

A compact, solid-state UV (266 nm) laser system capable of burst-mode operation for laser ablation / desorption processing

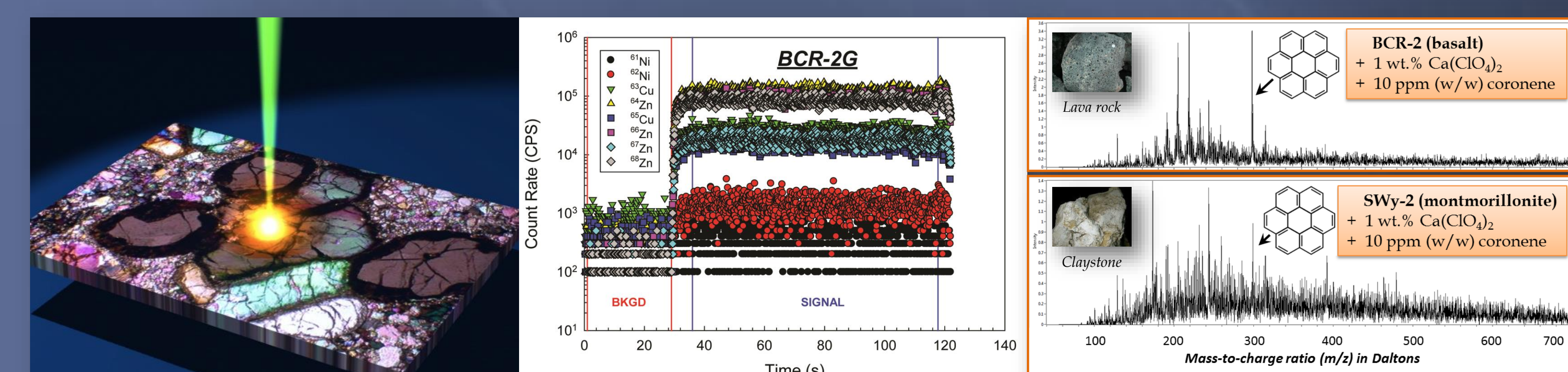
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Planetary and Lunar Science FY14 IRAD - Poster Exhibit C-2

Introduction to Laser Desorption/Ablation

Compared to wet chemistry and pyrolysis techniques, in situ laser-based methods of chemical analysis provide an ideal way to characterize precious planetary materials without requiring extensive sample processing. In particular, laser desorption and ablation techniques allow for rapid, reproducible and robust data acquisition over a wide mass range, plus:

- Quantitative, spatially-resolved measurements of elemental and molecular (organic and inorganic) abundances;
- Low analytical blanks and limits-of-detection ($\leq \text{ng g}^{-1}$); and,
- The destruction of minimal quantities of sample ($\leq \mu\text{g}$) compared to traditional solution and/or pyrolysis analyses ($\geq \text{mg}$).



Artistic depiction of laser processing of a geological thin section with a laser beam at a normal angle of incidence.

Chromatogram of signal intensity of select transition metals versus time during laser ablation sampling of a basaltic glass.

Mass spectrum of Mars analog samples doped with organic material and oxychlorine species.

Laser desorption techniques rely on low irradiances on the order of $\leq 0.1 \text{ GW}\cdot\text{cm}^{-2}$; this "soft ablation" allows fragile organic molecules to be liberated from the surface via photochemical transitions (e.g., interband and intraband promotions of electrons). Ultraviolet wavelengths and short pulse widths are commonly employed to enhance photon-substrate coupling (and single-photon excitation) and minimize thermal effects, respectively.

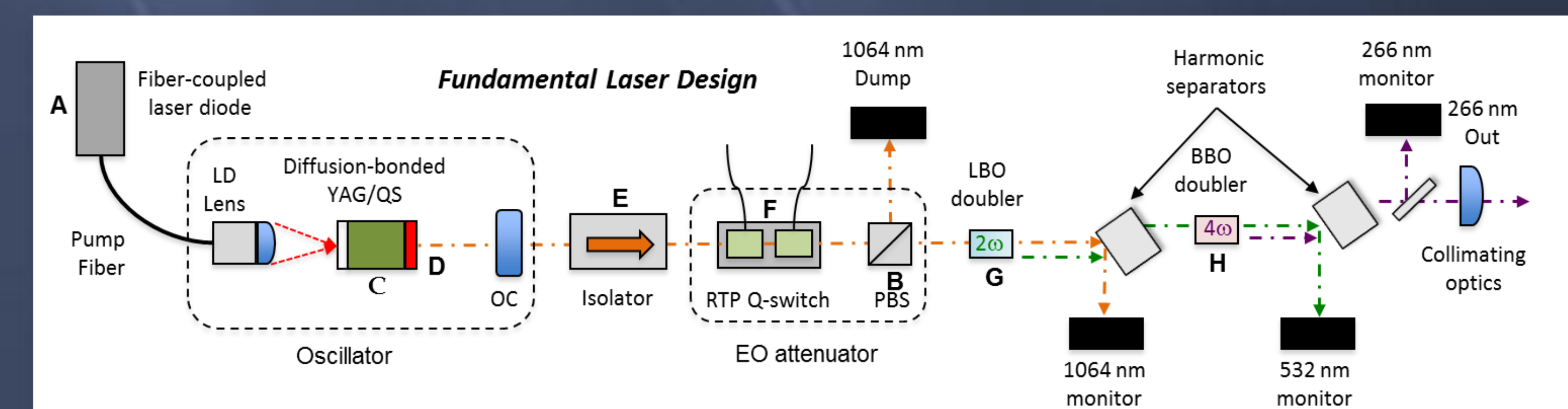
Laser desorption mass spectrometry is sensitive to the detection of semi- and non-volatile organics up to many kDa in mass.

Laser ablation techniques rely on higher irradiances (e.g., $>1 \text{ GW}\cdot\text{cm}^{-2}$) to break the covalent and ionic chemical bonds of crystal lattices and atomize/ionize geological materials.

Laser ablation mass spectrometry is better suited to the analysis of the fundamental (elemental) composition of rocks and minerals.

Laser Design Pioneered Here

Here, we developed a breadboard laser system that is capable of producing $\geq 250 \mu\text{J}$ of 266 nm wavelength radiation, $<2.5 \text{ ns}$ pulse widths at 100 Hz, variable attenuation, and an operational lifetime of $>10\text{M}$ shots.



Optic	Component	TRL	Heritage
A	Fiber-coupled pump laser	6	ICESat-2
B	Mirrors, lenses, PBS	6	GLAS, MLA, MOLA
C	Nd:YAG crystal	9	GLAS, LOLA, MOLA, MLA
D	Cr ⁴⁺ :YAG passive QS	9	GLAS, LOLA, MOLA, MLA

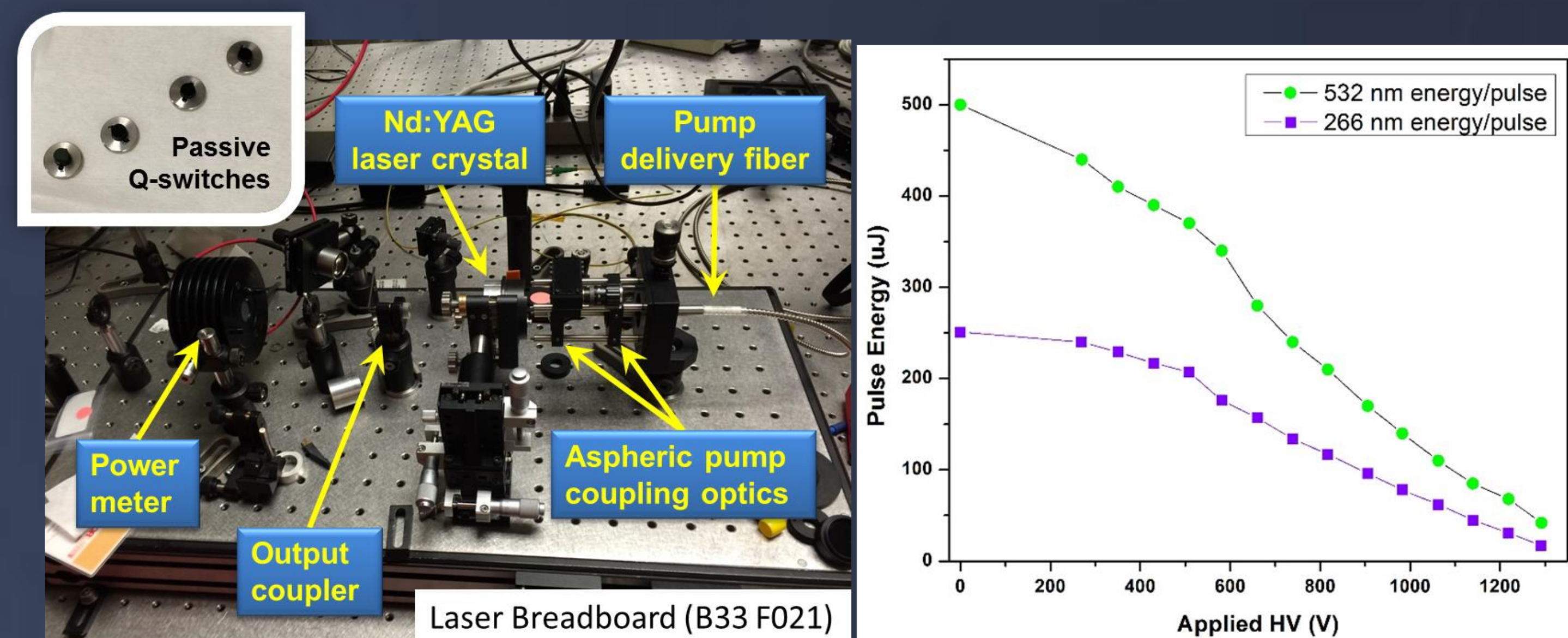
Optic	Component	TRL	Heritage
E	Faraday Isolator	6	GLAS
F	RTP Pockels Cell	6	ICESat-2, CHEMCAM
G	LBO SHG crystal	6	GLAS, ICESat-2
H	BBO FHG crystal	6	ALADIN

The system consists of three stages: i) a Q-switched oscillator; ii) an electro-optic (EO) attenuator; and, iii) two nonlinear frequency conversion crystals. Like the MLA, LOLA and GLAS flight lasers, the laser concept tested here utilizes Nd:YAG as the laser gain medium with a Cr⁴⁺:YAG passive Q-switch to achieve peak power output in an end-pumped configuration.

Breadboard Buildup and Testing

The requirements levied on the laser system designed here included:

- Generation of 266 nm light in $<2.5 \text{ ns}$ pulses;
- Output energy of $\geq 250 \mu\text{J}$ (maximum) at 266 nm;
- 1% - 100% attenuation with uncompromised beam quality ($M^2 > 4$);
- Repetition rate of up to 100 Hz with "burst-mode" operations;
- Duty cycle of $\geq 5\%$ and operational lifetime of $>10\text{M}$ shots.

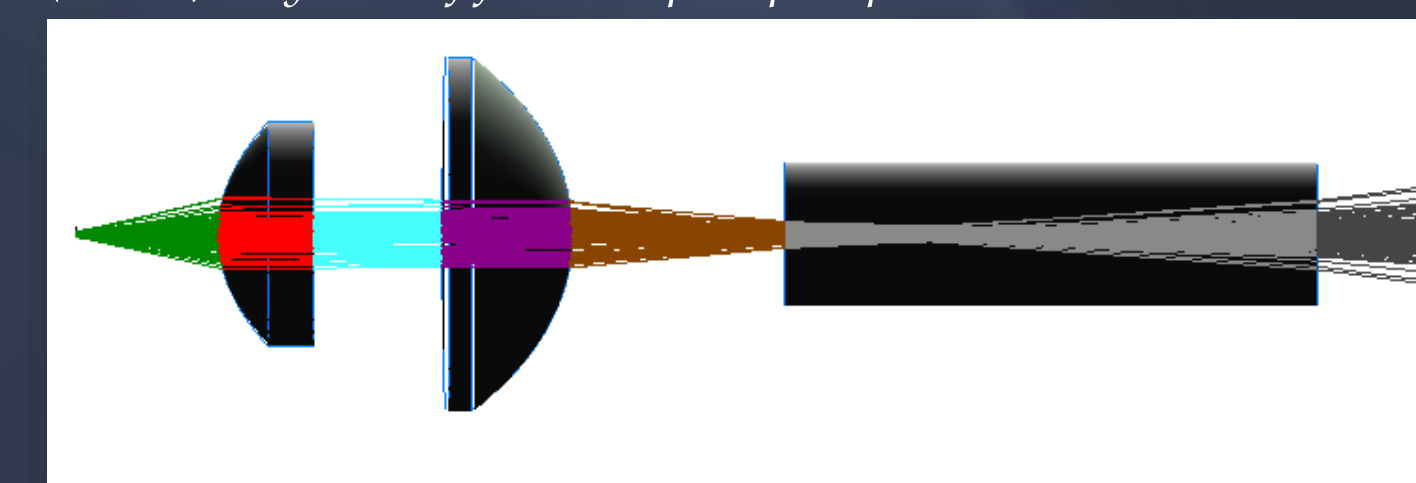


Laser breadboard housed in Building 33 Room F021, which was shown to meet the functional and lifetime requirements levied on the system. (Right) The output power of the laser is controllable to 1% increments via a high-voltage RTP Pockels cell. At full power, the laser produces $>250 \mu\text{J}$ pulses of 266 nm wavelength radiation.

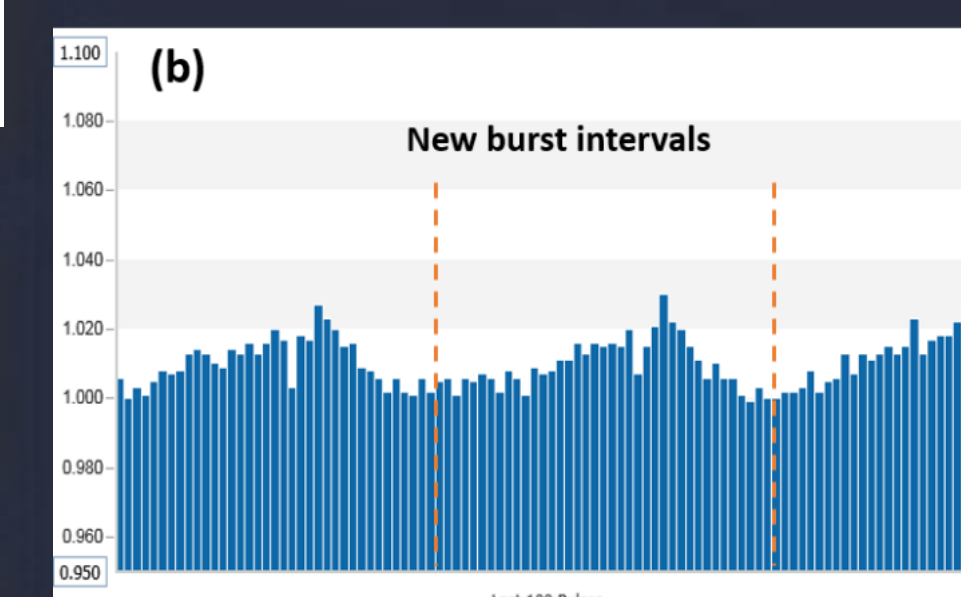
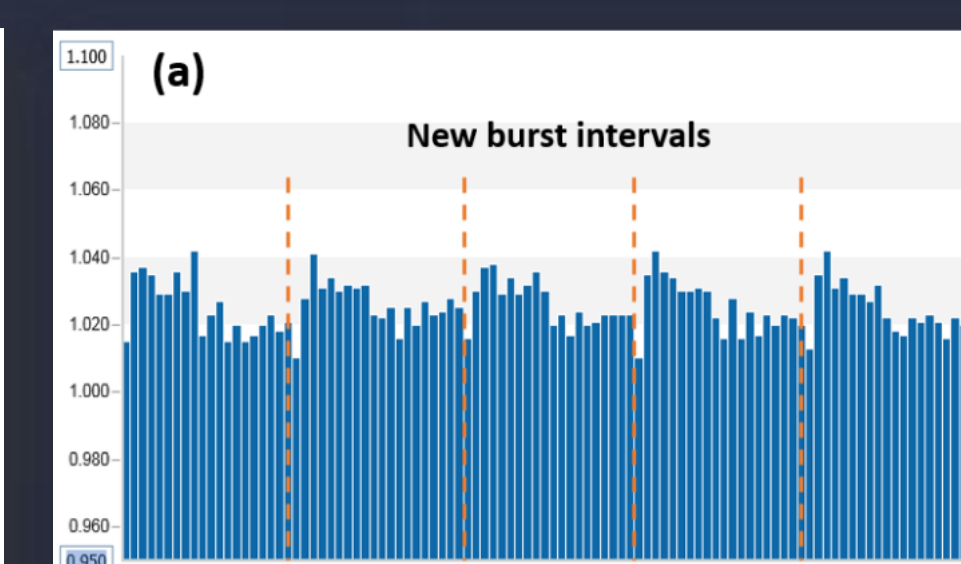
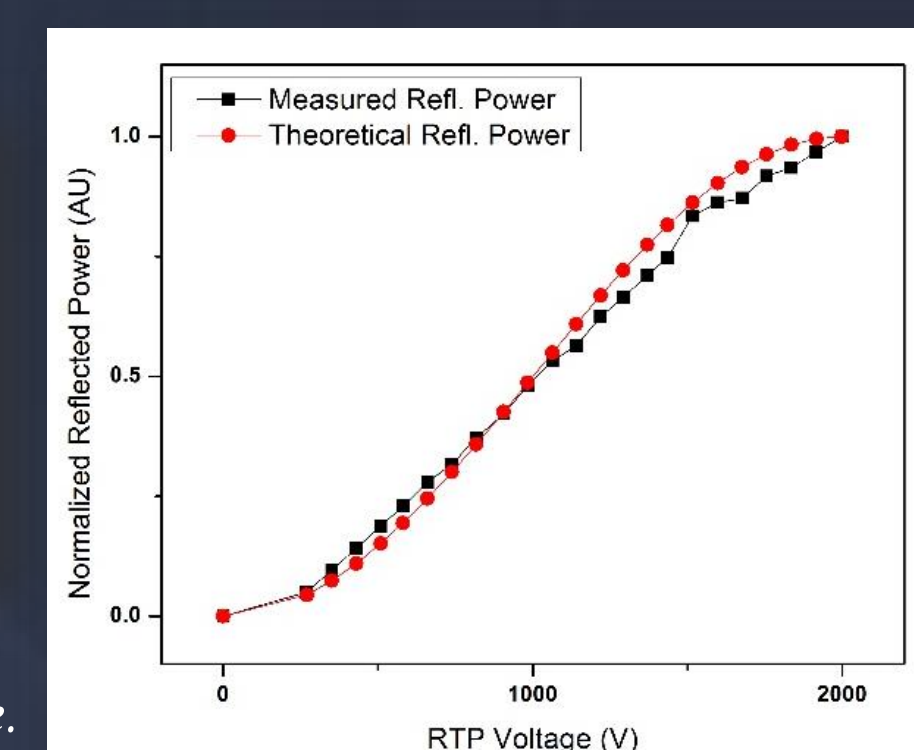
Demonstrated Performance

The laser tested here exceeds the performance capabilities of the Mars Organic Molecule Analyzer (MOMA) laser system developed by Laser Zentrum Hannover e.V. Specifically, our laser system offers controllable attenuation from 1 - 100% in 1% increments without a compromise in beam quality, and $<5\%$ (2σ) variation in pulse energy even during burst-mode operations, both *significant* improvements over the MOMA laser.

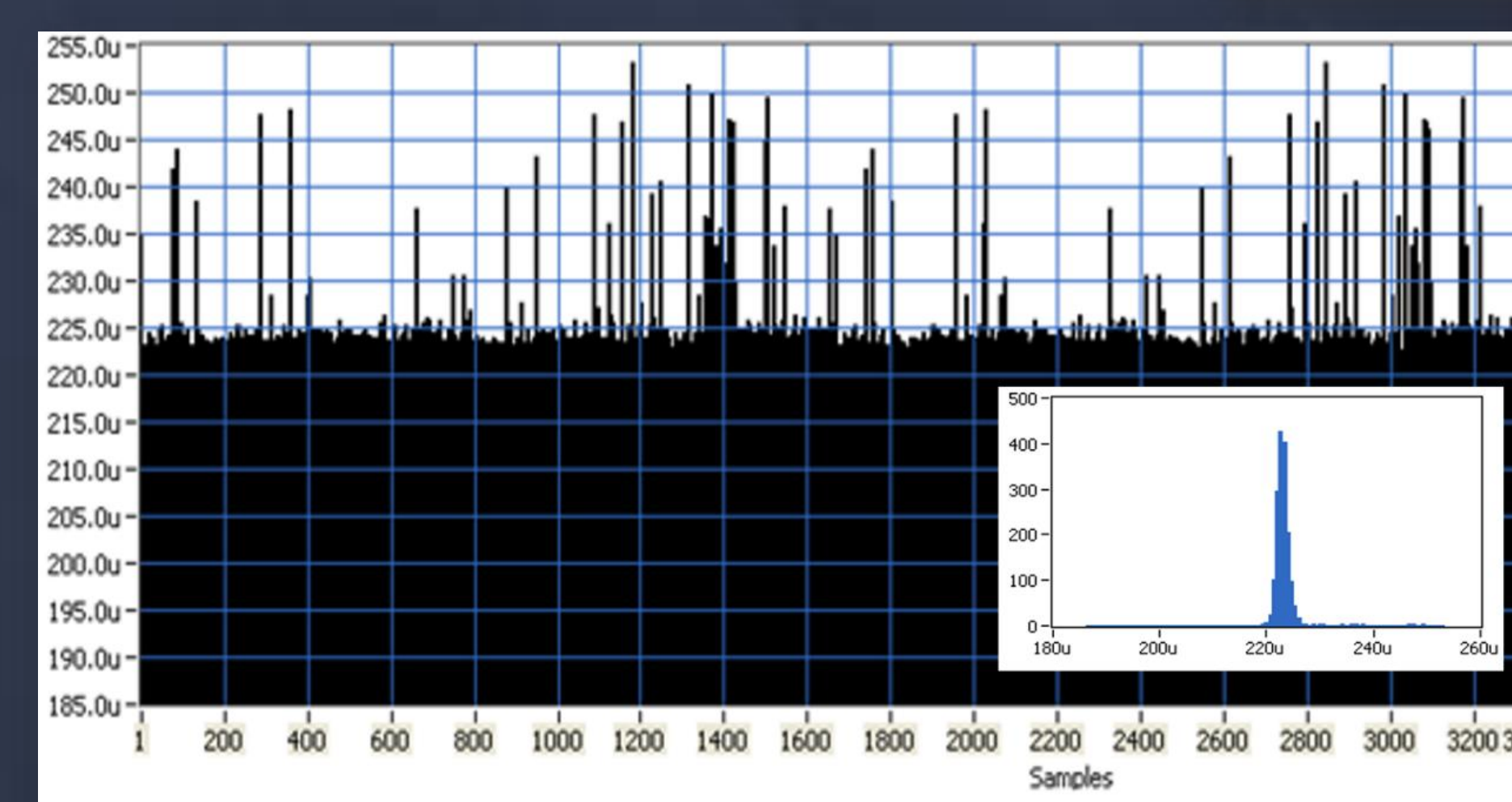
(Below) Raytrace of fiber-coupled pump source.



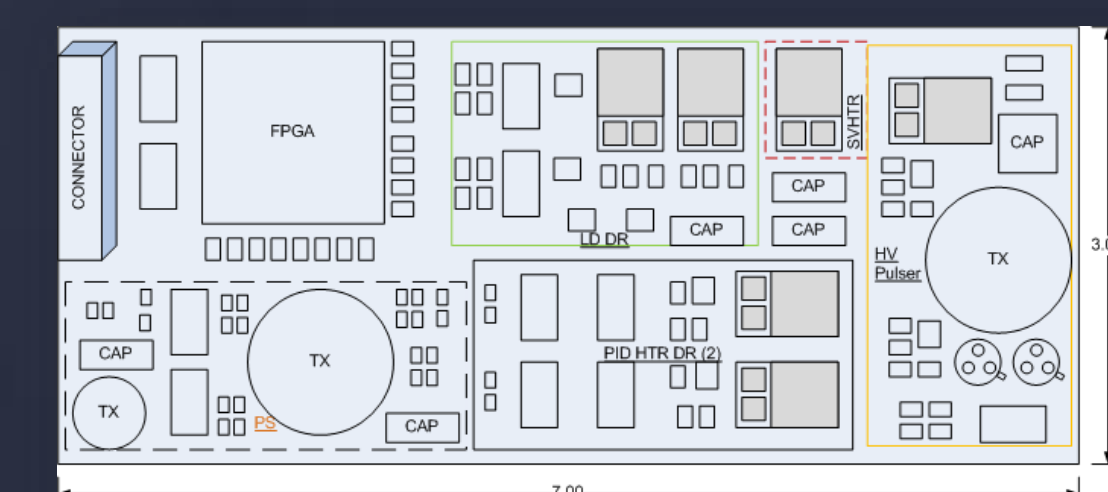
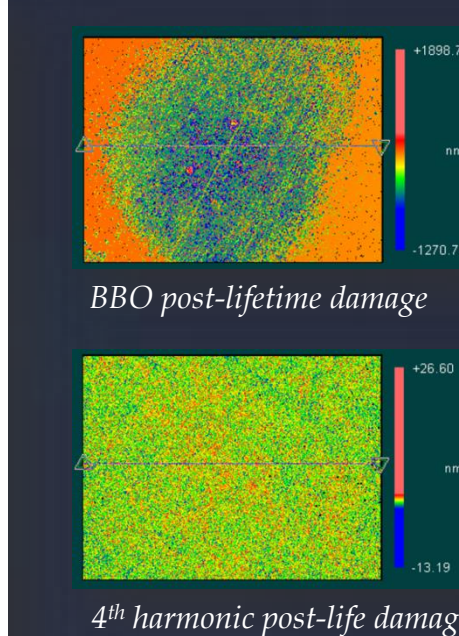
(Right) Reflected power versus applied RTP voltage.



(a) 20 pulse and (b) 40 pulse burst modes. Pulse-to-pulse amplitude variation is less than 5% (2σ) in both cases (above).



(Above) Lifetest data for 266 nm pulse energy showing no degradation over 10M shots. Ordinate axis represents pulse energy in μJ , and abscissa the number of shots. (Inset) Histogram showing clustering of energy about $225 \mu\text{J}$ over 10k shots. Ordinate axis represents number of shots, and abscissa the output energy in μJ .

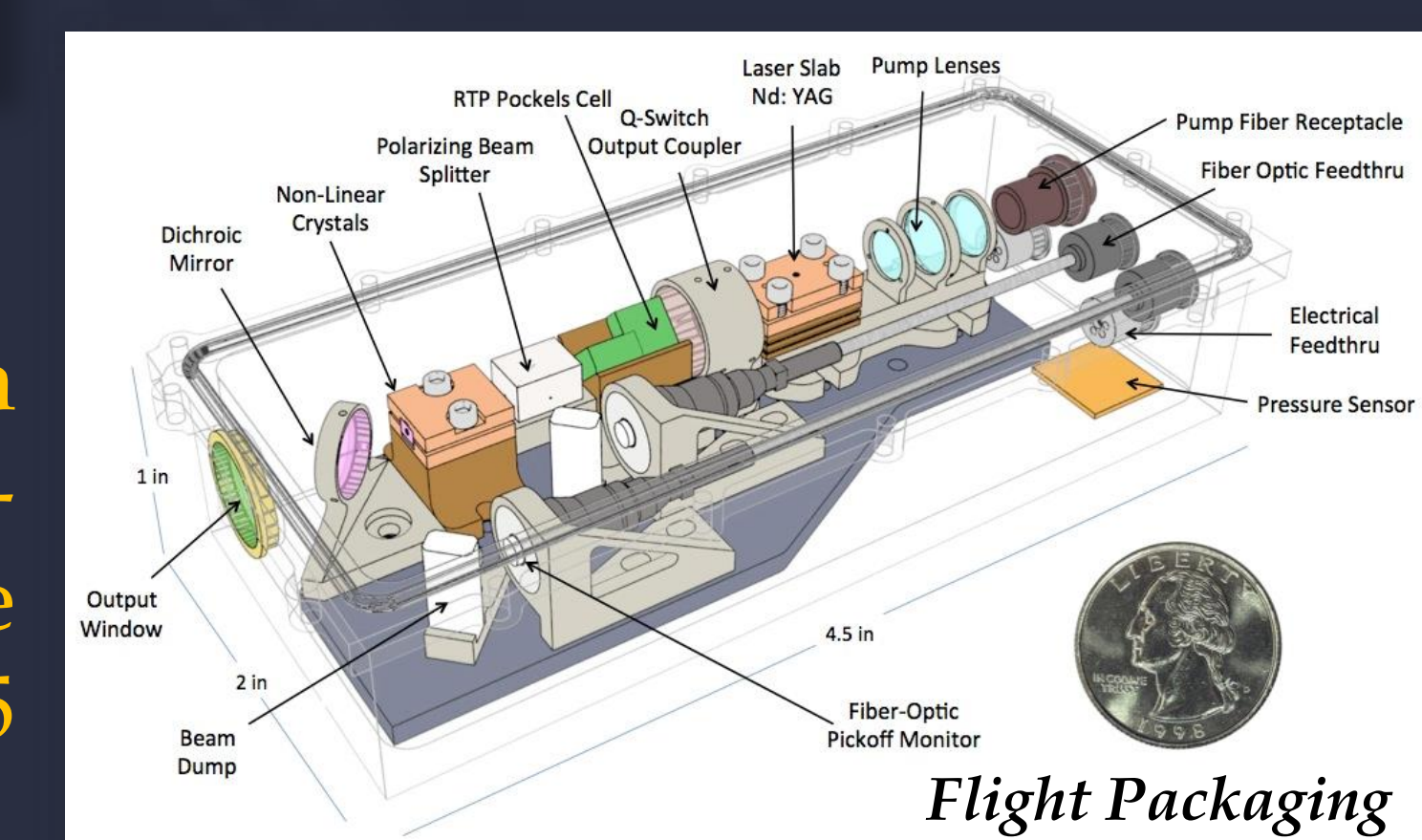


(Above) Flight packaging of control electronics. Minimum size: $3'' \times 7'' \times 1''$ double sided. The slice may grow to $4'' \times 8'' \times 1''$ depending on power supply sizing with actual loading, FPGA selection, and interface with instrument.

This IRAD effort represents a rescope of an original FY14 IRAD proposal. The laser system demonstrated here was developed in order to increase the maturity and selectivity of a component Mars 2020 proposal.

Next Steps

Assemble and environmentally test an Engineering Test Unit (ETU) with flight-like form, fit and function to bring the system to TRL-6 (funded through FY15 IRAD; PI: Coyle)



Flight Packaging