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Development of a pulsed ultraviolet solid-state laser system for Mars surface analysis by laser desorption/ionization mass spectroscopy

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Introduction

The Martian Organic Molecule Analyzer (MOMA) [1-3] is part of the ExoMars Pasteur Payload for Martian planetary surface exploration. It is accommodated inside a rover vehicle. MOMA consists of a pyrolysis/gas chromatography (GC) and a laser desorption/ionization mass spectrometry (LDMS) subsystem. The purpose of the instrument is the investigation of the potential for life on Mars, i.e. searching for signatures of organic molecules and their geochemical context. As an excitation source for the desorption/ionization process of soil samples, a laser with nanosecond pulse duration in the ultraviolet (UV) spectral range is required. In the framework of the instrument's technology preparation program, a compact prototype model of a pulsed UV laser system, which meets the optical requirements for MOMA, has been developed.

Conceptual Laser Design

A passively Q-switched neodymium-doped yttrium aluminium garnet (Nd:YAG) based laser oscillator, which is longitudinally pumped by fiber coupled pump diode was selected as a result of a design trade-off study. The active laser medium Nd:YAG is optically pumped by a fiber-coupled laser diode module, which is operated in quasi-continuous (qcw, pulsed) mode (Fig. 1). The nanosecond laser pulses are generated by a saturable absorber, which acts as a Q-switch, inside the laser oscillator cavity. Second harmonic generation (SHG) of the Nd:YAG emission at a wavelength of 1064nm is achieved by a potassium-titanyl-phosphate crystal (KTP). The resulting green light at 532nm is subsequently converted to 266nm in the fourth harmonic generation (FHG) stage by a beta barium borate crystal (BBO).

This conceptual approach was successfully verified in a miniaturized laboratory setup. Laser pulse durations around 1ns with typical pulse energies of more than 0.25mJ at 266nm and repetition rates above 10Hz were demonstrated.

Prototype Model

The solid-state laser optical design of the laboratory setup was implemented in a robust and lightweight prototype model of the laser head (LH, Fig. 2). The LH accommodates the Nd:YAG laser oscillator, the temperature controlled frequency

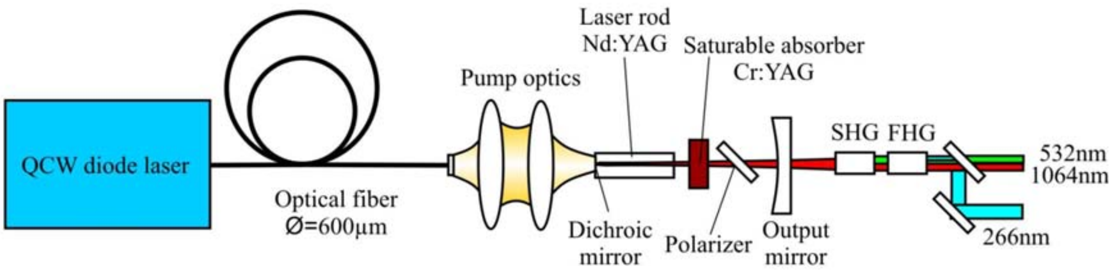

Figure 1: Laser design concept

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conversion stages and photodiodes for laser pulse energy monitoring.

Figure 2: Laser head

The pump unit (PU, Fig. 3), which is a separate box, contains the complete laser electronics including command interface, diode laser driver and the fiber coupled diode laser module itself. In addition, the temperature control electronics for the pump diode, which has to be stabilized within a temperature interval of ±5K, as well as for the non-linear crystals of frequency conversion (±1K) is located in the PU. For the temperature control, a heating only approach was chosen, i.e. the diode laser and the non-linear crystals are internally operated slightly above the upper limit of the boxes environmental operating temperature.

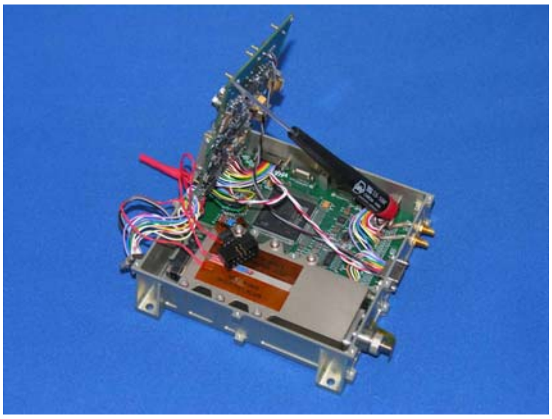

Figure 3: Pump unit with opened top lid

The mass of the complete prototype including harness is around 850g and shows further potential for mass reduction resulting in around 700g for the engineering qualification model. The power consumption of the laser system is <1W without thermal control. The prototype model is designed to operate under relevant environmental conditions.

Environmental Tests

In order to investigate the suitability of the laser system for the MOMA instrument, thermal cycling (non-operating environmental temperature: -40°C to +50°C, operating environmental temperature: -30°C to +25°C) has been performed successfully under vacuum as well as under Martian atmospheric conditions. The experimental results were utilized to improve the thermal model of the laser system. Moreover, the laser system has passed structural tests up to $13g_{rms}$ random and 20g sine vibration. The eigenfrequencies are in good agreement to the structural finite element model. Critical optical components such as the non-linear optical crystals for frequency conversion have been tested for their compatibility to proton irradiation (10 MeV) at levels up to 60 krad.

Summary

A prototype model solid-state laser system with laser pulse parameters of more than 0.25mJ at a pulse duration of around 1ns and a wavelength of 266nm, which is suitable for the MOMA instrument, has been developed, manufactured and environmentally tested.

Acknowledgement

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References

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