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ELECTRIC POWER TRANSMISSION AS LASER RADIATION

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ABSTRACT

The present paper intends to link power system and optical system to describe an application of optical systems in power system in the field of transmission. Back in the middle age, optics has been the fundamental in understanding our universe and changing our views of its place in our universe. Optics in form of laser communication and the use quantum encryption are entering the field of space research and might well reveal to be the single most enabling technology for the introduction of high intensed and high bandwidth communication. In the present paper a different application of laser not only as a communication medium but also as a means to transfer energy without wires. Different concepts and applications of wireless power transmission as laser radiation has been discussed.

Keywords: resonant coupling, WiTricity, rectenna, lasant, Nd:YAG.

INTRODUCTION

One of the major issues in power system is the losses during the transmission and distribution of electrical energy. As the demand increases day by day, the power generation increases and the power losses is also increased. In our present electricity generation system we waste more than half of our resources. Much of this power is wasted during transmission from power plant generators to the consumer. The resistance of the wire used in the electrical grid distribution system causes a loss of 26-30% of the energy generated. This loss implies that our present system of electrical distribution is only 70-74% efficient. We have to think of alternate state-of-art technology to transmit and distribute the electricity. Now-a-days global scenario has been changed a lot and there is tremendous development in every field. If we don,,t keep pace with the development of new power technology we have to face a decreasing trend in the development of power sector. The transmission of power without wires in the laser form may be one noble alternative for electricity transmission.

LITERATURE SURVEY

The concept of wireless electricity is not new. In fact it dates back to the 19th century, when Nikola Tesla used conduction based systems instead of resonance magnetic fields to transfer wireless power.

In 1905, **Nikola Tesla** with a team of construction workers in the small village of Shoreham, New York labored to erect a truly extraordinary structure. Over a period of several years the men had managed to assemble the framework and wiring for the 187-foot-tall Wardenclyffe Tower, in spite of severe budget shortfalls and a few engineering snags. The project was overseen by its designer, the eccentric-yet-ingenious inventor Nikola Tesla. Atop his tower was perched a fifty-five ton dome of conductive metals, and beneath it stretched an iron root system that penetrated more than 300 feet into the Earth's crust.

The first power stations in Earth orbit, taking advantage of the absence of day-night cycles to harvest the energy of the sun were described by the early space pioneers **K. Tsiokovski** and **H. Oberthyy**. Peter Glaser is recognised as the first to combine the visions of these early space pioneers with the practical advances in transmitting energy without wires by **W. Brown** in his 1968 publication in Science, which contained the first engineering description of a solar power satellite (SPS). It established a vision of a sustainable, practically non-depletable and abundant source of energy to meet world energy demands and triggered the imagination of researchers around the globe.

In 2007, **Soljacic's team** has done is that they have specifically tuned the transmitting unit to the receiving device. The transmission is also not hindered by the presence of any object in the line of sight. If the object to be charged is in the vicinity of the WiTricity source, then the energy transfer will undoubtedly take place. In this 'coupling resonance' system, the electric energy that is not used up by the receiver does not get radiated into the surrounding environment, but remains in the vicinity of the transmitter.

In 2010, **Ick-Jae Yoon** demonstrated that electrically small antennas can be designed to approach the recently derived theoretical bounds for wireless power transfer. Short dipole coupling is first simulated to determine the antenna design specifications for efficient coupling beyond the coupled mode region. Electrically small (kr=0.31) but highly efficient folded cylindrical helix dipoles with 50- input impedance are designed. The power transfer efficiency between two such antennas is simulated for the collinear and parallel configurations. Two folded cylindrical helix dipoles are constructed, and the power transfer efficiency between them is measured and compared to the simulation. The measured results show a power transfer efficiency of 40% at a distance of 0.25 (0.39 m at 195 MHz) in the collinear configuration.

In 2011, **Fei Zhang** explored a technology in Wireless power transfer using strongly coupled electromagnetic resonators. Although this technology is able to transmit electrical energy over a much longer distance than traditional near field methods, in some applications, its effective distance is still insufficient. In this paper, we investigate a relay effect to extend the energy transfer distance. Experiments are conducted to confirm the theoretical results and demonstrate the effectiveness of the relay approach. This approach significantly improves the performance of the present two-resonator system and allows a curved path in space to be defined for wireless power transfer using smaller resonators.

In 2012, **Ram Rakhyani** A.K. proposed an inductive link based wireless power transfer (WPT) is a common method for powering implantable electronics. The efficiency of a WPT system depends on the driver resistance and the effective resistance of the implant. In different operation modes of implant electronics, the effective load resistance varies causing significant variation in efficiency. For the same physical dimensions, the multi-coil system shows twice the better efficiency tolerance than a traditional two-coil based WPT system.

In 2013, **Dr. Joachim Taiber** of Clemson university international center for automotive research proposed advances in wireless power transfer in electrical vehicle. He also categorized the location as stationary WPT for vehicle is parked no driver is in the vehicle. Then quasi dynamic WPT for vehicle stopped driver is in the vehicle. And dynamic WPT for vehicle is stopped.

The present paper argues that advances in laser technology and operational as well as engineering advantages of concepts based on laser power transmission provide ground for further interest in this concept and a stronger involvement of the scientific laser community. This paper concentrates on technologies for long-distance wireless power transmission technologies. Short and medium range wireless power transmission (e.g. via induction or evanescent wave coupling) are not considered.

WIRELESS POWER TRANSMISSION TECHNOLOGY

In general, effective wireless energy transmission concepts need to comply with a range of fundamental constraints:

*Possibility to transfer the energy though an atmosphere: transparency of the atmosphere to the used wavelength;

*Possibility for directional emission;

*Possibility to convert the energy from the form of its source (solar, electric, heat) to a transmittable form (e.g. microwave, laser, acoustic);

*Possibility to convert the transmittable energy form back into a useful form of energy.

While this paper concentrates on laser energy transmission, it is useful to compare its performances and parameters with microwave energy transmission, the most widely studied wireless energy transmission technology. In principle, laser energy transmission systems are very similar to energy transmission via microwave technology: the power source (solar, electricity) is converted into an emitter or an emitter array that generates the directional electromagnetic radiation, which is subsequently absorbed in a receiver, which transforms the energy back into a more useful, transportable form, e.g. electricity, heat, hydrogen. The key difference, the wavelengths used, implies the major other differences between the laser and microwave-based concepts: While most wireless power transmission rely on microwave frequencies of either 2.45 or 5.8 GHz (0.12-0.05 m; both in the industrial, scientific and medical (ISM) frequency band), laser energy transmission takes advantage of the atmospheric transparency window in the visible or near infrared frequency spectrum.

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WIRELESS POWER TRANSMISSION EXPERIMENTS

The principles of wireless power transmission as considered for SPS and other applications have already demonstrated for both technologies: RF and laser systems.

MICROWAVE BASED EXPERIMENT

Microwave based experiments demonstrated so far the possibility to supply power to e.g. helicopters, balloon-based platforms, experimental airplanes, experimental cars, rovers and cell phones. The first experiment was conducted by W.Brown in 1964, when also the first "rectenna" invented and used. The longest distance between emitting and receiving points achieved so far is in the order to hundred kilometres. The largest amount of energy transmitted so far was during an experiment by the US Jet Propulsion Laboratory in 1975, when 30kW were transmitted from a 26m diameter parabolic dish to a 1.54 km distance rectenna with 85% efficiency.

In a completely different power range and for completely different applications, also the power supply to RFID chips is to be considered an application of wireless power transmission by microwaves. Furthermore, these generally use the same ISM frequency band.

LASER BASED EXPERIMENTS

While over the years, several laser-based wireless power transmission experiments and applications have been suggested and described only relatively few actual experiments have been carried out compared to the number and diversity of microwave-based experiments described in the previous section. Classified experiments involving laser power transmission technology demonstration have been reported to have taken place in the 1980s during the US Strategic Defence Initiative. These seem to have been conducted building on a heritage from the Apollo programme that used ground-based lasers with reflectors on the Moon to measure the Earth-Moon distance. Once of the observatories involved has been the Air Force Maui Optical Station (AMOS) located on top of the mount Haleaki in Hawaii, US. The SDI concepts would use ground based eximer lasers with adaptive optics and a roughly 5 m mirror in GEO and another mirror in a polar orbit at roughly 1000 km altitude.

In 2002 and 2003, Steinsiek and Schafer demonstrated ground to ground wireless power transmission via laser to a small, otherwise fully independent rover vehicle equipped with photovoltaic cells as a first step towards the use of this technology for powering airships and further in the future lunar surface rovers. [28] The experiment was based on a green, frequency-doubled Nd:YAG laser at only a few Watts. It included the initiation and supply of the rover including a micro-camera as payload as well as the pointing and tracking of the moving rover over a distance up to 280 m by applying active control loops.

Recently, similar experiments, however focussing less on the beam control and beam steering aspects but rather on the total transmitted power levels have been carried out in the frame of a context related to space elevators, organised and co-funded by NASA. Ground-based lasers have been used to power small PV-covered "climbers" attached to a tether with the objective to achieve maximum climbing speeds.

LASER POWER TRANSMISSION

Lasers generate phase-coherent electromagnetic radiation at optical and infrared frequencies from external energy sources by preferentially pumping excited states of a "lasant" to create an inversion in the normal distribution of energy states. Photons of specific frequency emitted by stimulated emission enter and are amplified as standing waves in a resonant optical cavity. The most efficient DC-to-laser converters are solid-state laser diodes commercially employed in fiber optic and free-space laser communication. Alternatively, direct solar-pumping laser generation has a major advantage over conventional solid state or gas lasers, which rely on the use of electrical energy to generate laser oscillation since the generation of electricity in space implies automatically a system level efficiency loss of roughly 60%. To generate a laser beam by direct solar pumping, solar energy needs to be concentrated before being injected into the laser medium. The required concentration ratio is dependent on the size of the laser medium, the energy absorption ratio and the thermal shock parameter (weakness of the material to internal stress caused by a thermal gradient).

LASER SELECTION

In general all types of laser can be used for transmitting power. Only the following parameters have to be considered:

*efficiency of the laser generation processes.

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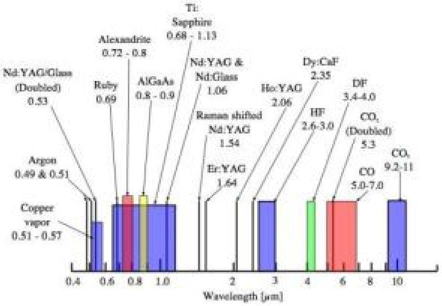
*efficiency of the absorption and laser- to-electric conversion processes.



Specifically for direct solar pumped lasers, there are several types of materials suitable as laser medium: From the standpoint of resistance to thermal stress, sapphire seems the optimal material for the laser medium. Since large sapphire crystals are very difficult to produce, most concepts rely on YAG (yttrium aluminium garnet) laser crystals. Concerning the required energy densities, solar energy compression ratios of a few hundred times are required for YAG lasers.

Scholars on terrestrial solar pumped lasers generally differentiate between two types of "solar pumped lasers": direct and indirect solar pumped versions. In this classification, the solar pumped description relates to the sun as origin of the power source, with indirect solar pumped lasers first converting it via e.g. PV panels into electricity which is then used for population inversion inside the gain medium. Direct solar pumped lasers use the solar irradiation directly as energy source injected into the laser gain medium. Under this classification, practically all space based lasers would fall under the category of "solar pumped lasers". Therefore, literature related to space applications usually makes the distinction between standard lasers (in the terrestrial laser power community called indirect solar pumped lasers) and solar pumped lasers (called direct solar pumped lasers in the standard literature on lasers.

STANDARD INDIRECTLY PUMPED LASER

An analysis of the suitability of different laser types has shown that for the visible frequency range, solid state lasers are in general considered as the most suitable candidates for (space) solar power applications, including diode lasers and diode-pumped thin disk lasers. Especially the later ones have achieved very high power levels of up to kW and overcoming some of the limitations of high power diode lasers, like thermal lensing by reducing the thermal gradients in the material. In general, these lasers rely e.g. on a laser diode or on materials like Nd:YAG. Currently, the laser diode is the most efficient laser, with an up to 80% plug-in efficiency and an emitted wavelength in the range of 795-850 nm. The most important development effort seems to be made for diodes emitting in the range of 950 nm. For larger scale space applications for wireless power transmission, large area emitting system with thousands of individual diodes could be realised. In this case, the main limitation is the thermal control of such diode panels to maintain optical coherence. Most of the solid state lasers are based on crystal technology (Nd:YAG, Nd:Y2O3, Ruby, etc.). These lasers are optically pumped in the visible range. The Nd:YAG laser (1.064 µm) is the most widely used; it can be efficiently pumped by laser diodes or solar radiation, emitting visible radiation at 0.532 µm. The overall system efficiency for the laser diode pumped concept is reported at about 15%.

CONCLUSION

The present paper intended to provide an overview over a relatively neglected are of research related to lasers using lasers to transmit energy over large distances, and especially in and from space. Concepts and candidate technologies have been presented. Laser power transmission systems are still considered as less mature than microwave based systems. However, it is argued that due to recent advances in direct solar pumped lasers, the potential integration of space and terrestrial based solar power plants and potentially radical simplifications on the space system design; laser-based wireless power transmission concepts should be matured further in order to represent a credible alternative. Both microwave and laser power transmission systems are being considered, with laser systems offering larger improvement capacities and potentially much smaller systems. Among the most important challenges for the maturation of laser power transmission technologies to industrial applications in space are the following key are

Thermal Control: A key to large scale laser power transmission is the thermal system design. The concentration factors and lasing efficiencies require the efficient rejection of substantial amounts of heat.

Laser Rod Material: Research on the optimal laser rod material to balance the frequency, temperature, efficiency, modularity and stability requirements of space based direct solar pumped lasers.

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