Earth Science Technology Forum 2015

Review of the UV Laser Demonstrator Program

Contract #NG13VS03C

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Fibertek, Inc.
Herndon, VA

Presentation Overview

- Program background and motivation
- System design overview
- Build status and performance test results
- Lifetest and environmental test plans

Design Motivation

- A 40 W, 50-200 Hz, 1 µm laser supports multiple lidar based Earth Science measurements
  - Next generation cloud and aerosol (IR, green, and UV)
  - Winds (green and UV)
  - Ocean color (green)
  - Ozone
- Current airborne demonstrators meet most requirements for a space-base mission
  - Needs conversion to fully conductively cooled
  - UV lifetime needs to be demonstrated

Design Heritage

FIBERTEK, INC.

- **3rd generation, 1064 nm pump laser technology is well developed**
  - 200 Hz, injection-seeded, single-frequency
  - 20 W/channel, configurable 1 or 2 channels
- **Successfully demonstrated in multiple airborne lidar systems**
  - Tropospheric Wind Lidar Technology Experiment
  - High Spectral Resolution Lidar 2
  - Global Ozone Lidar Demonstrator
  - Optical Auto-Covariance Wind Lidar
  - Airborne Cloud Aerosol Transport System

HSRL-1 on the NASA Langley King Air

TWiLiTE Integration onto Global Hawk

Optical Autocovariance Wind Lidar in a WB-57 Pallet

Laser Performance Goals

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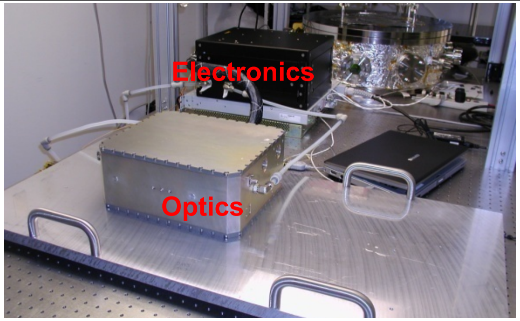
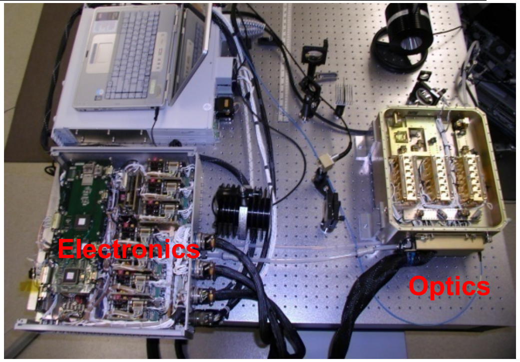
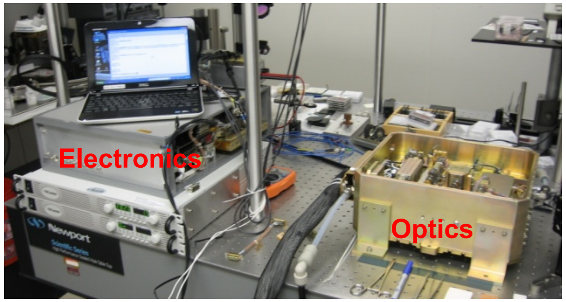
- 40 W, 50-200 Hz, 1 µm pump source
- Injection seeded, single-frequency
  - Required for most next generation lidar systems
  - Improves reliability
- High efficiency 532 nm generation
  - Validation through performance and lifetime testing
- **Improved 355 nm lifetime**
  - Focus is on contamination control
- **Full conductive cooling**
  - Required for space-based systems
- **Validated TRL-6 design**
  - Derived from previous airborne systems



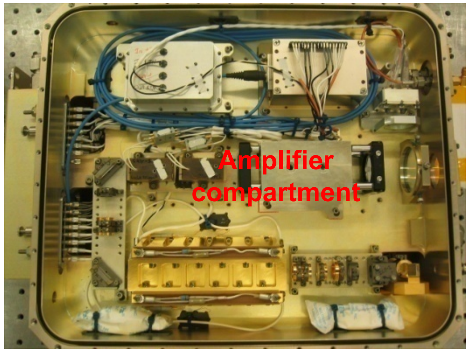
Tropospheric Wind Lidar Technology Experiment



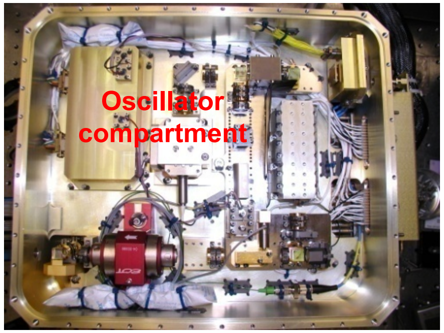
High Spectral Resolution Lidar-2



Global Ozone Lidar Demonstrator



Optical Autocovariance Wind Lidar



Airborne Cloud/Aerosol Transport System

Updated Program Objectives & Approach

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- Develop a 100 mJ, 150 Hz UV laser transmitter with a lifetime of > 5×10^9 shots
  - Develop an improved 1064 nm final power amplifier that can achieve 250 mJ/pulse at 150 Hz with an $M^2 \leq 2$
  - Develop a purely conductively cooled Laser Optics Module (LOM) design
  - Develop a UV module design that converts the 250 mJ pump to 100 mJ at 355 nm
- Conduct high repetition rate (20 kHz) UV testing of candidate LBO triplers
- Conduct 4 month life testing of the laser transmitter to assess 532 nm lifetime
- Conduct 4 month half power 355 nm life testing of the laser transmitter for initial UV lifetime assessment
- Conduct 4 month full power 355 nm life testing of the laser transmitter for final UV lifetime assessment
- Conduct environmental testing to advance the design from TRL 4 to TRL 6
  - Thermal-vacuum & vibration

Heritage Airborne Design

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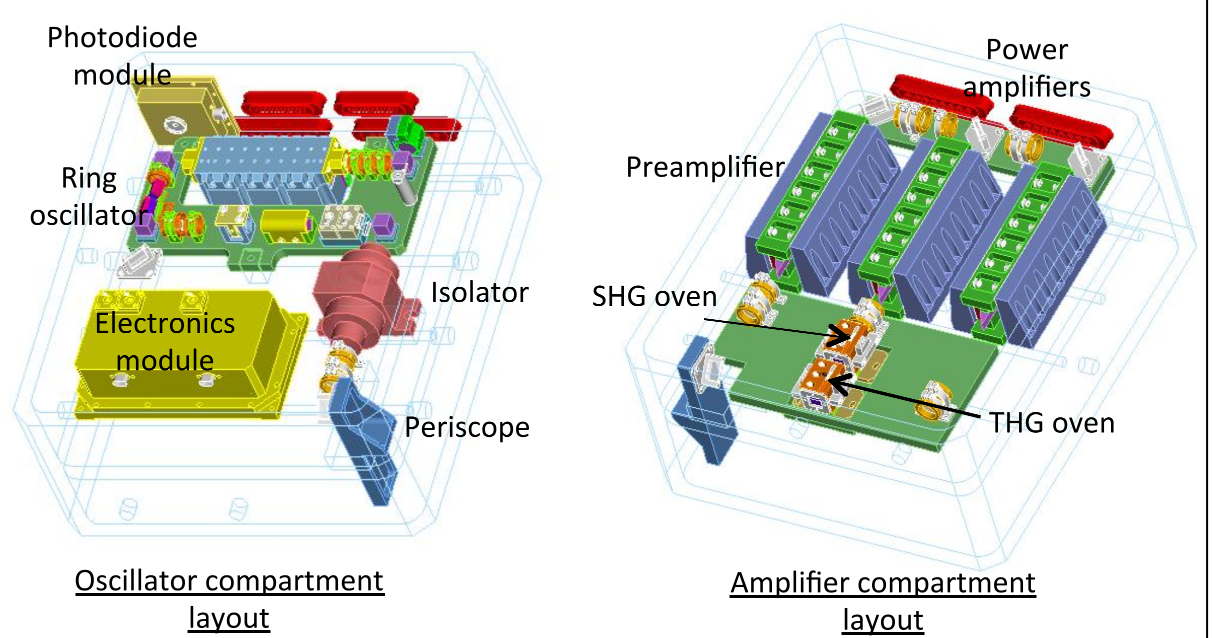
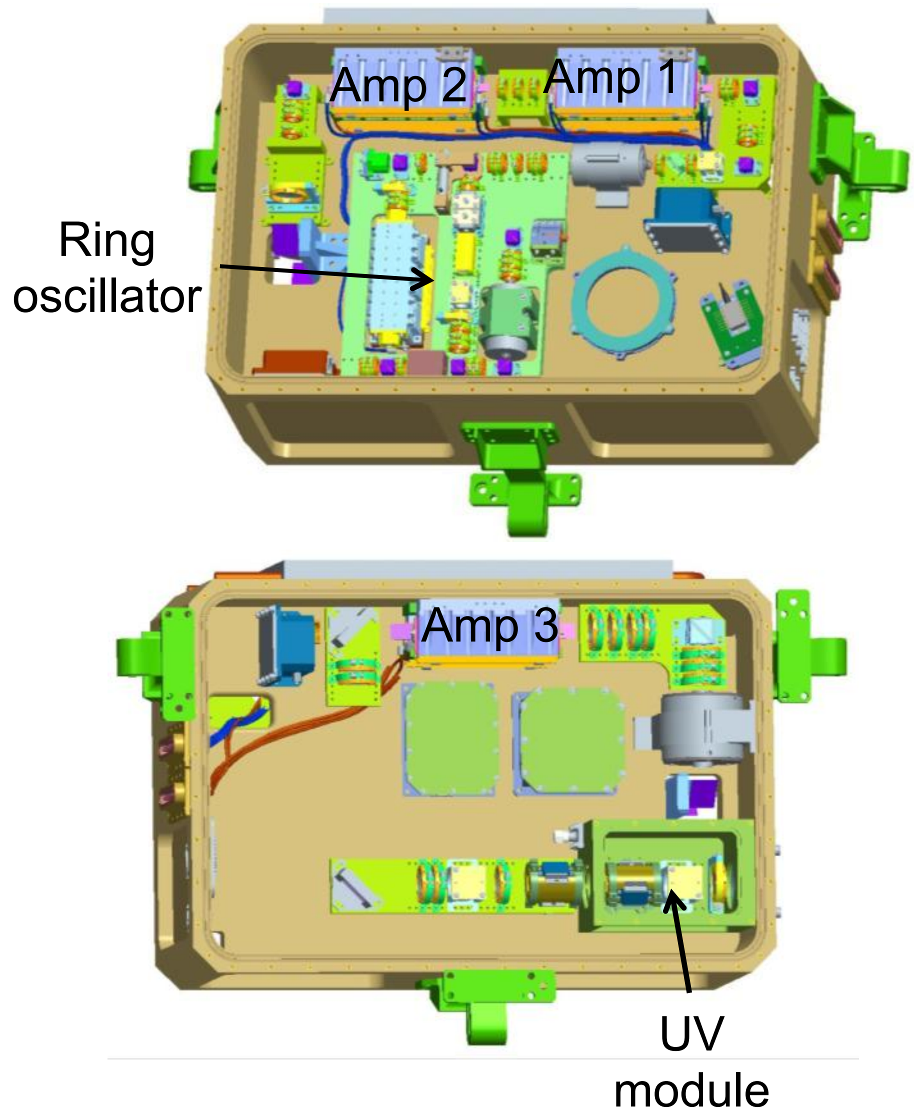
- Injection seeded ring oscillator
- Dual compartment
- Dual 20 W output channels
- Sealed and air pressurized
- Diode-pumped zig-zag slabs
- Liquid cooled center plane



Typical airborne laser design

Heritage System Design Updates

- All UV components in a hermetic, polymer free environment
  - Improved lifetime
- Internal telescope in UV box
  - Reduces fluence on down stream optics
- Pure conductive cooling to a single external thermal interface
  - Simplifies thermal design
  - Required for a space-based system
  - Amplifiers mounted on laser module wall
- Improved final power amp design
  - Reduced beam distortion



Previous high energy amplifier achieved energy, but spoiled beam quality

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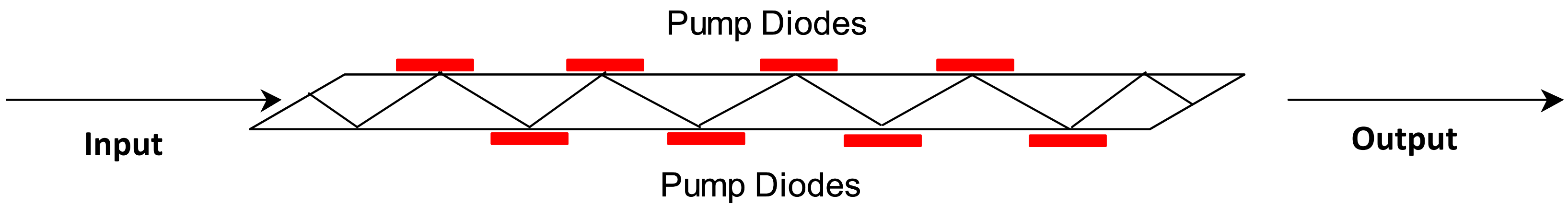
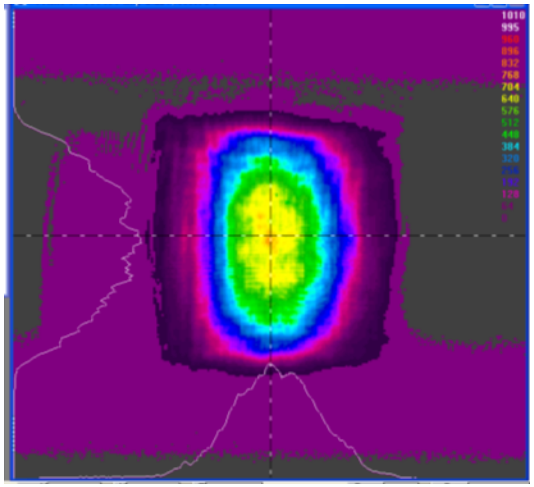


Pump-on-bounce amplifier

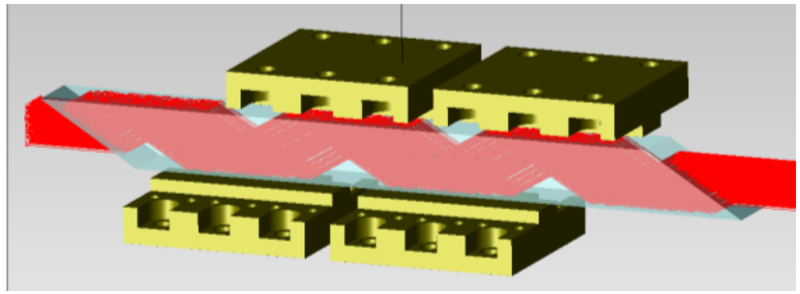
- 2-sided pumped and cooled
- Footprint length is limited to diode bar length of 1 cm
- Previous pump on bounce design achieved >900 mJ pulse energies but with $M^2 > 2.5$
- Input beams >3 mm input beam overfilled pump spot
- Overfilled pumping leads to non-spherical, difficult to correct aberrations

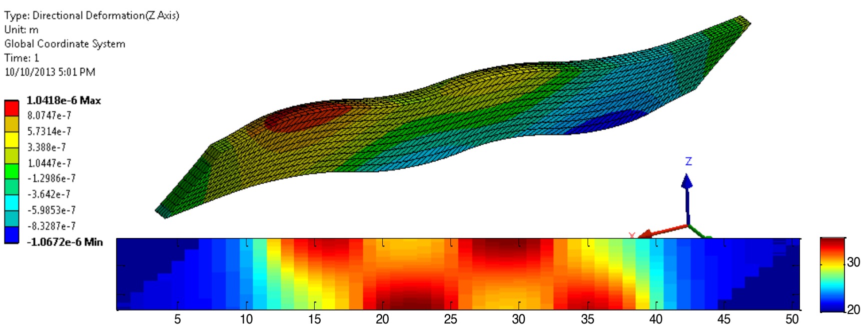


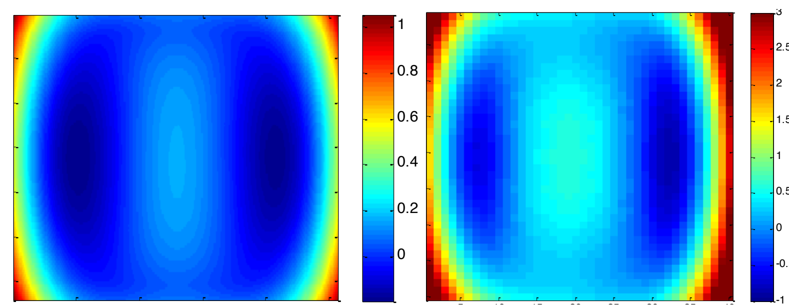
910 mJ/pulse, 4.5 mm x 6.7 mm

$M_x^2 = 2.5$, $M_y^2 = 2.5$

Final Amp Design: Higher power diodes pumping a larger footprint







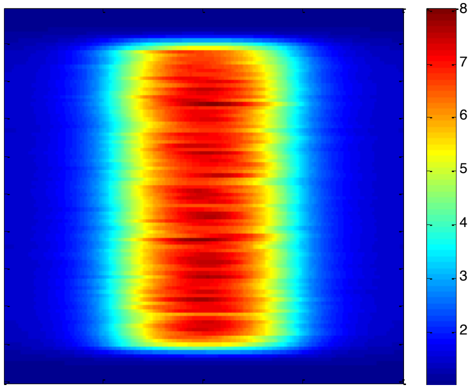
Twice the local heating, twice the deformation, but half as many bounces

dn/dT and deformation induced wavefronts are ~ same as the long slab

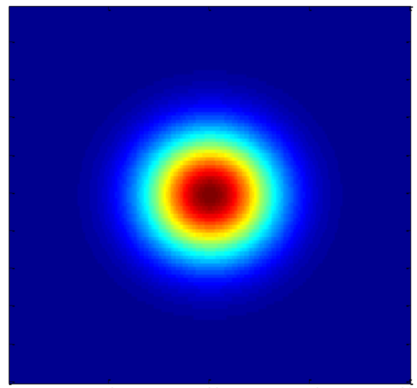
- 200W bars derated to 150-175W, Still allows ~120-150ms pumping and good efficiency
- Diode array lengths of 2 cm match well to a 5-6 mm input beam

Power Amp Is Built and Characterized

- Performed a weighted average over the probe beam shape to get the expected measured small signal gain.

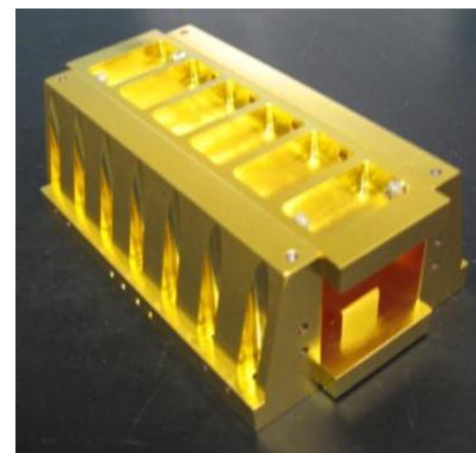


X



= 6.3

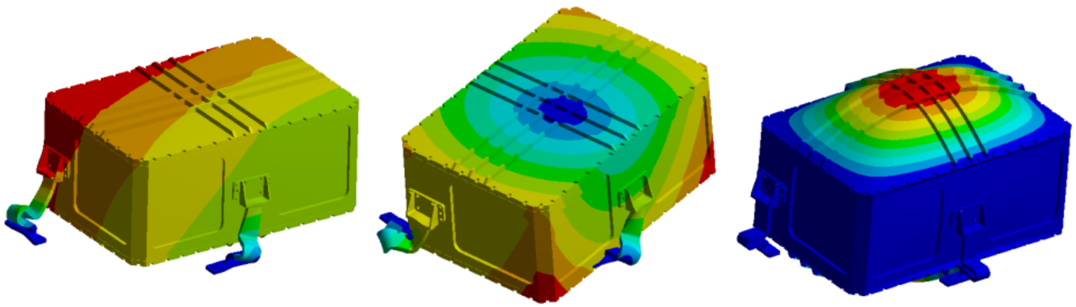
- Actual measured small sigma gain is 6.5
- Difference can be explained by uncertainties in parameters, in particular sigma at elevated temperature

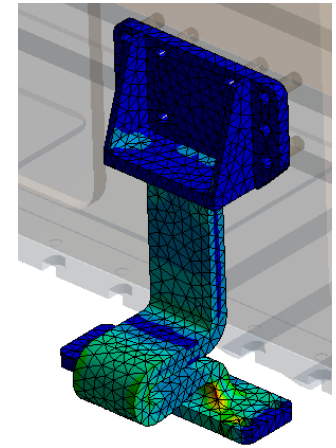


Final Power Amp

Vibration analysis indicates selected design will perform well

Mode 1 Mode 6 Mode 7

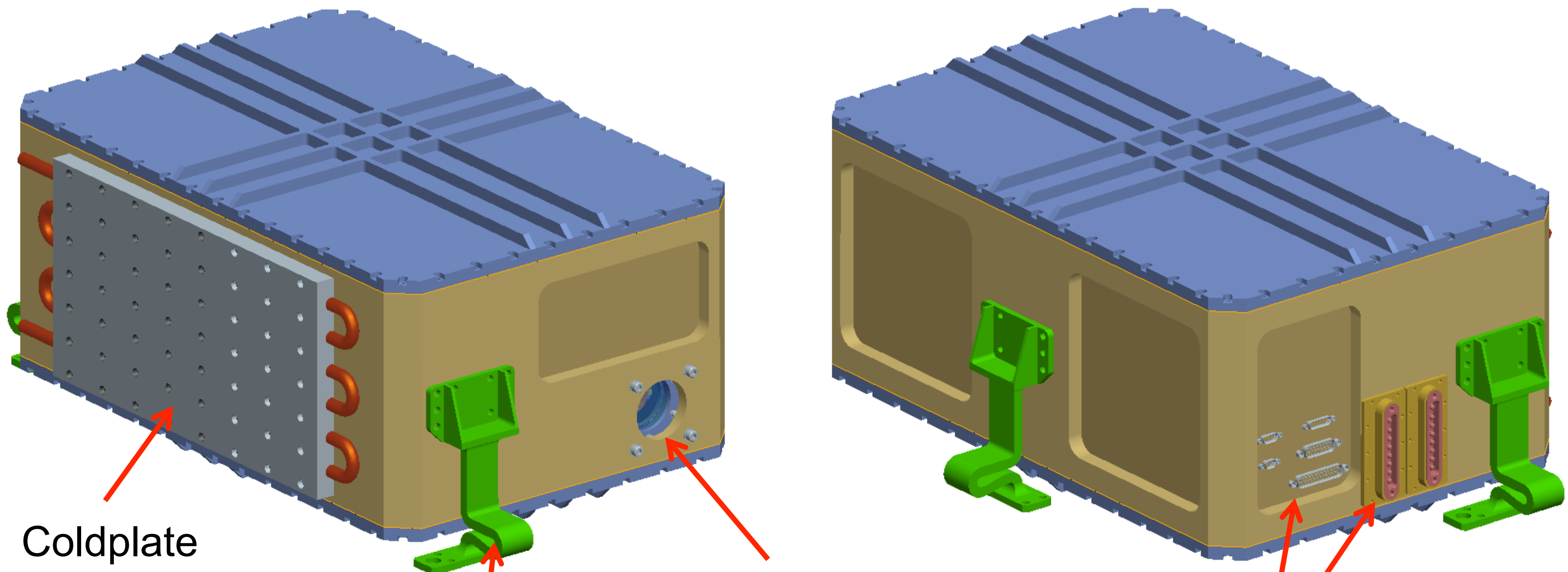




- Using modified ICESat-2 flexures for the box.
- Optimized flexures to minimize the frequency of rigid body modes
  - Flexures designed to resonate from 75 to 150 Hz band width
  - 3 translation and 3 rotation modes (6 total)
  - Flexures will survive GEVS 14.1 GRMS with notching.
- Optimized mounting of the resonator bench to the mid-plane to maximize the frequency of the internal mid-plane drum mode
  - Since this is the largest bench in the laser, it was light weighted and stiffened with ribs. Bench is aluminum.
  - Selected 5 mounting feet which achieves a frequency of >1000Hz

Exterior LOM Views

Overall Dim: 18.0” x 12.0” x 8.5”
Weight: 88 lbs



Coldplate

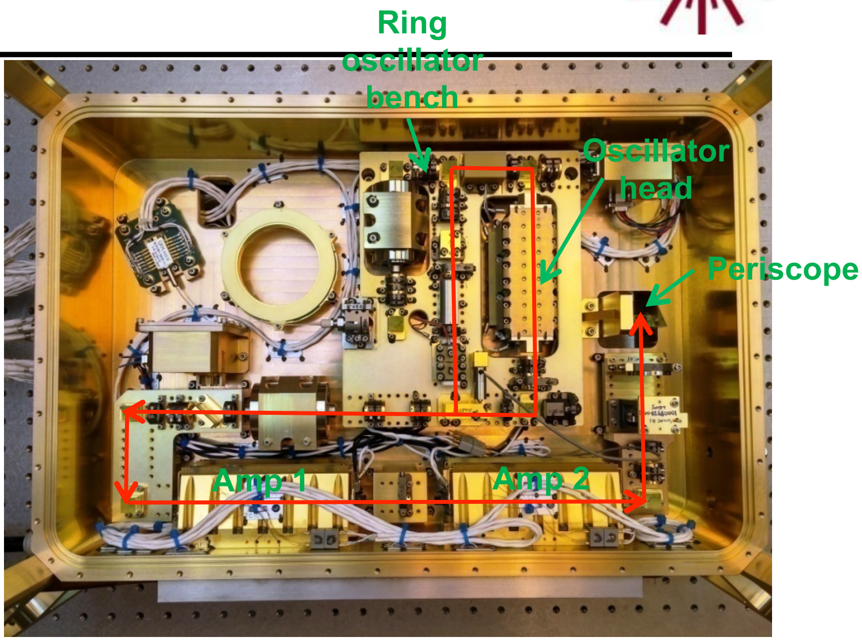
Flexures modified from ICEsat-2

Output Window

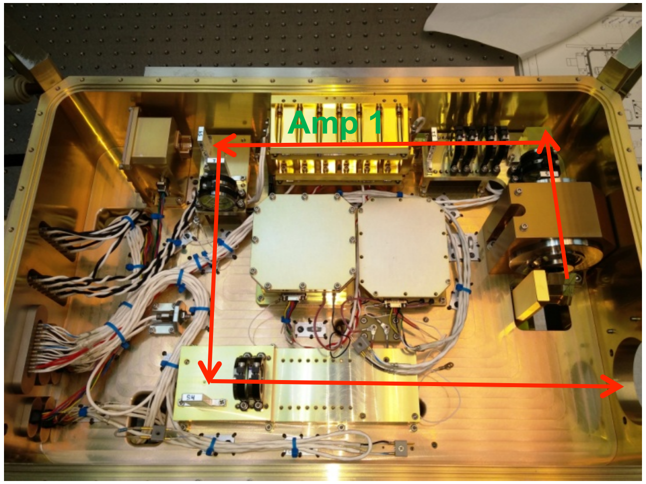
Power and signal connectors

Hardware Assembly Status
LOM – Main Housing

- Assembly & processing complete
- Major component fit checks completed
- He leak check in vacuum environment completed
- Harnessing of the housing is complete
- All four laser pump heads have been installed and thermally balanced
- Alignment of the ring oscillator and first two amplifiers is complete
- Final amplifier installation and characterization is nearly complete



Oscillator/Amp 1/ Amp 2 Compartment



Amp 3/ SHG/THG Compartment

Hardware Assembly Status

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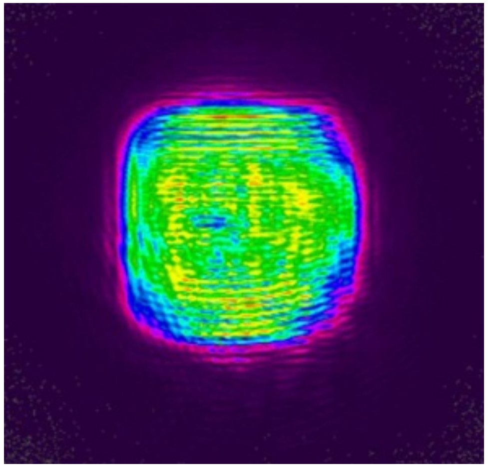
Resonator Performance Summary

Parameter	Units	Goal	Demo'd	Status
Wavelength	*nm (air)*	1064 (*nom*)	1064.393	☑
Pulse Rate	*Hz*	150	150	☑
Pulse Energy	*mJ*	≥ 25	34	☑
Pulse Width	*ns*	10 – 20	14	☑
Beam Quality	M^2	≤ 1.5	1.3	☑
Spectral Width	*MHz*	≤ 100	≤ 70	☑

Hardware Assembly Status

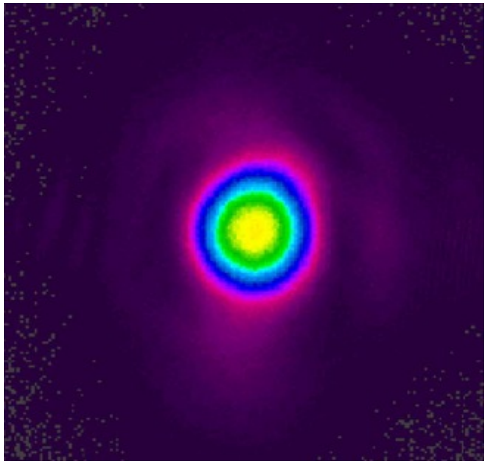
Resonator Spatial Distribution

Intra-Cavity Field Distribution



Imaged Location
2.5 mm intra-cavity aperture

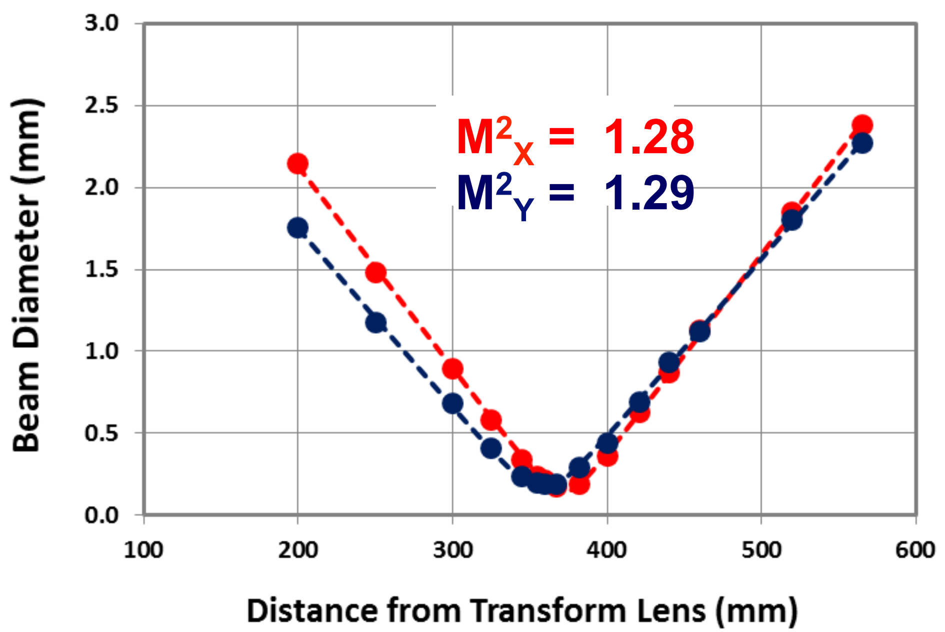
Far Field Distribution



Uncorrected Divergence
890 µr

Hardware Assembly Status

Resonator Beam Quality



Hardware Assembly Status

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Amp 1 & 2 Performance Summary

Parameter	Units	Goal	Demo'd	Status
Pulse Rate	*Hz*	150	150	☑
Pulse Energy	*mJ*	≥ 150	>200	☑
Pulse Width	*ns*	10 – 20	14	☑
Beam Quality	M^2	≤ 1.8	1.5	☑

Hardware Assembly Status

Remaining Assembly Tasks

- Installation of Amp 3 is in work
  - Installation and final characterization is expected in late June
- SHG assembly is ready for installation
  - Installation and final characterization is expected in mid July
- 532 nm lifetime testing will begin after the SHG installation

Lifetime Testing

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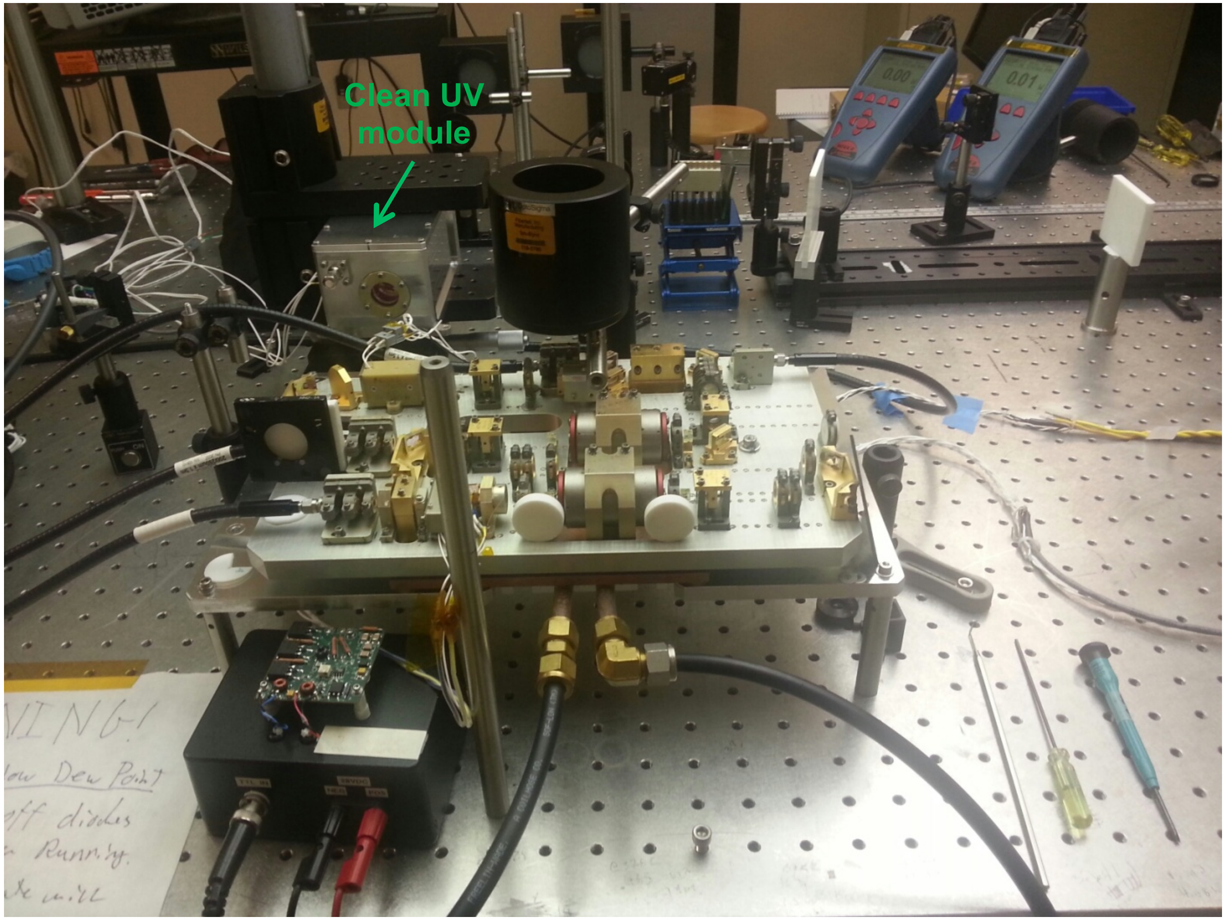
20 kHz UV Module Life Test

- Uses ICESat-2 20 kHz brassboard MOPA as the pump source
- A deliverable identical UV module is built up with a 6x6x25 mm THG coated in the same run as the larger deliverable crystals
- Set-up is completed and testing is has just started



Summary

- Assembly of the UV demonstrator is complete through the first two amplifiers
  - Oscillator and Amp 1 & 2 performance meets the design goals with margin
- Characterization of the performance with Amp 3 is underway
- The 20 kHz UV lifetest has started
- SHG installation and beginning of 532 nm lifetime testing is expected by mid July