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## POTENTIAL CONVERTER FOR LASER-POWER BEAMING

## USING DIODE LASERS

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Future space missions, such as those associated with the Space Exploration Initiative (SEI), will require large amounts of power for operation of bases, rovers, and orbit-transfer vehicles. One method for supplying this power is to beam power from a space-based or Earth-based laser-power station to a receiver where laser photons can be converted to electricity. Previous research has described such laser-power stations orbiting the Moon and beaming power to a receiver on the surface of the Moon by using arrays of diode lasers. This paper describes photovoltaic converters that can be efficiently used with these diode lasers.

## INTRODUCTION

A number of space-related missions and objectives which require large amounts of power have been identified by NASA (reference 1 and 2). Two such missions are the establishment of a lunar habitat and exploration of the lunar surface by a roving vehicle. The power for these (and many other) missions could be supplied by laser beam transmission. Reference 3 describes a typical system for beaming power to a habitat or rover on the Moon.

This system consists of three laser satellites which orbit the Moon in a plane oriented to receive continuous solar irradiation (figure 1). The orbit precesses and the satellites are separated by 120 degrees of arc to provide continuous coverage directly below the satellites and intermittent coverage to each side of the orbital plane.

As shown in figure 2, each satellite is composed of a solar collector/concentrator, solar photovoltaic cells, power conditioning equipment, heat radiators, a powerful laser subsystem and

transmission optics. Power from the Sun is collected and concentrated 300 times to irradiate the solar cells which power the laser. Power in the laser beam is transmitted to receivers at the habitat or on the rover. Figure 3 is a flow diagram for such a rover system. The receivers use GaAs photovoltaic converters to convert laser radiation to electrical power.

There are other scenarios for transmitting power by laser beam. Examples are: (1) transmitting from L1 LaGrange point, making most of the visible half of the Moon accessible by one satellite and (2) transmitting from Earth's surface through the atmosphere (with adaptive optics) to the lunar surface or to satellites. However, all scenarios have a common element - the power converter at the destination of the laser beam. This paper describes preliminary efficiency measurements for a GaAs concentrator photovoltaic converter irradiated by a diode laser.

## LASER

The light source used for these measurements was a 10-watt CW laser diode (SDL-3490-S). It emitted light at a wavelength of 813 nanometers through a slit-like aperture with dimensions of 1 centimeter (horizontal) and 1 micrometer (vertical). The aperture was composed of 30 ten-stripe, phase-coupled arrays. Beam divergence angles were  $50 \times 10$  degrees full width, half maximum (FWHM) (vertical plane, horizontal plane). The output beam was focused by two plexiglass cylinders 2 inches in diameter by 6 inches long into a square area that covered the solar cell or an equal aperture (through which power measurements were made with a heat-sensitive detector).

The laser diode was driven by a DC power supply which limited the diode's output to about 7.5 watts. At that output power, about 22.5 watts of heat were conducted away from the diode through a thermoelectric cooler into a circulating water coolant. The thermoelectric cooler provided fine temperature control, and the diode operated at  $29.9^\circ\text{C}$  within  $0.1^\circ\text{C}$ .

## PHOTOVOLTAIC CONVERTER

The concentrator converter was a GaAlAs/GaAs photovoltaic device on a Ge substrate. Table I shows the characteristics of this converter. Figure 4 is a photograph of the converter-laser experimental setup. The outer portion of the converter's surface is completely covered with a metal contact, while the center of the converter consists of a circular region  $0.412\text{ cm}^2$  in area. For the measurements described in this paper, the laser-beam diameter was adjusted to just fill this circular region. Although 22.6 percent of this circular region was covered with a metal contact grid, power density, current density, and efficiency are based on the total area of this circular region, uncorrected for contact area. Figure 5 shows the current density-voltage characteristics of this converter with the laser beam incident at a power density of  $2.45\text{ W/cm}^2$ . At this power density, the power-conversion efficiency was 45.0 percent.

Figure 6 shows the efficiency and fill factor as functions of laser-power density. The efficiency initially increases with increasing power density because of an increase in converter voltage; however, the decrease in fill factor causes a decrease of efficiency above a laser-power density of  $2.45 \text{ W/cm}^2$ . The corresponding current density obtained at  $2.45 \text{ W/cm}^2$  is approximately 45 times the current density that would be expected from this converter at air mass zero (AM0).

In conclusion, a peak power conversion efficiency of 45 percent has been demonstrated for a GaAs concentrator device irradiated with a diode laser. Further optimization of the converter structure will be required for efficient operation at power densities above  $2.45 \text{ W/cm}^2$ .

#### REFERENCES

1. Ride, Sally K.: LEADERSHIP and America's Future in Space. A Report to the Administrator, August 1987.
2. The Report of the National Commission on Space. PIONEERING THE SPACE FRONTIER, May 1986.
3. Williams, M. D.; Kwon, J. H.; Walker, G. H.; and Humes, D. H.: Diode Laser Satellite Systems for Beamed Power Transmission. NASA TP 2992, July 1990.

Table 1: GaAs photovoltaic converter.

p - Ga <sub>0.15</sub> Al <sub>0.85</sub> As	
Thickness =	600 Å
p - GaAs	
Thickness =	0.5 μm
Doping Density =	2 × 10 <sup>18</sup> /cm <sup>3</sup>
Diffusion Length =	4 μm
Surface Recombination Velocity =	1 × 10 <sup>4</sup> cm/sec
n - GaAs	
Thickness =	6 μm
Doping Density =	2 × 10 <sup>17</sup> /cm <sup>3</sup>
Diffusion Length =	2 μm
Surface Recombination Velocity =	1 × 10 <sup>4</sup> cm/sec
Substrate is inactive n - Ge	

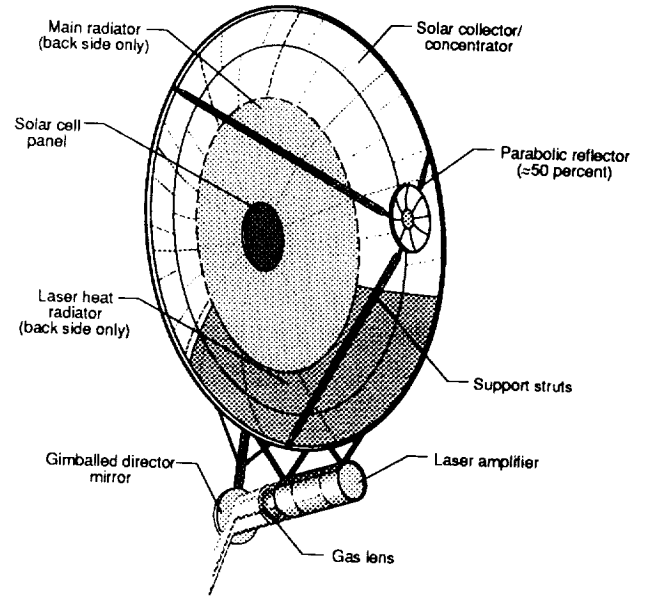


Figure 2: Diode laser satellite.

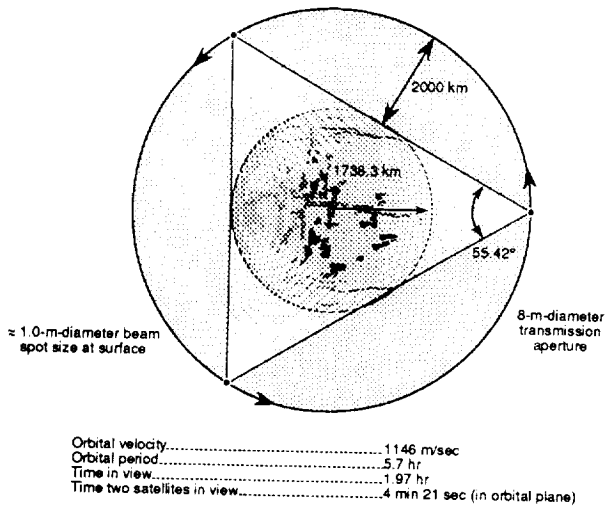


Figure 1: Lunar orbit data.

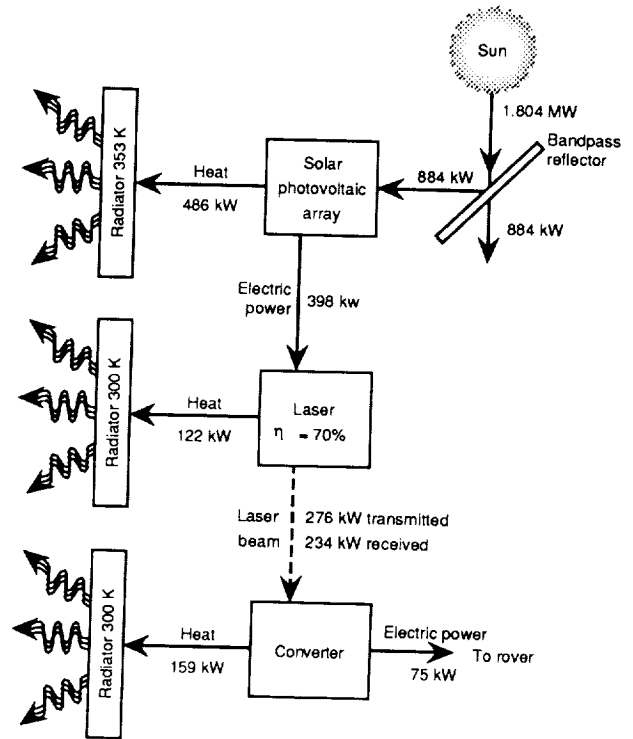


Figure 3: Power flow of laser satellite for rover.

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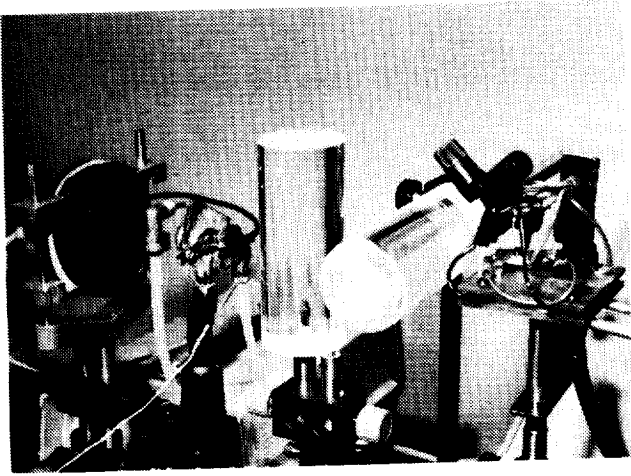


Figure 4: Experimental arrangement of laser diode and converter.

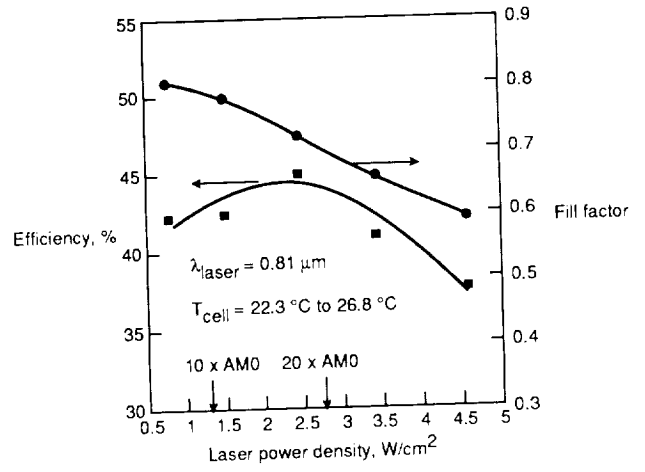


Figure 6: Response of diode converter to laser radiation.

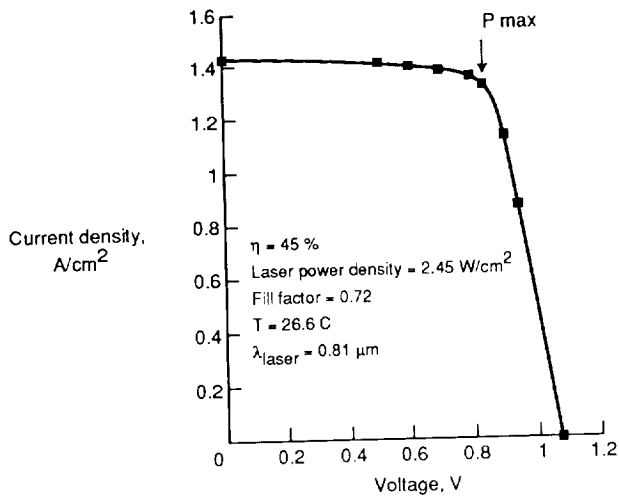


Figure 5: GaAs converter diode irradiated with laser.

