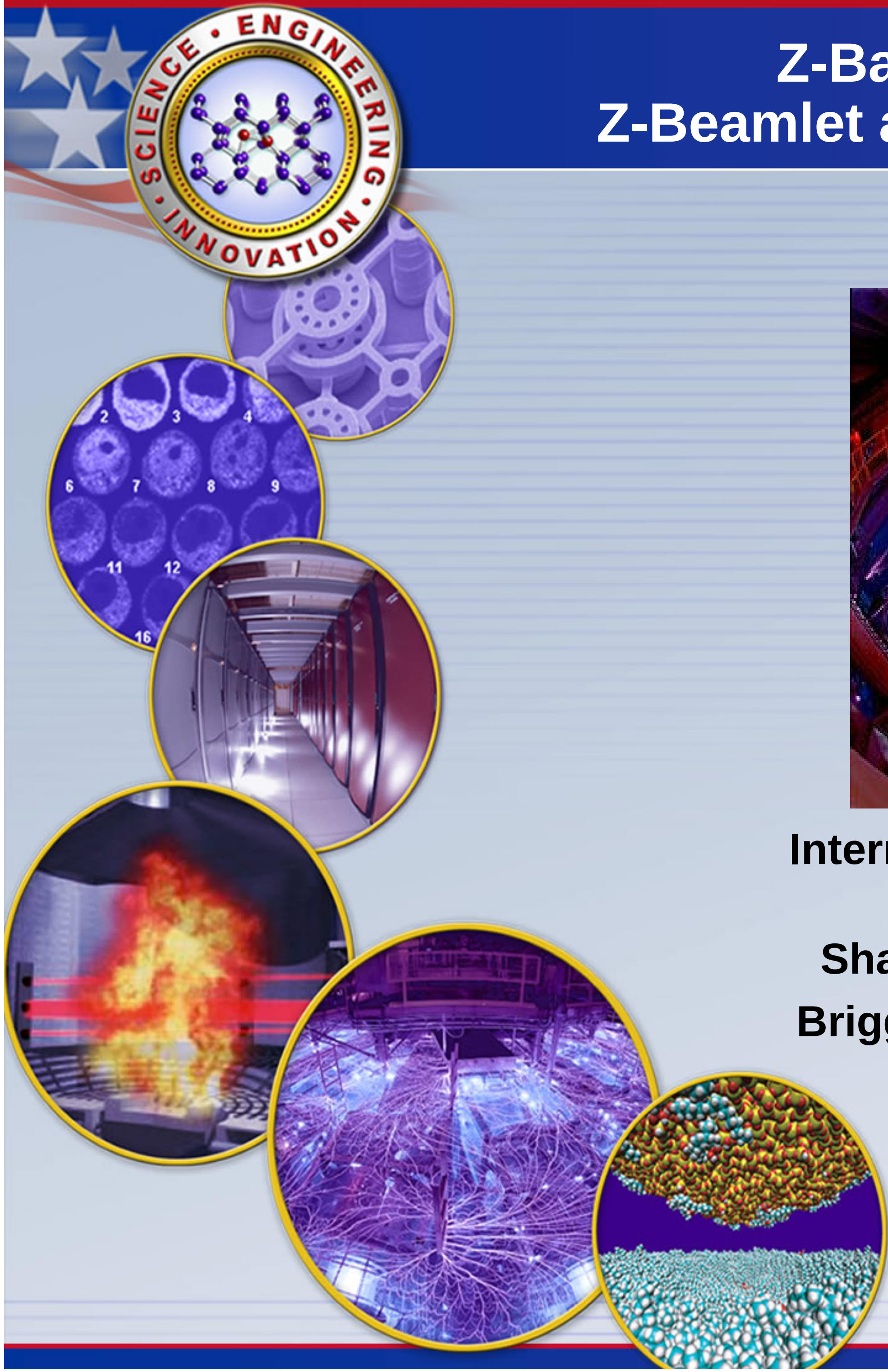
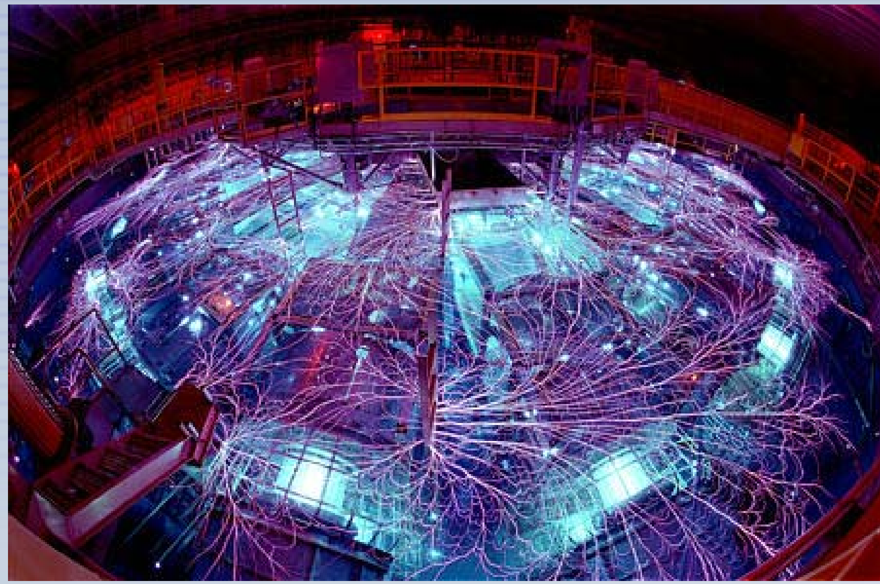


Z-Backlighter Laser Facility
Z-Beamlet and Z-Petawatt Laser Systems

A shot on the Z Machine



International Conference on Ultrahigh Intensity Lasers

Shanghai-Tongli, China, October 27-31 2008

Briggs Atherton, Sandia National Laboratories

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Sandia National Laboratories

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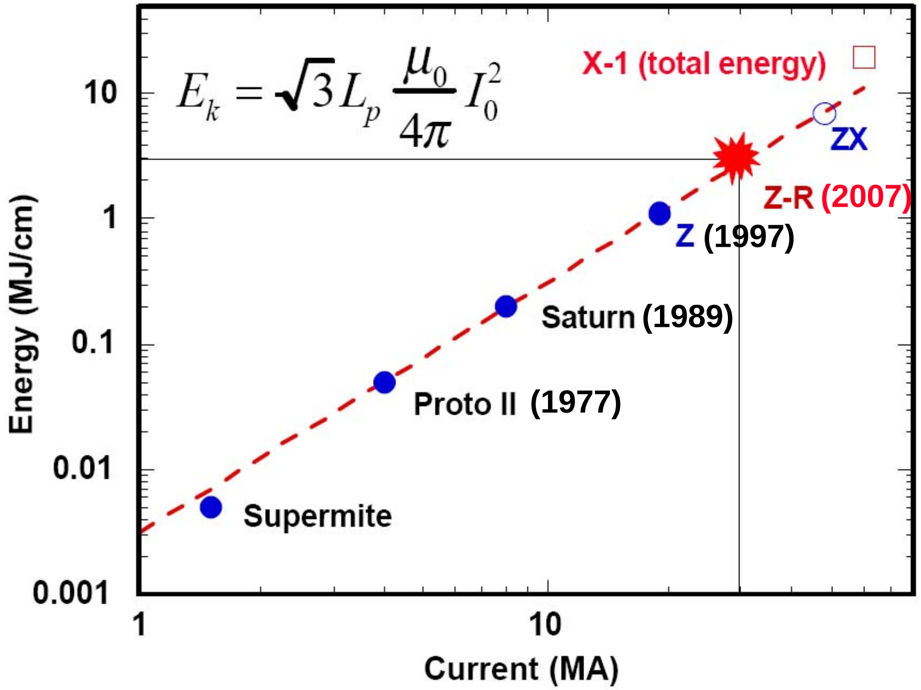
Damon Kletecka
Wade Nead
James Potter
Joanne Wistor

Engineering
Daniel Headley
Jeff Kellogg
Marc Ramsey
Grafton Roberson

The new ZR facility in operations

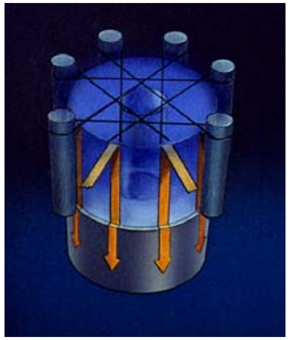


Capability	Z	ZR
Peak load current reproducibility	5%	2%
Pulse shaping flexibility	Minimal	Significant Variability
Peak Current	18 MA	26 MA
Full current operation	100 ns	130ns, 300ns
Diagnostic Lines of Sights	9	18

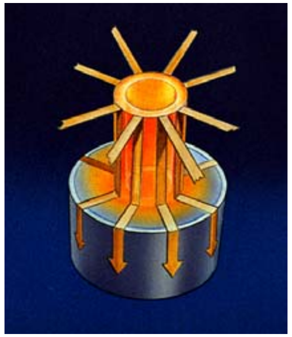
Sandia's ZR z-pinch facility

Phases of a z-pinch implosion

initiation

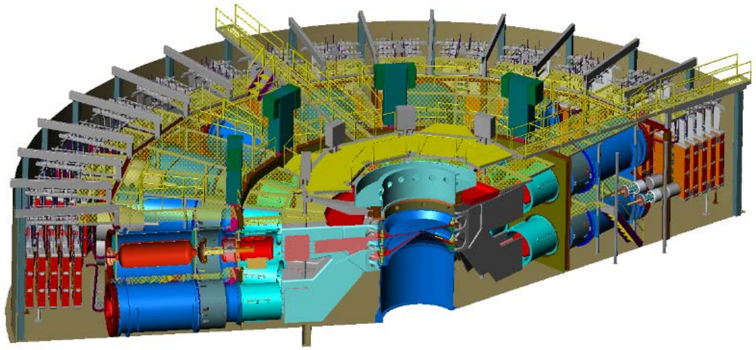


implosion

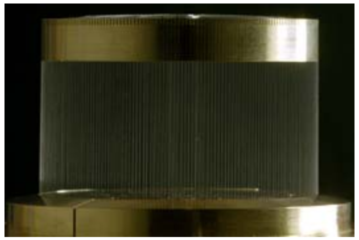


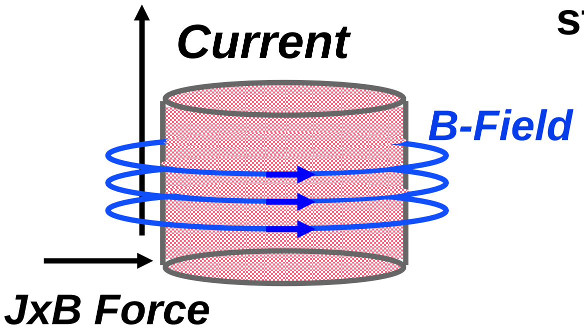
stagnation

ZR z-pinch facility

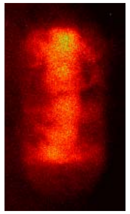


wire array





stagnation



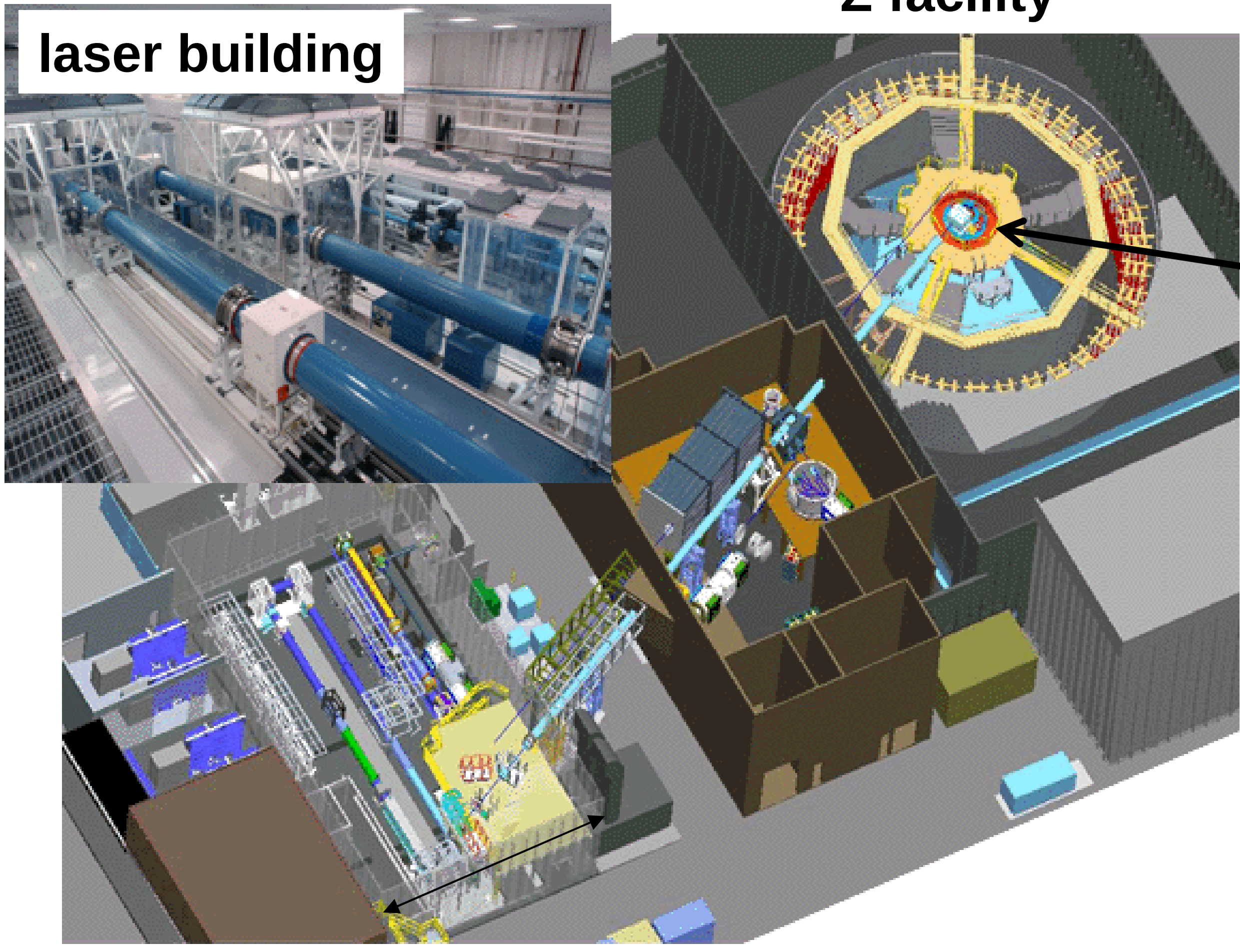
ZR parameters

20 MJ stored energy
26 MA peak current
100 TW electrical power pulse
⩾ 300 TW x-ray power
⩾ 2 MJ x-ray energy
⩾ 200eV Blackbody radiation

The Z-Backlighter Laser facility

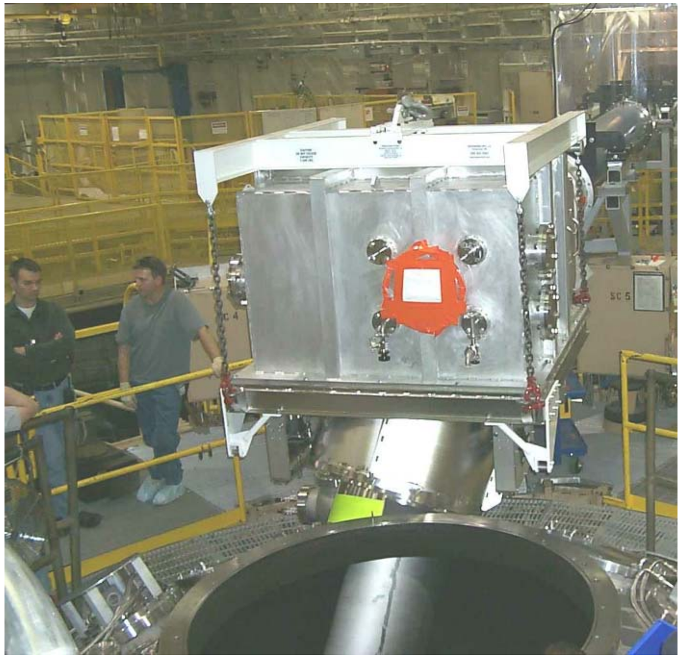
- The terawatt-class Z-Beamlet laser creates backlighting x-ray sources in the 1-9 keV range.
- The Z-Petawatt laser creates backlighting > 8keV range

Z facility

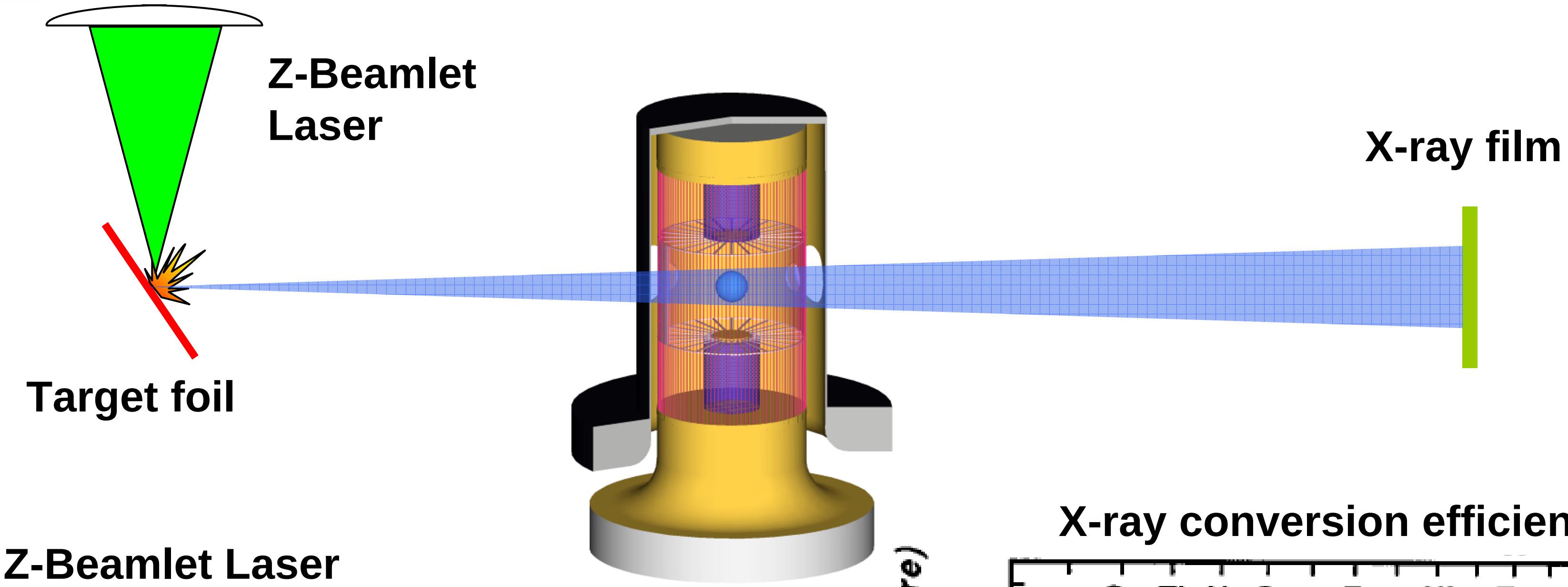


Z-Backlighter laser facility

Final Optics Assembly Installed on Z

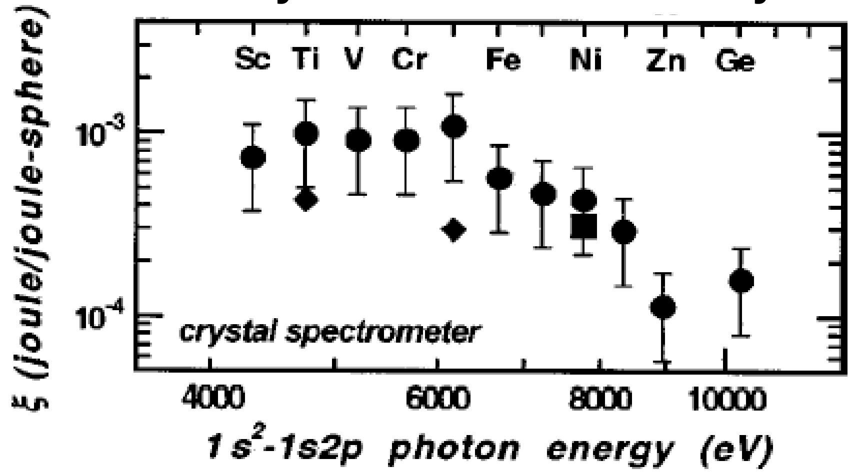


Point projection x-ray backlighting using the Z-Beamlet Laser



Z-Beamlet Laser

X-ray conversion efficiency



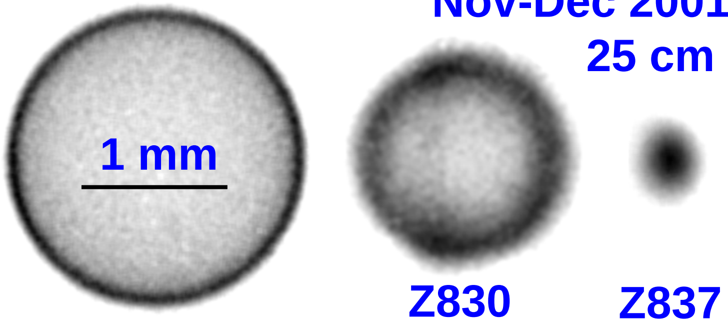
L. E. Ruggles,a) et. al.
REVIEW OF SCIENTIFIC INSTRUMENTS VOLUME 74, NUMBER 3 MARCH 2003

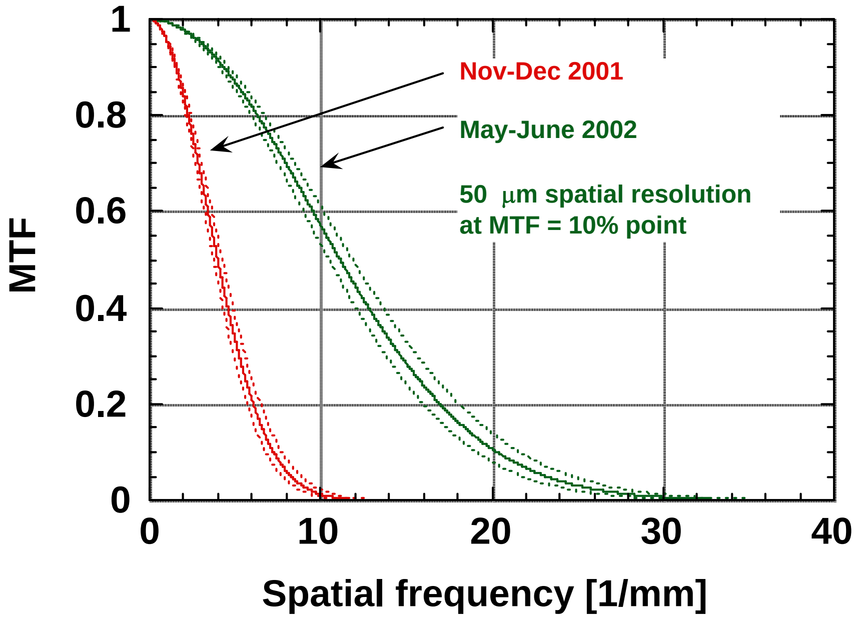
Point-projection x-ray backlighting has been used extensively to study ICF capsule implosions

Initial 6.7 keV imaging used a 4.8x imaging geometry with a large laser focal spot size

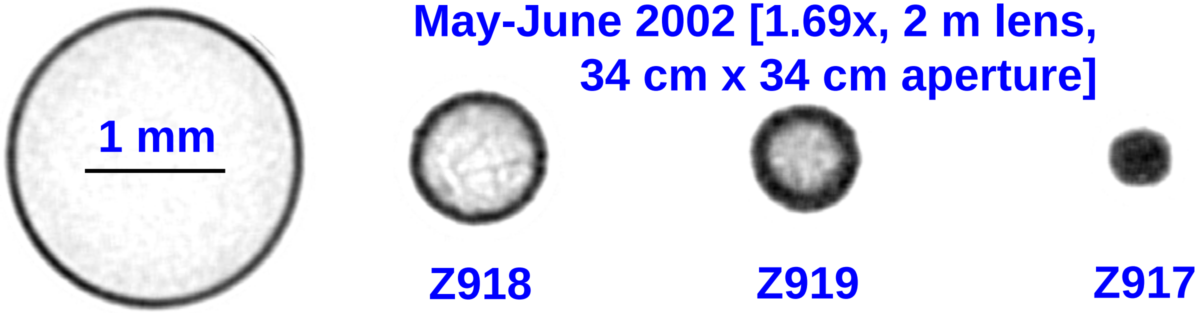
Improved 6.7 keV system used 1.7x imaging with 100 μm spot sizes to yield 50 μm spatial resolution

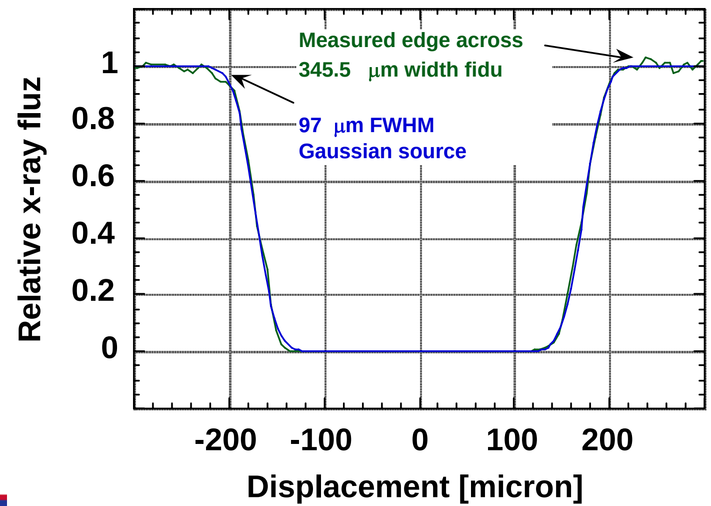
Nov-Dec 2001 [4.8x, 3.2 m lens, 25 cm x 25 cm aperture]





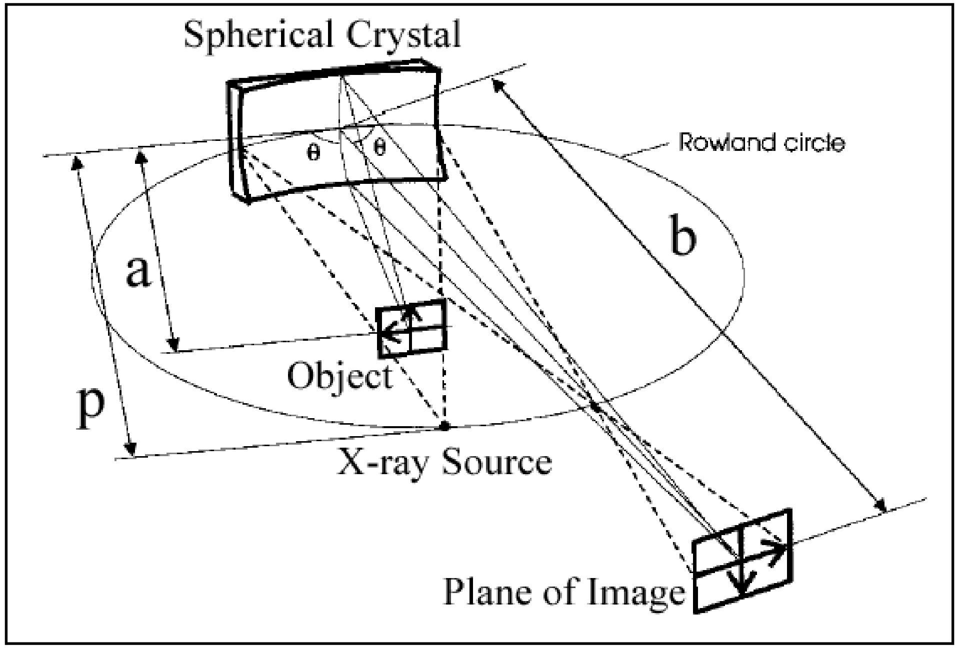
May-June 2002 [1.69x, 2 m lens, 34 cm x 34 cm aperture]

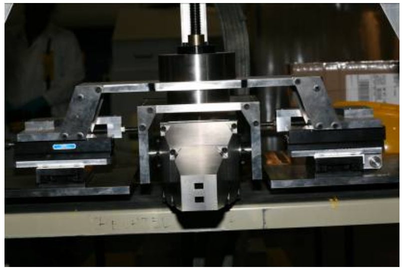


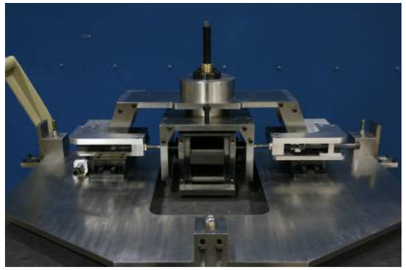


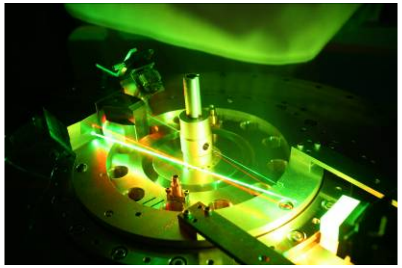
* G.R. Bennett *et al.*, Phys. Rev. Lett. 89, 245002 (2002).

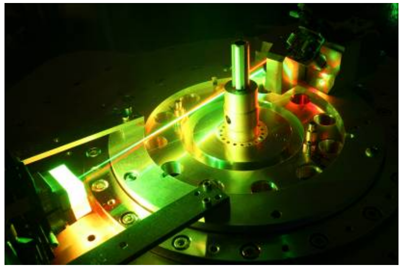
Curved-crystal imaging offers an elegant solution for backlighting in hostile environments











Bent-crystal Imaging

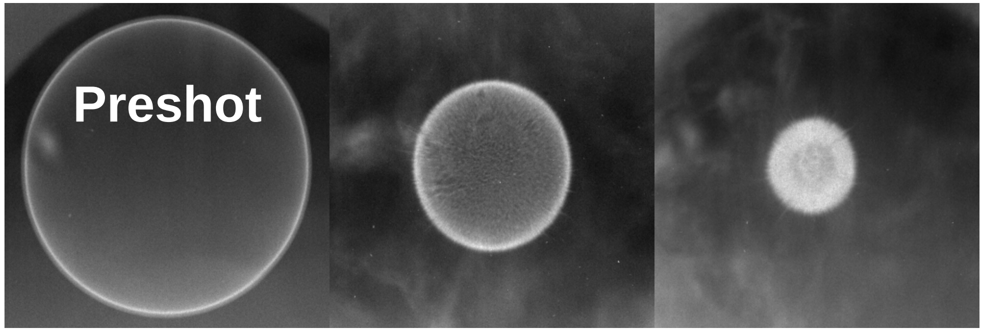
- Monochromatic (~0.5 eV bandpass)
- 10 micron resolution
- Large field of view (e.g. 20 mm x 4 mm)
- Debris mitigation

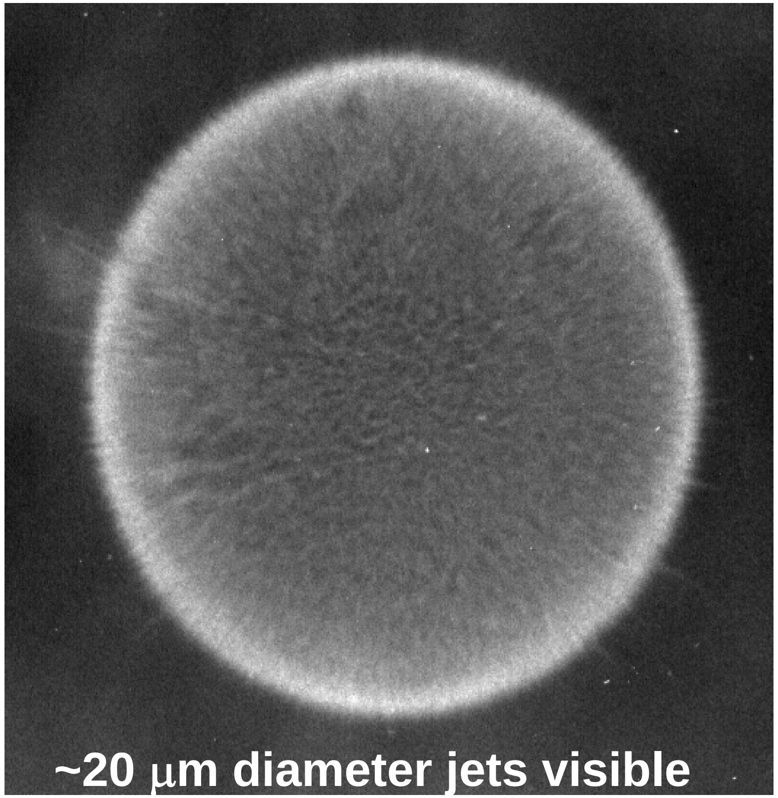
- **Concept proposed in mid-1990s.**
  - S.A. Pikuz *et al.,* Rev. Sci. Instrum. **68**, 740 (1997).
- **A 1.865 keV backlighter built at NRL**
  - Y. Aglitskiy *et al*., Rev. Sci. Instrum. **70**, 530 (1999).
- **Crystal imaging techniques proposed for microscopy/backlighting on NIF**
  - J.A. Koch *et al*., Rev. Sci. Instrum. **70**, 525 (1999).
- **1.865 and 6.151 keV diagnostics successfully implemented on Z facility**
  - D.B. Sinars *et al*., Rev. Sci. Instrum. **75**, 3672 (2004).

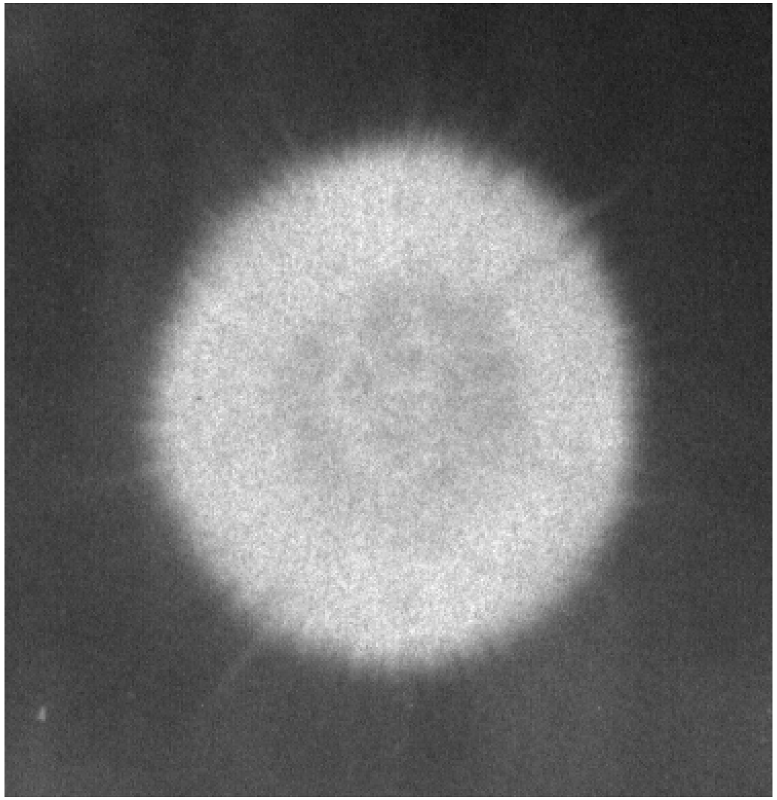
The higher spatial resolution bent-crystal imaging system revealed new features in imploding capsules

3.4-mm diameter plastic ICF capsule

Capsules had 100s of known defects on surface that apparently produced a myriad of small jets







Available Laser Systems

Z Backlighter

Z Beamlet

- λ=527nm
- τ=0.3-8ns
  (2ns common)
- ϕ~75μm spotsize
- E<2kJ
- I<10^{17} W/cm^2
- ~3 hr/shot
- 2 pulse MFB

Z Petawatt

- λ=1054nm
- τ=500fs min
- ϕ~30μm spotsize
- E<60J (<500J pending)
- I>10^{19} W/cm^2
- ~3 hr/shot
- Sub-ps probe
  @ 527nm, <20mJ

NLS

- λ=1064nm (532nm option)
- τ=150ps
- ϕ~5μm spotsize
- E<10J
- I<10^{17} W/cm^2
- ~20 min/shot
- Pending: 8-10ns operations
  at >100J @1ω

Large Scale Coating Chamber

• Backlighting operations require a continuous supply of AR coated debris shields.

• To this end, we installed a 90” e-beam deposition coating chamber.

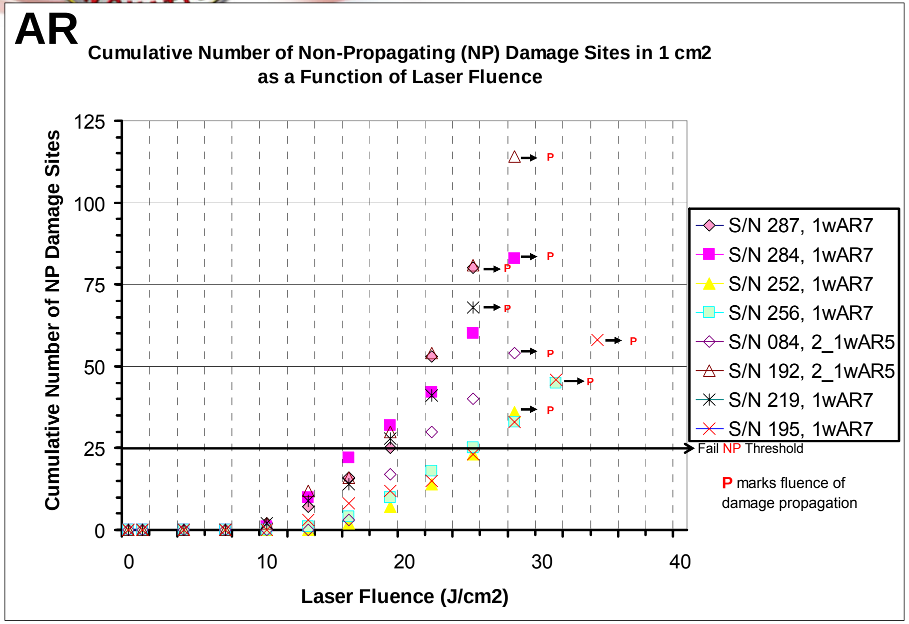
• Single-run capability: 3 at 94 cm optics
1 at 1.5 m option

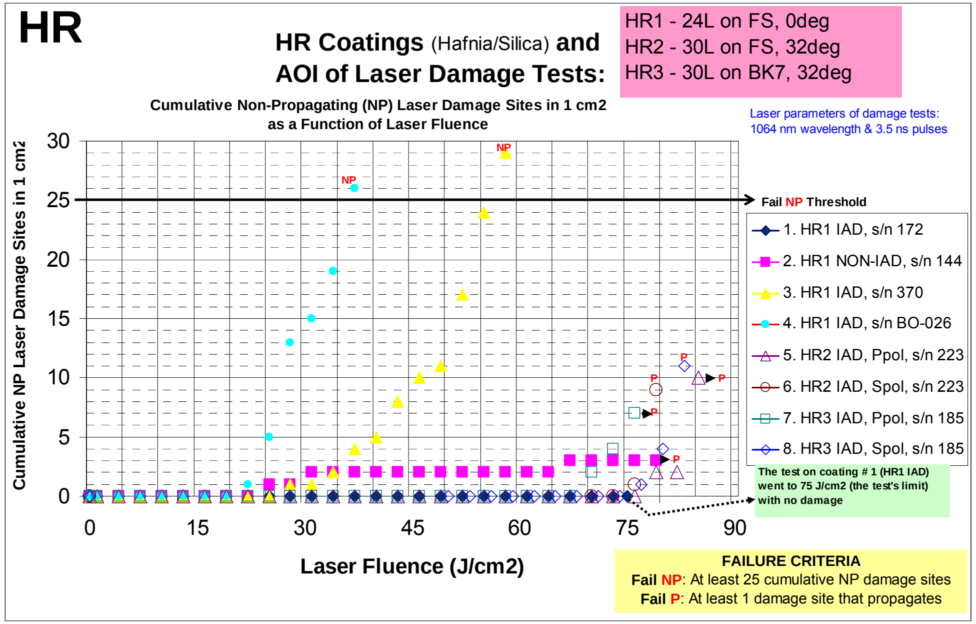
• Ion-assisted deposition (IAD) optional

• Recent coating efforts have focused on Z-Petawatt needs, including 94 cm truncated HR mirrors.

FY07 Optics	*30 cm*	*60 cm*	*94 cm*
Z-Beamlet	**42 AR**	**4AR**	
Z-Petawatt	**6AR & 4HR**	**3AR**	**3HR**

Large Scale Coating Chamber

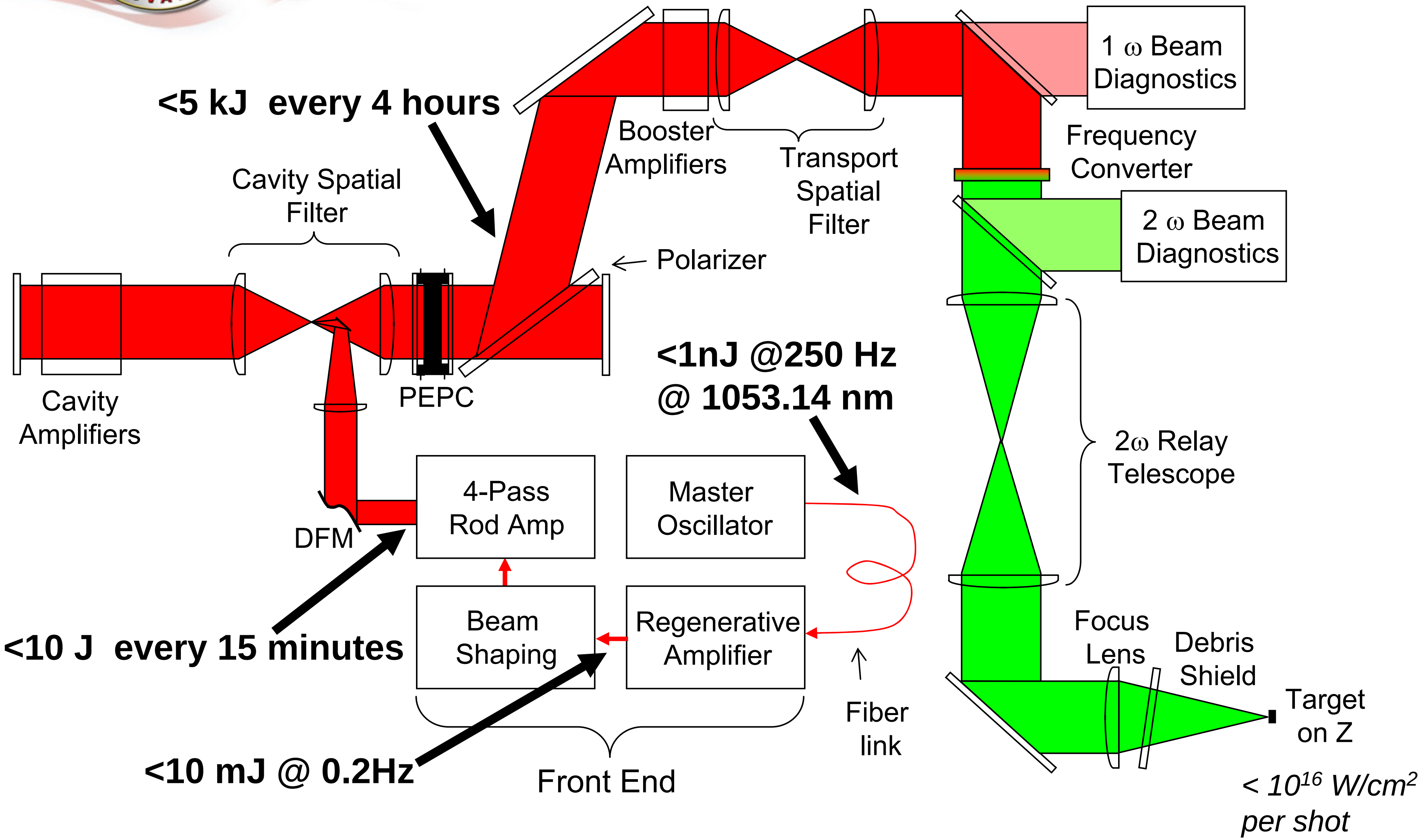




- Independent damage testing (SPICA) has shown good test results. Using a definition of 25 cumulated damage sites (non-propagating) gives thresholds:
  - In the range of 17-25 J/cm^2 for AR coatings
  - In the range of 75-85 J/cm^2 for HR coatings
- Successful application to both air and vacuum use environments.

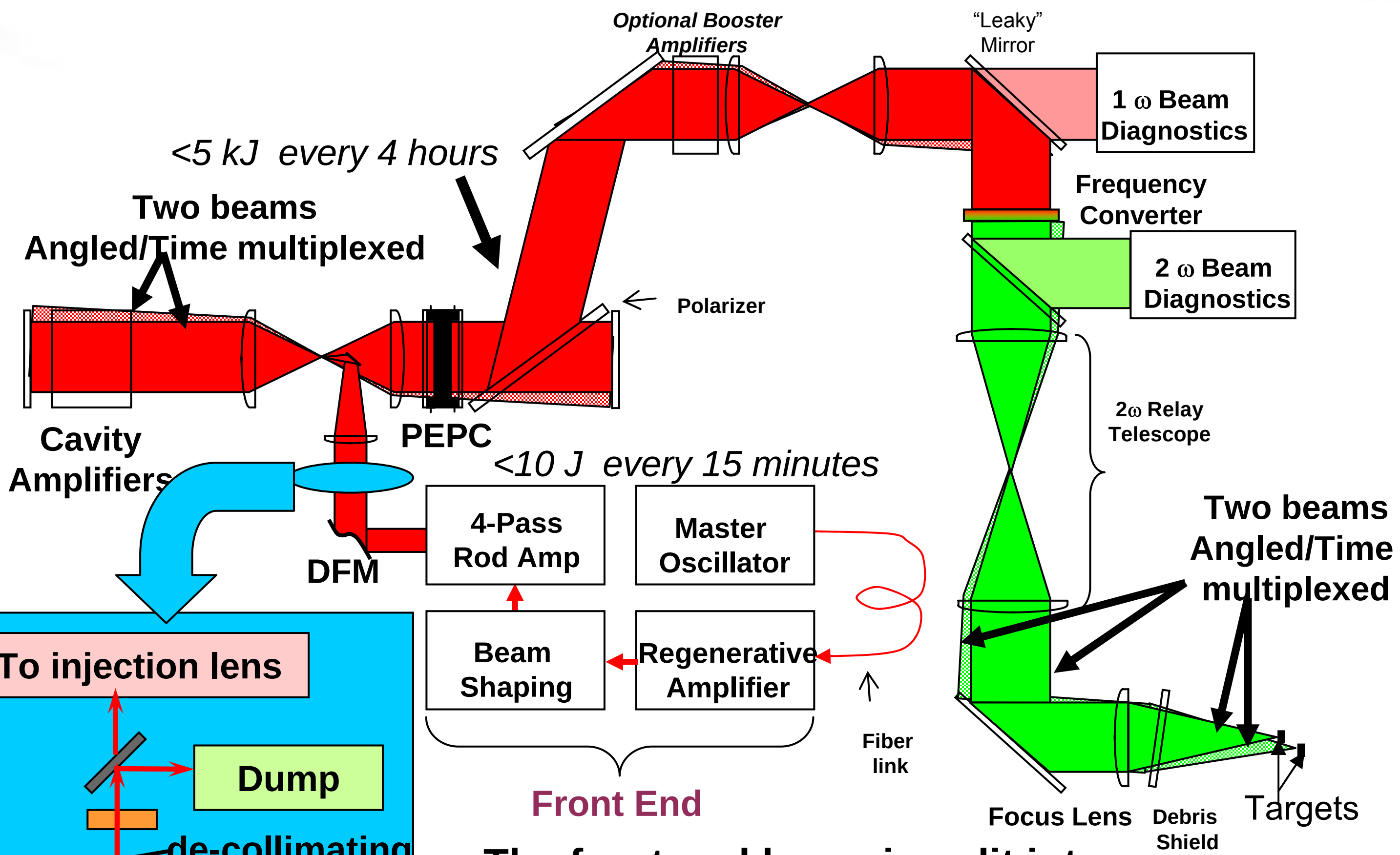
* 1064nm, 3.5ns pulse, 1.06mm spot scanned to fill 1cm^2 with 2300 shots for each of 13 levels from 1-37 J/cm^2, NP sites are of size 15μm

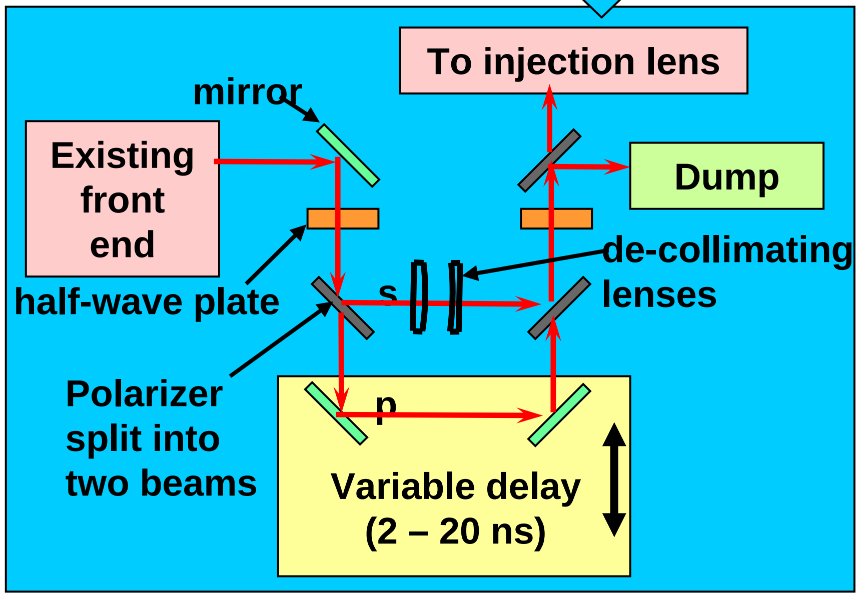
The Z-Beamlet Laser system



The Z-Beamlet Laser has recently being modified to provide a “2-frame” backlighting capability

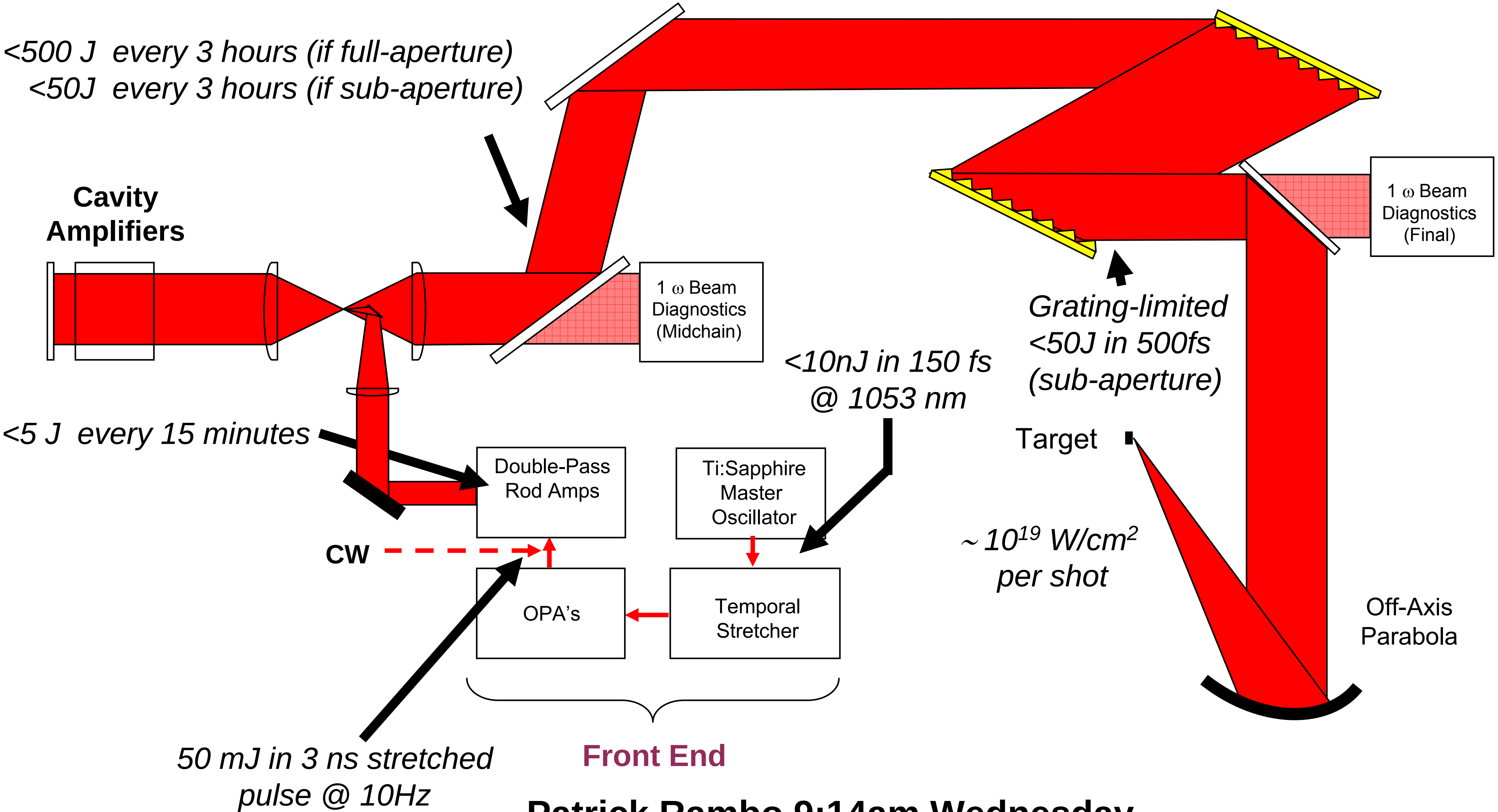
Injection Box with 10’ trombone addition





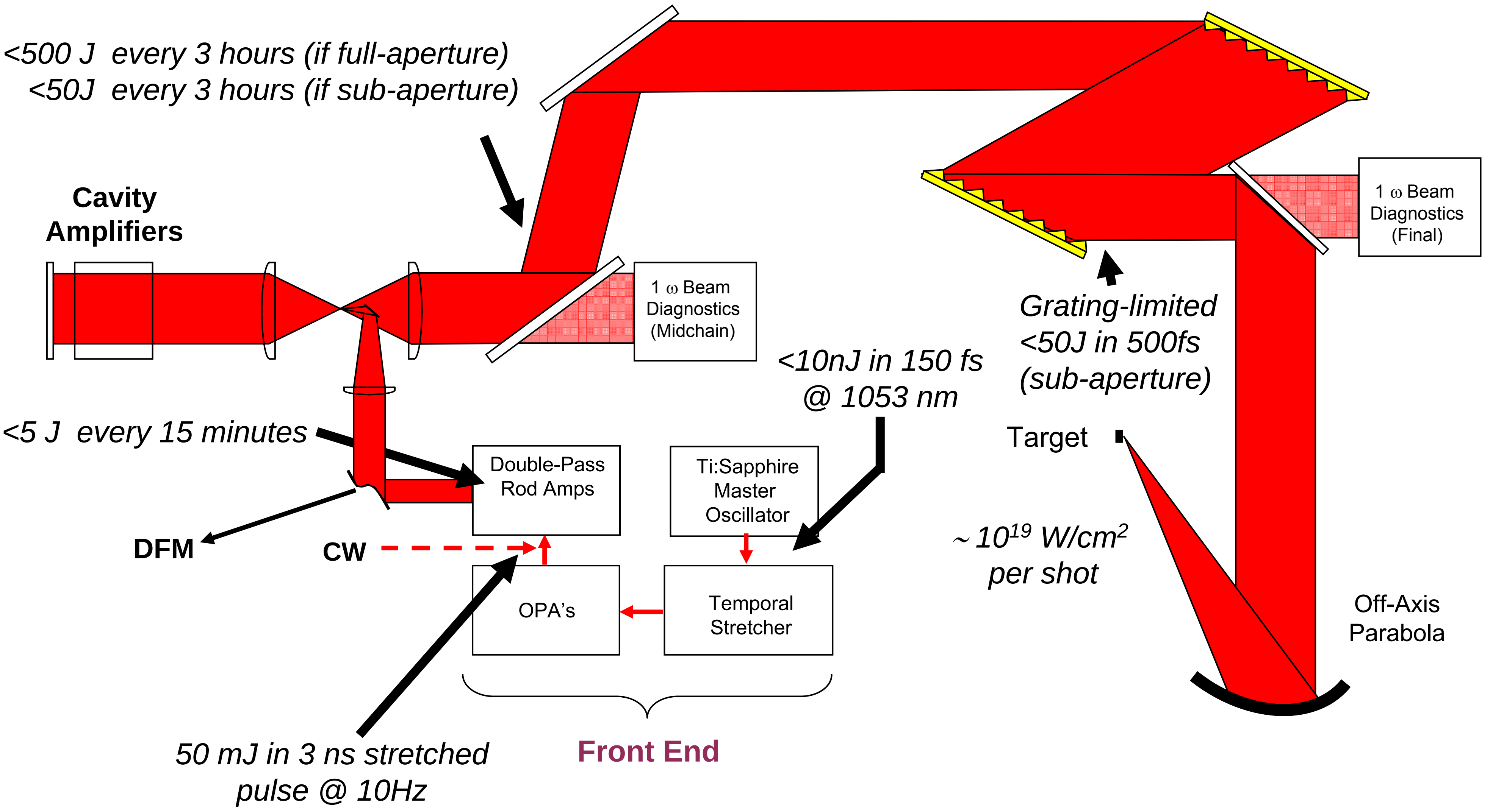
- The front end beam is split into two variable energy ratios beams
  - 1st beam
    - The focus is changed
  - 2nd beam
    - delayed 2-20 ns
    - Small change in angle (1.3 mrad)

The 100TW/Petawatt System



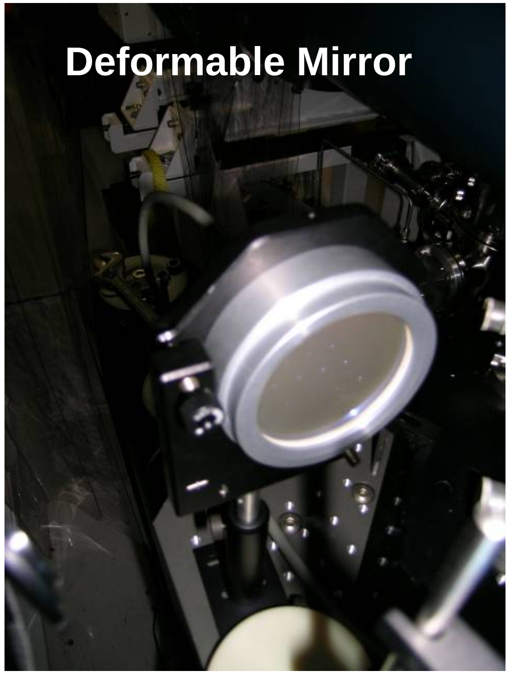
Patrick Rambo 9:14am Wednesday

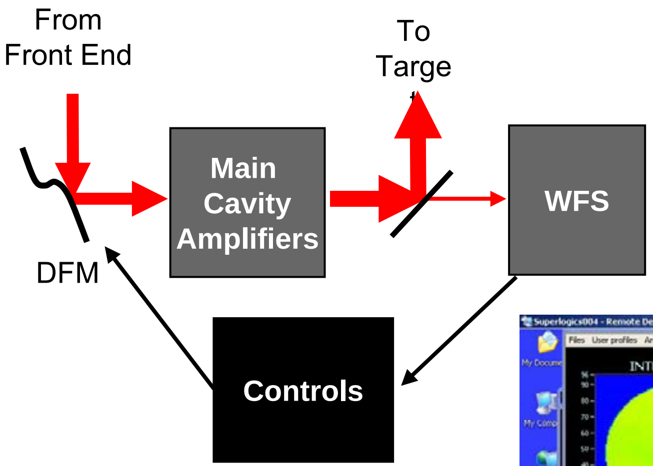
The 100TW/Petawatt System



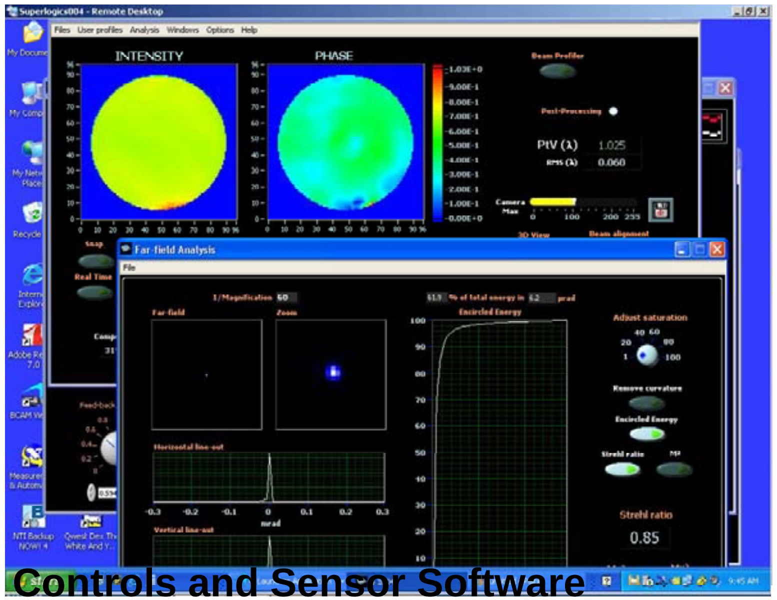
Adaptive Optics

- For higher order corrections, a commercial Phasics adaptive optics system has been installed in August 2007.

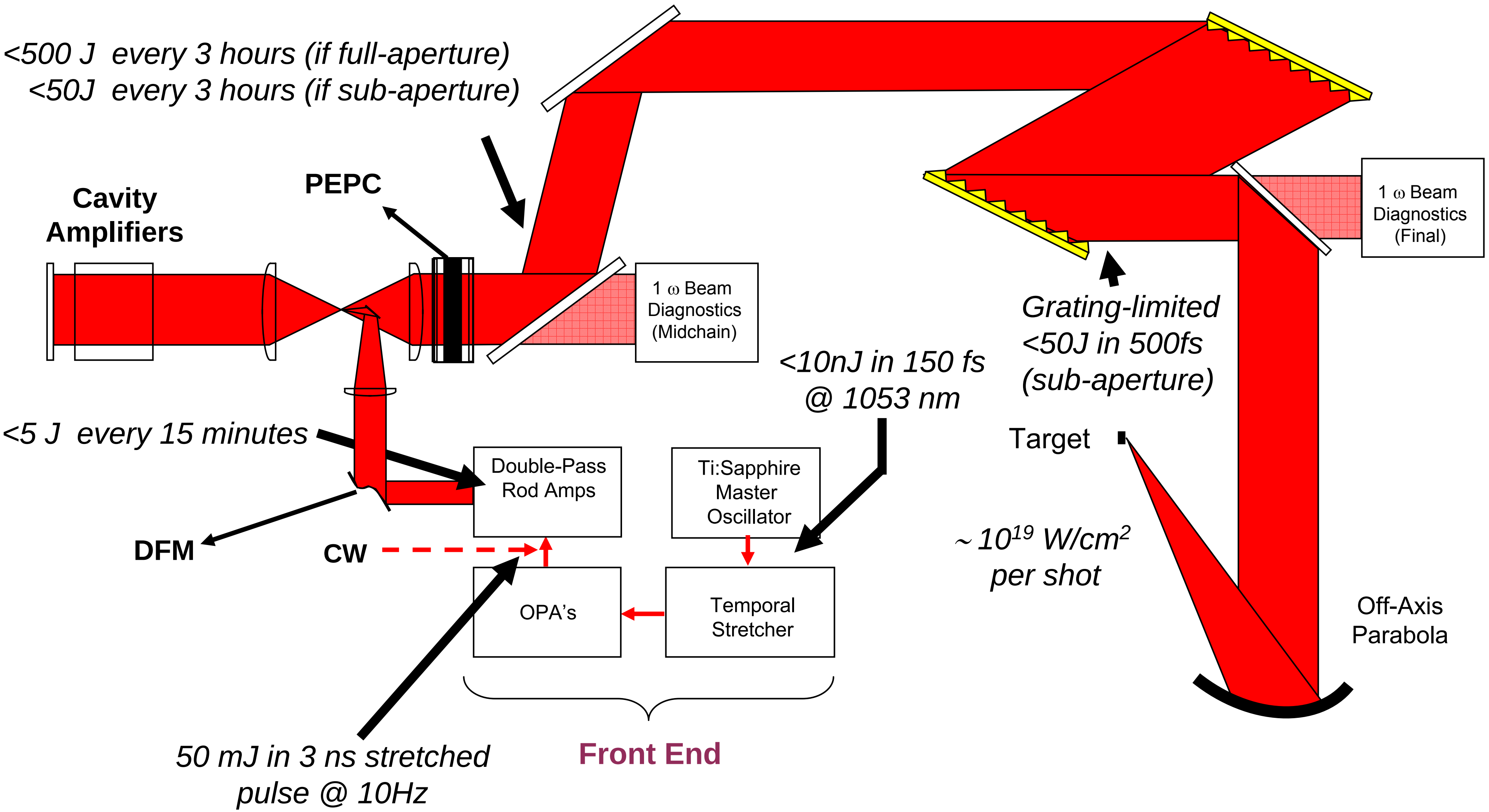




- This screen shot shows a compensated full system shot:
  PV: 1.03 waves
  RMS: 0.07 waves
  Strehl ratio: 0.85.



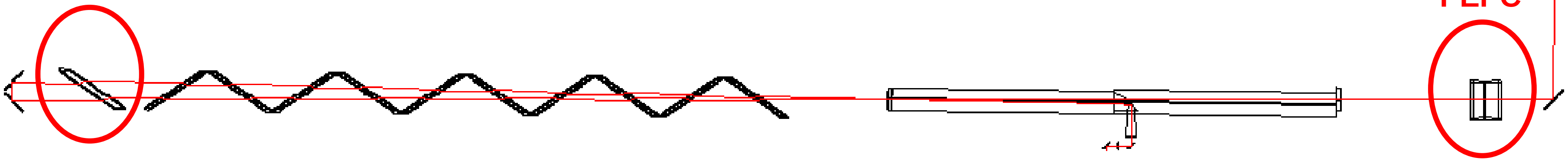
The 100TW/Petawatt System



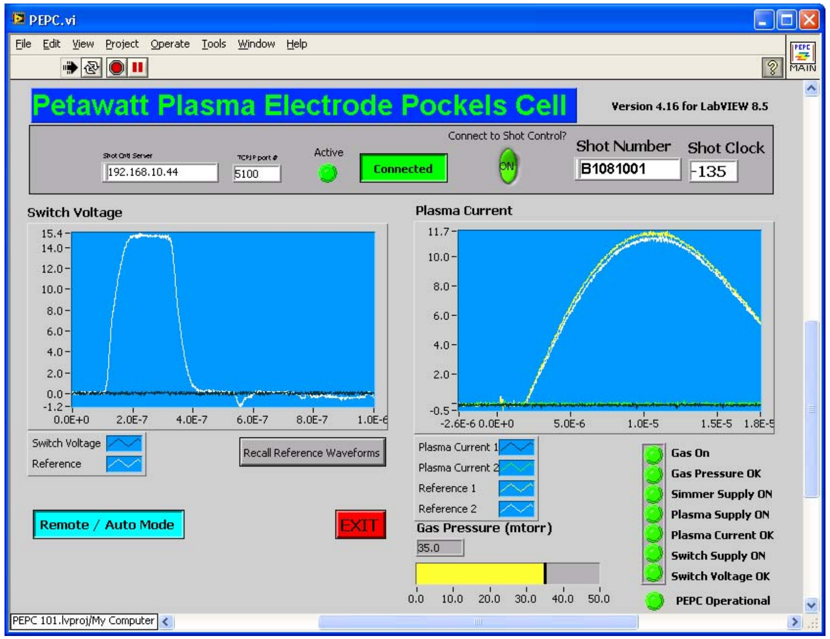
PEPC for Backreflection Isolation

- Initial tests on 100 TW system showed that target back reflection would cause laser damage at 1 PW level.

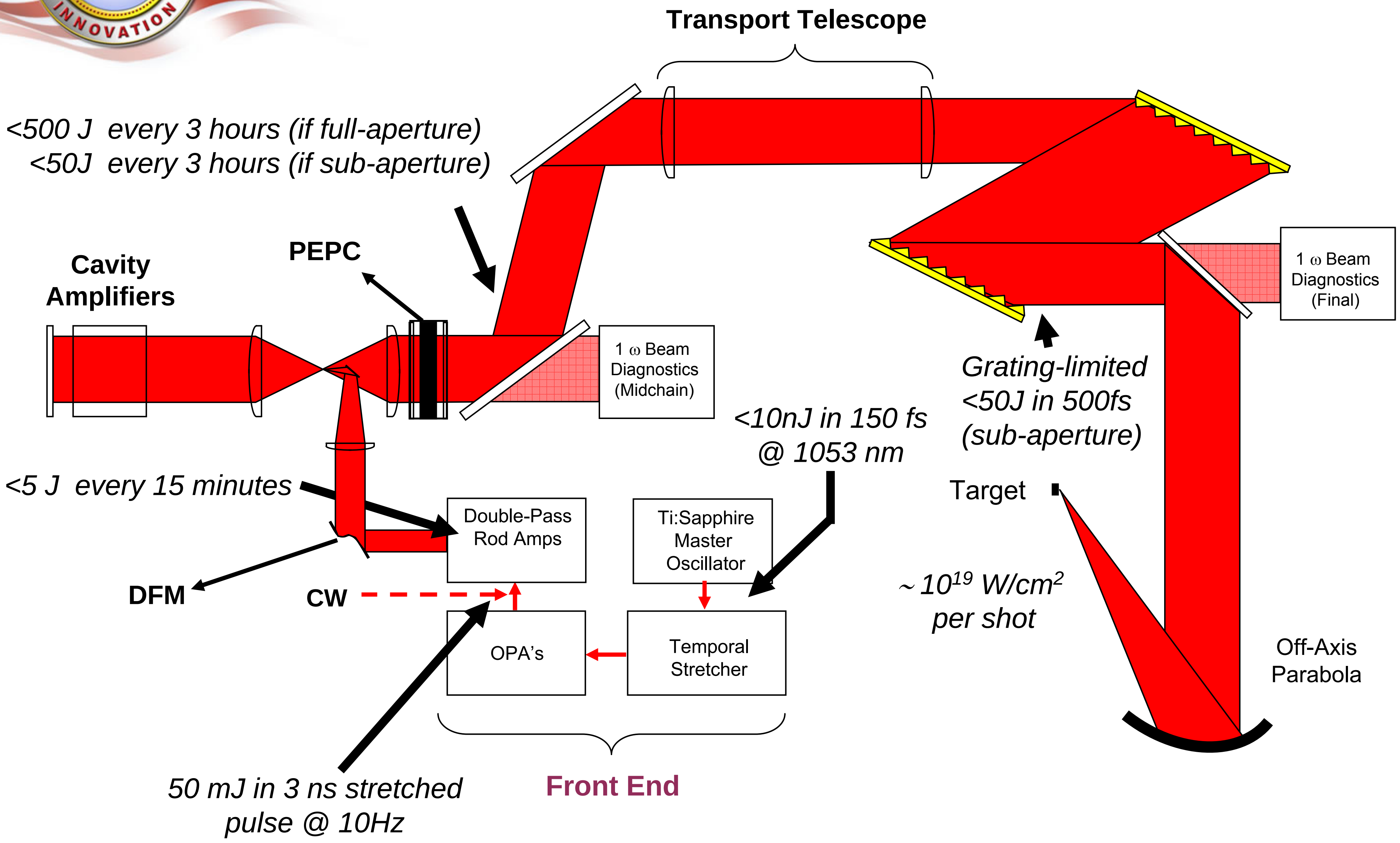
=> Installation of plasma electrode Pockels cell for isolation



pepc

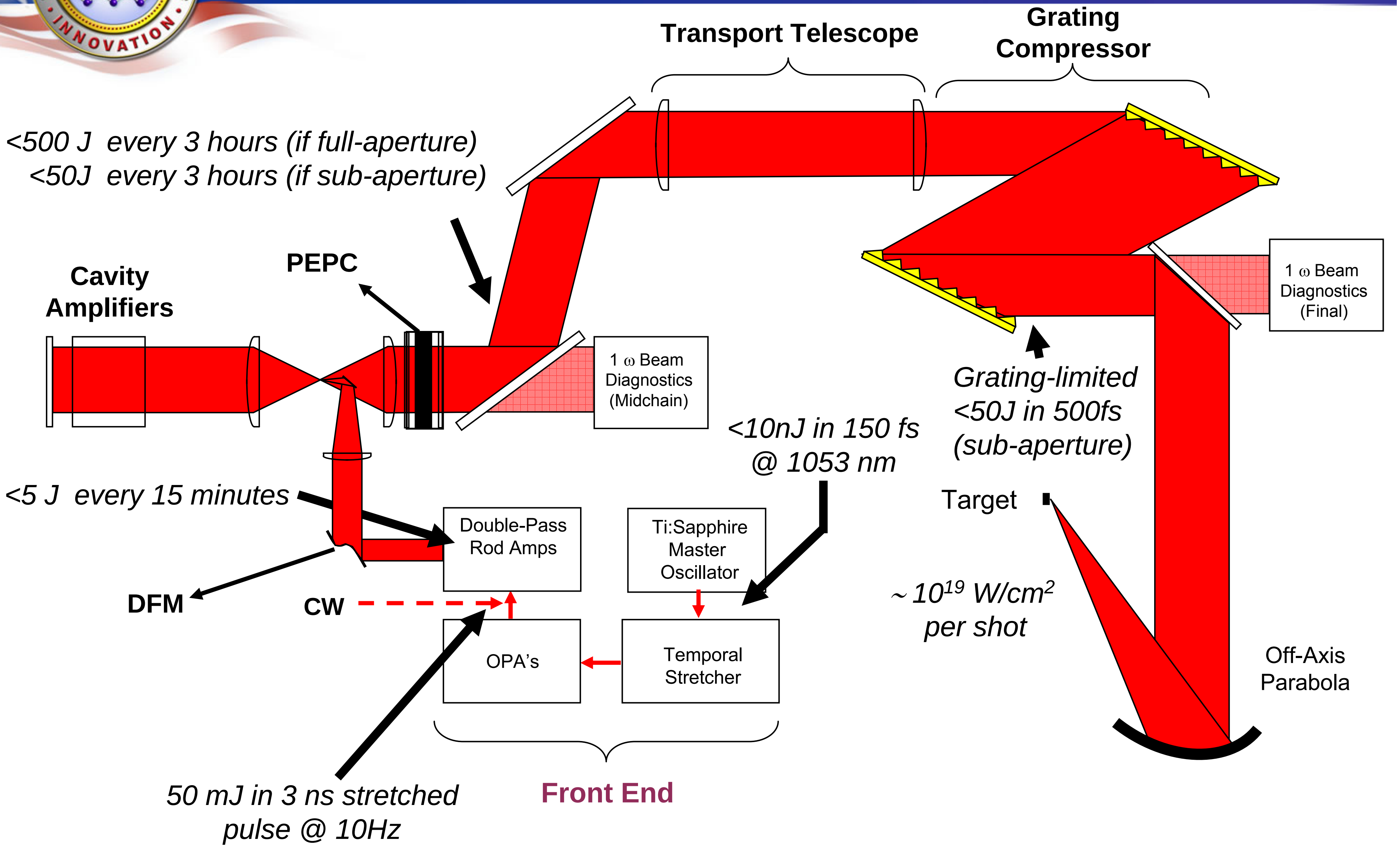


The 100TW/Petawatt System



Transport Telescope

The 100TW/Petawatt System

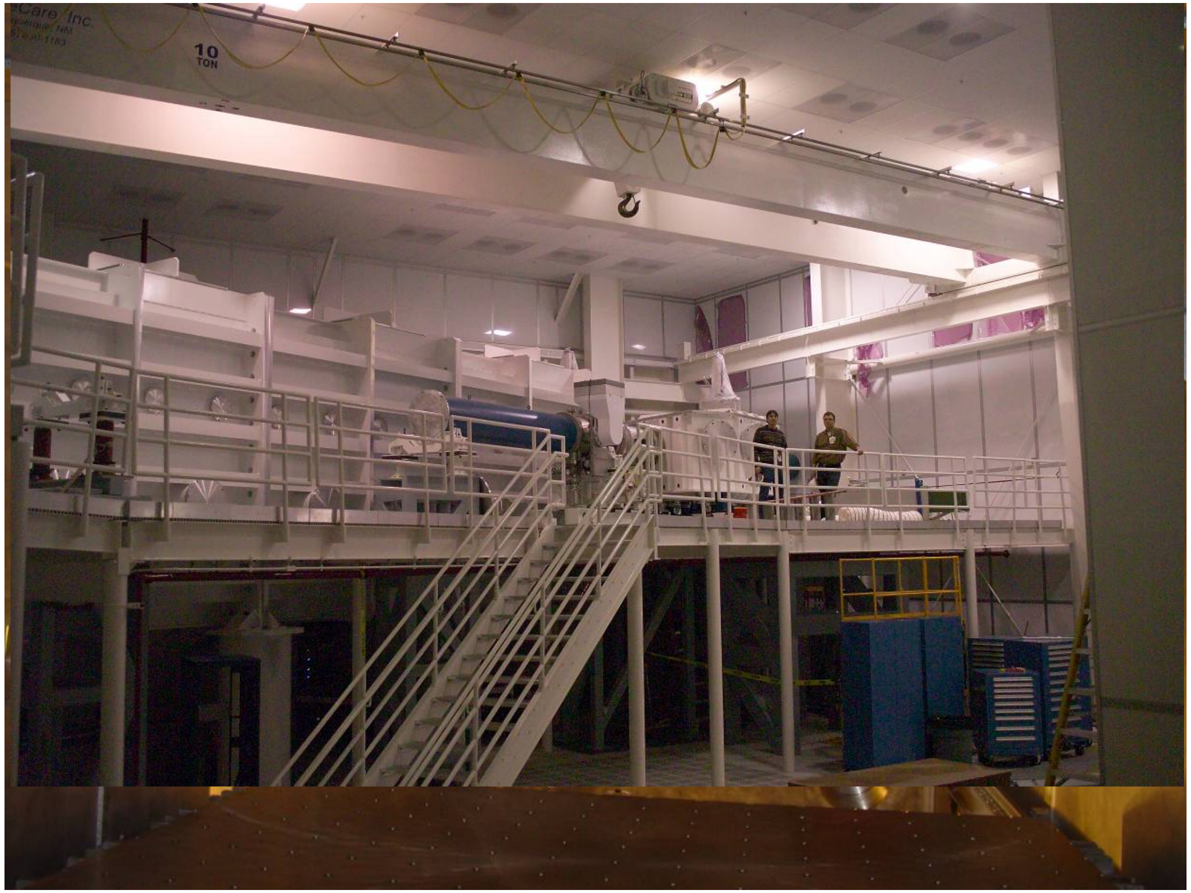


Petawatt Compressor Vessel

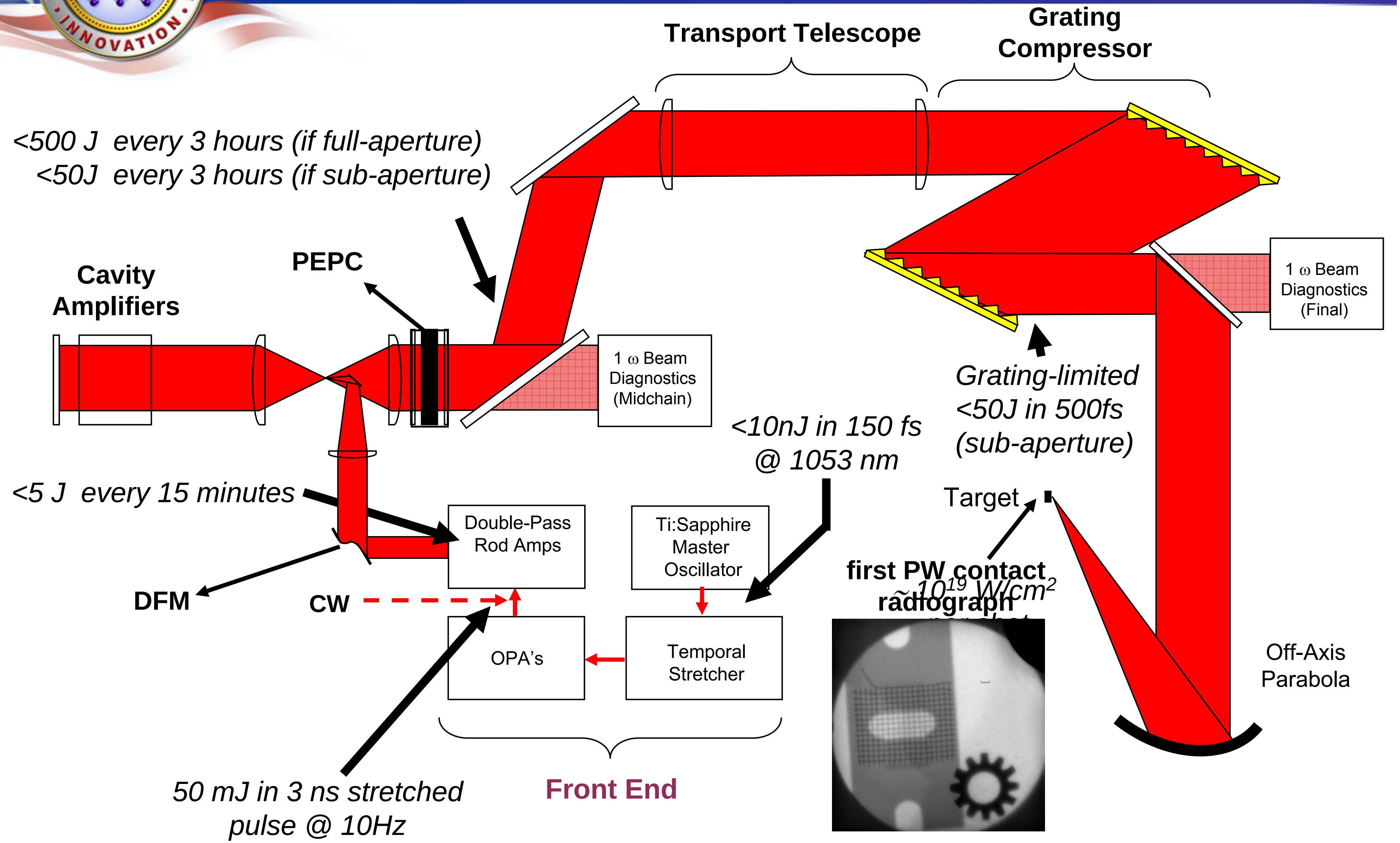
Three sections form vessel:
4.4 x 4.4 x 13.2 m^3
• 2 Tier design
• weight: 43 tons
• 4600m^3/h roughing + 3 ISO 500
Cryos allow:
$1x10^{-5}$ Torr in 3 hours or
$2x10^{-7}$ Torr in 15 hours

Uncompressed energy: 420 J

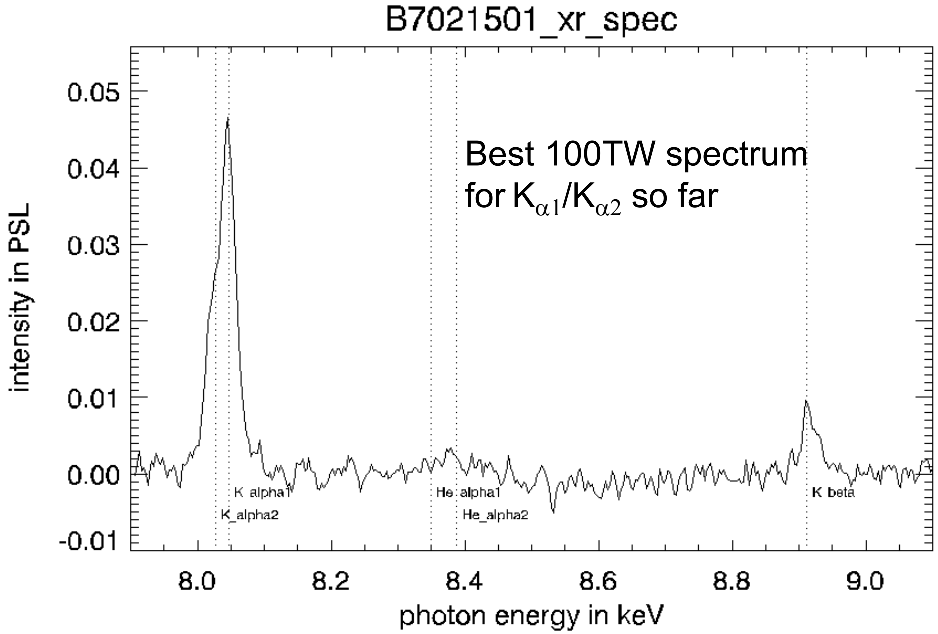
Compression: < 2ps
Compressed energy: 225 J

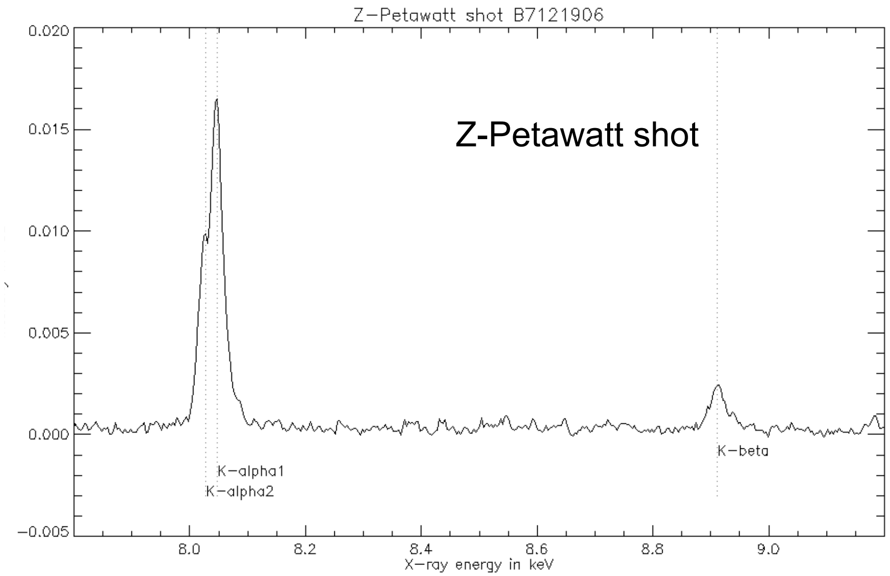


The 100TW/Petawatt System

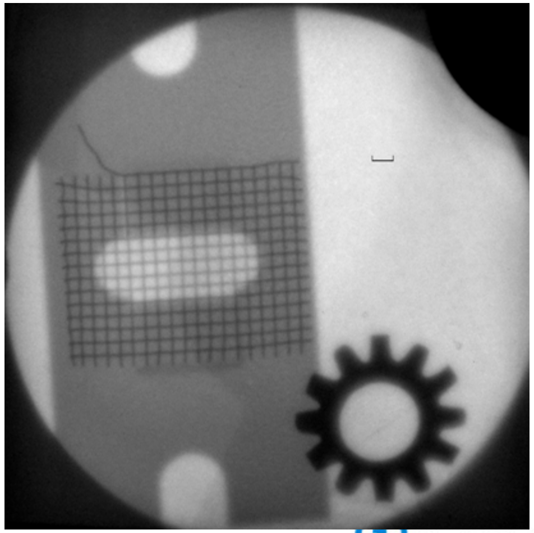


1st Z-Petawatt Shot (Spectrum)





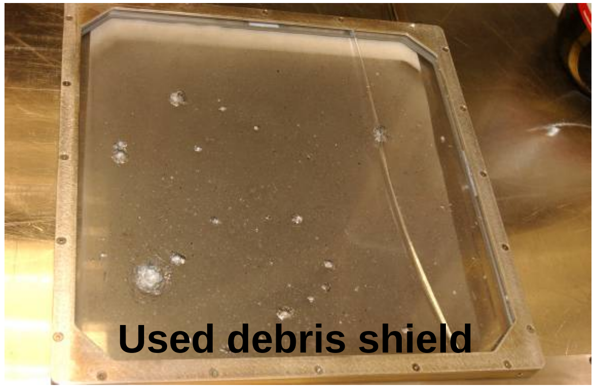
- Intensities don't scale (different scanning parameters).
- Signal-to-noise ratio for the Z-Petawatt shot is the best we have ever achieved for K_α measurements.
- Very nice resolution/separation of $K_{\alpha1}/K_{\alpha2}$ doublet.



PW FOA Debris

- Debris is generated from laser target interactions (minor) and z-pinch (major) sources.
  - Vapor debris <25km/s
  - Particulate debris <1km/s

- Terawatt/nanosecond scale backlighting deals debris via debris shields (30X30X1cm^3)



Used debris shield

Target s
• Forces c
optics to r
• Possibly
against la

on

ebris

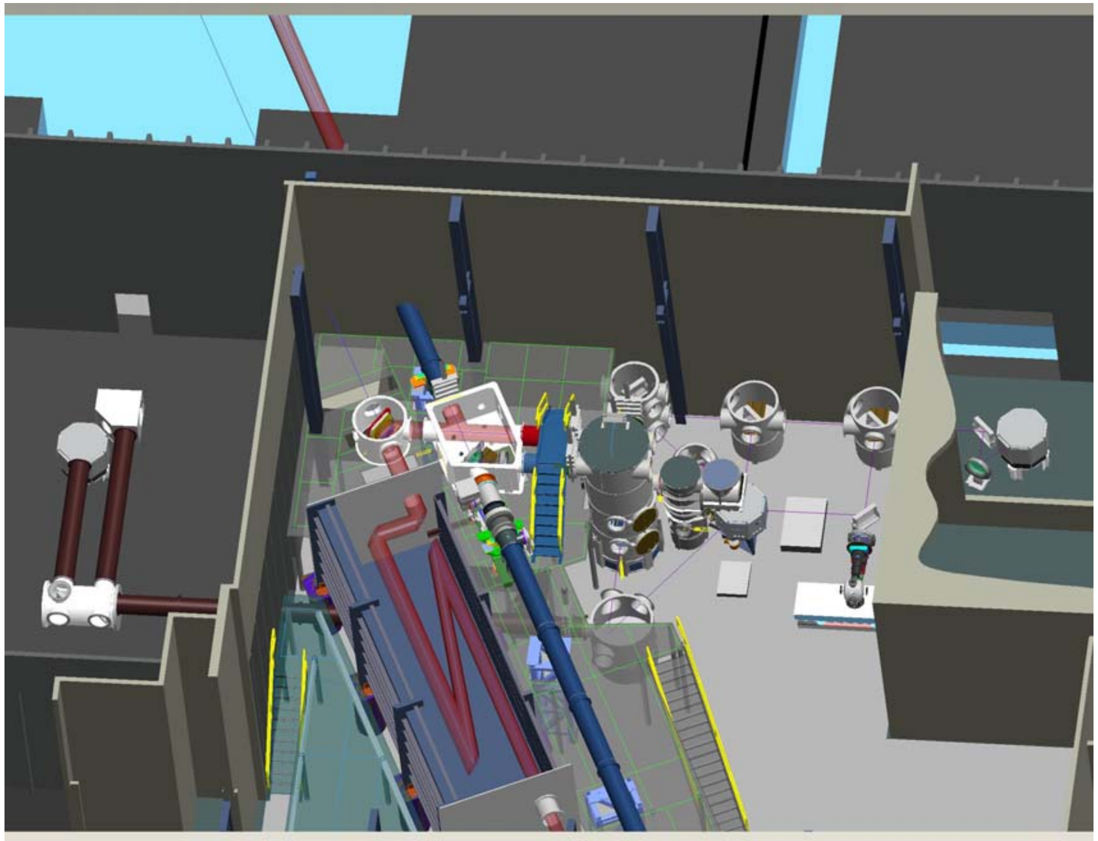
- Petawatt/picosecond scale backlighting must deal with debris differently due to B-integral effects:
  - Thin (2.7 μm) polymer film shields (passive)
  - Intelligent optics enclosure design
  - Fast debris shutters (active)

Jens Schwarz 9:04 Friday

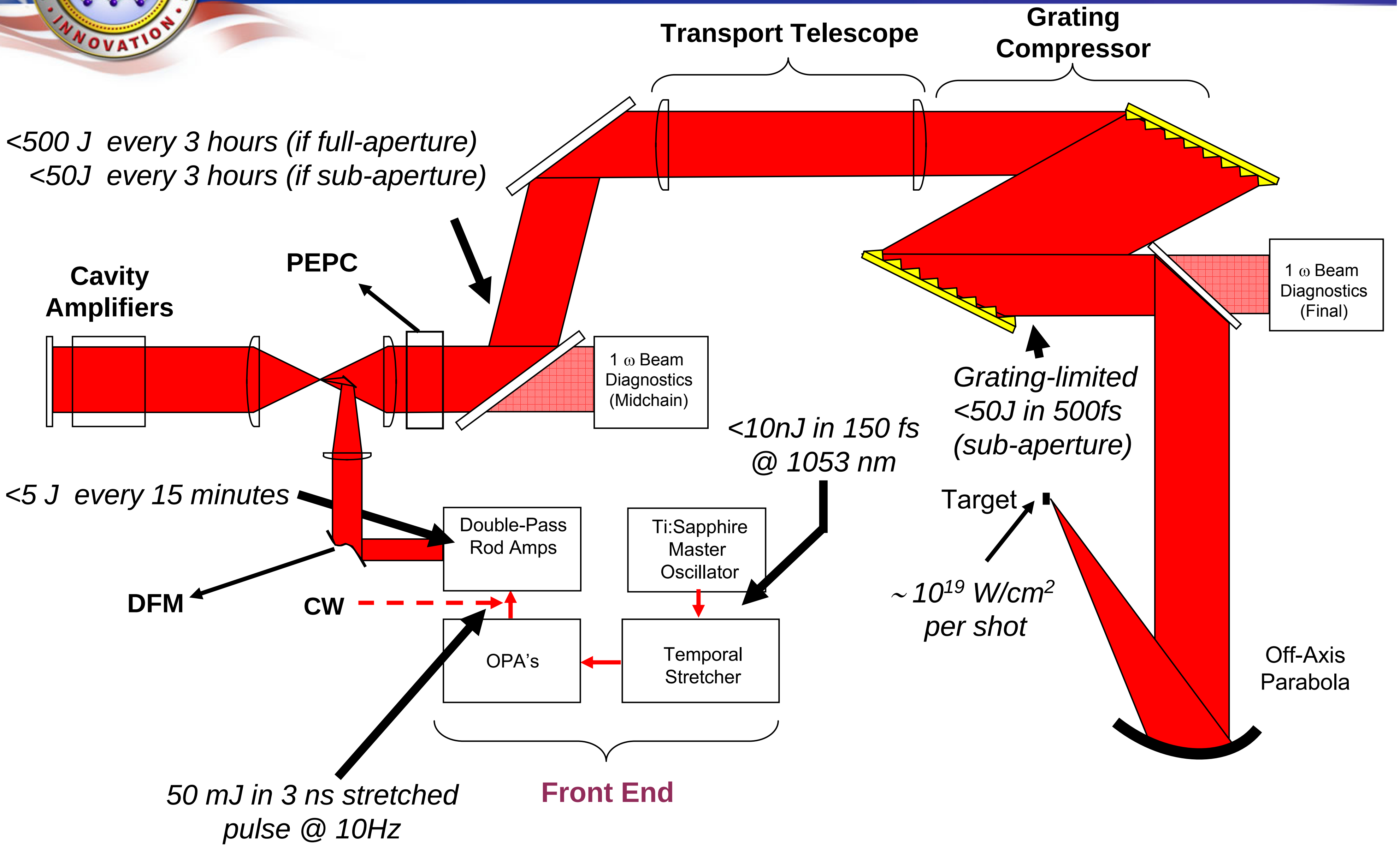
PW Target Area

•Experimental Capabilities:

- ZBL only
- Z-PW only
- ZBL and Z-PW
- Small pulsed power supply
- High grade radiation shielding



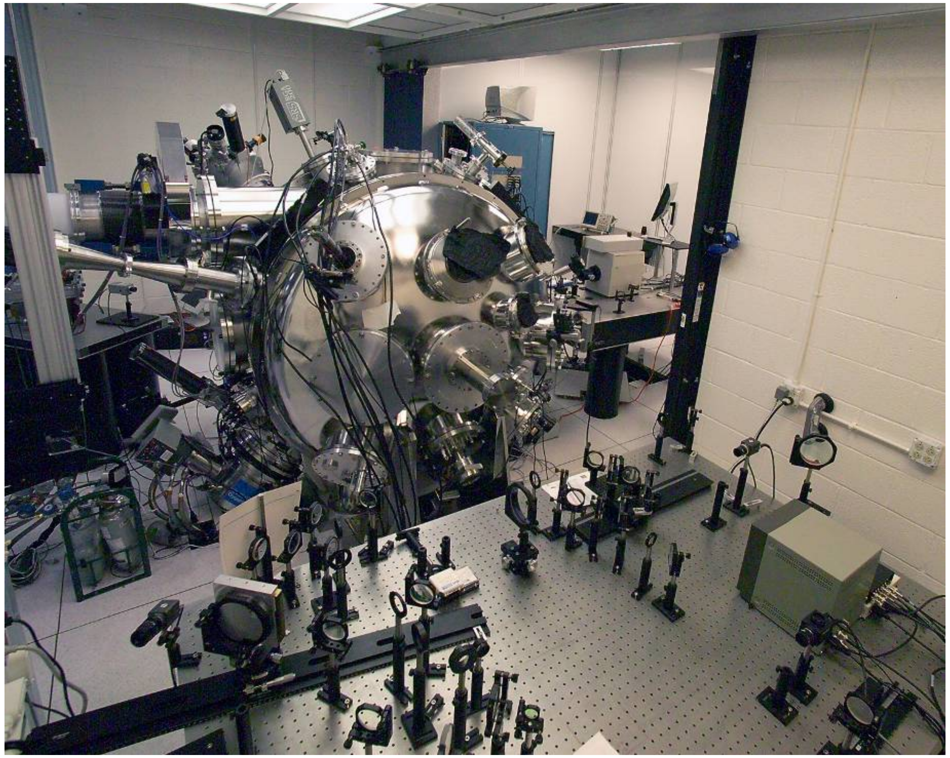
The 100TW/Petawatt System



100TW Target Area

Lasers:

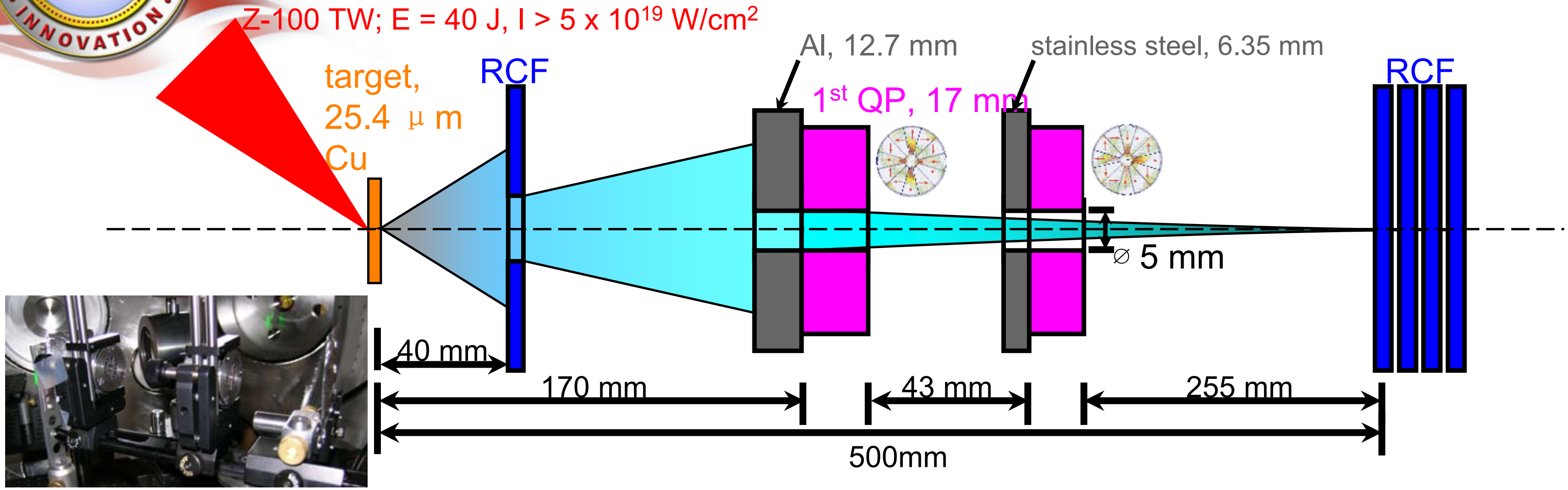
- Typical: 1054 nm, 50 J, < 1 ps, ~ 10^{19} W/cm^2
  laser intensity pointing stability < 50 μm
- Optical probe beam at 1054/527 nm, 30/10 mJ,
  τ < 500 fs, ps to multi ns delay possible

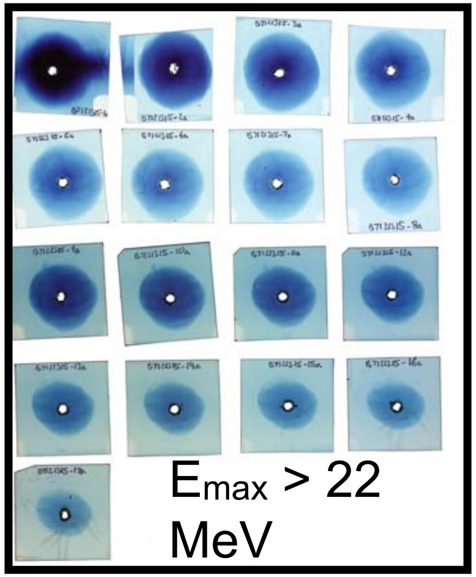


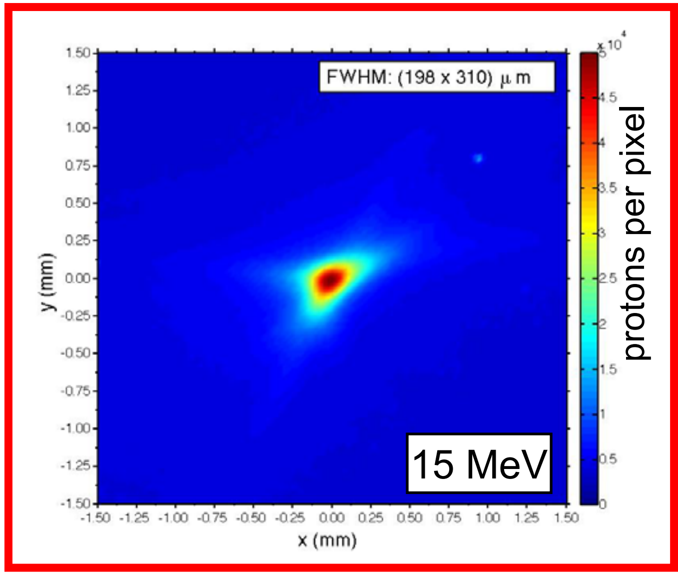
Diagnostics:

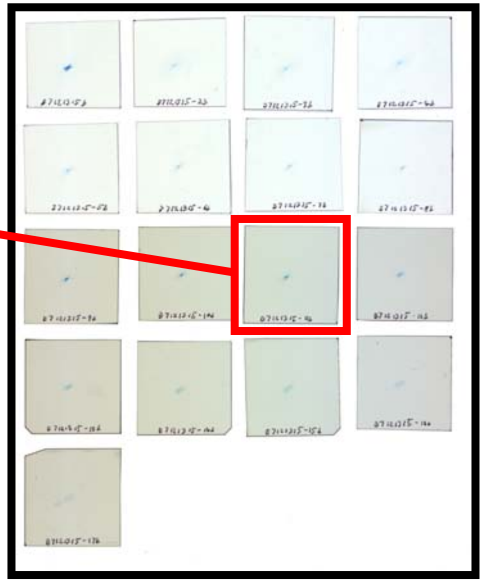
- Kα imager, X-ray pin-hole cameras
- multiple X-ray and optical streak cameras, 200 fs resolution at 1:40 dynamic range, 5 ps at 1:1000
- various X-ray and optical spectrometers
- single photon counting CCD's
- 12 GHz digital scopes
- Thompson parabola
- HV supplies up to 20 kV
- IP and CR39 detectors
- EMI shielded instrumentation cabinets up to 120 dB

Quadrupole Focusing Experiments









PRL: "Controlled Transport and Focusing of Laser-Accelerated Protons with Miniature Magnetic Devices“, 1 August 2008

Matthias Geissel: Tuesday 14:24pm

Conclusion/Future Upgrades

• Every component of the PW system has been exercised and the commissioning shot last year demonstrated integrated system functionality.

• New PW FOA needs to be assembled and installed for ZPW on Z.

• Several subsystems need to be optimized, e.g.: PEPC, DFM, laser diagnostics

• Dichroic mirror will enable ZBL/ZPW on same shot; focusing needs to be addressed

• PW target chamber in Target Bay will allow ZBL/ZPW experiments (planned FY08/09)

• Upgrade to MLD gratings (80cm X 20cm) will allow 240J@600fs operation in the 100TW target chamber

• Upgrade to MLD gratings (1.2 m x 0.4 m) will safely allow: 4.2 kJ @ 10 ps

94 cm x 40 cm gratings already demonstrated at Osaka, 60 cm x 20 cm for testing in house 1.4 kJ @ 600 fs

• Main cavity redesign to full aperture 4-pass configuration will allow to extract up to 5 kJ long pulse; cavity lenses and transport telescope lenses are on order