

FIBER-BASED LASER TRANSMITTER TECHNOLOGY MATURATION FOR SPECTROSCOPIC MEASUREMENTS FROM SPACE

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OUTLINE


- Introduction
- Seed Module
- Pre-Amplifier
- Power Amplifier
- Packaging
- Conclusions

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NASA's ASCENDS MISSION

Active Sensing of CO₂ Emissions over Nights, Days, and Seasons (ASCENDS) Mission


Science Mission Definition Study
Draft

ASCENDS Ad Hoc Science Definition Team:

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April 15, 2015

Avail from:
http://cce.nasa.gov/ascends_2015/index.html



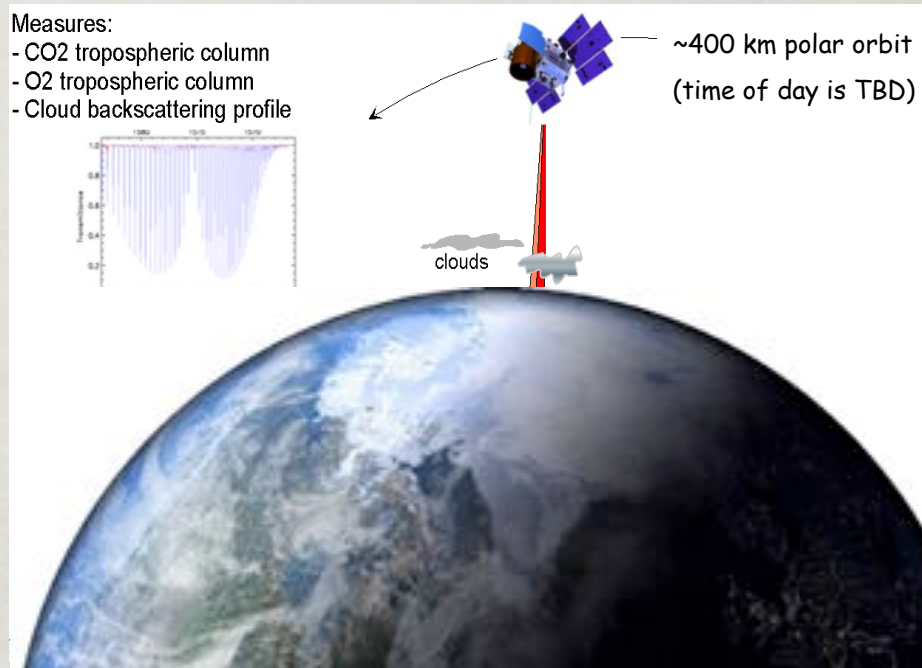
Home | Agenda and Presentations | Workshops | ad hoc Science Definition Team

ASCENDS Workshop
June 19, 2015
California Institute of Technology

This workshop will be held after the 11th International Workshop on Greenhouse Gas Measurements from Space at California Institute of Technology, Pasadena, California, USA, Friday, June 19th.

View their website for logistical information: <https://sites.google.com/site/iwggms11/>

- Measures:
- CO₂ tropospheric column
 - O₂ tropospheric column
 - Cloud backscattering profile



Requirements for CO₂ Mixing Ratio:

Random error: ~ 1 ppm in ~100 km along track, or
~ 0.5 ppm in ~10 sec over deserts

Bias: < 0.5 ppm (< 1 part in 800)

Lower errors provide more benefit for flux est's.



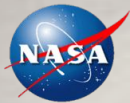
2018 NSF DECADAL SURVEY



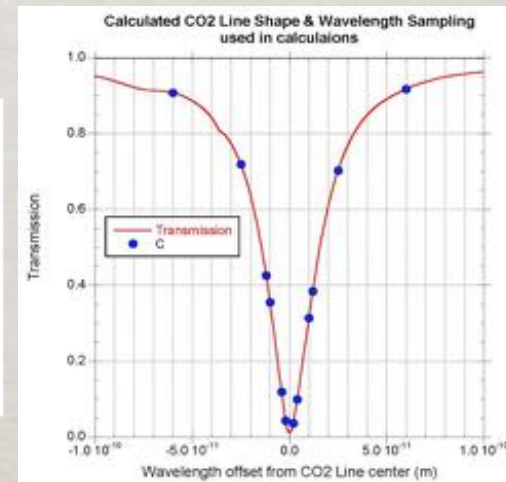
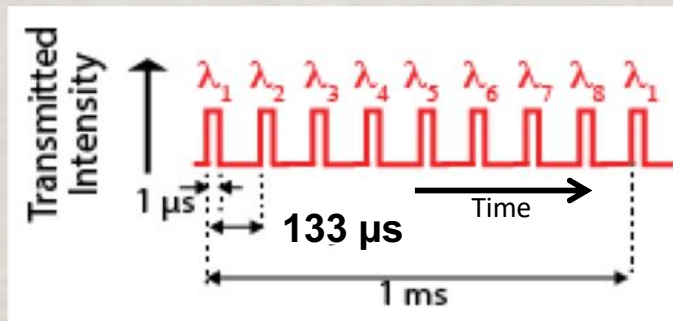
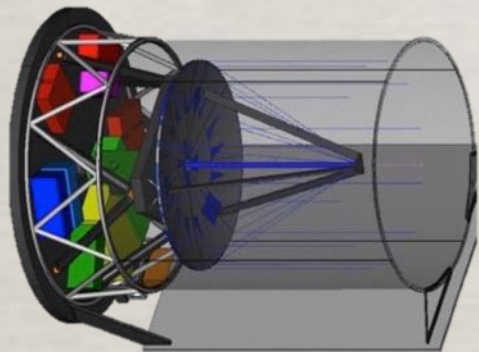
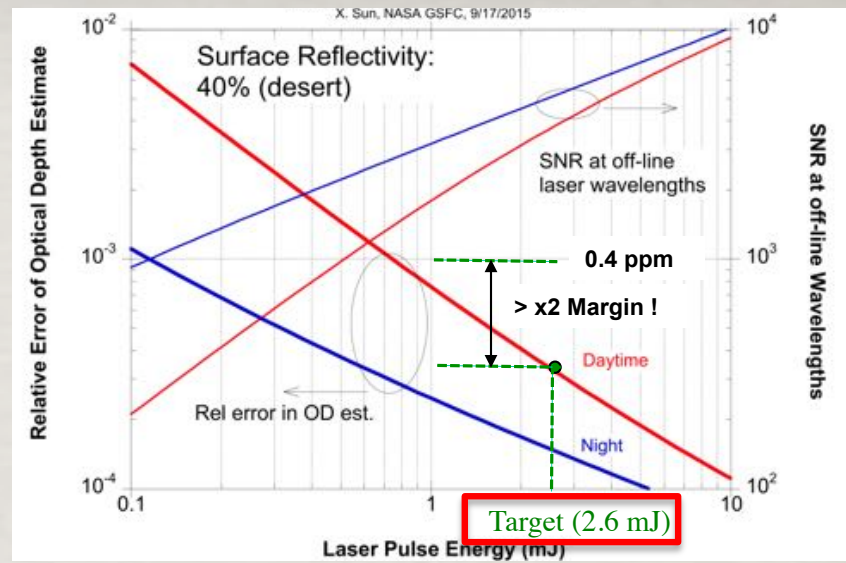
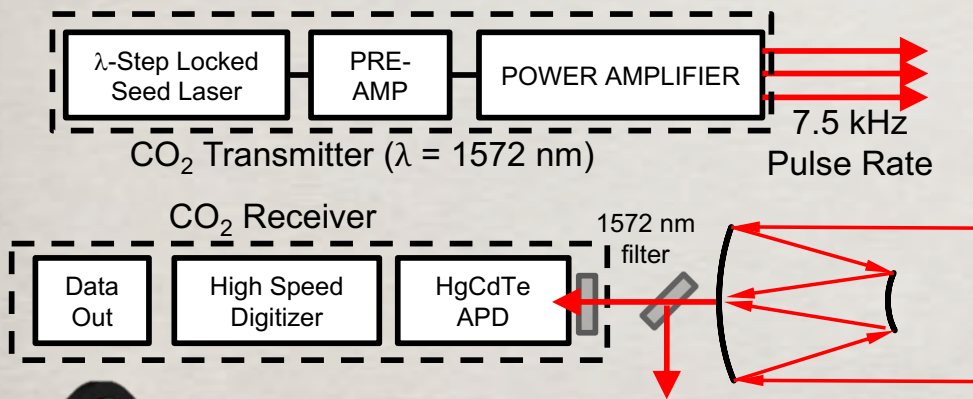
Recommended NASA Priorities: Explorer

TARGETED OBSERVABLE	SCIENCE/APPLICATIONS SUMMARY	CANDIDATE MEASUREMENT APPROACH	Designated	Explorer	Incubation
Greenhouse Gases	CO ₂ and methane fluxes and trends, global and regional with quantification of point sources and identification of source types	Multispectral short wave IR and thermal IR sounders; or lidar**		X	

- The recent Earth Science Decadal Survey significantly reduced the anticipated funding for a potential ASCENDS-like measurement.



Scaling CO₂ Sounder Lidar to Space

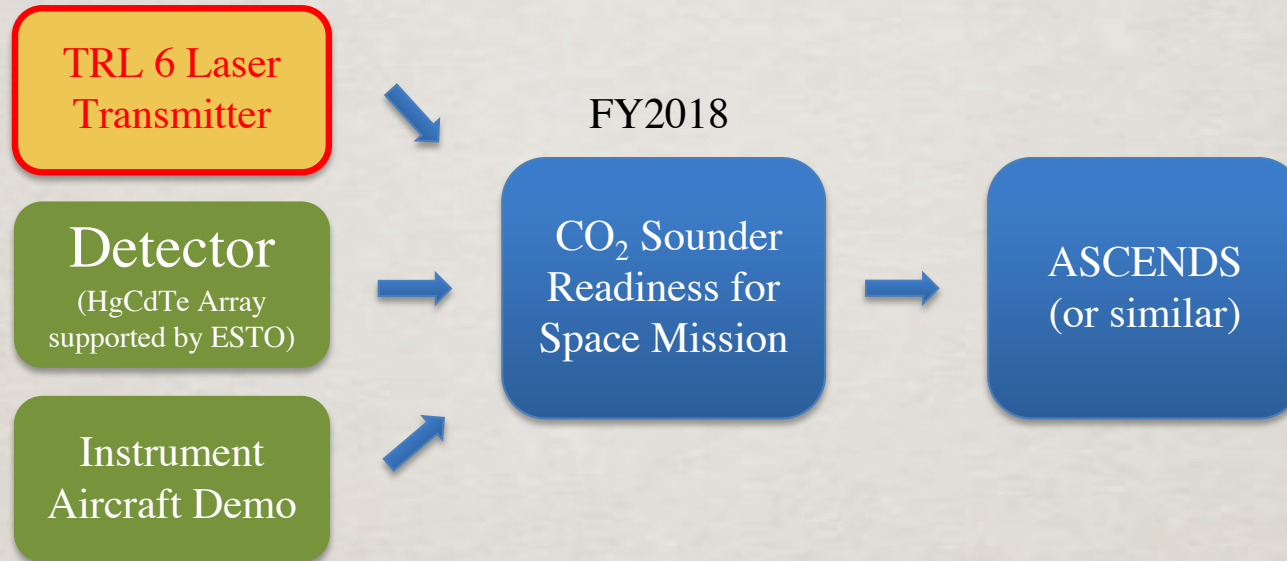


Ref: J. Abshire, et. al., "Progress in developing the CO₂ sounder Lidar as a candidate for the ASCENDS Mission," presented at SPIE Optical Engineering and Applications, San Diego, CA, August 2015.

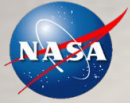


SPACE LASER TRANSMITTER (TRL 6) ROADMAP

FY2015-18



- Previous work has demonstrated most key elements needed for ASCENDS
- The main obstacle remaining for a CO₂ Sounder-based mission is the laser TRL
- A CO₂ precursor mission could be an intermediate step, as a science and technology demonstration (eg. for Earth Venture, or similar)
- **This program will increase laser TRL to 6 for flight opportunities in 2018 & beyond**
- This high peak power fiber laser also serves as a pathfinder for other space applications



LASER REQUIREMENTS



Performance Parameter	<u>Laser Transmitter</u>
Center Wavelength	Nominally centered at 1572.335 nm
Linewidth (each wavelength channel)	≤ 100 MHz
Pulse repetition frequency	7.5 KHz
Pulse Width	1-1.5 μ s
Pulse Energy	>3.2 mJ/pulse (goal); >2.6 mJ/pulse (operating, 18% derating)
PER [TBR]	20 dB (TBR)
Wall-plug Efficiency	> 6%

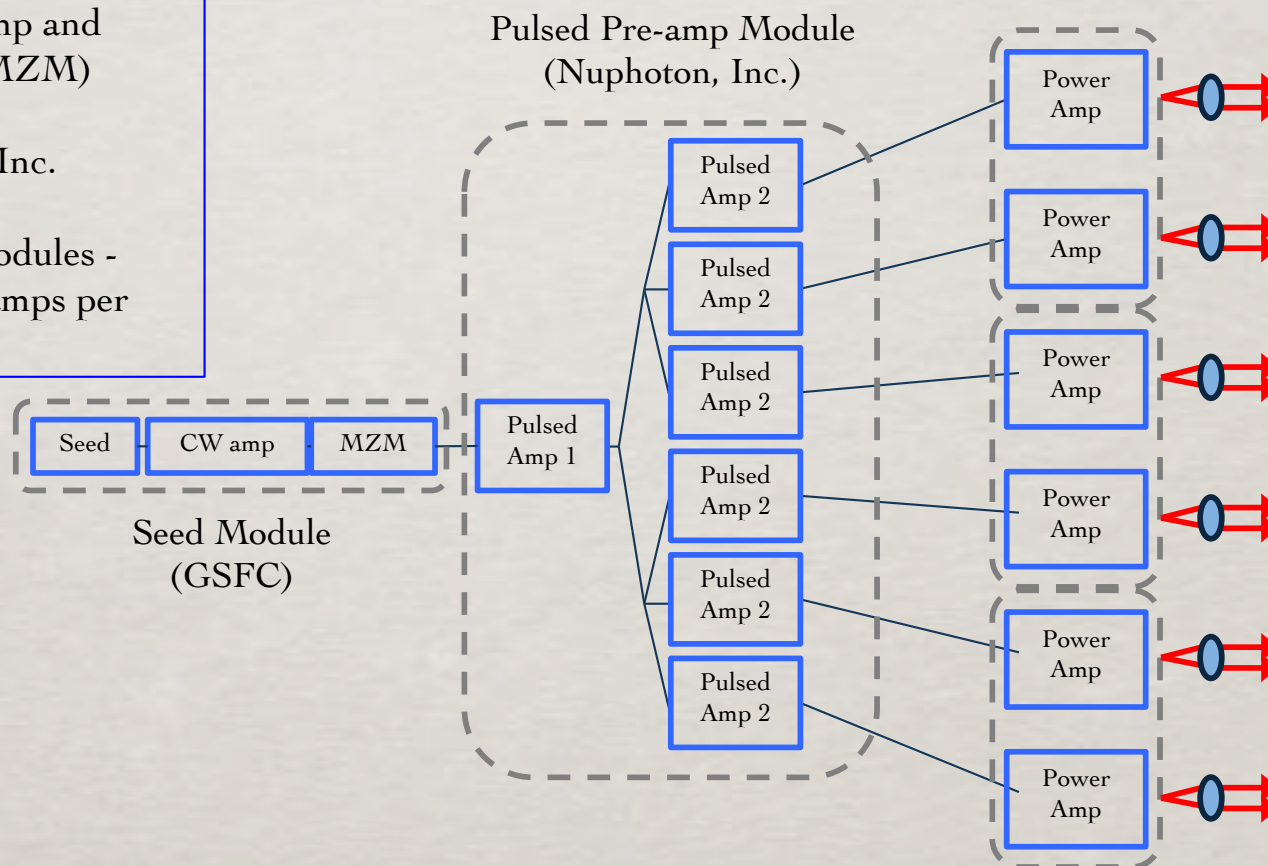


Architecture Overview

Power Amplifier
Modules
(GSFC, DII, OFS)



- Seed Module includes CW amp and Mach-Zehnder Modulator (MZM)
- Pulsed Pre-Amp Module
 - being built by Nuphoton, Inc.
- Power Amplifier
 - Design uses 3 amplifier modules - Packaging concept has 2 amps per module

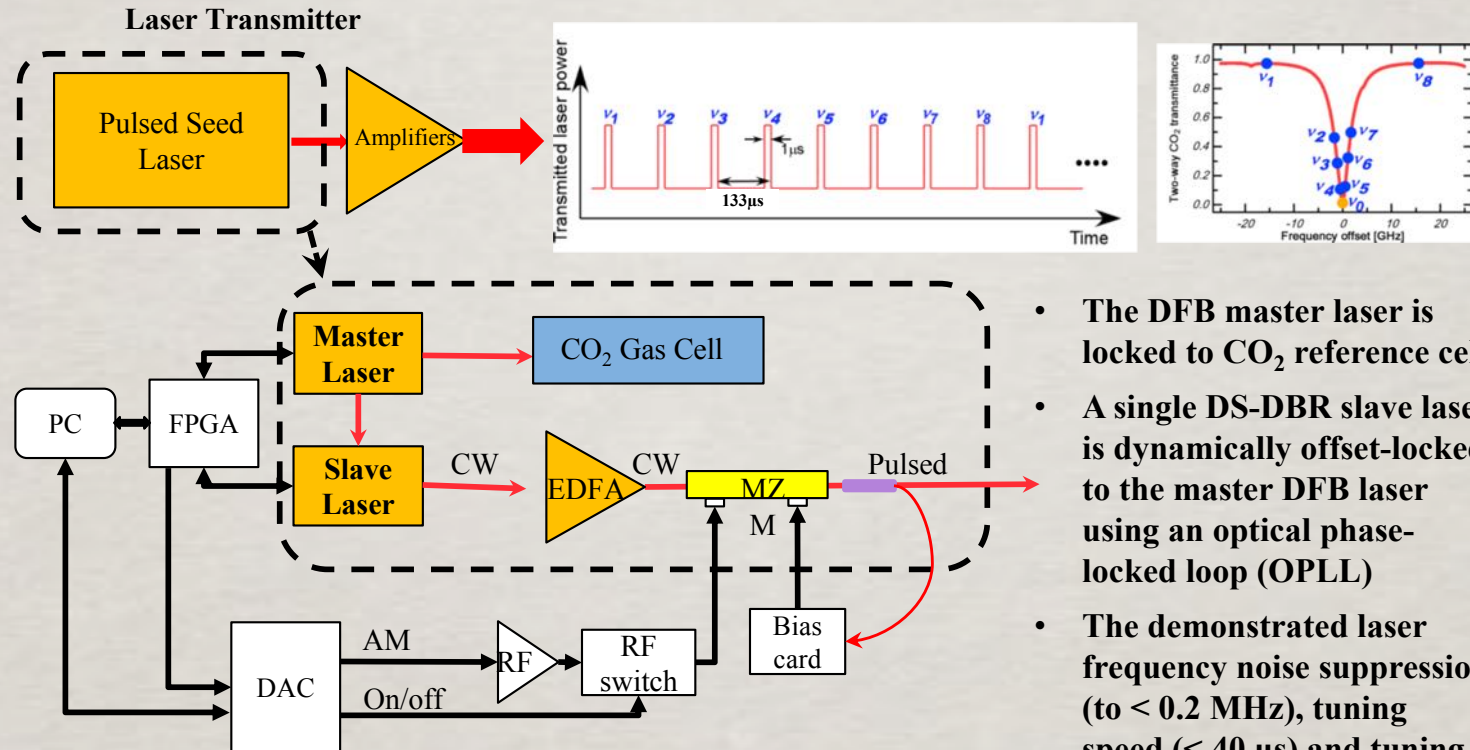


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SEED LASER PULSE-SHAPING

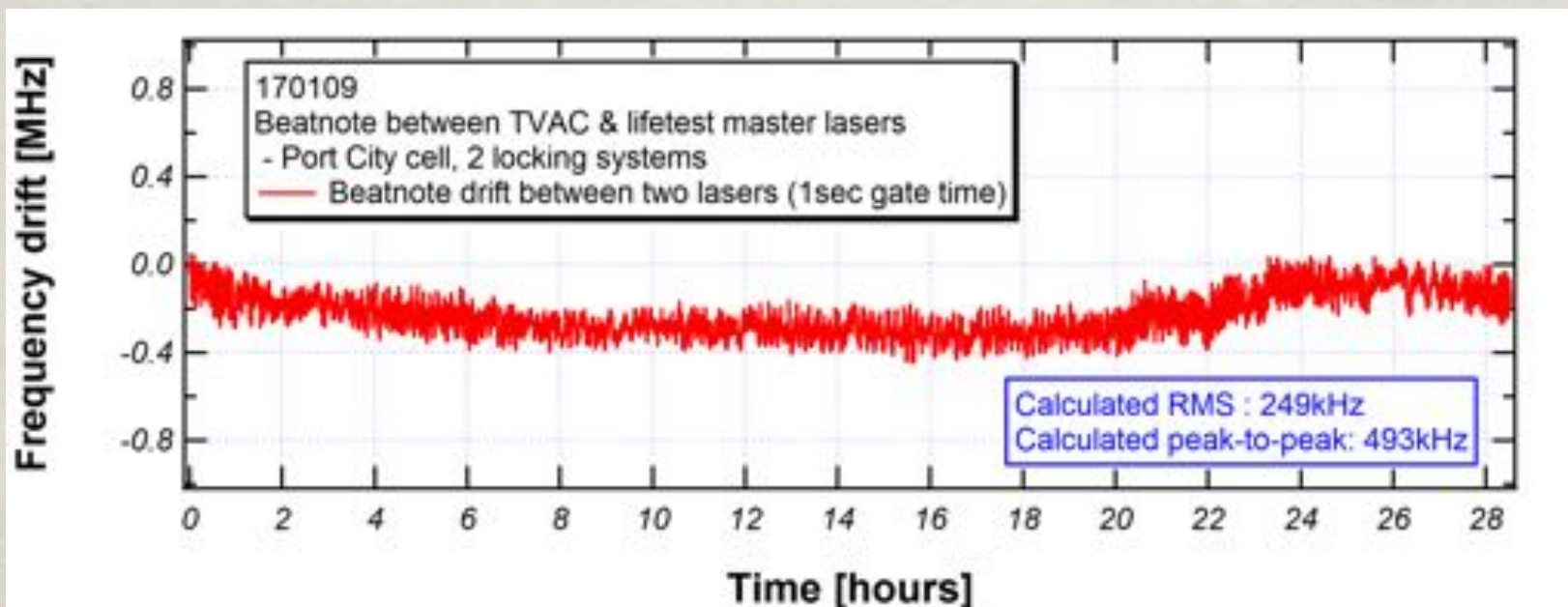


- Pulse shaping will compensate for distortions by Pre-Amp and Power Amp modules. Desire “flat top” output pulses.
- Capability to perform pulse-shaping through use of high-speed DAC currently in development

- The DFB master laser is locked to CO₂ reference cell
- A single DS-DBR slave laser is dynamically offset-locked to the master DFB laser using an optical phase-locked loop (OPLL)
- The demonstrated laser frequency noise suppression (to < 0.2 MHz), tuning speed (< 40 µs) and tuning range (~32 GHz) satisfies ASCENDS requirements



FREQUENCY DRIFT OF MASTER LASER



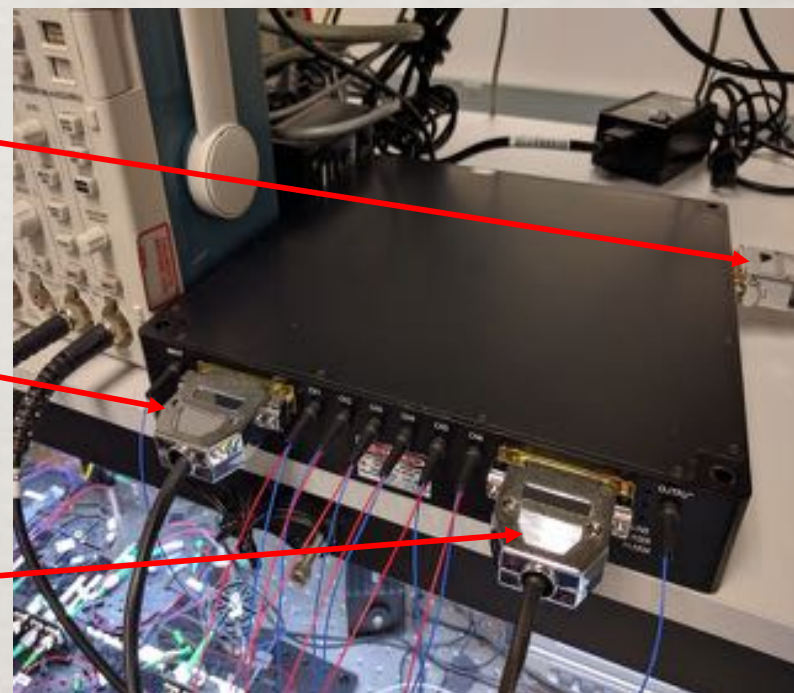
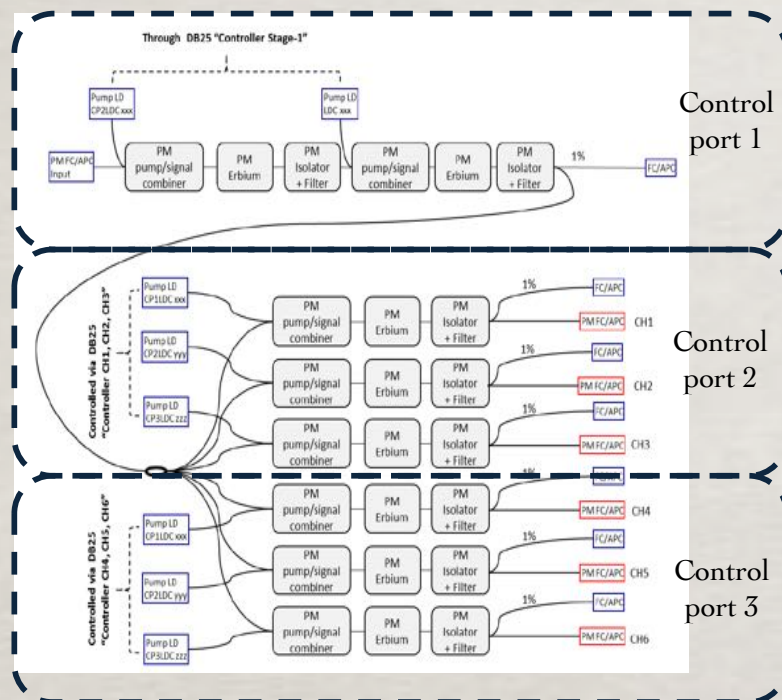
Less than 1 MHz absolute drift between two independently locked sources over a 1-day test

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NUPHOTON PRE-AMP MODULE



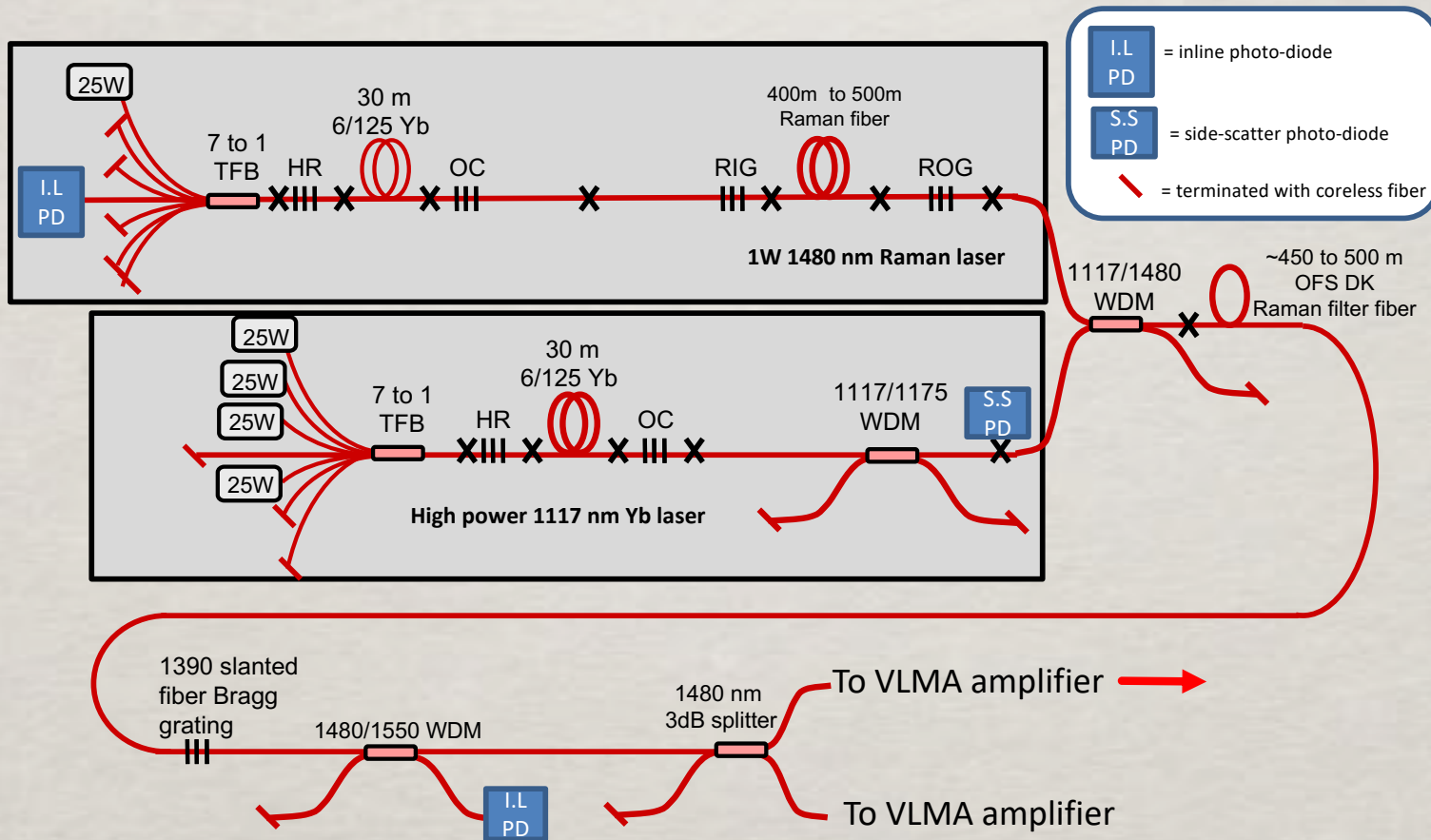
- ❑ The unit has 1 input and 13 outputs (including 7 monitor ports)
- ❑ Each output provides $>5 \mu\text{J}$ pulse energy
- ❑ OFS requires $2.5 \mu\text{J}$ for the power amplifier
- ❑ Three serial interface for controlling different sections with hyper-terminal
- ❑ **Module meets all optical performance requirements**
- ❑ **Worked with vendor to use vacuum compatible components**

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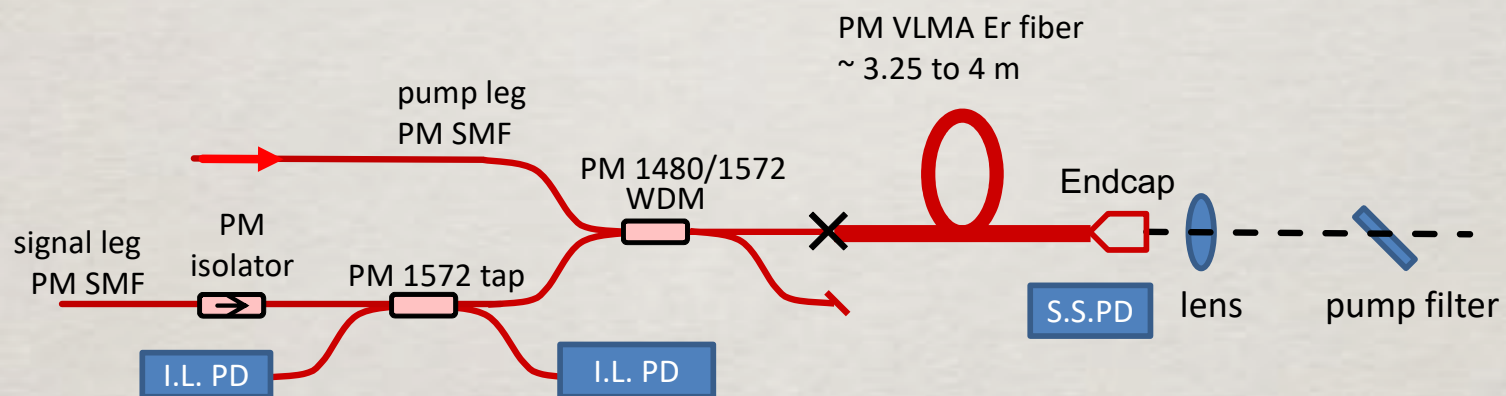


30W RAMAN AMPLIFIER 1480NM PUMP: DETAILED SCHEMATIC



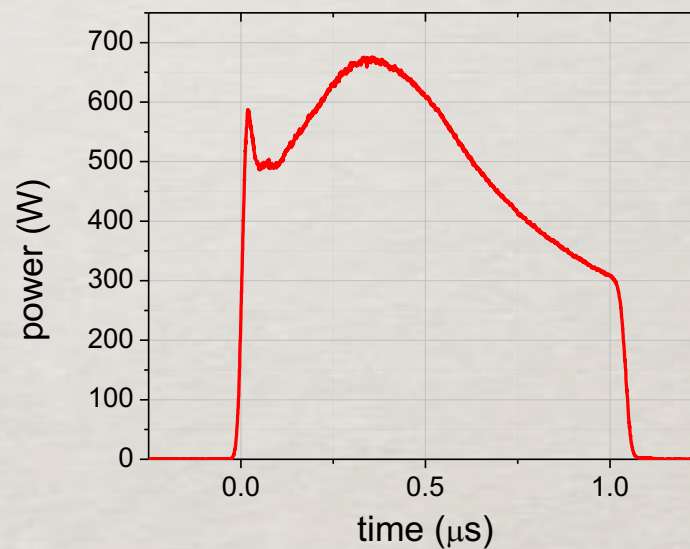
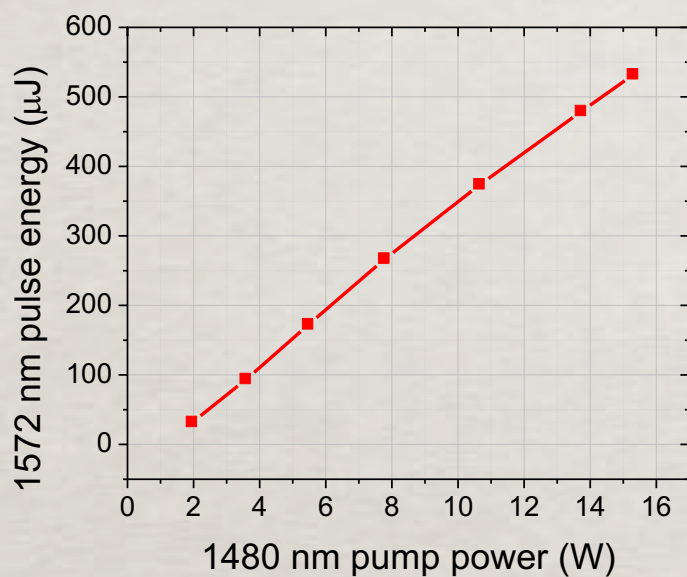


PM-VLMA-ER SCHEMATIC





PM VLMA AMPLIFIER PULSE ENERGY AND PEAK POWER



Pulse energy : 531 μJ

Peak power : 675 W



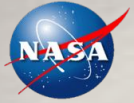
POWER AMPLIFIER SUMMARY



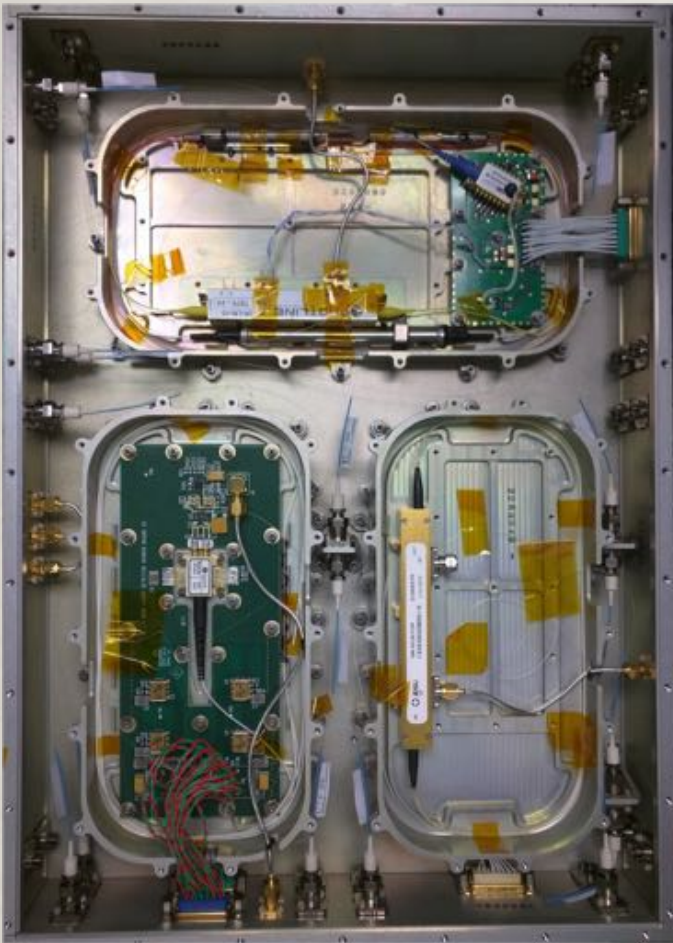
- Raman laser –
 - 30 W output power at 1480 nm (after slanted FBG and 1480/1550 WDM) for 49.2 W diode power
 - O-O efficiency = 61%
 - Sufficient for pumping two PM VLMA amplifiers
- PM VLMA amplifier
 - 531 μ J, 675 W peak power, single frequency microsecond pulses at 7.2 kHz rep rate.
 - 1480 nm power required for 500 mJ pulses = 14.2 W
 - O-O efficiency = 25%

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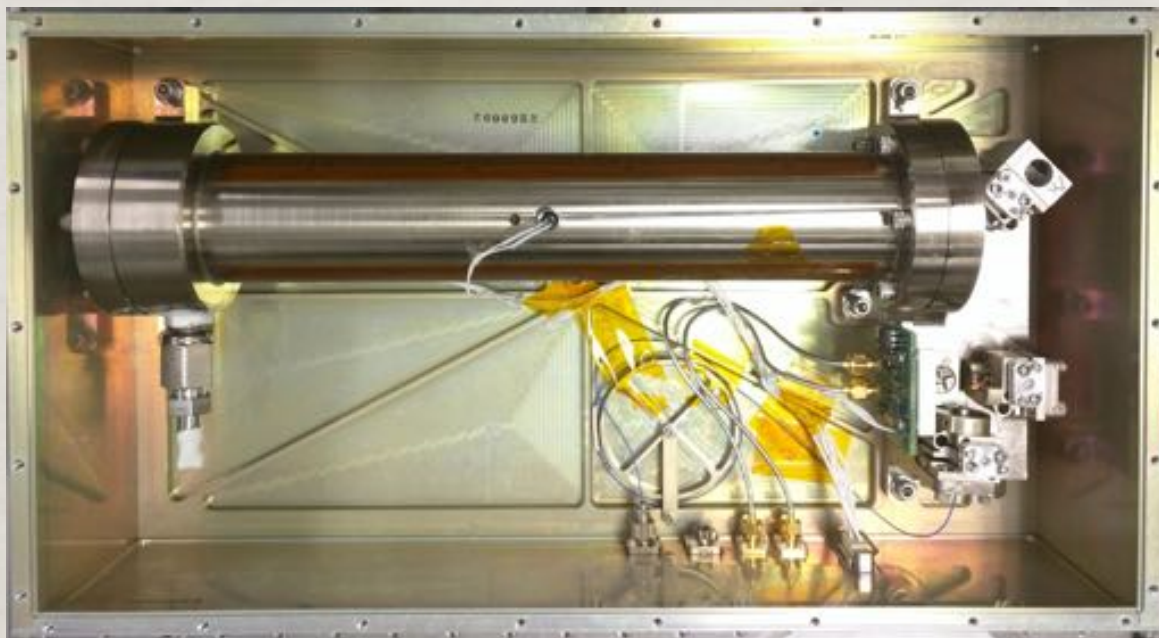
COMPLETED SEED MODULE



- Completed seed laser module with reference laser, tunable laser detector/divider board, CW Er-amplifier and Mach-Zehnder modulator
- Meets optical performance requirements
- Dimensions: ~25-cm x 18-cm x 7-cm



HERRIOTT CELL



Herriott cell filled with CO_2 gas with integration optics in a ruggedized package to lock the reference laser to an absolute wavelength standard.

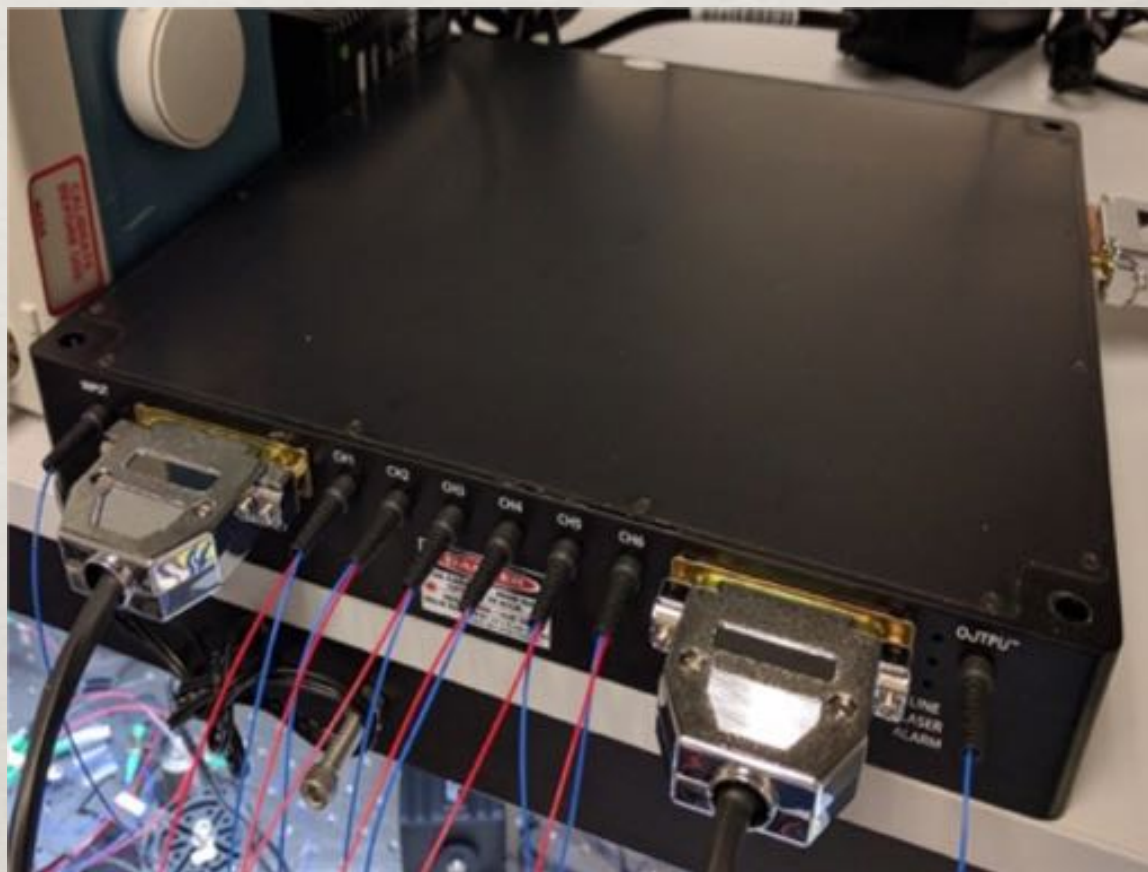
Module Dimensions: 25.5-cm x 12.5-cm x 10-cm

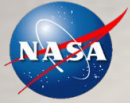


PRE-AMPLIFIER MODULE

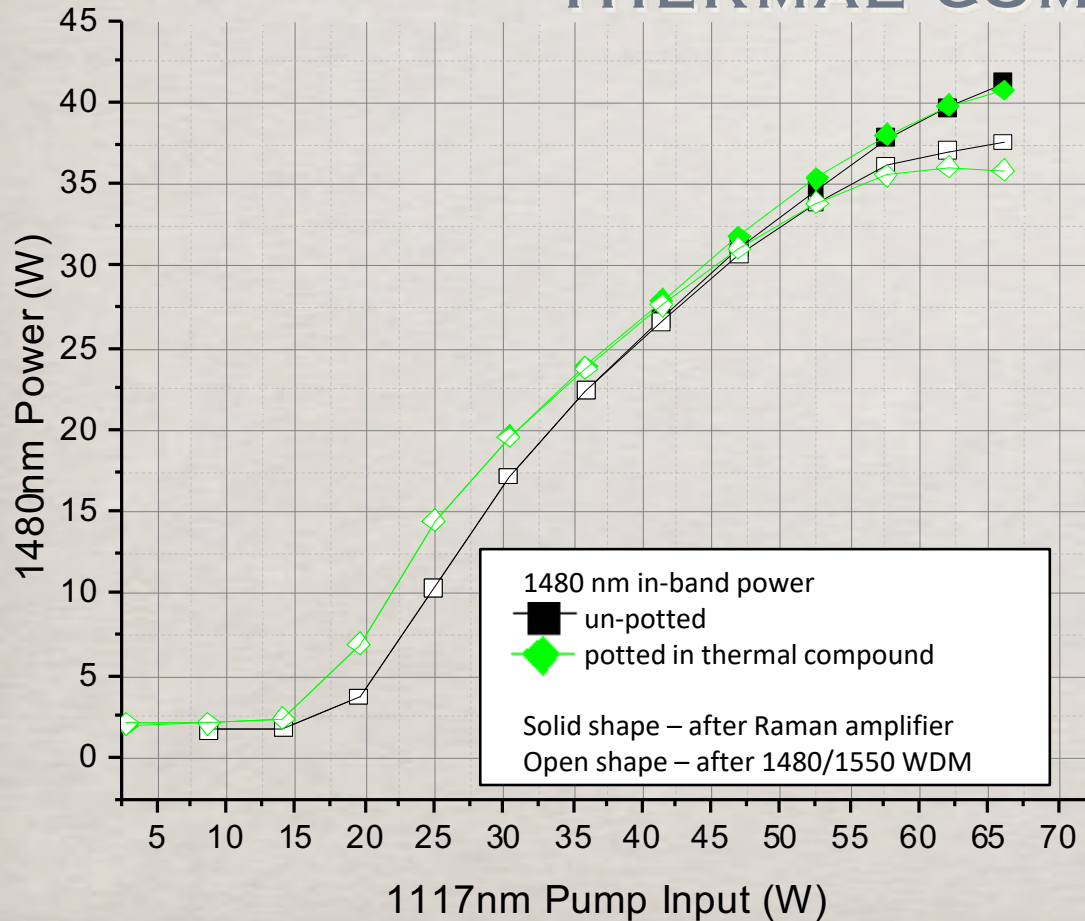


- Photo of pre-amplifier prototype.
- Built by NuPhoton, Inc.
- Meets optical requirements
- Module dimensions: 28-cm x 28-cm x 5-cm

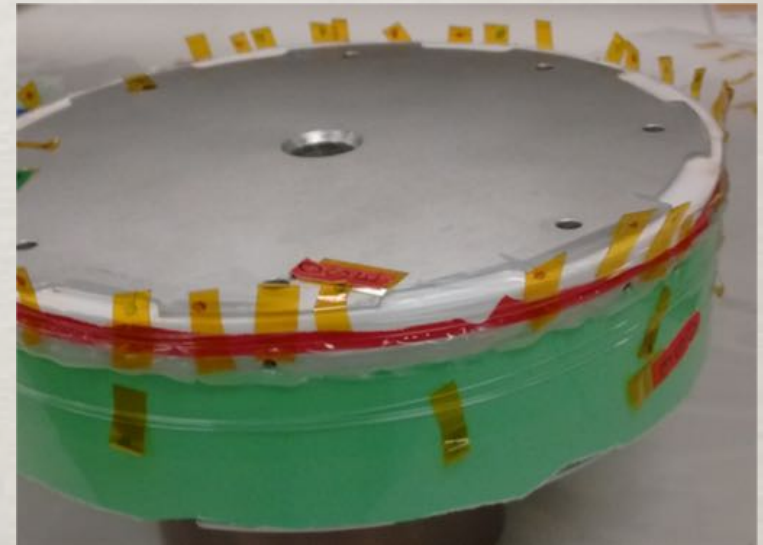




POTTING AMPLIFIER FIBER IN THERMAL COMPOUND

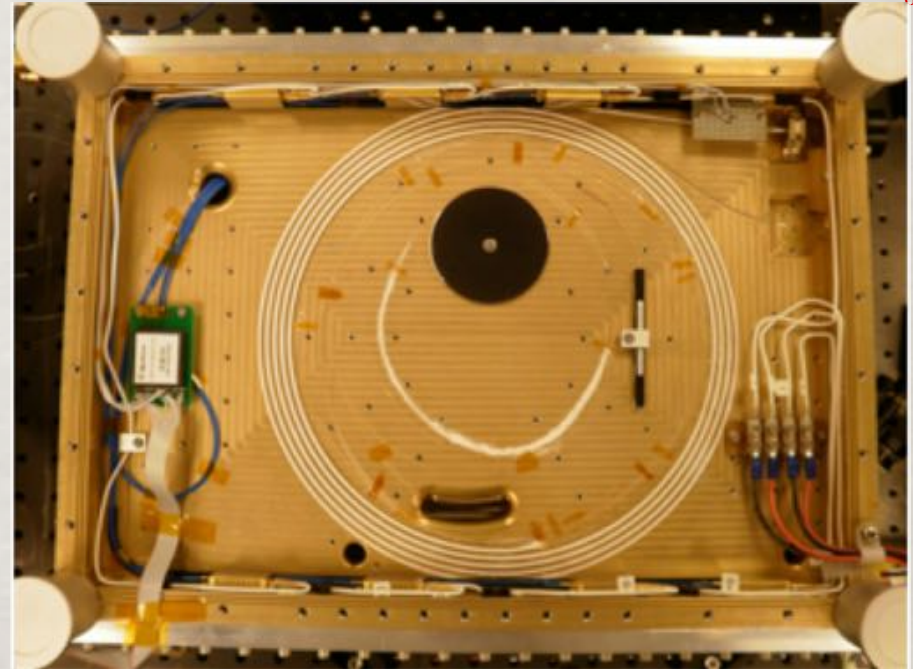
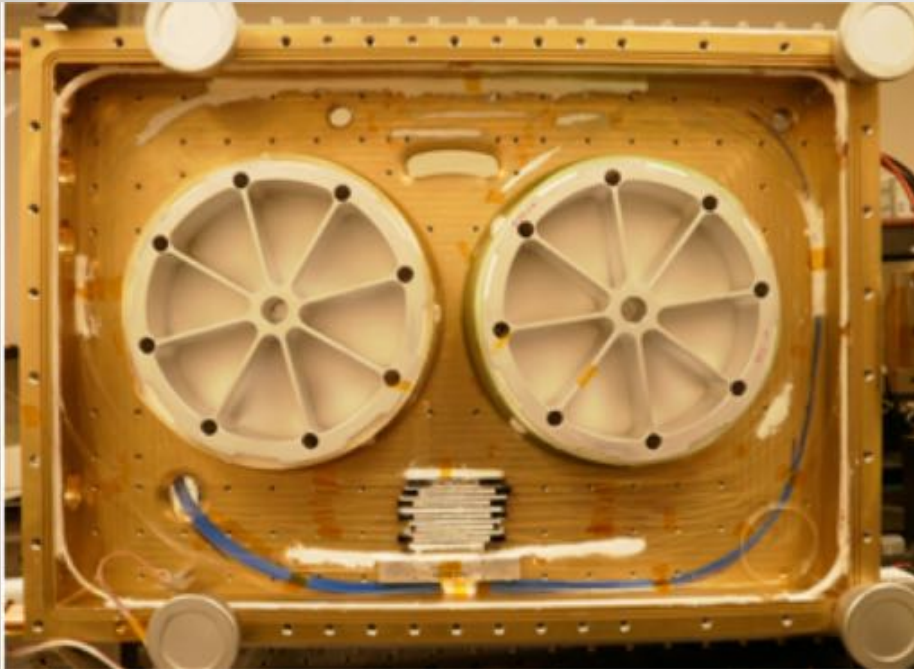


Process of vacuum potting amplifier fibers in thermal compound did not affect Yb or Raman cavity efficiencies. Over-all system efficiency was un-changed after potting process.





POWER AMPLIFIER MODULE



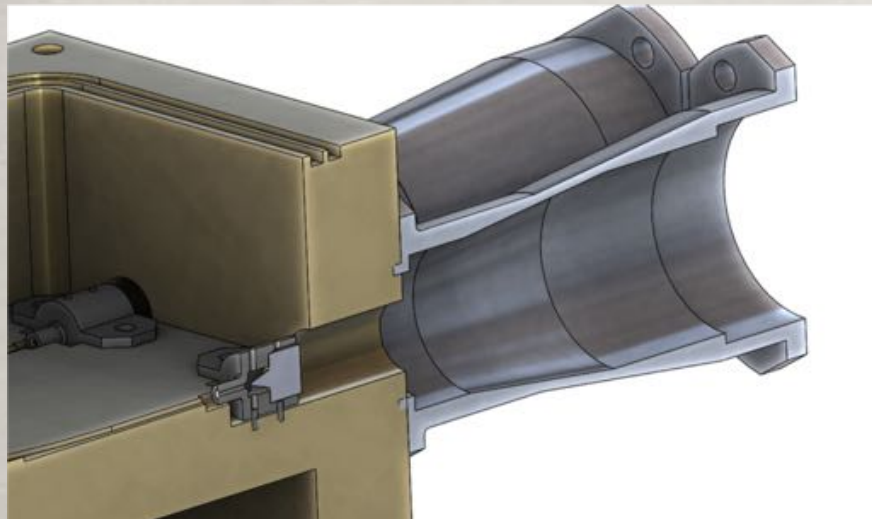
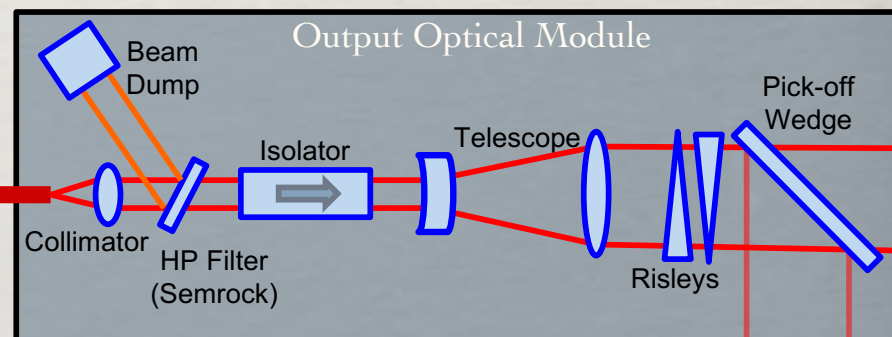
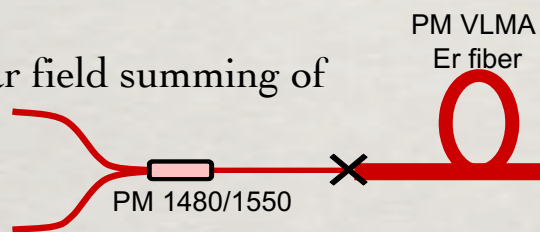
Photos of VLMA power amplifier prototype. The left photo shows the bottom half of the box with the Raman pump system. There are two spools and the fiber components are in the lower center of the photo. The right photo shows the PM-VLMA fiber. The white fiber potting material makes the spiral groove easy to visualize. Module dimensions: 44-cm x 32-cm x 9-cm.



OUTPUT FREE-SPACE OPTICS



- PM-VLMA fiber amplifier terminated with an end-cap
- Hermetically sealed to minimize contamination
- Co-boresighted to allow far field summing of output power

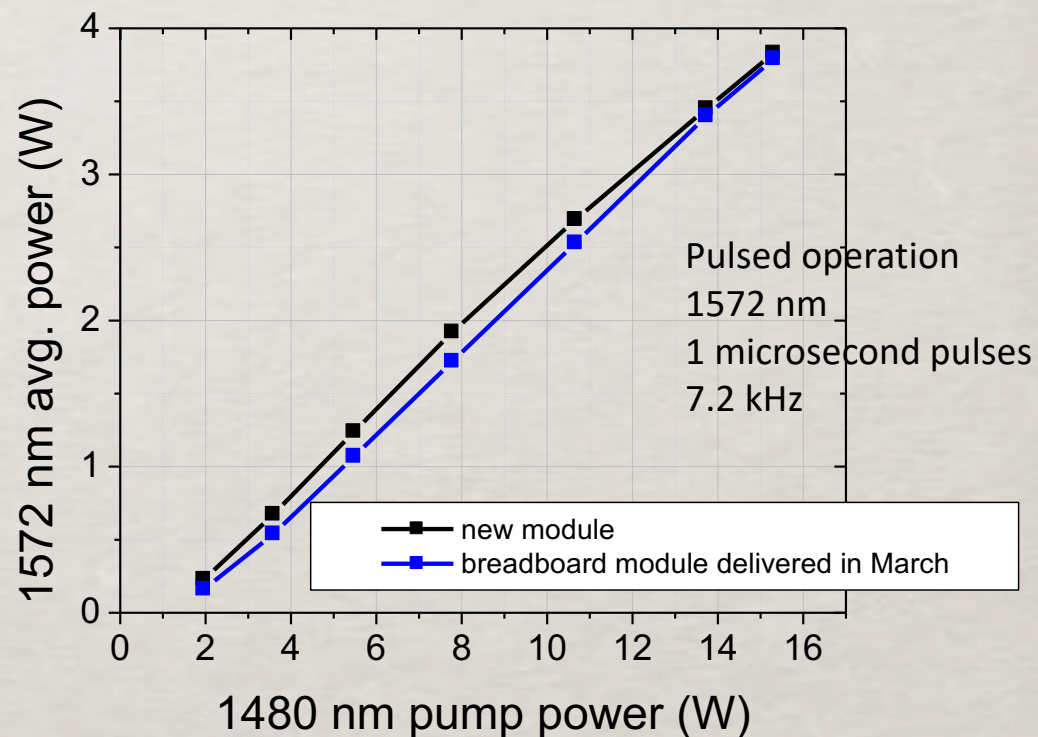


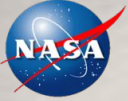


PM-VLMA AMPLIFIER COMPARISON WITH BREADBOARD MODULE



- Output power is slightly higher at low pump power in new module
- Could be due to differences in end-cap type
- **Packaged Power Amplifier meets optical requirements**





SEED MODULE ON VIBRATION TABLE (Z-AXIS)



- We have vibrated the seed module, cell module and pre-amplifier module
- Preliminary post-vibe measurements look good but we haven't completed a full characterization

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CONCLUSION & NEXT STEPS



- Demonstrated all optical performance requirements with margin
- Mechanical design complete
- Mechanical and Thermal analysis complete
- Prototype Build complete
- Environmental testing underway
 - Vibration underway
 - Thermal vacuum and Radiation testing coming up
- Full power demonstration with all 6 amplifier channels planned