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10. A Comprehensive Analysis of Laser's Application in Sustainability

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Abstract:

This chapter has examined the uses of lasers in a variety of scientific and technological domains. In the current day, resource sustainability is crucial. Because of people's avaricious use of resources, many are running out. Sustainable practices in healthcare and environmental conservation are made possible by the applications of lasers in the fields of environmental sensing, water treatment, and medicine. Advances in laser technology are being driven by the expansion of its applications and ongoing innovations, which are in line with sustainability goals. Lasers are essential in helping to shape a more sustainable future across industries and global initiatives because they enable precise, efficient, and environmentally friendly processes. These days, laser technology is fascinating. We have also looked into the numerous uses of laser technology in the fields of renewable energy, agriculture, and medical.

Keywords:

Laser, technology, sustainable development, ecology, renewable energy.

10.1 Introduction:

Light Amplification by Stimulated Emission of Radiation can be abbreviated as LASER. The invention of the laser radically changed science. The development of lasers opens up new applications in various fields of science and technology. The development of the laser brings about a revolutionary shift in the fields of medical and biological sciences [1,2].

Without a doubt, the environmental, economic, and social pillars are the centre of sustainability [3]. Without sacrificing the capacity of future generations to meet their own needs, it seeks to meet the needs of the present. A more sustainable and just world depends on striking a balance between ecology, economic development, and societal equity. To guarantee a harmonious and balanced approach to progress and development, each of these interconnected pillars needs to be given attention. Of course, solid-state diode laser pumping holds great promise for the development of high-average-power laser technology. Businesses may improve the effectiveness and power of lasers by utilising this technology, which has broad implications for a number of industries. Increased energy conversion efficiency and lower costs are achieved by using solid-state diode laser pumping to produce higher-power lasers.

This breakthrough opens up new applications and industries that were previously restricted by power or cost barriers, in addition to increasing the capabilities of current laser systems [4]. These developments will probably have a big positive impact on sectors like research and development, manufacturing, healthcare, and telecommunications. Among other things, high-power diode lasers are used in scientific research, medical treatments, cutting, welding, materials processing, and telecommunications infrastructure. Furthermore, a greater demand for high-power diode laser technology may lead to more economies of scale, competition, and innovation, which could further reduce costs [4-7]. Consequently, a wider range of industries and applications may find laser technology more accessible. Solid-state diode laser pumping, which is being used to develop high-average-power laser technology, has the potential to transform a number of industries while promoting efficiency, economy, and creativity in laser-based systems.

In this modern era the sustainable use of resources is vital. To attain the sustainable development the use of modern technology is also essential. Laser is one among them. Laser technology is now an integral component in many industries, providing creative solutions that greatly advance environmental initiatives. Because of its accuracy, effectiveness, and flexibility, it has been widely used in a variety of industries, completely changing the way we tackle sustainability issues. Lasers are essential for the advancement of sustainable practises in a variety of fields, including manufacturing, energy, healthcare, and environmental monitoring. Lasers facilitate the development of environmentally sustainable solutions by maximising output and minimising waste through focused and resource-efficient processes. Let's check out the various uses for lasers that have a significant positive influence on sustainability.

10.2 Application of Lasers in Sustainability:

Lasers are used in a variety of contexts for sustainability. These are some crucial topics that point out how they can be implemented:

A. Green Manufacturing
B. Renewable Energy
C. Resource Conservation in Agriculture
D. Environment Sensing and Monitoring
E. Medical Applications
F. Water Treatment

A. Green Manufacturing:

Green manufacturing, sometimes referred to as sustainable manufacturing, utilises laser technology in a variety of production processes to increase productivity, cut waste, and reduce environmental impact. The reason behind the ongoing rise in demand for laser processing is that the high-speed processing. unparalleled consistency and precision are provided by laser processing, guaranteeing excellent outcomes throughout large-scale production [8,9]. Modern industries are using new materials with higher melting points, harder textures, and lower thermal conductivities as a result of technological advancements [10]. Unquestionably, production run size and component complexity are two areas where

traditional manufacturing techniques frequently have limitations. Due to the need for specialized tools, longer setup times, and inefficiencies when handling small or complex designs, these limitations may result in higher costs. Additive manufacturing techniques provide significant competitive advantages due to their ability to adjust to the geometrical complexity and customized design of the part to be manufactured [11,12].

B. Renewable Energy:

For use in the production of solar cells, high-power lasers have been modified, and novel techniques like laser doping, laser transfer of metal contacts, laser annealing, etc. are being developed further for industrial use [13]. Although they are not directly used to produce renewable energy like solar panels or wind turbines, lasers are essential to many aspects of the production, improvement, and upkeep of renewable energy. Indeed, bioenergy from biomass has great potential to meet the world's growing energy needs as a sustainable and renewable energy source [14,15]. The production of bioenergy can be facilitated by the use of biomass, which comprises organic materials like wood, agricultural residues, dedicated energy crops, and organic waste. By precisely cutting and processing photovoltaic materials, lasers help in the production of more durable and efficient solar panels. Additionally, they support the development and upkeep of wind turbines and help to improve the energy efficiency of different renewable energy systems [16].

C. Resource Conservation in Agriculture:

A contemporary method for precisely contouring and levelling agricultural fields uses laser technology: laser-assisted precision land levelling. By maximising resource utilisation, boosting crop productivity, and fostering environmental sustainability, laser-assisted precision land levelling is a shining example of how technology—more especially, laser technology—can dramatically improve agricultural practises. This method demonstrates the potential of technology advancements to promote sustainability and efficiency in contemporary agriculture [17]. To increase the sustainability of yields in RWCS, resource conservation techniques like laser-assisted land levelling, no-till wheat, and direct-seeded rice (DSR) can be applied. Remaining residue in the soil and avoiding tillage improve its carbon and nitrogen pools, according to several studies [18].

D. Environment Sensing and Monitoring:

Any region's capability to achieve sustainable development depends on its knowledge of local hazards and resource management [19]. Yes, there is a serious environmental risk associated with the amount of waste produced by the production and consumption of food to support the world's population of 7.2 billion. The strain on agricultural resources grows as the world's population rises. A significant amount of land, water, and energy are needed for food production. The loss of food and wasteful consumption habits waste these resources, making the shortage of resources and the impact on the environment worse [20]. A strong technology for obtaining accurate and comprehensive 3D data about objects [21,22], settings, or landscapes is laser scanning. It works by generating a point cloud that depicts the geometry of the scanned area by firing laser pulses and timing how long it takes for them to return after striking an object.

E. Medical Applications:

With its ability to provide precise and minimally invasive solutions for a wide range of medical applications, laser technology has revolutionized many aspects of medicine. As laser light is focused, it is used for the diagnosis of tissue and in operations also [23]. The development of turnkey laser systems emitting ultrafast laser pulses in the femtosecond (fs) range has been a significant advancement in laser technology [24]. These ultrafast lasers emit extremely short pulses, typically lasting only a few femtoseconds, enabling precise and high-energy laser processing in various applications. These systems usually arrive pre-configured and ready to use, which makes it easier to integrate them into different applications and promotes greater innovation and progress in a variety of fields. The precise effects on tissues, which affect optical, thermal, and mechanical results, depend on how laser energy is delivered—whether continuously wave or in pulses, and through contact or non-contact methods [25].

F. Water Treatment:

There are various ways in which the use of lasers in water treatment could support sustainability. In water treatment processes, laser technology can be used in a variety of ways to improve productivity, cut down on energy use, and lessen environmental effect. Our water supplies are severely strained as the global population grows—not in terms of water volume, but in terms of water quality. Thus, depending on the kind of pollutants in the water, different water treatment techniques such filtration, adsorption, photocatalysis, and electrolysis are used. Divergent progress in several businesses and scholarly study is evident in 3D printing (3DP) [26]. By focusing on and eliminating bacteria, viruses, and algae, lasers can be used to disinfect water. The photodisinfection process has the potential to be more energy-efficient than more conventional techniques like chlorination. When it comes to both organic and inorganic contaminants, semiconductor photocatalysts have demonstrated notable efficiency. Because of its adaptability, simplicity in synthesis, stability, and superior controllability, TiO2 is one of the most widely utilized and effective photocatalyst materials for the degradation of various organic contaminants [27].

Advanced sensor systems that detect minute pollutants in water can make use of lasers. This enables more accurate control over treatment procedures, early pollution detection, and real-time monitoring. Processes like reverse osmosis that include desalination can be made more efficient with the use of lasers. Lasers can help desalination facilities use less energy by focusing on and eliminating contaminants like salt crystals [28 – 30].

10.3 Summary and Conclusion:

In summary, the use of laser technology has emerged as a key component in supporting sustainability in a variety of industries. Its accuracy, effectiveness, and adaptability have transformed a number of industries by providing solutions that cut down on waste, preserve resources, and have a minimal negative influence on the environment. Through accurate cutting, welding, and additive manufacturing processes, lasers in manufacturing greatly reduce material waste and energy consumption, enabling green practices. In the field of renewable energy, lasers are used in the manufacturing and upkeep of wind turbines and

solar panels, which increases their efficiency and promotes the production of clean energy. Precision farming, where targeted applications minimise chemical use and optimise crop management, is one way that agriculture benefits from laser technology. Recycling and waste management powered by lasers improves sorting procedures, increases resource recovery, and decreases waste going to landfills.

Although the use of lasers in water treatment has promise for sustainability, it's important to take into account aspects like cost, scalability, and the laser technology's environmental impact. The field is undergoing continuous research and development, with the aim of augmenting the function of lasers in sustainable water treatment methodologies.

Laser technology is still evolving, leading to new applications and innovations that support sustainable development objectives. Lasers play a critical role in shaping a more sustainable future across industries and domains by enabling precise and efficient processes while minimising environmental impact.

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