



National Aeronautics and
Space Administration



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

NASA Langley Research Center

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October 30, 2014

NASA Earth Science Technology Forum (2014)



Outlines



- **Introduction**
- **Integrated Path Differential Absorption (IPDA) Lidar for CO₂ measurement**
- **2 micron laser transmitter requirements**
- **Technical challenges**
- **Laser performances (100Hz and 200Hz)**
- **Single transverse mode and single longitudinal mode**
- **Conclusions**

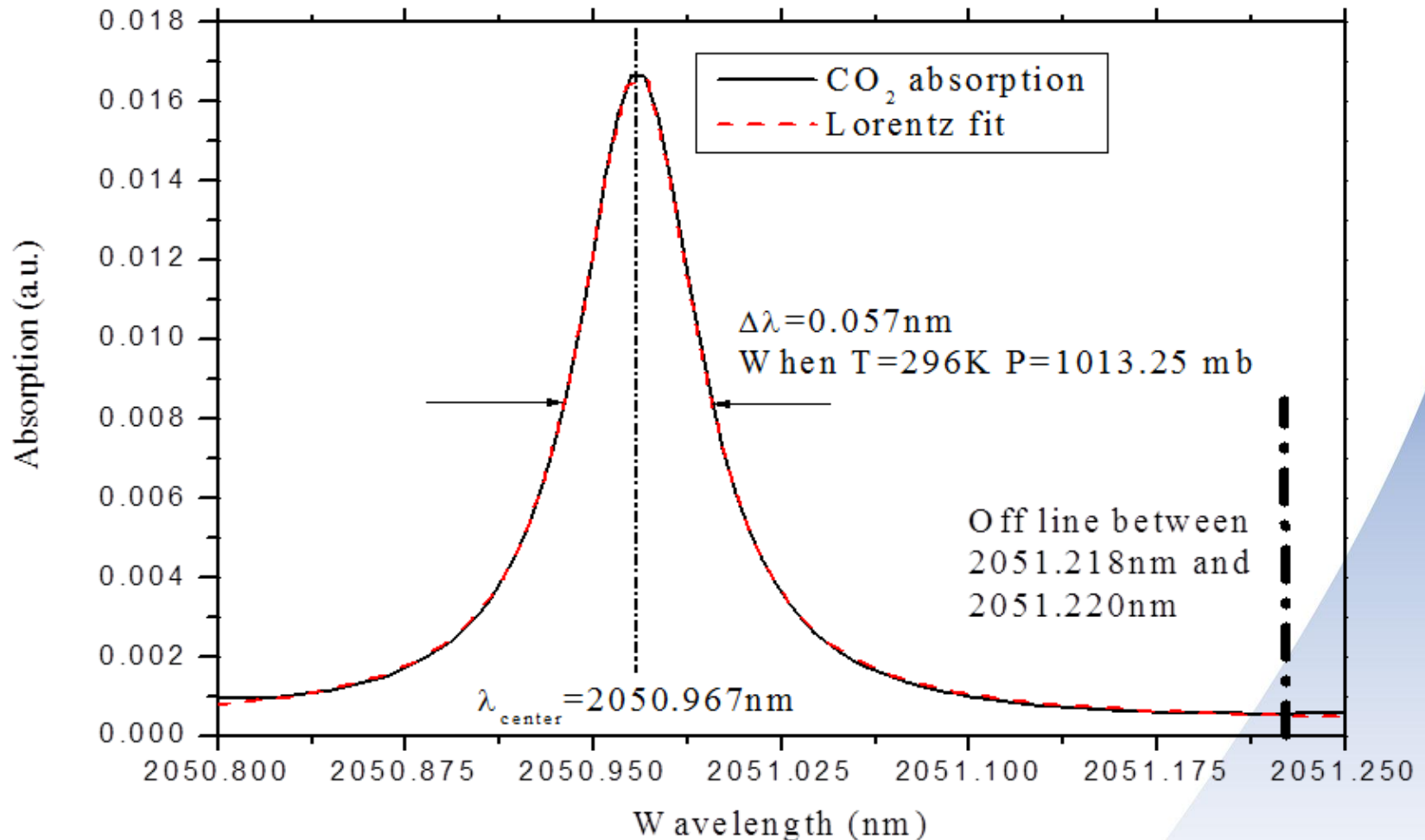


Objectives



- Develop an efficient and compact 2 μ m pulsed laser for an innovative pulsed lidar instrument to make precise, accurate, high-resolution atmospheric CO₂ measurements
- Develop a pulsed 2 μ m 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.

CO₂ R30 Absorption Line





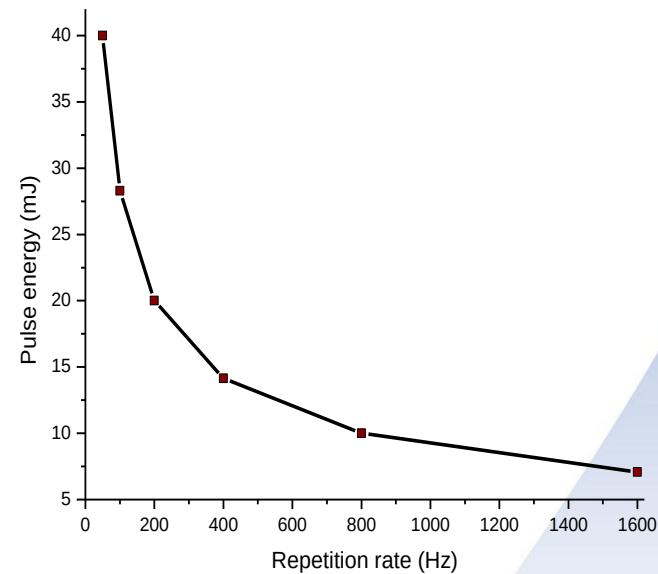
2 micron Laser Transmitter



Laser performance goals

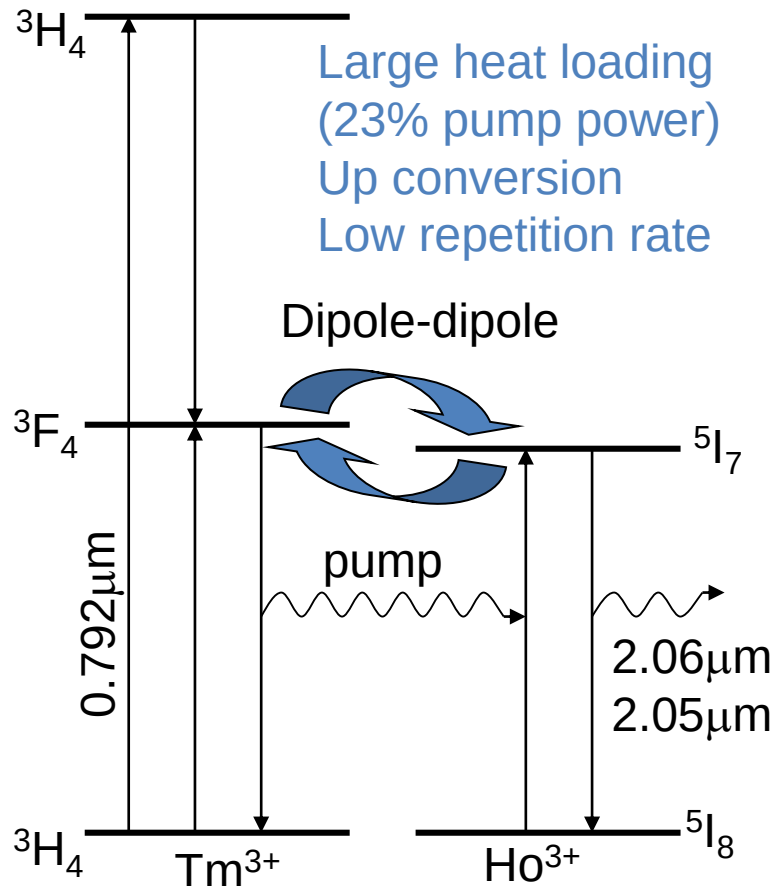
Performance parameter	Value
Spectral line width, MHz	<60
Pulse energy, mJ	>40
Pulse repetition rate, Hz	>50
Pulse width, ns	<50
Beam quality, M ²	<2
Spectral purity (% energy within 1 GHz spectral bandwidth)	>99.98
Polarization extinction ratio, dB	>20
Wall plug efficiency, %	>2

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.



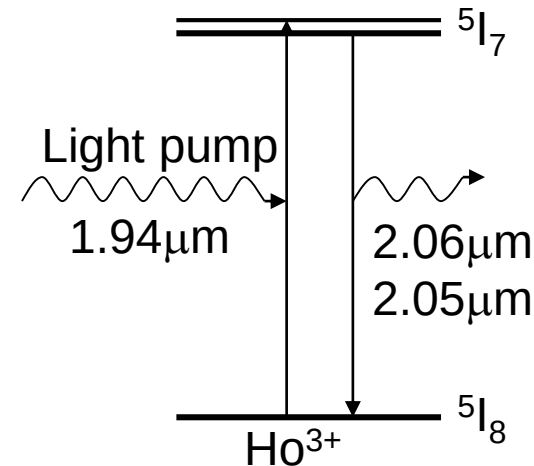
Laser Energy Level diagram

Diode pumped Ho:Tm:laser

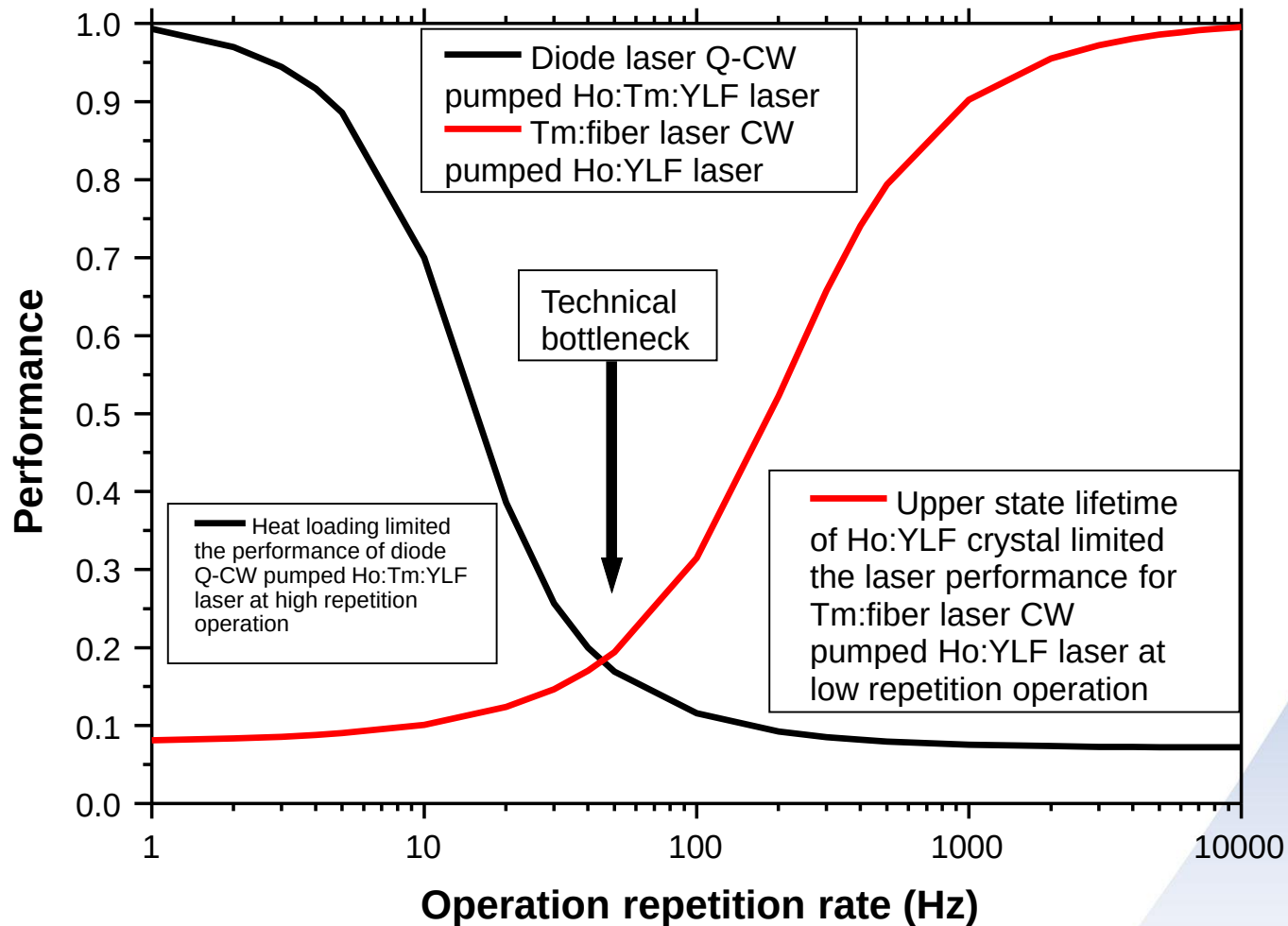


Tm:fiber laser pumped Ho:laser

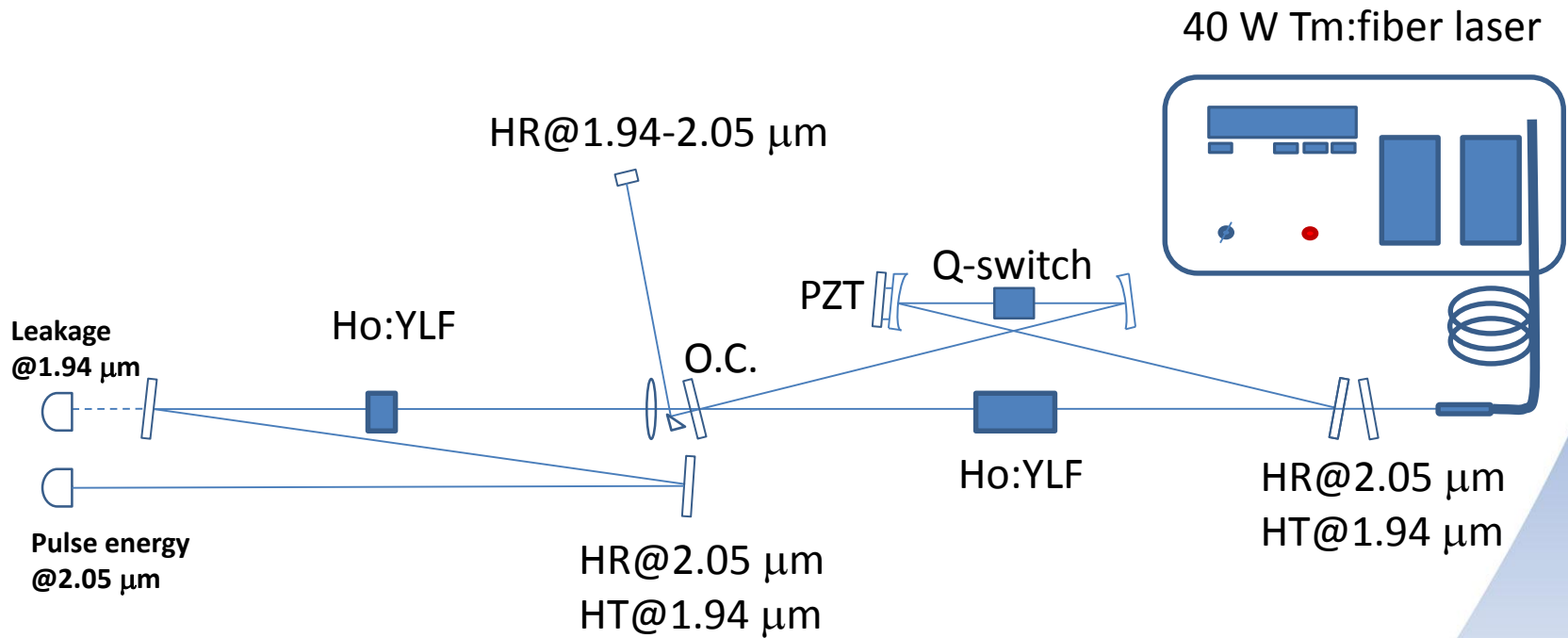
Small heat loading
(5% pump power)
No up conversion
High repetition rate



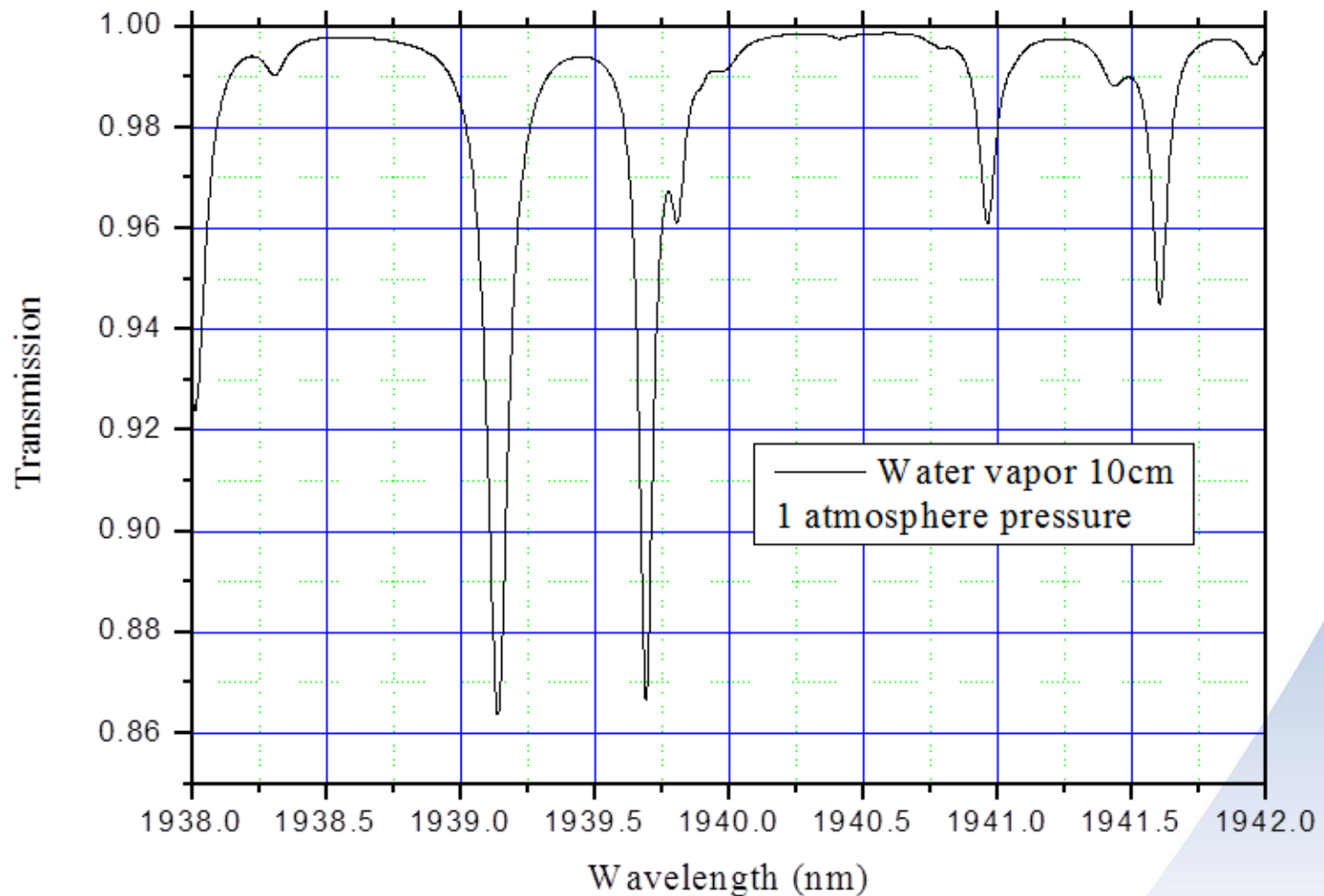
Technical bottleneck



Laser Configuration

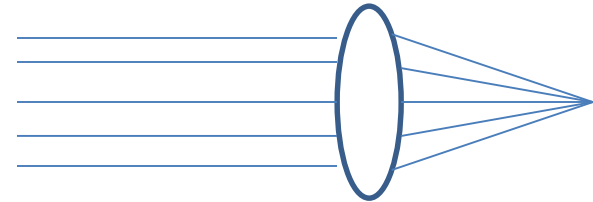


Water Vapor Absorption at Pump wavelength



Q-switching Hold-Off

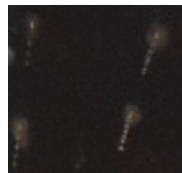
Q-Switch hold-off need be properly checked to make sure the laser is operated at single pulse off problem.



Without focusing



With focusing



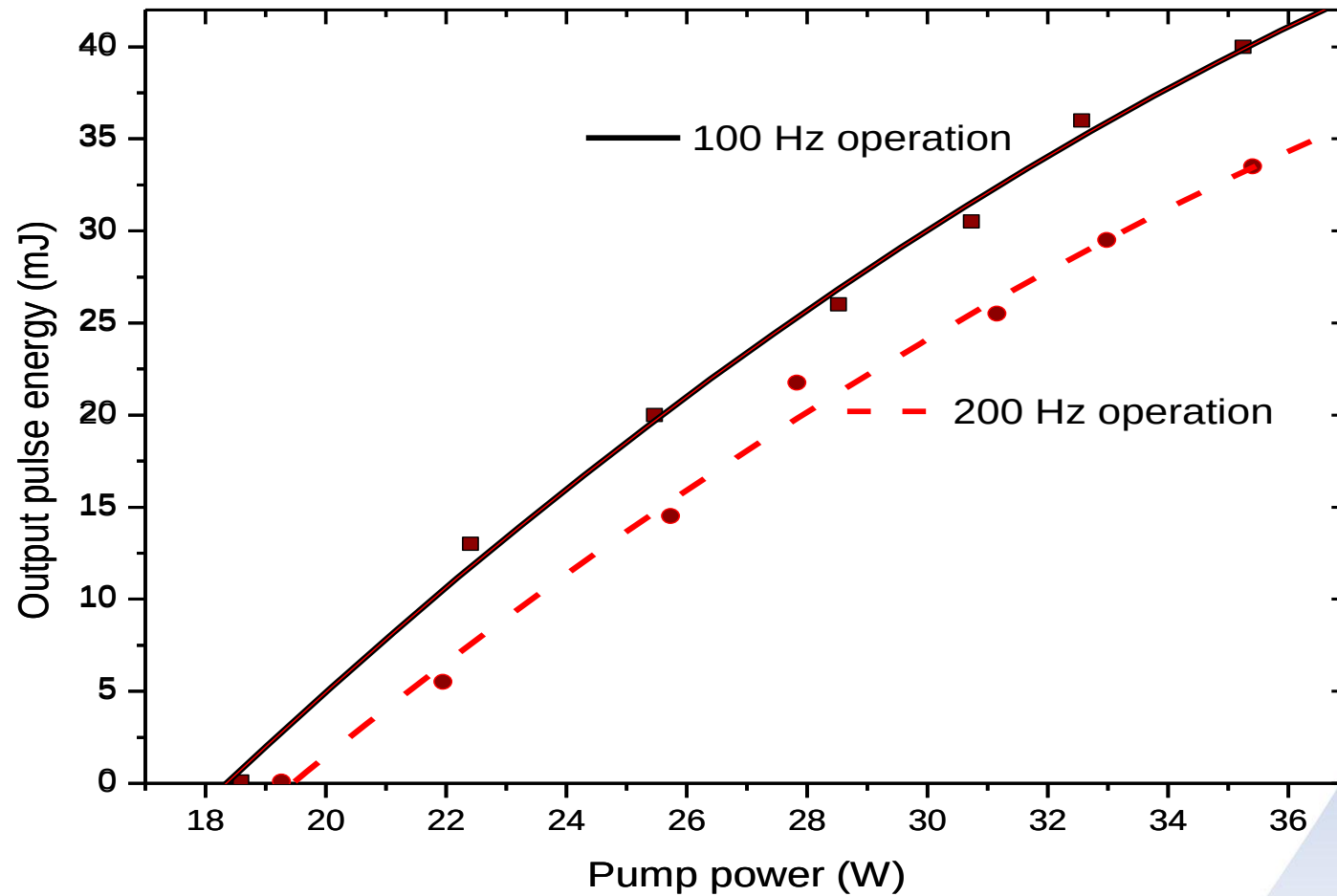
No hold off



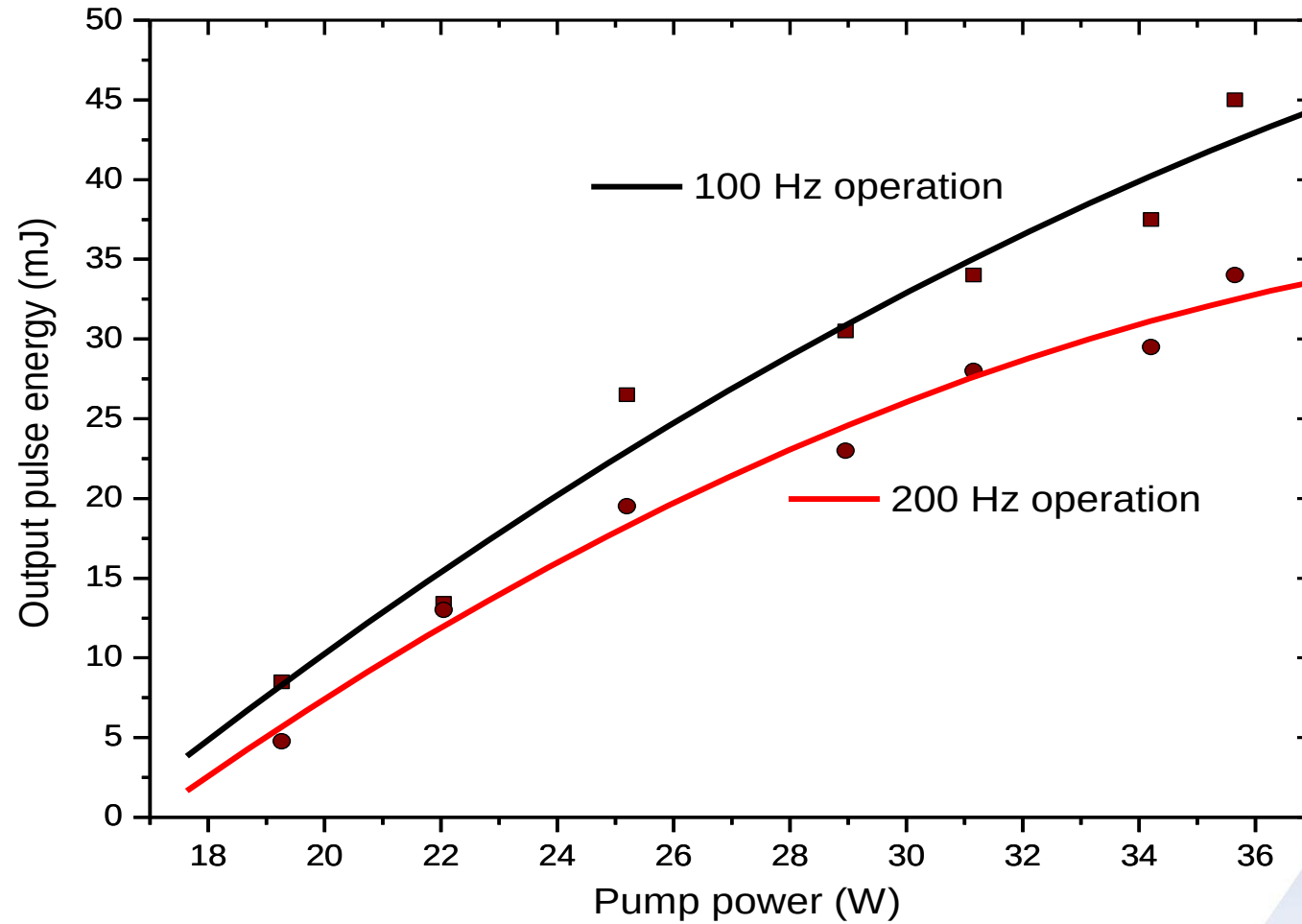
Hold off



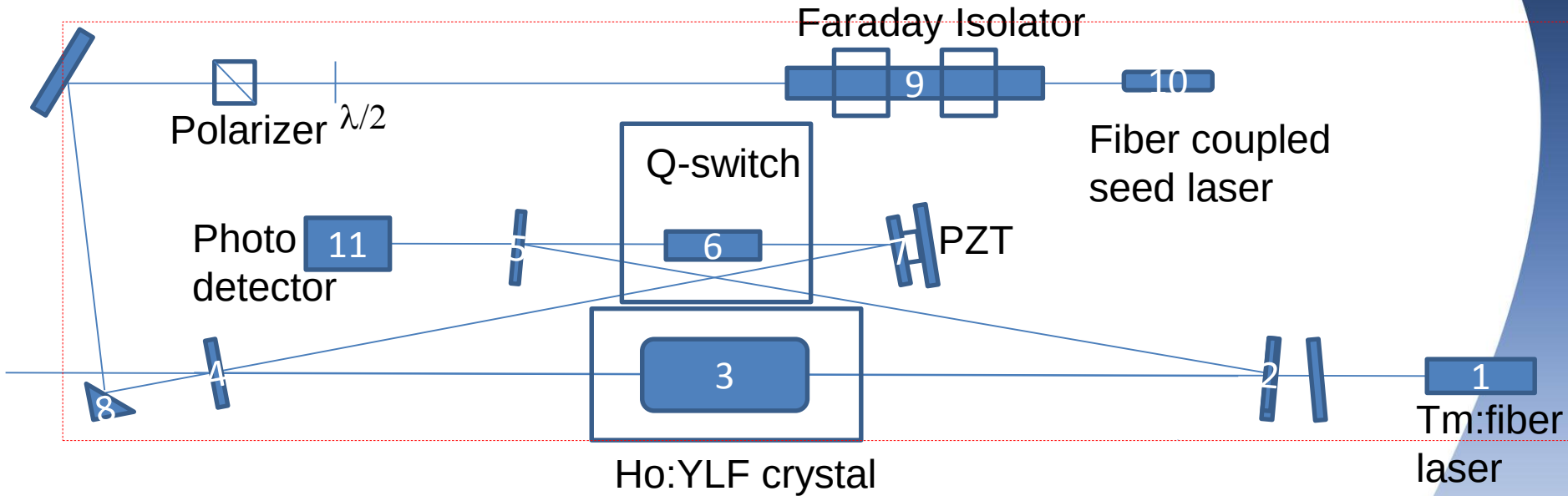
Oscillator Performances



Oscillator & Amplifier Performances

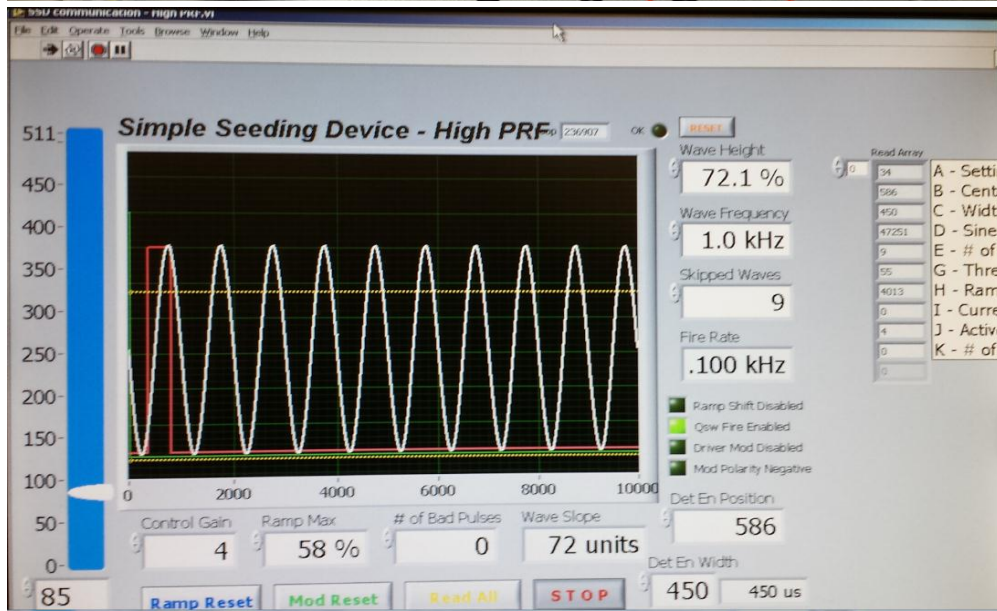
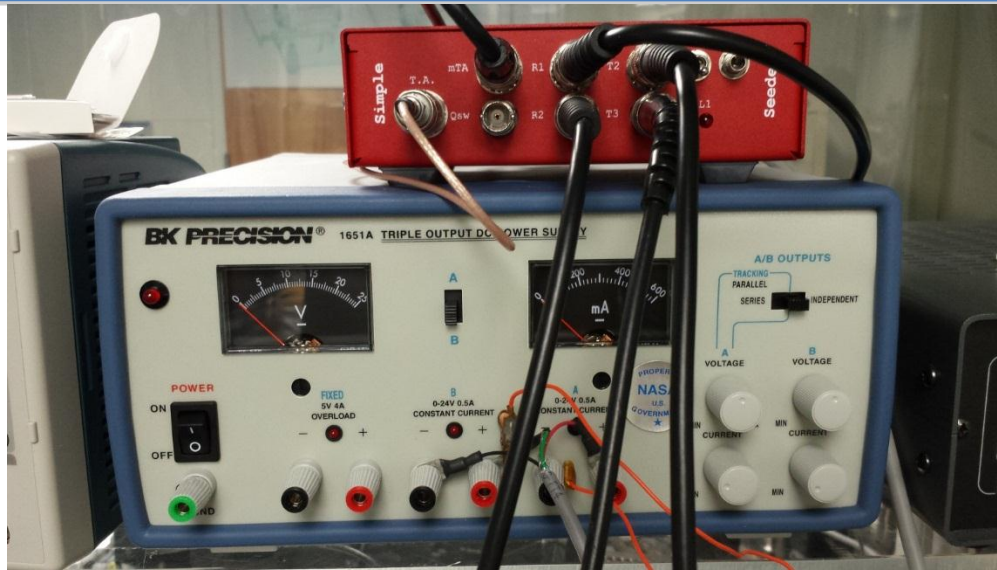


Injection Seeded Laser



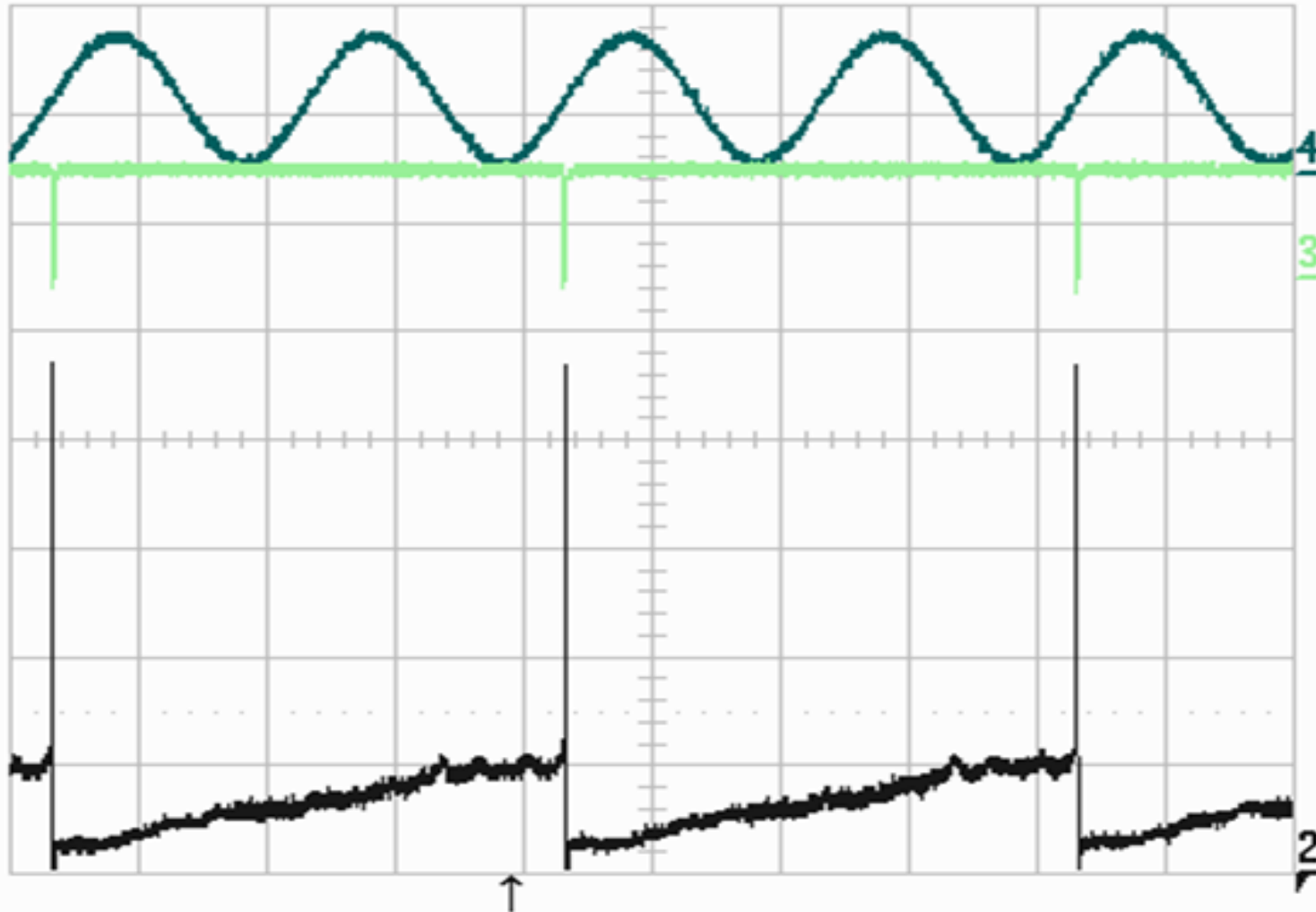
- | | |
|-----------------------------|------------------------------|
| 1. CW Tm: fiber laser (40W) | 6. Q switch mount |
| 2. Cavity mirror | 7. PZT mounted Cavity mirror |
| 3. Ho:YLF Laser crystal | 8. Adjustable prism mount |
| 4. Output coupler | 9. Faraday isolators |
| 5. Concaved cavity mirror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

In House Designed Seeding Electronics



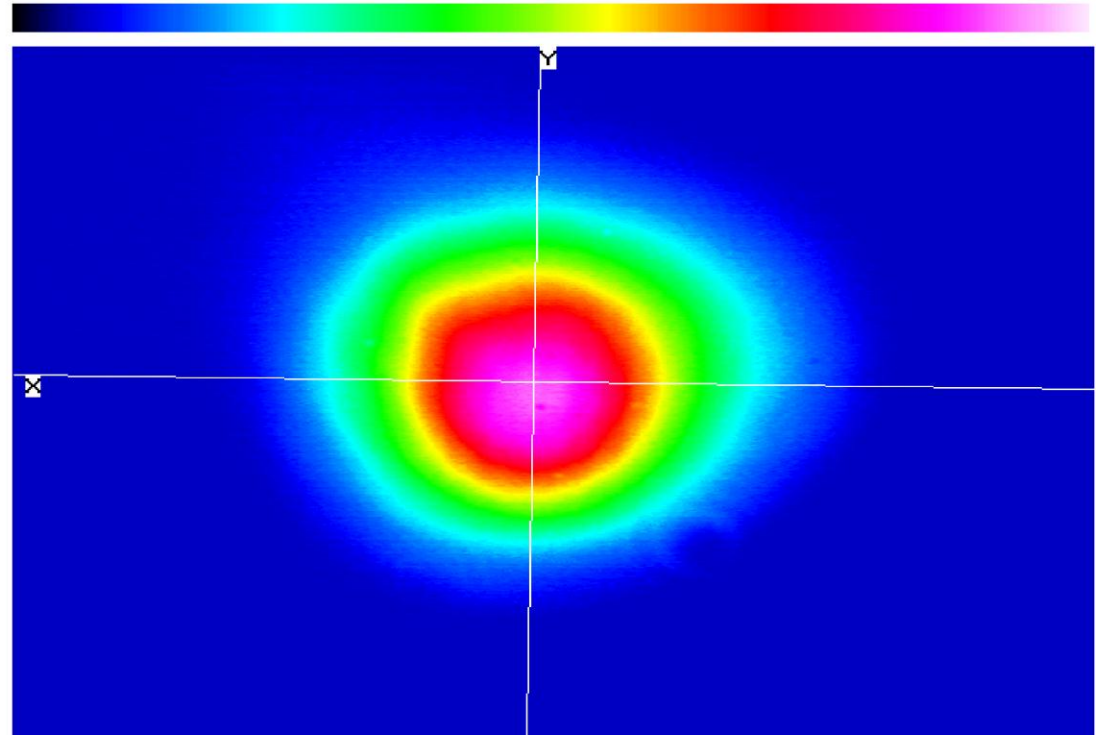
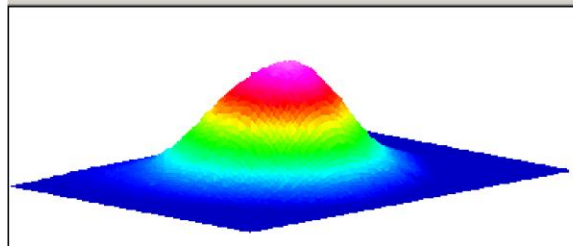
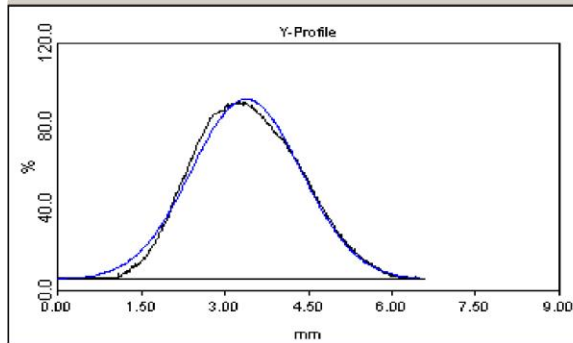
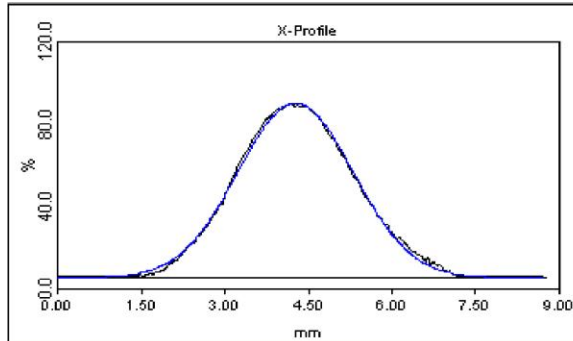


Ramp/Fire Injection Seeding





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

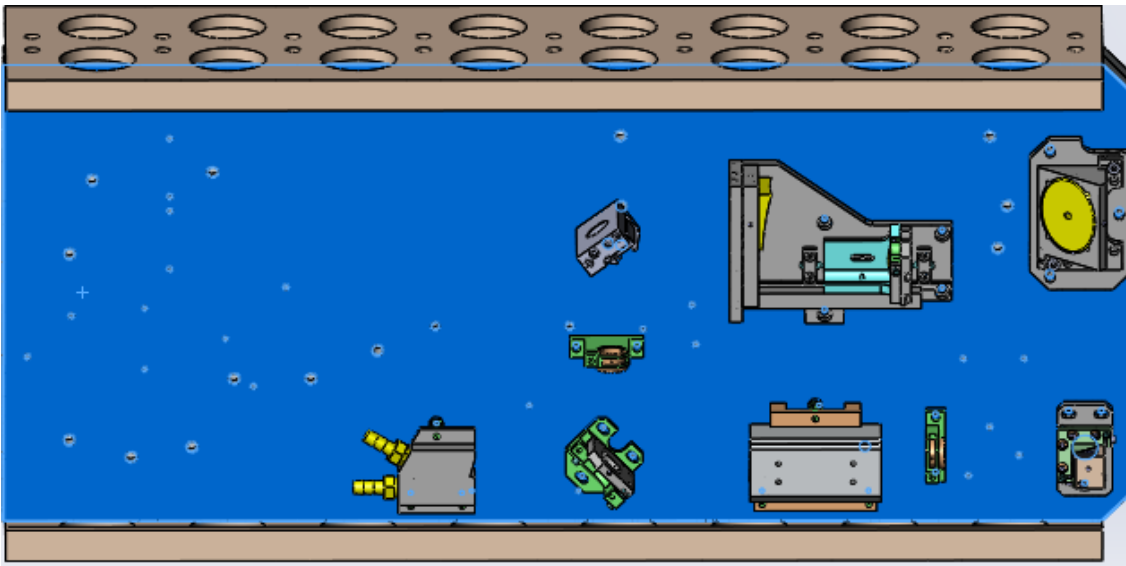
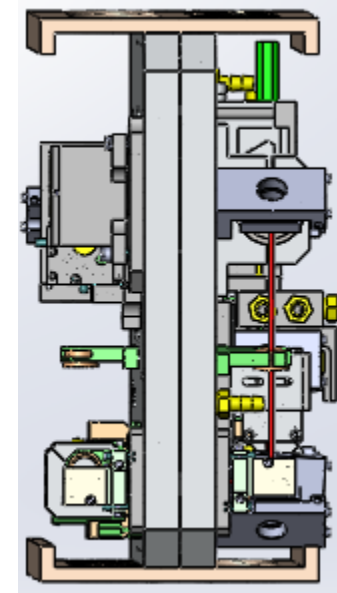
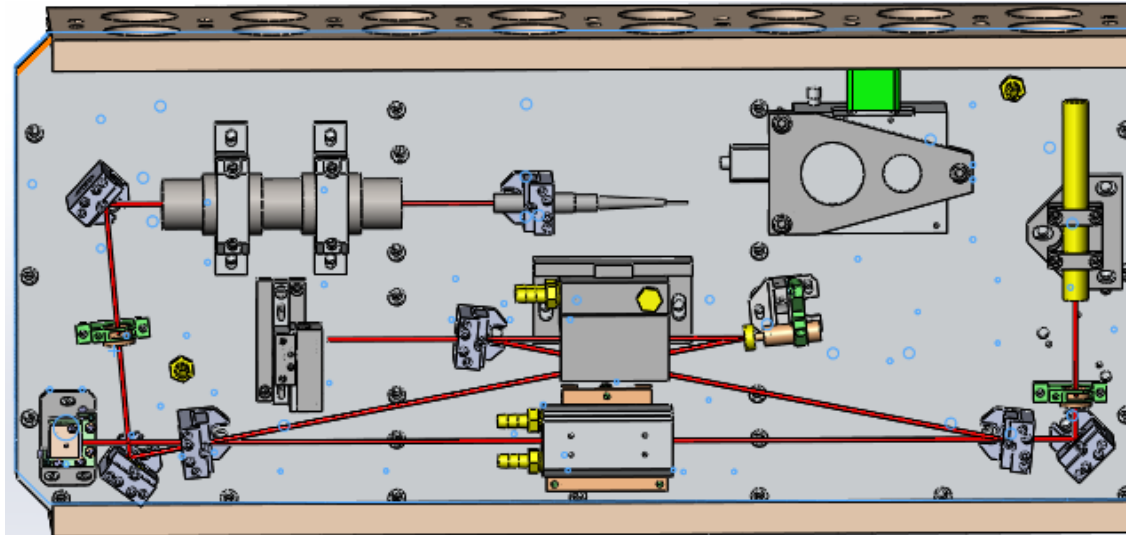
➤ Bench Design

- 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

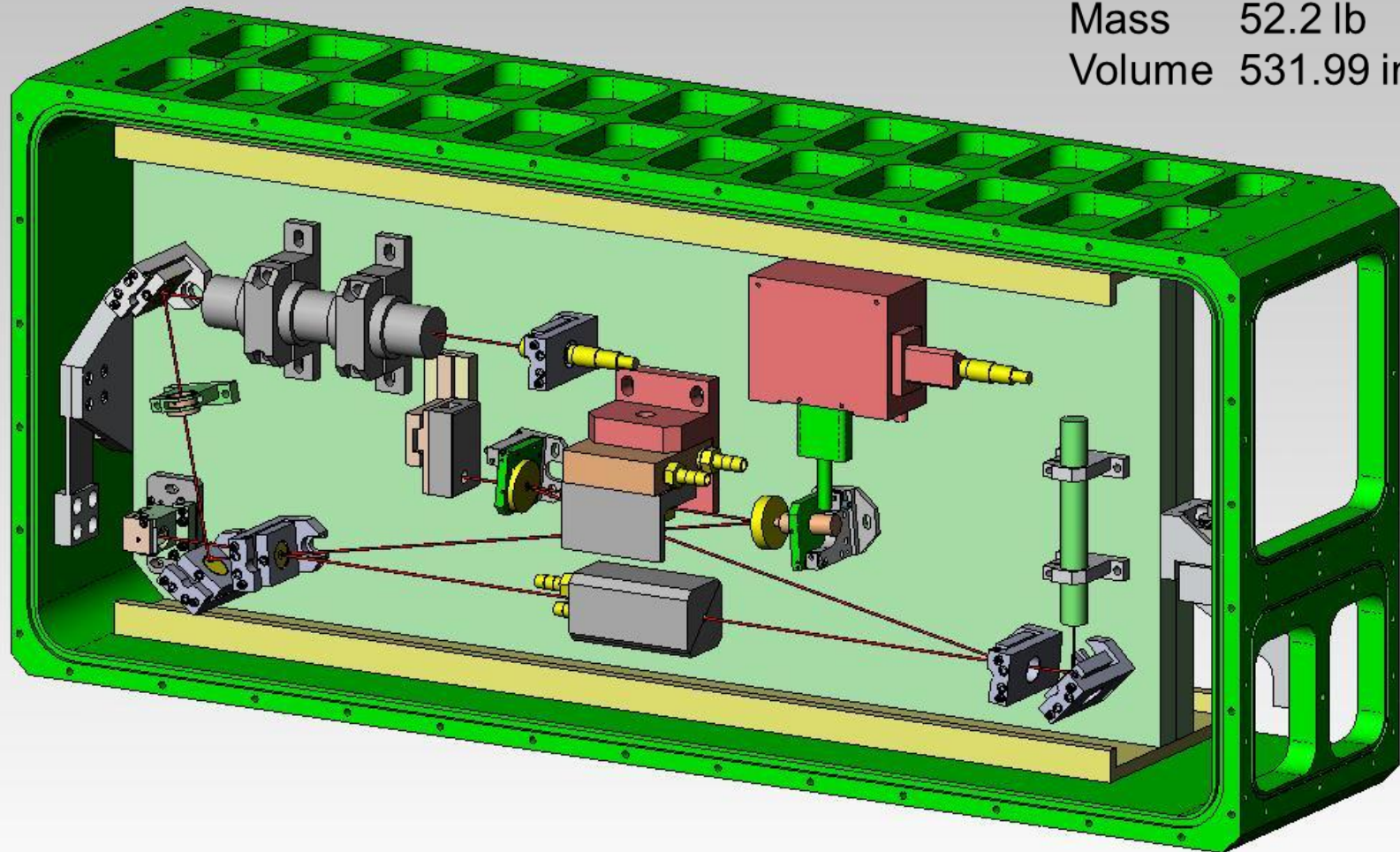
➤ Laser Design

- Optical height = 1"
- Two sides bench design

Optical Bench Design



Laser Enclosure



Mass 52.2 lb
Volume 531.99 in³



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 CO₂ Measurement from Space

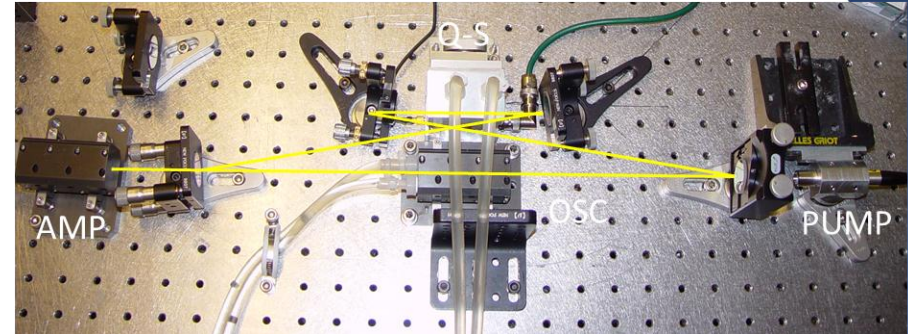


PI: Jirong Yu, NASA LaRC

- Develop a compact, efficient two-micron pulsed laser for a lidar instrument to make accurate, high-resolution atmospheric CO₂ 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 $\geq 35\text{mJ}$ at 100-200Hz needed for the space Integrated Path Differential Absorption (IPDA) instrument in a robust prototype format.
- Leverage two-micron laser technologies developed at NASA LaRC over two decades.
- Demonstrate pulsed laser MOPA system delivering $\geq 35\text{mJ}$ 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.

Co-Is/Partners:

Upendra Singh, LaRC ; Robert Menzies, JPL



Fiber-pumped Holmium-only laser MOPA architecture

- | | |
|---|-------|
| • 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