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The Titan Laser at LLNL

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May 22, 2006

CLEO
Long Beach, CA, United States
May 21, 2006 through May 26, 2006

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The Titan Laser at LLNL

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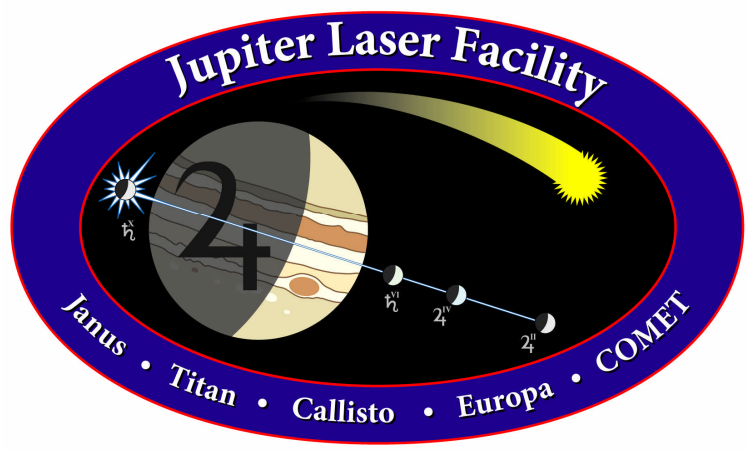
NATIONAL IGNITION FACILITY

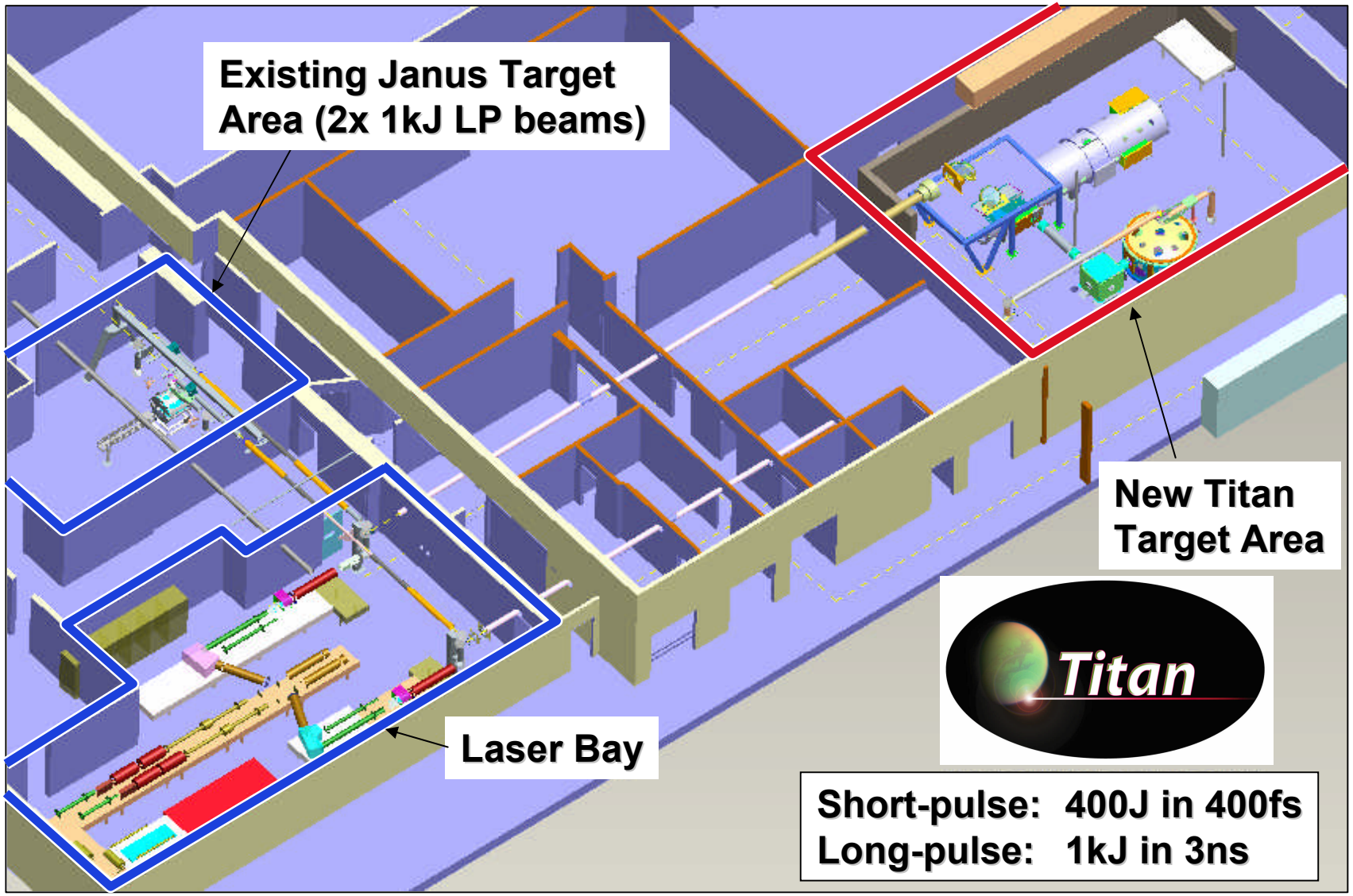
Physics & Advanced Technologies

Titan brings high-energy short-pulse capability to the Jupiter facility

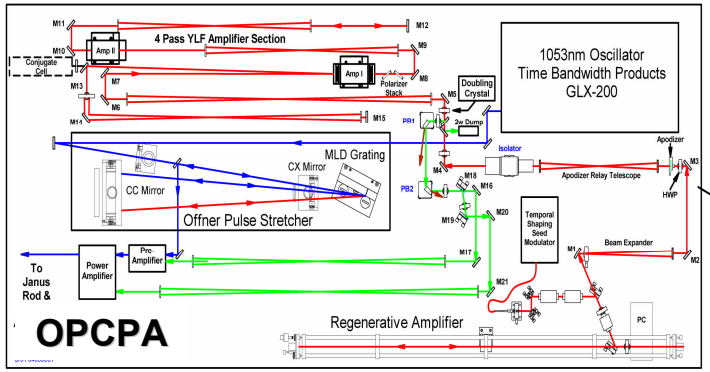


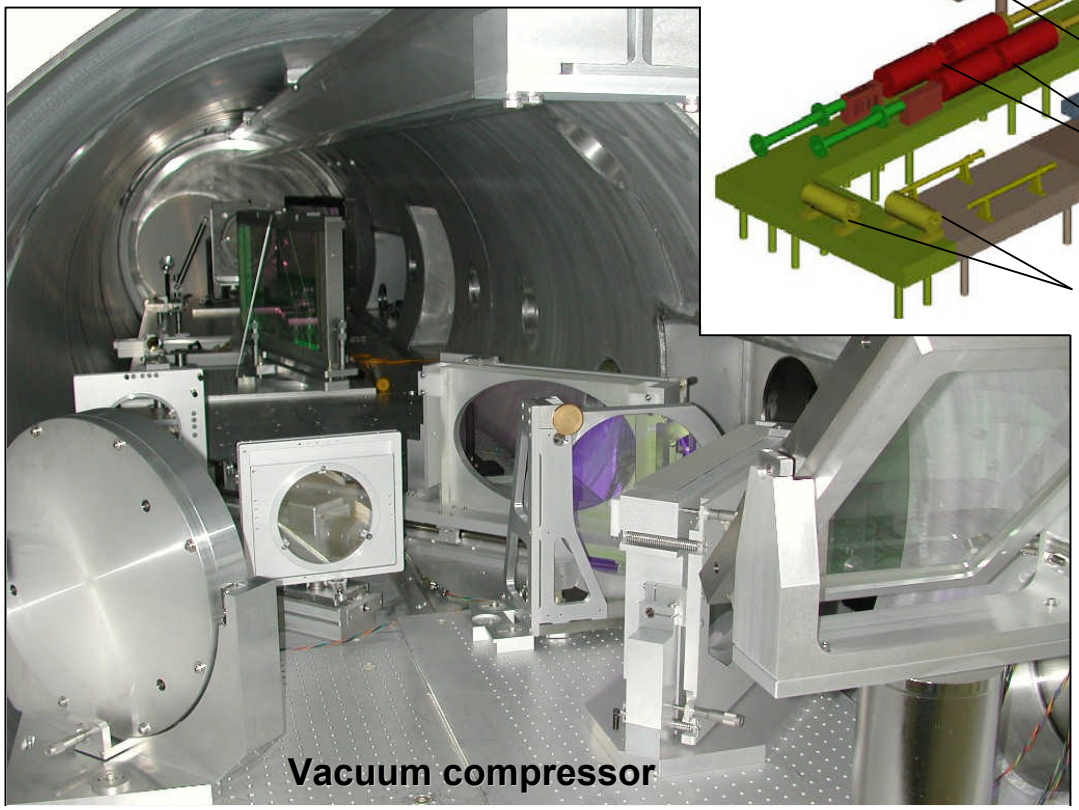
System	λ (nm)	E (J)	rep	pulse duration
Janus	1053, 527	2x1 kJ	2/hr	0.1-6 ns
Callisto (JanUSP)	800 (400)	15 (7)	3/hr	80-100 fs
Europa (USP)	800, 400	0.1	10 Hz	80-100 fs
COMET	1053	15 (7.5)	3/hr	600 ps (0.5 ps)
Titan (in progress)	1053	400 (650)	2/hr	400 fs (10 ps)
	1053, 527	1 kJ	2/hr	0.1-6 ns

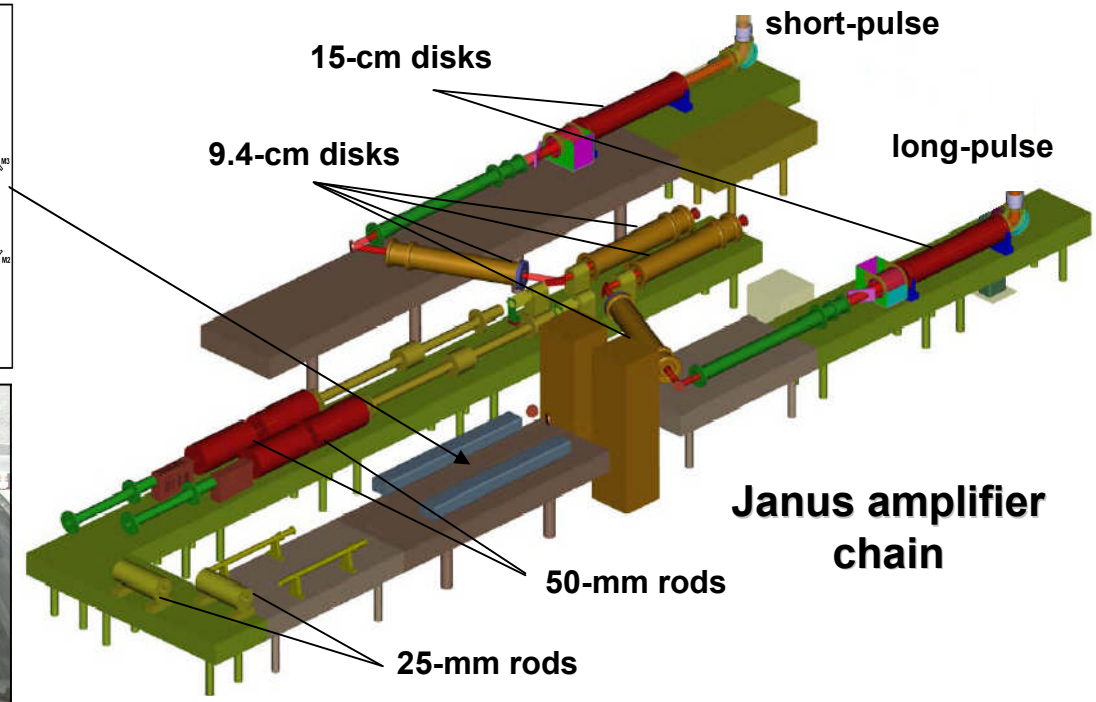
Titan couples a high-energy Petawatt-class laser with a kJ long-pulse drive laser



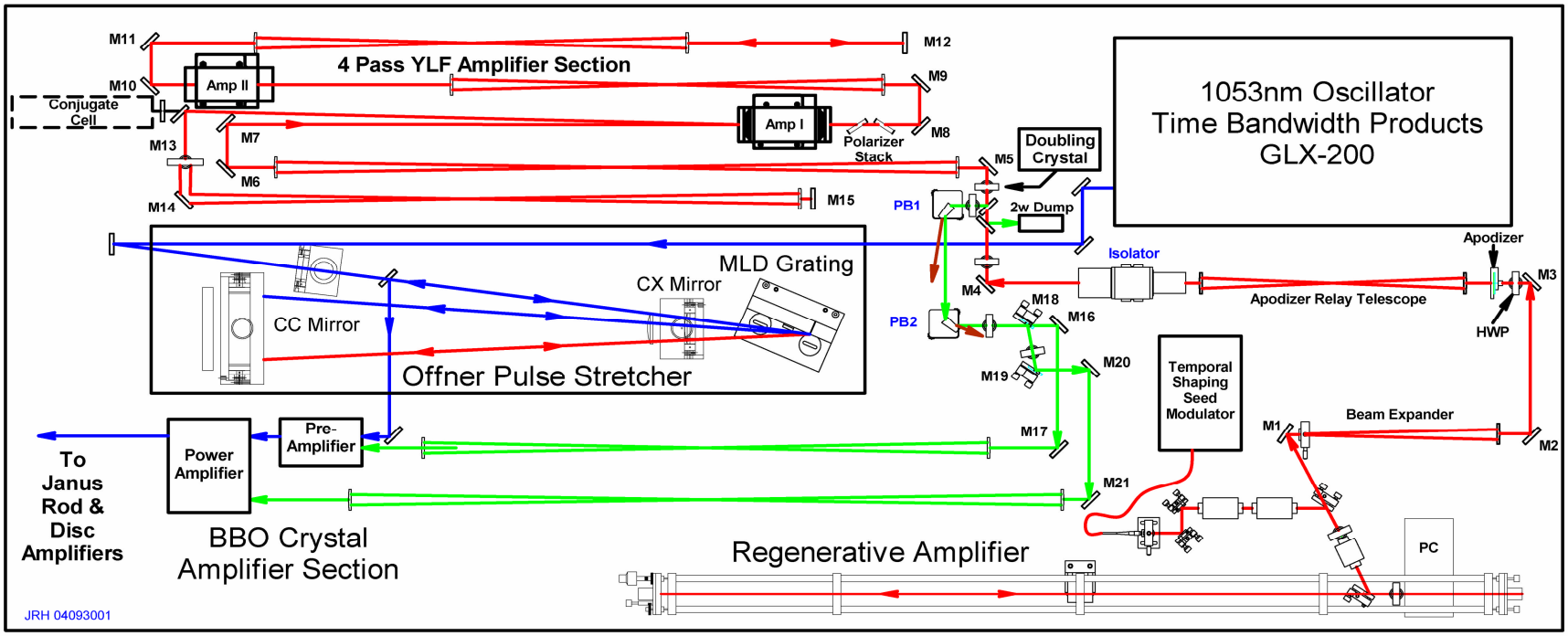
Titan has utilized both existing and new technologies in its design and construction





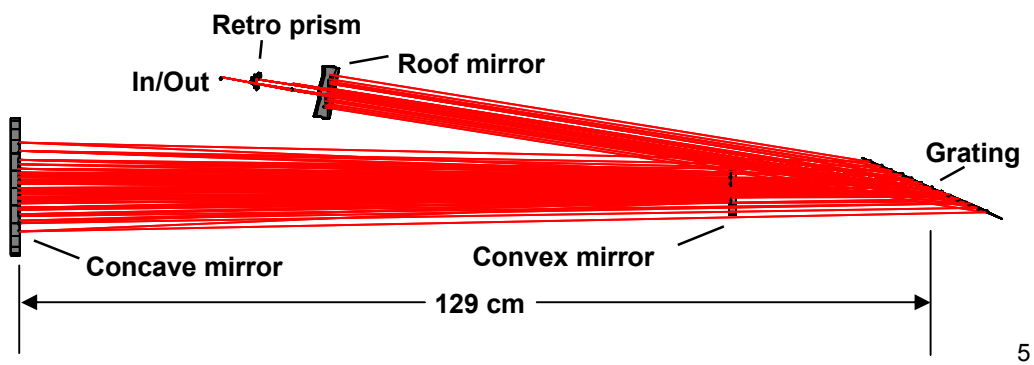


Titan front-end includes a custom pump laser and 2 stages of OPCPA



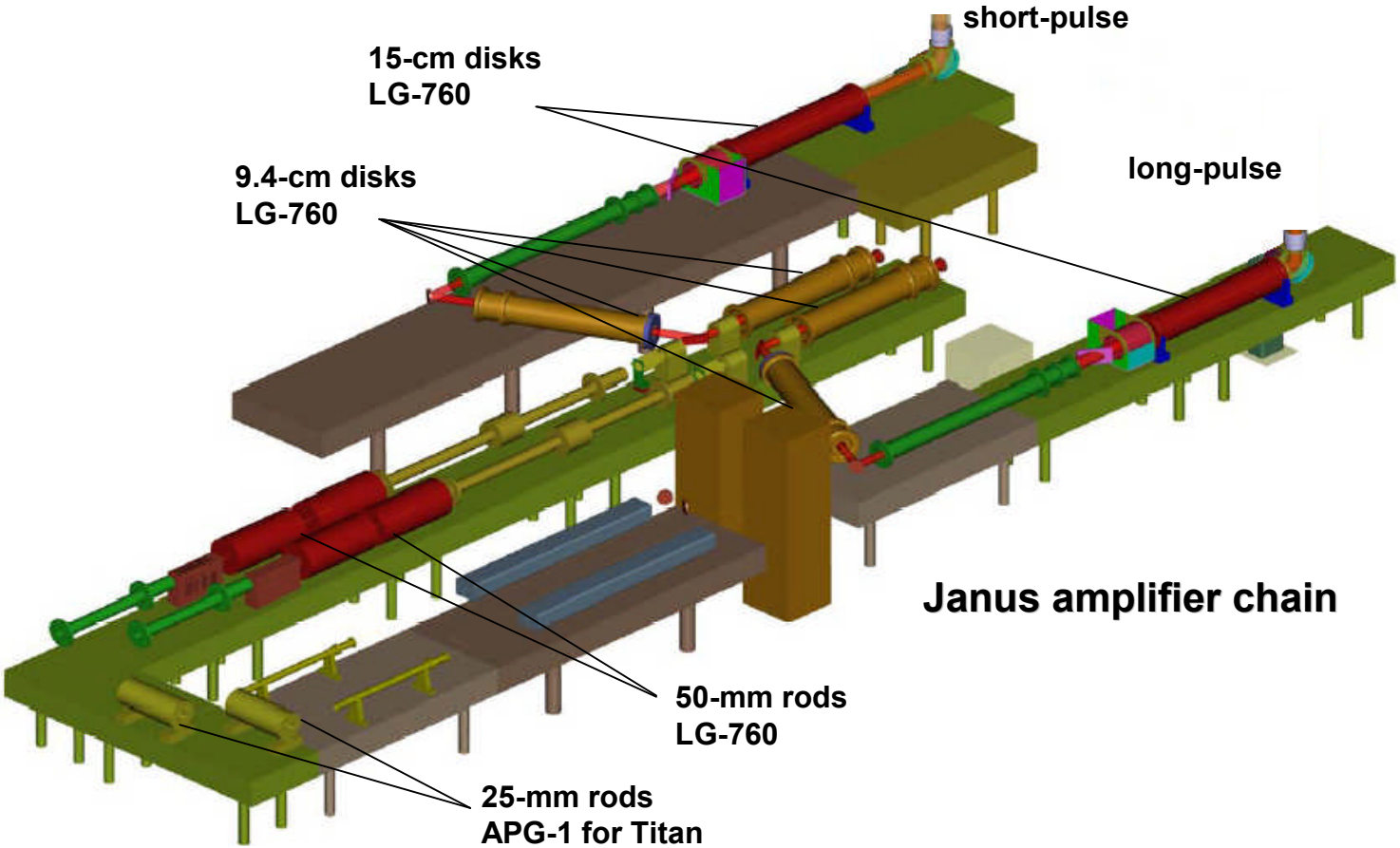
Offner stretcher:

- 1.6 ns stretch @ 4.1 nm (387 ps/nm)
- 73.5˚ input, 12-nm hard cut, “8-pass”
- tunable 0.4 ps to 200 ps



Titan main amplification is through the Janus kJ chain

- B-integral limit (B=2) at 1.6 ns (FWHM) is 750 J (fill factor = 0.8)



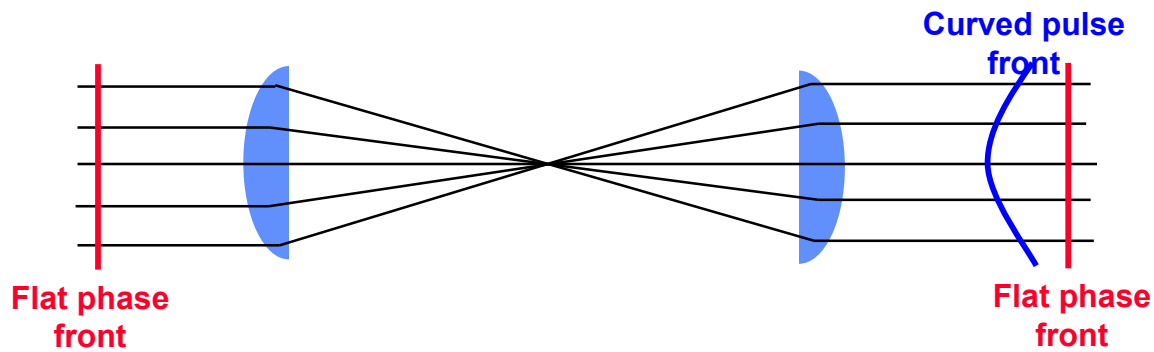
Radial Group Delay (RGD) is an issue to be addressed on Titan

- At 1053 nm in fused silica:
  - Vp = 0.6881c
  - Vg = 0.6816c (0.9906 Vp)

BK7:

Vp = 0.6621c

Vg = 0.6554c (0.9898 Vp)

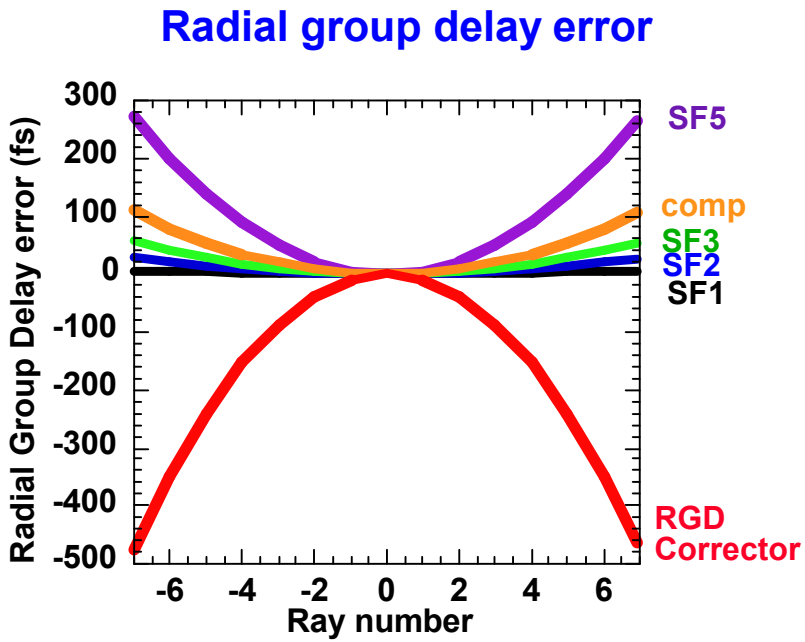


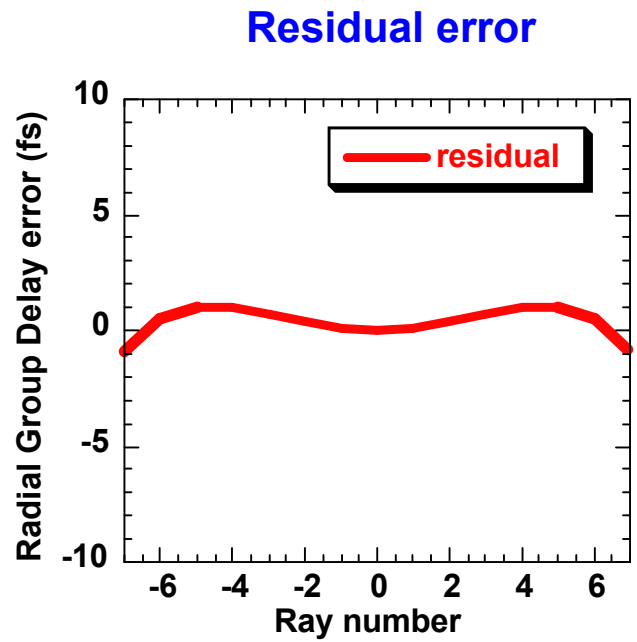
JISP chain has ≈9 mm more material along axis than at OD

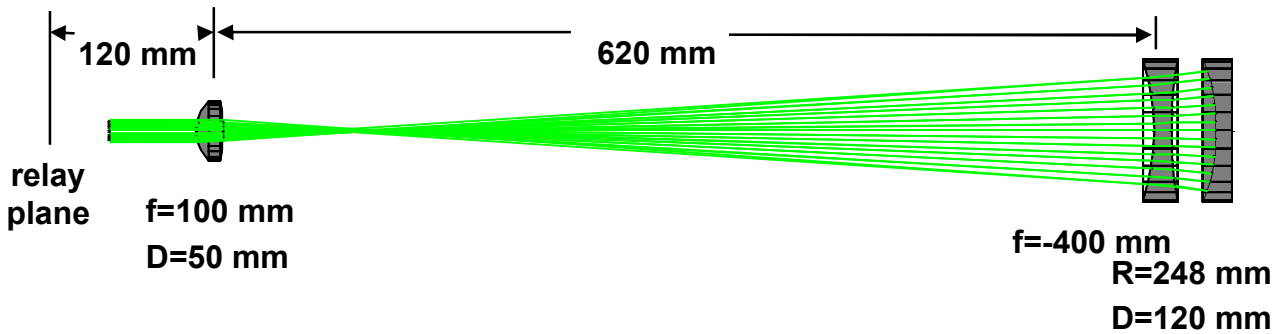
Relay	M	lens	R1 (mm)	R2 (mm)	f (mm)	t (mm)	mat.	beam D (mm)	RGD @ D (fs)
SF1	2.0	L1	259.36	inf	511.9	3.2	BK7	9.6	2.3
		L2	inf	-518.7	1023.7	2.5	BK7	19.2	4.9
SF2	2.07?	L1	270.46	-2595.1	483.7	5	BK7	19.2	9.7
		L2	5369.2	-559.4	1000.3	8	BK7	37.4*	20.1
SF3	2.28	L1	559.4	-5369.2	1000.3	8	BK7	37.4	17.8
		L2	inf	-1157.5	2284.4	12	BK7	85.5	40.8
SF5	1.64	L1	870.03	-877.108	973.3	12	FS	85.5	96.2
		L2	5048	-836	1595.9	12	FS	140	146.2
Titan	1.83	L1	4032.3	-24321	7693.1	20	FS	140	32.8
		L2	44507	-7379	14078.1	35	FS	257	64.3

Total RGD 435.1 fs

RGD can be compensated



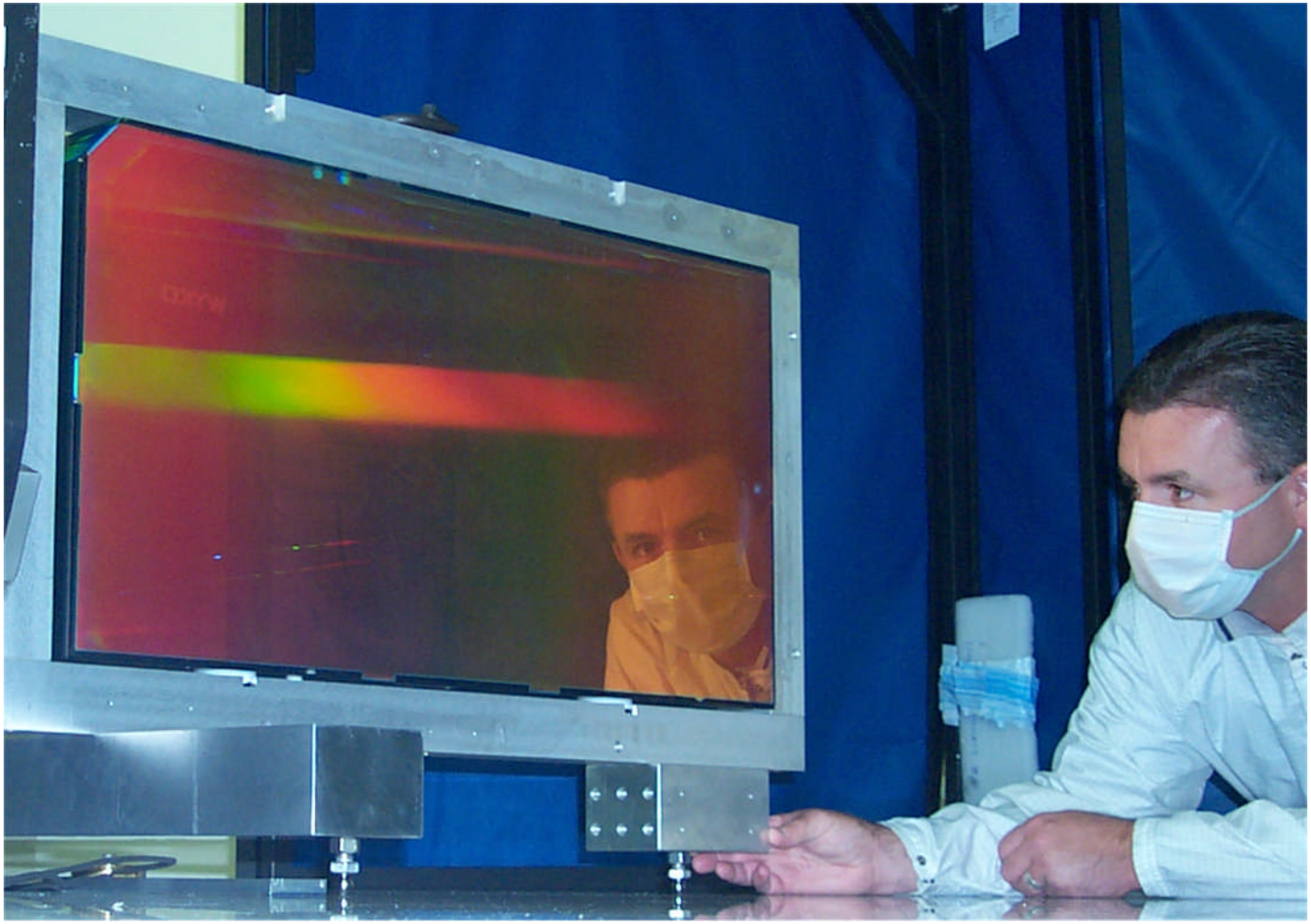




We need a good way to measure RGD!

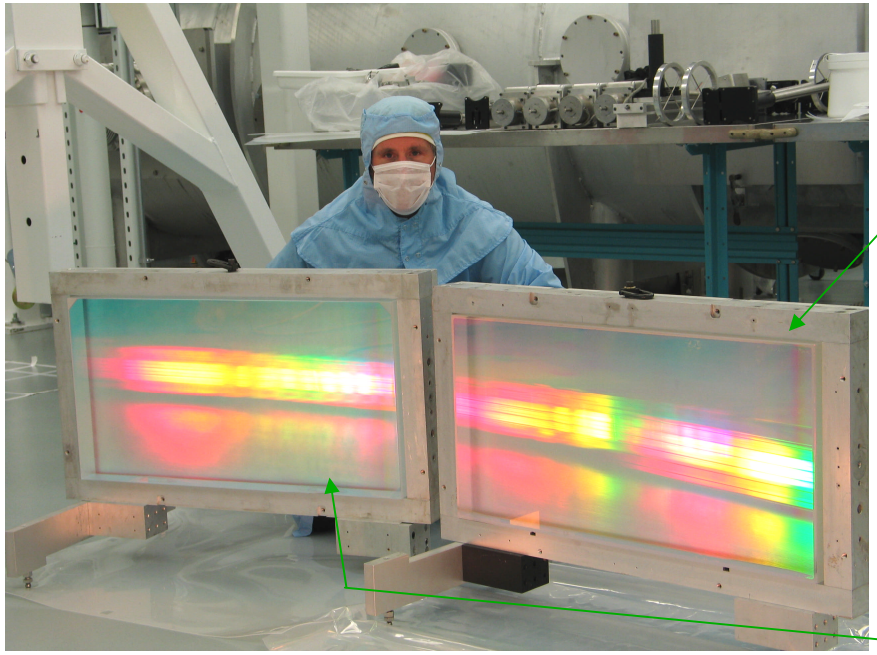
40x80 cm multilayer dielectric diffraction gratings are deployed on Titan

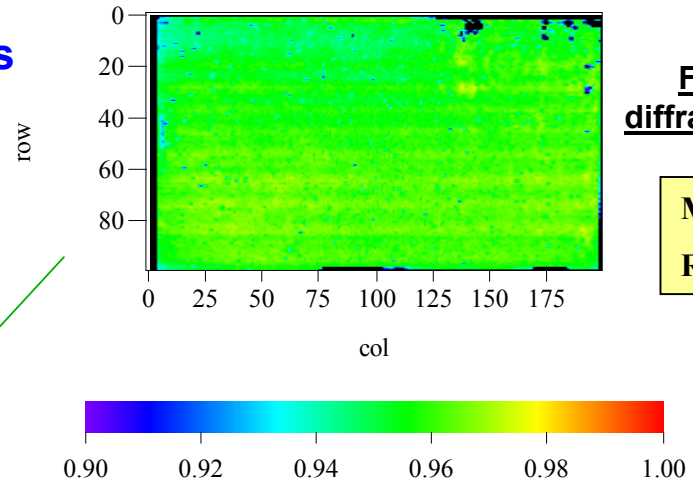
- Up to 5x improvement in damage threshold over gold



MLD gratings delivered to Titan 4/11/05

First ever 80 cm aperture production gratings

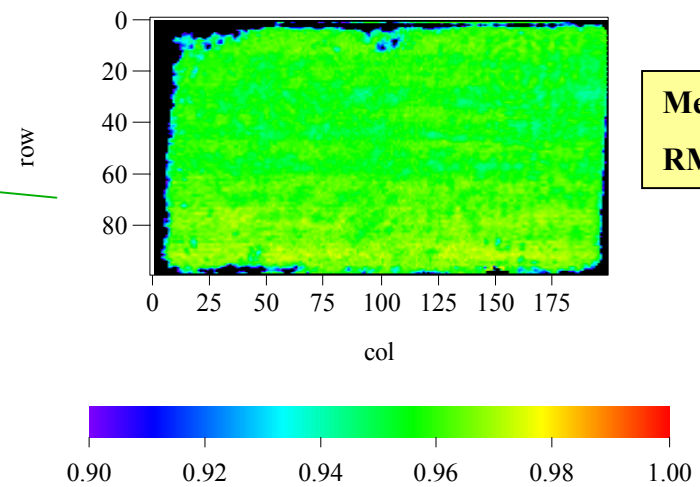




Full-aperture diffraction efficiency

Mean: 95.9%

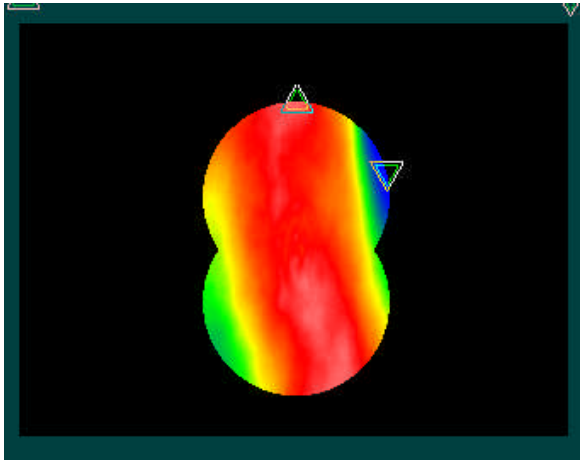
RMS: 0.8%



Mean: 95.9%

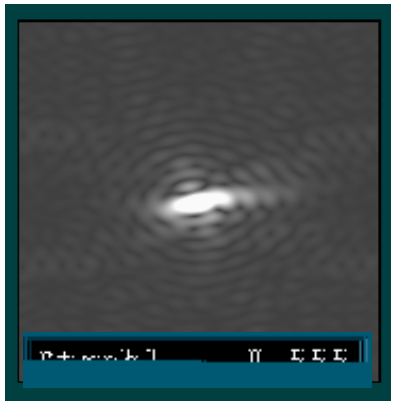
RMS: 0.7%

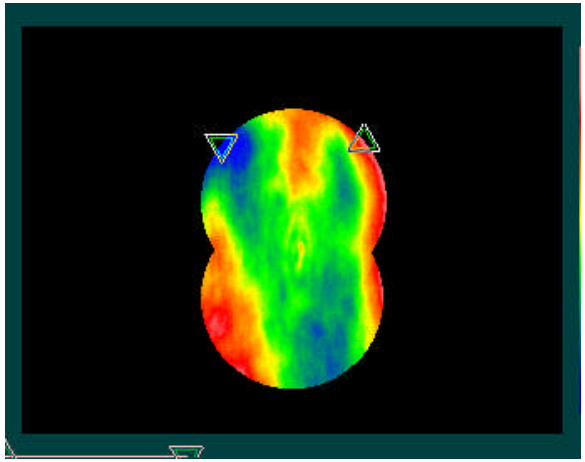
Use-aperture diffracted wavefront @ 1064 nm, 71˚: LLNL Titan Gratings (250 mm beam double-passed)



PV	1.125	wave
rms	0.215	wave
Power	-0.158	wave
Size X	24.8	cm
Size Y	39.3	cm

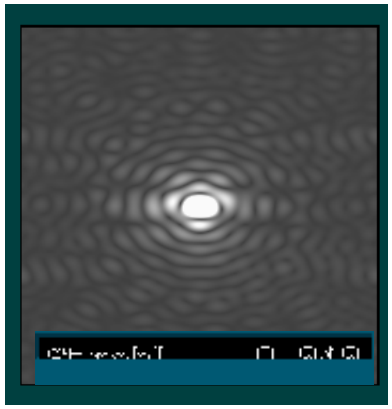
SN1 – dominated by compressive coating stress (e-beam deposited)





PV	0.356	wave
rms	0.062	wave
Power	0.052	wave
Size X	25.1	cm
Size Y	37.9	cm

SN3 – dominated by holographic phase error (Ion Assisted Deposition)



Measured at U. Rochester LLE

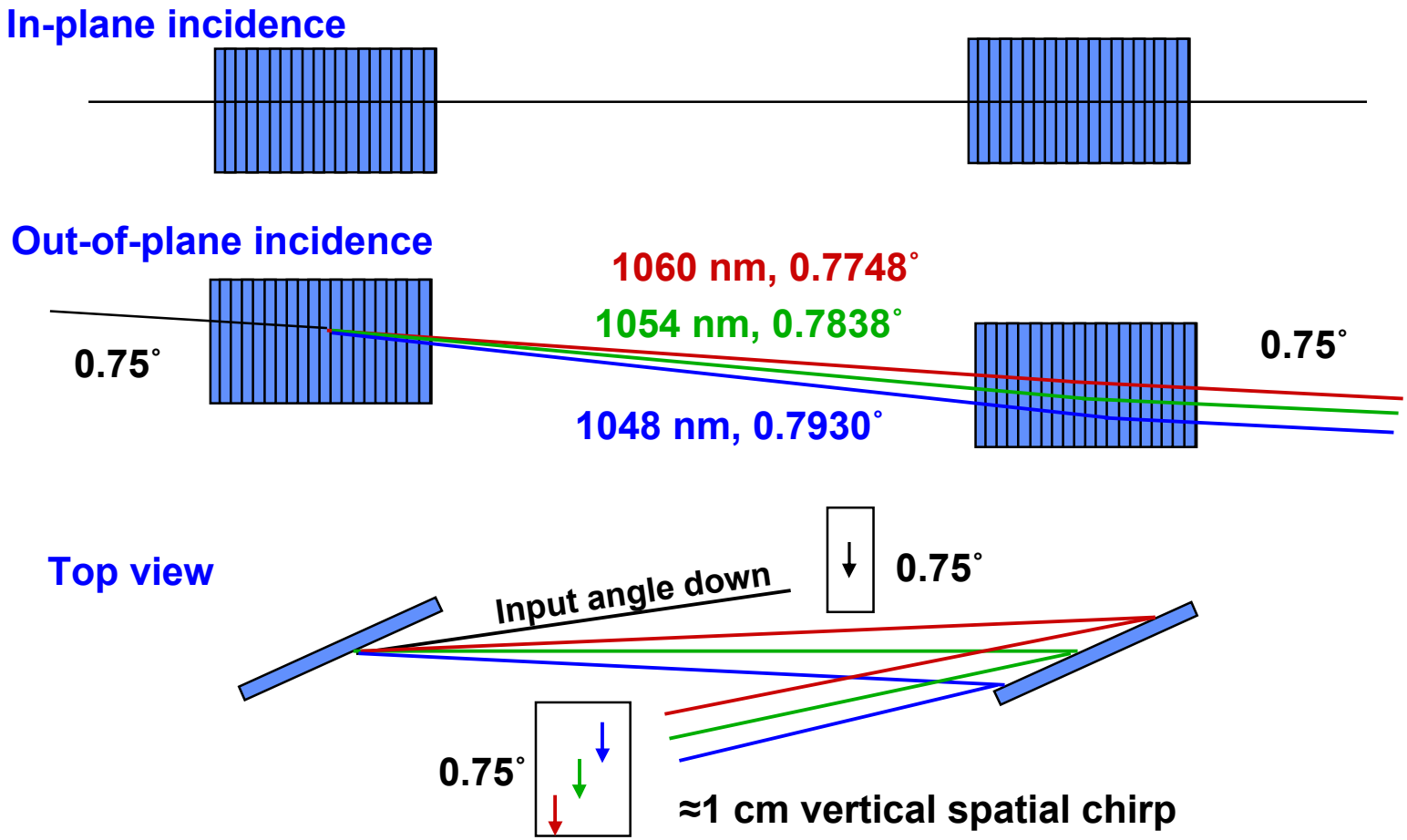
Three options were considered for compressor configuration

- "Standard" 2-pass roof-mirror
  - No spatial chirp, beam diameter limited to ≈18 cm
- Single-pass
  - Large residual horizontal spatial chirp
- Angled 2-pass
  - Small vertical spatial chirp (few percent)
  - Larger beam size possible (up to 25 cm)

design	beam diameter	# gratings 2 compressors	energy ratio	irradiance ratio
Roof mirror	18 cm	4	1.0	1.0
Single-pass	18 cm	2	0.97	0.50
Angled (no diff.)	25 cm	4	1.66	1.57

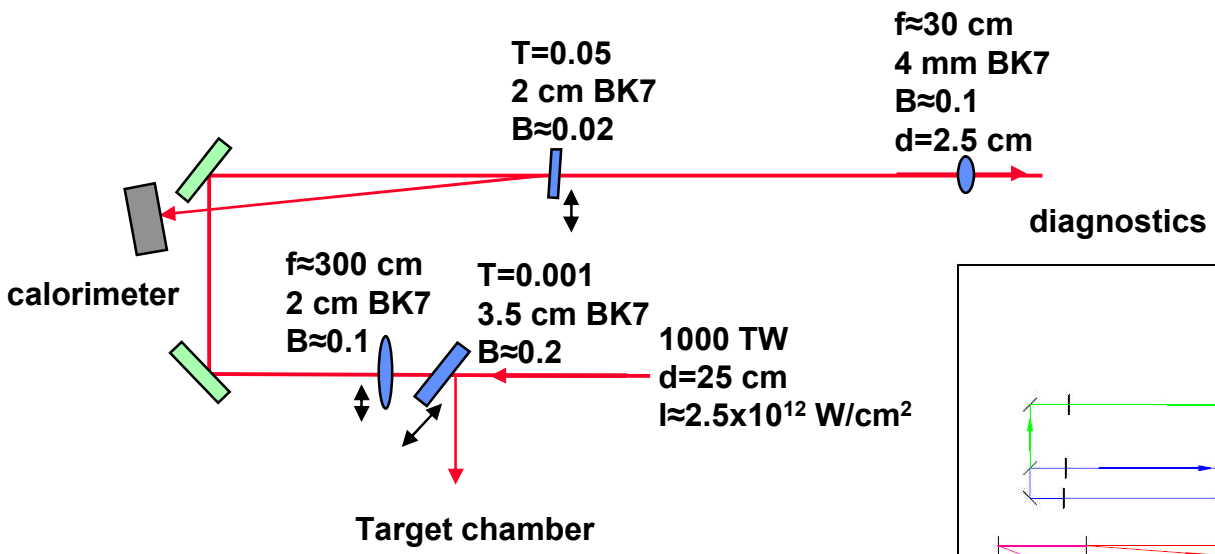
Rays exit parallel, but with slight vertical chirp

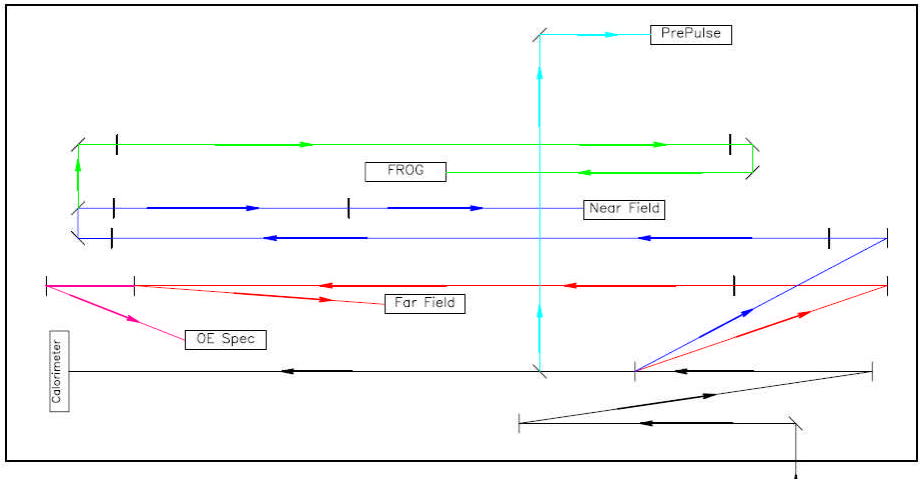
- Conical diffraction is compensated by symmetry of parallel gratings
- Small reduction (≈15%) in spatial chirp and dispersion compared to out-of-plane incidence not accounting for conical diffraction



Titan diagnostics

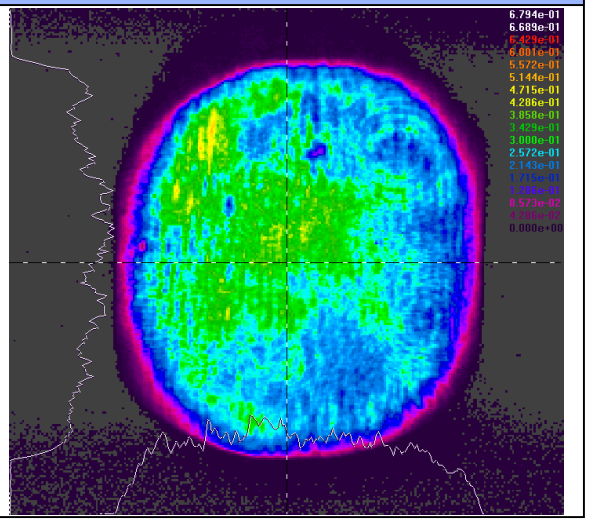
- ≈ 1 mJ @ 5 Hz for initial alignment (two mirrors removed)
- 5 mJ/100J on high energy shots with minimal B (0.42 @ 1000 TW)
- Down-collimation telescope only 2.5xDL



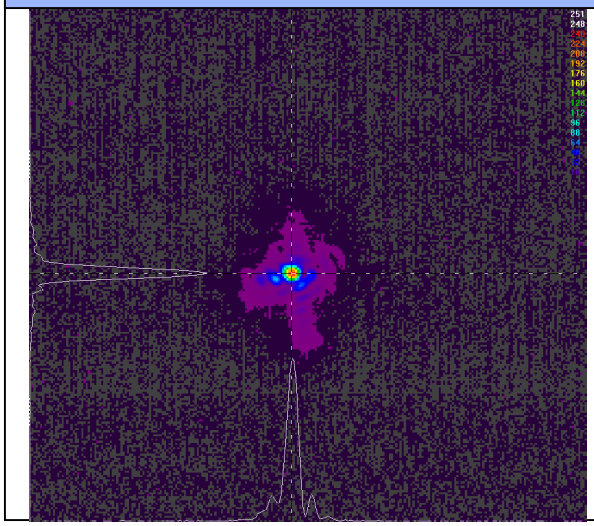


We have installed an extensive suite of diagnostics to characterize the laser pulse

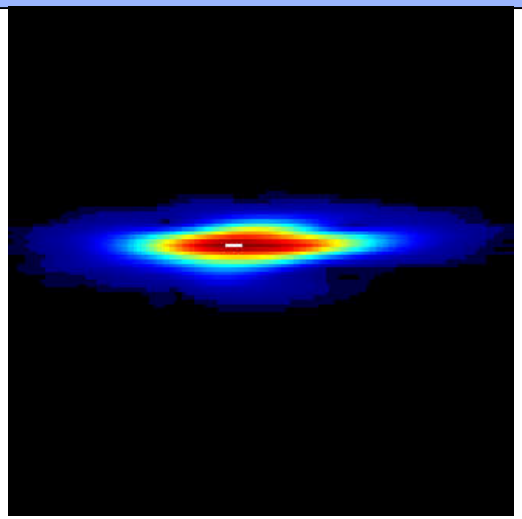
Near-field



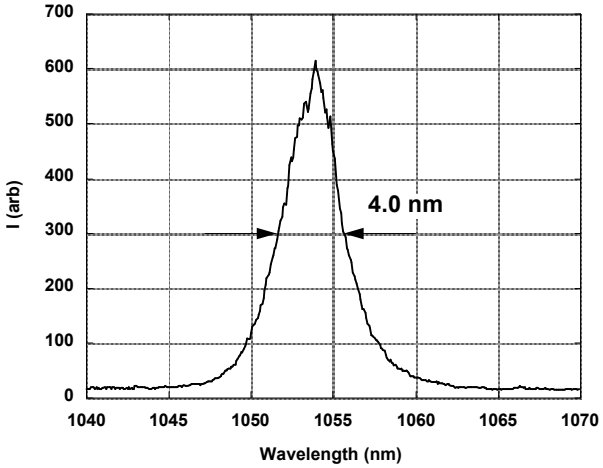
Far-field



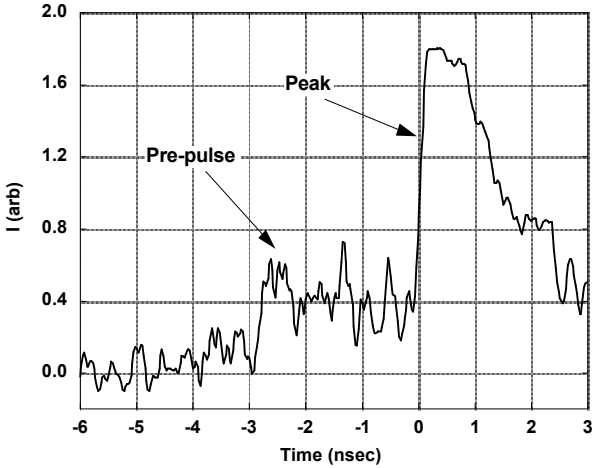
Frog



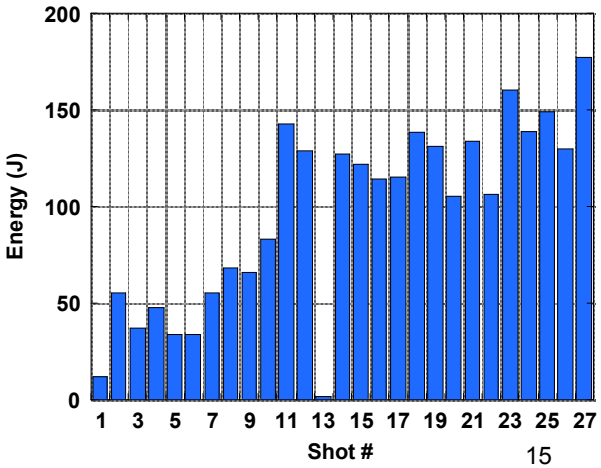
Spectrum



Pre-pulse

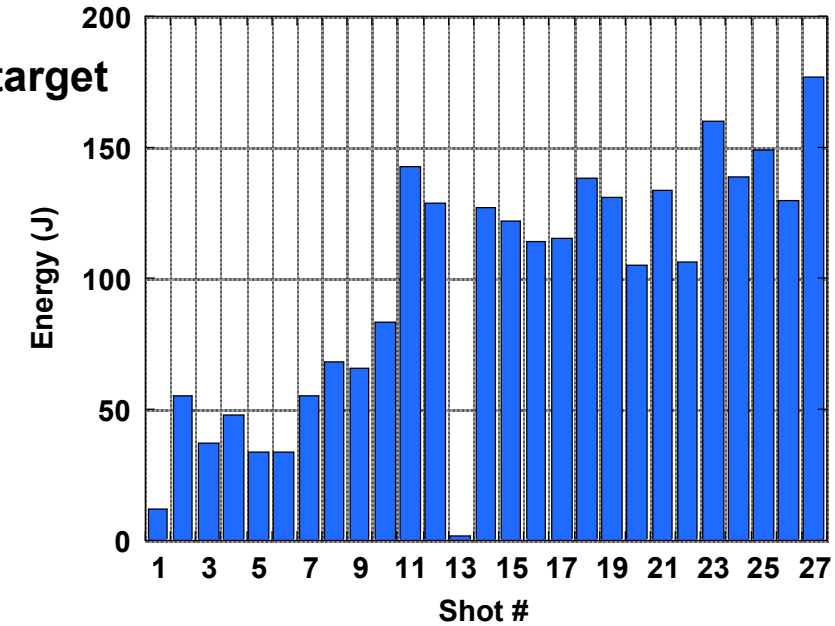


Energy



We are carefully ramping up the energy

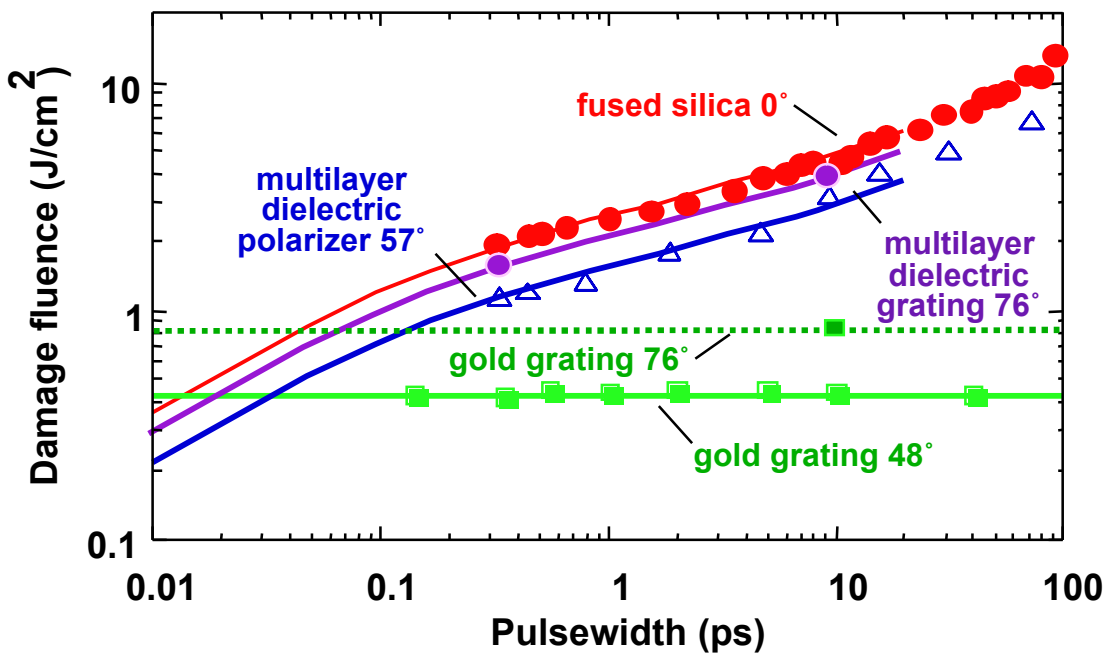
- Current output:
  - 180 J at 400-600 fs
  - 300 J at 10-40 ps
  - Pointing accuracy 10 μm
  - Fill factor 0.6
  - Focused spot size 10-20 μm, Strehl 0.2
  - Prepulse contrast > 10^6
  - Irradiance 10^{19}-10^{20} W/cm^2
  - 70% throughput laser bay -> target



Titan is limited by short-pulse damage to optics

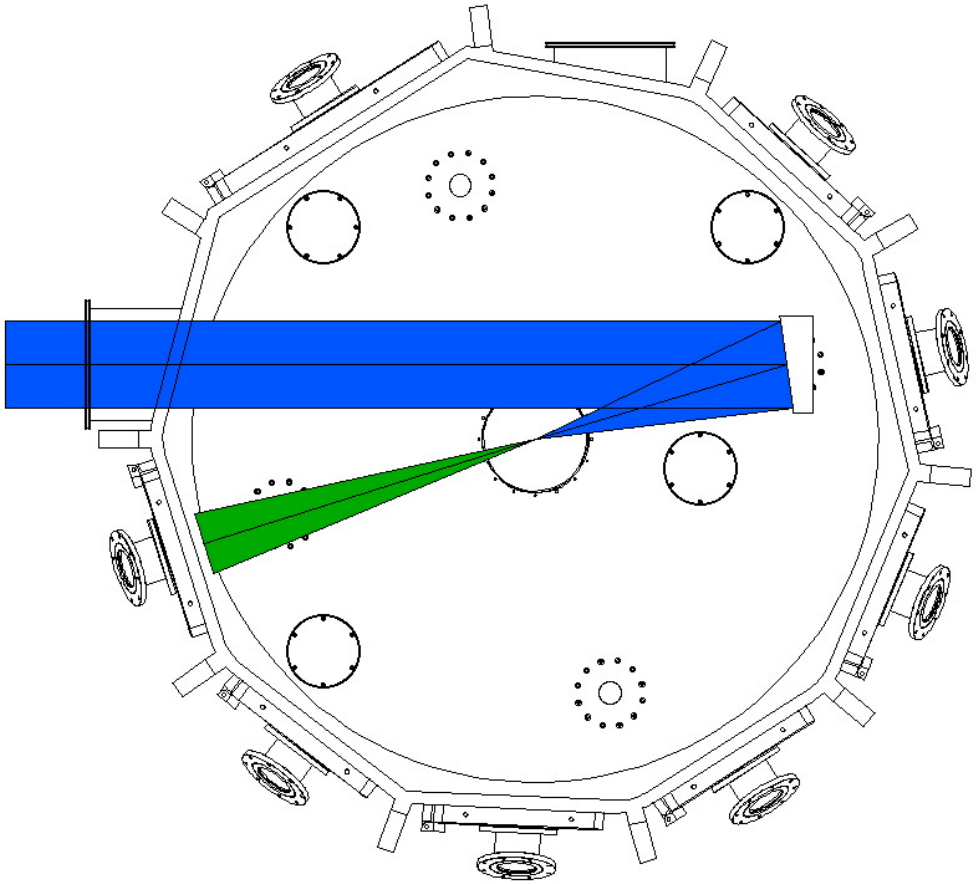
- Damage threshold (J/cm^2), 1053 nm, R:1

Optic	300 fs	1 ps	10 ps
45 mirror	1.2-1.5	1.7-2.0	4.0-4.5
0 mirror	0.9-1.3	1.3-1.7	3.2-4.2
MLD Grating (72-76 deg)	1.1-1.5	1.4-1.9	3.5-4.5

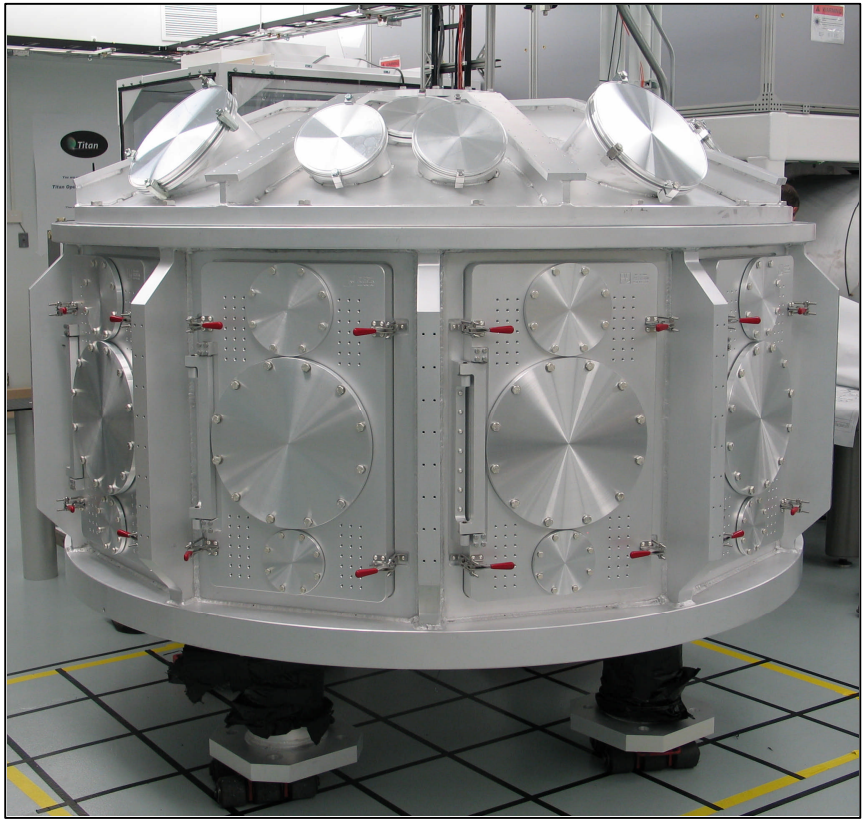


Tested at 1053 nm

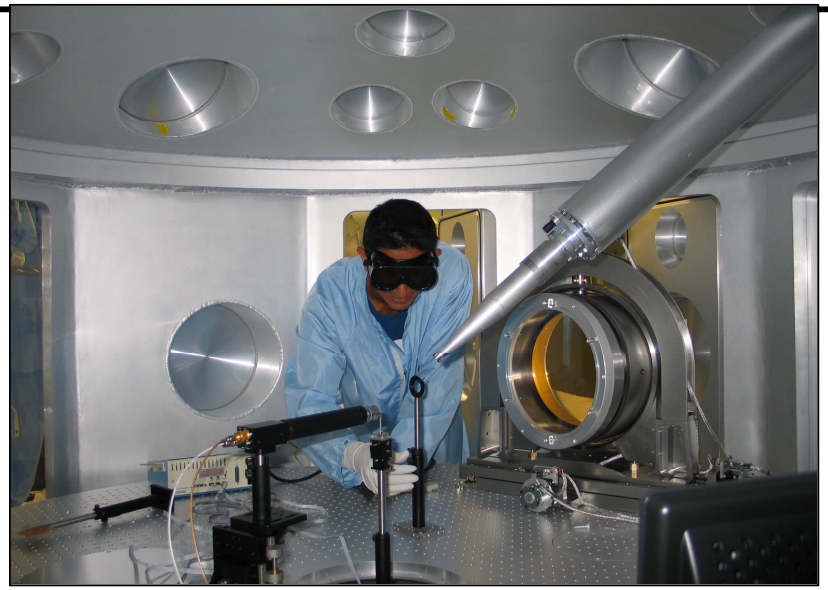
We designed a new target chamber specifically for combined long pulse-short pulse experiments



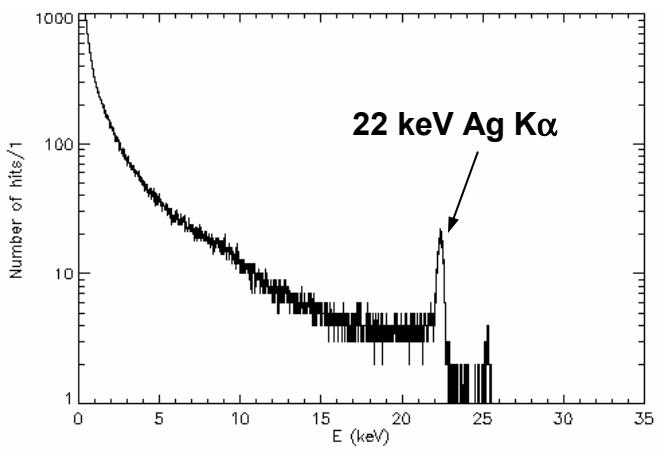
2.5 m diameter chamber



Titan first-light shot series, Oct 6-11, 2005
50 J laser energy focused on target in 600 fs pulse

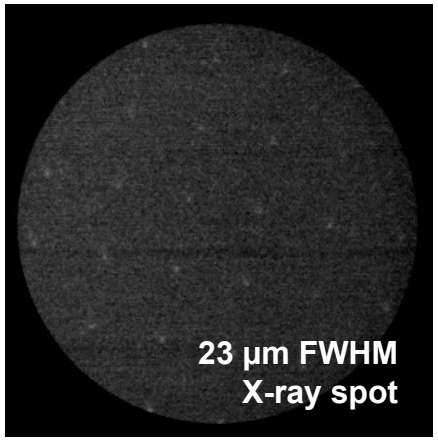


Shot #1 25μm Ag foil



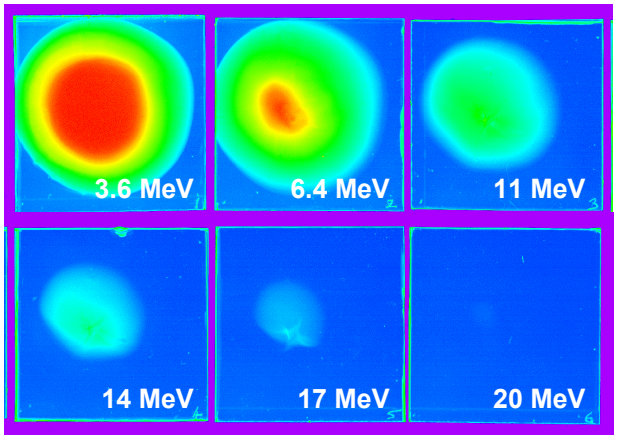
Single-hit X-ray spectrum

Shot #2 20μm Ti foil



X-ray pinhole imaging

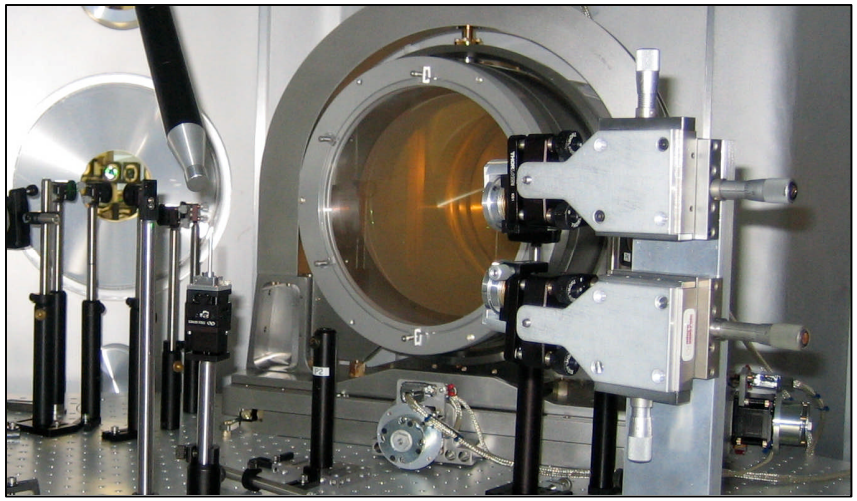
Shot #3 15μm Au foil

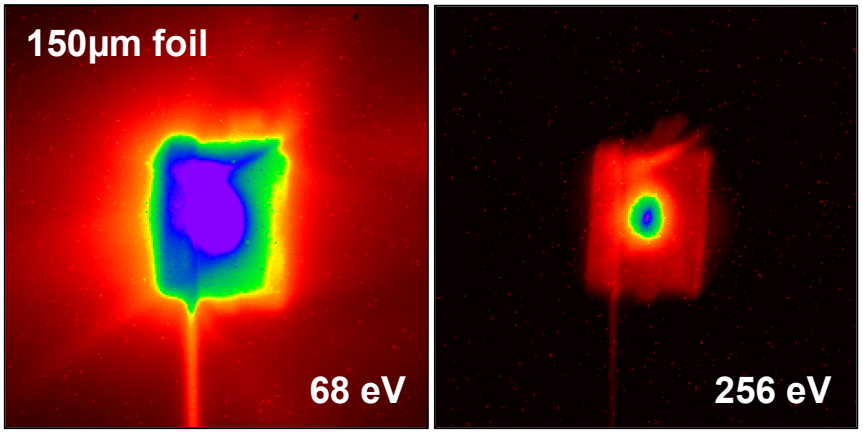


Proton beam

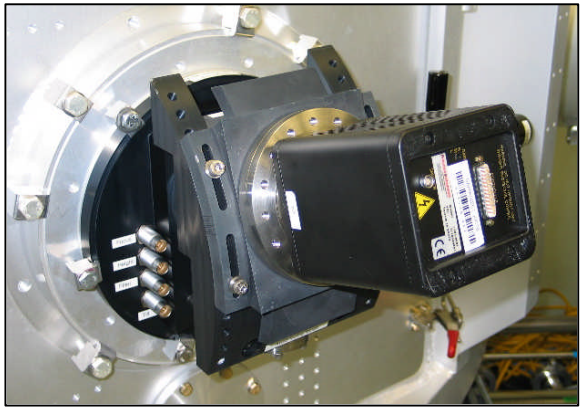
We installed a permanent suite of XUV diagnostics to characterize laser, electron & proton-heated plasmas

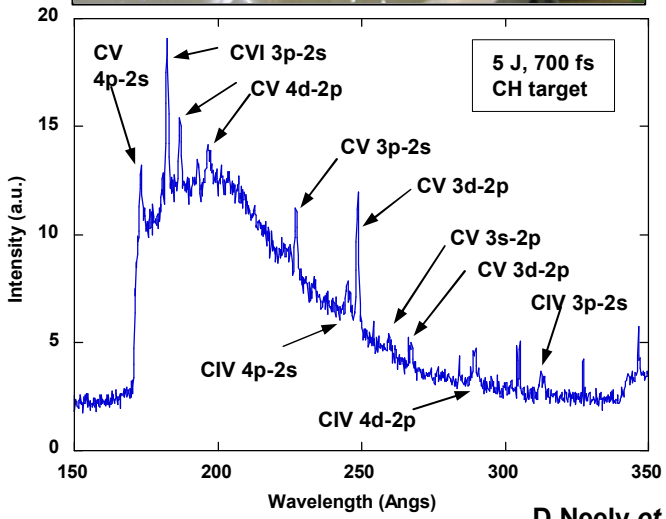
2-color temperature diagnostic





Flat-field XUV spectrometer



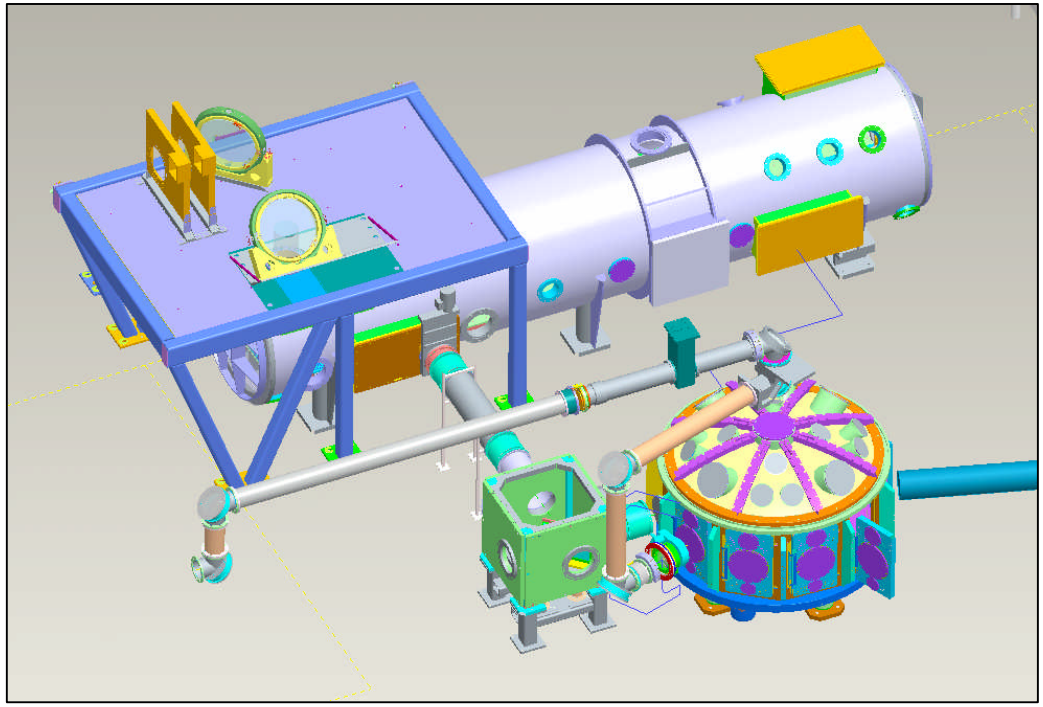


D Neely *et al.*

XUV imaging diagnostics demonstrated a laser pointing accuracy of better than 10µm—necessary for planned small target experiments

Summary

- Titan adds high-energy short-pulse capability coupled with a kJ long-pulse beam to the Jupiter Laser Facility

- Current short-pulse performance – ramping up slowly:
  - 180 J at 400-600 fs
  - 300 J at 10-40 ps
  - Pointing accuracy 10 μm

- Long-pulse arm operational July 2006