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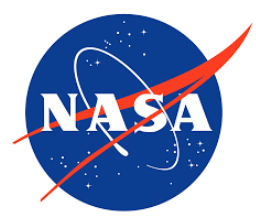
# Solid-state Laser Development for the *in Situ* Spectroscopic Europa Explorer Instrument

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- Introduction
  - Science Overview
  - iSEE Instrument
  - Laser Development
  - Model Predictions
  - Prototype Performance
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  - Acknowledgments



# Introduction

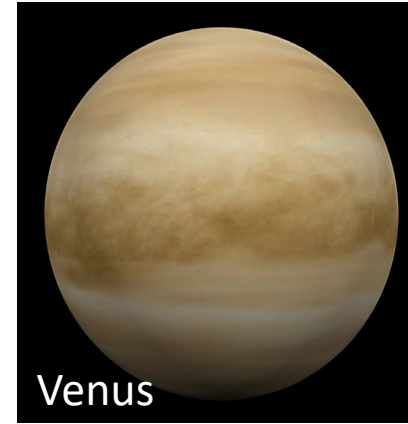
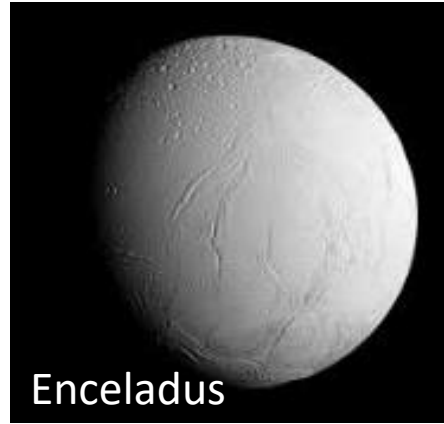
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- Goddard Space Flight Center (GSFC) is developing solid-state lasers for future *in situ* lander missions to explore the surface chemistry of planetary bodies across the Solar System.
- The in Situ Spectroscopic Europa Explorer (iSEE) instrument is an ultra-compact laser-enabled Raman spectrometer instrument.
- GSFC is developing a compact and robust solid-state laser operating at 515 nm that serves as the excitation source for the iSEE investigation.
- The laser is designed to meet the performance requirements of the science instrument and mission objectives.
- When possible, high TRL or heritage laser design and components are used.
- The laser enclosure is pressurized with >1 atm of clean dry air to minimize the risk of contamination induced damage associated with lasers operating in vacuum.



# Science Overview



## Science Themes

- Search for extraterrestrial life and potentially habitable environments beyond Earth.
- Further our understanding of the timing and formation of the Solar System.
- Identify potentially viable economic resources such as water and/or valuable metal assets.

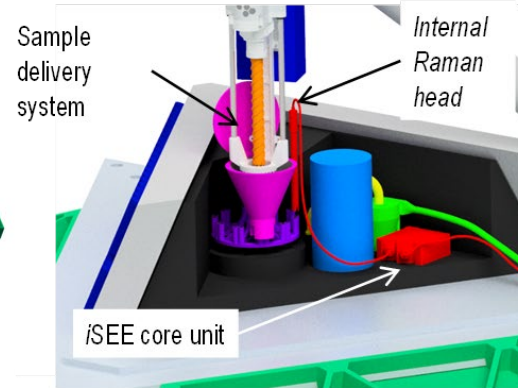
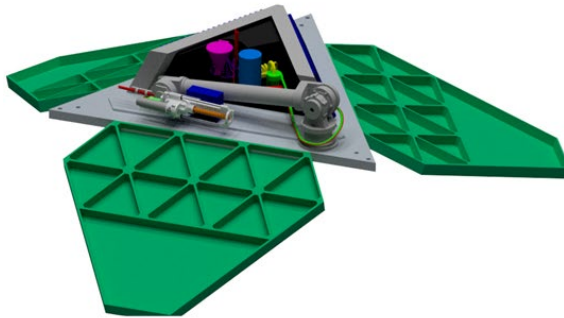




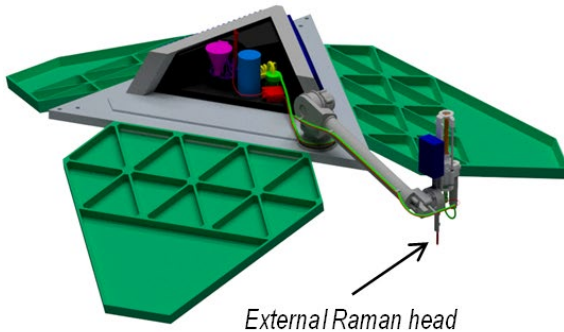
# iSEE Instrument Overview



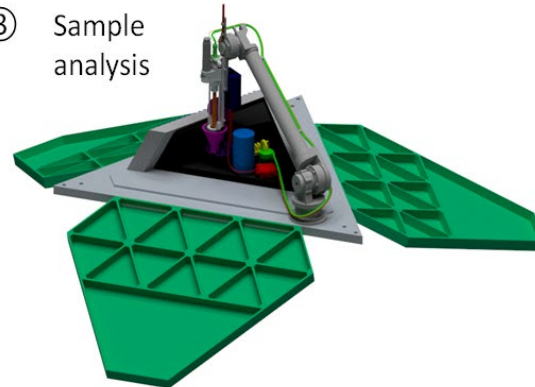
① Stowed iSEE



② Surface exploration



③ Sample analysis



- ***In Situ Spectroscopic Europa Explorer (iSEE)***
- ***Instrument PI: Pablo Sobron/Impossible Sensing***
- ***NASA MatISSE Program***
- ***Instrument Objectives:***
  1. ***Develop a TRL 6 Raman Spectrometer Instrument.***
  2. ***Deliver fast molecular and structural analysis without the need for sample processing.***
  3. ***Provide lean screening capabilities that can inform downstream, more complex operations.***

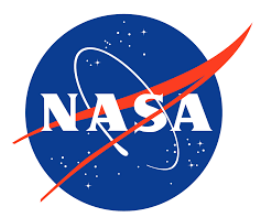
- Notional robotic lander implementation and two concepts of operation: Surface Exploration Mode for analysis of surface samples and Analytical Laboratory Mode for analysis of samples delivered to the spacecraft body. iSEE elements in red.



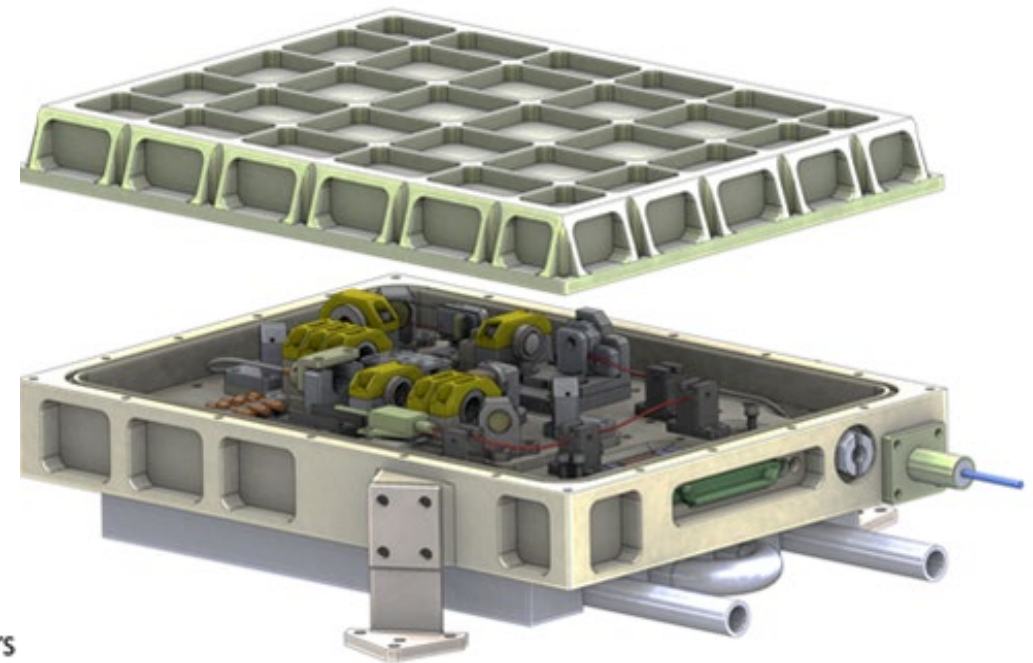
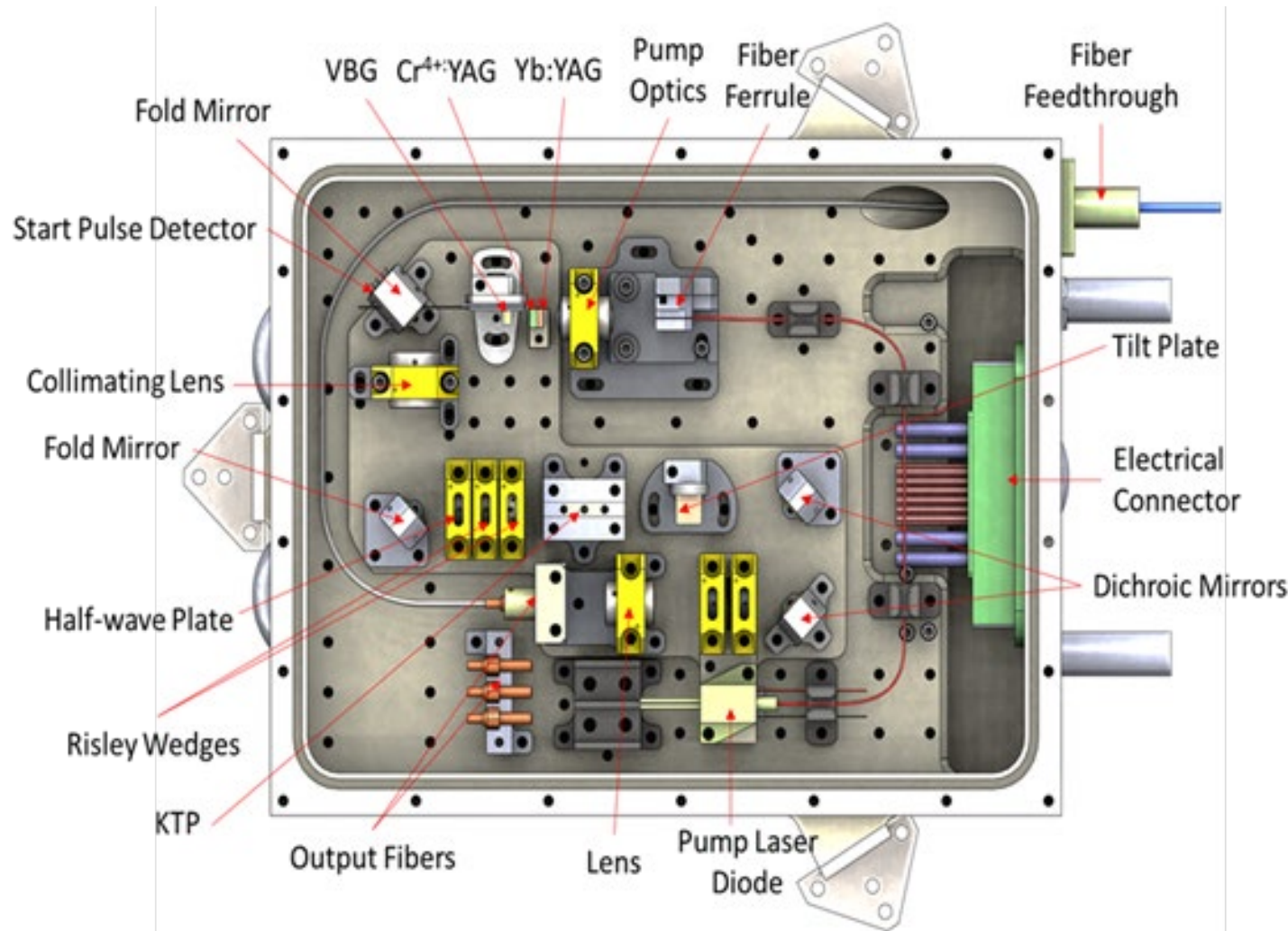
# iSEE Laser Requirements



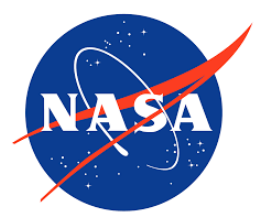
<b>Development Program</b>	MatISSE
<b>Period of Performance</b>	4 Years
<b>Targeted Mission</b>	TBD - Planetary Astrobiology
<b>Laser Baseline</b>	Yb:YAG Microchip Laser
<b>Mission Lifetime</b>	TBD
<b>Output Wavelength</b>	515 nm
<b>Frequency Conversion</b>	SHG of 1030 nm
<b>UV Pulse Energy</b>	20 $\mu$ J (output of fiber)
<b>Output Beam</b>	Multimode fiber optic: 105 -200 $\mu$ m core, NA = 0.22 (Assuming 50% CE, $\sim$ 0.5J/cm <sup>2</sup> )
<b>Pulse Rate</b>	10 kHz
<b>Pulse Duration</b>	$\leq$ 1 ns
<b>Wavelength Stability</b>	$\pm$ 0.1 nm
<b>Spectral Bandwidth</b>	<20 pm
<b>Laser Enclosure</b>	>1 atm Clean Dry Air



# iSEE Laser Design



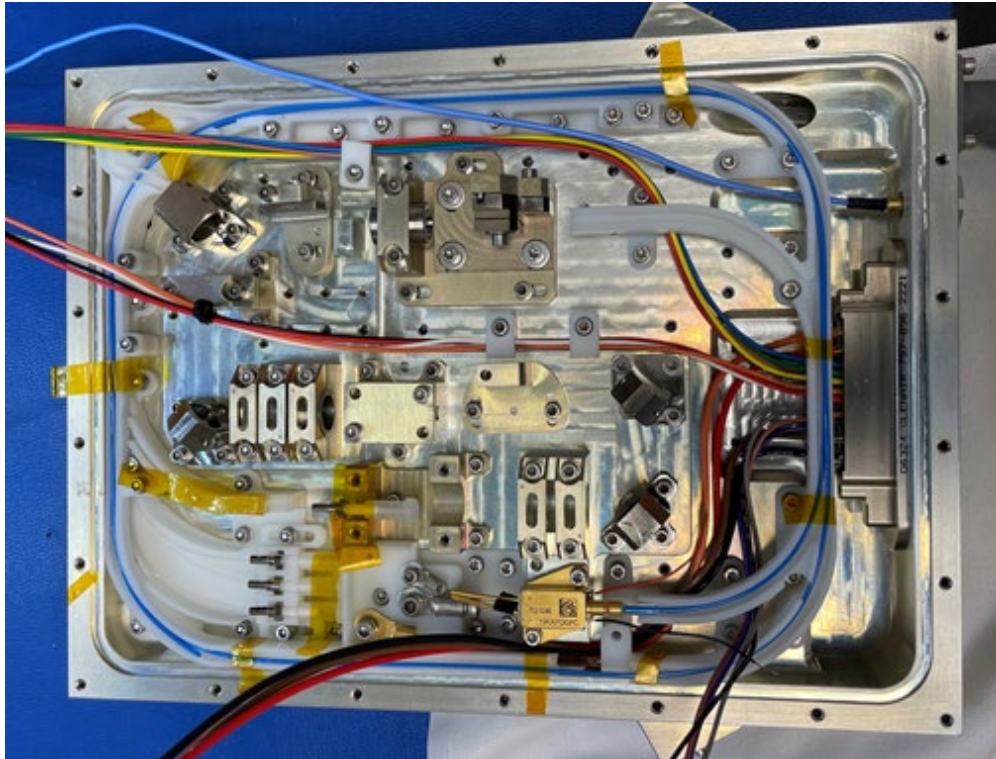
- **Dimensions: 5.75 in x 7.75 in x 1.8 in**
- **Mass: 1.77 kg**



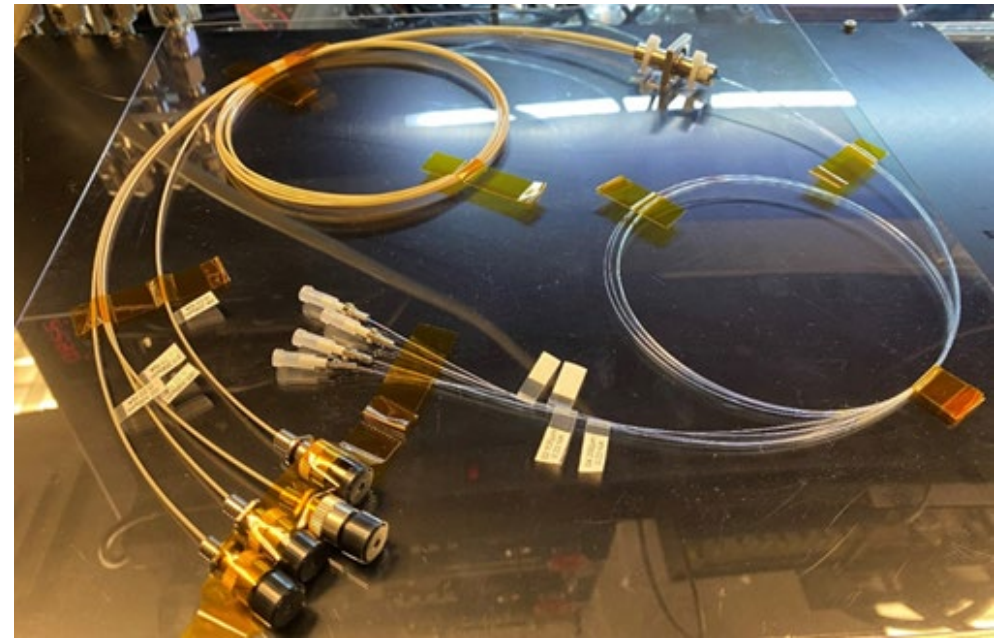
# Engineering Test Unit



ETU Laser Enclosure



Vacuum Fiber Feedthrough





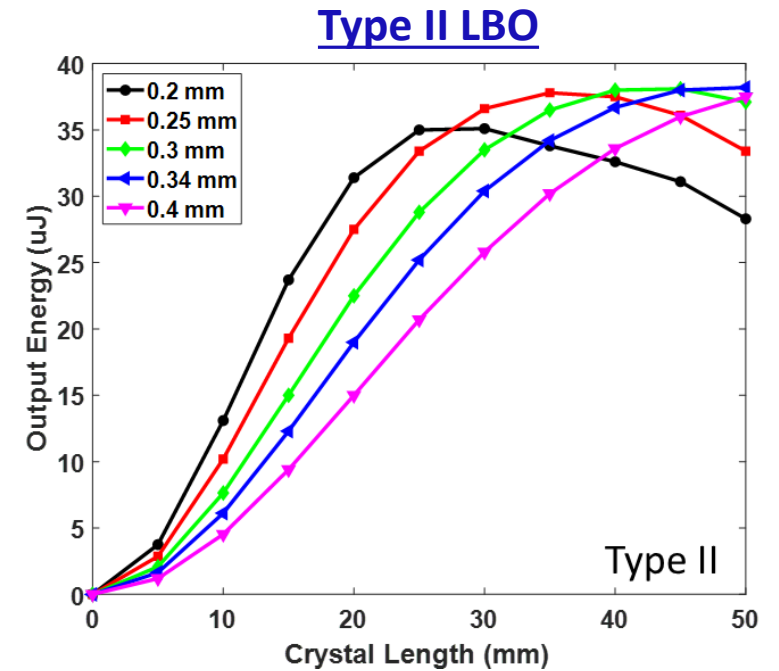
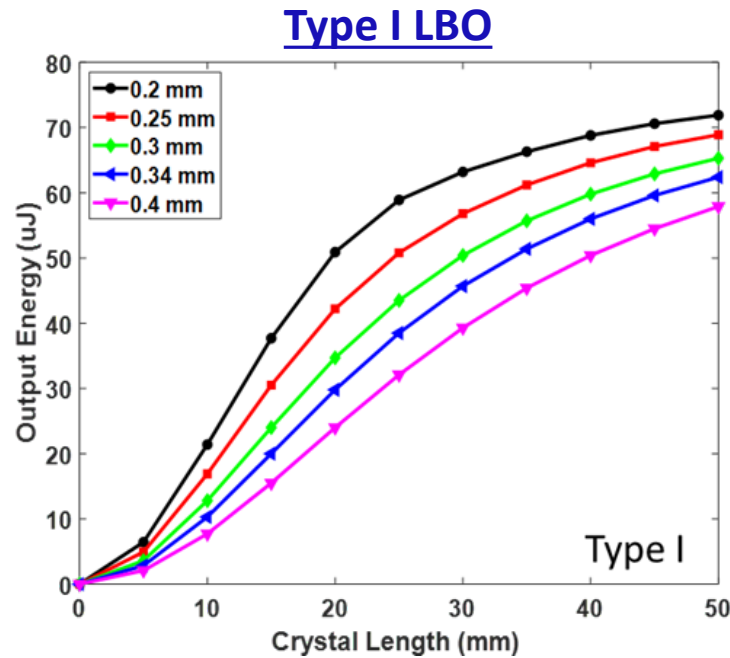
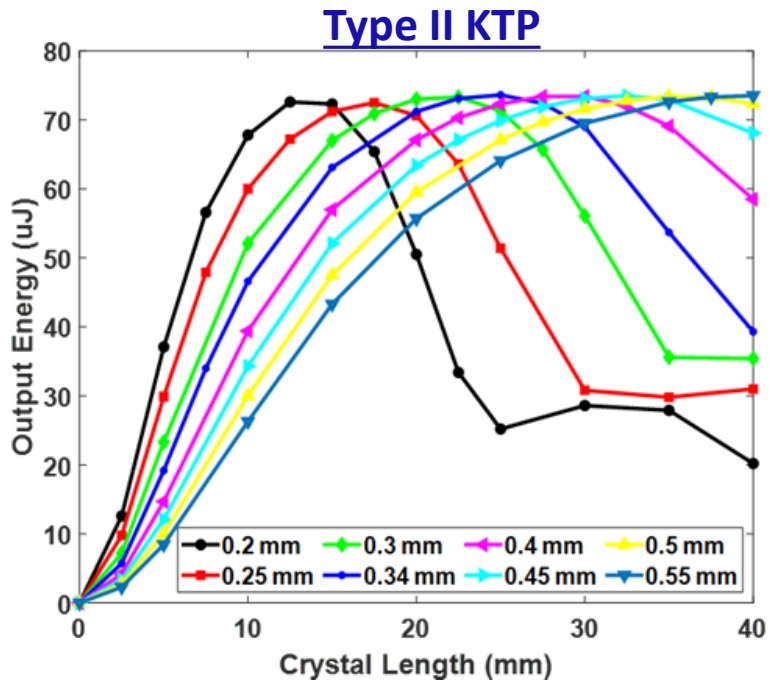
# Second Harmonic Generation (SHG)

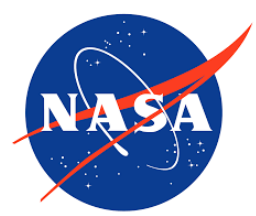


## SHG Non-linear Optical Crystals:

- Type II KTP (potassium titanyl phosphate)
- Type I LBO (lithium triborate)
- Type II LBO (lithium triborate)

## 2<sup>nd</sup> Harmonic Generation



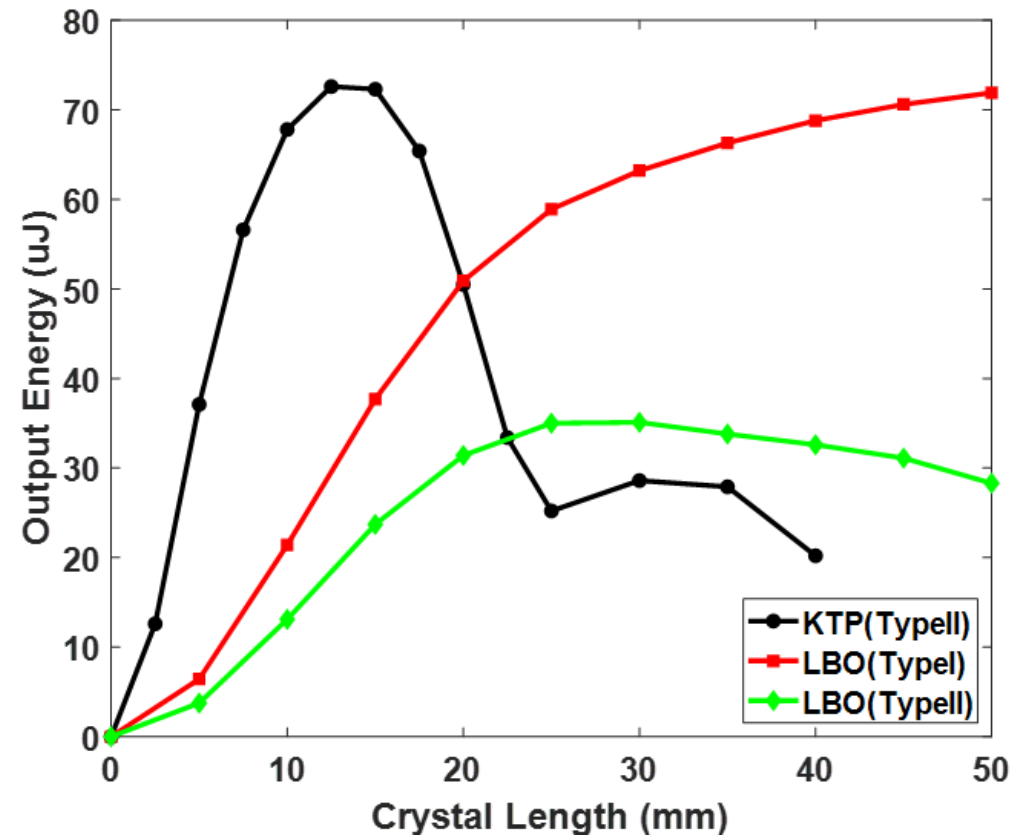


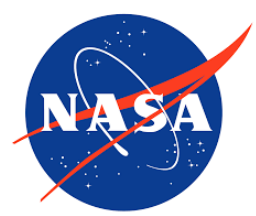
# Second Harmonic Generation (SHG)



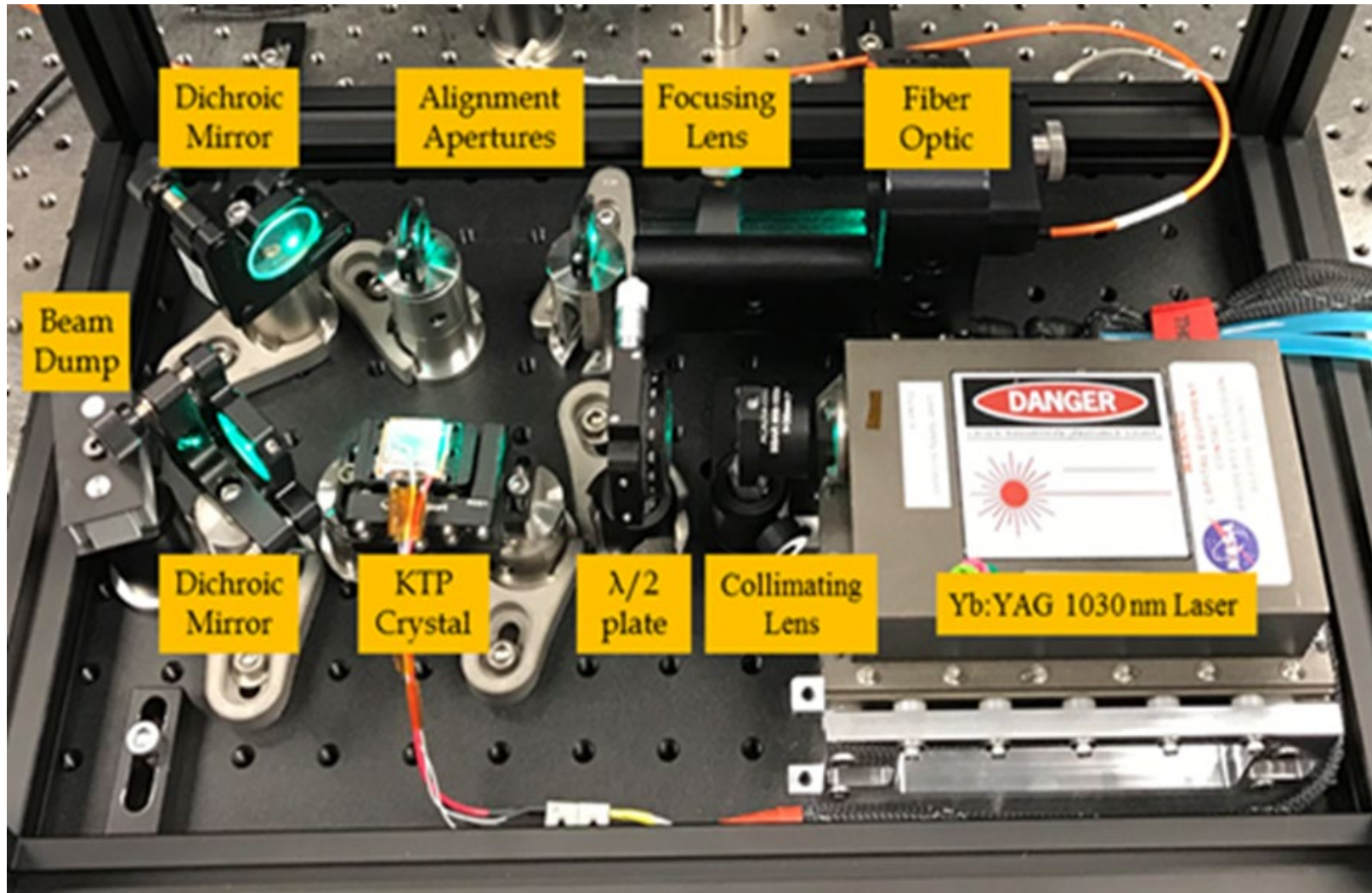
## Non-linear Optical Model Summary:

- KTP performance is superior to LBO between the crystal length 10 -20 mm
- LBO Type I crystal could generate the 515 nm energy needed if the longer length (> 30 mm) could be used in the system.
- LBO Type II crystal is not generating high enough energy in any length.





# iSEE Laser Breadboard

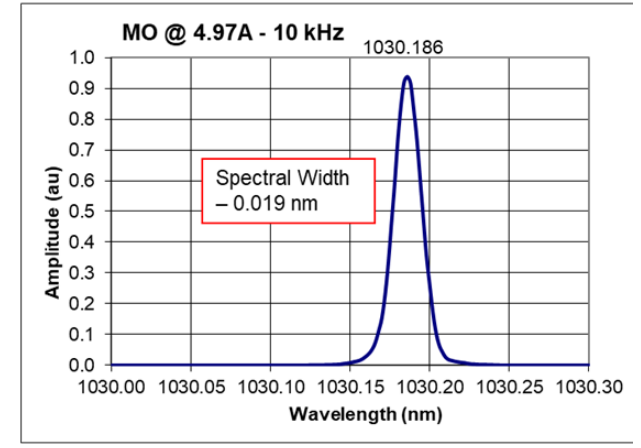
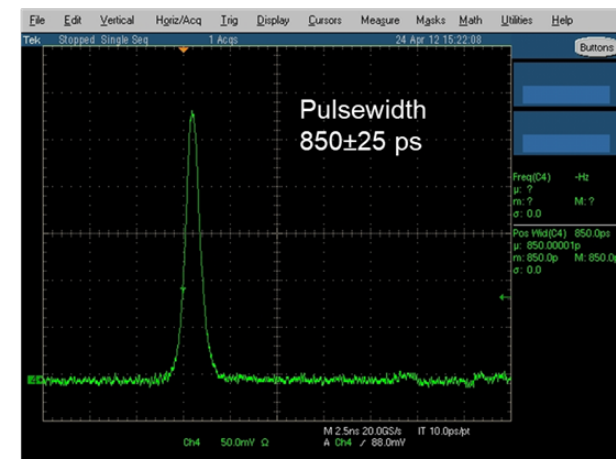
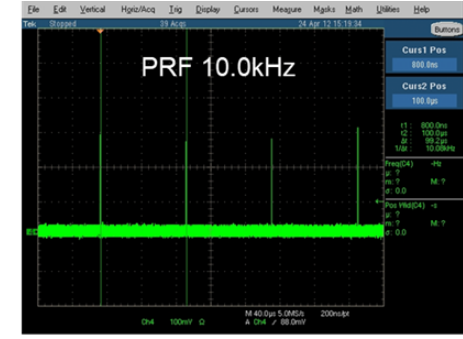
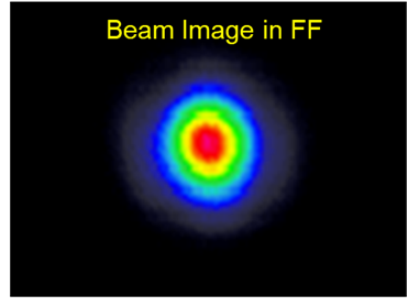




# iSEE Laser Breadboard Performance



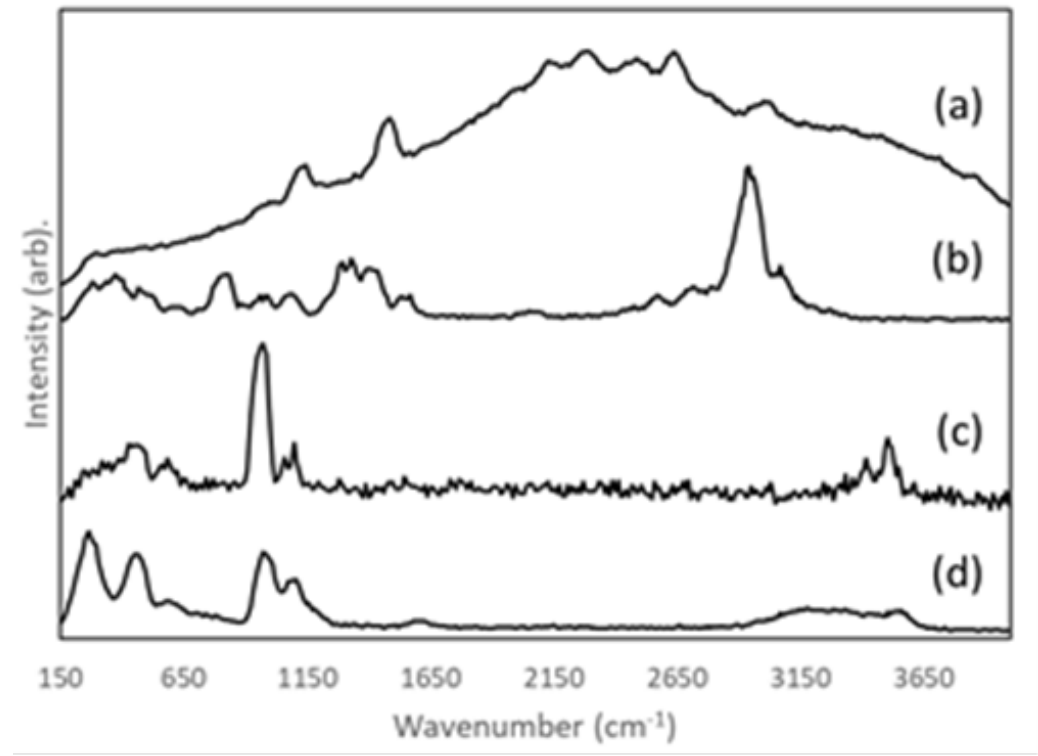
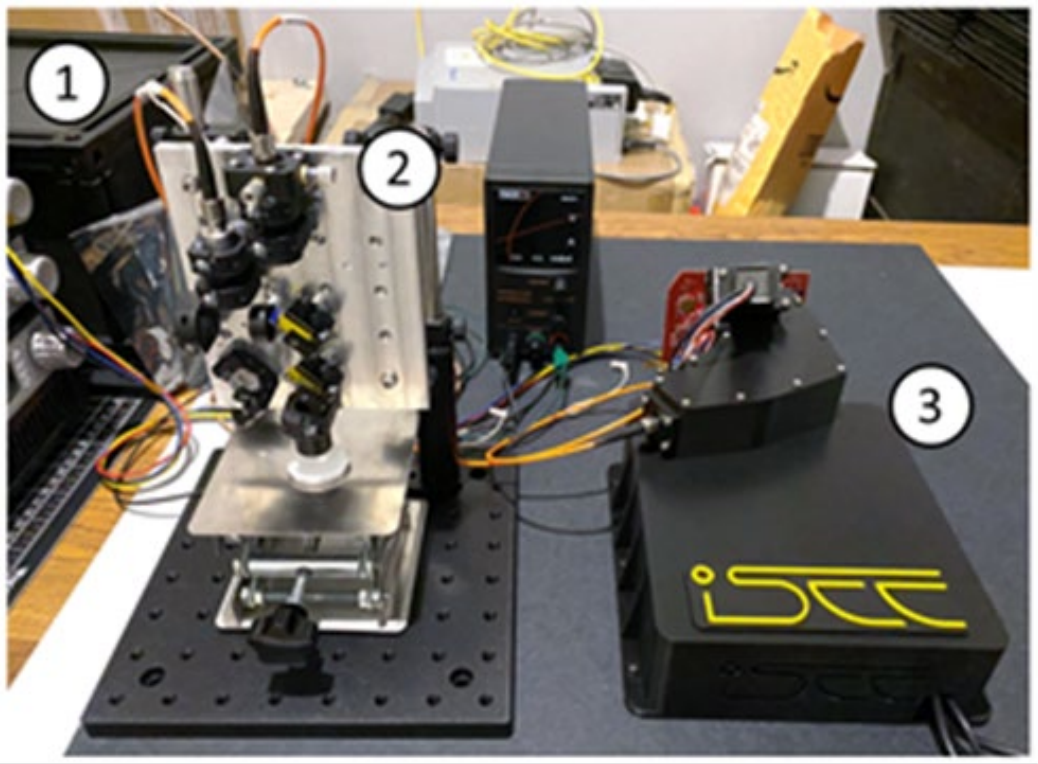
- Yb:YAG microchip laser oscillator
- Pulse energy @ 1030 nm = 95  $\mu\text{J}$
- Pulse repetition rate = 10 kHz
- Pulse width = 850 ps
- SHG: Type II KTP (15 mm)
- Output wavelength = 515 nm
- Fiber coupled pulse energy @ 515 nm = 20  $\mu\text{J}$
- Multimode fiber: 105  $\mu\text{m}$  or 200  $\mu\text{m}$  core diameter, 0.22 NA



PRF	Pump Current	VBG Temp	1030 nm Pulse Energy	515 nm Pulse Energy	Conversion Efficiency	Fiber Output Energy
10 kHz	5.5 A	27 °C	92 $\mu\text{J}$	61 $\mu\text{J}$	66%	20 $\mu\text{J}$

## iSEE instrument breadboard

1. GSFC breadboard laser
2. iSEE Optical Probe
3. iSEE spectrometer and electronics.



- Raman spectra of organic compounds and mineral standards obtained by the iSEE instrument prototype.
- (a)  $\beta$ -Carotene, (b) L-Alanine, (c) gypsum, (d) copiapite



# Summary



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- GSFC is developing a fiber coupled 515 nm solid-state laser for the iSEE instrument investigation.
  - The laser will serve as the excitation source for the Raman spectrometer instrument
  - When possible, high TRL or heritage laser design and components are used.
  - The iSEE laser is designed to meet unique science instrument requirements and top-level science requirements for multiple planetary *in situ* missions across the Solar System.



# Acknowledgement

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- Thank you to all the team members for their contributions to the development of the iSEE instrument!
- Thank you to NASA for funding this work under the MatISSE program.

