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UAV REMOTE POWER SUPPLY SYSTEM BY LASER RADIATION

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Abstract

Creation peculiarities of UAV remote power supply (RPS) system by the narrow-beam infrared laser radiation are considered at this paper. Research objective is the theoretical justification and experimental verification of WET system components to make an UAV RPS system.

1 Introduction

The main purpose of this work is creation of remote power supply system (RPS) by laser radiation for unmanned aerial vehicle (UAV). RPS system (Fig. 1) will help to solve UAV problems concerning their limited flight time.

The RPS system is based on the wireless energy transfer (WET) technology by the narrow-beam infrared radiation.

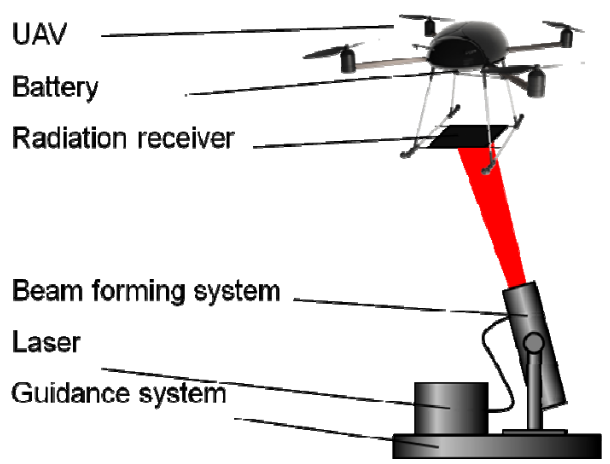

Fig. 1. Scheme of the UAV RPS system

The one of the significant issues is the laser beam propagation in atmosphere. Attenuation of laser density strongly depends on the location and altitude. In this work we considered 809 nm wavelength of laser radiation. For the sub-micron wavelengths the most significant conditions are the absorption, scattering and scintillation [1]. For the 809 nm wavelength the main attenuation is the scattering by fog and dry snow (rain effects to laser density only if it is an extremely heavy rain – greater than 5 inches per hour [1]).

Modeling and environmental experiments are need for the 809 nm laser radiation attenuation estimation.

2 Laser Radiation Conversion Efficiency

LPC is the one of the key and most difficult system elements. We have investigated laser radiation conversion possibilities of specific GaAs photovoltaic cells (PVC). This work was implemented in cooperation with Ioffe Physical-Technical Institute of the Russian Academy of Sciences.

Four different GaAs PVC was made by vapor phase heteroepitaxy and liquid-phase heteroepitaxy.

The first laboratory model of RPS system (Fig. 2) was made for studying of produced cells laser radiation conversion efficiency. The first laboratory model consisted of GaAs PVC, beam forming system and laser radiation source, device for getting PVC I-V curves and laser power sensor.

Fig. 2. First laboratory model of RPS system

For all cells were received similar results, which are shown on Fig. 3.

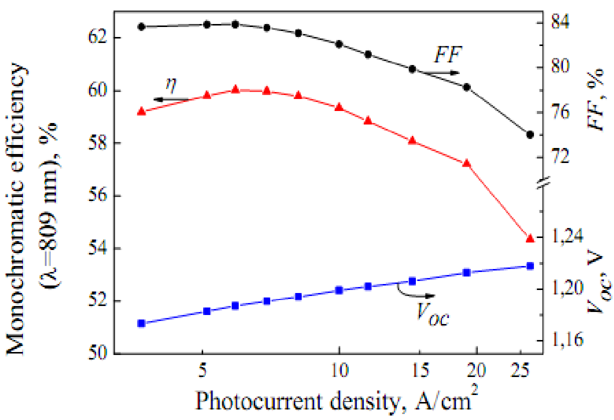

Fig. 3. Photocurrent dependence of the 3.5×3.5 mm GaAs PVC conversion efficiency of laser radiation with wavelength 809 nm η, fill-factor FF and open-circuit voltage V_{OC}

The maximum conversion efficiency for laser radiation with wavelength λ=809 nm we have got is about 60%.

3 Second Laboratory Model of RPS System Elements

Three different laser power converters were made.

To study of produced LPC laser radiation conversion efficiency second laboratory model of RPS system was made (Fig. 4). The laboratory model consisted of GaAs PVC, beam forming system (Fig. 5) with micropositioning device and laser radiation source.

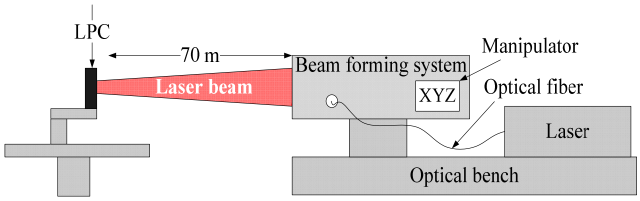

Fig. 4. Scheme of laboratory model of RPS system

Extra-axial system is used for narrow beam forming. There are the three optical inputs for three laser radiation wavelengths in this system. Micropositioning device provides fine adjustment of the laser beam position and dimension. Rotating platform realized coarse adjustment.

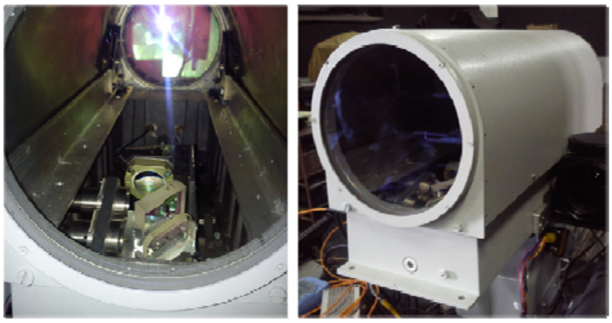

Fig. 5. Beam forming system

The semiconductor laser diode with wavelength 809 nm and maximum power 45 W was used as the laser source.

Navigation system consists of scanning device, laser pointer with green light, video camera, corner reflectors on the LPC and computer. Scanning device with green laser beam scan in given solid angle. Green light reflects then hitting on the corner reflectors. Video camera transmits to computer 15 frames per second in full resolution (1280 x 1024). Computer processes pictures, transforms them to LPC's coordinates and transmits coordinates to the rotating platform and micropositioning device.

4 Laser Power Converters

The first LPC (LPC-1) consisted of four specific 20×20 mm GaAs cells series connected (Fig. 6). GaAs cells were made for the converting laser radiation with low power density (such solar ~

130 mW/cm^2). Efficiency of each cell was about 48%.

Fig. 6. LPC-1

Conversion characteristics of LPC-1 are shown on the Fig. 7.

Maximum conversion efficiency for this LPC is about 47%.

Second LPC (LPC-2) consisted of sixteen 41×42 mm solar GaAs cells (Fig. 8). LPC-2 was made for understanding of solar cells conversion efficiency of laser radiation. LPC-2 consists of four parallel connected modules. Such as LPC-1 each module in LPC-2 consists of four series connected PVC.

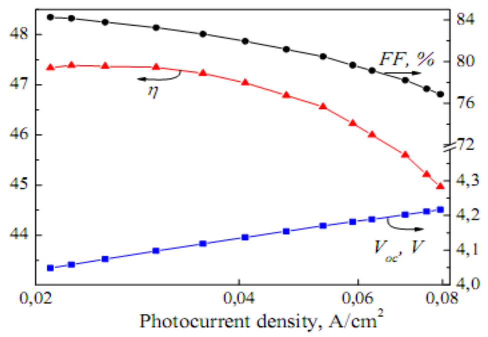

Fig. 7. Photocurrent dependence of the LPC-1 conversion efficiency η, fill-factor *FF* and open-circuit voltage V_{OC}

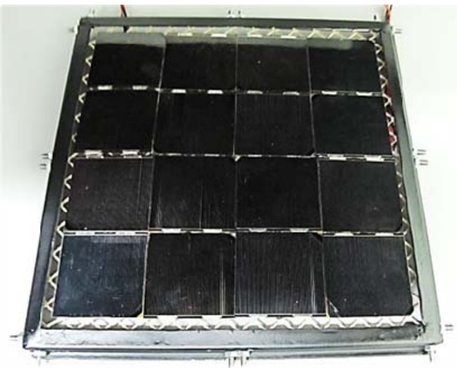

Fig.8. LPC-2

Laser power density dependence of monochromatic efficiency for LPC-2 is shown on Fig. 9. All laser radiation was at the LPC-2 area during measuring.

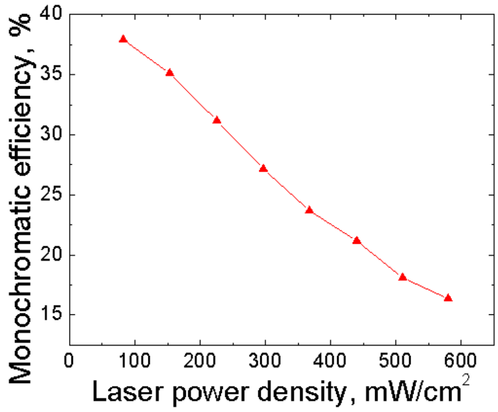

Fig. 9. Laser power density dependence of monochromatic efficiency of LPC-2

Monochromatic efficiency of each solar cell in LPC-2 is about 46%. Efficiency reducing for the LPC-2 from 46% to 37% is related to the nonoptimal radiation conditions. For high power density of laser radiation conversion efficiency of LPC-2 diminished from 37% to 15-20% because of ohmic losses in contact grid and cell structure [2].

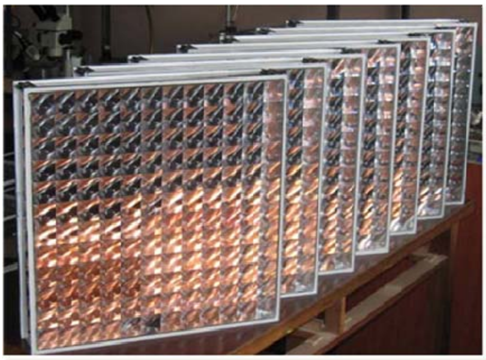

Fig. 10. LPC-3

Construction of third LPC (LPC-3) is similar to construction of concentrating solar panels with Fresnel lens. LPC-3 consists of 64 3.5×3.5 mm PVC. LPC-3 (Fig. 10) consists of 16 parallel connected modules. Each module in LPC-3 consists of four series connected PVC such as LPC-1.

Dependence of conversion efficiency of the 4 cells of LPC-3 (conversion efficiency of each cell is about 47-48%) in parallel connection and estimated power for whole module from photocurrent density are shown on the Fig. 11.

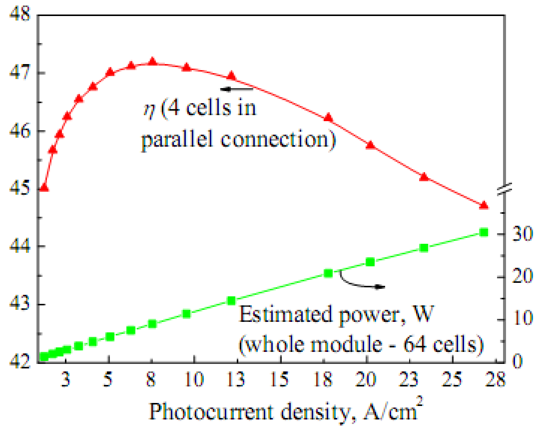

Fig. 11. Laser power conversion characteristics of LPC-3

Maximum conversion efficiency for LPC-3 is about 47%.

Real operating conditions differ from laboratory ones. Operational efficiency of photoconverting devices depends on the external conditions such as temperature, incident radiation density and connected load. In order to minimize the influence of external conditions photoconverting elements are connected to the load not directly but through dc/dc converter with maximum power point tracking (MPPT) device. MPPT device also defines output voltage of LPC.

5 UAV for Experimental Development of RPS System

For the remote power supply purposes ultralight four-rotor UAV helicopter type was made (Fig. 12).

UAV carcass is the rigid carbon frame, which was designed taking into account minimum resonance appearing as a result of thrust system. Brushless motors with propellers, engines governors, control and stabilizing systems platform, protective shroud and chassis with the photovoltaic receivers frame are install on the carbon frame. UAV control system elements are situated inside protective shroud: 2.4 GHz receiver; buffer battery (Lipo - 2S, 300-900 mAh.); tri-axis gyroscope; triaxial accelerometer.

Fig. 12. Experimental UAV

Some technical characteristics of experimental UAV are shown in the Table 1.

Table I: Technical characteristics of experimental UAV

Technical parameter	Value
Span (without propellers), mm	305
Gross weight, kg	0.39
Average power consumption, W	100
Airborne time (the power supply from buffer battery, with wind 0-1 m/sec), sec	180

100 W of power is need for the UAV takeoff. Such power can ensure LPC with 100 cm^2 area (only 10×10 cm) and incident laser radiation density about 10 W/cm^2 and photocurrent density about 3 A/cm^2.

6 Experiment

In the air UAV power supply experiments are carried out. LPC-3 was on the laboratory table and was connected to UAV via 3 meter wires. During experiment UAV was supplied from buffer battery and LPC-2 (monochromatic efficiency ~ 35%). Incident laser radiation power was equal 42 W. Power from LPC-2 was about 14 W.

7 Conclusion

For further research it is necessary to increase power of laser radiation source. Increasing of laser radiation power will allow to run experiments by illuminating of the LPC that is mounted on the board of UAV.

It is also important to research how different atmospheric agents effect on the power of laser radiation.

References

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