FIBERTEK, INC.

Earth Science Technology Forum 2014

Review of the High Efficiency UV Demonstrator Program

Contract #NG13VS03C

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Background

- A 40 W, 50-200 Hz, 1 μm laser can be the pump for multiple lidar based Earth Science measurements
  - High pulse energies in the IR, visible, and UV
  - Next generation cloud and aerosol (IR, green, and UV)
  - Winds (green and UV)
  - Ocean color (green)
  - Ozone
- Single-frequency is required for many applications
- Single-frequency improves reliability for all
- Current airborne demonstrators meet most requirements for a space-base mission
  - Needs conversion to fully conductively cooled
  - UV lifetime needs to be demonstrated

Primary Program Objective
Single-Frequency UV Demonstrator

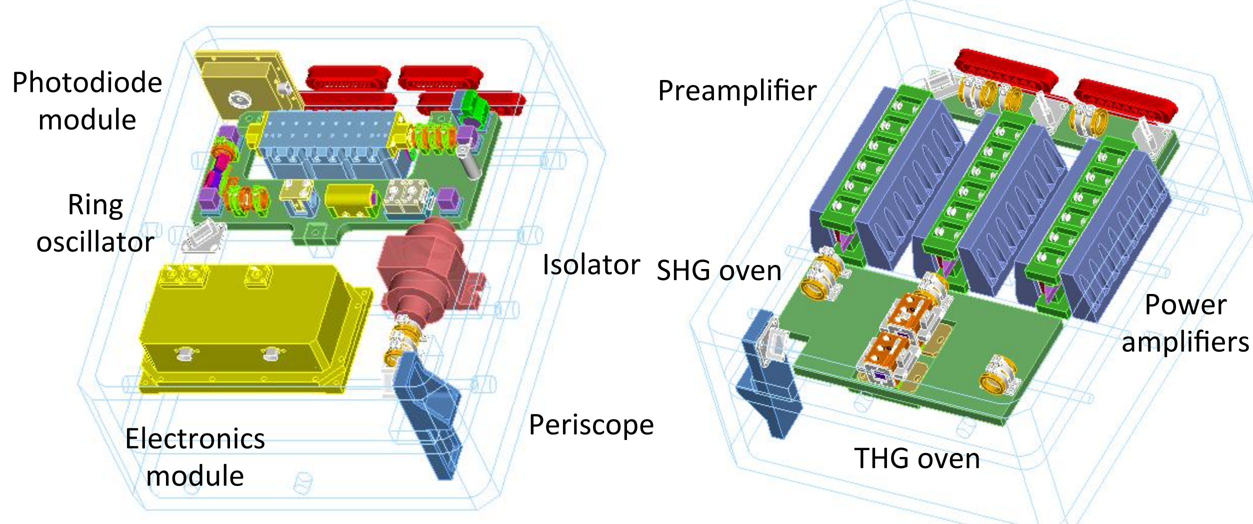
- Focus is on higher pulse energies at lower rep rates
  - Typically require for aerosol and direct detection wind lidars
- Improved 1064 nm final power amplifier
  - 750 mJ/pulse @ 50 Hz, $M^2 < 2$
- Fully conductively cooled Laser Optics Module (LOM)
- 350 mJ UV conversion module with a lifetime goal of $>10^9$ shots
- Testing to advance the LOM design from TRL 4 to TRL 6
  - Vibe & TVAC
- 8 month life test of the pump laser and UV conversion

Secondary Program Objective
532 nm Demonstrator

- Intermediate performance testing optimized for 532 nm output at 150 Hz
  - 170 mJ @ 532 nm
  - 80 mJ @1064nm
  - $M^2 < 2$ @ 532 nm
  - $M^2 < 3$ @ 1064 nm
- Demonstrates requirements for next generation of space-based cloud and aerosol or ocean color lidar systems

Design approach

- Derived from current airborne designs
  - Injection seeded ring oscillator
  - Dual compartment
  - Sealed and air pressurized
  - Diode-pumped zig-zag slabs
- All UV components in a hermetic, polymer free environment



Oscillator compartment layout

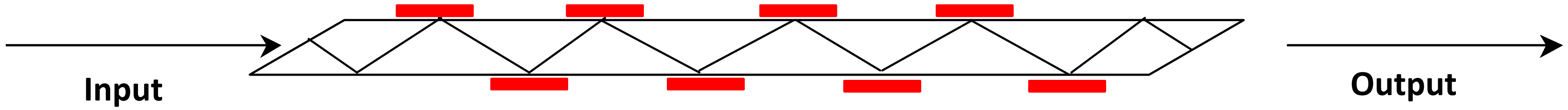
Amplifier compartment layout

Typical airborne laser design

- Internal telescope in UV box to reduce fluence on down stream optics
- Implement pure conductive cooling to an external thermal interface
  - Power amplifiers mounted on LM walls
- Improved final power amp design

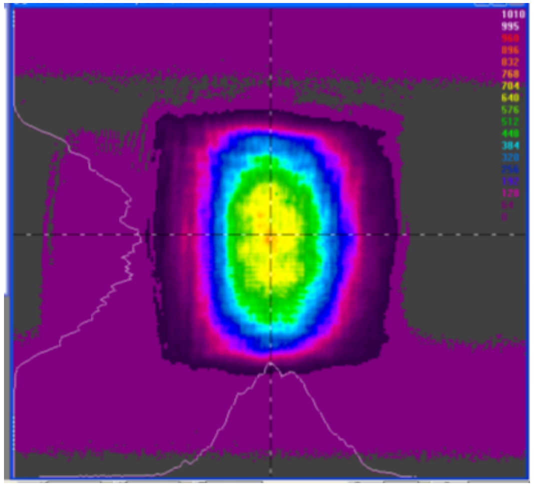
Final Power Amplifier Design and Test

Previous amplifier achieved energy, but spoiled beam quality



Pump-on-bounce amplifier

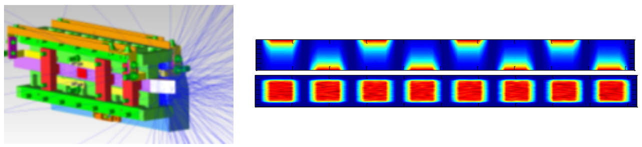
- 2-sided pumped and cooled
- Previous pump on bounce design achieved >900 mJ pulse energies but with $M^2 > 2.5$
- Pump spot size was too small. A 3 mm input beam fully overlaps each pump array
- Beam extended into edges of heated region resulting in higher order aberrations



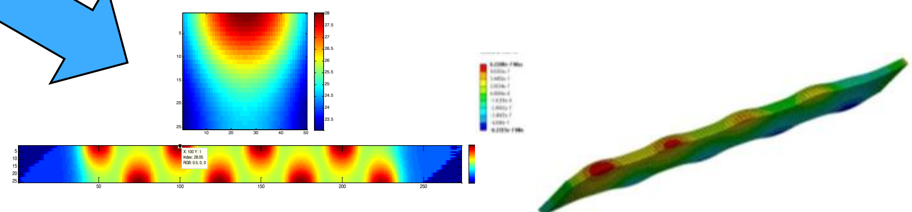
910 mJ/pulse, 4.5 mm x 6.7 mm

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

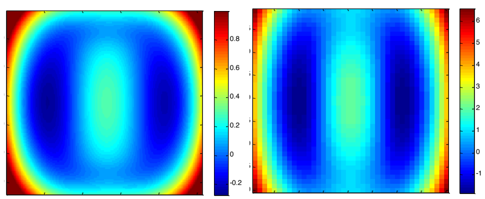
Developed an "all-effects" amplifier model



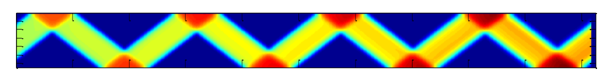
Non-sequential ray trace in TracePro produces absorption, gain and heat profiles



FEA in ANSYS produces temperature, stress, and deformation profiles



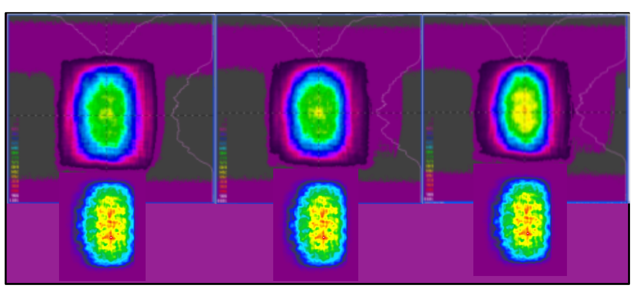
Analysis in MatLab produces dn/dT and deformation induced wavefronts



Diffractive propagation in GLAD finds 3D extraction, energy, beam quality

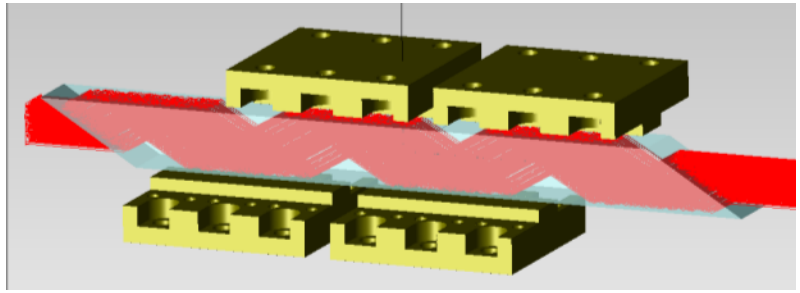
Meas.

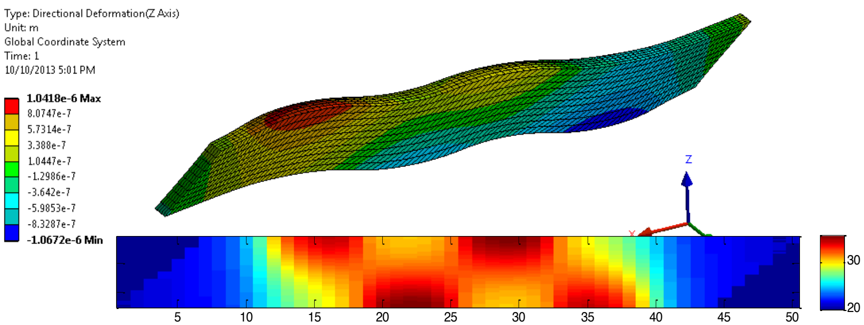
Model



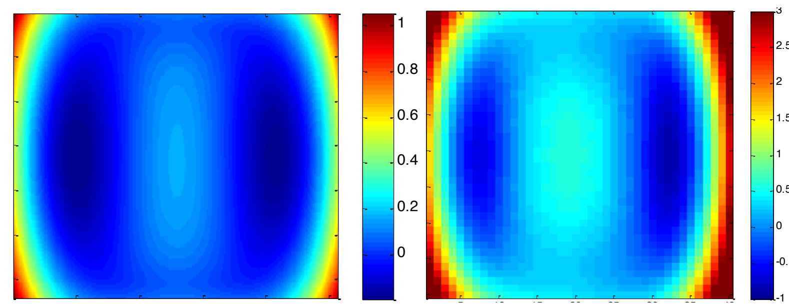
Mode, beam quality, pulse energy, and pulse shape were validated against real laser performance. Good fidelity. M^2 is a little low but shows trends

Final Amp Design: Higher power diodes pumping a larger footprint





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

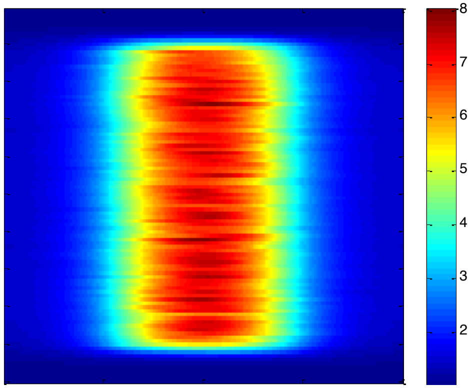


dn/dT and deformation induced wavefronts are ~ same as the long slab

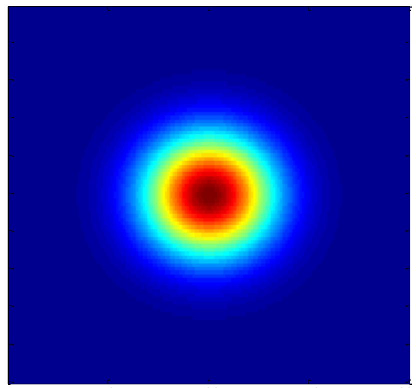
- Mode and beam quality same as long slab
- 200W bars derated to 150-175W, Still allows ~120-150ms pumping and good efficiency
- Short slab with large patches selected for program

Power Amp Is Built and Characterized

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

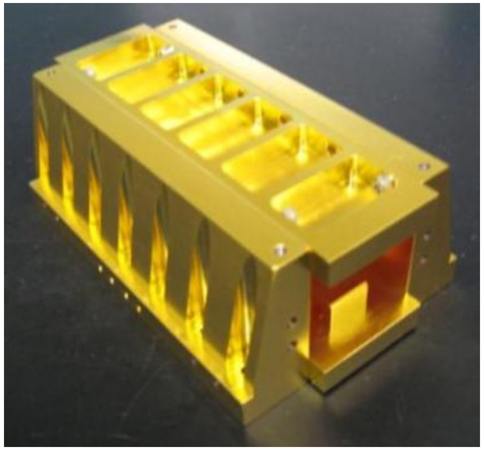


X



= 6.3

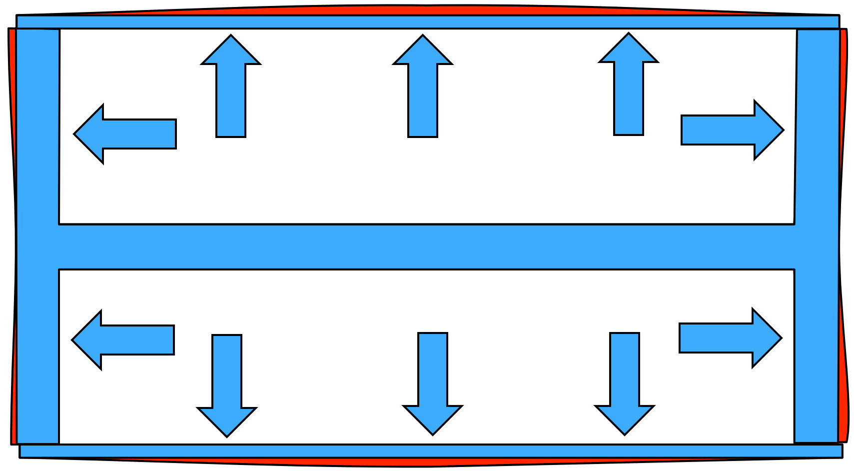
- Actual measured small sigma gain is 6.5
- Difference can be explained by uncertainties in parameters, in particular sigma at elevated temperature



Final Power Amp

Laser Optics Module (LOM) Analysis and Design

Laser optics module (LOM) packaging approach



- A dual compartment box provides a low distortion center plane
- The dual compartment approach has been used successfully on several programs
- Need to eliminate liquid cooling in the mid-plane used in airborne laser designs.

FEA Analysis Used to Select Conductive Cooling Strategy

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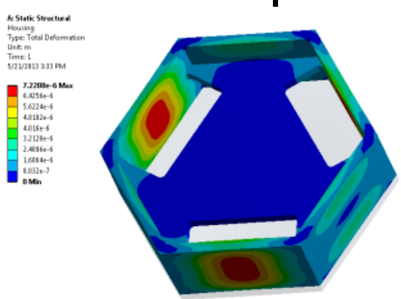
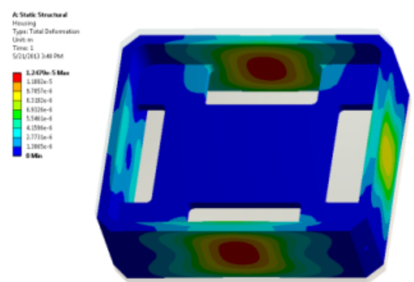
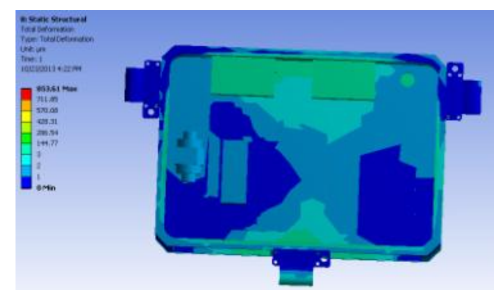
- Updated design must be fully conductively cooled
  - All heat must be conducted to the canister wall
  - To reduce distortion, amplifiers will be mounted directly to the wall at the cold-plate interface. Resonator head is still on mid-plane.
- Investigated three concept: hexagonal 3-wall, rectangular 3-wall, rectangular 1-wall

Concept 1 **Concept 2** **Concept 3**

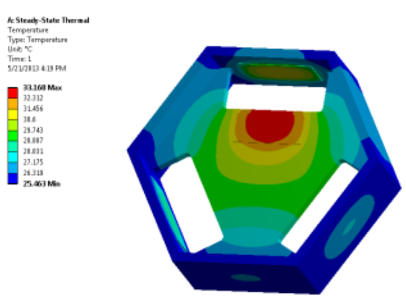
Distortion under pressure

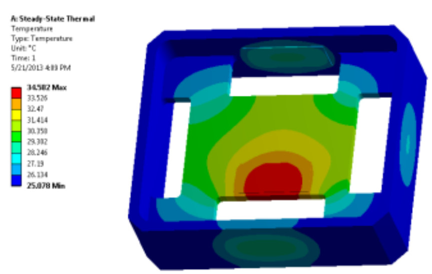


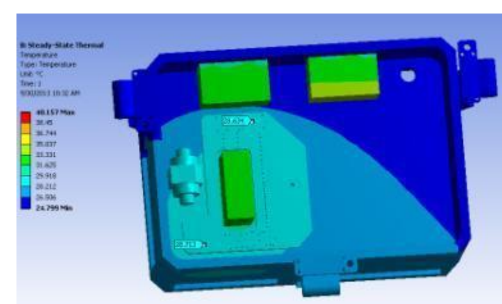




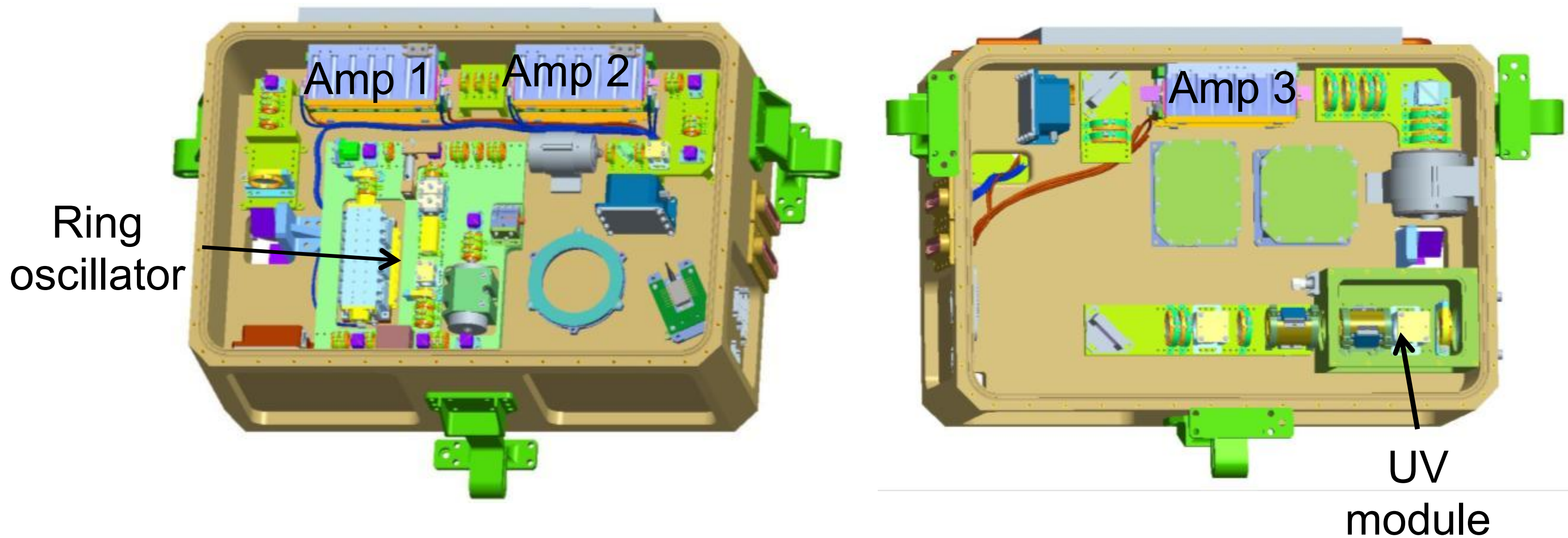
Temperature distribution





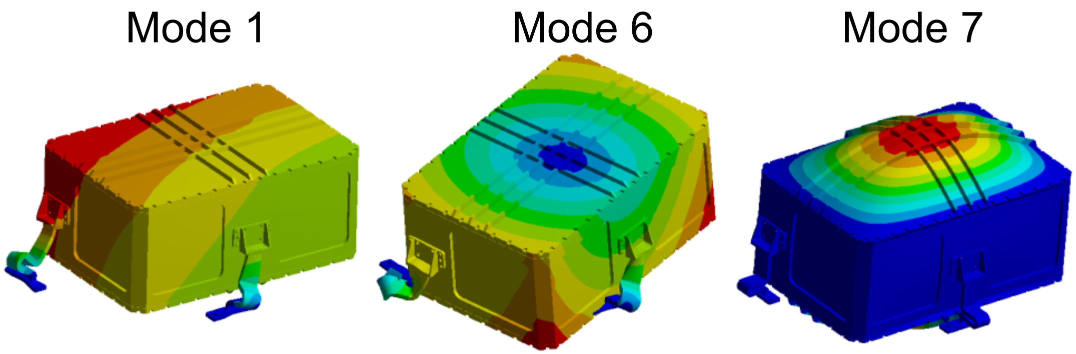


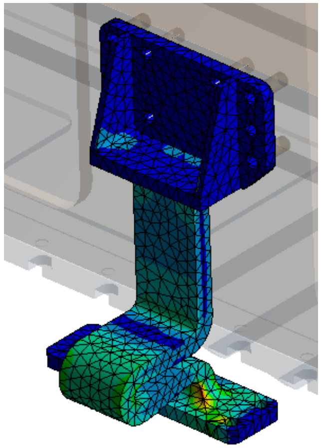
Final Design
Single Wall Cooling



- All amplifiers are mounted on one wall
- Warm-up motion of resonator pump-head relative to resonator bench is still symmetric and small
- Mid-plane remains stable to pressure and rotation of the amplifiers is minimal.
- Simplifies system design and integration

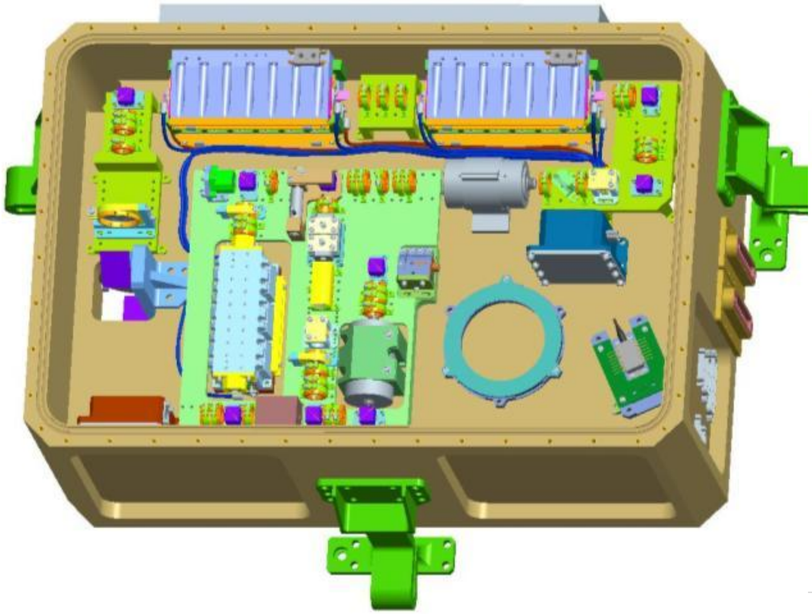
Vibration analysis indicates selected design will perform well

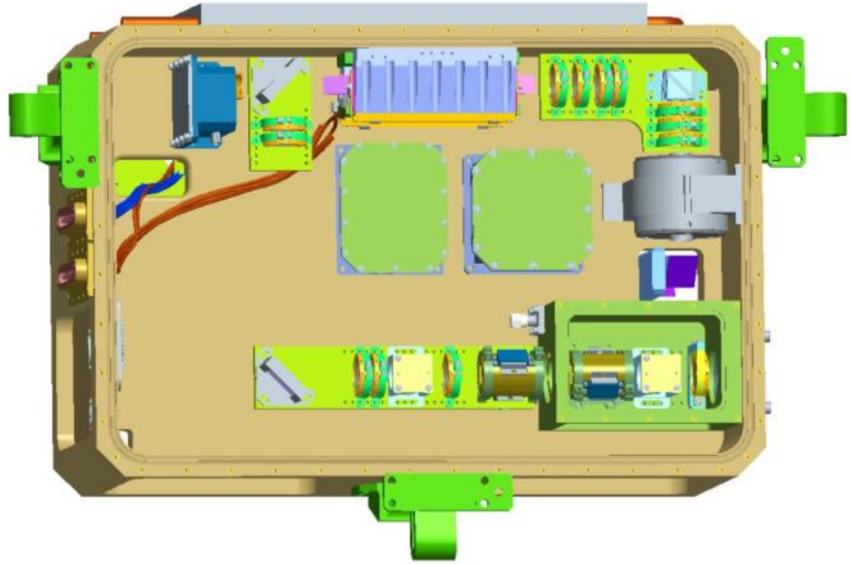




- Using modified ICESat-2 flexures for the box.
- Optimized flexures to minimize the frequency of rigid body modes
  - Flexures designed to resonate from 75 to 150 Hz band width
  - 3 translation and 3 rotation modes (6 total)
  - Flexures will survive GEVS 14.1 GRMS with notching.
- Optimized mounting 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

Simple mid-plane with benches reduces complexity of box

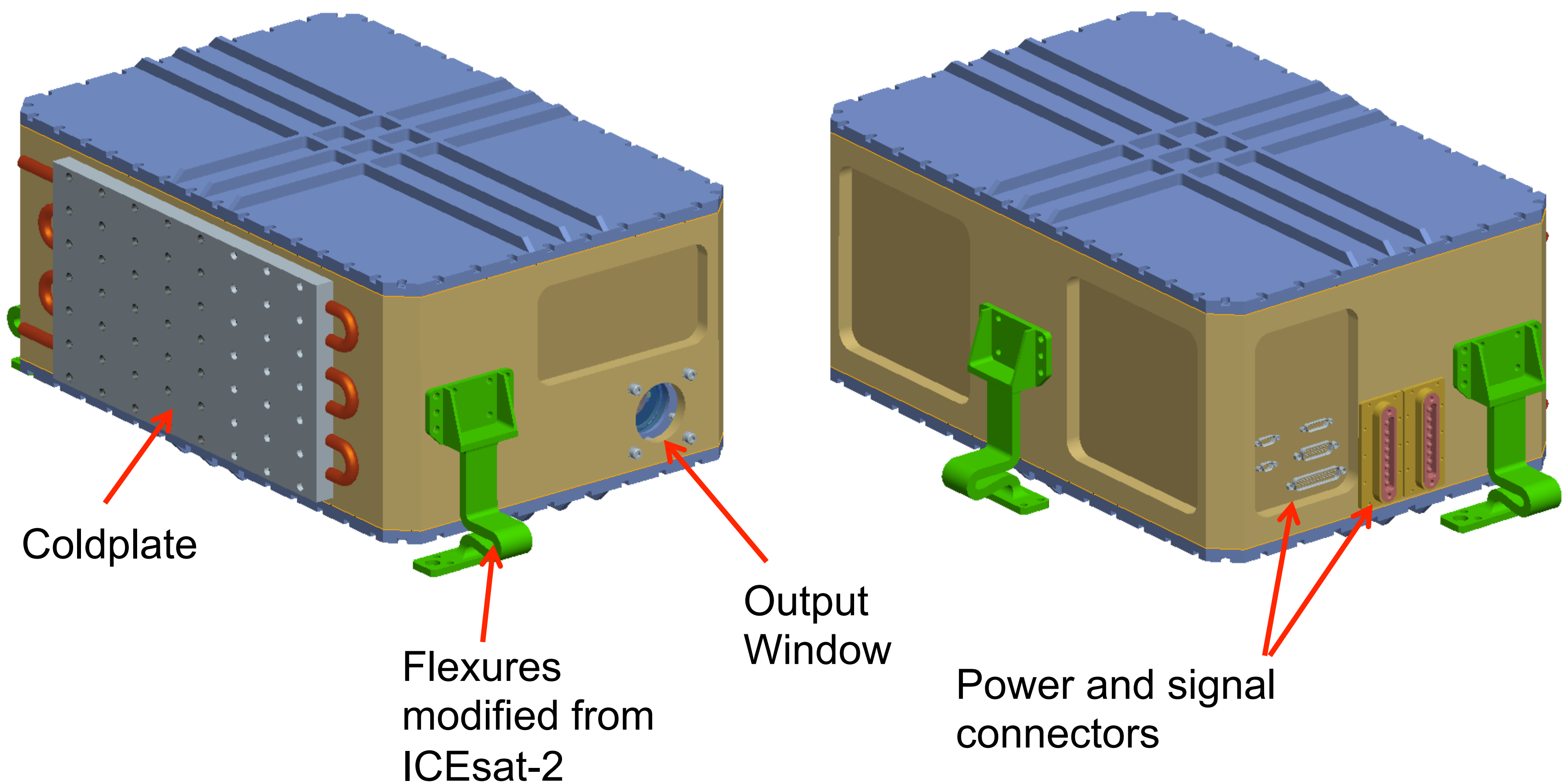




- Resonator pump-head and heavy rotators mounted directly to mid-plane. Most other optics on benches.
- Resonator pump-head has an adapter plate to keep the mid-plane flat and simple for maximum flexibility.
- Minimizes the tapped holes and bosses on the mid plane reducing risk and cost of the box.

Exterior LOM Views

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



Laser Electronics Module (LEM) Design

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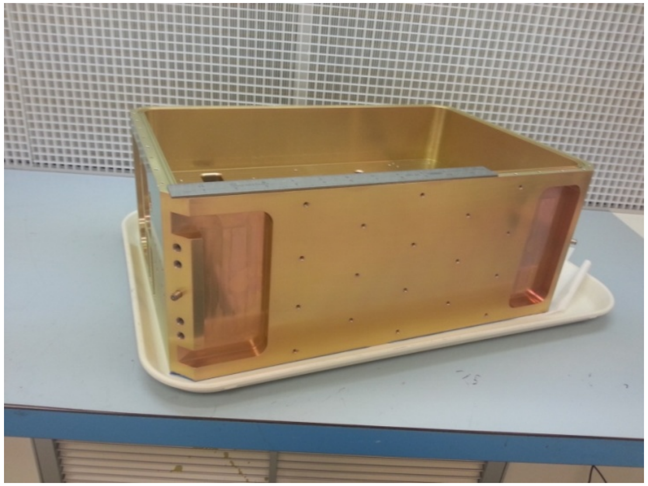
- Rack mounted, not intended to demonstrate TRL 6
  - Combination of COTS and custom electronics modules
- COTS Modules
  - Diode drivers
  - Oven controllers
  - Seed laser controller
- Custom electronics
  - Q-switch driver
  - EO modulator
  - Control electronics
  - Locking electronics

Assembly Status of Laser Optics Module (LOM)

- Match drilling of the flexure mounts to the laser is complete
- Laser housing is cleaned, helicoils are installed, and harnessing is underway
- All optical subassemblies, including the diode-pumped heads, are built
- Installation and thermal balancing of the heads will begin shortly



Assembly Status of Laser Electronics

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- COTS electronics are assembled into rack
  - Four diode drivers
  - Two oven controllers
  - Seed laser TEC controller
  - Seed laser power supply
- All custom boards are assembled and tested
- Assembly of boards into the custom control box has begun

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Program Status

- Solutions have been found for all critical design challenges
  – High power amplifier design shows excellent performance in detailed modeling.
  – Symmetric mid-plane structure provides environmentally stable optical bench while allowing simple conductive thermal interface
  – Opto-mechanical solution exceeds requirements for stability under vacuum, vibration, and thermal load
  – Low out-gassing structure for thermal control of harmonic crystals
  – Near polymer free environment for all UV components.
- Other aspects of the design are low risk legacy components
- Anticipated completion date is early Q1 2015
- Discussions on order of testing is ongoing
  – 150 Hz, 532 nm performance testing will likely be added to the program
  – Conversion to 50 Hz UV for TRL 6 testing will follow
    - TVAC
    - Lifetime
    - Vibration