Laser Power Beaming: Novel Method for Wireless Power Transmission

Ketan Pandit[1], Muhammad Faisal[2], Revanasidappa M[3]

[1]Department of Mechanical Engineering PES Institute of Technology-Bangalore South Campus, Karnataka-560100, India [1]e-mail:ketanmpandit@gmail.com

[2] Department of Engineering Physics PES Institute of Technology-Bangalore South Campus, Karnataka-560100, India [2]email:faismuhammad@gmail.com

[3]Department of Engineering Chemistry PES Institute of Technology-Bangalore South Campus, Karnataka-560100, India [3]email:revum75@gmail.com

Abstract: ***In response to alarming effects of overuse of fossil fuels and ever depleting coal and oil reserves there's an urgent need to pioneer an affordable and self-sustaining energy source that could act as a substitute for present day energy sources. It's estimated that oil reserves could last only for 50 more years as per current rate of consumption. Solar energy is a promising field but its accessibility is the biggest hurdle. Keeping in mind the overall principle of harnessing of solar energy, laser could be used as a substitute to sun. A laser system which once initialized will not only produce power to generate laser beam but also to keep itself in working condition as long as required. The present study attempts the early stages of a laser power beaming system for energy harvesting. Expected outcomes will be presented with the details of prototype design. Here electricity from a portable generator source is converted into light via a suitable diode laser system. This laser beam is then focused at a remote laser panel (photovoltaic receiver of thin film solar cells) which converts the light back into electricity to be used to charge a battery, run a motor, or power an electronic device. Once developed this technology can be used to power anything like laptops, automobiles, fighter jets, space probes, drones, etc.***

Keywords: affordable and self-sustaining energy, solar energy principle, laser power beaming, portable generator, photovoltaic receiver, diode laser

1. Introduction: Laser Power Beaming (LPB), the need of future

There are two types of energy sources: renewable and non-renewable energy sources. Non-renewable sources, especially fossil fuels are the main culprits behind global warming. WHO says that over seven million premature deaths worldwide directly or indirectly due to air pollution .More people die due to air pollution than HIV and malaria combined! **BP's** annual report (2014) on proved global oil reserves says that crude oil reserves can last only for **53.3 years** at current rate of extraction. Uranium-235 isotope (fuel for nuclear reactors) is available to extent of 1% of total uranium reserves. At current installed capacity it can last only for 50 years. Also, safety issues regarding nuclear power plants, post Fukushima and the disposal of radioactive waste is also a major concern. Renewable energy sources aren't reliable since they have many major disadvantages like: -1) Power is generatedintermittently.2) Very high initial and maintenance cost.

Based on the above facts, the title, 'laser power beaming, the need of future', can be accepted.Use of laser technology can help us overcome limitations of solar technology as the overall principle remains same. The only major change is that laser will replace sun in the process. Laser can produce and provide energy as long as required. Also they need very small amount of energy for initialization when compared to the overall energy produced. The transmission and distribution loss associated with traditional electricity grids can be overcome.

2. Brief Historical Background

Rudimentary test demonstrating electrical energy transmission without using wires was first conducted by Nikolas Tesla, one of the pioneers of electromagnetism, almost a century ago.William Brown published the first paper on the topic in 1961 and in 1964 demonstrated the technology with a model helicopter powered by microwave beam. The concept of Laser propulsion was first predicted by Kantrowitz, about 25 years ago.

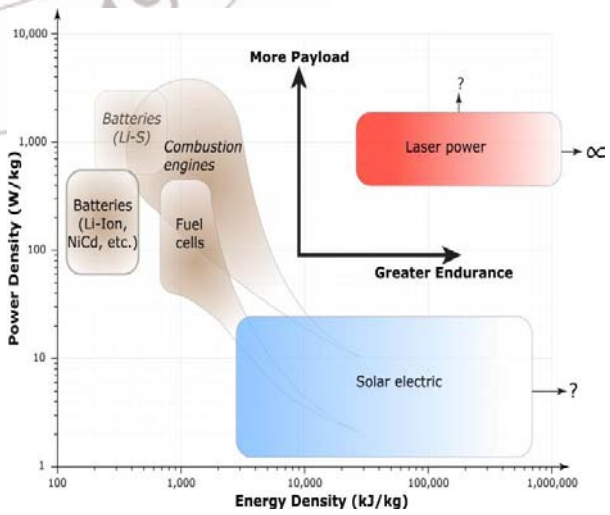

Figure 1

Figure 1 depicts power generated by various energy sources with respect to their density of usage [5]

Figure 2(source: internet)

3. Working of LPB

Laser power beaming (LPB) uses electricity from a common source, such as the electrical grid or a portable generator, and converts it into laser energy. This laser beam is then shaped with a set of optics and then directed via a gimballed mirror (also called the beam director) to a remote photovoltaic receiver [figure5]. The PV receiver converts the laser energy back into electricity to be used to charge a battery, run a motor, or do other work [2].

Other methods include: **1.** Use of laser sustained plasma to heat flowing propellant by localizing it near focal point of laser beam.[figure 3]**2**.By molecular absorption of radiation. In this method molecules are excited by using laser beam which then transfers heat to propellant gas present in engine during relaxation collisions. **3**.By means of laser ablation propulsion where in intense laser beam is focused over condensed solid or liquid fuel, which produces jet of vapors. It works just like a conventional engine where fuels are combusted to produce exhaust gases which in turn provide thrust to rocket or missile. Laser beam is produced by lasers present in the rocket or missile.[figure4]

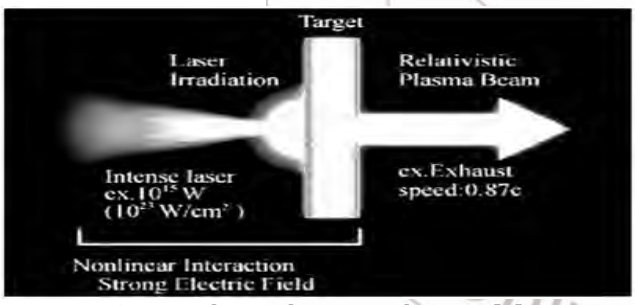

Figure 3: laser–plasma acceleration [6]

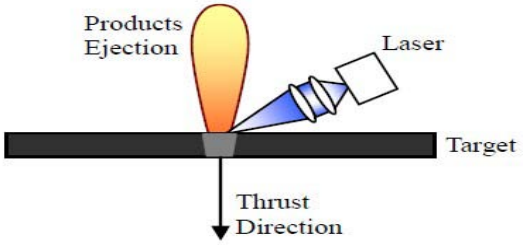

Figure 4: Laser ablation propulsion (source: internet)

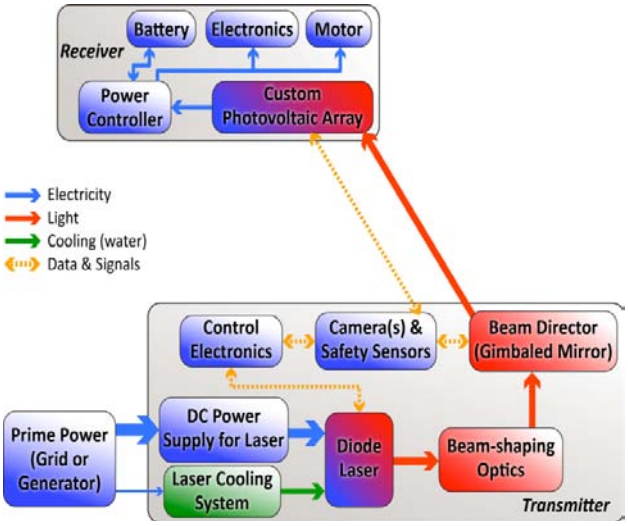

Figure 5

Schematic diagram of a laser power beaming system, showing the flow and conversion of power through the system [5]

Some specific applications in which wireless power will be the preferred power solution are [5]:

1. In small scale level the unmanned aerial vehicles (UAVs), are expected to have longer flights, power-intensive capabilities, quiet and reliable electric motors. This is a high military priority. **2**. Unattended sensors, including underwater, increasingly used for border security and industrial applications from oil exploration to agriculture.**3**. In unmanned underwater vehicles, the weight of copper wire cables significantly affects their performance**4**. Telecommunication relay towers are often located far from roads and power line and frequently at sites where weather, terrain, or even appearance limit the use of solar panels.**5**. Disaster relief. Whether it is providing power for communications and hospitals after an earthquake destroys the infrastructure or powering water cooling pumps to prevent a nuclear meltdown, like in Fukushima, a Navy shipped anchored offshore of a disaster area could beam power in for emergency response.**6**. Forward military operating bases: Fuel delivery is expensive, not only in terms of amount that needs to be spent but also in terms of loss of lives during hauling fuel for forward military operations.**7**. Electric power from space-based power plants can be delivered to the ground by laser.**8.** Cheap, routine space access, via rockets with inert propellants heated by ground-based lasers.

4. Laser Powered UAV's

Unmanned aerial vehicles [figure7] are seeing widespread military usage, and are growing in civilian applications as well. Many of the situations in which UAVs are used can benefit greatly from greater endurance.

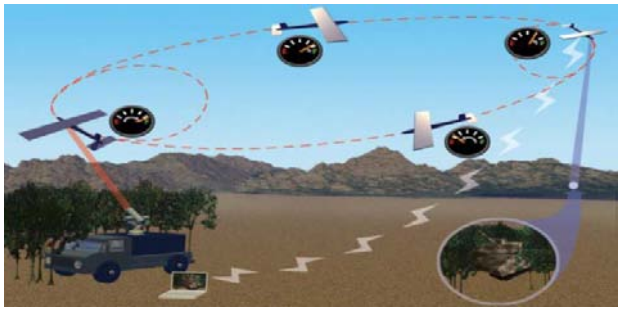

Figure 6

Figures 6 depicts working of an laser powered UAV (Recharge and fly out of sight) [2]

Figure 7(source: internet)

Schematic diagram of proposed model

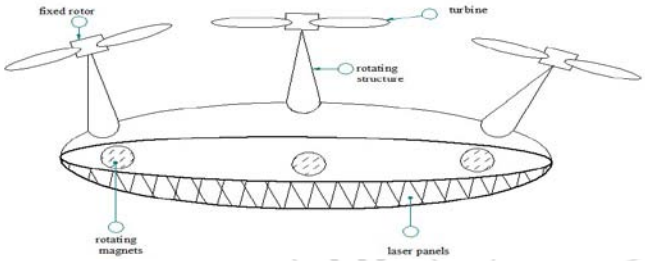

Figure 8

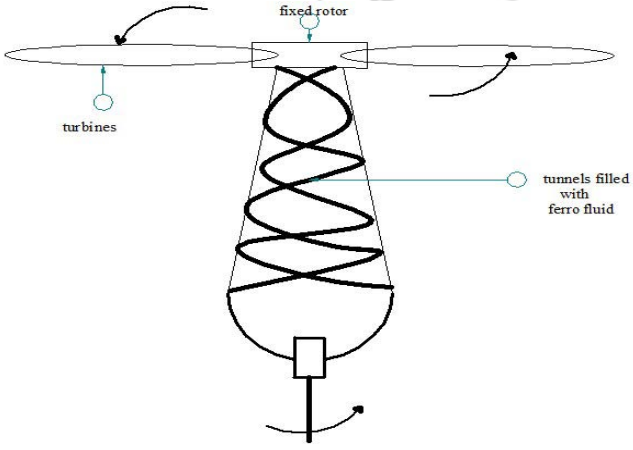

Figure 9

Figure 8 illustrates the structure of proposed UAV which is to be powered by laser power beaming method. Figure 9 illustrates a rotor of the proposed UAV (proposed name: Anthill rotor)

Different parts of proposed Laser Powered UAV

a) Ant hill rotor

Rotors have fixed turbines as shown in the figure 9 but the whole structure can be rotated. It consists of tunnels which are filled with Ferro fluids. Electricity generated with help of lasers will be used to power stepper motors (magnet).Under their influence Ferro fluids force the entire Rotor structure to rotate in order to generate enough thrust to keep UAV aloft. Tunnels will have small beadslike spherical structures, in which Ferro fluid density will be maximum as indicated in figure 10]. A fundamental property of the magnetic fluids is that, in presence of a non-homogeneous magnetic field, they are attracted to the region where the field intensity is maximum. Thus, under the influence of magnetic field, Ferro fluid will flush at one side of the spherical structure as illustrated in the figure 10. When stepper motor begins to rotate, Ferro fluid will force the rotor to rotate in the direction determined by flow of electricity through the electromagnets. The reason for ant hill rotor, to be named so is because it is been inspired by an ant-hill. The bead like tunnels of the rotor resembles the burrows dug by ants in an ant-hill.

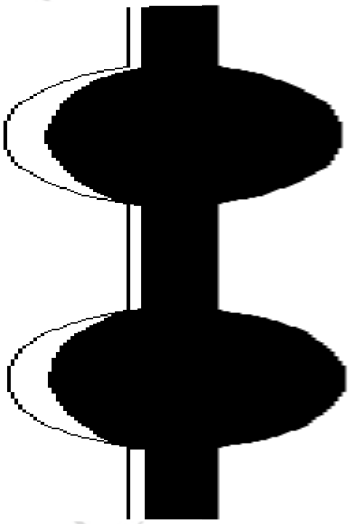

Figure 10

b) Surplus energy storing unit: Excess of energy transmitted via laser needs to be stored for future use. Laser will be fired in equal intervals of time for charging purpose. Ultra-capacitors or an array of lithium ion batteries will have to be put in use, for this purpose. While considering ultra-capacitors, they have two metal plates (like capacitors), but each one of them is coated with activated carbon and is immersed into an electrolyte. They also store electricity in electric field. Since it doesn't need chemical reactions to do that, charging and discharging is much faster than batteries. Also, there is no need of replacing it. But, the major disadvantage regarding ultra-capacitors is that they can store only five percent of the total energy of comparable Li-ion battery. Presently, Li-ion battery is the best choice.

c) Photo voltaic receiver/ laser panel

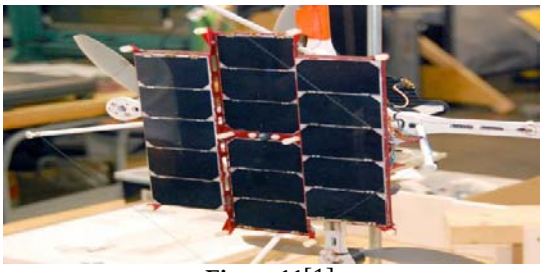

Figure 11[1]

The role of a photo voltaic (PV) receiver [figure11]is to convert incoming laser energy into useful electric energy to power all the equipment on board. In most of conventional PV receivers, ITO (Indium Tin oxide) is used as transparent conductive layer. But it's rare and expensive. Many researchers are working on a possibility to use graphene for this purpose, because of its excellent conductivity and transparency. Graphene (single layered graphite) is abundant and relatively inexpensive material. Graphene best suits our requirement. It has relatively high optical transmittance. PV receivers can be manufactured by an inexpensive screen printing technique on glass or an elastic polymer substrates.

5. Applications of laser powered UAVs

They can be used in numerous fields: - 1)Spying on enemy territory to get strategically important information about troop's movement without risk of loss of life deep inside enemy territory.2) Monitoring of terrorist camps.3)Surveillance of nuclear plants and defense installations like air and naval bases.4) Providing of real time and accurate locations of enemy targets like terror camps, tanks, missiles, weapon and fuel store houses etc., in order to launch a covert military operation.5) By mounting LIDAR system on one of them it is possible to measure pollutants in the atmosphere. It can also be used to determine topography of surface of the earth.

6. Advantages of proposed UAVs

1) Very high endurance2) Stealthy due to smaller size and ability to fly at very high altitudes which is beyond range of radars and reach of fighter jets.3) The UAVs could operate at any practical altitude 24/7, providing continuous surveillance without the risks and personnel requirements of repetitive take-offs, landings and refuelling.4) A permanently-stationed, high-altitude UAV would behave, in many ways, like a low-cost high-performance geostationary satellite, except that it would be located only a few miles above ground. Such an eternal UAV would be able to provide surveillance and communications across a pre-determined region continuously. 5) There are also ways to provide a rapidly deployable rotary wing craft to an altitude of ~100m to provide a communications relay platform as well as surveillance capability. 6) In this technique using laser beam for the production of electricity hence it is ecofriendly.7) Economically viable.

7. Future enhancements of LPB

The use of solar cells is limited only by the imagination. All the needed technical know-how exists to design photovoltaics for application to any system. There are many areas, even today, where photovoltaics can be practical and/or cost-effective for producing electricity. However, considerable work remains to develop a broad range of long-lasting, practical, affordable devices. Proposed prototype is explained in next part of this paper.

8. Proposed Laser powered laptop charger

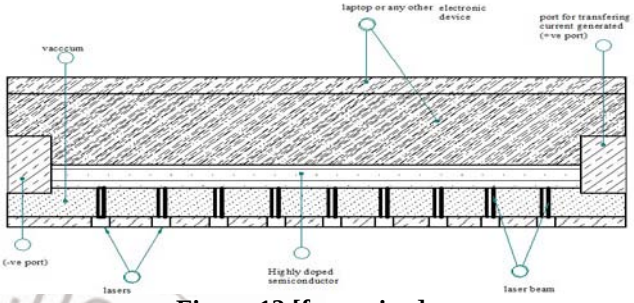

Figure 12 [front view]

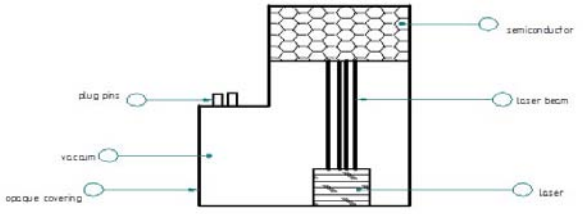

Figure 13 [side view]

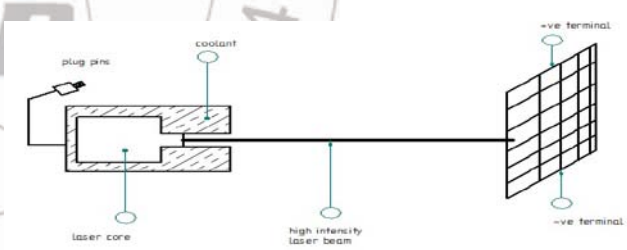

Figure 14 [mechanism]

Figure 12, clearly illustrates the structure of proposed LPB charger which is to be connected to a laptop. It consists of three major layers. First layer consists of an array of Gallium Arsenide based diode lasers immersed into a suitable coolant. The second layer consists of a vacuum chamber, through which laser beams will be fired to a highly doped semiconductor coating in the third layer. On providing sufficient potential to the third layer, electricity is obtained, that in turn will power/charge the laptop. Figure 13 shows side view of the charger and its different parts. Figure 14 depicts the mechanism by which electricity will be generated. It shows a Gallium Arsenide based diode laser immersed into a suitable coolant, firing laser onto a layer of semiconductor coating, which is connected to a negative and a positive terminal of a battery which is to be charged.

Gallium Arsenide based diode lasers

High power GaAs-based diode bars produce wavelengths in the range of 780 to 980 nm and are widely used for

pumping a broad range of rare earth doped solid-state lasers [4]. As the markets for these laser systems mature, diode lasers that operate at higher power levels with greater overall efficiency and higher reliability will be available. Its efficiency is above 60%. It's an III-V direct band gap semiconductor with zinc blende crystal structure.

9. Applications and other possibilities

Similar systems can be used for mobiles, water heaters and all other electronic systems paving way for smart homes, bringing about drastic changes in our day to day life. Automatic all electric hybrid military and commercial vehicles, airplanes, fighter jets etc. can be developed. Also, smart homes can be designed, which will be capable of generating electricity, therefore all the money that is wasted for electric transmission towers, cables etc. can be saved.

10. Advantages of LPB technology

1) Once initialized by providing small amount of energy these systems can run infinitely.2) This is an age where in mobile phones, MP3 players, laptops etc. exist alongside old-fashioned power wires and bulky batteries. Unlike information, electrical energy is still physically confined to these borderline anachronistic appliances. LPB can help us overcome this discomfort.3) The monthly electricity bills using conventional electricity supply can be cut to very low. 4) Use of battery for charging electrical and electronics devices can totally be eliminated.5) Eco-friendly

11. Economic Viability

- According to IEA (International Energy Agency), crude oil demand for the year 2016 worldwide is estimated to be 35 billion barrels (1 barrel = 159 liters) with each barrel costing $40 (presently) which implies a whopping $1.4 trillion will be spent. By using laser charging systems this wastage can be avoided to a large extent.
- By 2024, UAV industry is expected to be an $11 billion dollar industry. Each military drone costs millions of dollars depending on model and thousands of dollars is spent per hour flight. All the money that is being spent on procuring, maintaining and fueling them can be saved using laser beaming technology.
- Armed forces around the world are cutting manpower because in present age, victory in any war is no longer dependent on the army's strength but rather on how well the army is equipped. Also, maintaining a huge army, in the sense spending on salary and pension is too costly. This reduces capital expenditure meant for procuring weapons. Therefore, by use of laser powered drones, tanks etc., sharp cuts in manpower can be achieved. This can also reduce loss of valuable lives and burden on taxpayer.
- Millions of dollars that needs to be spent for power transmission infrastructure can be saved.

12. Challenges for LPB

- Very efficient cooling systems will have to be developed .(in case of portable laser powered chargers)
- The biggest limitation of laser power beaming is that it requires a line of sight (either direct or reflected off mirrors) between the transmitter and receiver. Light weather can reduce efficiency and range, but heavy weather (heavy rain or snow, or fog) can block transmission altogether.(In case of drones)
- Currently, only 50% of transferred laser energy can be converted into useful form. More research needs to be done to design a more efficient system

13. Conclusion

Transmission of power without wires isn't a theory or mere possibility, it's now a reality. Electricity can be transferred to any relevant distance by using LPB. Whether it is charging a handheld or far-off device, to changing the effect of global warming on this planet, LPB has an answer. If implemented successfully, LPB can bring about radical change in our society. It has a potential to start a new age altogether. An age where in there will be no power cuts, no wires, no electric meters, no electricity bills, no petrol bunks and no pollution. It sounds like a dream, but it's still achievable. A lot of research and investment is all that is required.

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