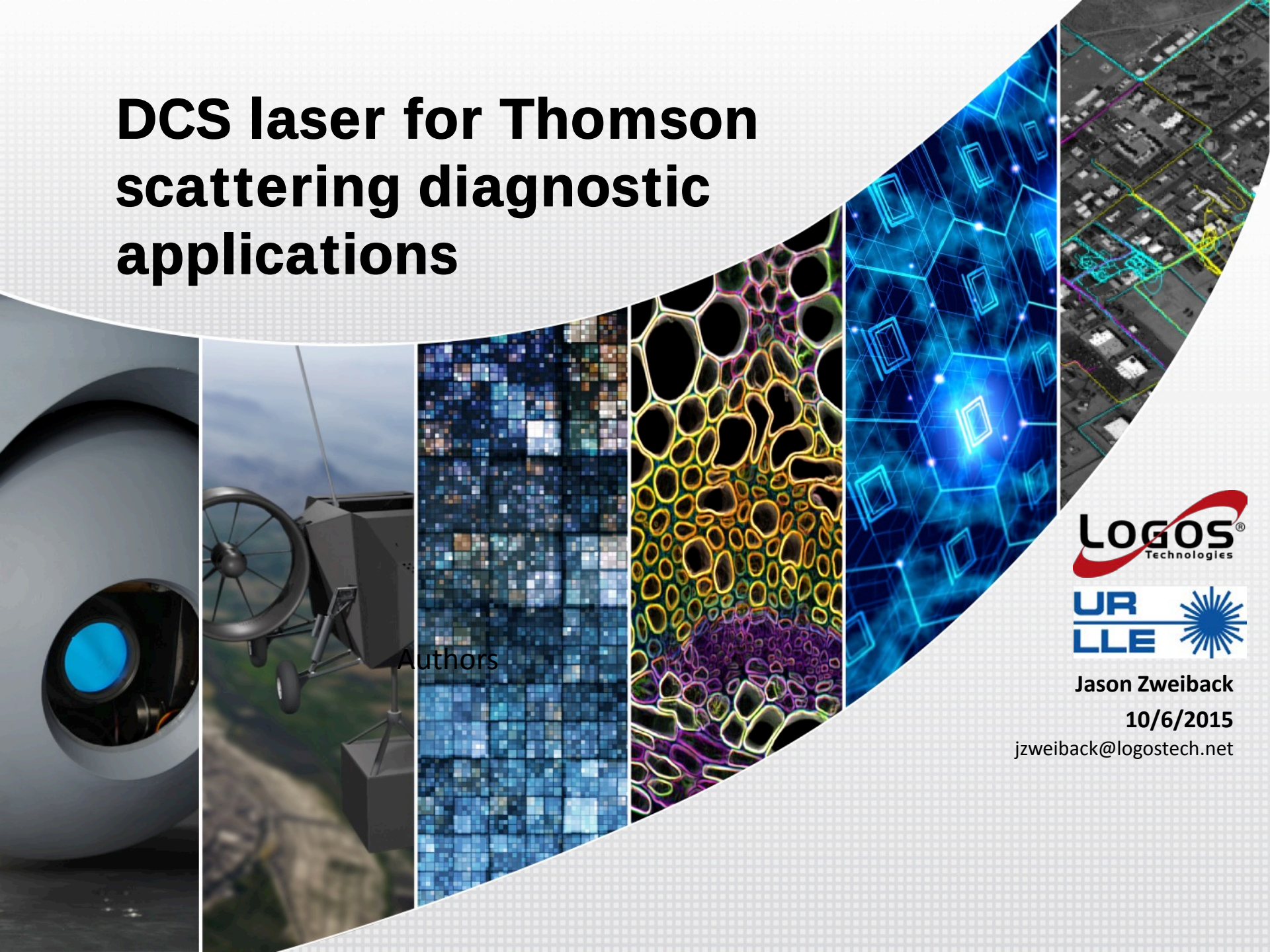
DCS laser for Thomson scattering diagnostic applications



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Summary

- Motivation
- DCS laser
- Laser for Thomson scattering diagnostics

What is the Dynamic Compression Sector?

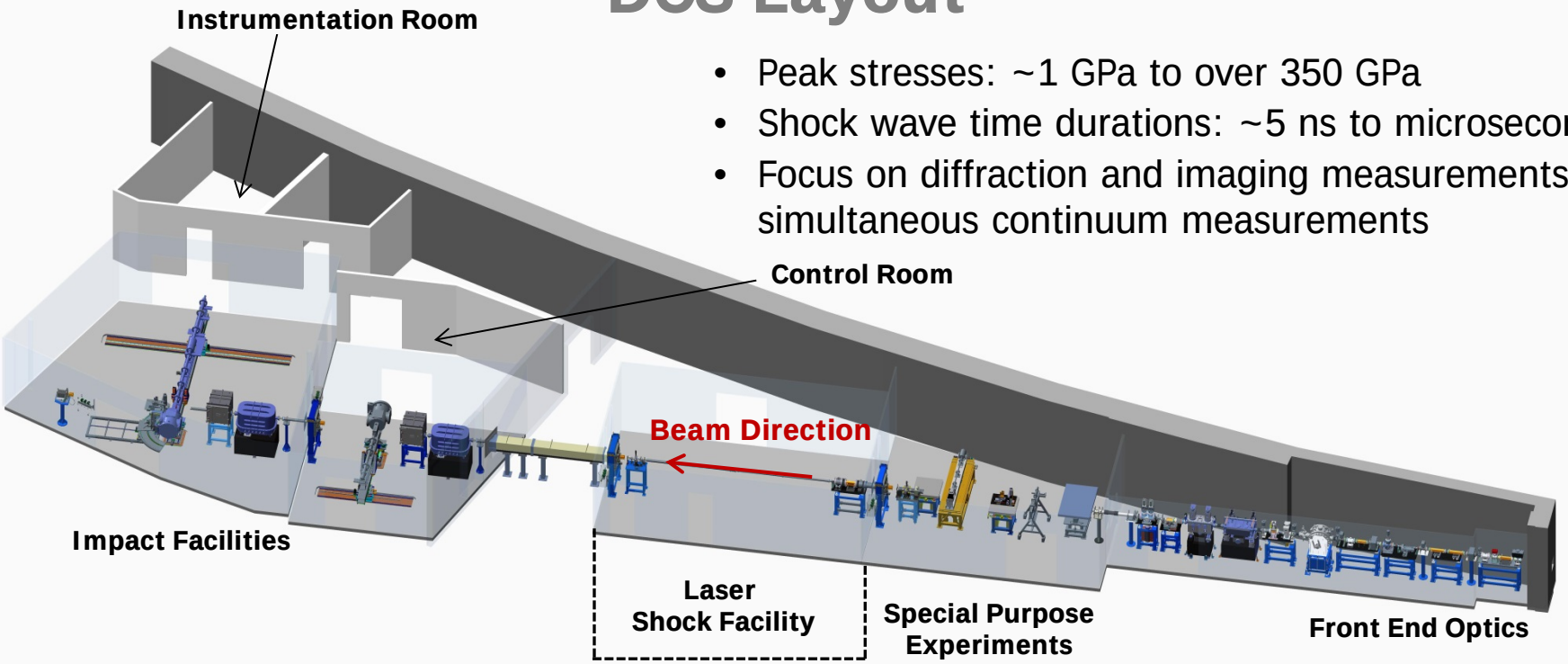
- A DOE/NNSA sponsored user facility dedicated to understanding dynamic compression of condensed matter
- WSU/APS partnership to optimally link dynamic compression platforms to a dedicated synchrotron beamline
- WSU will operate the DCS as a national user facility
- "Movies" in single event experiments; APS upgrade important
- Examine time-dependent changes under dynamic compression
  - Peak stresses (~1 GPa to over 350 GPa)
  - Time durations (~5 ns to μs)
  - Focus on time-resolved, in-situ diffraction, scattering, and imaging measurements; simultaneous continuum measurements
  - Special purpose experiments to complement dynamic compression

Advanced Photon Source

A new paradigm to understand dynamic compression of materials at multiple length scales

For more information on DCS contact Dr. Yogendra Gupta, WSU ymgupta@wsu.edu

DCS Layout



- Peak stresses: ~1 GPa to over 350 GPa
- Shock wave time durations: ~5 ns to microsecond
- Focus on diffraction and imaging measurements; simultaneous continuum measurements

- Energy range from 7-35 keV – with energies to 100 keV for imaging
- Focused X-ray beam spot sizes: ~14 (V) x 20 (H) μm^2 to ~19 (V) x 68 (H) μm^2
- Special purpose experiments to complement dynamic compression

DCS measurements will address long-standing scientific questions regarding materials dynamics

UR LLE

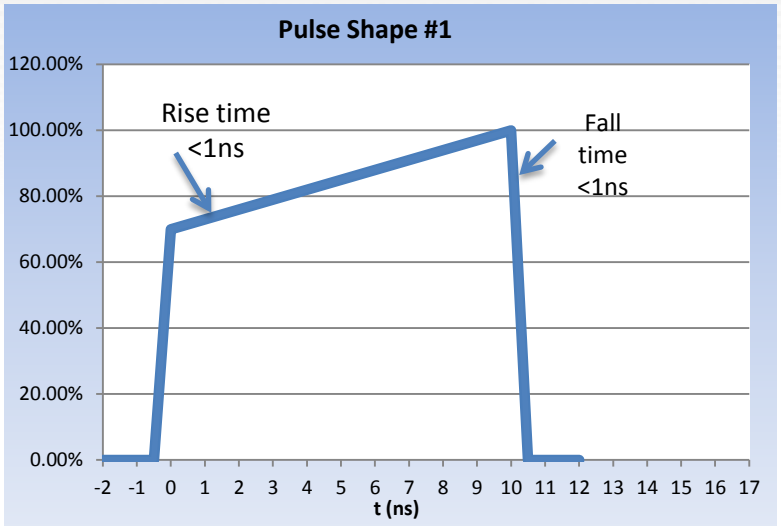
Design philosophy emphasizes proven technology and operational robustness

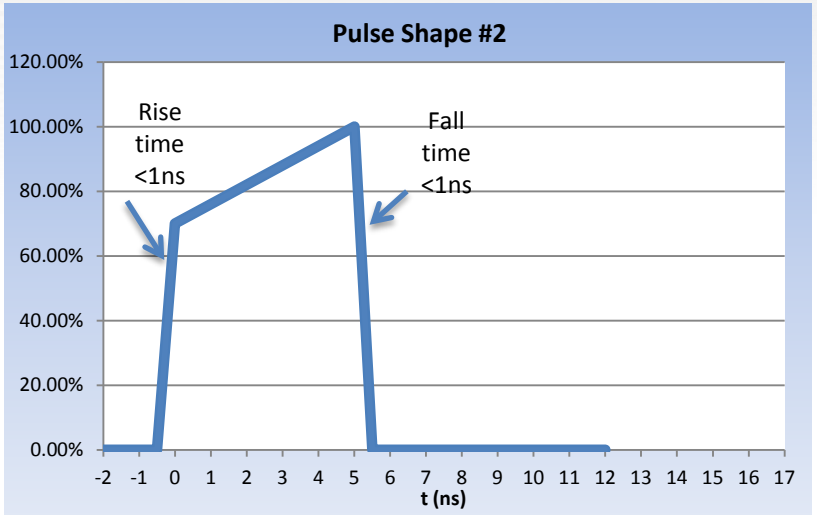
- Laser is designed to be part of a high productivity user facility
- Laser uses technologies that are currently operating in the OMEGA, OMEGA-EP, and Multi-Terawatt (MTW) laser facilities at LLE.
- Controls software are being developed for ease of use and high reliability.
- Laser is designed to be flexible and upgradable to arbitrary pulse shape (with software upgrades) and higher repetition rate (with power amplifier development and upgrade)

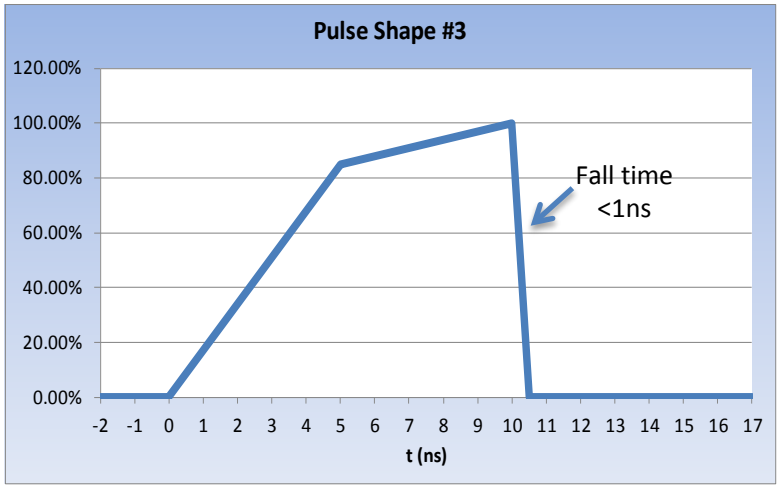
DCS Laser Design Summary

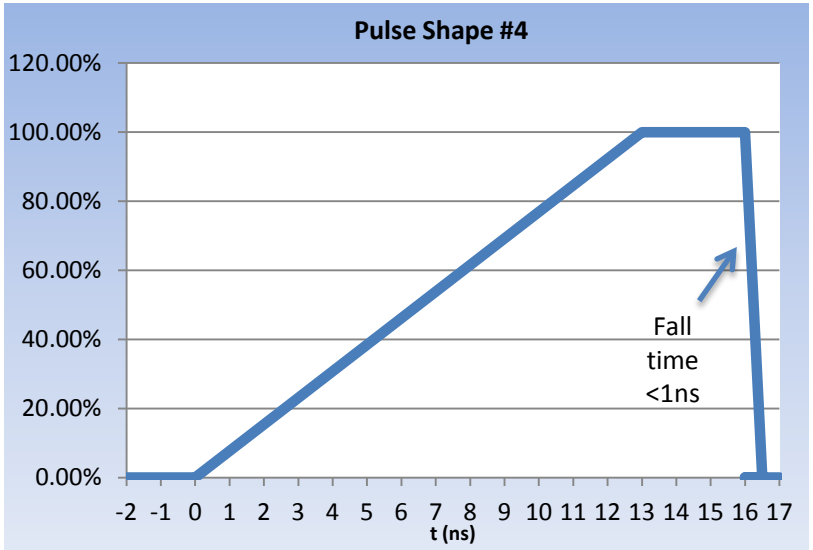
Parameter	Value
Laser energy	100 J (3ω) 200 J (1ω)
Wavelength	351 nm (3ω)
Repetition rate	1 shot every 20 minutes
Spot size	500 μm flat top
Prepulse contrast	>10^6:1 for 100 ns >10^8:1 for 100 ms
Shot to shot reproducibility	<+/- 3.0%
Pulse shape control	• <1 nsec rise to a 5 nsec pulse that starts at 70% of the peak intensity and linearly increases to 100% peak intensity over the 5 nsec. (Pulse 1) • <1 nsec rise to a 10 nsec pulse that starts at 70% of the peak intensity and linearly increases to 100% peak intensity over the 10 nsec. (Pulse 2) • 5 nsec linear ramp to 85% of peak intensity and linear increase to 100% peak intensity over an additional 5 nsec. (Pulse 3) • 13 nsec linear ramp from 0% to 100% peak intensity followed by 3 nsec flat top at 100% peak intensity. (Pulse 4)
Operating Crew	Single trained operator

4 standard pulses will be preprogramed into the DCS laser.





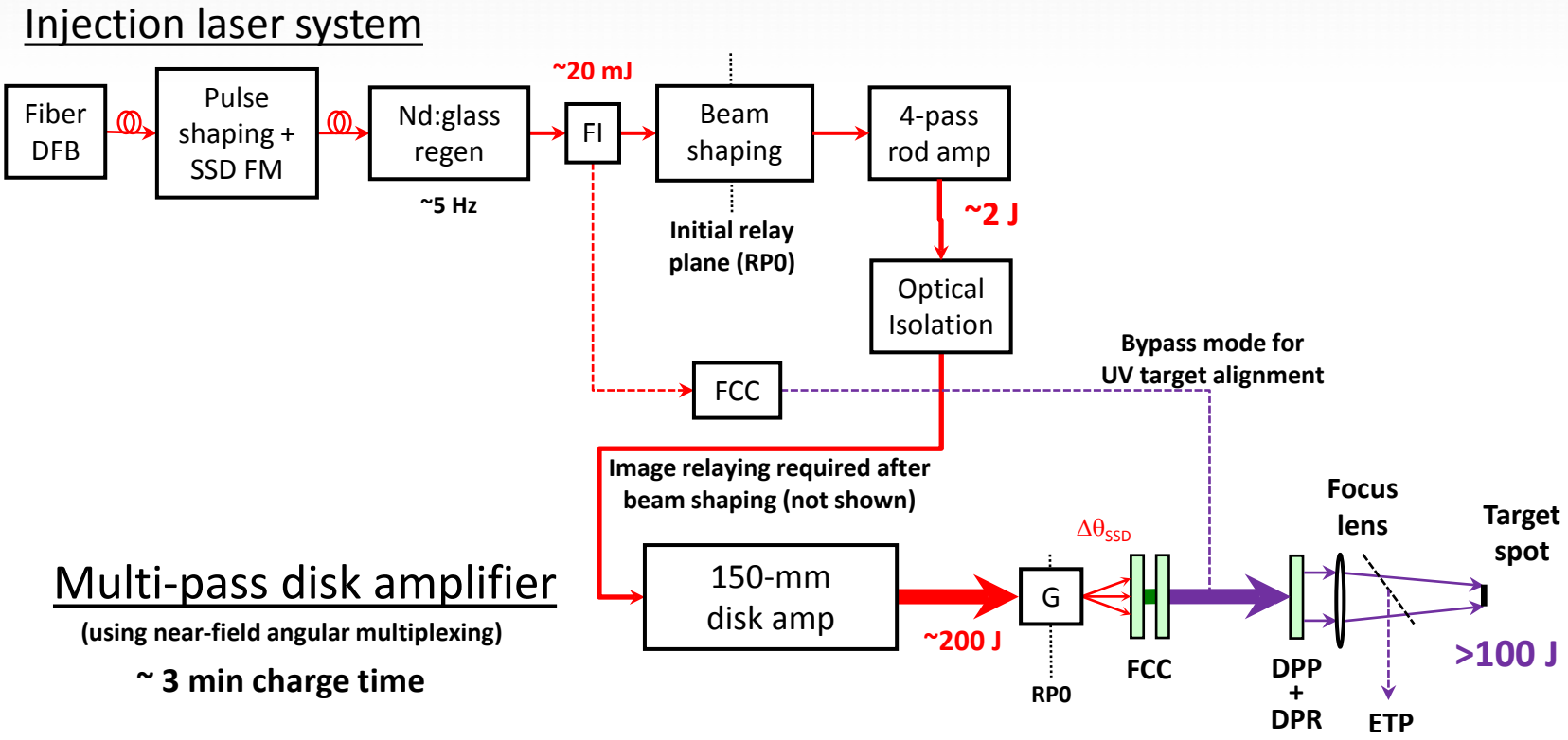




The DCS laser pulse shaping system is capable of arbitrary pulse generation.

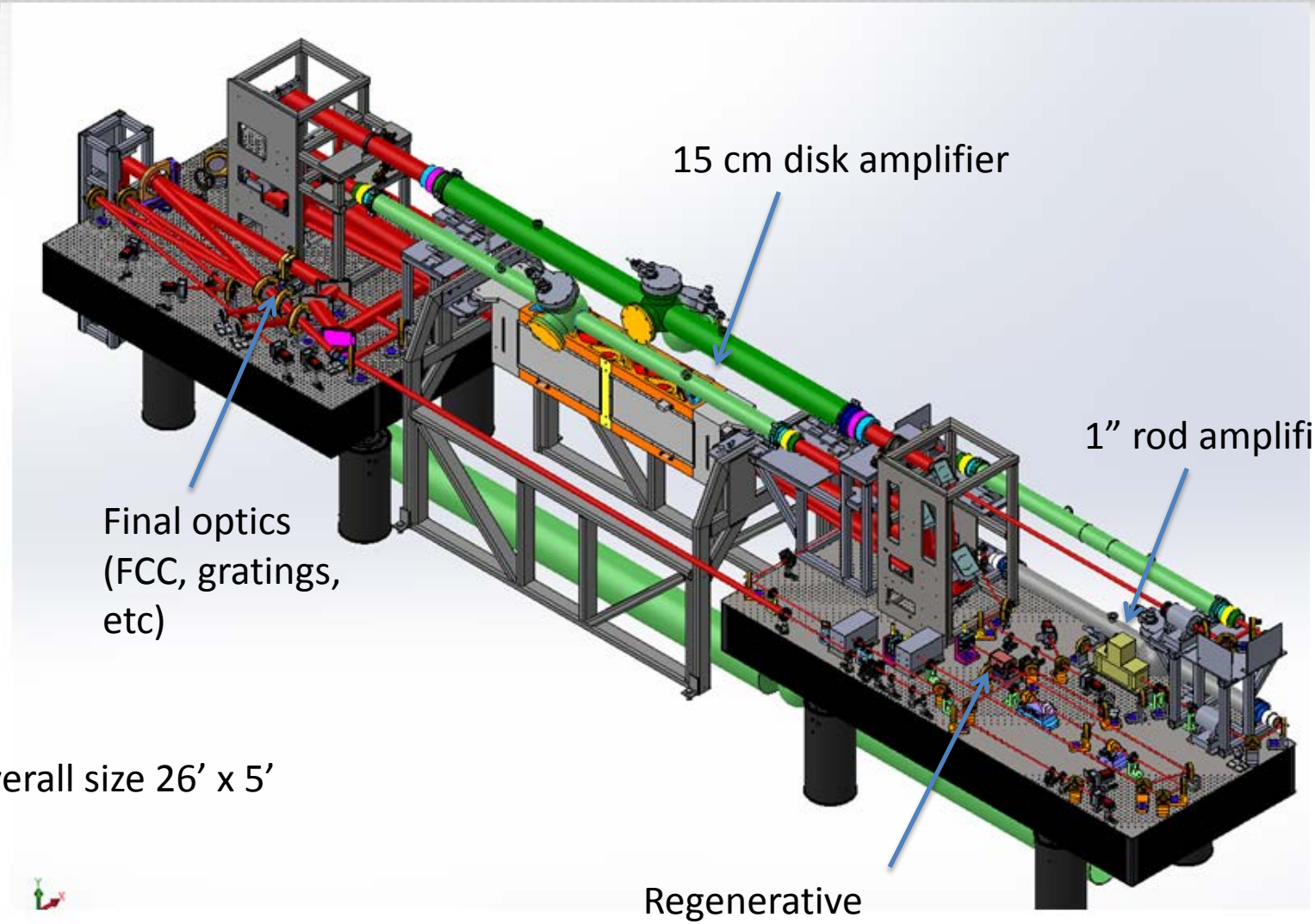
Laser Schematic

200 J will be required in the IR for 100 J of UV (est. ~52% beam delivery losses)



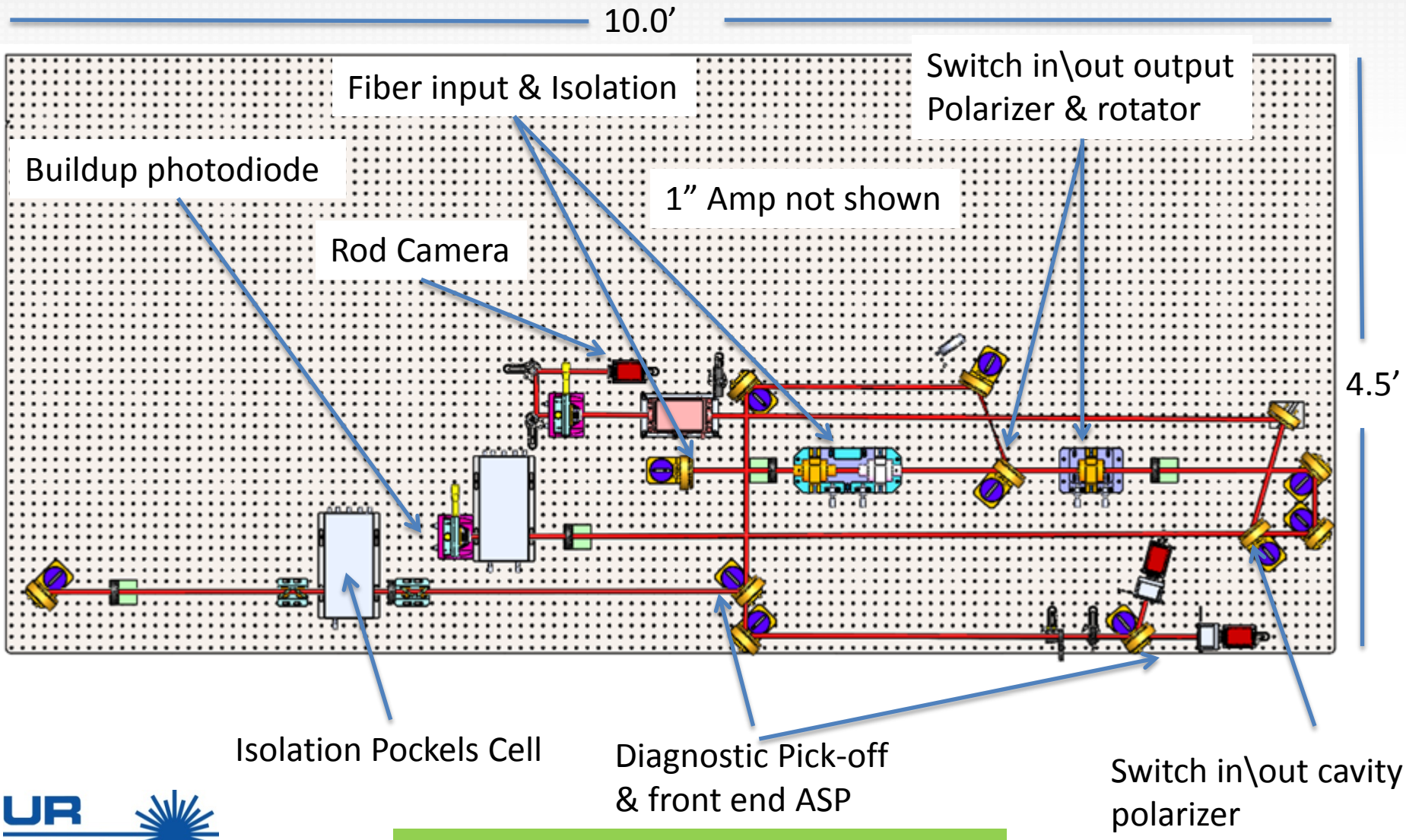
All subsystems have been demonstrated in laboratory environments

Overall laser design layout



Overall size 26’ x 5’

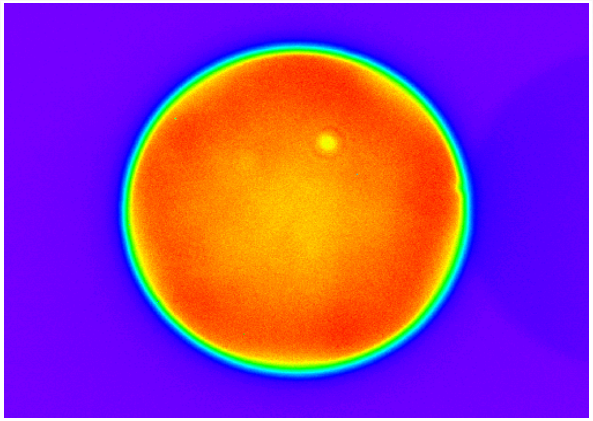
Regen is designed for a 20 ns pulse.

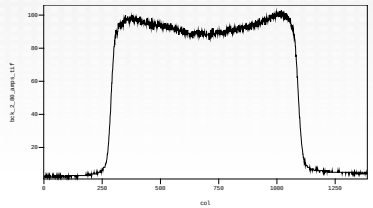


Length can be reduced for OTS laser

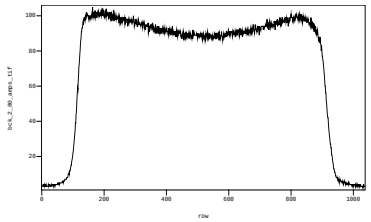
Diode pumped regen operates at <1% energy variability

Amplifier fluorescence

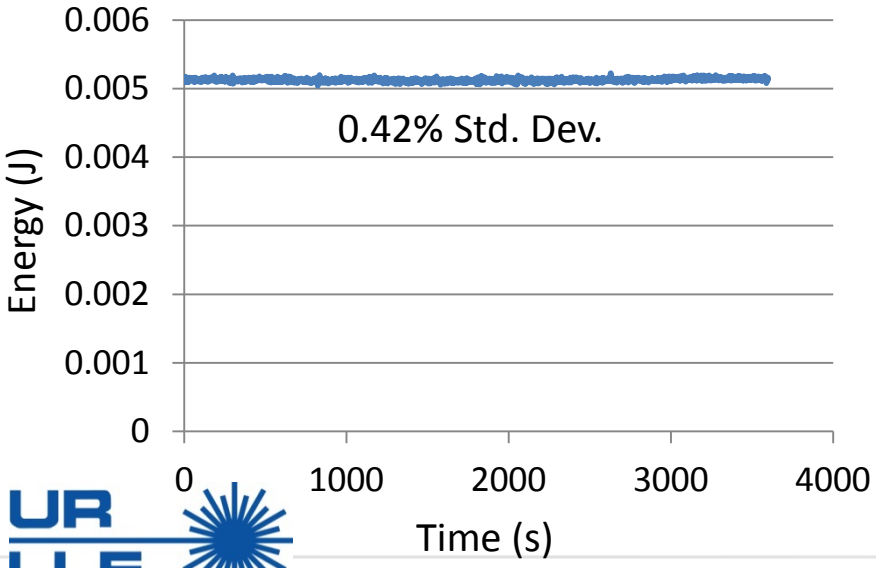




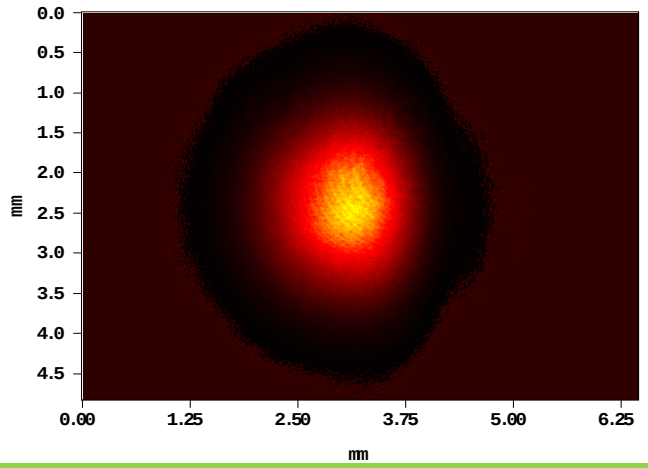
Horizontal lineout



Vertical lineout

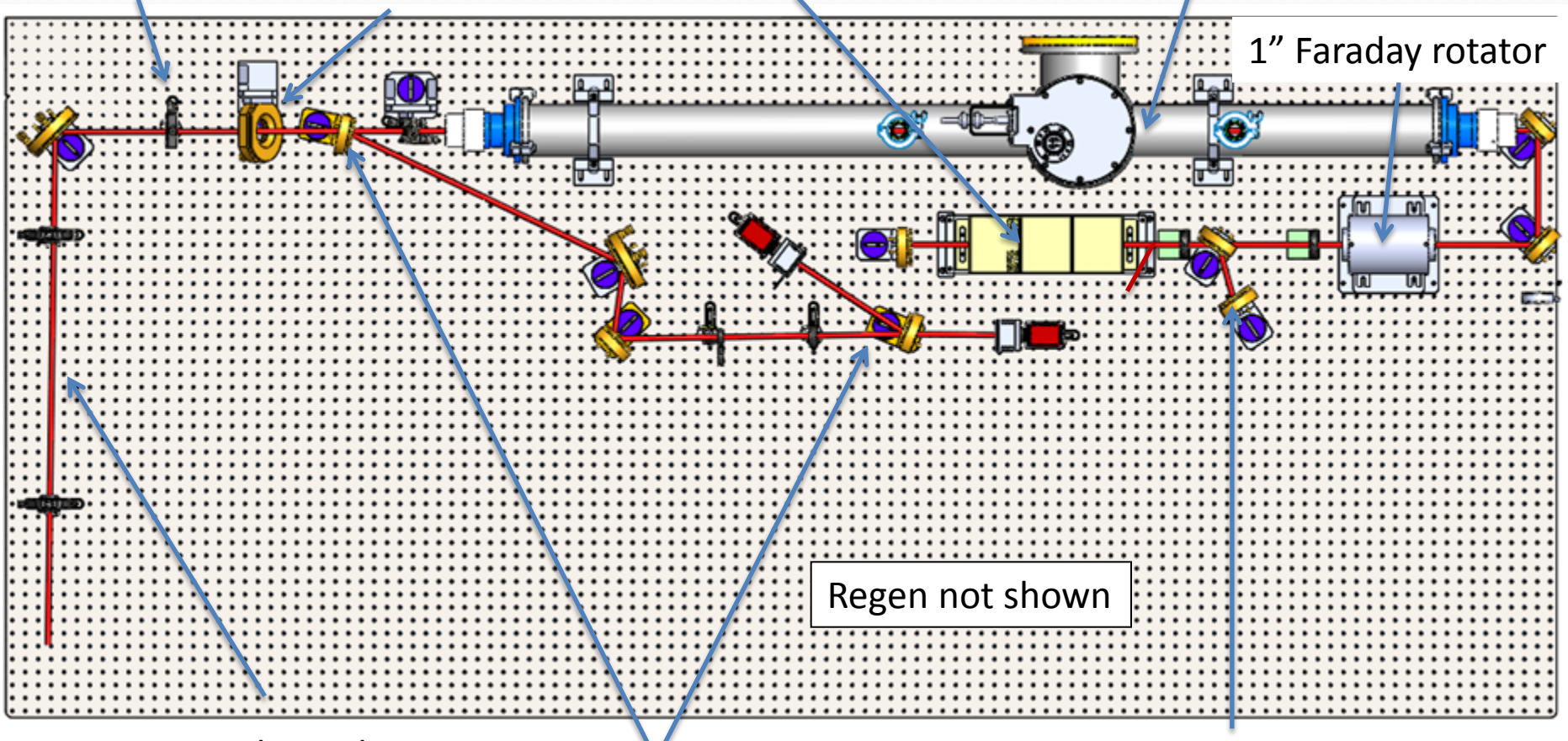


Near field output



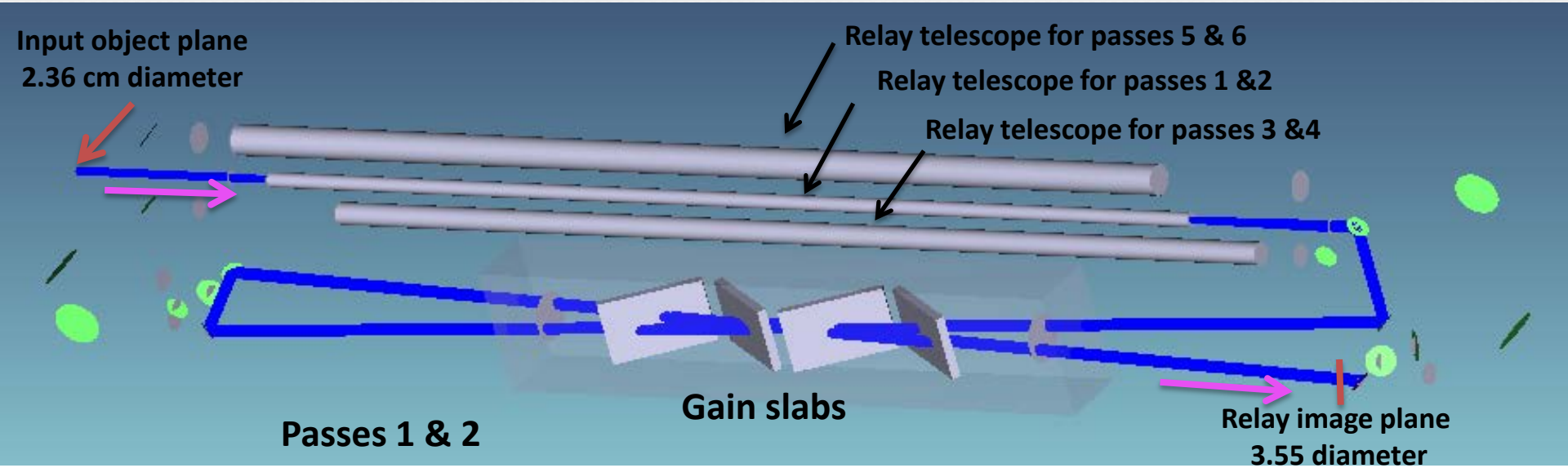
Regen is designed for 20 mJ output.
Lenses are on order to reach full energy.

Pre-amplifier will use a 1” Continuum laser head and a NIF like 4-pass architecture



Current design produced 1.6 J

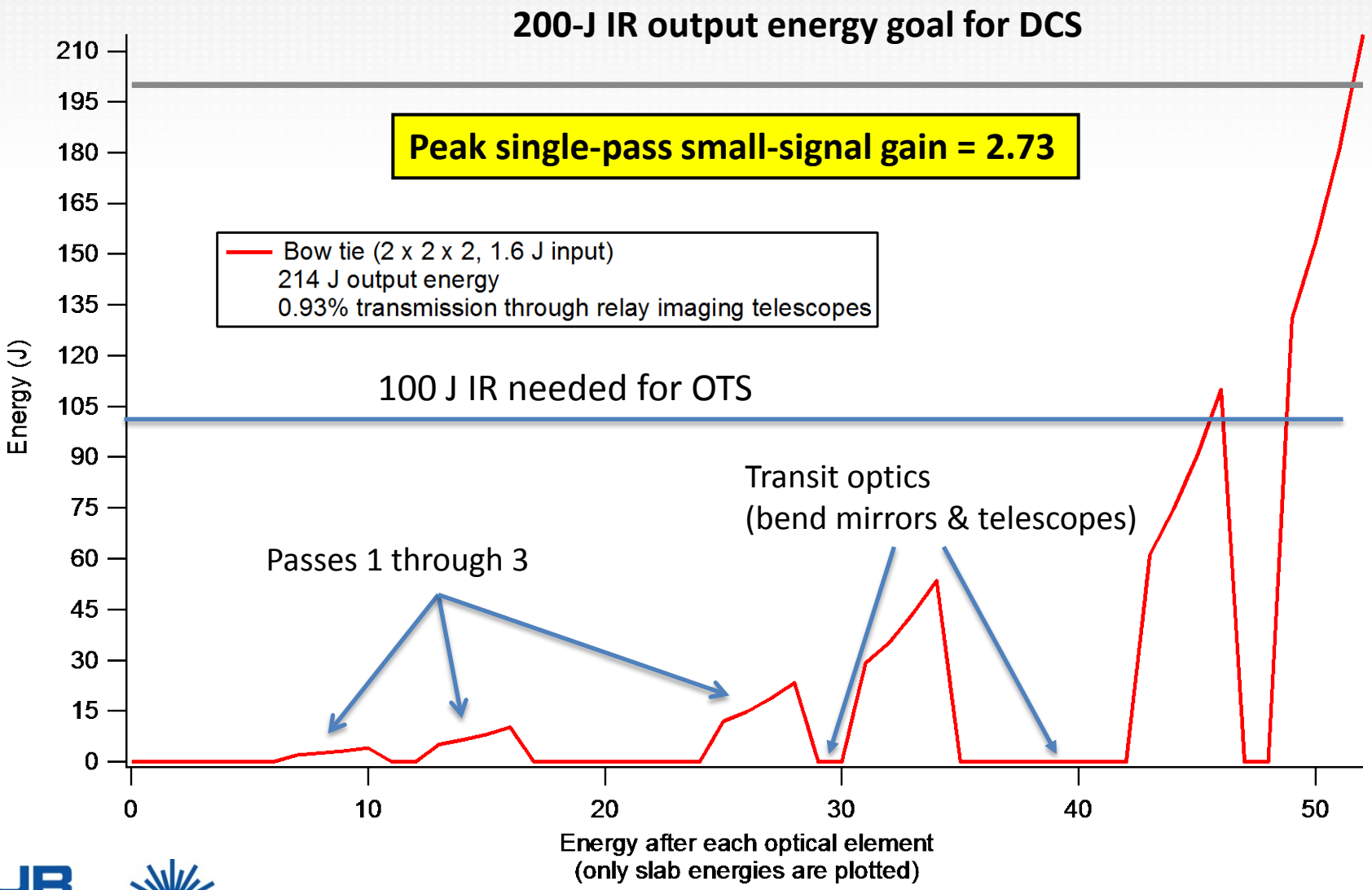
Disk amplifier uses a multi-pass bow-tie design



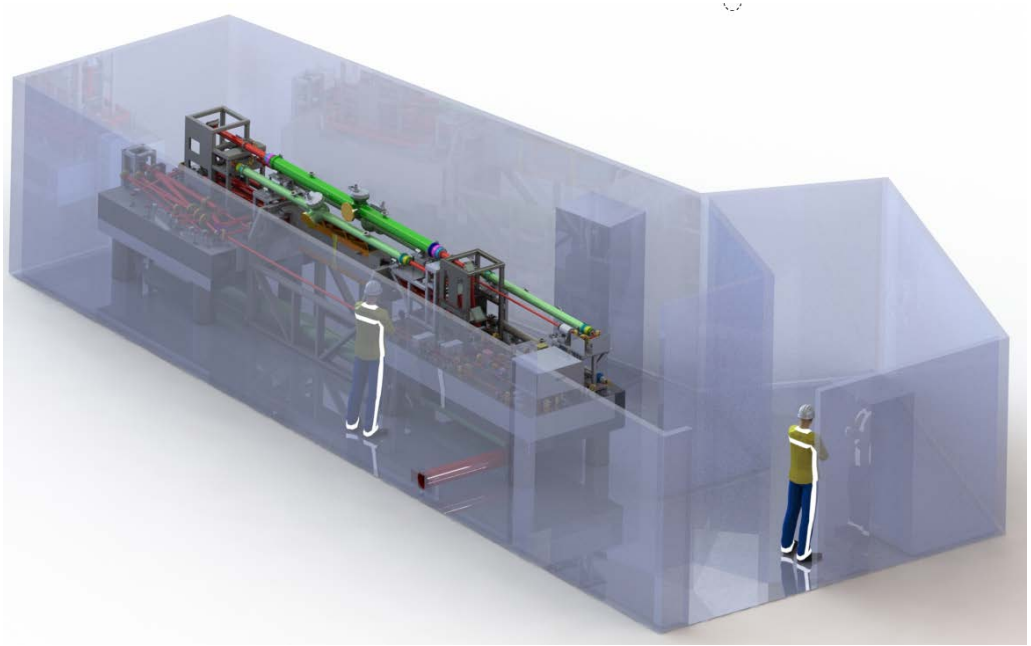
2 x 2 x 2 passes
Magnification of 1.5 between every two passes
4 element relay imaging telescope (reduces required telescope length for imaging distance)
Beam Sizes

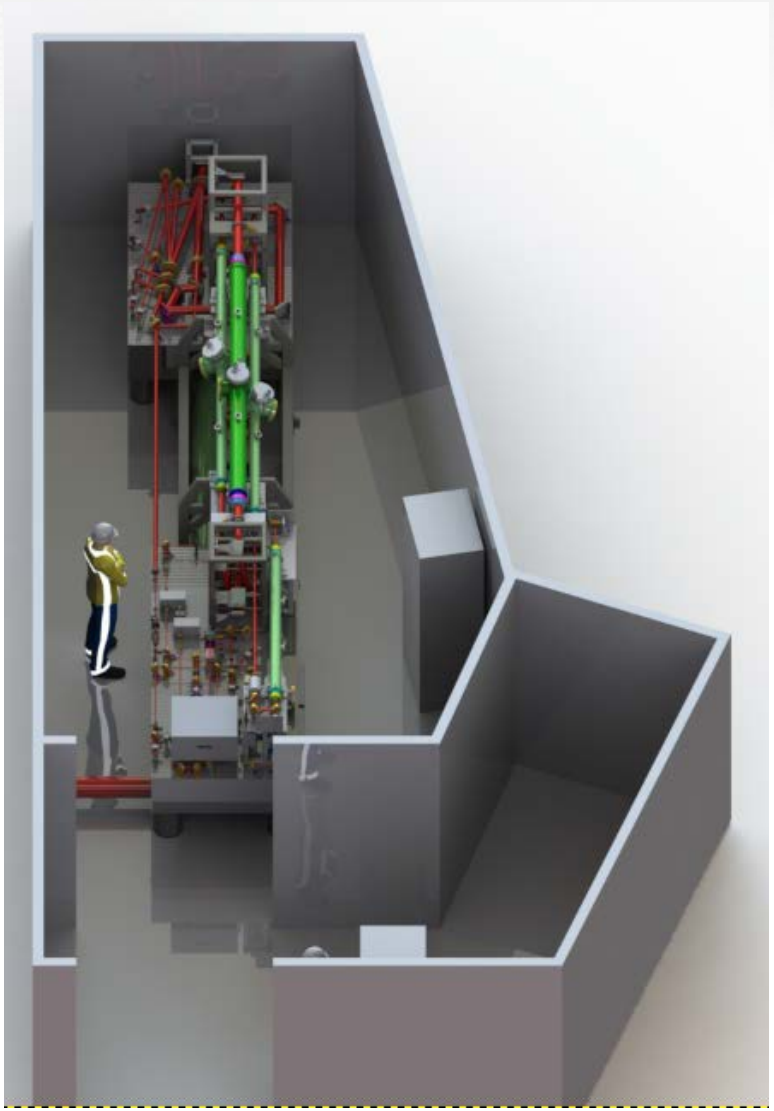
- 2.36 cm (input) - 3.55 cm (pass 1,2) – 5.33 cm (pass 3,4) – 8 cm (pass 5,6)
- Relay imaging repeats after every 2 passes

Predicted main amp energy buildup



Room layout at DCS facility



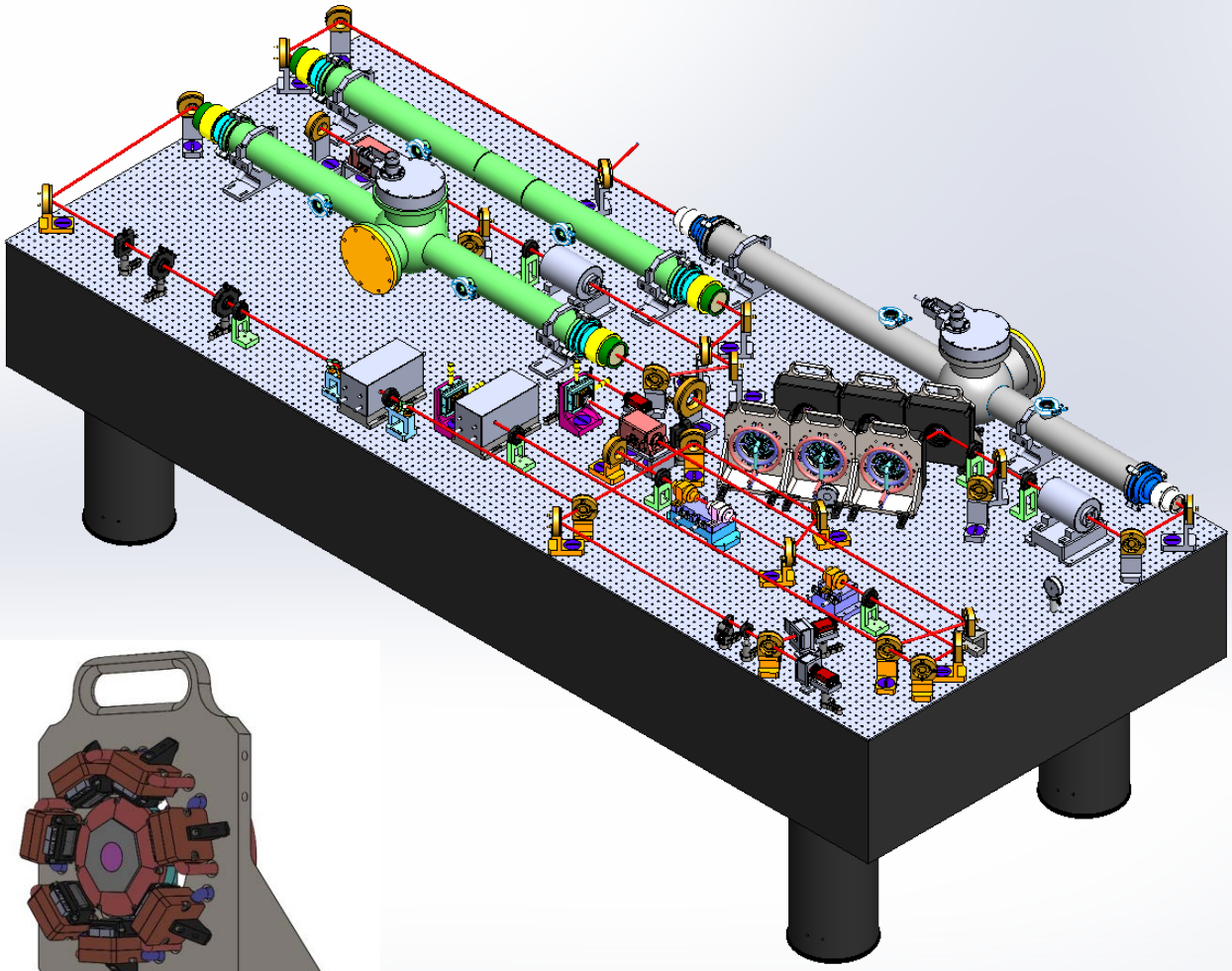


Web based GUI integrates all operations at a single location.

Main GUI panel

All diagnostics are collected and displayed on a single platform

Higher average power is possible with redesigned power amplifier



DCS Front end and regen can run at 5-10 Hz

Diode pumped pre-amplifier can produce sufficient seed energy at several hertz for the power amplifier

Diode pumped thin disk amplifier has the potential to produce 100 J at 10 Hz

The DCS laser can be adapted for use with OTS

- Seed energy to disk amplifier can be reduced to bring energy to ~100J
- Number of passes could be reduced to 4, eliminating one telescope from the main amplifier
- A DCS type laser can be built in 18-24 months, depending on requirements.
- LLE equipment is designed into the laser for robustness and design maturity. A smaller laser could be developed, but it would require a redesign of the power amplifier.
- LLE is investigating alternative architectures to reduce overall footprint.