1.1 Petawatt Hybrid OPCPA-Glass laser

Presented at the ICUIL 2008, Tongli, China

Texas Center for High Intensity Laser Science

The University of Texas at Austin

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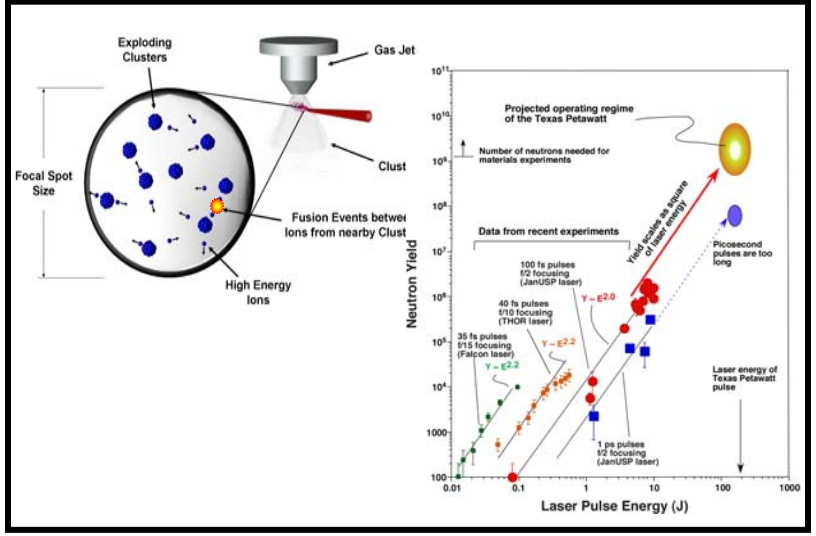
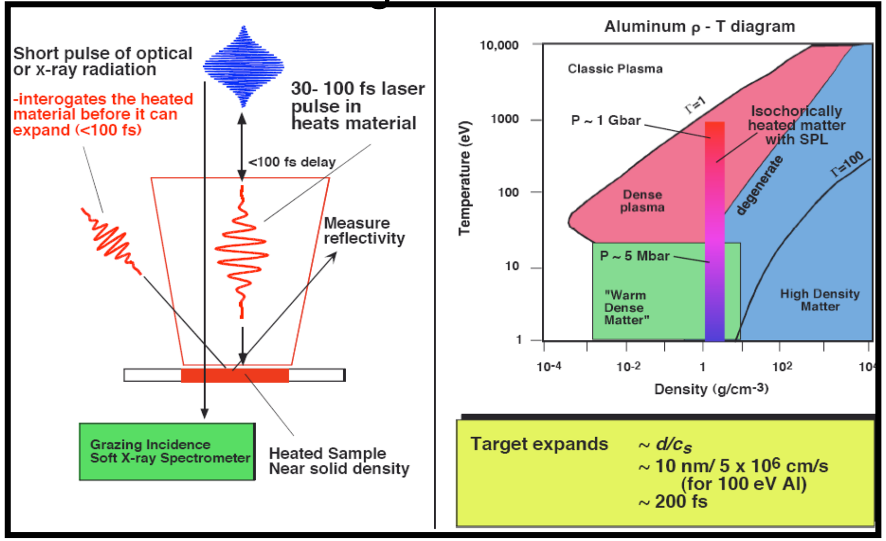
The experiments require a 100-300 fs laser with 100-200 J energy

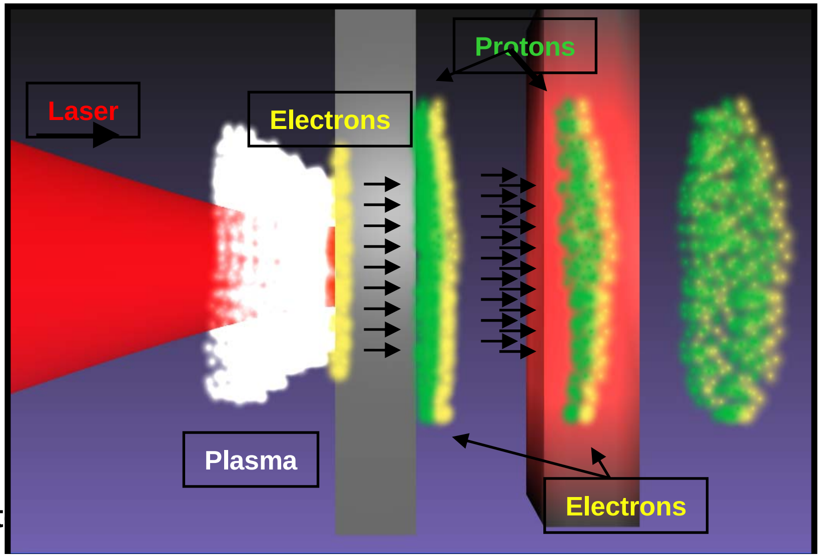
Neutron production by cluster fusion



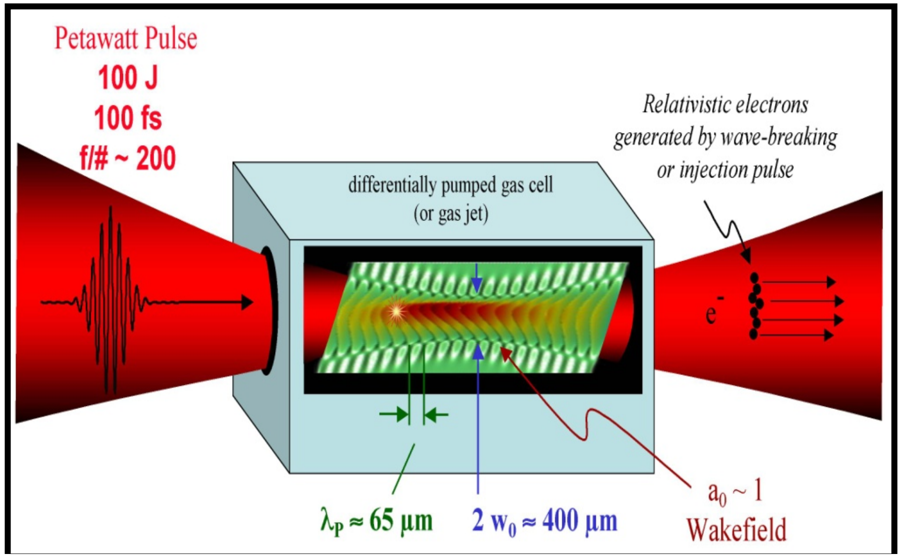
Isochoric heating



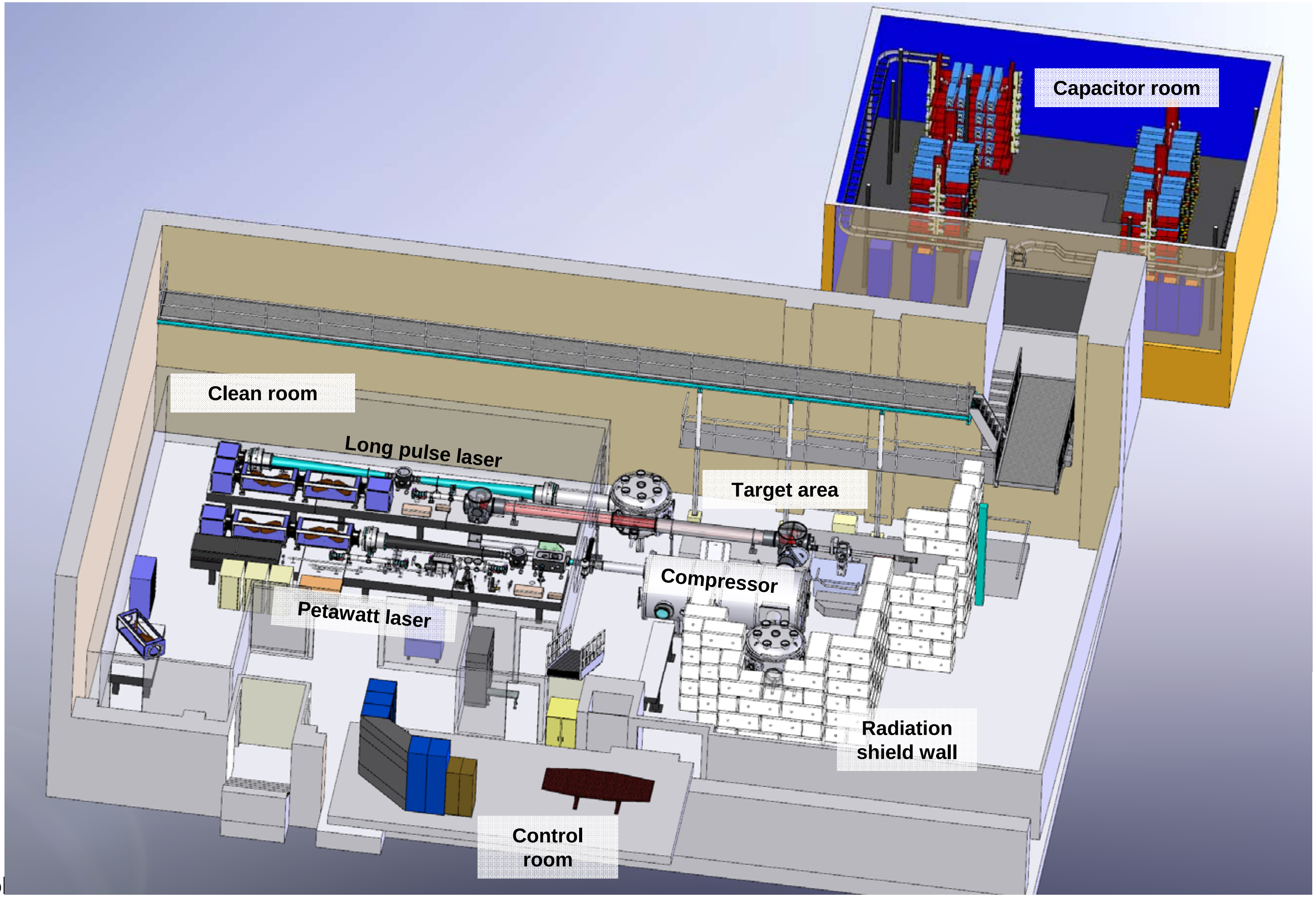
Material at extreme conditions



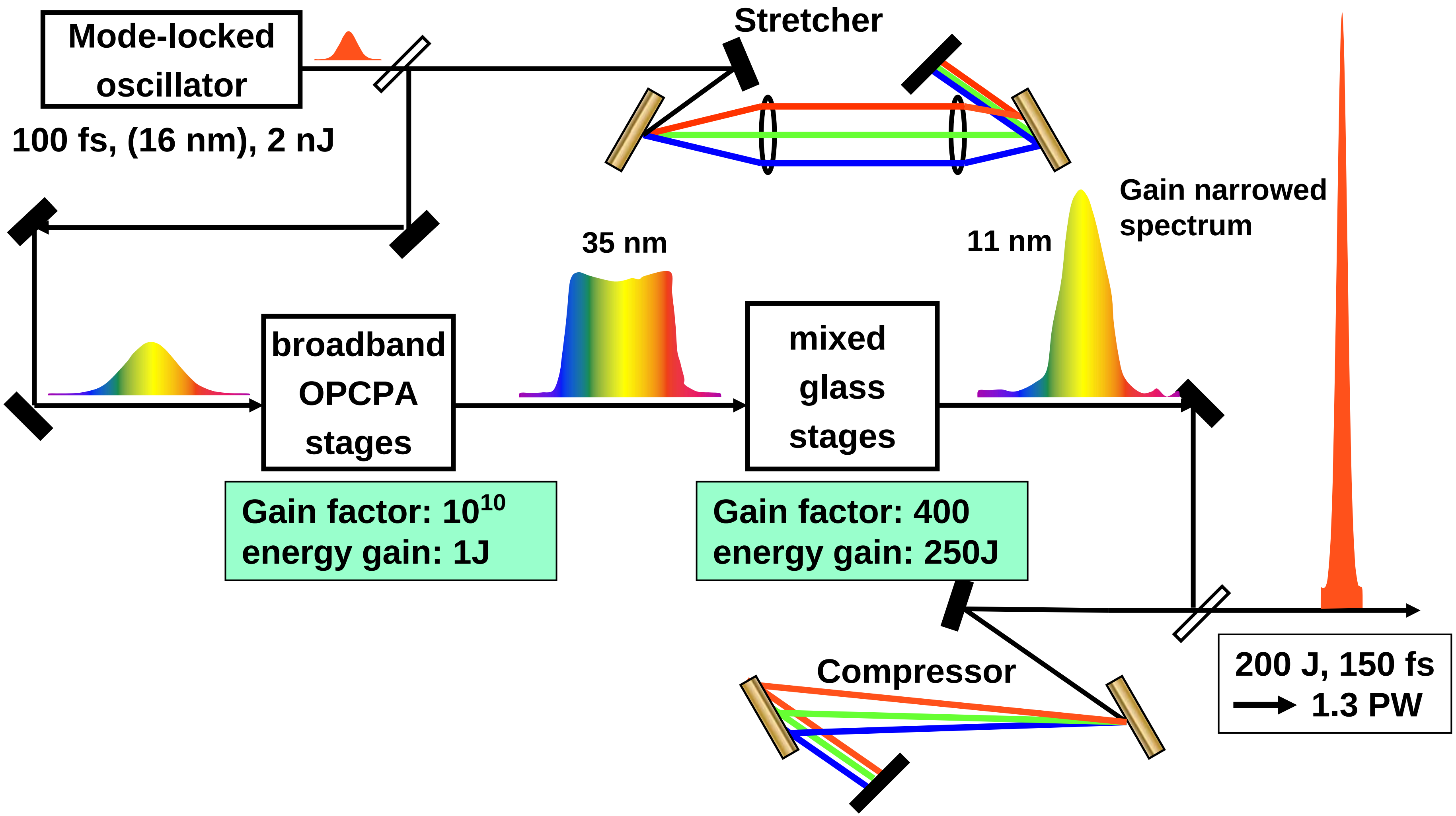
Laser driven particle acceleration



The Texas Petawatt Facility will have two lasers and multiple target areas

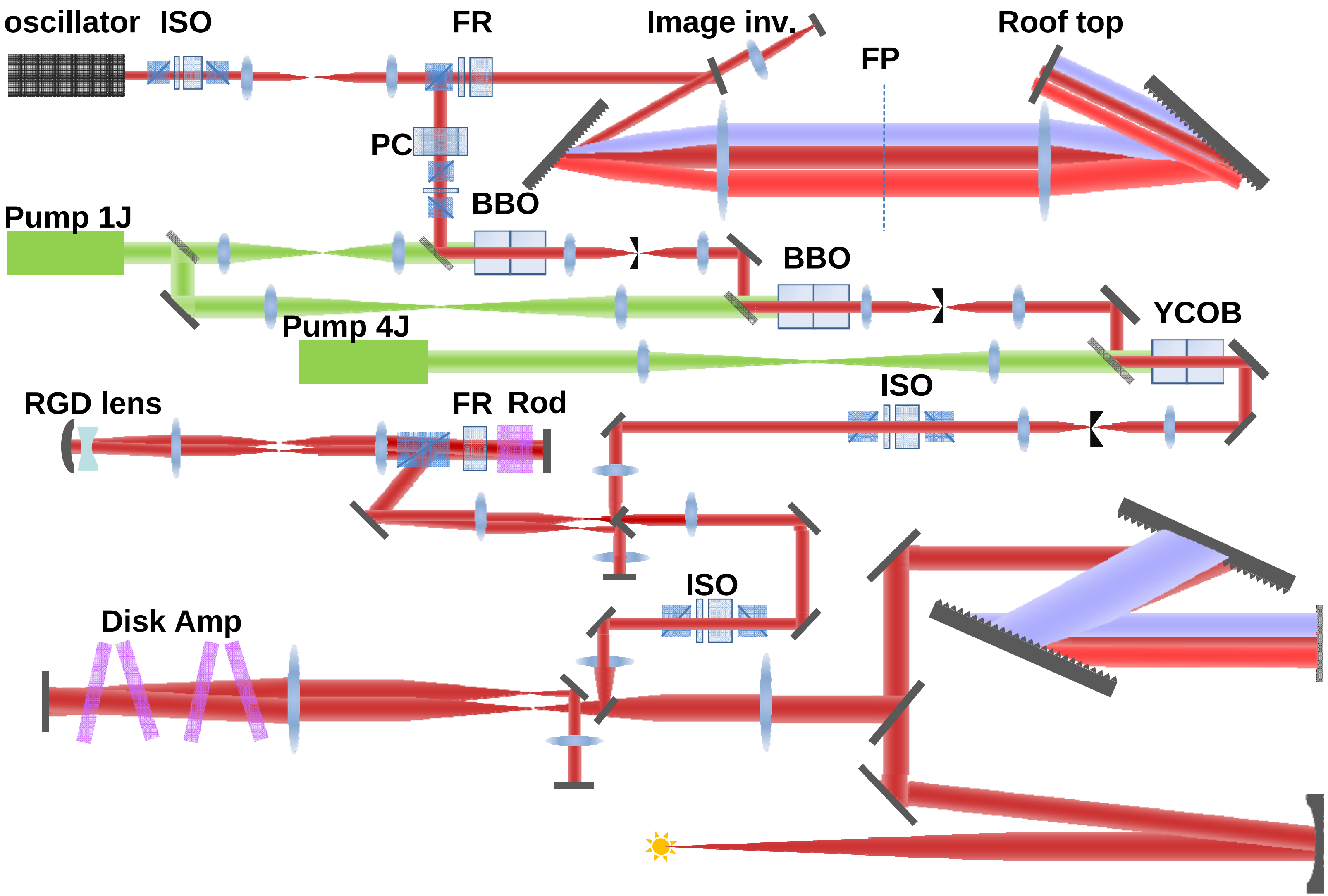


Optical Parametric Amplification and mixed glass amplification produces a new type of Petawatt laser

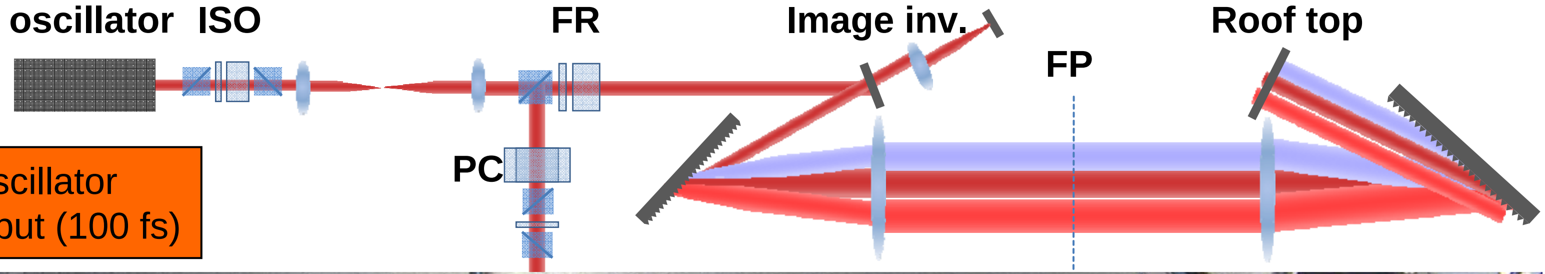


Goal: > 1 Petawatt

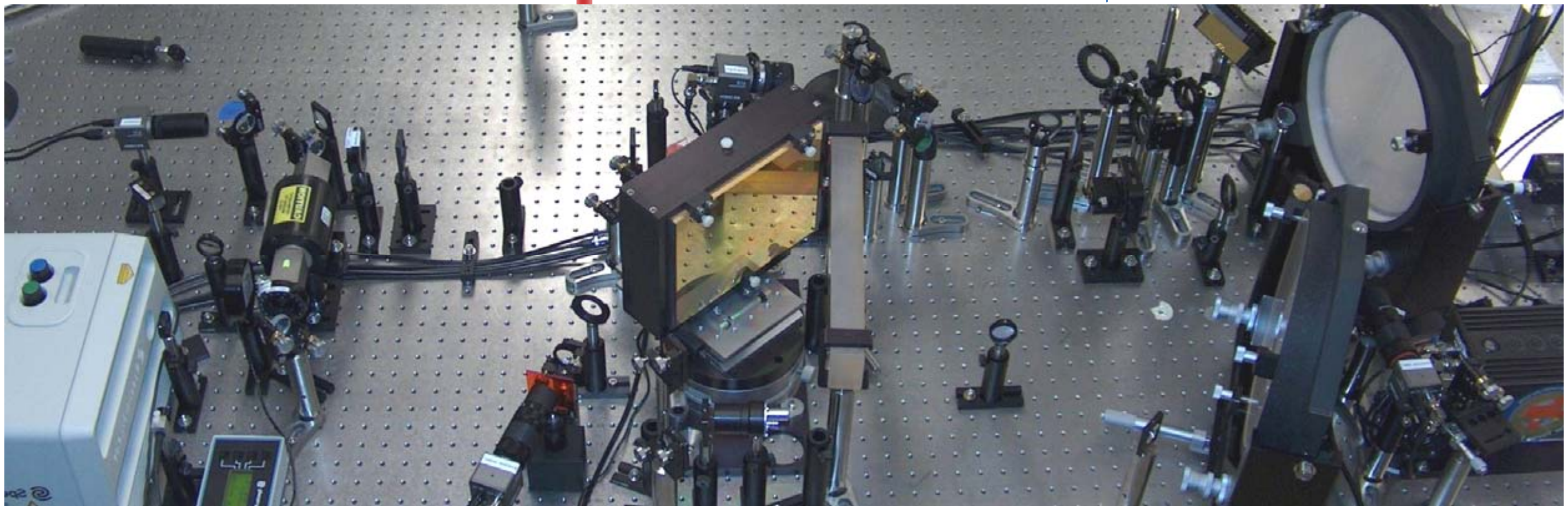
The Texas Petawatt laser uses three OPCPA and two Nd:glass amplifier stages



Stable oscillator and stretcher are important for reliable OPCPA operation



Oscillator Input (100 fs)

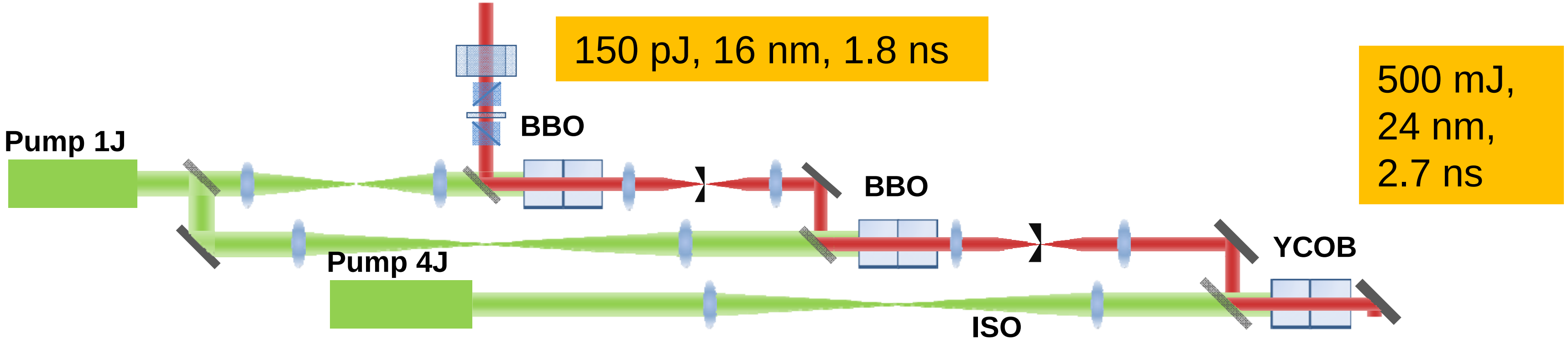


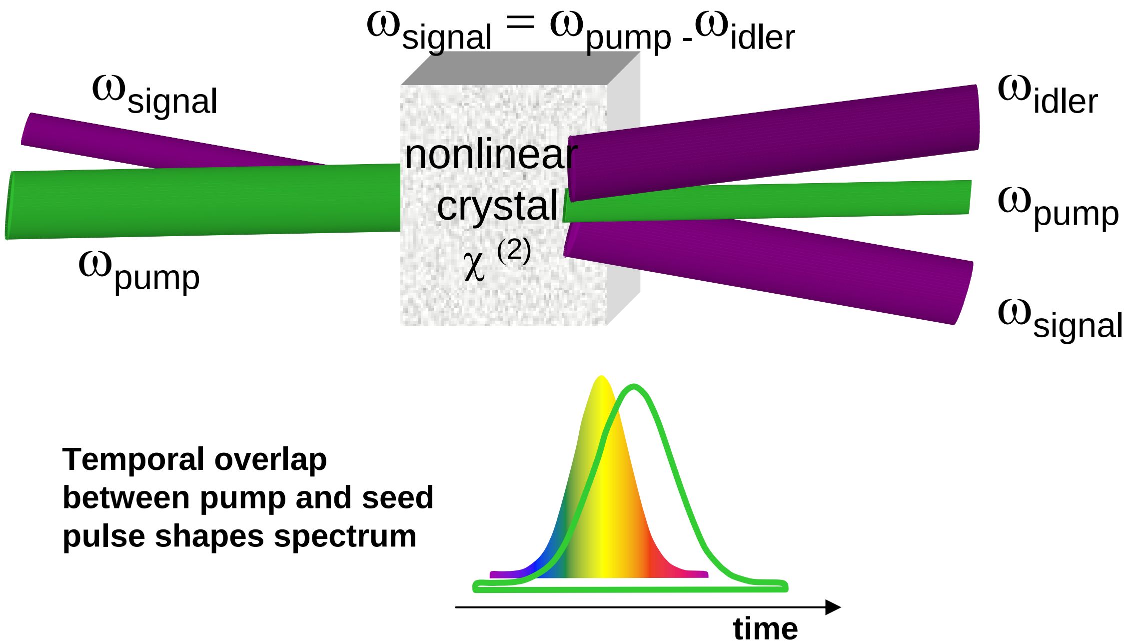
To OPCPA 1.8 ns

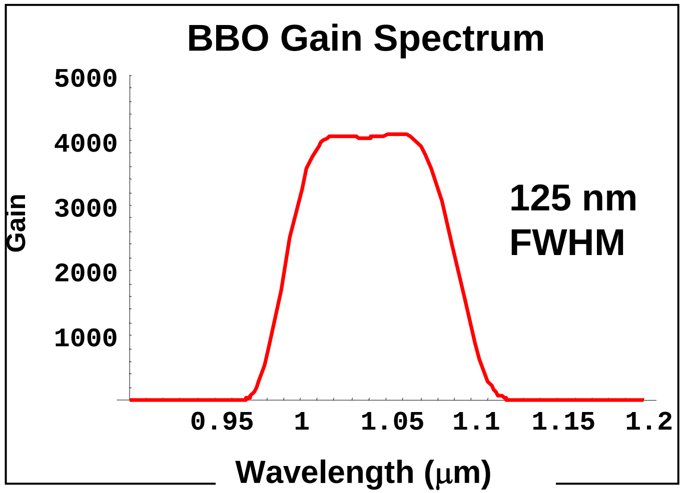
- Transmitted bandwidth: 1035 -1077 nm
- 2-pass stretcher (i.e. 8 grating reflections)
- 12 degrees separation angle
- Chirp: 116 ps/nm
- Image inversion corrects all aberration in 2nd pass !

Small changes in pointing, collimation, aberration, wavelength, timing… affect the output of the OPA stages

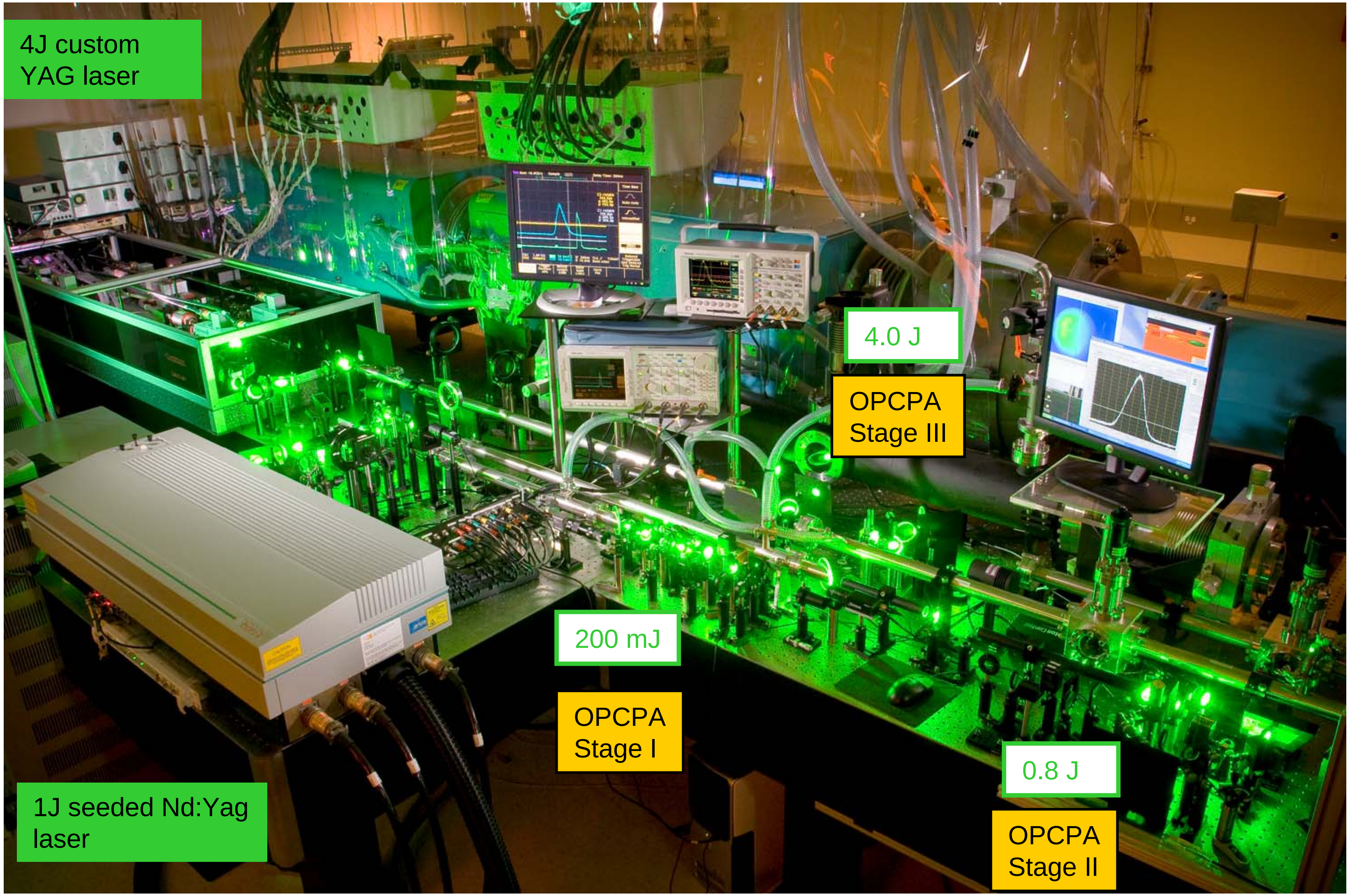
Optical Parametric Chirped Pulse Amplification provides 10^{10} gain and broadens the spectrum





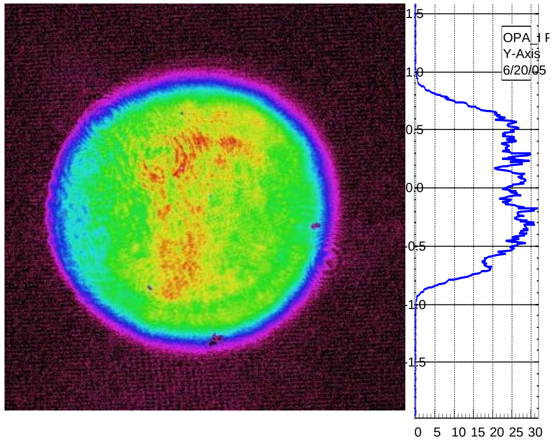


Two pump lasers were used to allow for separate timing between OPCPA stages II and III

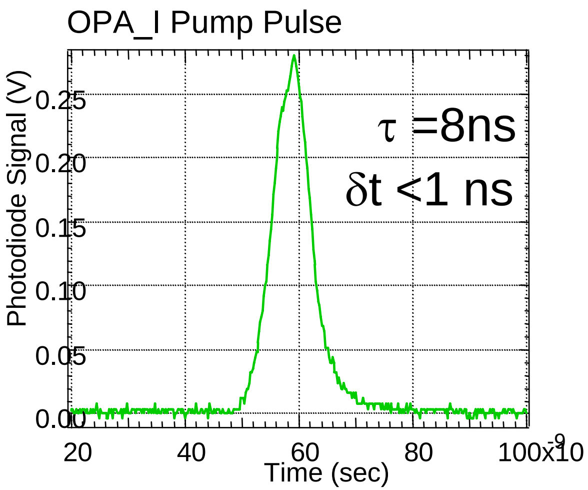


We have characterized all pump beam parameters which are crucial for stable OPCPA operation.

1J commercial laser

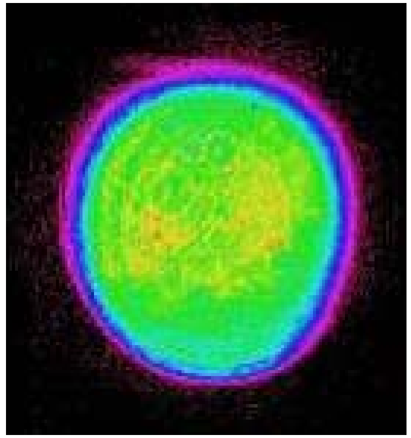


•spatial-temporal profile is important for uniform amplification of beam at all colors

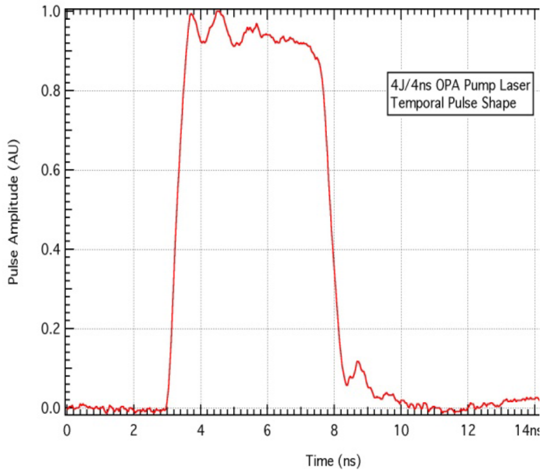


For more detail see poster session on Wednesday 15:20
Mikael Martinez *et al*
Novel, 1Joule Class, 2.5Hz, Broadband OPCPA Front End for High Intensity Laser Systems

4J custom laser

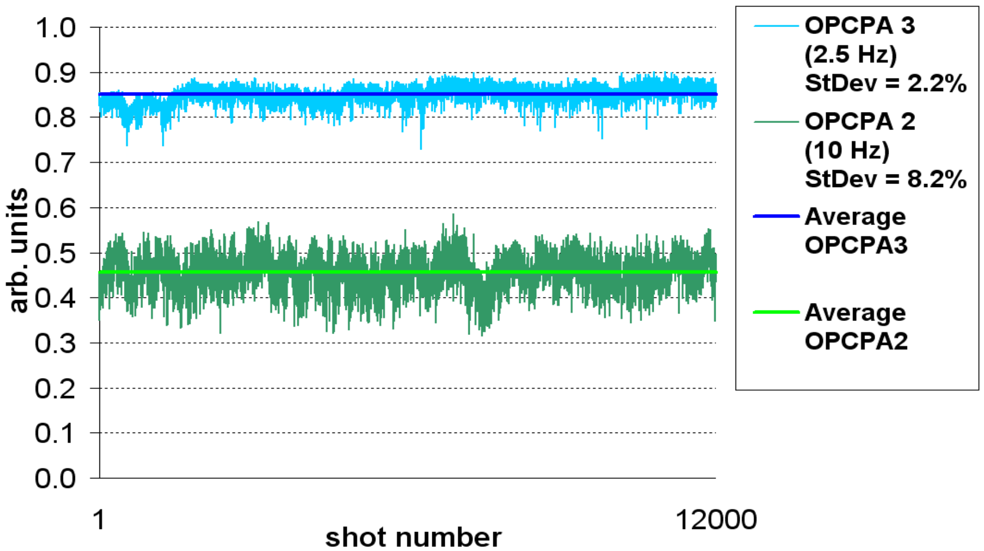


τ = 4.3ns timing <0.2 ns

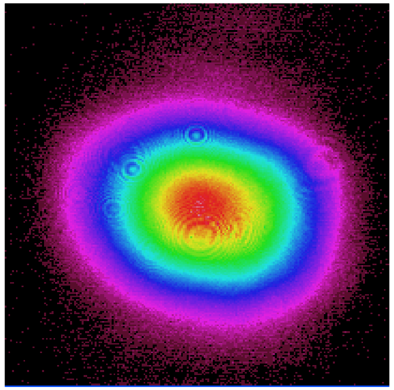


We have achieved good stability from the OPCPA

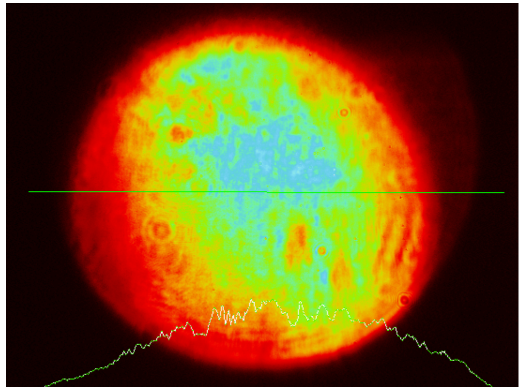
OPCPA output stability

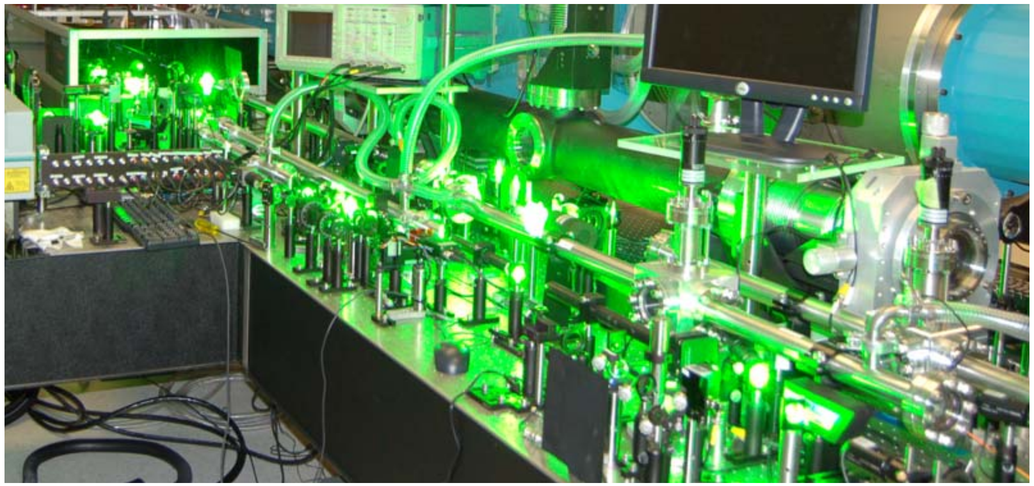


Nearfield stage II



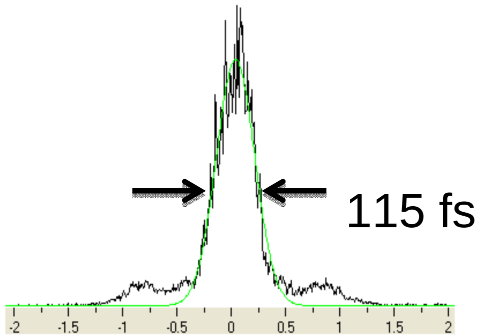
Nearfield stage III





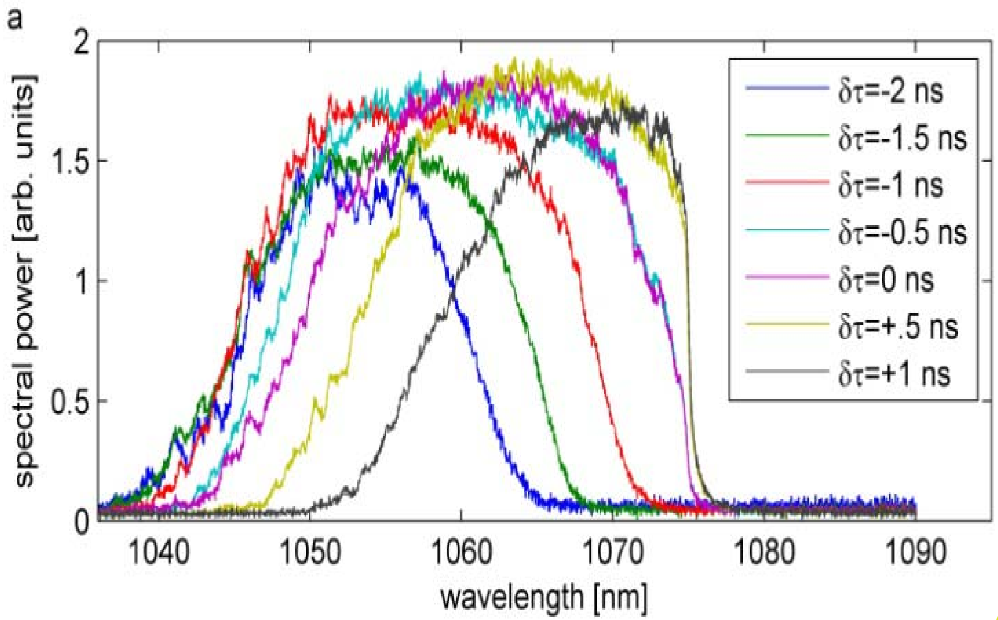
October 2008

Compression of OPCPA output in large compressor

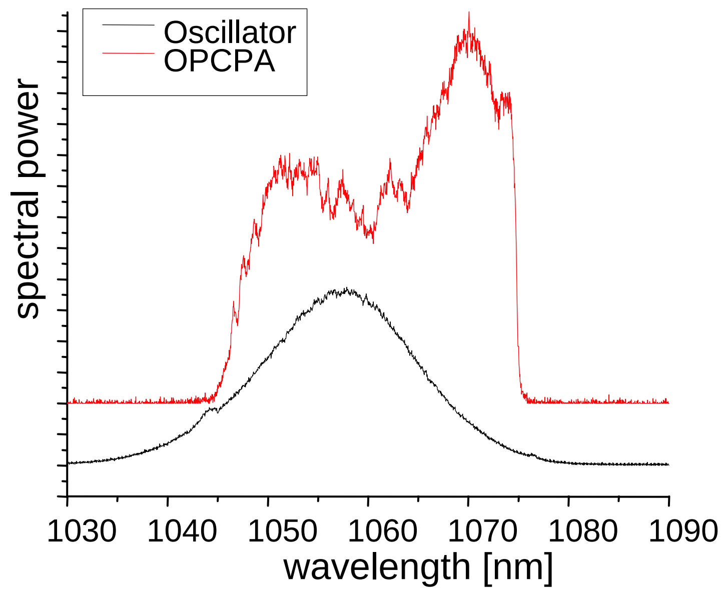


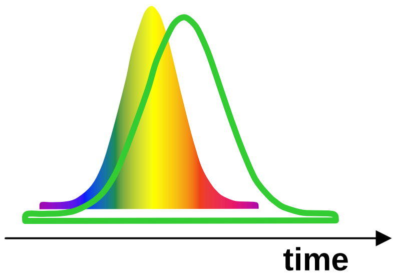
Spectral control in the OPCPA stages allows for broadening of the final bandwidth

Spectral saturation in stage II and shiftidgedue temporal overlap with the pump pulse.



Spectral preshaping or the pulse due temporal control of the 4 J pump pulse.





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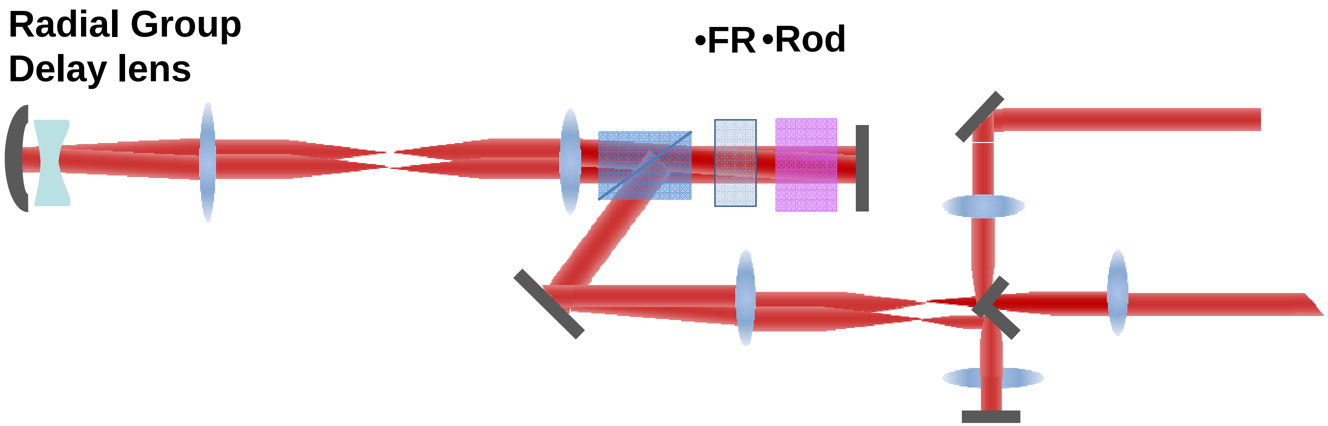
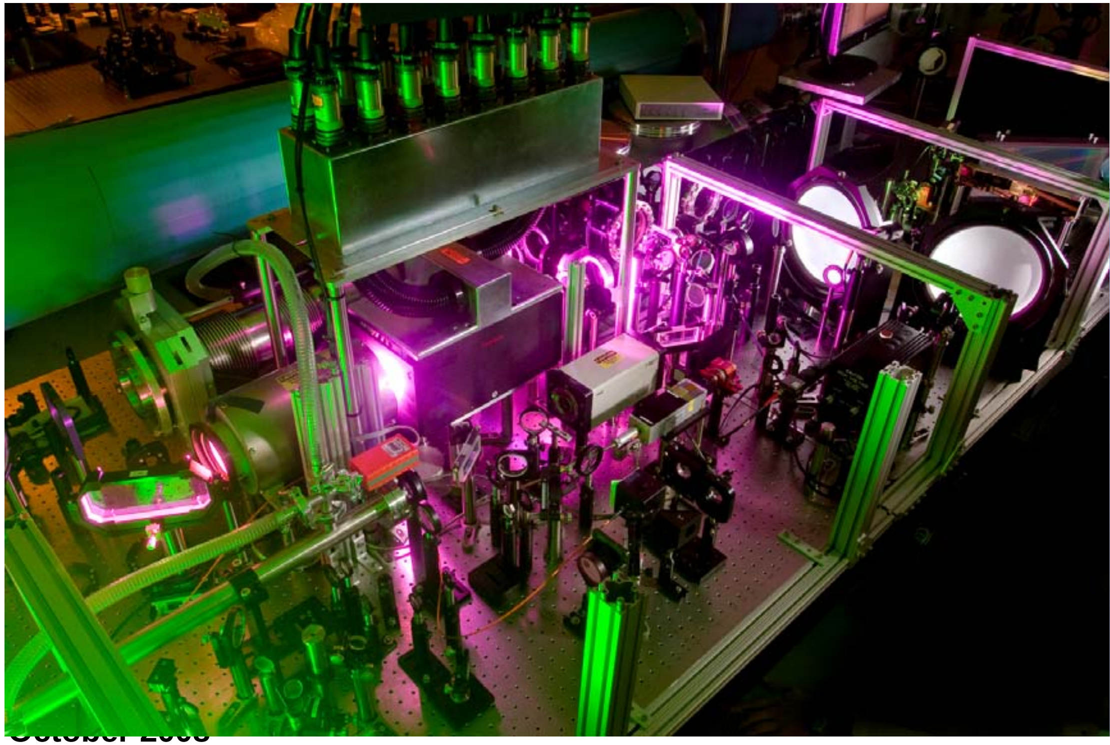
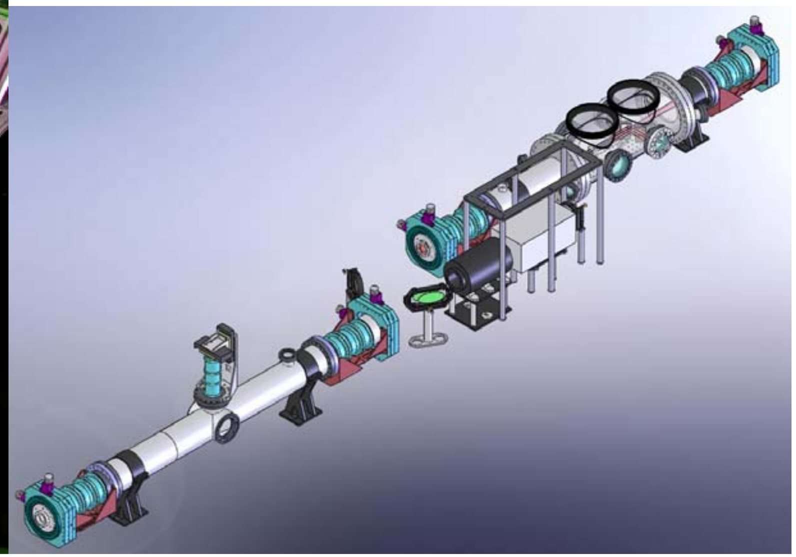
An 8-pass, 64 mm, silicate Nd:glass rod amplifier brings the energy up to 20 J

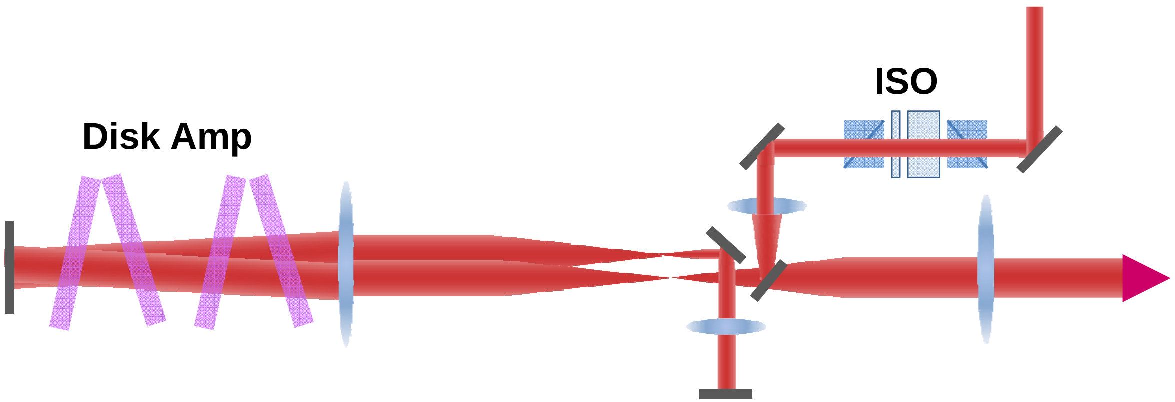


- up to 27 J achieved,
- 15-18 J goal for compression and low B-integral



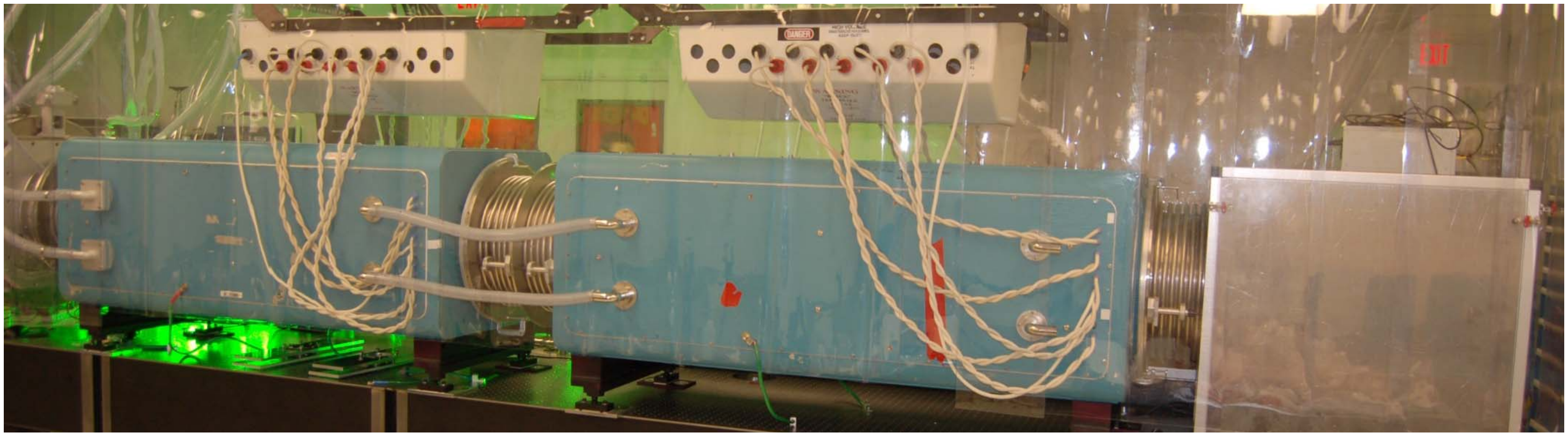


The final amplifier use two Nova amplifiers with phosphate Nd:glass disks



315 mm Phosphate Nd:glass disk

- up to 248 J achieved, with 80% charge voltage
- Energy limited by gratings, not by gain.



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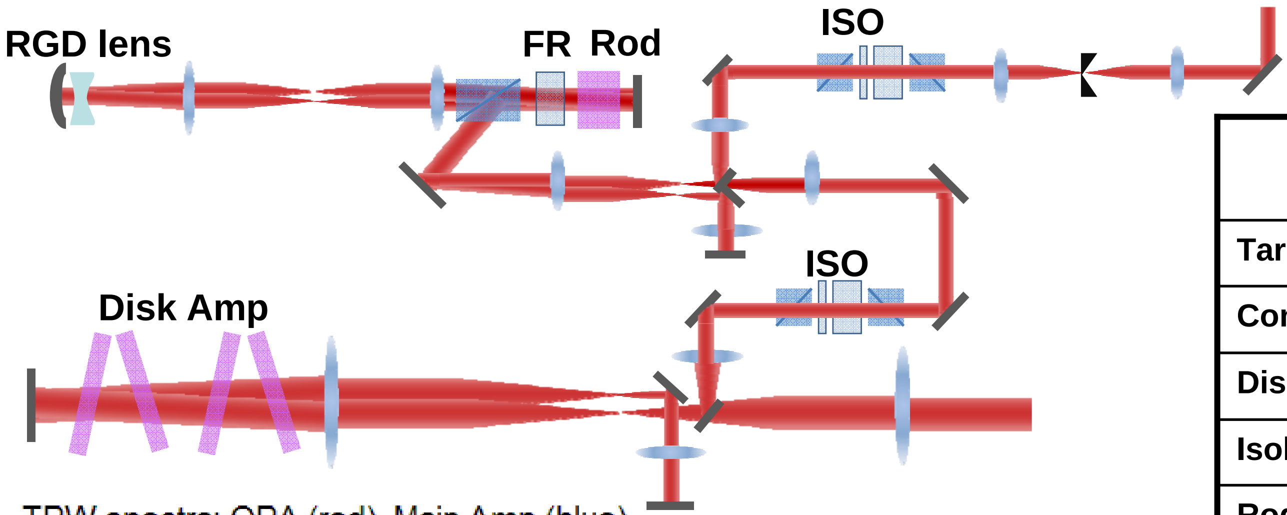
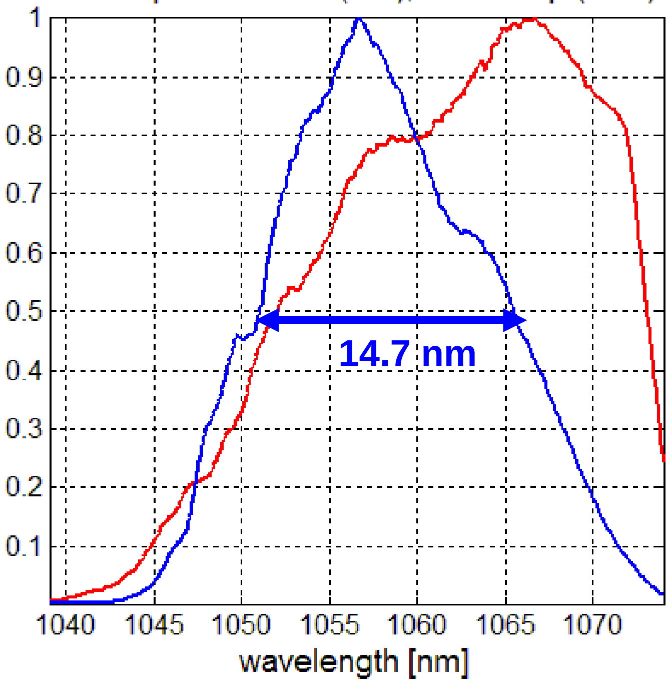
Mixed Nd:glass and relatively low net gain help amplify with high bandwidth fidelity

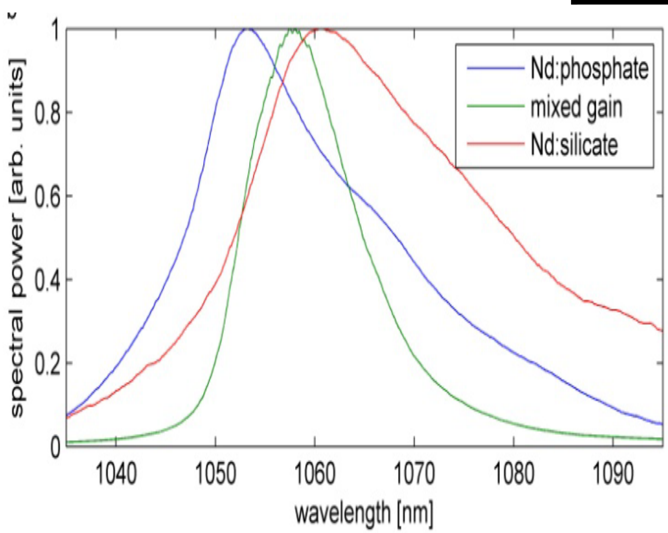


Isolation from up to 1% back scattered energy

	Gain	Energy [J]	Fluence [J/cm2]
Target	0.01	2	0.006
Compressor	filter	2	0.006
Disk amp	16	32	2.7
Isolator	0.01	0.32	0.03
Rodamp	25	8	3.2
Isolator	0.01	0.08	0.05

TPW spectra: OPA (red), Main Amp (blue)





Nd:Silicate Glass

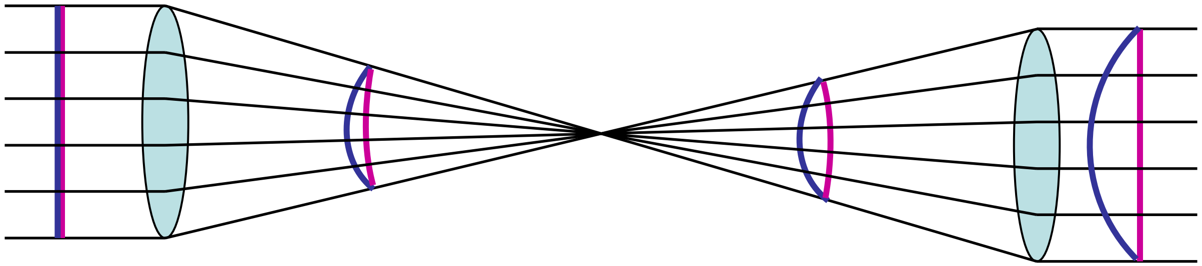
- Peak emission is 1.062 mm
- Line width is 28.5 nm
- 8-pass in 64 mm rod amplifier

Nd:Phosphate Glass

- Peak emission is 1.054 mm
- Line width is 27.5 nm
- 4-pass in 315 mm disk amplifier

Radial group delay of pulse front caused by large lenses must and can be corrected

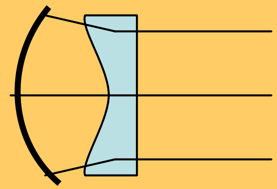
Problem:



Phase front: $v_{phase} = c/n$ → Phase front is flat for proper imaged system

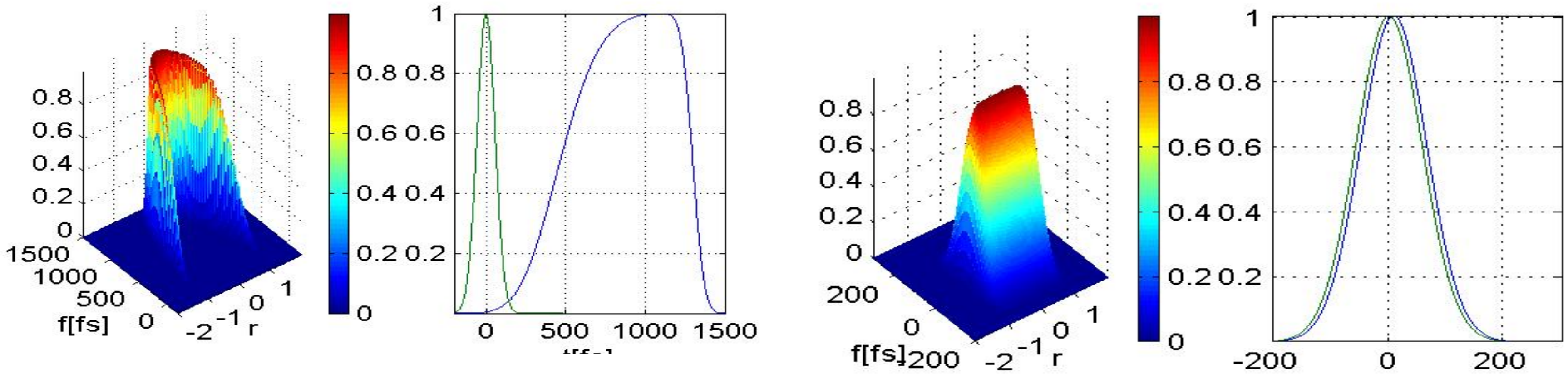
Pulse front: $v_{group} = c/(n-\lambda\, dn/d\lambda)$ → Pulse front needs correction ($\phi_1(x,y)$=const)

Solution requires:
$(\lambda\, dn/d\lambda)_{system} = 0$



We have a negative lens/ aspheric mirror to correct this problem and built an special autocorrelator to measure Radial group delay

Pulse broadening of 5th order super-Gauss with ~70% fill factor



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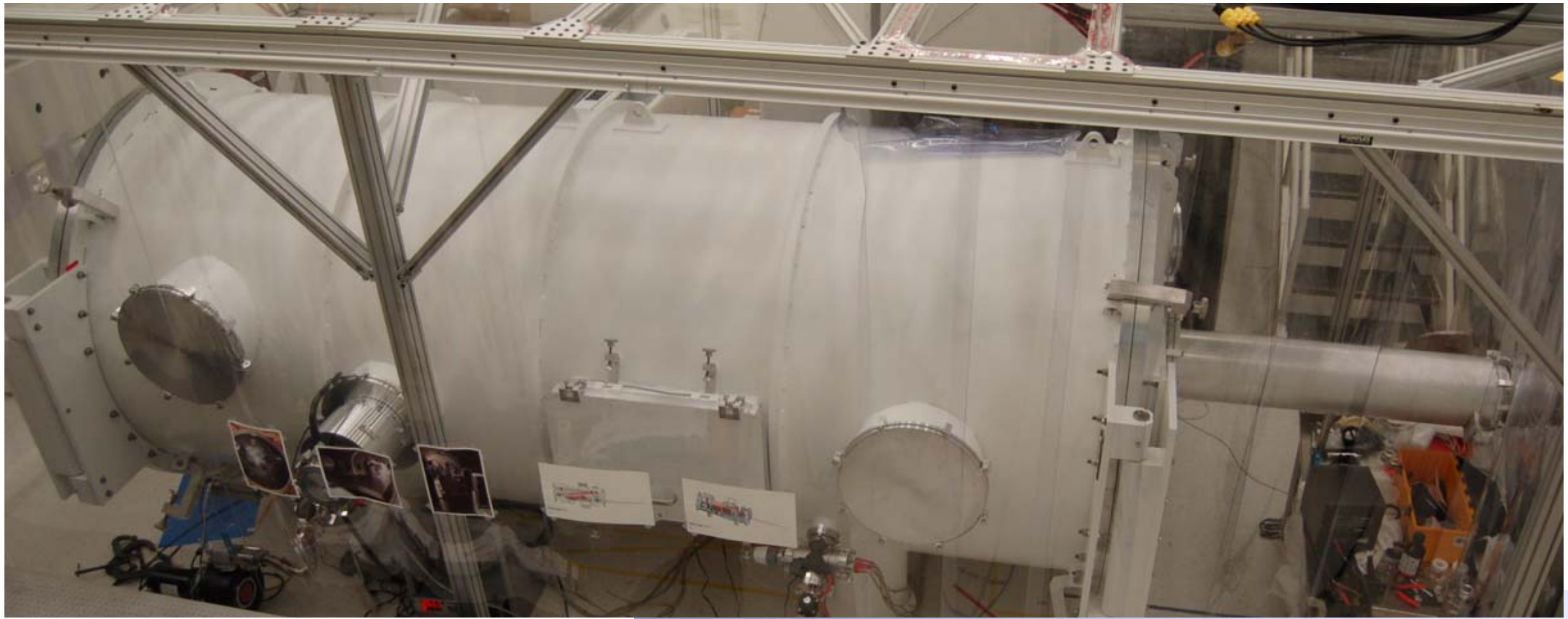
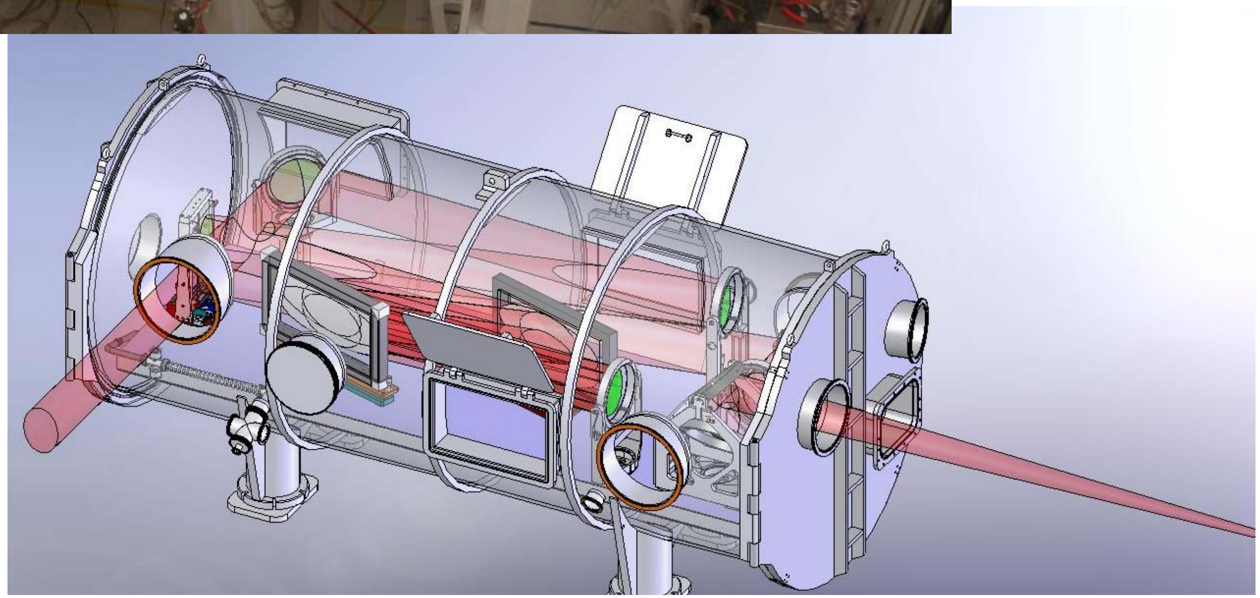
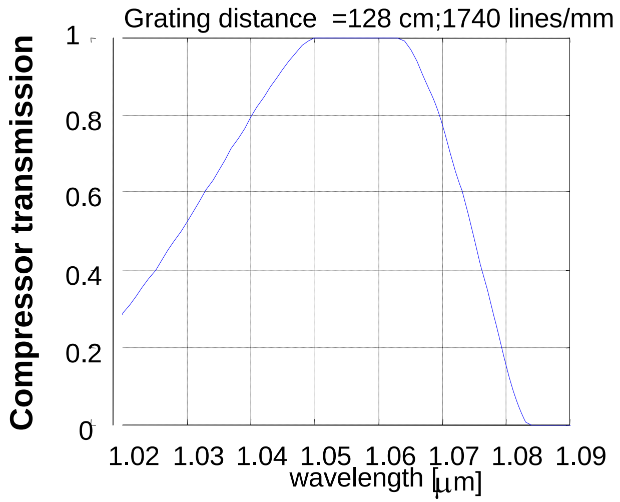
The compressor is inside a 6x14 ft Aluminum vacuum chamber



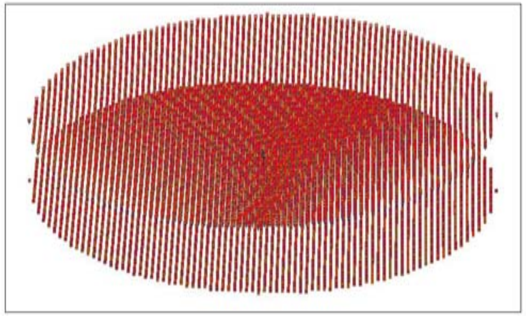


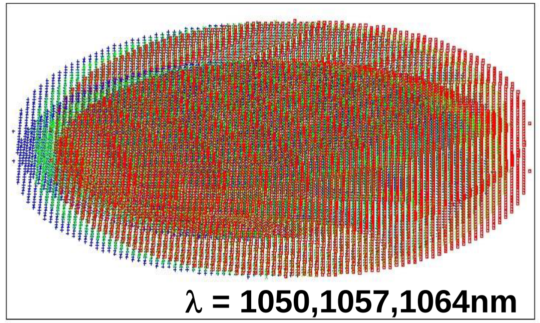
Aluminum was chosen for radiation safety due to the proximity to target. Chamber has been evacuated below 10-6 Torr fully equipped.

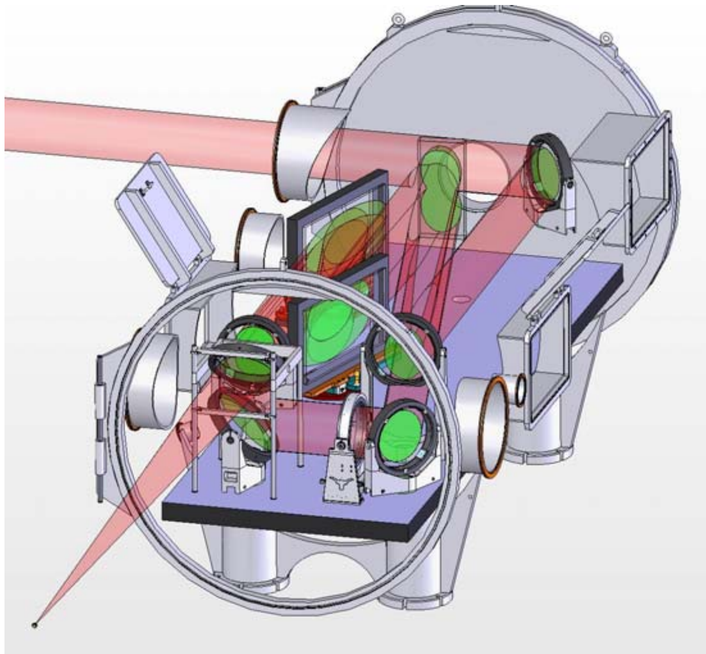
The Compressor has 85% efficiency with MLD (Multi Layer Dielectric) Gratings from LLNL

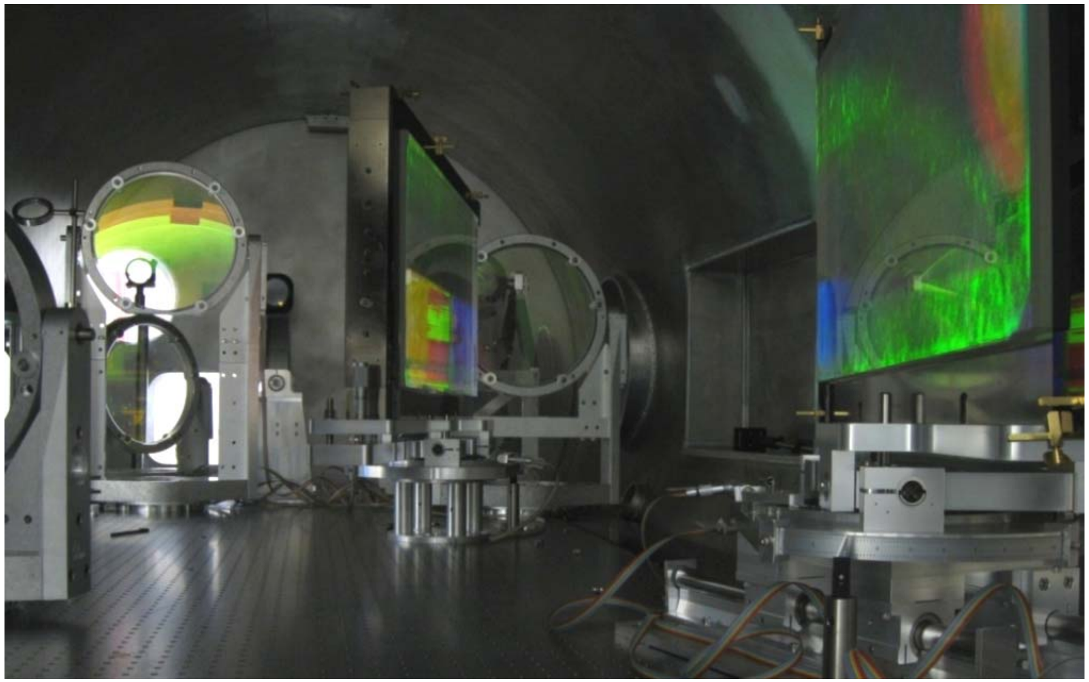


Footprints of beam of both passes overlap partially for efficient use of gratings (405x805 mm² at 1740 l/mm)



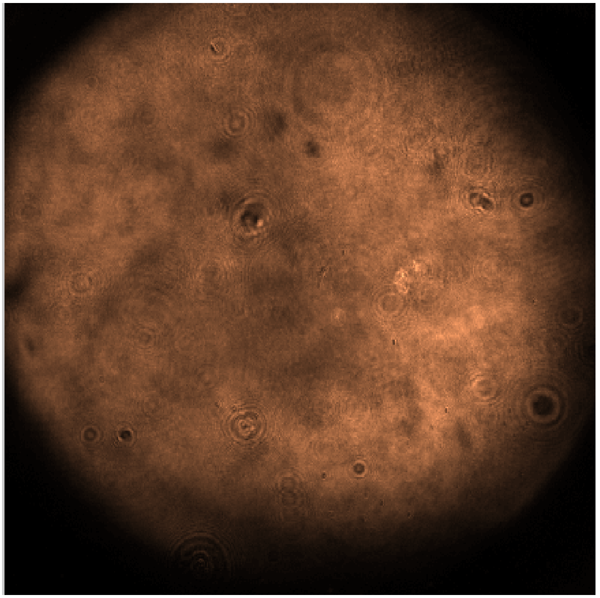




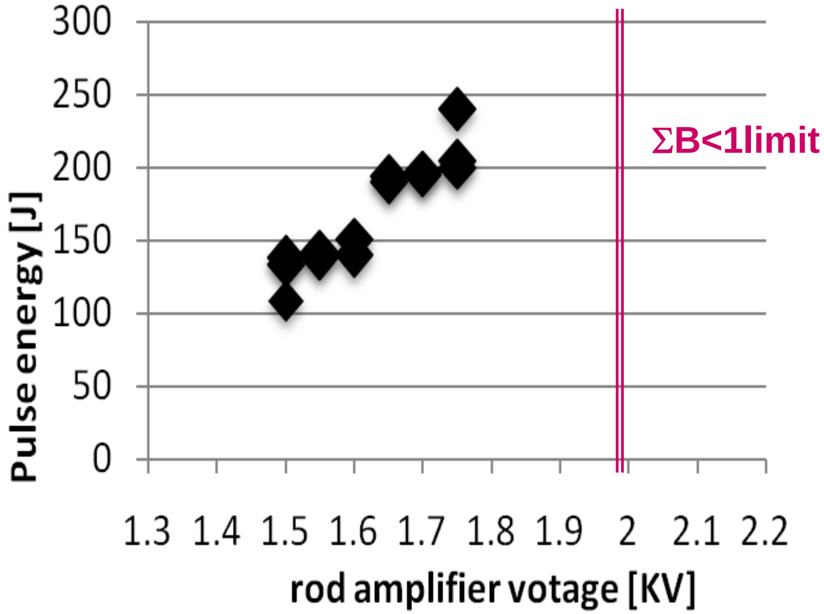


We achieved nearly 200 J compressed energy

186 J compressed nearfield (at 167 fs)



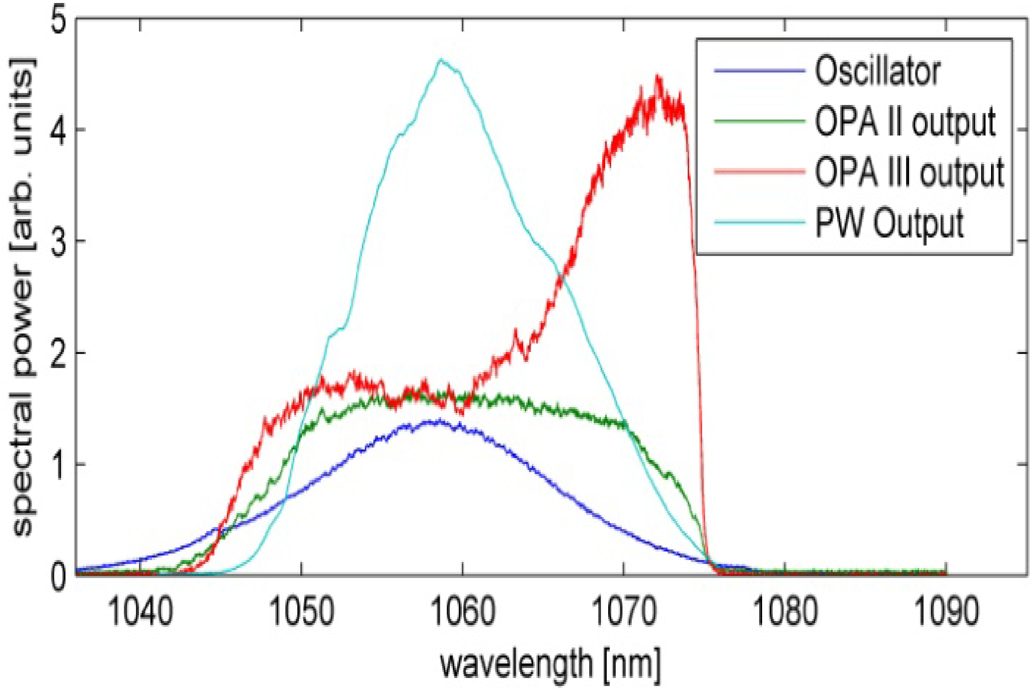
Energy at 17.5 kV main amp voltage (out of 22kV)



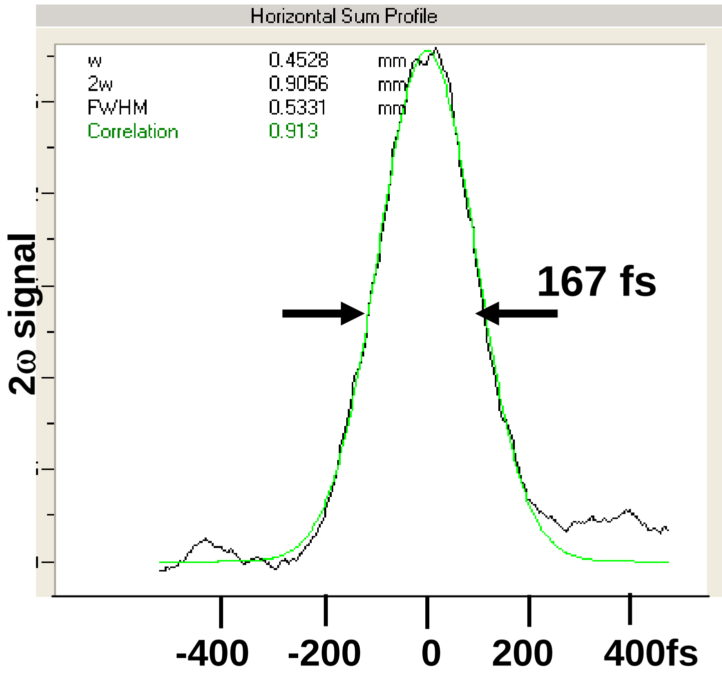
Gratings have been conditioned with > 100 shots between 50-200 J.
Peak beam fluence <0.8 J

Energy is with +/- 10% of target energy, fluctuation are due to spectral shift from timing of first pump laser.
The energy was measured of fused silica reflections near 0 degree.

We have achieved 1.1 PW laser pulses

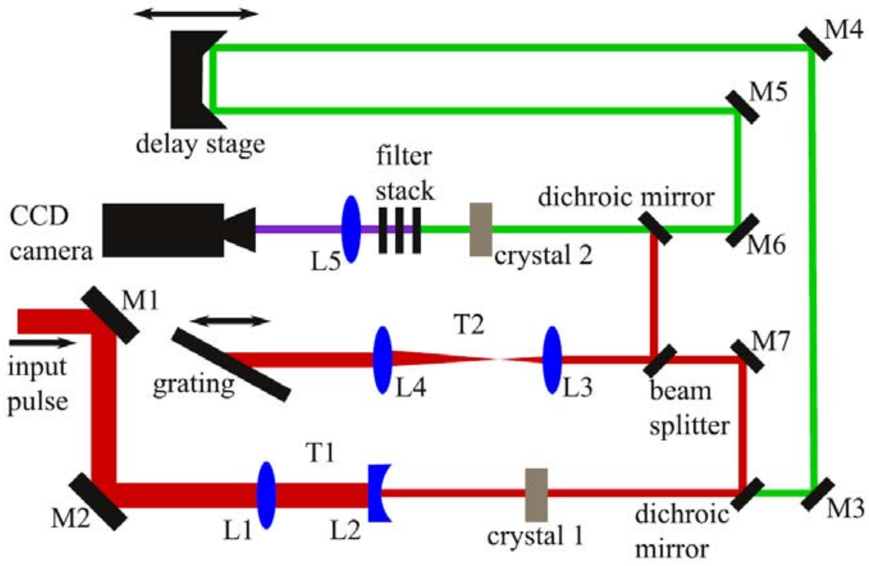


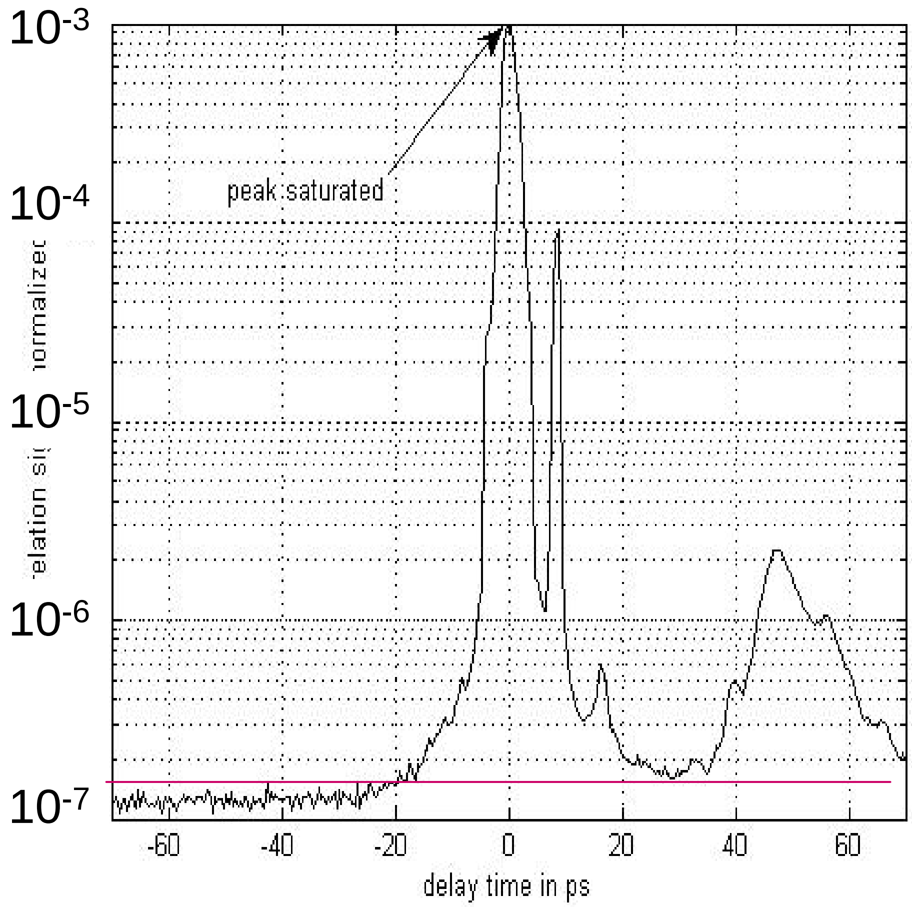
Second order autocorrelation and (assumed) Gaussian fit



We have made a preliminary contrast measurement on the GHOST OPCPA-Glass hybrid laser

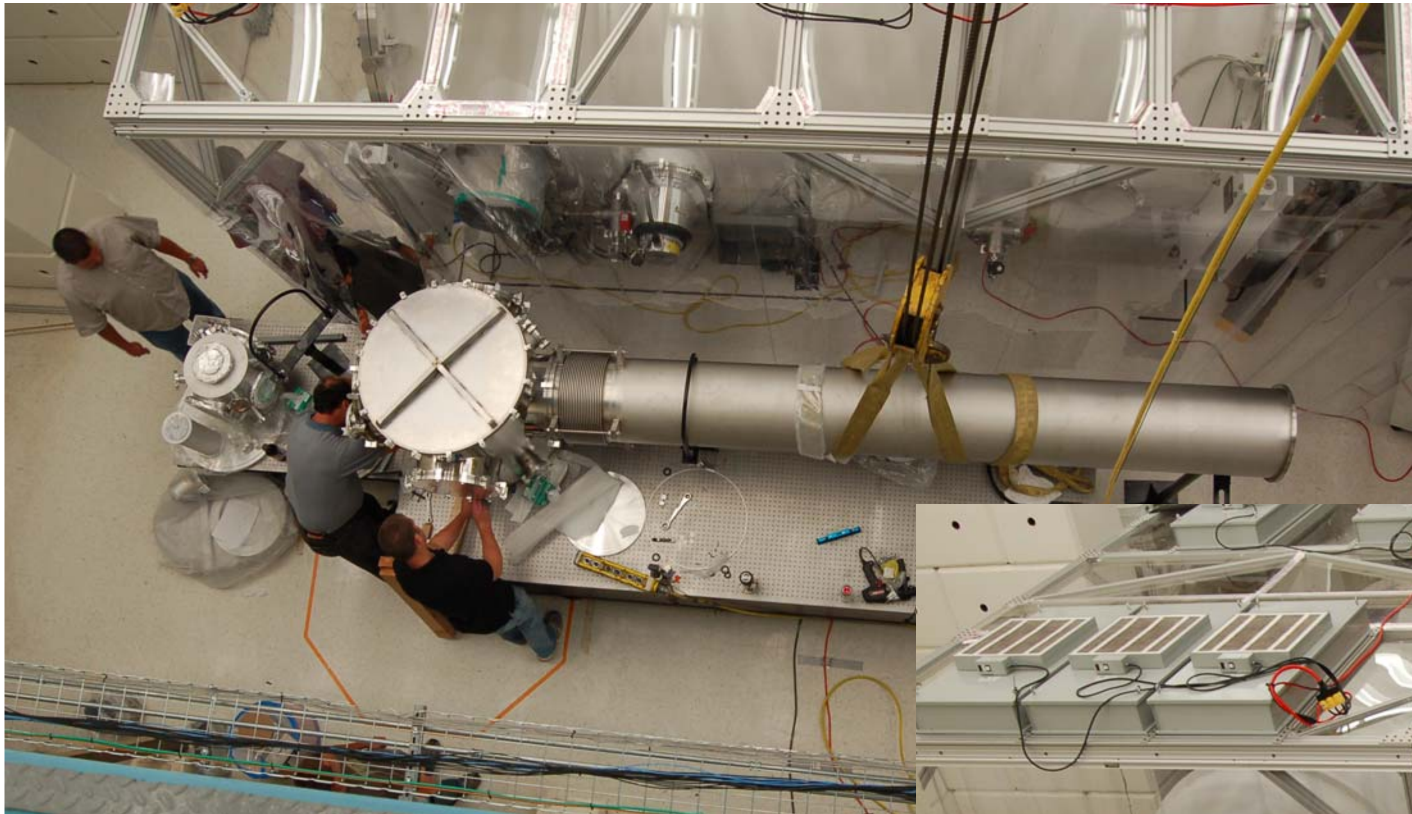
Single shot third order autocorrelator

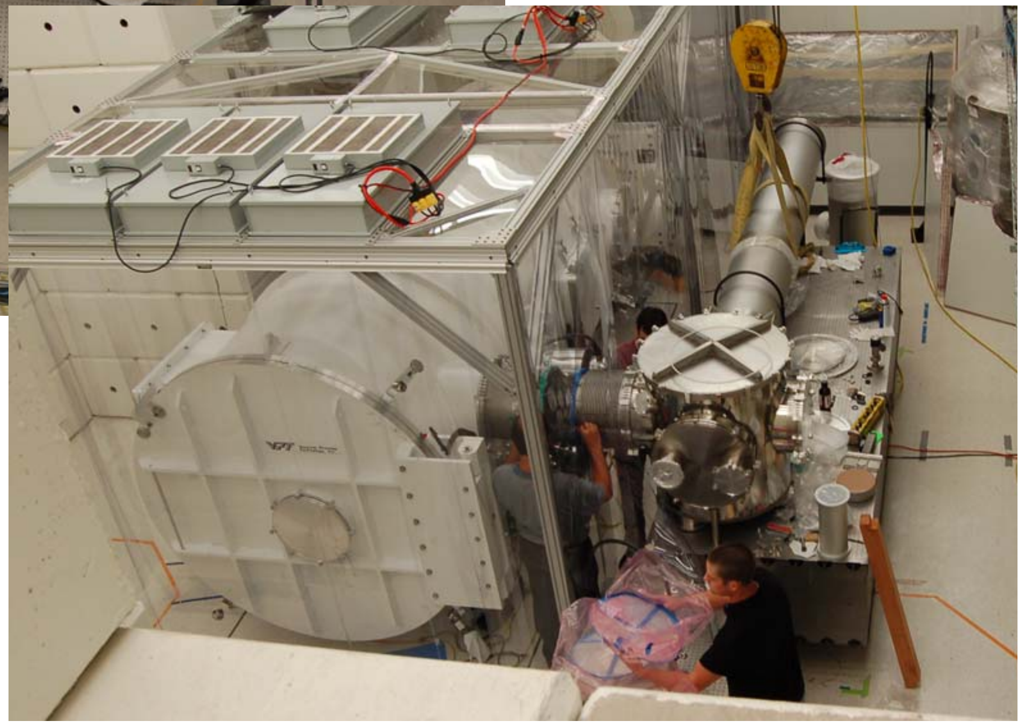




- data taken on OPCPA - mixed glass laser (GHOST: 50mJ OPA, 3 J Glass) at UT by J. Schmidt ***et al***
- **Contrast better than 10^7 at 20ps**
- **Parasitic Fluorescence level is typically lower on the TPW despite higher gain**

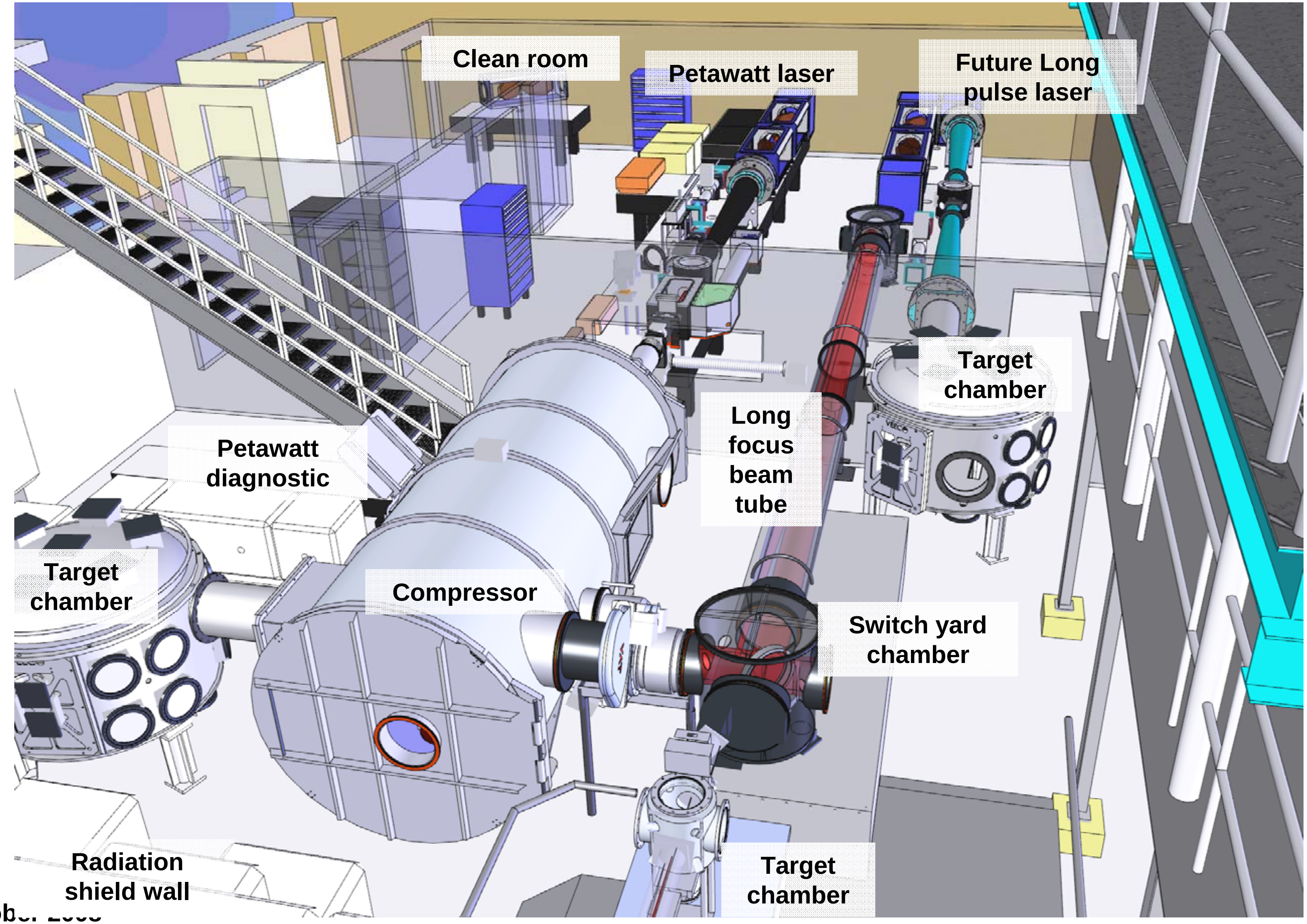
The beamline and target chamber for the long focusing geometry (F/40) have been installed





- Intensity is still 10^{19} W/cm^2
- Long interaction in gas (several cm)
- Focusing optic is outside the target chamber
- Pointing might be an issue, but <10 μrad required for good pulse compression

We will build a 2-100ns long pulse laser to compliment the Texas PW laser



Summary

- We have achieved 1.1 PW (186 J, 167 fs) laser pulses.
- In 9 cm of material we achieved 10 orders of magnitude gain, saturated the pulse to broaden and control the spectrum. We extracted up to 250J and >14 nm bandwidth out of mixed glass amplifiers seeded by broadband pulses. This is sufficient for 1.5 PW pulses after compression.
- We efficiently compressed pulses with MLD gratings compressor.
- A beamline with F#/40 focusing geometry has been setup for experiments (Nov 08)
- The university of Texas lit up its tower orange for the PW dedication (August/08)