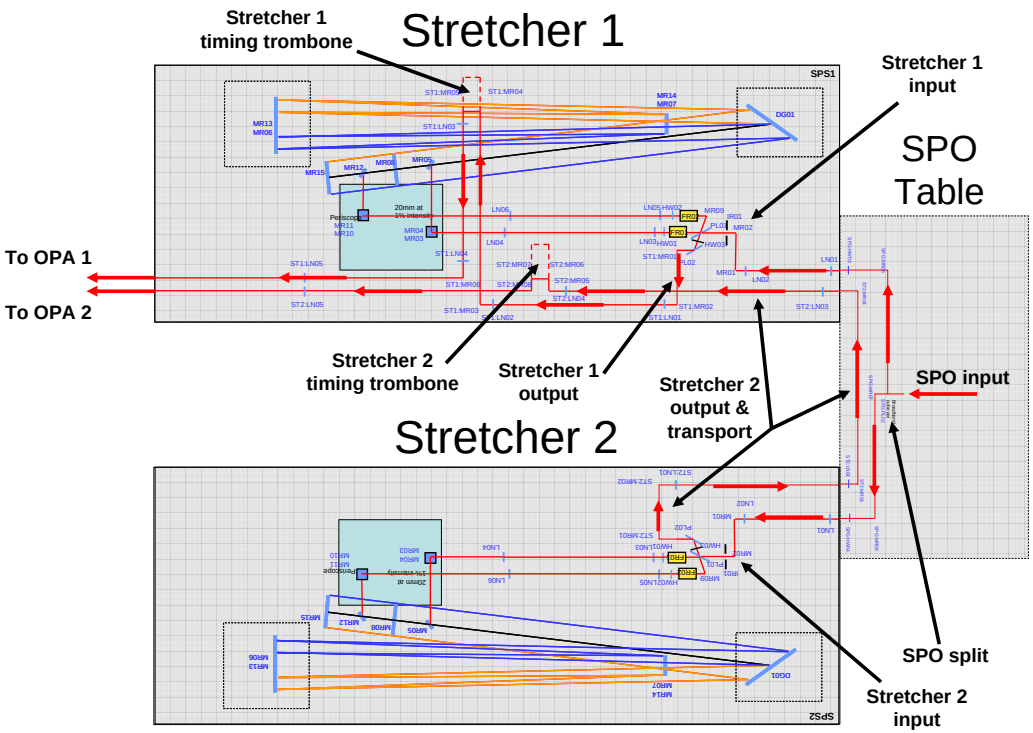


- Commercial modelocked Ti:Sapphire oscillator – Tsunami (Newport Spectra Physics)



SPO Performance	
Centre Wavelength	1054nm
Spectral Bandwidth	>12nm (FWHM)
Pulse Duration	<150fs
Pulse Energy	>3nJ
Spatial Profile	Gaussian TEM_{00}
Rep Rate	80MHz

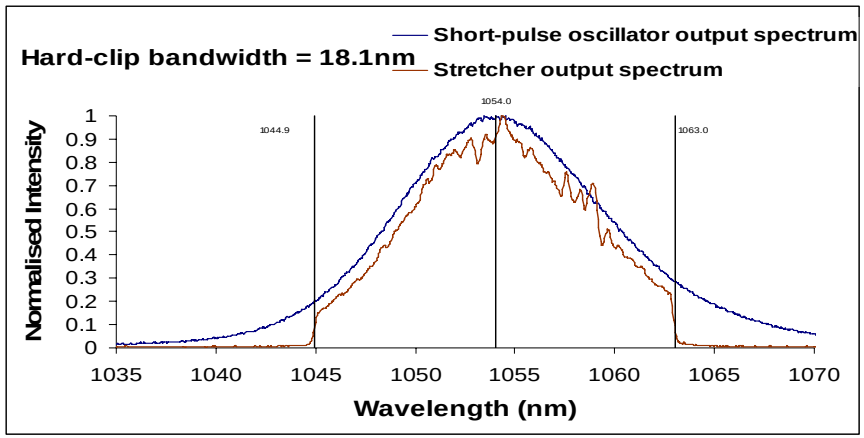
Pulse Stretching



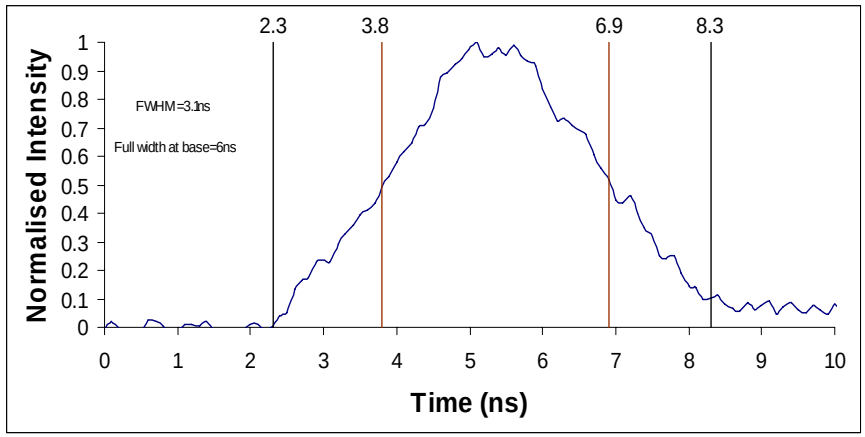
- Offner triplet stretcher design equivalent grating separation of 13m.
- User requirement to provide pulses in the range of 0.5ps-20ps duration at target. Stretchers are detuned to achieve this.
- Two separate stretchers allows independent detuning of both short pulse beamlines
- Optical trombones ensures both stretcher outputs are synchronous in the OPCPA stages

Pulse Stretching - Results

Spectral



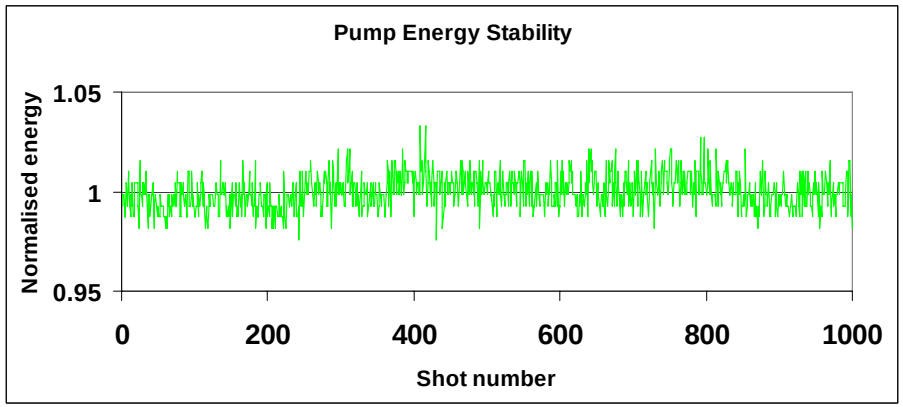
Temporal



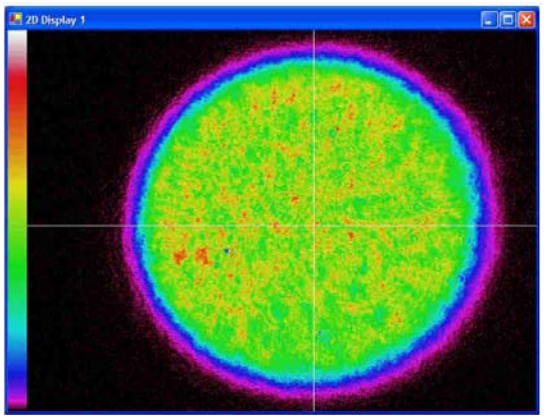
- Spectral “hard clip” of stretcher is 18nm
- Temporal duration of stretched pulse is >3ns FWHM, 6ns at feet of the pulse

OPCPA – Pump Laser

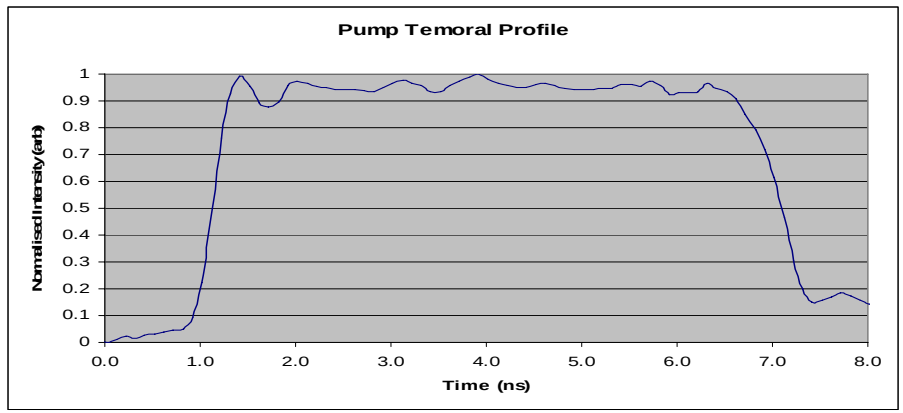
- High energy output >2J at 2ω



- Energy stability <1% RMS



- Excellent spatial beam quality – top-hat

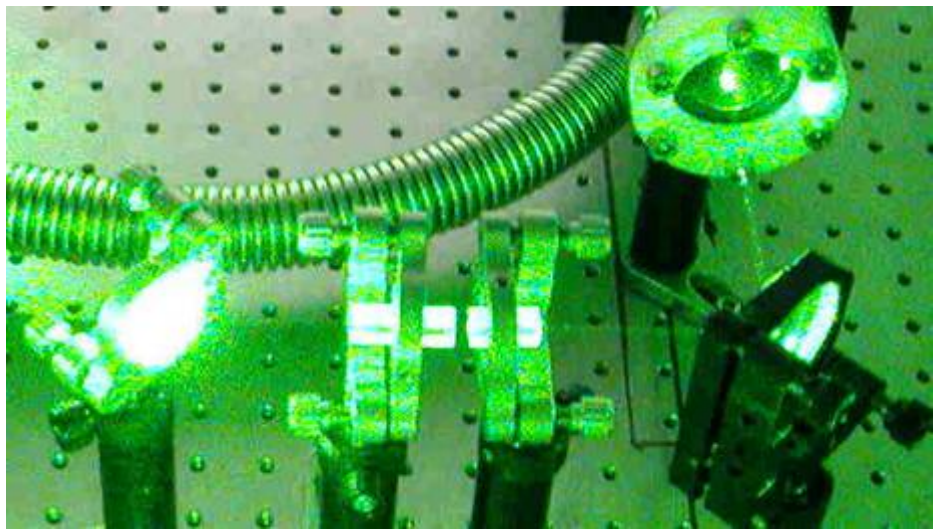


- Tuneable temporal profile from 4-6ns

OPCPA Design

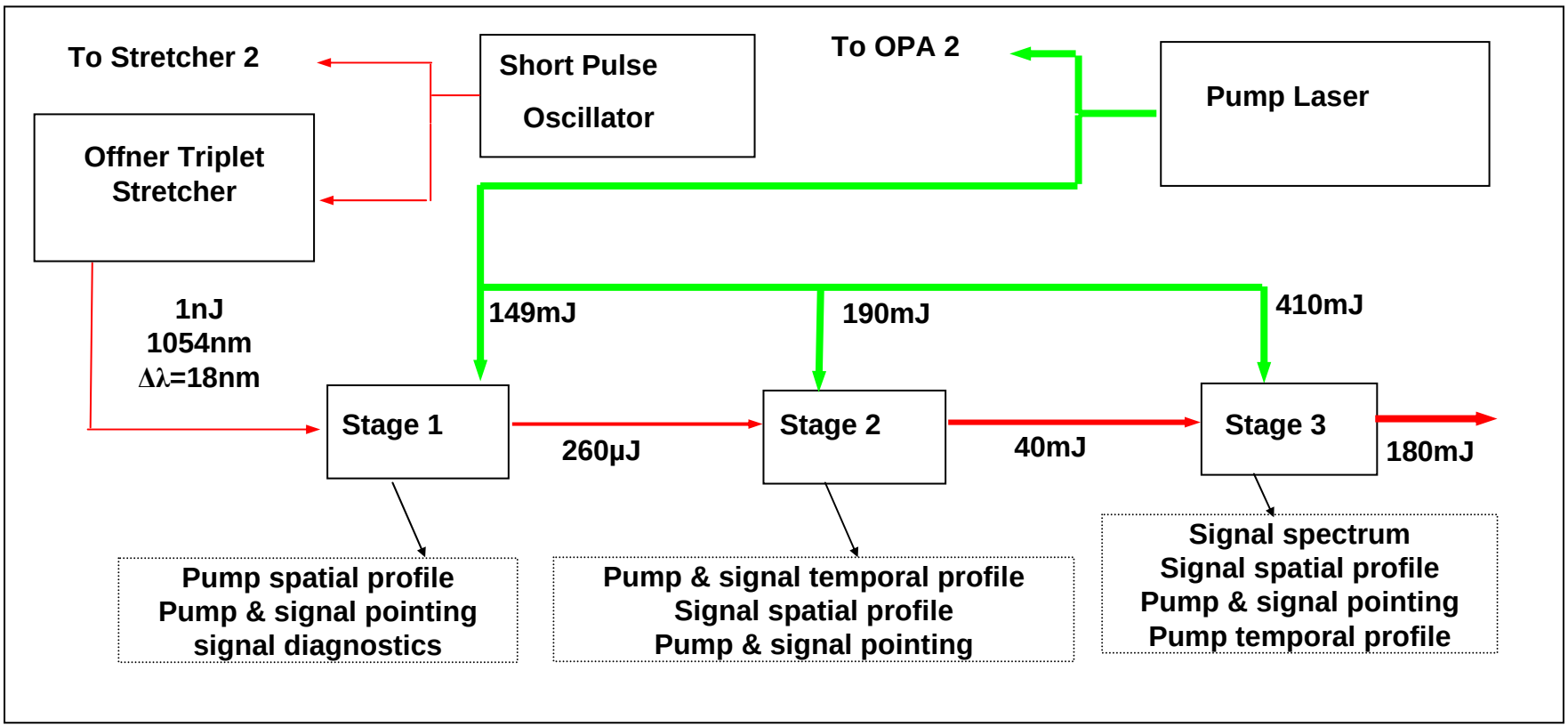
The stretched pulses are pre-amplified without reduction in spectral width to energies suitable for injection into the rod-amplifier stage.

- Two LBO crystals per amplification stage – matches walk off in crystals
- 3 stages per OPA
- Stage 1 high amplification, no pump depletion – G~100,000
- Stage 2 saturated - G~150 partial spectral, temporal and spatial reshaping achieved. Tuned to point of back conversion
- Stage 3 G~8 full spectral, temporal and spatial reshaping, increased energy stability



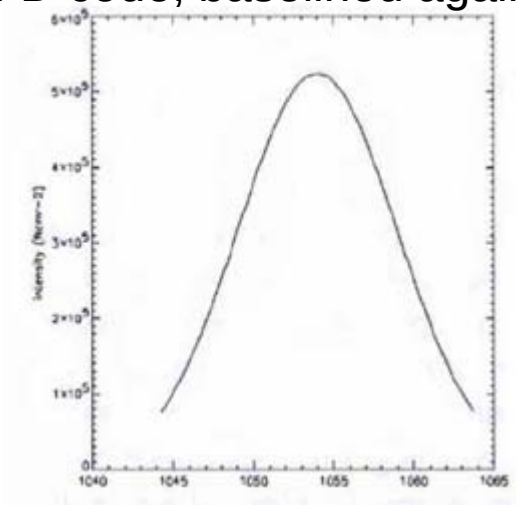
OPCPA Design

- The pump laser output is split and image relayed to each stage OPA stage
- Inter-stage beam transport is image relayed and spatially filtered
- Diagnostics at each stage allows optimisation of OPA performance



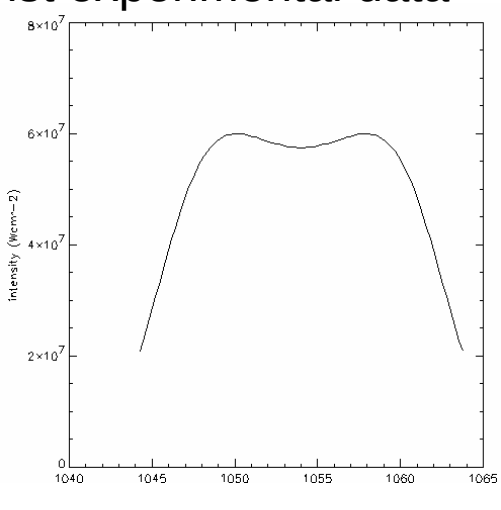
OPCPA – Spectral Gain Saturation Modelling

1-D code, baselined against experimental data



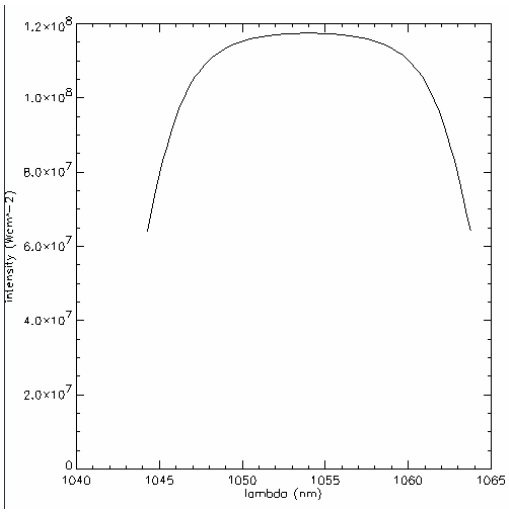
Stage 1

- Input Gaussian
- High gain G~100,000x



Stage 2

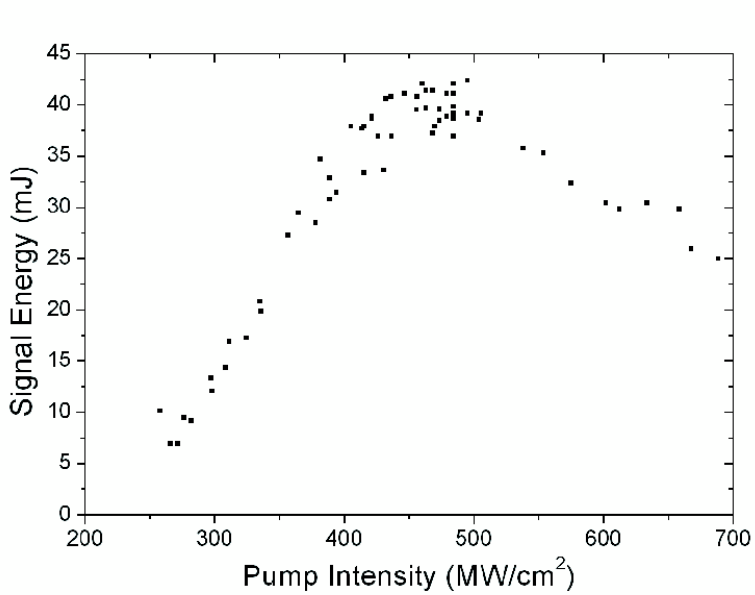
- G~150
- “Wings” of spectrum experience more gain
- Back conversion in centre of spectrum



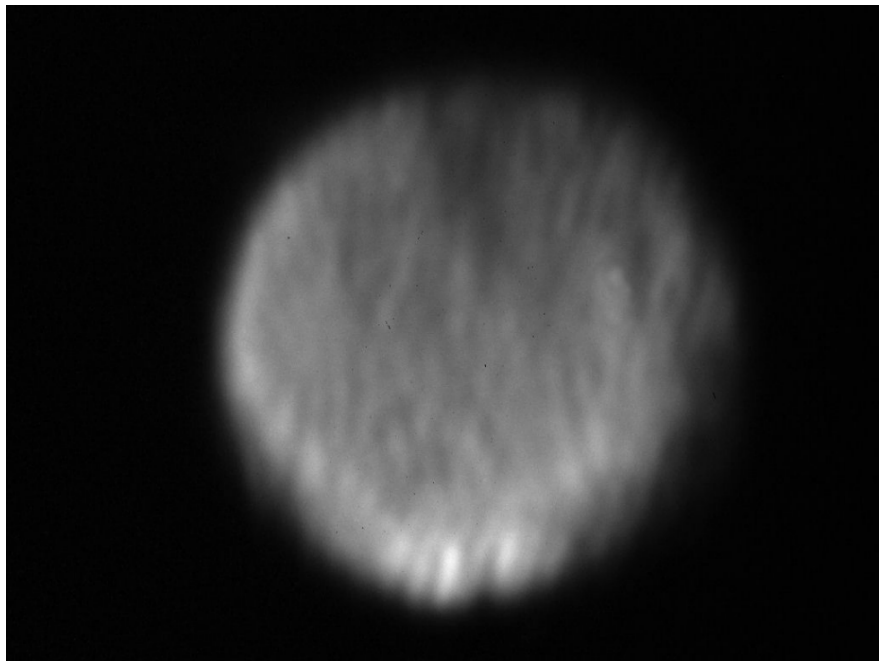
Stage 3

- G~8
- Increased flattening of spectral profile

OPCPA – Stage Two

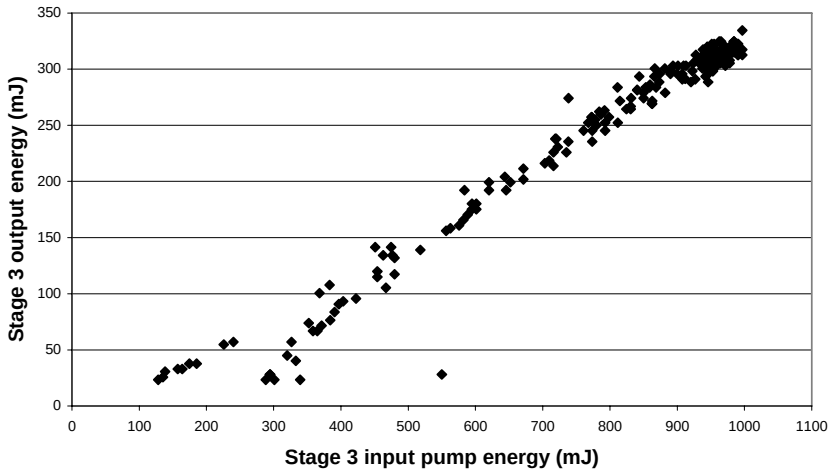


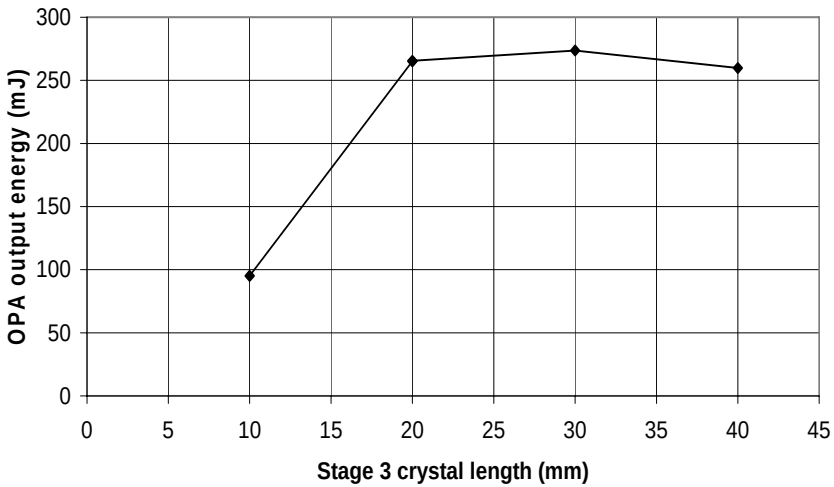
- Stage two amplified signal energy as a function of pump intensity. Gain saturation occurs at 460MW/cm^2, equivalent to ~190mJ



- Stage two spatial output, partial spatial reshaping occurring – equivalent temporal and spectral effects

OPCPA – Stage Three

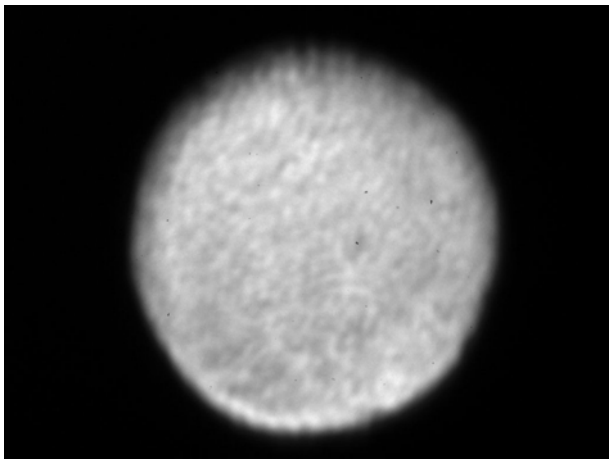


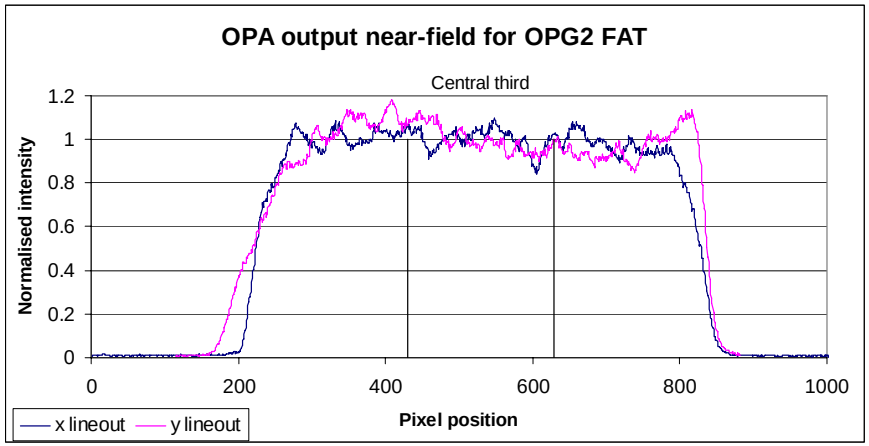


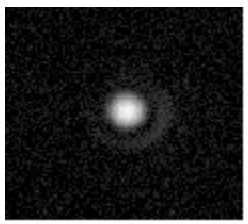
- Strong stage three pump depletion gives nearly linear relationship between pump and output energy
- Altering stage three crystal length shows gain saturation with a combined crystal length in excess of 20mm

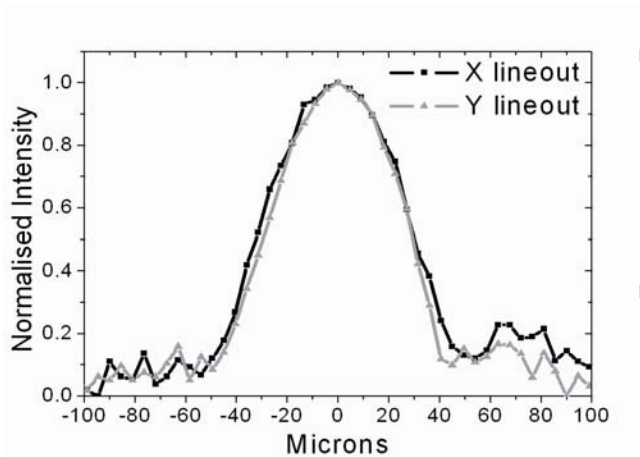
Optimised OPA parameters				
	Pump beam diameter	**Pump energy**	**Crystal length**	**Output energy**
Stage 1	**3mm**	**149 mJ**	**40 mm**	**264 μJ**
Stage 2	**3mm**	**170 mJ**	**60 mm**	**40 mJ**
Stage 3	**6mm**	**410 mJ**	**30 mm**	**180 mJ**

OPCPA – Spatial Output



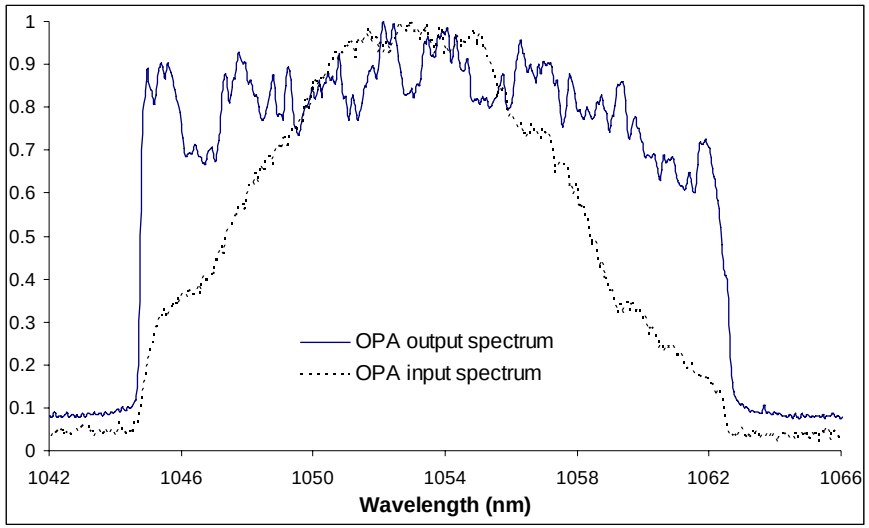


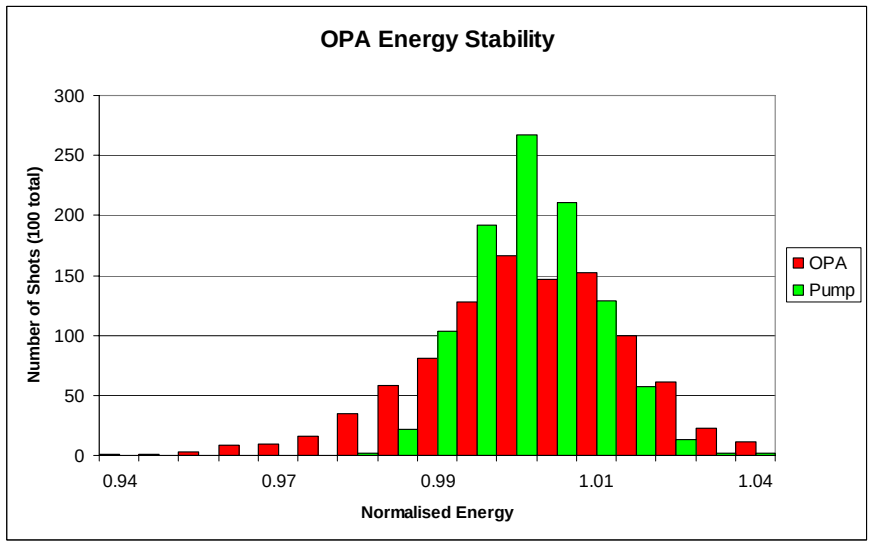




- Output beam diameter: ~5.8mm FWHM
  - Intensity varies by <7.5% rms over the central 90%
- Near diffraction-limited far field
  - Pointing variation of less than 1/12 of an airy radius in normal operation

OPCPA – Spectral Output / Energy Stability

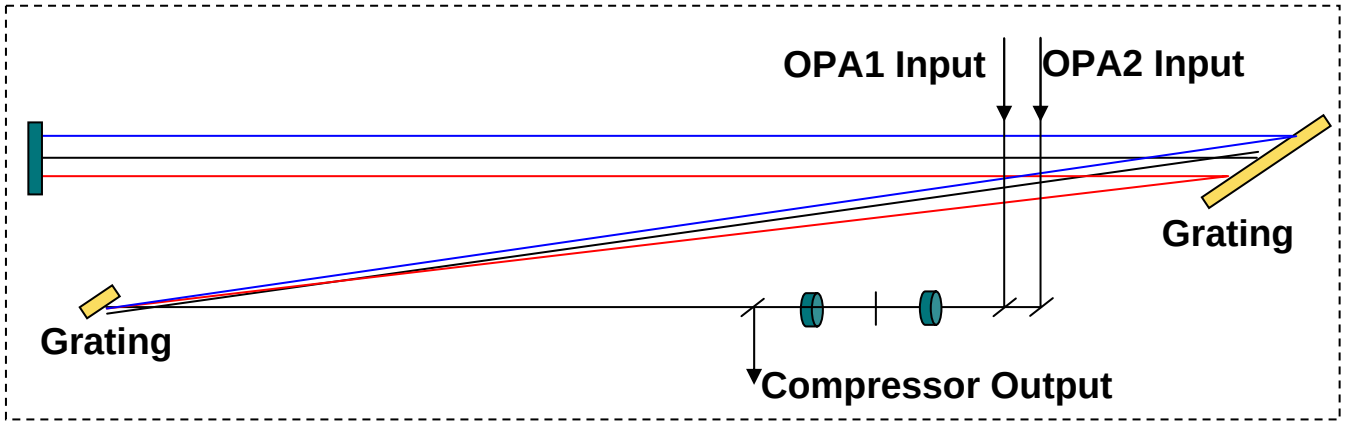


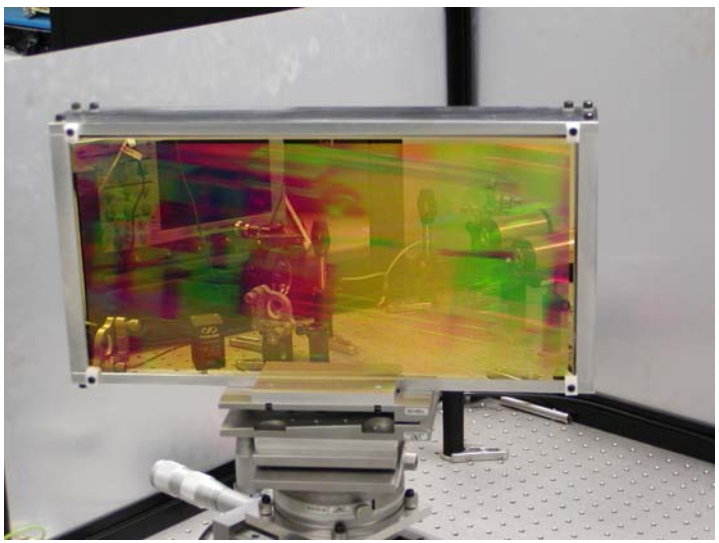


- OPA output spectral bandwidth:~17.5nm
- Spectral intensity varies by less than 11% rms
- OPA enhances the spectral bandwidth (FWHM)
- Equivalent temporal profile
- Spectral profile is adjustable by tuning the temporal profile of the pump laser.

- Energy stability: 1.2% rms over 1000 shots
- Pump laser energy stability: 0.7% rms
- Timing Improvements should yield improved OPA stability

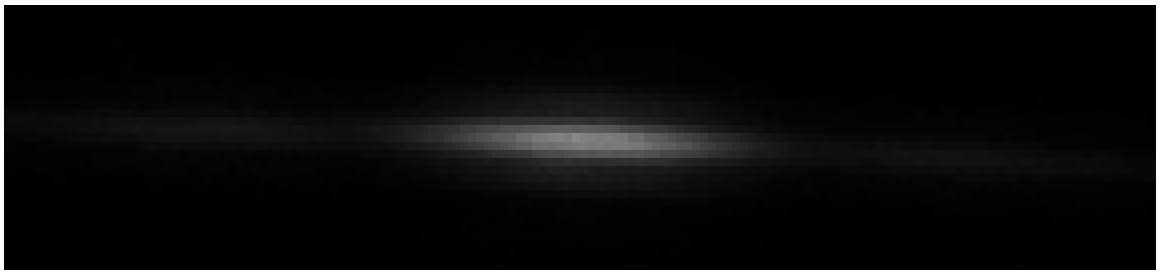
OPCPA – Recompression

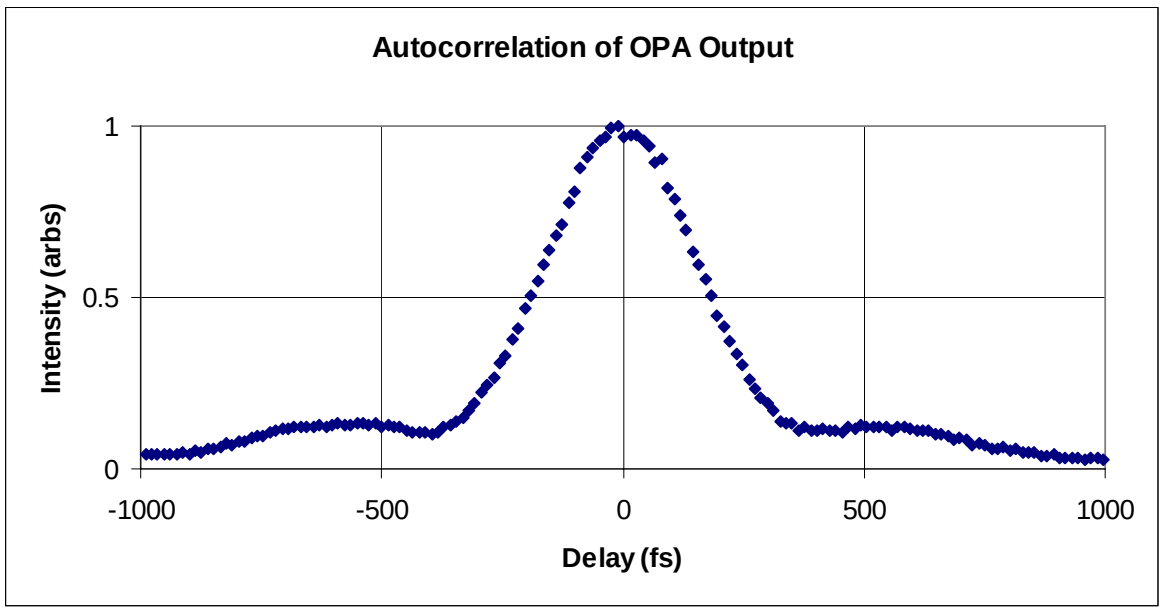




- The diagnostic compressor is a 4 passed dual grating arrangement with an effective grating separation equivalent to the two 13m compressors
- Compression of the OPA output allows the evaluation of OPA performance
- A single shot second order autocorrelator measures pulse duration post recompression

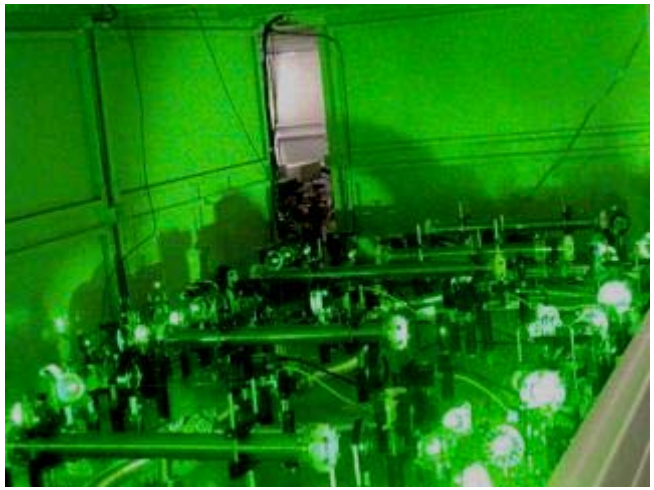
OPCPA – Recompression Results

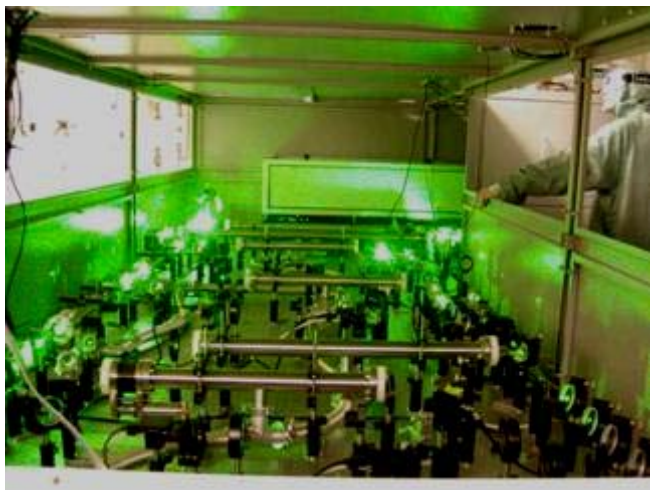




- Single shot second order autocorrelator image of diagnostic compressor output
- Initial operation has resulted in a measured pulse duration of <250fs FWHM
- Matches measurement made at oscillator output

OPG2 - Overview





- Two Stretchers fully commissioned producing two 6ns pulses
- First OPA operational and second in progress
- 180mJ output energy
- <1.5% rms energy stability
- Spatial profile varies by <7.5% rms over the central 90%
- Near diffraction limited far-field with excellent pointing stability
- Spectral bandwidth ~17.5nm
- Pulse recompressed to <250fs