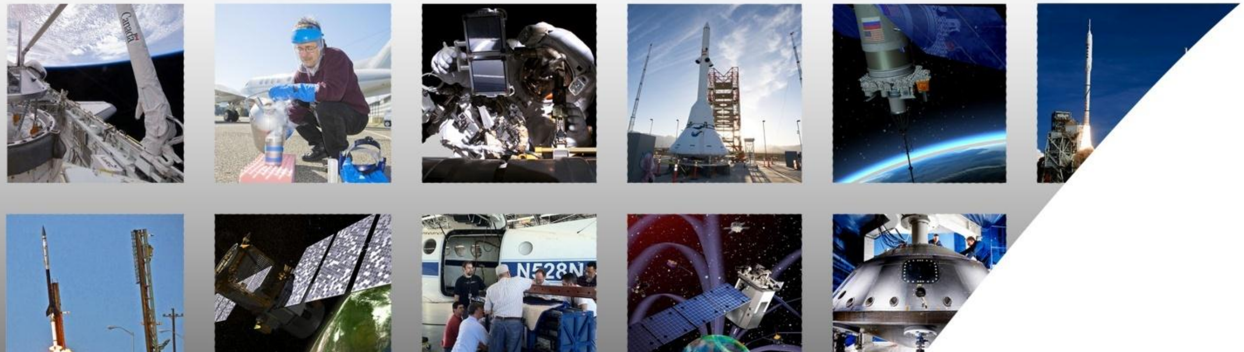

National Aeronautics and
Space Administration

Single Mode, High Repetition Rate Ho:YLF Laser for Space-borne Lidar Applications

NASA Langley Research Center

Jirong Yu, Yingxin Bai, Teh-Hwa Wong, Mulugeta Petros, Karl Reithmaier, Robert Menzies, Upendra Singh

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Outlines

- Introduction
- Integrated Path Differential Absorption (IPDA) Lidar for CO_2 measurement
- 2 micron laser transmitter requirements
- Technical challenges
- Laser performances (100Hz and 200Hz)
- Single transverse mode and single longitudinal mode
- Conclusions

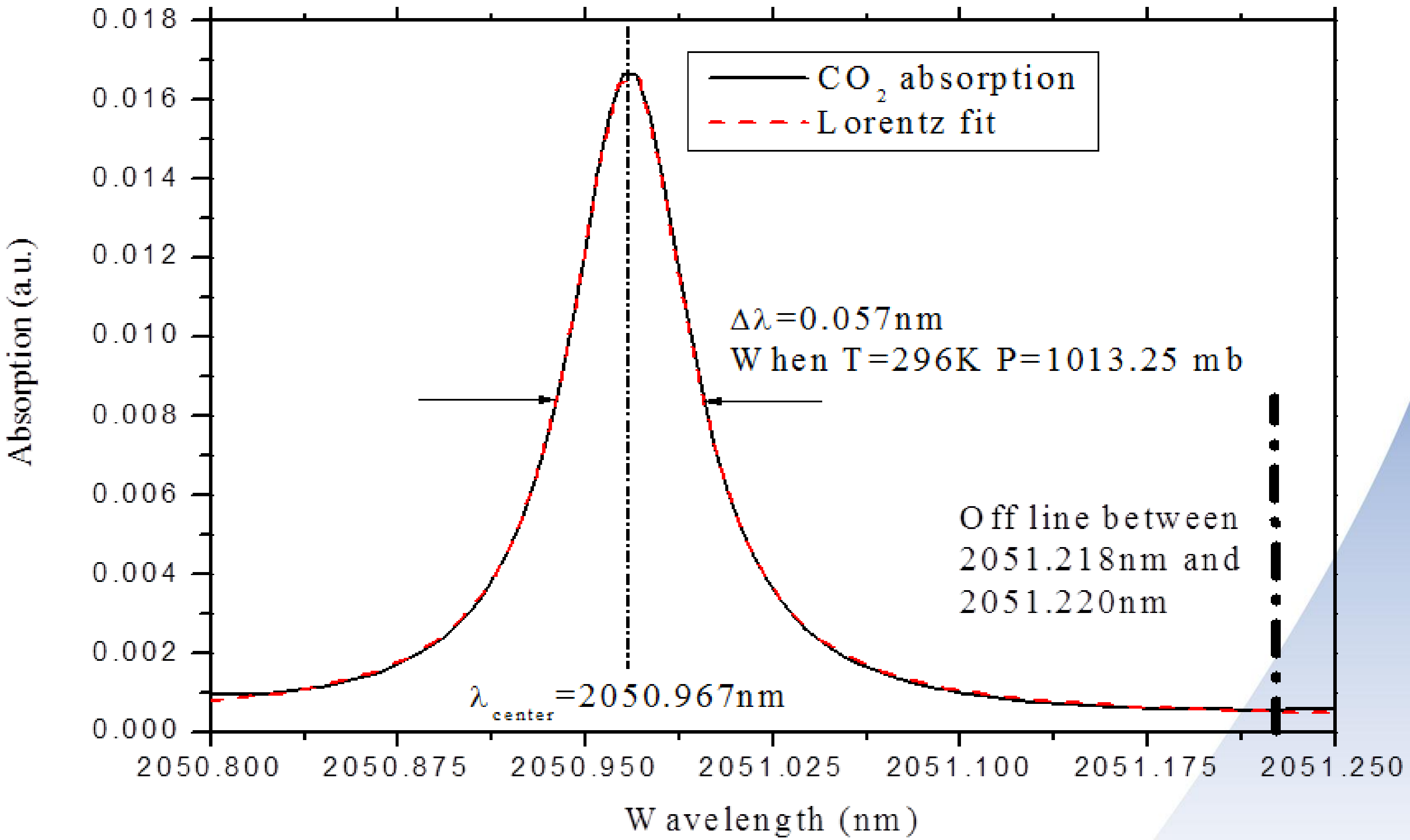
Objectives

- Develop an efficient and compact 2µm pulsed laser for an innovative pulsed lidar instrument to make precise, accurate, high-resolution atmospheric CO_2 measurements

- Develop a pulsed 2µm laser based on Thulium fiber laser pumped Holmium solid state laser Technology

- Demonstrate a laser transmitter with the energy and repetition rate meeting the space Integrated Path Differential Absorption (IPDA) instrument in a robust prototype format.

CO_2 R30 Absorption Line

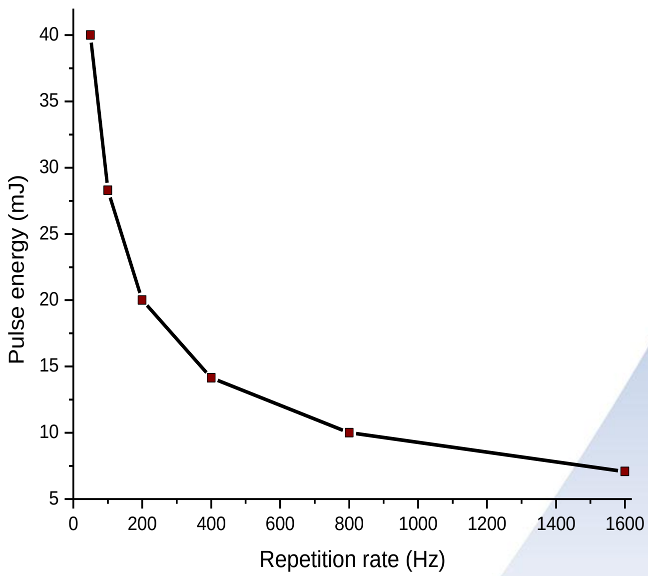


2 micron Laser Transmitter

Laser performance goals

Performance parameter	Value
Spectral line width, MHz	<60
Pulse energy, mJ	>30
Pulse repetition rate, Hz	>50
Pulse width, ns	<50
Beam quality, M^2	<2
Spectral purity (% energy within 1 GHz spectral bandwidth)	>99.98
Polarization extinction ratio, dB	>20
Wall plug efficiency, %	>2

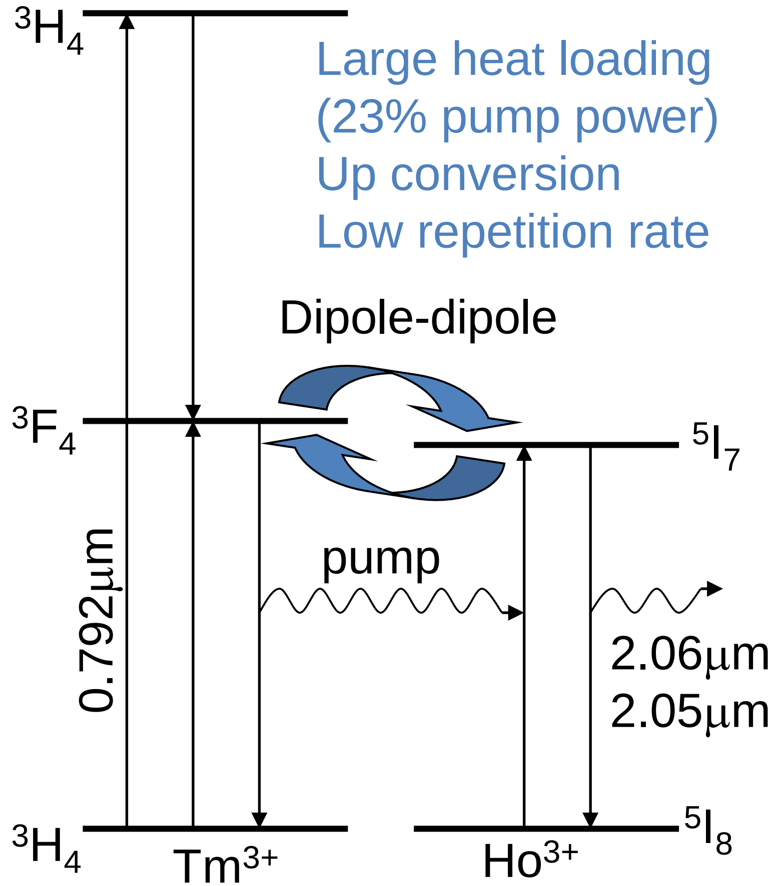
Signal to noise ratio can be improved by increasing the repetition rate because the signal superposition could be coherent superposition with a deterministic phase but noise superposition is incoherent superposition with random phase.



Laser Energy Level Diagram

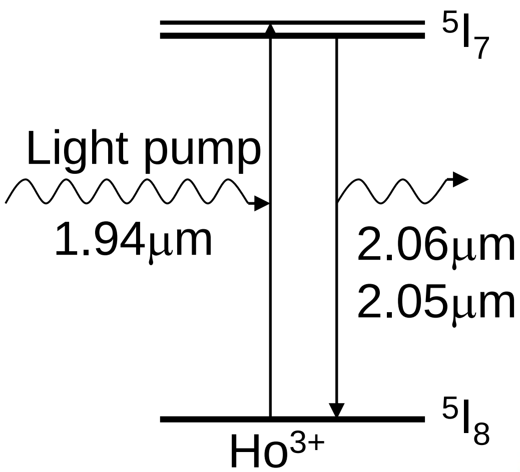
Diode pumped Ho:Tm:laser

Large heat loading
(23% pump power)
Up conversion
Low repetition rate

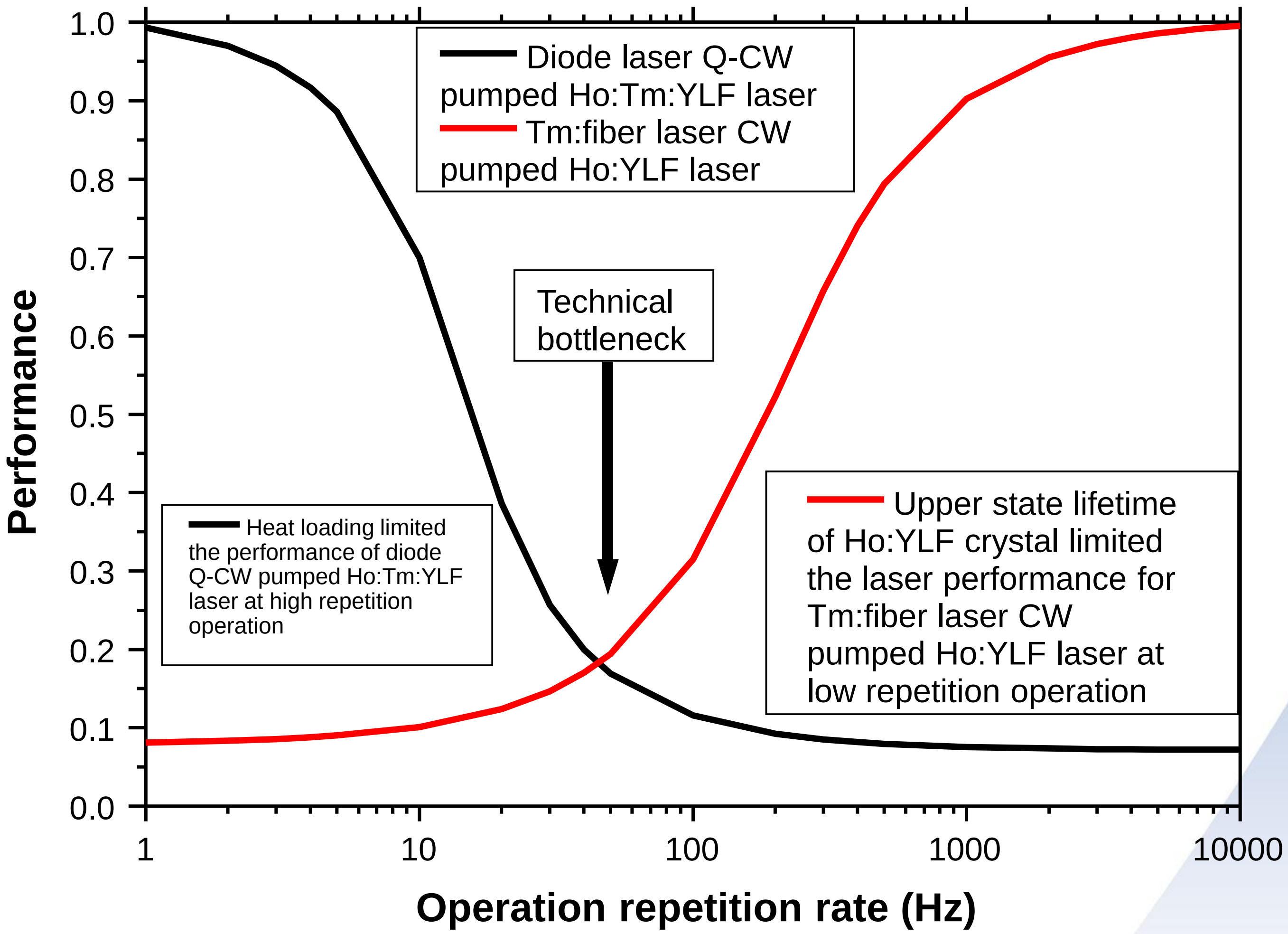


Tm:fiber laser pumped Ho:laser

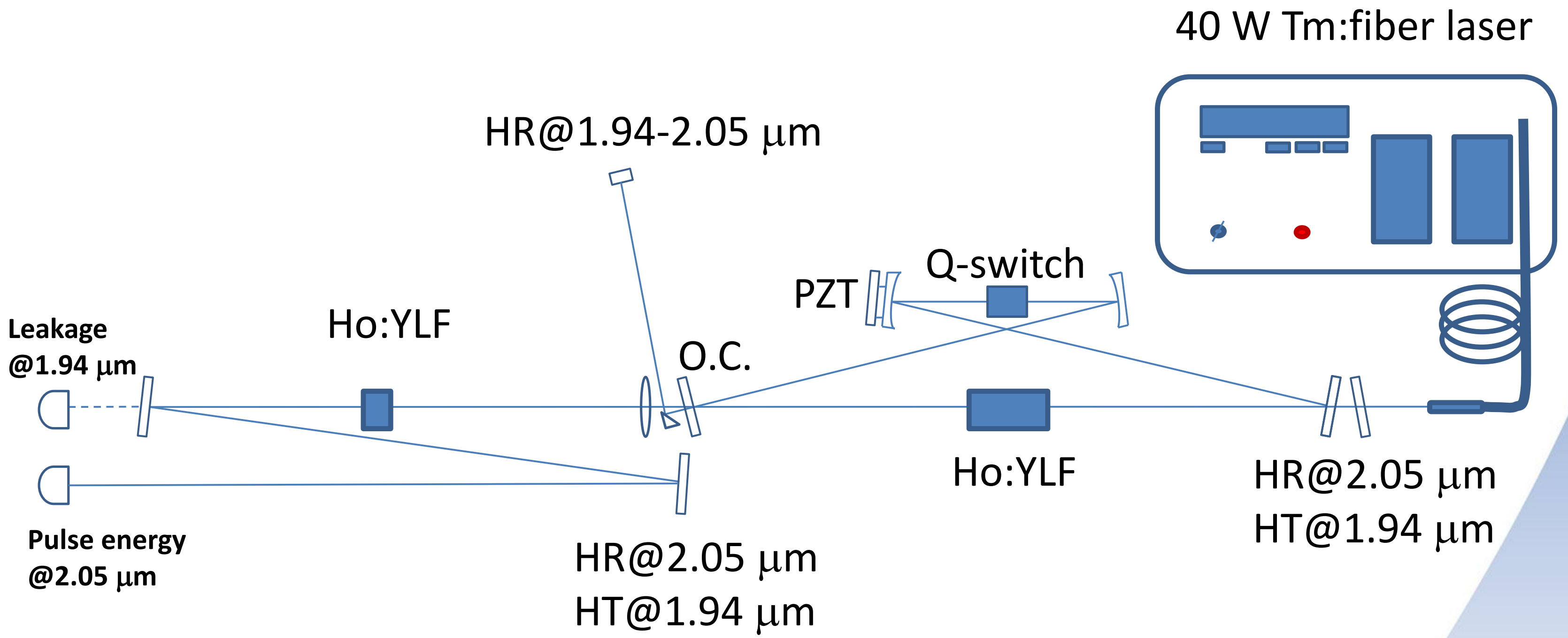
Small heat loading
(5% pump power)
No up conversion
High repetition rate



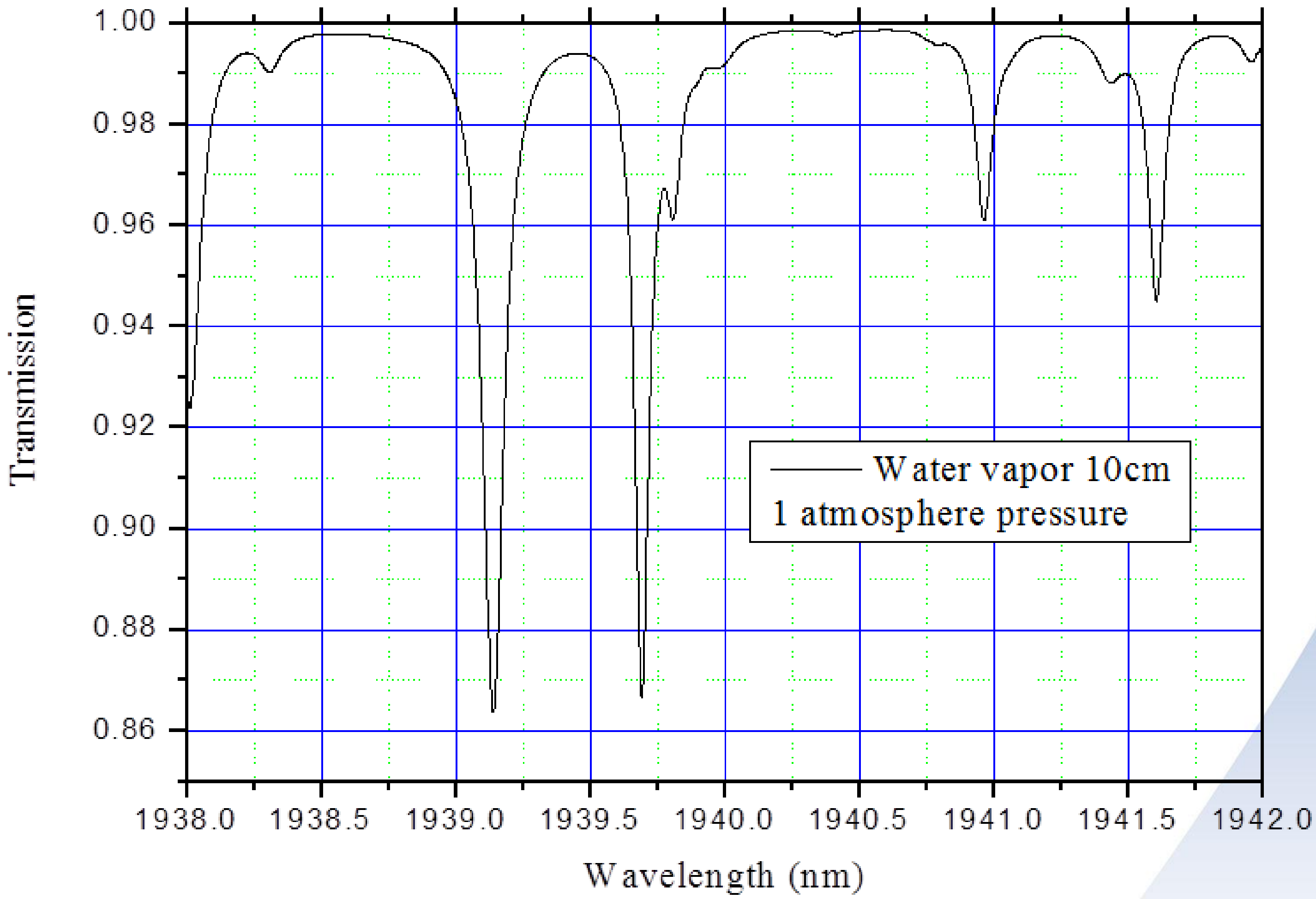
Technical Bottleneck



Laser Configuration

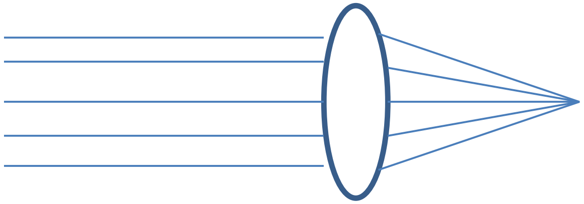


Water Vapor Absorption at Pump Wavelength



Q-switching Hold-Off

Q-Switch hold-off need be properly checked to make sure the laser is operated at single pulse off problem.



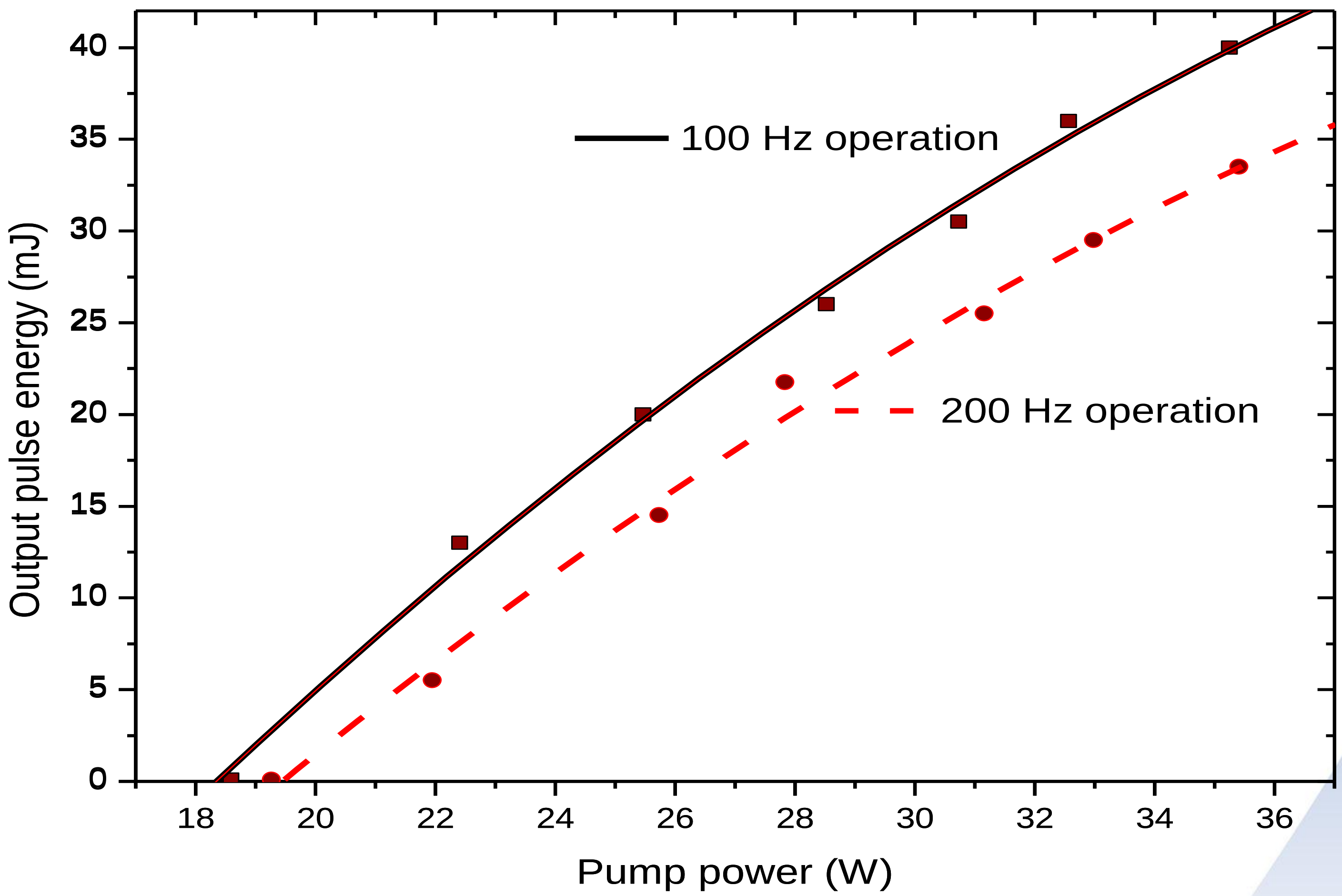
Without focusing

With focusing

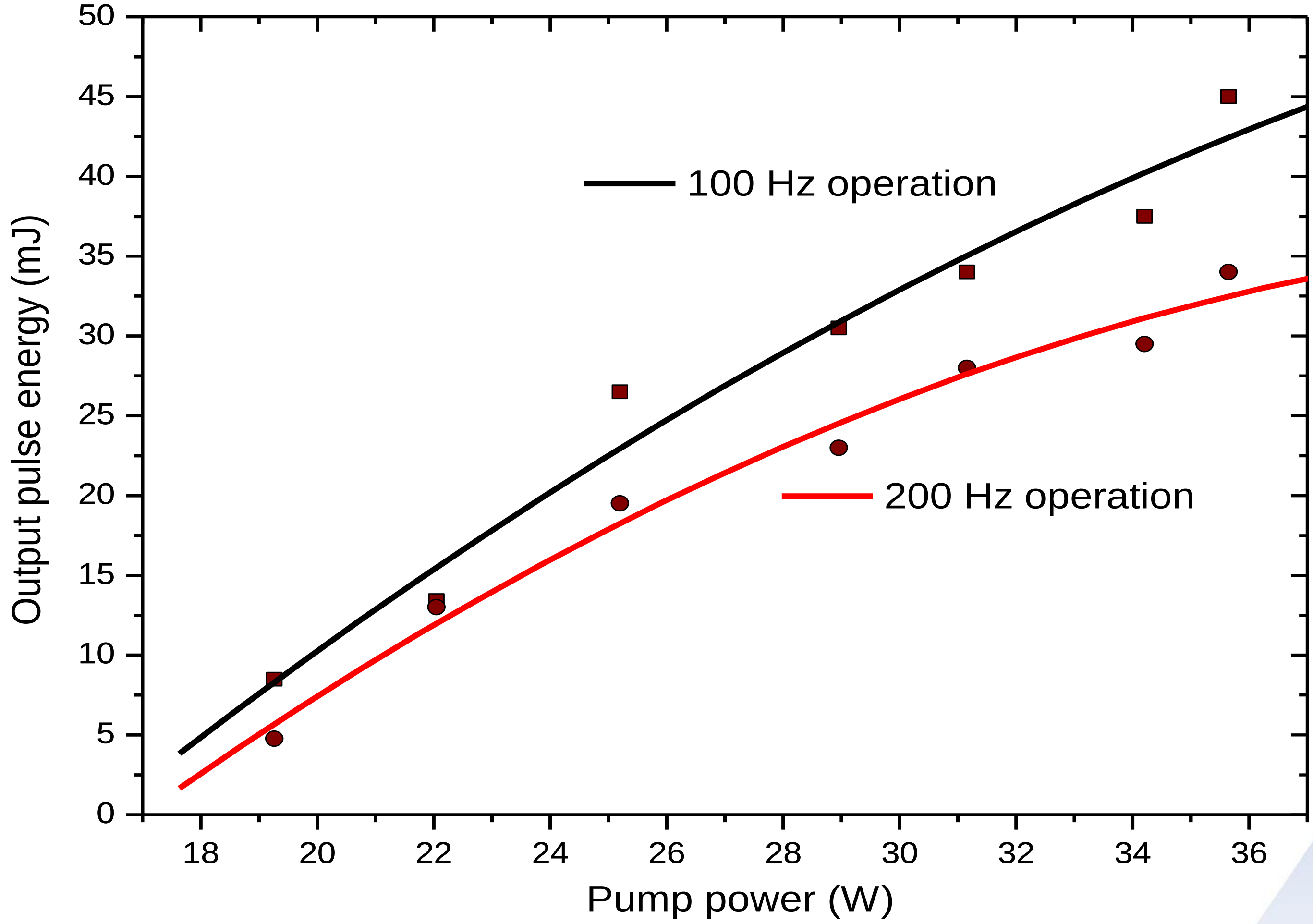
No hold off

Hold off

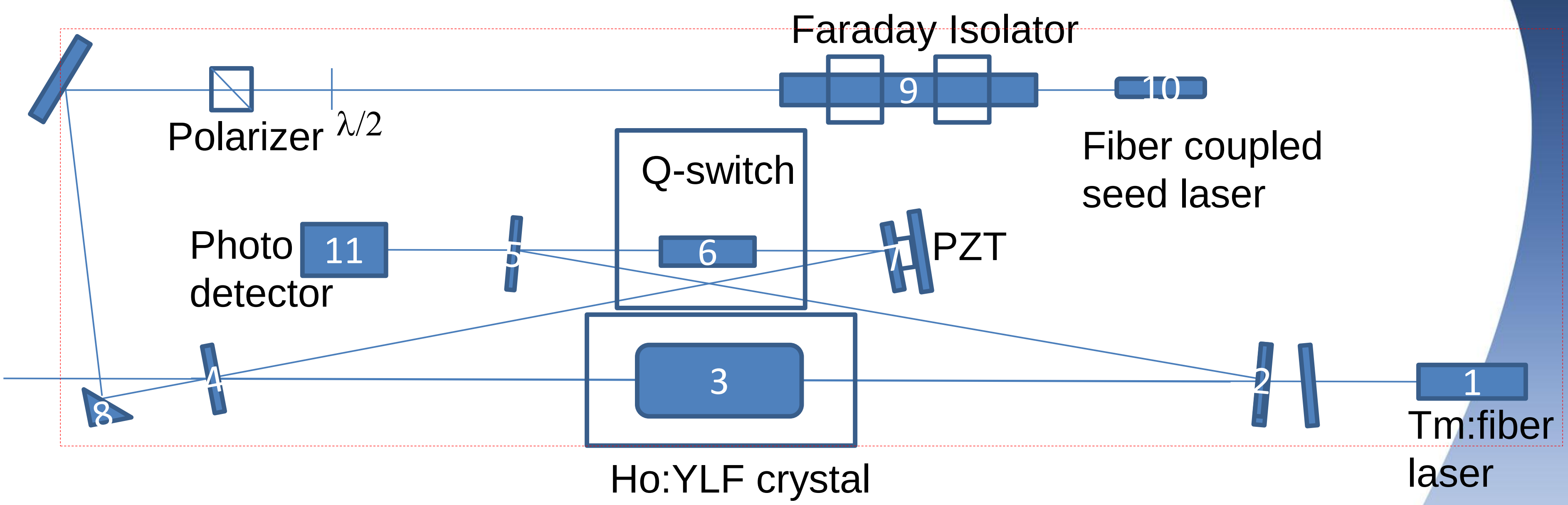
Oscillator Performances



Oscillator & Amplifier Performances

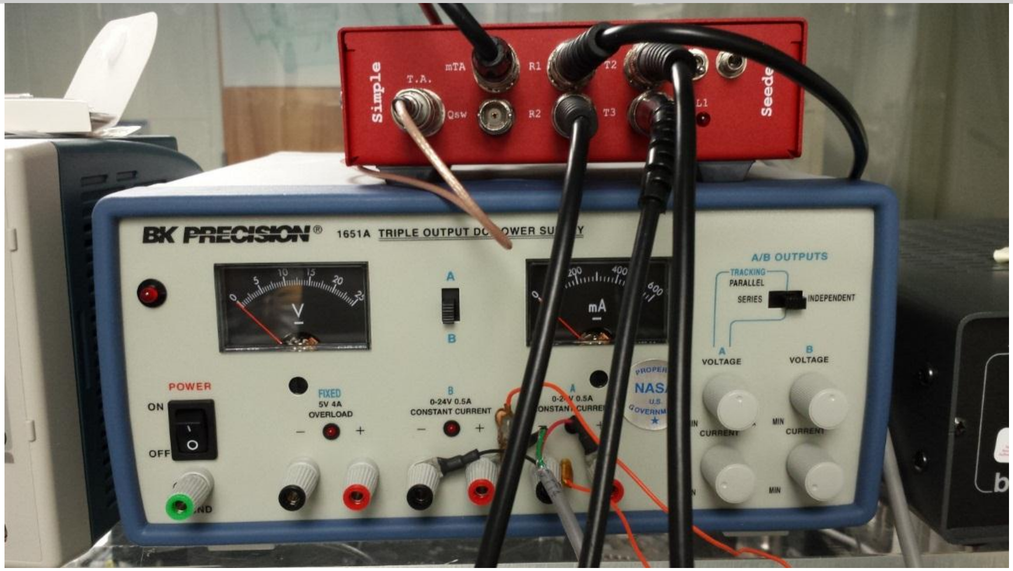


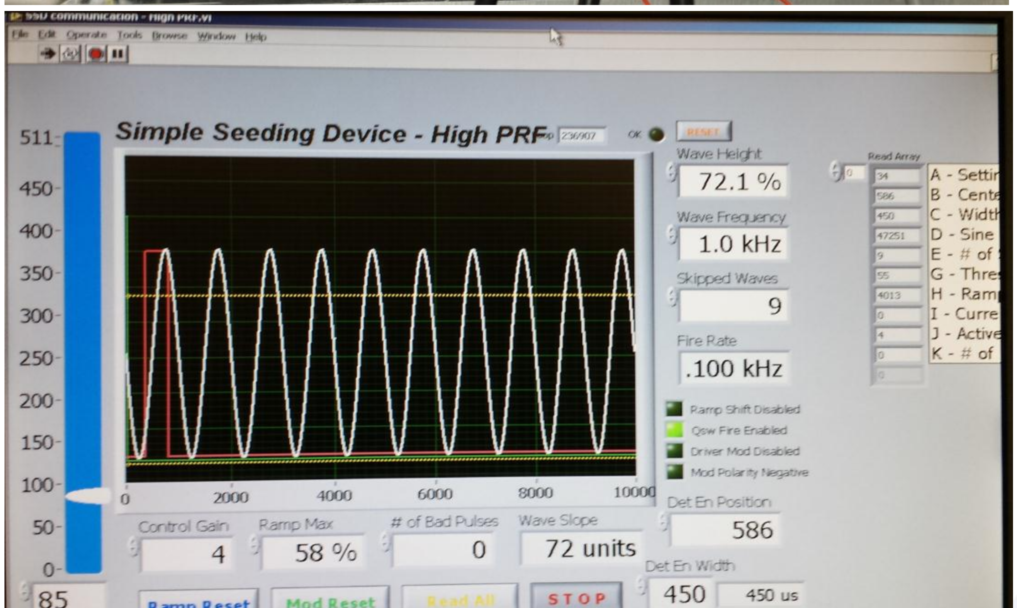
Injection Seeded Laser



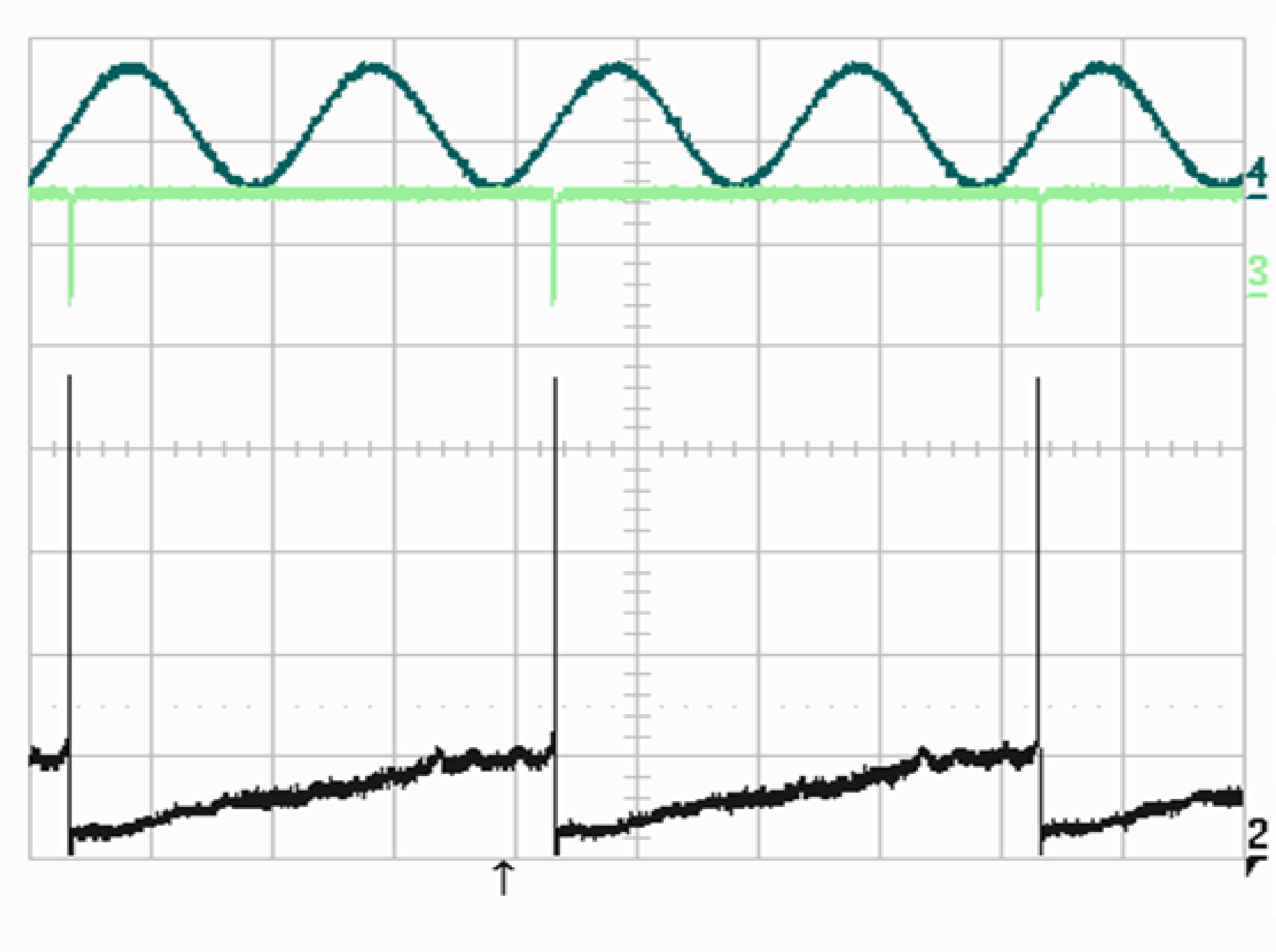
1. CW Tm:fiber laser (40W)
2. Cavity mirror
3. Ho:YLF Laser crystal
4. Output coupler
5. Concaved cavity mirror
6. Q switch mount
7. PZT mounted Cavity mirror
8. Adjustable prism mount
9. Faraday isolators
10. Fiber coupled seed laser

In House Designed Seeding Electronics

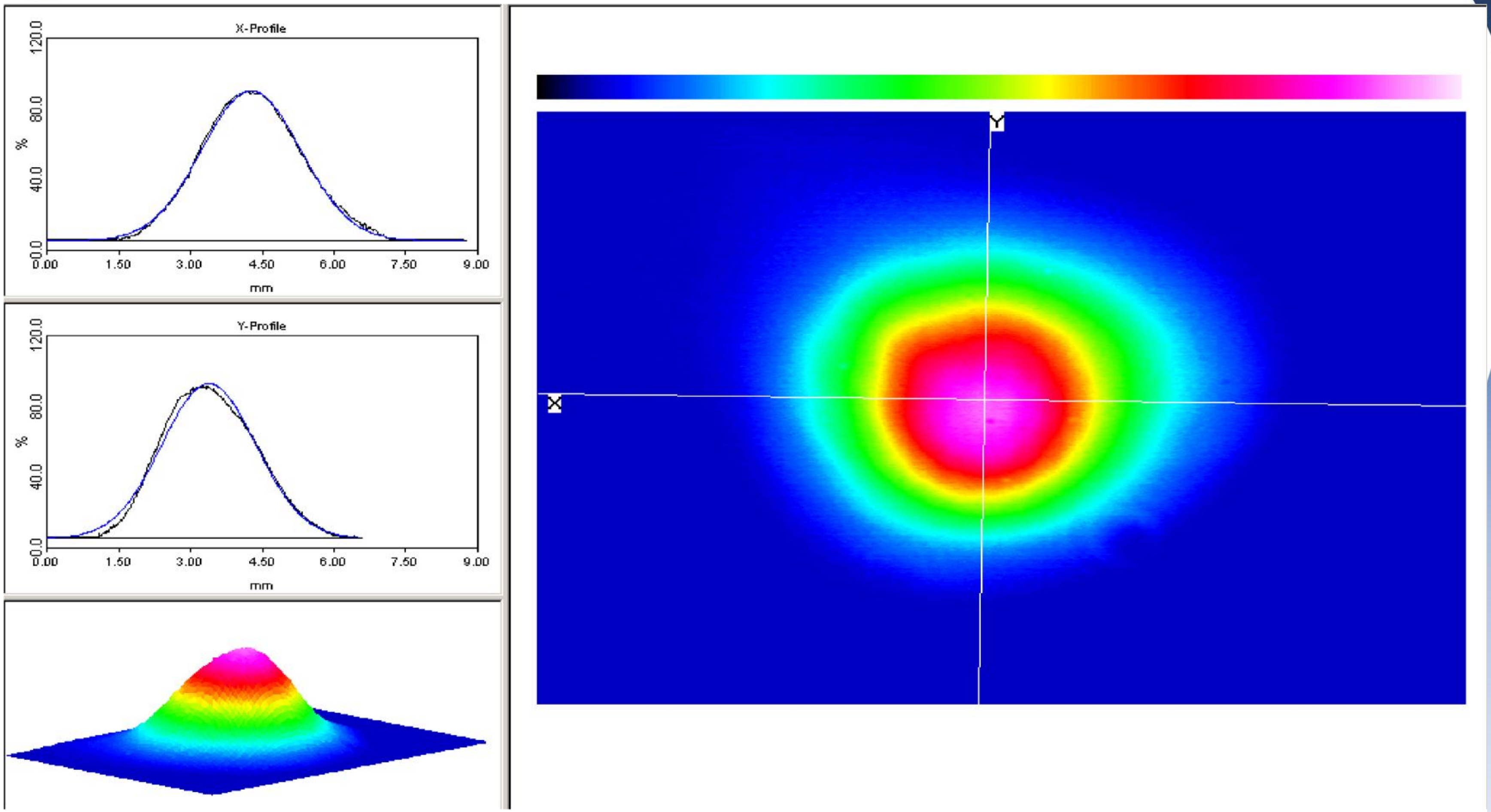




Ramp/Fire Injection Seeding



Near Diffraction Limited Beam



Mechanical Design Points

Objective

- Package a 100Hz 40mJ laser and engineer it
- Laser mechanical stability better than existing airborne laser
- Laser operates any orientation vertical and horizontal

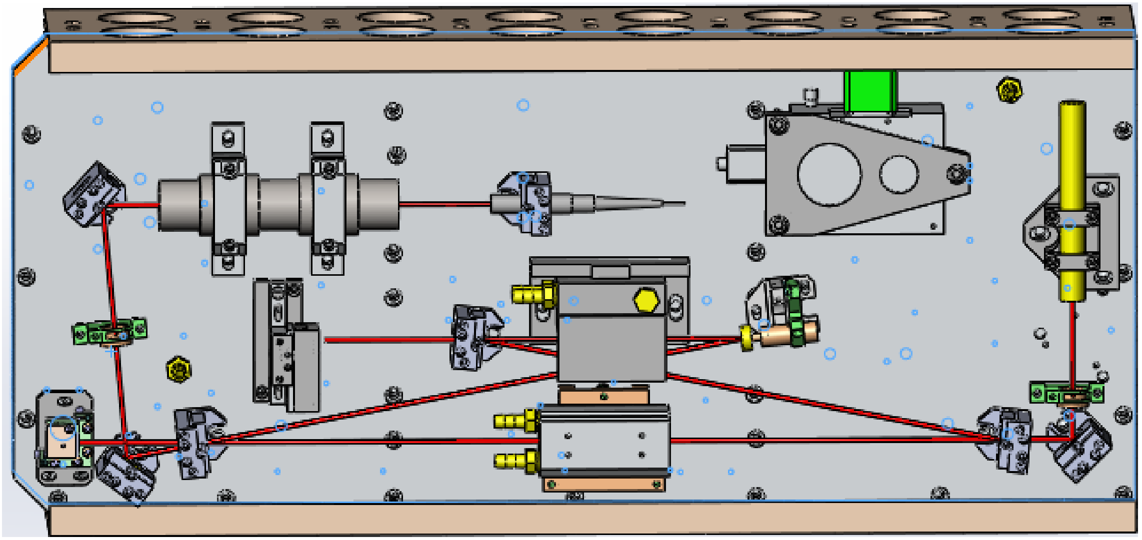
Bench Design

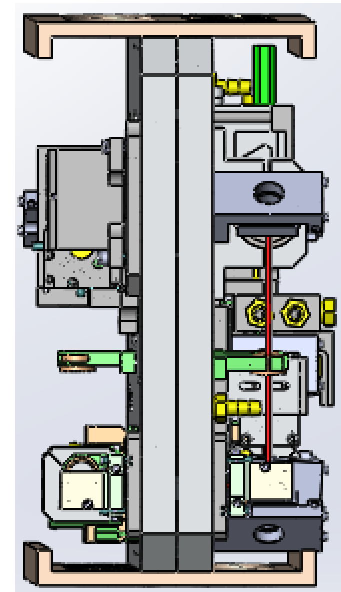
- Optical bench designed with I-beam stiffness on the top and bottom
- two piece parts bolted
- cooled
- Hole patterns Oscillator both sides and amplifier option on one side

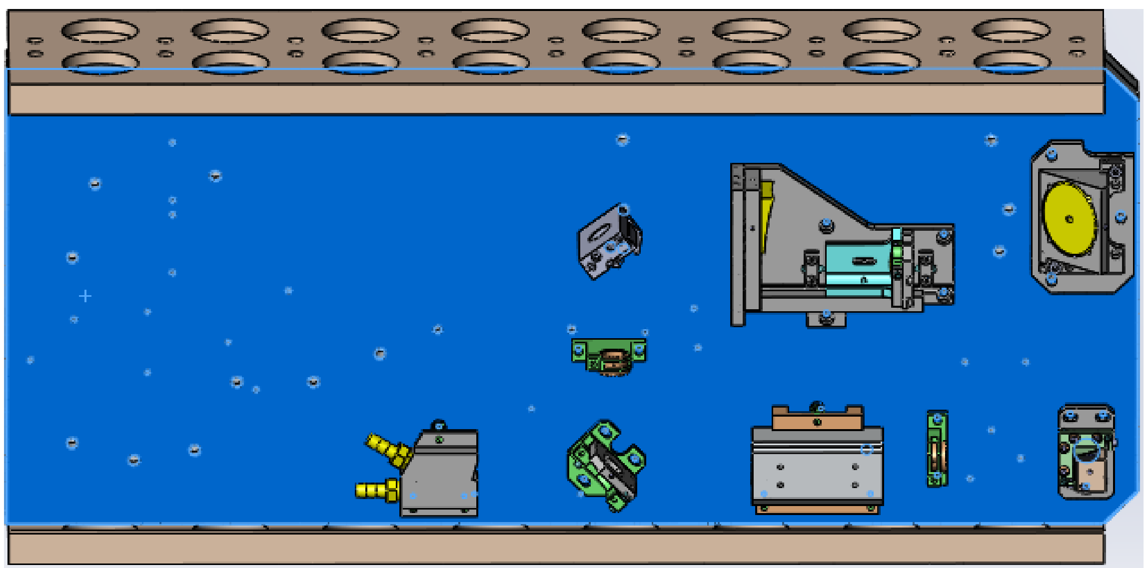
Laser Design

- Optical height = 1”
- Two sides bench design

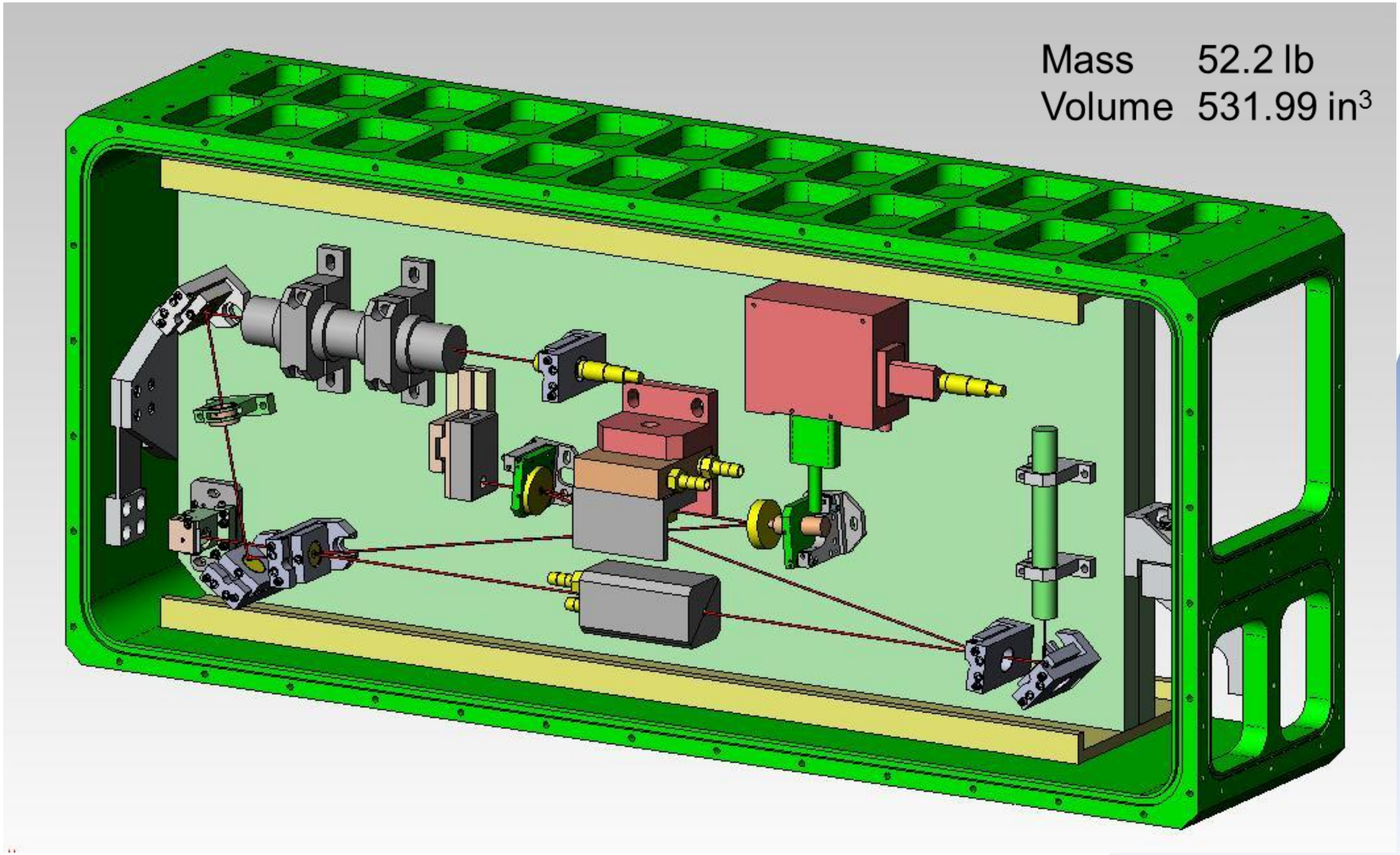
Optical Bench Design







Laser Enclosure



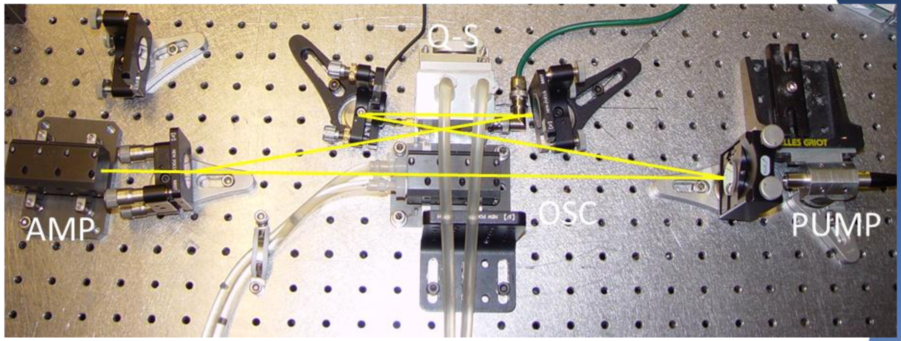
Conclusions

- ✓ Single-mode, high repetition rate, compact Ho:YLF laser has been demonstrated for space-borne lidar applications
- ✓ Addressed technical challenges include water vapor absorption at pump laser wavelength and accompanying thermal lens effect, cavity dielectric mirror damage, Q-switch hold off
- ✓ The oscillator only approach can achieve output pulse energy that meets the requirement of lidar application
- ✓ The laser efficiently operates in single transverse mode and single longitudinal mode
- ✓ The success rate of injection seeding is higher than 99.5%
- ✓ Engineering packaged laser design has been completed and hardware in manufacture

A 2-micron Pulsed Laser Transmitter for Direct Detection Column CO_2 Measurement from Space

PI: Jirong Yu, NASA LaRC

- Develop a compact, efficient two-micron pulsed laser for a lidar instrument to make accurate, high-resolution atmospheric CO_2 column measurements in support of the ASCENDS mission.
  - Develop a pulsed two-micron laser that is based on a Thulium fiber-laser pumped Holmium (Ho) solid state laser in a Master Oscillator Power Amplifier (MOPA) configuration.
  - Demonstrate ≥35mJ at 100-200Hz needed for the space Integrated Path Differential Absorption (IPDA) instrument in a robust prototype format.



Fiber-pumped Holmium-only laser MOPA architecture

- Leverage two-micron laser technologies developed at NASA LaRC over two decades.
- Demonstrate pulsed laser MOPA system delivering ≥35mJ at 100-200Hz .
  - Verify beam quality, energy, and frequency stability, as well as beam size and pulse width.
  - Demonstrate injection seeding.
  - Verify linewidth, single frequency stability, and seeding quality.
- Build the engineering package of the Ho:YLF laser MOPA for mobile operations.

• Complete Ho:YLF MOPA design/modeling	03/12
• Demonstrate Ho:YLF oscillator performance	11/12
• Characterize seed laser	12/12
• Demonstrate wavelength control	06/13
• Demonstrate seeding performance	12/13
• Characterize laser performance	2/14
• Complete engineering of laser design	05/14
• Manufacture and assemble prototype	10/14
• Complete prototype characterization	12/14

TRL_{in} = 3 $TRL_{current}$ = 3

Co-Is/Partners:

Upendra Singh, LaRC ; Robert Menzies, JPL