MARS ROVER POWER SYSTEM FOR SOLAR AND LASER BEAM UTILIZATION. T. Nakamura, Physical Sciences Inc., 6652 Owens Drive, Pleasanton, CA 94588-3334, nakamura@psicorp.com

Introduction: Mars rover utilizes solar or RTG power systems as its power source. Mars Exploration Rover (MER) Mission's rovers, *Spirit* and *Opportunity*, each used a GaAs/Ge solar array which generates 140We max power. Mars Science Laboratory's *Curiosity* has plutonium radioactive thermoelectric generator (RTG) which will generate 125We. For future Mars rover missions much higher power will be needed as the mobility, range and operability requirements will be increased significantly. Futhermore, as Mars rovers conduct *in situ* resource utilization (ISRU) tasks, much higher power, on the order of several or tens of kW, will be needed to process *in situ* materials. Supplying higher power should be accomplished with light power systems. Physical Sciences Inc. (PSI) proposes to develop a power system which is based on its technology heritage developed for lunar ISRU applications. The proposed system utilizes solar/laser beams to generate electric power or high intensity thermal power for a multitude of ISRU processes using a signle system hardware.

Proposed Concept: The proposed system is described in Figure 1. In this system, primary and secondary reflectors concentrate solar radiation on the high concentration PV cells (left figure). The high concentration PV cells convert the solar radiation to electric power at high conversion efficiencies (~ 35% for InGaP/GaAs/InGaAs). For the CW laser beam, the diode pumped fiber laser ($\lambda = 1.07\mu m$) will be the most likely laser source. Conversion of this monochromatic light will be made with Si cells at an efficiency higher than 60%. One of the unique capabilities of the proposed power system is that it is capable of delivering high intensity solar or laser beams though an optical fiber cable for various ISRU applications (right figure in Figure 1).

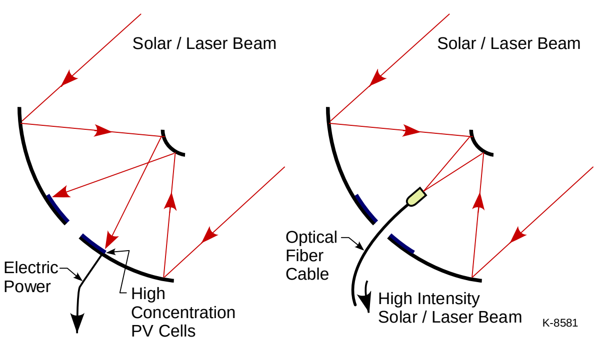

Figure 1. Solar/Laser beam power system.

Background: Since 1995, PSI has been developing the laboratory prototype and the engineering demonstration unit of the Optical Waveguide (OW) solar power system (right figure in Figure 1) for thermochemical, thermal and photosynthetic lighting applications. During the past three years, PSI has developed the ground-based engineering OW systems for: (i) experimental demonstration for oxygen production from lunar regolith [1, 2]: and (ii) solar plant lighting for biomass production in exploration missions [3]. A photo of the engineering prototype system for oxygen production from regolith is shown in Figure 2. The system consists of: (1) A single solar concentrator array with seven 27-inch concentrators and a solar tracking system; (2) Optical fiber cables that transmit the solar radiation from the concentrator array to the oxygen production reactor; and (3) Reactor interface optics to inject the high concentration solar radiation into the carbothermal oxygen reactor.

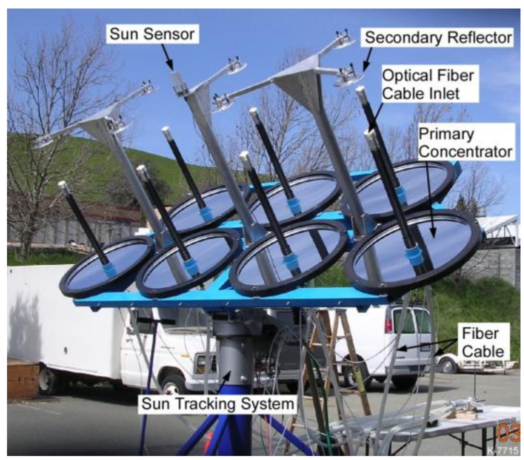

Figure 2. The OW Solar Thermal System.

During Jan – Feb 2010, the OW solar power system was used in NASA's ISRU Analog Test held at Mauna Kea, HI. Figure 3 shows the OW solar power system at the field test site.

PSI participated in two projects: solar sintering of the native volcanic soil (Tephra) at 1100°C; and solar thermal carbothermal oxygen production which requires the max process temperature at 1800°C. During the ISRU Analog Test, the solar concentrator system was deployed in hostile field conditions, such as a wide temperature swing, strong wind which caused dust storm, and occasional cloud cover obscuring the sun. In spite of the adverse field test conditions, the OW solar power system operated reliably during the test and completed all of its tasks successfully.

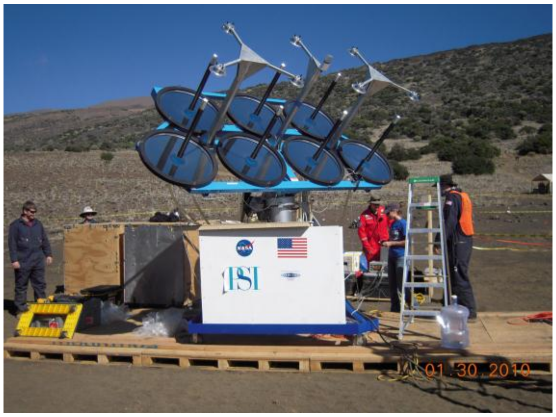

Figure 3. Assembled solar thermal power system at ISRU Analog test at Mauna Kea, HI.

Proposed Rover Power System: Based on the successes achieved in the ISRU analog test, we propose to develop a versatile, multi-use power system for the Mars rover which is capable of converting a solar/laser beams to electric power and supply high intensity solar/laser power for material processing in ISRU applications. A concept of the rover power system is given in Figure 4.

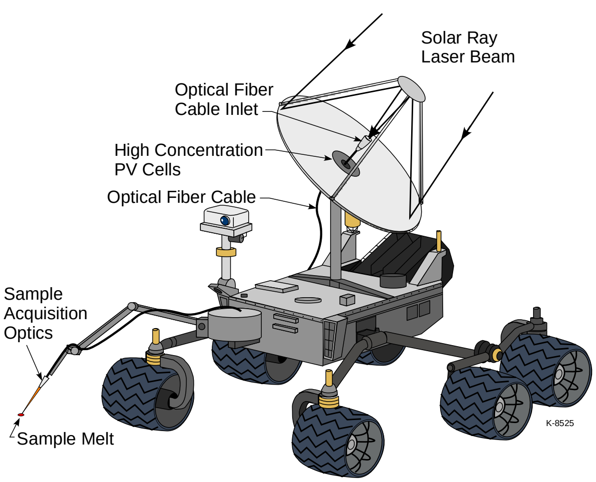

Figure 4. Solar/Laser power system on Mars rover.

The power system on the rover consists of a Cassegrain concentrator system (e.g., D = 2 m) with high concentration solar cells placed on the center part the primary mirror. The optical fiber cable is placed at the focal point of the concentrator system. When the optical fiber cable is removed from the focal point, the solar or laser beams illuminate the high concentration PV cells (e.g. InGaP/GaAs/InGaAs for solar beam; Si for laser beam at 1.07μm). If both solar and laser beams are to be used during the rover operation, two PV cells will be placed at two different positions on the shadow parts of the primary concentrator. The waste heat from the PV cells is rejected at the back of the primary concentrator. When high intensity thermal power is needed for ISRU applications, the optical fiber cable will be placed at the focal point of the concentrator. The optical fiber cable (e.g., ~ 10m) will deliver the thermal power to the ISRU reactor.

Table 1 summarizes the electric power and thermal power available from the rover power system. The electric and thermal power values are calculated based on our database. It is shown that 500W of electric power or 1.2 kW of thermal power will be generated with solar radiation. When the rover receives 10 kW of laser beam, the system generates 5 kW of electric power or 7.5 kW of thermal power. More detailed discussion will be given at the conference.

Table 1. Summary of the Rover Power System with a Primary Concentrator Daimater of 2 m.

	Solar Ray (600 W/m²)	**Laser Beam (10 kW)**
PV Cells	InGaP/GaAs/InGaAs	Si
Electric	500 W	5 kW
Thermal	1.2 kW	7.5 kW

Summary: The Mars rover power system discussed here is a departure from the conventional concept and will offer an order of magnitude higher power for rover mobility and ISRU processes. The proposed concept is based on our technology basis obtained in our participation in NASA's ISRU programs.

References:

1. Nakamura, T. and Smith, B.K. "Multi-use Solar Thermal System for Oxygen Production from Lunar regolith," SBIR Phase II Final Report, NASA/JSC, November 2010.
2. Nakamura, T. and Smith, B.K. "Solar Thermal System for Oxygen Production from Lunar Regolith — Ground Based Demonstration System", SBIR Phase III Final Report, NASA/GRC, April 2009.
3. Nakamura, T., Rossi, D.C., Smith, B.K., and Yorio, N.C., Phase II SBIR Final Report , NASA/KSC, January 2009.