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Advanced Laser Architecture for the Two-Step Laser Tandem Mass Spectrometer

Molly E. Fahey, Steven X. Li, Anthony W. Yu, Stephanie A. Getty
NASA Goddard Space Flight Center
Greenbelt, MD

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Agenda

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- Motivation
- L2MS Instrument Overview
- L2MS Laser Architecture
- Preliminary Laser Performance
- Future Work
- Conclusions

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Science Motivation

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- Contribute to and compliment our understanding of the processes governing the formation, distribution and evolution of primitive materials throughout the solar system
- Future astrobiology missions will focus on small, primitive bodies and the icy moons of the outer planets that may host diverse organic compounds
- These missions require advanced instrument techniques to fully and unambiguously characterize the composition of surface and dust materials
- Targeted missions include flybys, orbiters, landers and rovers to Europa, Trojan, a main belt asteroid, comet, Kupiter belt object (KBO), Titan, Enceladus or Mars

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L2MS Instrument Overview

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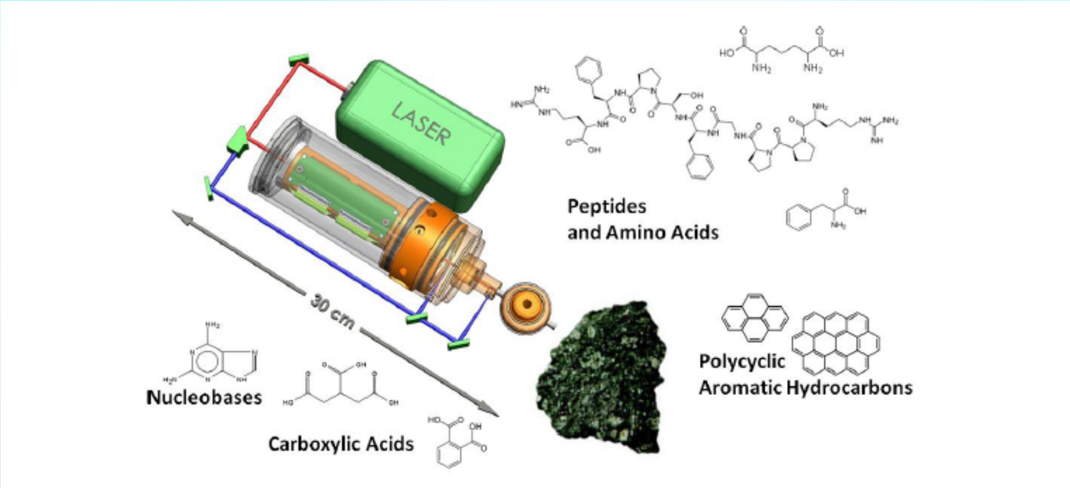
- Combines TOF-MS (time-of-flight mass spectrometry) and LDMS (laser desorption/ ionization mass spectrometry)
- In situ measurements of non-volatile samples to determine both mass assignments and clues to structural information
- Wavelengths are selected based on key vibrational and electronic resonances in the targeted species aligned with the organic diversity and mineralogy expected for future planetary missions of high priority to NASA
- Uses mid-infrared (MIR) and ultra-violet (UV) wavelengths
    - 2.8 – 2.9 µm (TBD) - IR vibrational resonances of hydrated minerals
    - 3.4 µm - C-H vibration resonance of organic species
    - 266 nm - coincides with a short-lived metastable state in many aromatic molecules



L2MS Instrument Overview

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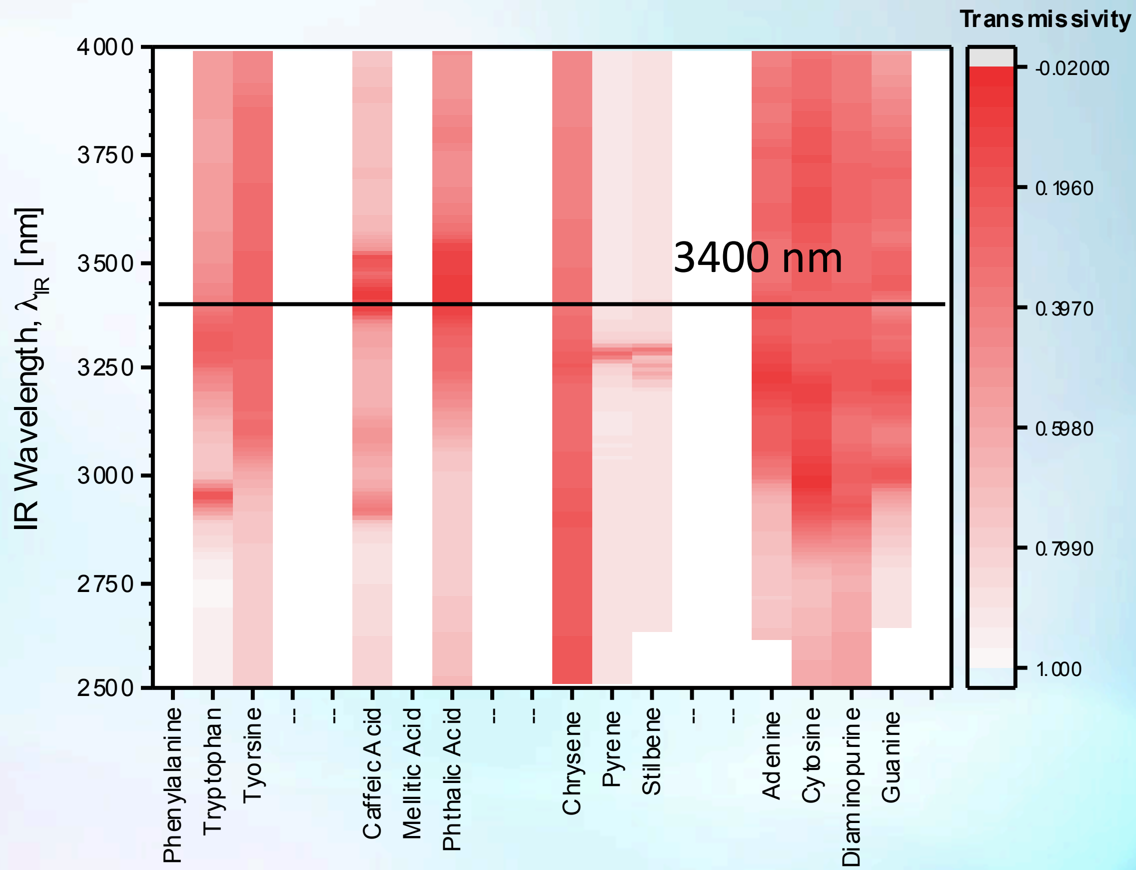
- Molecular desorption is enhanced when the IR laser wavelength matches the molecular vibrational resonance.
- NIST IR transmission measurements:
  - Red color indicates regions of decreased transmittance (increased absorption), thus this is the ideal IR wavelength to be used for that compound
  - Four different classes of aromatic molecules are plotted



L2MS Instrument Overview - UPDATE

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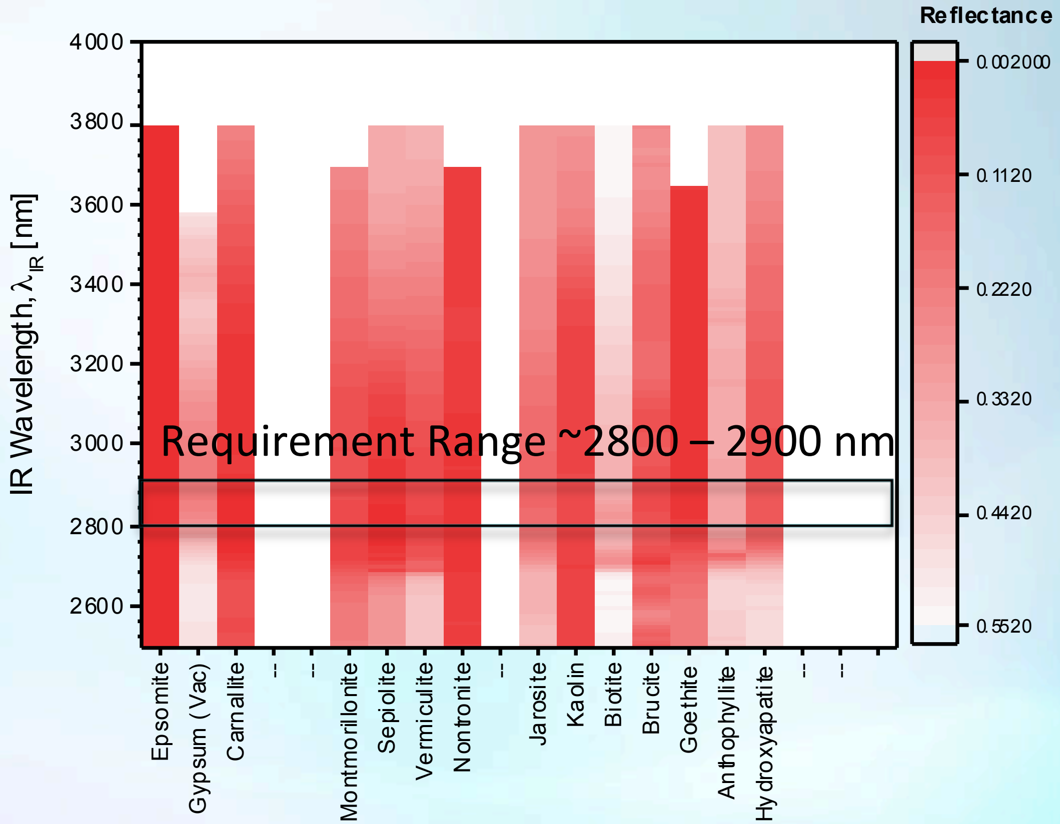
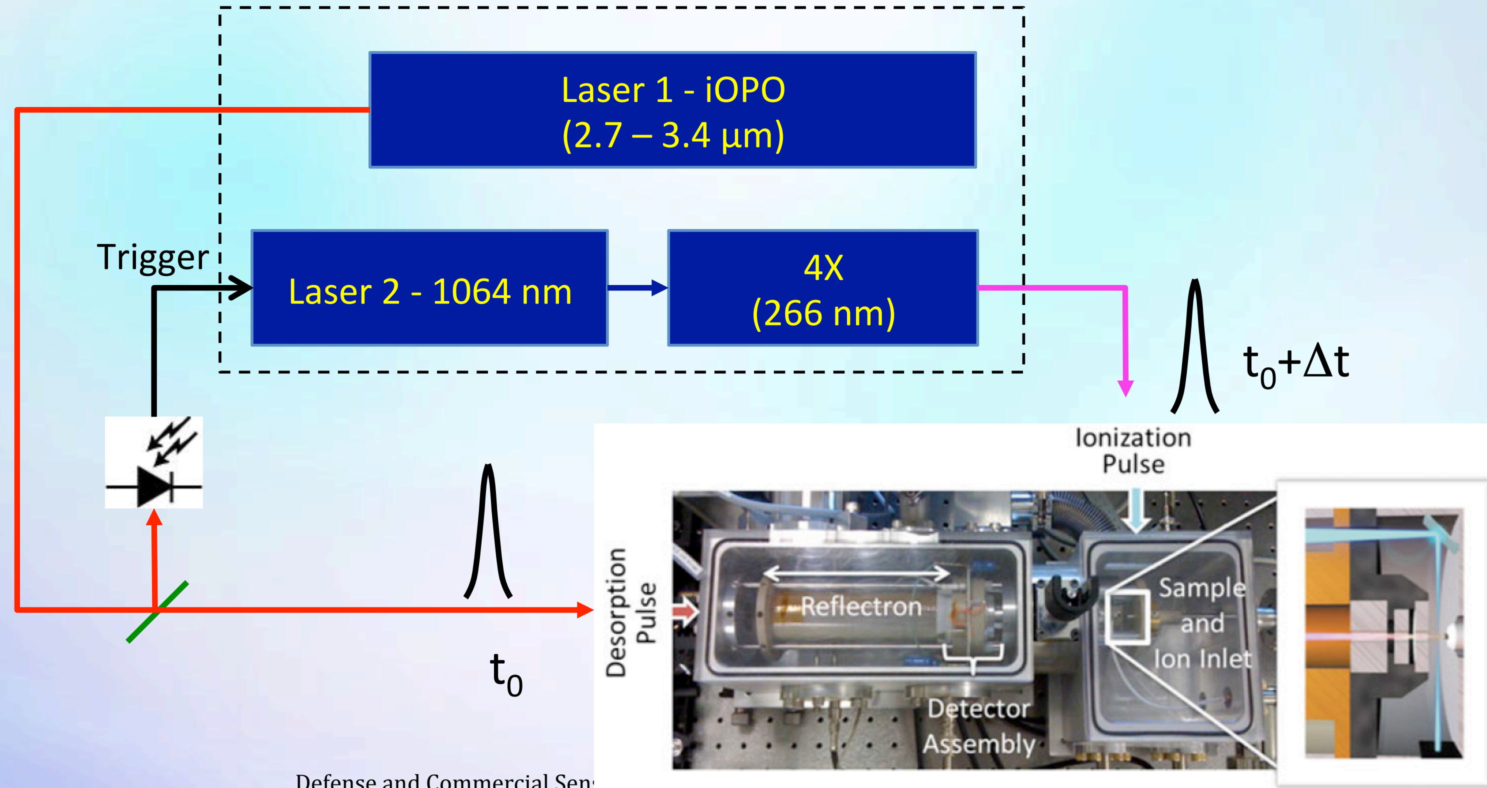
- Desorption is enhanced when the IR wavelength matches the mineral absorption resonances
- IR reflectance spectra from USGS (U.S. Geological Survey)or laboratory measurements:
  - Red color indicates regions of decreased reflectance (increased absorption), thus an ideal IR wavelength to be used for that mineral.
  - Three different classes of minerals are shown



L2MS Laser Overview

- Two discrete MIR wavelengths (~2.8 µm and 3.4 µm) and UV wavelength (266 nm) on the same bench
- Laser design is based on the previously flown Lunar Orbiter Laser Altimeter (LOLA) laser transmitter
- Monolithic intracavity optical parametric oscillators (iOPO) generate the MIR wavelengths
- Frequency quadrupled Nd:YAG generates the UV wavelength
- Typical delays range between 0.3-2 µs



OPOTek 2731 Measurement

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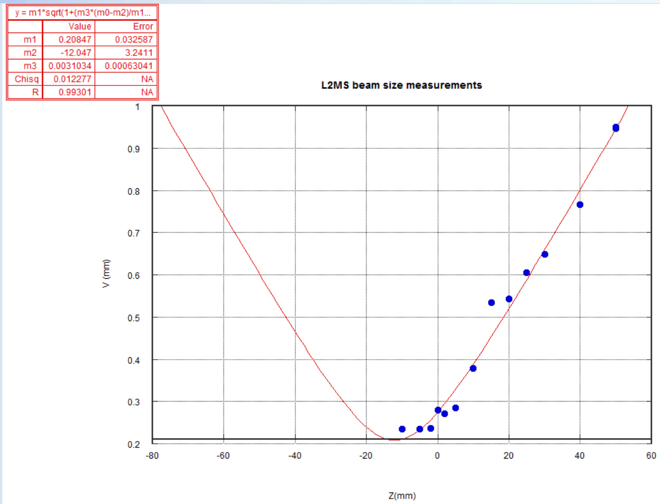
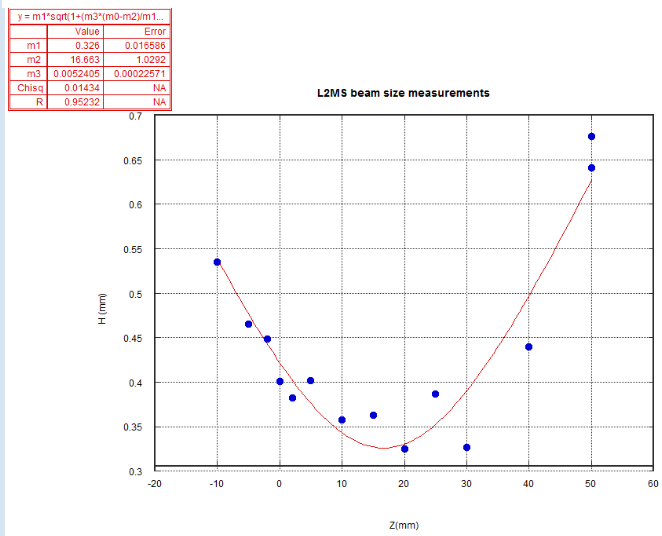
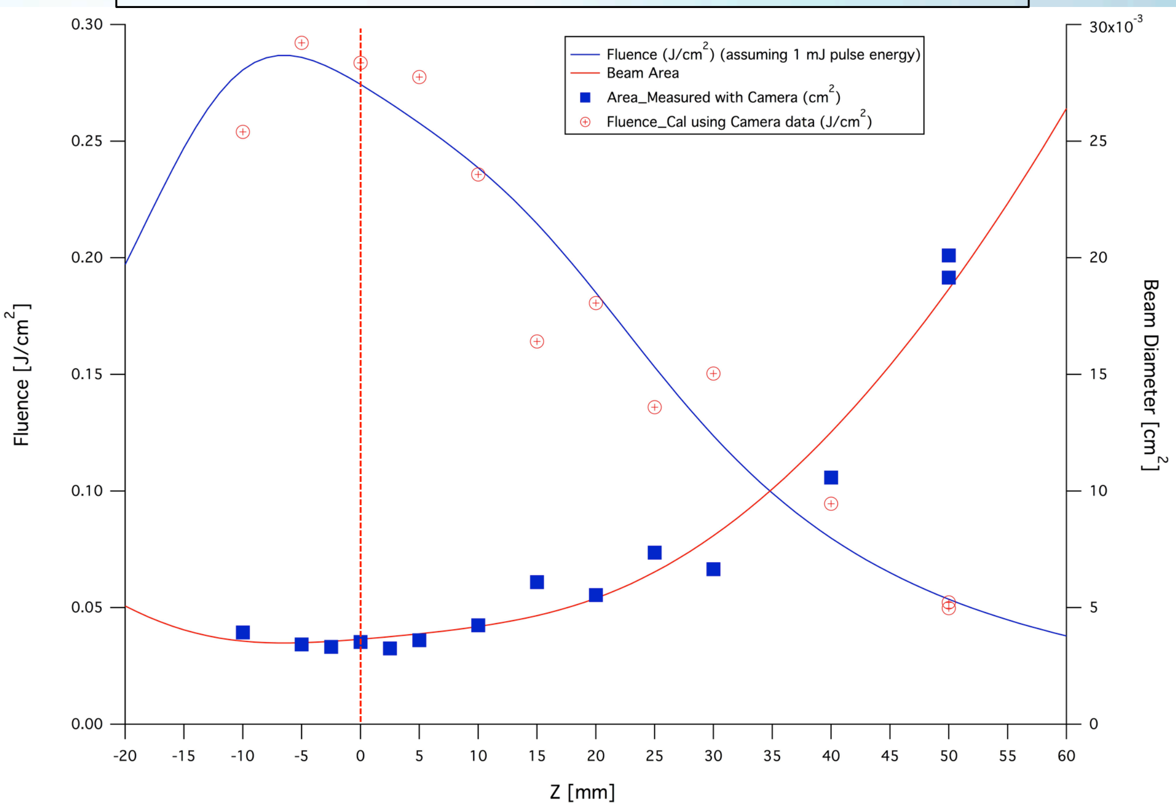




Fluence Estimation

- Assumptions – Pulse energy = 1 mJ
- Solid lines are from the fitted equation from previous three charts
- Markers are calculated values using the measured/fit beam size from the PV320 camera



We can obtain the same max fluence of ~0.3J/cm², using a 100 μJ pulse and 100 μm beam waist (radius)

L2MS Laser Requirements

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Lasers Requirement	MIR Laser	UV Laser
Pulse Repetition Frequency (PRF)	1 – 20 Hz	1 – 20 Hz
Wavelength	2.8X µm and 3.40±0.05 µm	266 nm
Energy	~ 100 µJ	~ 18 µJ
Pulse Width	< 7 ns	< 7 ns
Peak Power	~14 kW	~2.5 kW
Peak Intensity (assuming 100 µm beam diameter)	180 MW/cm^2	~30 MW/cm^2
Spectral Width	Few GHz	Few GHz
Timing	t_0	$t_o + \Delta t$; ~100 ns < Δt < few µs
Laser Lifetime	3 year mission at 10% duty cycle ~ 64 Mshots @ 20 Hz	

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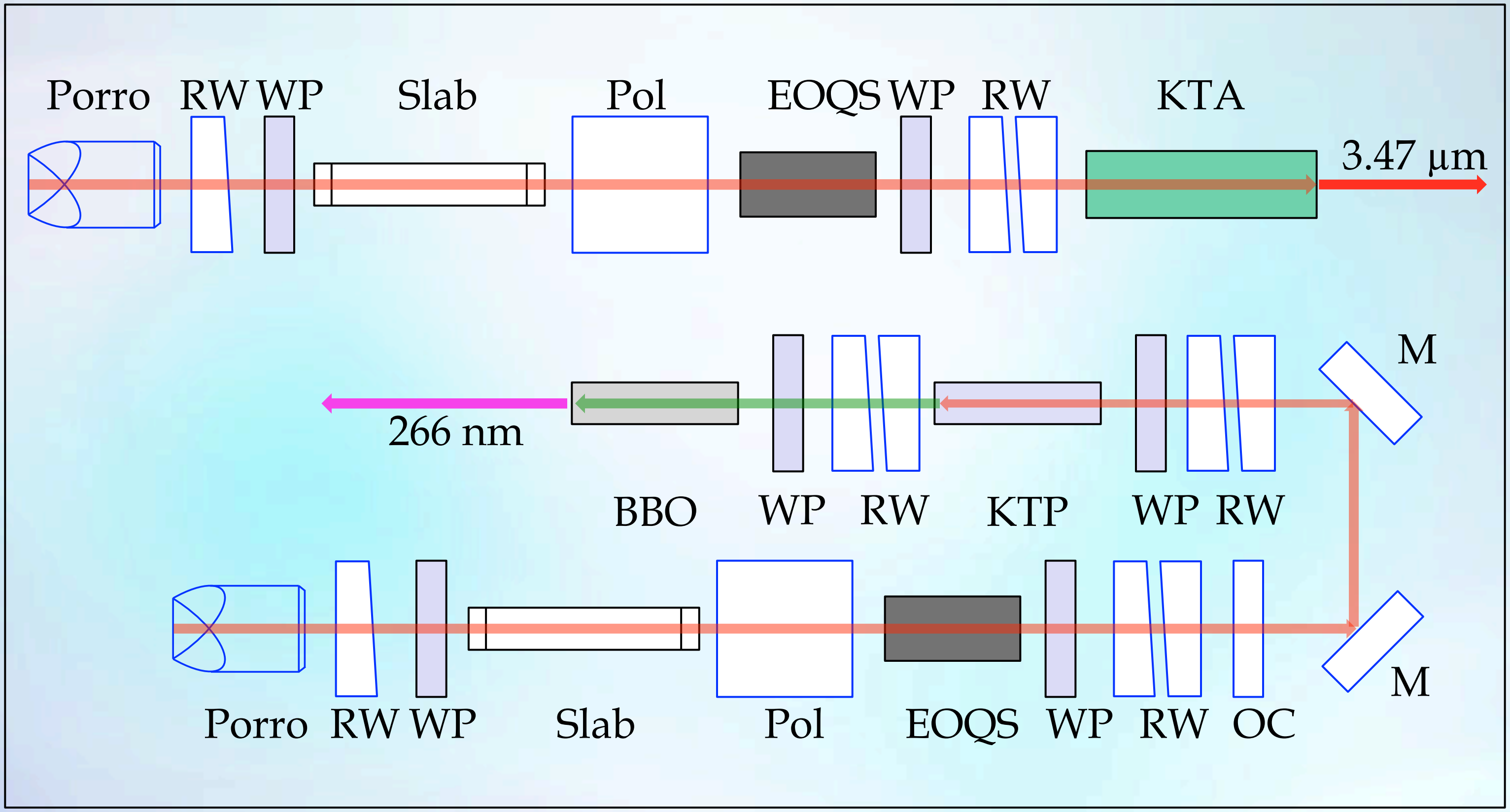
Laser Architecture



PP – Porro Prism; RW – Risley Wedge; WP – Waveplate; Pol – Polarizer; EOQS – Pockels Cell; M – Mirror; OC – Output Coupler

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MIR Laser Breadboard

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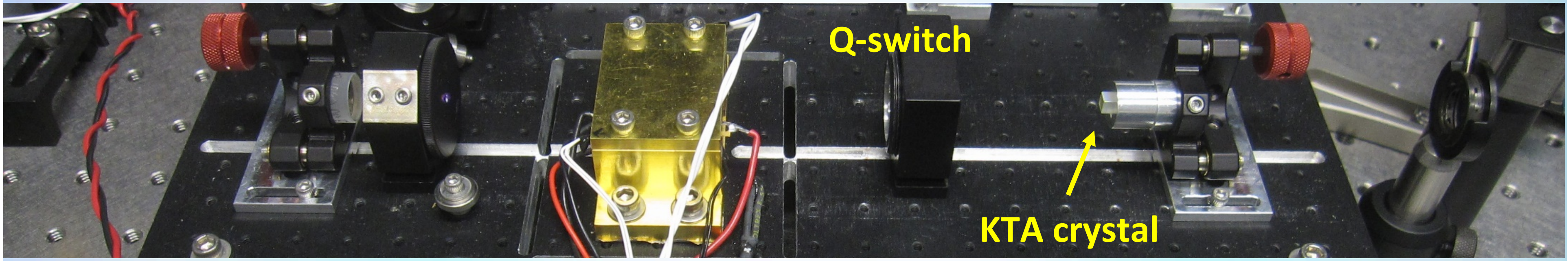

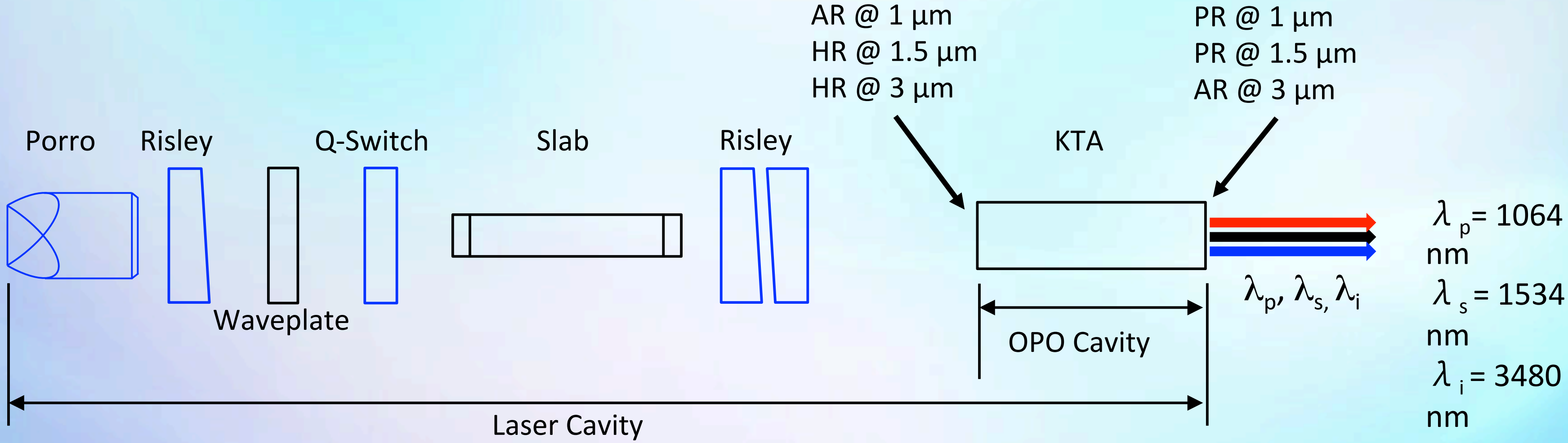

MIR Laser Breadboard Performance

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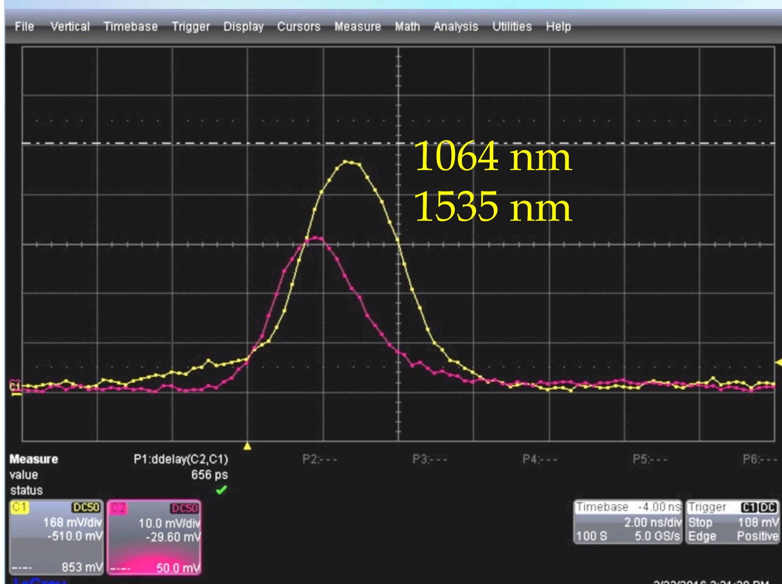
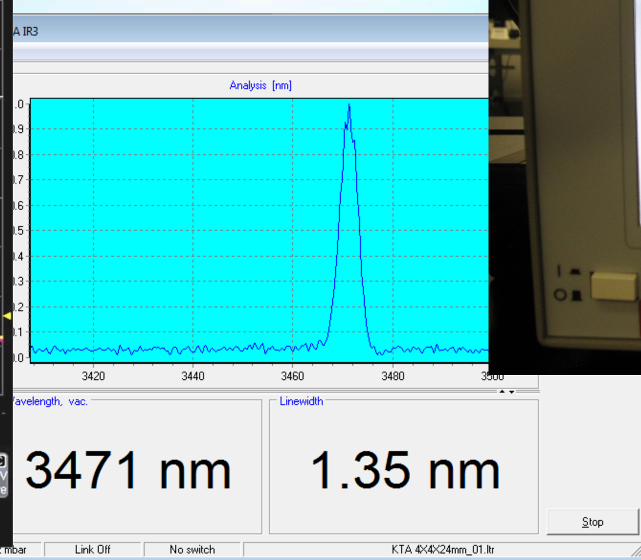
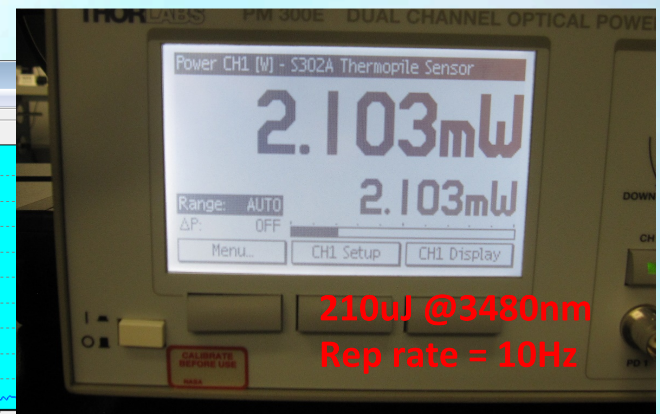
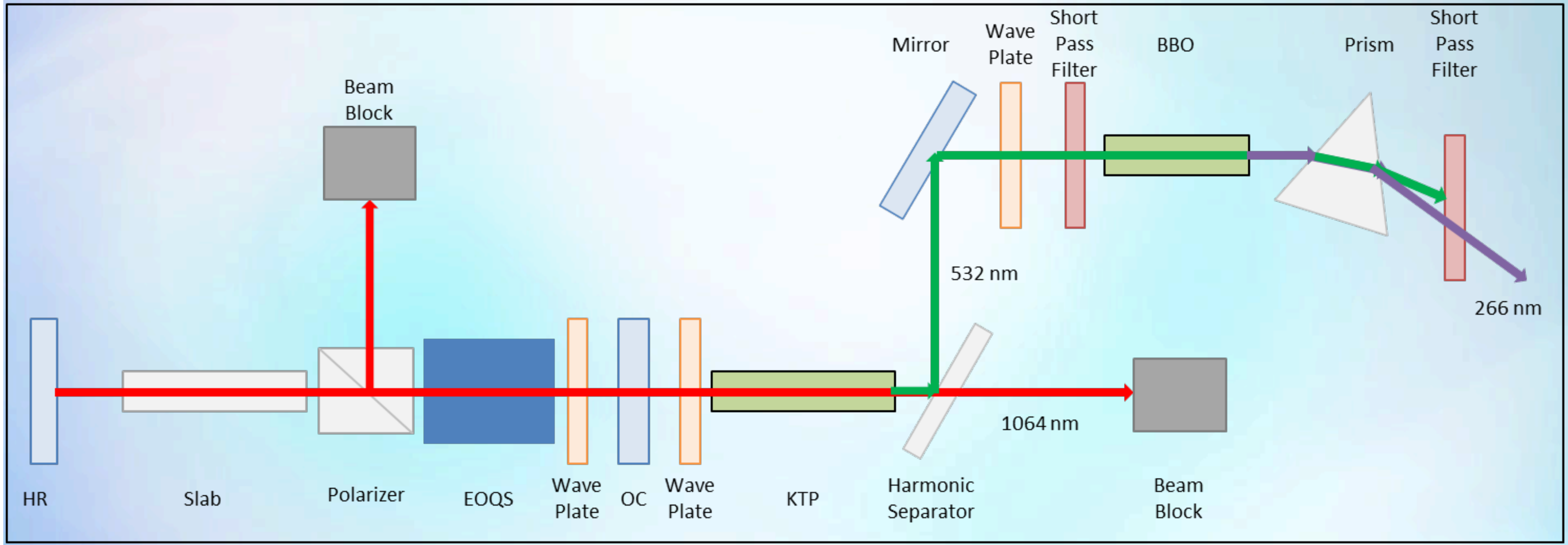
Parameter	Measurement
Wavelength	3471 nm
Pulse Repetition Frequency (PRF)	20 Hz
Average Power	4.2 mW
Energy	0.21 mJ
Pulse Duration	1.9 ns
Conversion Efficiency	10.5 %







UV Laser Breadboard



1064 nm Laser Performance

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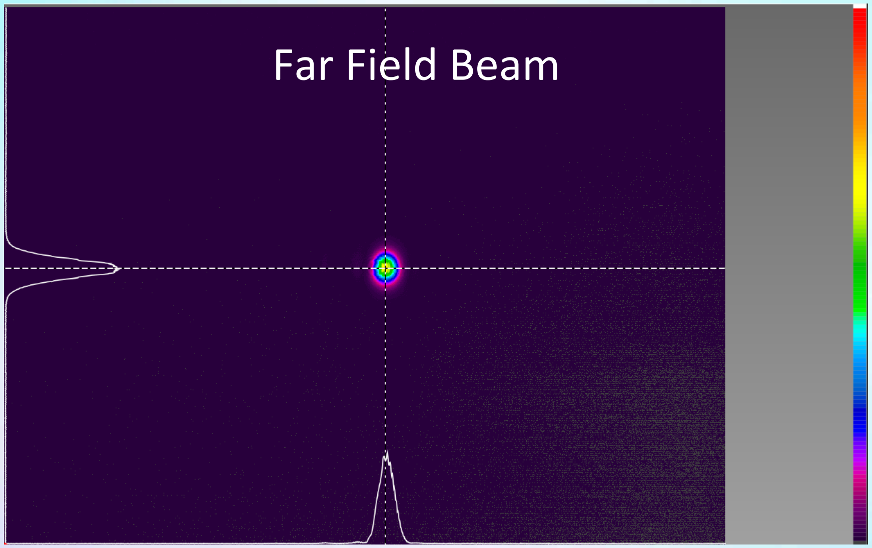
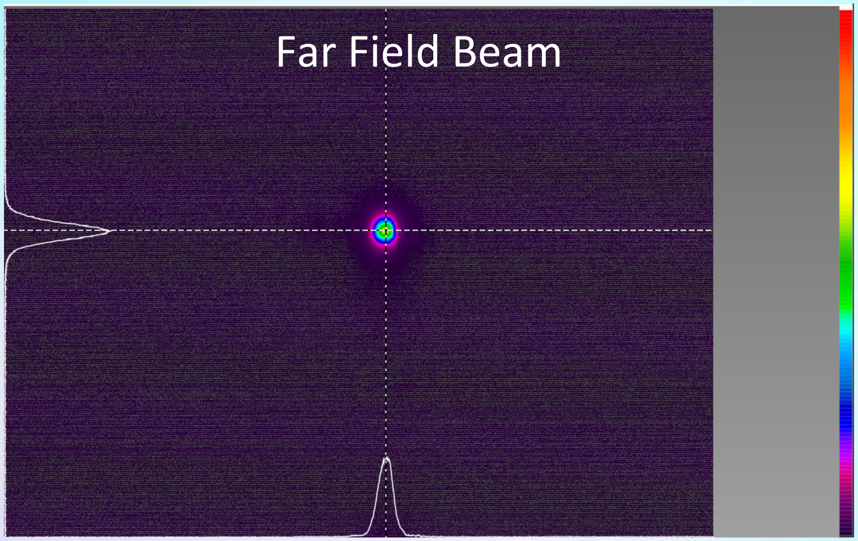
Parameter	Measurement
Wavelength	1064 nm
Pulse Repetition Frequency (PRF)	20 Hz
Average Power	41 mW
Energy	2.1 mJ
Pulse Duration	9.8 ns
Peak Power	210 kW
Divergence (full angle)	θ_x = 1.53 mrad θ_y = 1.83 mrad



532 nm Laser Performance

Parameter	Measurement
Wavelength	532 nm
Pulse Repetition Frequency (PRF)	20 Hz
Average Power	26 mW
Energy	1.3 mJ
Pulse Duration	8.7 ns
Peak Power	150 kW
Divergence (full angle)	θ_x = 1.53 mrad θ_y = 1.76 mrad
2^{nd} Harmonic Conversion Efficiency	64%



266 nm Laser Performance

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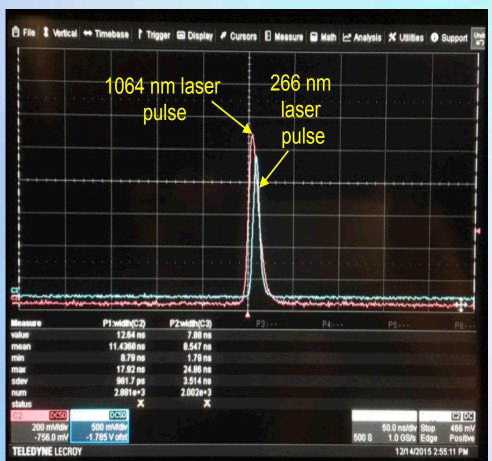
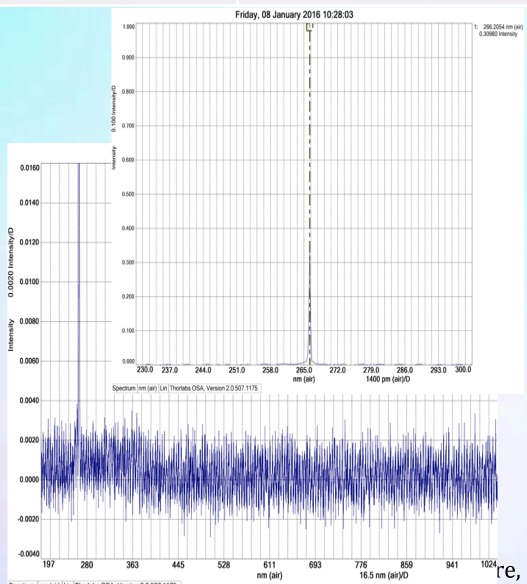
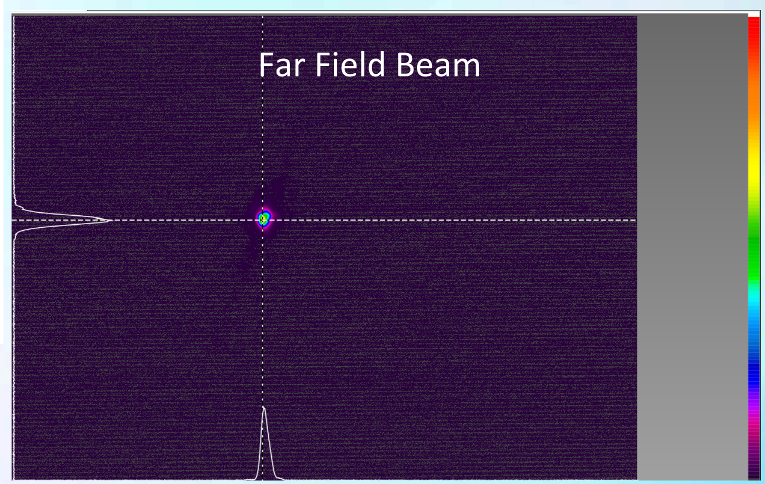
Parameter	Measurement	Requirement
Wavelength	266.2 nm	266 nm
Pulse Repetition Frequency (PRF)	20 Hz	1-20 Hz
Energy	220 µJ	18 µJ
Pulse Duration	6.6 ns	< 7 ns
Peak Power	32.5 kW	2.5 kW
Peak Intensity (assuming 100 µm beam diameter)	415 MW/cm^2	30 MW/cm^2
Divergence (full angle)	θ_x = 0.66 mrad θ_y = 1.12 mrad	NA
Overall 4th Harmonic Conversion Efficiency	10%	NA







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Future Work

Laser 1 – MIR Laser

- Measure and quantify 3.4 μm MIR iOPO breadboard beam quality
- Test 3.4 μm breadboard with L2MS laboratory instrument and compare with commercial OPO
- Finalize design for dual wavelength concept
- Continue to work on 2.8 μm iOPO breadboard and resolve coating damage issue

Laser 2 – UV Laser

- Replace KTP crystal with critically phase matched LBO crystal for SHG of 532 nm
- Improve mechanical design of LBO crystal housing for better conversion efficiency
- Optimize overall 4th harmonic conversion efficiency
- Test breadboard with L2MS laboratory instrument and compare with commercial UV laser
- Develop mechanical design for mounting optics without using epoxies to avoid contamination issues

Laser Transmitter

- Improve packaging of the laser transmitter for space flight
- Build brass board laser transmitter that will generate both MIR and UV wavelengths on a single laser bench

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Conclusions

- We are developing a multi-wavelength laser transmitter for the L2MS Instrument
- A new laser architecture based on the LOLA laser transmitter that generates a single discrete MIR and UV wavelengths has been demonstrated
- The approach provides a straightforward path toward space laser design and deployment
- Preliminary laser breadboard results show compliance with the L2MS instrument requirements