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Wireless Power Transmission using High Intensity Laser Power Beam

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ABSTRACT— **Laser Power Transmission (LPT) is one of the most promising technologies in the long-range wireless power transfer field. LPT research has been driven by the desire to remotely power unmanned aerial vehicles (UAVs), satellites and other mobile electric facilities. However, the low overall efficiency is the main issue that limits the implement of high intensity laser power beam (HILPB) system. As seen from the contemporary understanding of efficiency of laser powertransmission channel, the efficiencies oflaser and PV array are the main limiting factors to the HILPB system from the perspective of power conversion. Thus, a comprehensiveoverview of LPT technology is presented from the point ofefficiency optimization view in this paper. First, the basic principles of laser power transmission are brieflysummarized. Then, a survey of the efficiency optimization methods for HILPB system with regard to the laser and PV technologies is provided in detail. Additionally, the open issues and challenges in implementing the LPT technology are discussed.**

Index Terms—Laser, photovoltaic (PV), Gaussian beam,Optical propagation, Efficiency, Wireless power transmission

I.INTRODUCTION:

WirelessPower Transfer (WPT) is the technology that the electrical energy is transmitted from a power source to an electrical load without any electrical or physical connections. Compared to traditional power transfer with cord, wireless power transfer introduces many benefits such as better operational flexibility, user friendliness and product durability. Therefore, WPT technology is ideal in applications where conventional conduction wires are prohibitively inconvenient, expensive, hazardous or impossible [1]. Nowadays, WPT technology is attracting more and more attention and evolving from theories toward commercial products, from low-power smartphones to high-power electric vehicles, and the wireless powered products will come to a 15 billion market by 2020 [2].

The development of WPT technology is advancing toward two major directions, i.e., near-field techniques, which have a typical transmission distance from a few millimeters to a few meters, and far-field techniques, where the coverage is greater or equal to a typical personal area network. The former consists of two techniques: capacitive power transfer (CPT) [3], and inductive power transfer (IPT) [4-5], while the latter can be further sorted into microwave power transfer (MPT) [6] and laser power transfer (LPT) [7]. To date, both of the CPT and IPT can offer the capability of supporting high power transfer above

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kilowatt level with high efficiency in close distance [8-9]. However, the transferred power of these technologies attenuates quickly with the increase of the transmission range. Thus the power transfer distance is largely limited. Because of the ease and low-cost of implementation, these near field WPT technologies have found niche applications in everyday life, such as wireless charging of consumer electronics, electric vehicles (EV), robot manipulation and biomedical implanted devices.

With the near-field wireless power technology reaching a mature stage for domestic and industrial applications, far-field wireless power research has been gathering momentum in the last decade. Both the microwave and laser power transfer have the ability to transfer several kilowatts power over long distance up to several kilometers, which are more flexible than those near-field wireless power technologies. Despite the common advantage of long transmission range, the laser's efficient atmospheric propagation window and its ability to deliver large amounts of power to a small aperture separate it from the microwave technology and make it an enabling technology to extend the capabilities of existing applications and facilitate the development for completely new paradigms [10]. Benefits from the advancement of the laser and PV technologies, nowadays, the high intensity laser power beaming (HILPB) system has the capability to deliver energy indefinitely to remote mobile electronic devices, such as unmanned aerial vehicles (UAVs) [10], robots [11], and orbiting satellites [12]. Moreover, it is considered to have the potential to connect lunar habitats, landing sites and power-plant and can be easily reconfigured to serve as a flexible virtual power grid [13]. The vast application potential makes the pursuit of the HILPB system a worthwhile endeavor so that the full potential of the WPT will be realized in the near future.

The concept of LPT technology is based on the principle ofphotoelectric effect and has been proposed since 1965 [14]. However, the development of a practical HILPB system was slow at that time due to the low efficiencies of the system components.

II.EXISTING SYSTEM:

The discussion of significant amounts of wireless power transmission began with Nikola Tesla near the end of the nineteenth century[15]. Tesla built upon his previous research in radio transmission to successfully design, construct and demonstrate several wireless power transmitters. His designs were operated on the principles of electromagnetic radiation through tuned circuitry. Although he could power light bulbs and vacuum tubes within the vicinity of his transmitters, Tesla had a much broader vision for where his technology should be used. Rather than stringing up copper conductors on wooden poles in an effort to connect the country to a power distribution grid, he envisioned a worldwide system of radiated energy. His large scale experiments probed 4 the very fabric of our Earth's electrical conduction characteristics in an effort to exploit it for this purpose. Although Tesla was not afforded an opportunity to complete his research, much of his work is being revisited today for applications such as virtual lightning rods and weaponry. The potentially volatile nature of this technology due to the large amounts of uncontrollable radiated energy has partially prevented it

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from gaining support for wireless power transmission applications. Around the middle of the twentieth century, research on applying microwave communications technology to wireless power transmission was started.

This work mainly focused on utilizing the technology to transmit energy from solar power satellites down to Earth, or to provide power and propulsion to other spacecraft. Several large scale ground based microwave demonstrators have been constructed and operated. The drawback to this technology is that microwaves have very long wavelengths which exhibit a moderate amount of diffraction over long distances.

This necessitates a large power receiver dish, which limits the flexibility of this technology to certain applications. The ability for HILPB to focus large amounts of power to a small aperture across long distances is what separates it from the microwave technology, and this broadens the number of potential applications for the technology.

III.PROPOSED SYSTEM:

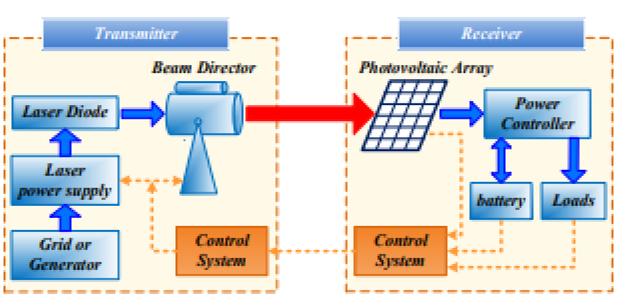

Fig. 1. Schematic diagram of a HILPB system.

Fig. 1 schematically shows a block diagram of the HILPB system [16]. As seen, the transmitter of the system converts power from a common source (battery, generator, or grid) into a monochromatic beam of light via a laser. This laser beam is then shaped with a set of optics, and directed via a beam director to the remote PV receiver. While in the receiver, specialized PV cells matched to the laser wavelength and beam intensity convert the laser light back into electricity to be used to charge a battery, run a motor, or do other work. In many ways, the HILPB system can be viewed as a kind of extension cord, with electrical power going in at one end, and electrical power coming out at the other end. Ideally, a HILPB system would have the ability to transmit any amount of power to any point in space, but practical limitations such as conversion efficiencies at the source and the receiver limit the performance of an implemented system [16]. Therefore, the end-to-end system efficiency must be considered in order to make a fair assessment, when considering the feasibility of a HILPB system in a particular application. Since each component contributes to the overall system efficiency, the use of high performance components is fundamental to developing a successful system.

TABLE I :COMPARISON OF SOME POSSIBLE LASER AND THEIR MATCHED PV CELL:

Available Commercial Laser	Wave-length λ(nm)	η_{laser} (%)	Suitable PV Material	η_{pv} (%)	Theoretical Transmission Distance
Diode,10 kW	850	50	GaAs	>50	<10km
Fiber, 20 kW	1060	25	CIS	17	<100km

IV.PROPOSED METHODOLOGY:

A. BASIC PRINCIPLES OF LASER POWER TRANSMISSION

1. ***HILPB System Architecture:***

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2.Available Types of Laser :

Nowadays, there are various types of lasers. In principle, the selection of a laser for HILPB system needs to comply with several fundamental constraints related to the: 1) the possibility to transfer the energy through the atmosphere, 2) the possibility to transfer the energy as long as possible. For the former constraint, as the atmosphere is comprised of various gases that fluctuate in composition due to environmental conditions, the atmosphere will absorb certain energies at particular wavelength. So, the lasers need to be considered must operate in the wavelength range centered around the spectrum in which the atmosphere is nearly transparent in order to maximizing energy transfer. It is reported that the window in the region between 780 and 1100 nm is particularly relevant for commonly available laser technologies that produce sufficient power for wireless power transmission.[17]

3. Available types of PV cell:

At the receiver of the HILPB system, the appropriate PV cell should be carefully designed so that the laser power can be effectively converted into electricity. In order to do so, the factors of the laser power, wavelength, temperature and the material of the PV cells should be considered. For a PV cell, the photons must have energy greater

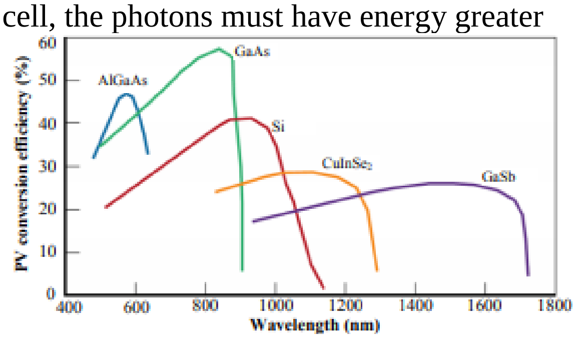

Fig 2: Spectral response of some PV materials.

than or equal to the band-gap in the material in order for the cell to generate electricity. Since the energy of a photon is proportional to its frequency, PV cells are responsive to particular frequencies of light corresponding to the cell's band-gap energies. As seen, the most widely used PV cells like Si and GaAs could reach the highest conversion efficiencies when illuminated with

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monochromatic beams of wavelengths 900nm and 850nm, respectively. On the other hand, it is the fact that when a PV cell is illuminated with more intense light than the solar radiation, the cell not only generates more absolute power, it is also more efficient for a given temperature. Thus, the PV cell that can provide efficient operation at high laser power intensity is more desirable.

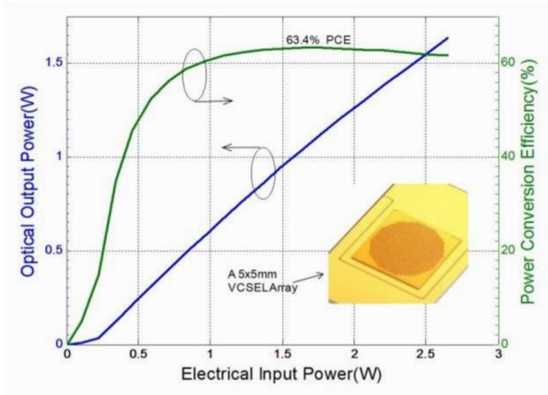
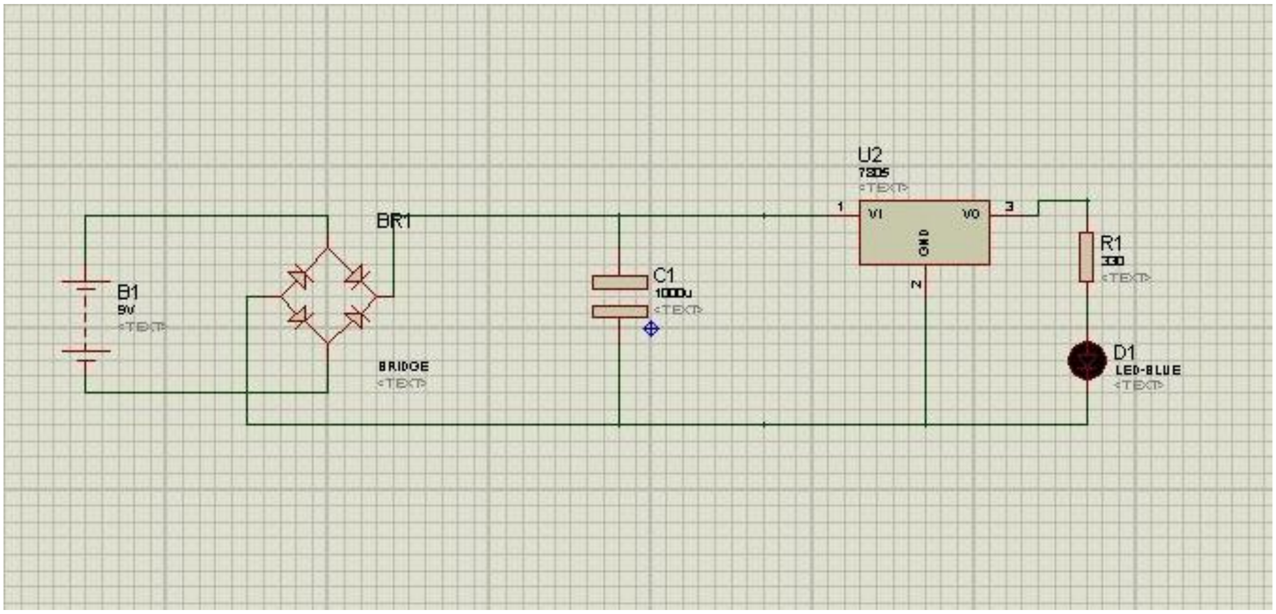


Fig 3: Electrical characteristics of LD.

V. CIRCUIT DIAGRAM:

TRANSMITTER CIRCUIT:



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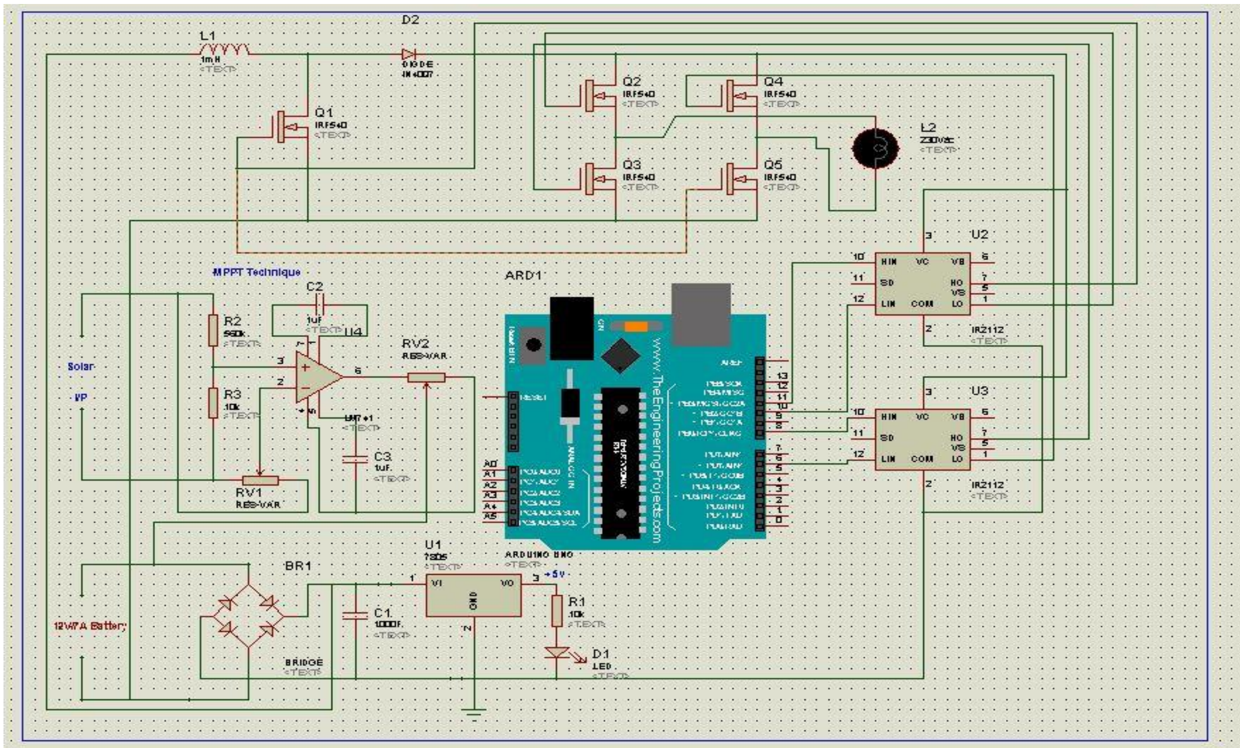
RECEIVER CIRCUIT:



VI. OUTPUT:

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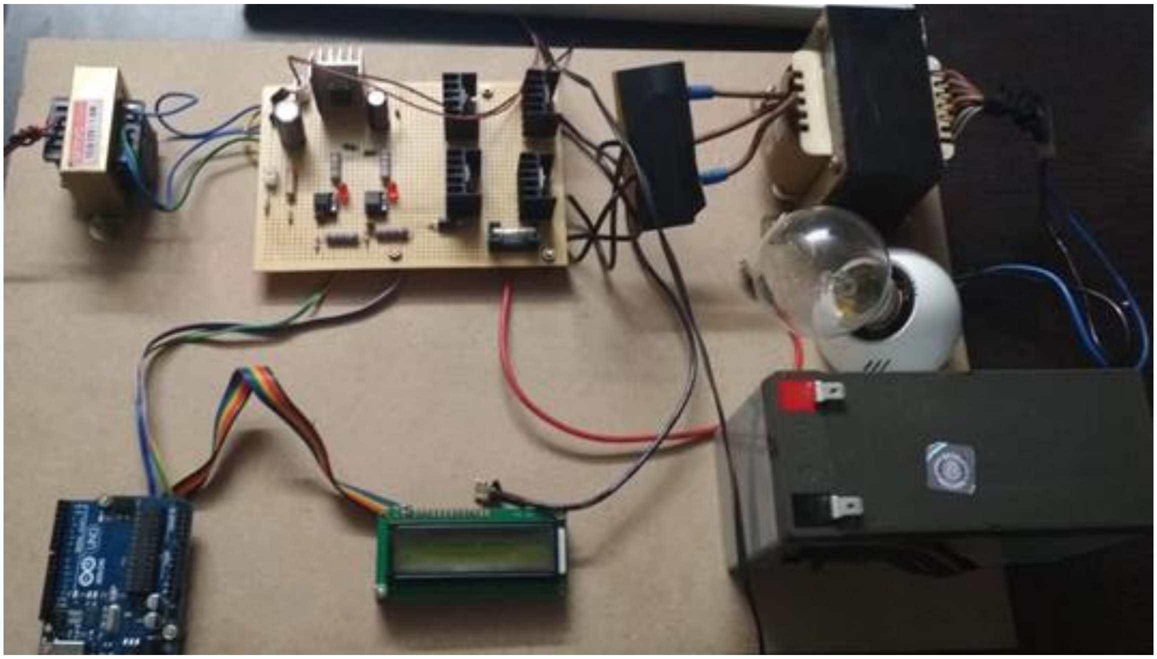

VII CONCLUSION

In this paper, the state of the art in LPT technology is reviewed. The recent progress on laser wireless power transfer is described. Several available types of lasers and PV cells are presented. The use of commercially available LD and GaAs PV cell proved to be effective. Current laser technology and reasonable apertures can produce useful beam intensity at the receiver within a range of 10km. In the operation of the HILPB system, it can be seen that the power system met with barriers arising from beam non-uniformity, which hinder the improvement of the system efficiency and may be overcome though the use of modified MPPT methods and different PV array configurations.

Moreover, the performance of the LD that operates in pulsed mode is presented, which has advantages in efficiency. Therefore, it may offer a chance to improve the operation efficiency of the system. Additionally, the open issues and challenges for future research are provided. Further research in laser wireless power transfer requires the combined efforts of the professionals and researchers in the areas of PE, control, laser, material science, and optical. The major challenge for the future is further improvements in laser wireless power transfer with better energy efficiency for a given transmission distance.

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