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Enhance Hydrogen Production from Water Using 532 Lasers

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ABSTRACT: hydrogen production via water electrolysis under the influence of laser sounds fascinating with its unique properties, was particularly effective in promoting hydrogen production. The mechanism by which the laser promotes hydrogen production The electrolytic cell used in this work contains 270 ml of distilled water stimulated with different amounts of alcohol (2 mL - 4 mL- 6 mL - 8 mL - 10 mL). This chamber consists of two vertically oriented cylinders. Inside each cylinder there are graphite electrodes, each measuring 10 x 5 x 7 mm^3, connected to the positive and negative terminals of a direct current power source, in addition to using a green laser source (532nm). An efficiency study was conducted using a green laser with a wavelength of 532 nanometers as an optical light source for water analysis through electrolysis. Results were obtained using both the standard electrolysis method and with the green laser source (532 nm). In the case of standard electrolysis, we obtained (When adding 5 mL of alcohol, we get 6.63 hydrogen), while (Adding 10 mL of ill we get 7.44 of hydrogen) was obtained when using the laser source. The results indicate that using the laser source enhances hydrogen production significantly compared to standard electrolysis, demonstrating the laser's high effectiveness in electrolysis due to its non-absorptive property in water. This could have significant implications for renewable energy and hydrogen fuel production.

Keywords: Hydrogen production; Water splitting; Green LASER.

1. INTRODUCTION

Hydrogen energy is essential for a broad spectrum of scientific and industrial applications, particularly garnering significant attention in automotive and transportation sectors [1]. Serving as an alternative fuel, hydrogen plays a pivotal role in reducing harmful emissions. Researchers have extensively investigated methods including photovoltaic electrolysis [2], alkaline water electrolysis [3], electrolysis to ascertain efficient hydrogen production.

It sounds like you're discussing the potential benefits of using laser with electrolysis cell for hydrogen production. Laser could indeed offer advantages in terms of operating cost reduction, high purity of hydrogen production, easy maintenance, and improved energy efficiency, all of which contribute to ecological cleanliness. This method holds promise for creating a more environmentally friendly and economically viable pathway for hydrogen production, which in turn could facilitate the development of true zero-emission vehicles.

However, it is easy to mention that electrolysis, despite its potential, faces challenges due to the strength of hydrogen bonding in water molecules. Overcoming these challenges will be crucial for maximizing the efficiency and effectiveness of water electrolysis processes.

To improve the efficiency of water electrolysis, some modifications need to be made regarding hydrogen production using the diode-pumped solid-state DPSS laser operating at a wavelength of 532 nanometers [8,9] during electrolysis. This comes with a focus on the recent research papers [7-12] that have concentrated on the effect of visible light on

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hydrogen evolution through water electrolysis. But this type of laser is very expensive comparing with diode laser type, so have to use cheaper source. Like simple diode laser.

Water, as a dielectric, can undergo polarization in the presence of an electric field. According to Ming et al. [13], a major drawback of water electrolysis is electrolytic polarization, which reduces its efficiency. Essentially, polarization induces ions that hinder smooth flow and lead to reverse reactions, converting gas molecules back into ions and causing a voltage drop. The external electric field assists in aligning dipoles that become randomly oriented during polarization.

Moreover, lasers are electromagnetic waves that carry both electric and magnetic fields. The presence of an external electromagnetic field likely influences hydrogen yields. The influence of the Lorentz force on charge transfer is a well-known and significant effect in water electrolysis under electric .The potential effects related to hydrogen yield mechanisms include hydrogen bonding, intermolecular forces, and the effects of the Lorentz force induced by the external magnetic field.

The ions are activated by external electric and magnetic fields, affecting the polarization of water dipoles.

Few studies have explored the combination of optical fields and water electrolysis. Therefore, this study investigates the coupling of optical fields (LASER), current and using graphite

+electrodes via water electrolysis and compares the results obtained from each individual field. This approach holds promise for the future of the energy industry, as the abundance of optical sources materials in nature offers significant potential for accessing limitless renewable energy resources. Additionally, using optical fields in water electrolysis represents a green technology that can mitigate the greenhouse effect caused by the emission of carbon dioxide from conventional fossil fuel processes. [23, 24]

2. EXPERIMENTAL SETUP

The electrolytic cell that using in this work is presented in Fig (1), containing 500 mL of distilled water catalyzed with different amounts of Alcohol (2mL – 4mL – 6mL – 8mL – 10mL). This chamber consists of two vertically oriented cylinders. Within each cylinder are graphite electrodes, each measuring 10 x 5 x 7 mm^3, connected to the positive and negative terminals of a DC power supply. Graphite is selected for its electrically neutral properties and resistance to dissolution in water under electron current. The electrolysis process is initiated using a direct current ISO-TECH power supply model IPS 3300.

A voltage of 10 V is applied, generating a current of 0.23 mA.

A direct current (DC) was applied to initiate the decomposition of water. The current passed through the electrodes, gaseous oxygen was generated at the anode (positive) and gaseous hydrogen at the cathode (negative). The resulting gases displaced water, and their volume was collected at the top of vacuum tubes. In the electrolysis process, a diode laser served as the optical light source, operating continuously (CW) at 532 nm. The laser's output power ranged from at 100 mW, with a beam diameter of approximately 3 mm. To optimize the acceleration of charges towards their respective terminals, the collimated laser beam was precisely aligned beneath both graphite electrodes.

The hydrogen production volume is collected every 10 minutes, with a 2-minute interval between collections. Two vacuum-sealed test tubes were employed to gather the hydrogen produced. The complete schematic diagram of the experimental setup is depicted in Fig. 1. The inset image in the figure illustrates the green laser positioned beneath the cylinder tube used for collecting hydrogen production in the actual field.

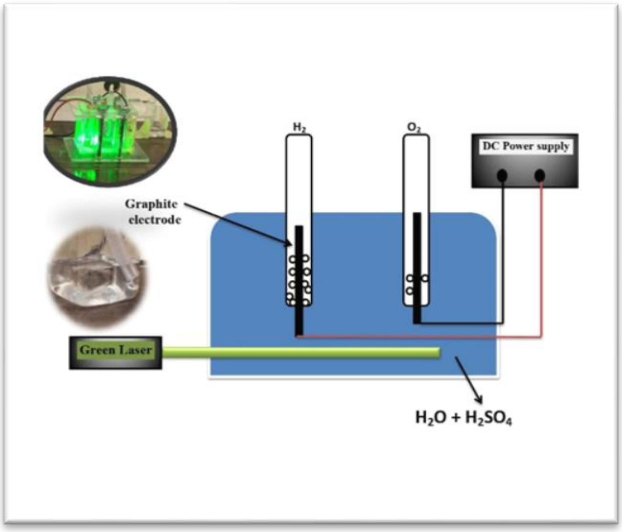

Figure 1. Experimental setup

3. Results and Discussions

Initially, the suitable optical light source was selected. In this study, a laser with a wavelength of 532 nm was tested at room temperature of 26°C and a constant power of 100 mW. The hydrogen yield through water electrolysis using the optical light source is depicted in Figure 2. Generally, the hydrogen yield increased linearly over time in both cases, with and without the presence of the light source. The linearity and production rate are summarized. The green laser at 532 nm demonstrated the highest hydrogen yield, approximately at a rate of 583 mL/min, nearly seven times higher compared to regular electrolysis. It is evident that the green laser at 532 nm is an excellent light source for electrolysis due to its non-absorbent property in water compared to other light sources. Enhancement of hydrogen yield by the 532 nm laser has also been reported in previous research.

The green laser irradiation, as indicated in reference [8], is considered transparent to water, meaning its intensity remains sustainable within the water. This

knowledge is crucial because it allows the total electric field to be utilized to support the deficient Faradic efficiency typically encountered in conventional water electrolysis. Therefore, the green laser serves as a source of an external electric field in the water electrolysis process, as also documented in other sources [9].

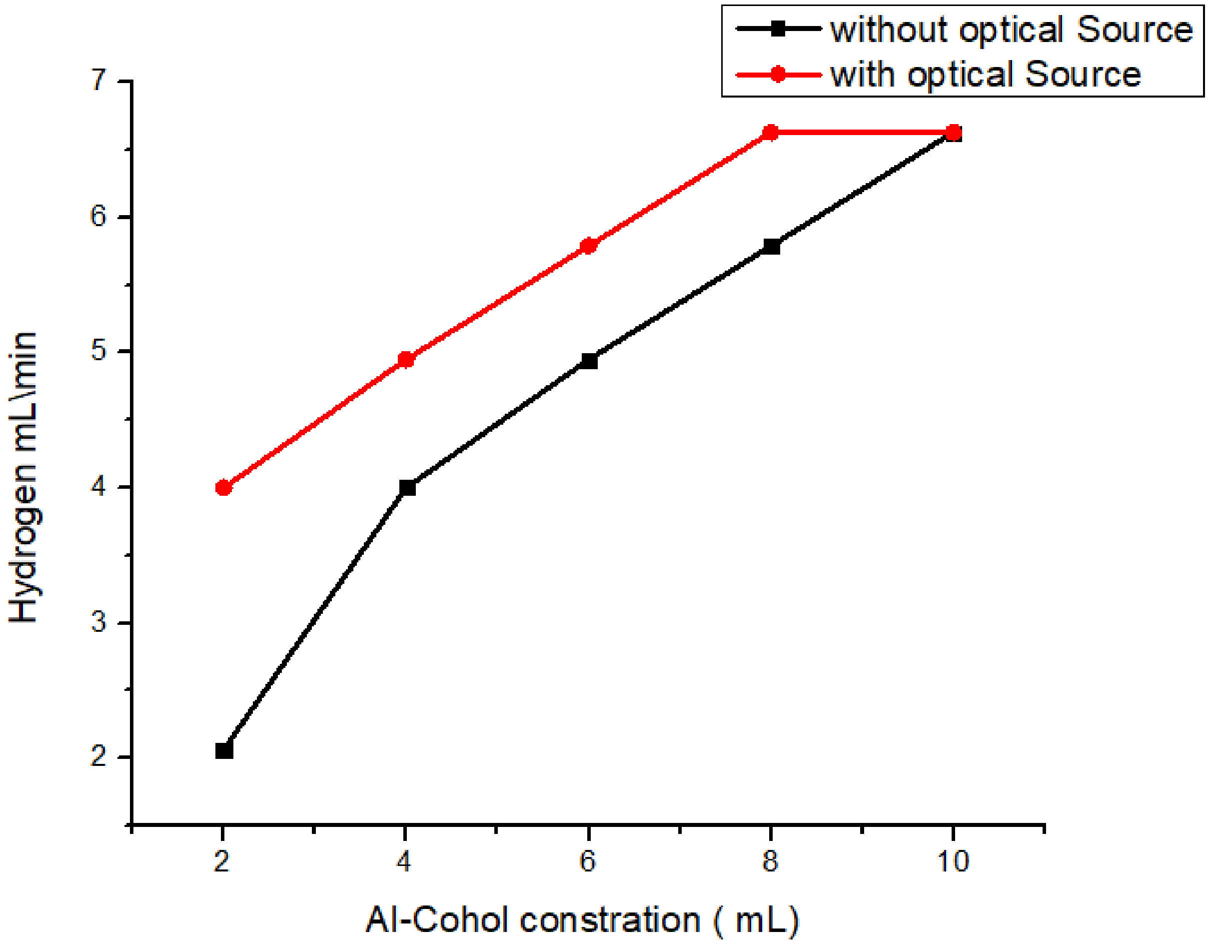

Figure 2: hydrogen production at different catalyst

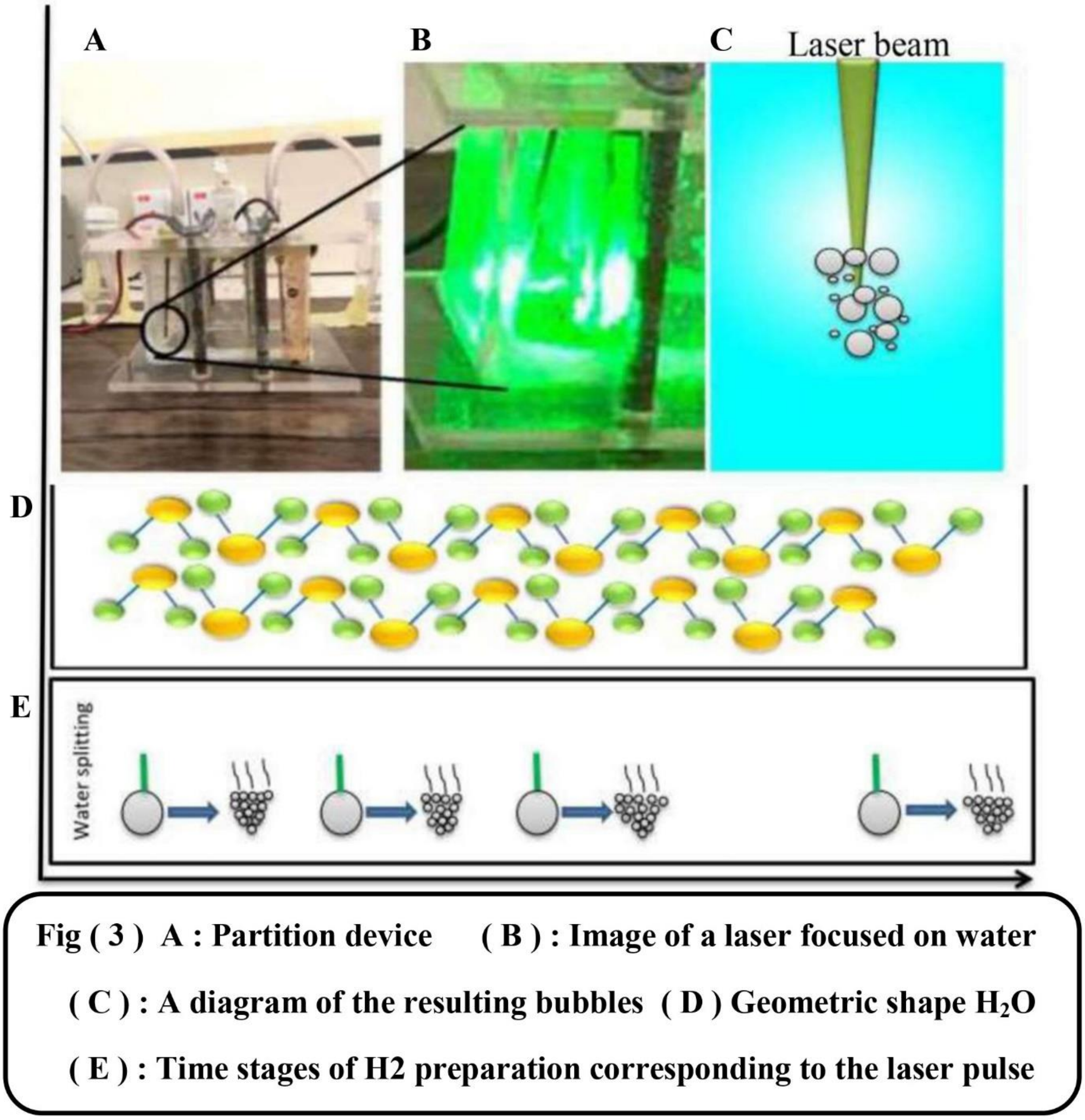

Figure 3: illustrates the hydrogen yields over time under four different operating conditions: normal water electrolysis, electrolysis with green laser irradiation at 532 nm and 184 mW power, electrolysis with an external magnetic field, and electrolysis with both 532 nm laser irradiation and an external magnetic field.

In general, all four conditions exhibited a linear relationship of hydrogen yields with respect to time. The hydrogen yield after 14 minutes from the conventional electrolysis process is 0.90 mL at a production rate of 65×10^{-3} mL/min with a repeatability (R^2) of 99%. The hydrogen yield from electrolysis with the presence of a 532 nm green laser increased to 2.3 mL at a production rate of 163×10^{-3} mL/min with a repeatability (R^2) of 99%. With the presence of a magnetic field in the electrolysis process, the hydrogen yield reached 6.9 mL at a production rate of 494×10^{-3} mL/min with a repeatability (R^2) of 99%. Finally, the combination of both optical and magnetic fields applied in the electrolysis process after 14 minutes resulted in a further increase in hydrogen yield to 8.3 mL at a production rate of 591×10^{-3} mL/min with a repeatability (R^2) of 99% .

The molecular structure of water, its dipole moment, and its hydrogen bonding properties have been extensively studied [32].

Before delving deeper into the mechanisms behind enhanced hydrogen production, it's crucial to grasp the fundamental knowledge of water's molecular structure. Water (H_2O) molecules are electrically neutral, composed of three nuclei and ten electrons (8 from O_2 and 2 from H_2) . Each hydrogen nucleus forms a covalent bond with the central oxygen atom, which holds six electrons in its outer shell. Only two electrons participate in covalent bonding with hydrogen, leaving four electrons available to pair with neighboring atoms. Consequently, the electronic charge is concentrated at the oxygen end of the molecule, where the oxygen nucleus exerts a strong attraction to these charged electrons. This arrangement allows the water molecule to act as an electric dipole moment, as depicted by the arrow in Figure.

Naturally, one end of a water molecule, carrying a negative charge, tends to attract a nearby positively charged end of another water molecule, forming what is known as a hydrogen bond. This weaker bond, approximately 23 kJ mol^{-1}, is considerably weaker than the covalent O-H bond strength of 492 kJ mol^{-1}. The resulting formation of these bonds leads to the creation of new water ions, such as hydronium (H_3O^+), marked by a red dashed circle. Another ion, the hydroxide ion (OH^-), is formed at a different site on the molecule. This phenomenon, termed autoprotolysis, involves the formation of hydrogen ions [33,34].

The water molecule returns to its original state and continues the cycle of autoprotolysis and auto-ionization during the orientation towards the polarization stage as long as voltage is applied in the water electrolysis process. This implies that water autoprotolysis and auto-ionization occur continuously in the presence of an external electric field. In the absence of such a field, the water remains in autoprotolysis. Finally, after experiencing the auto-ionization stage, the water molecule reforms and aligns in a polarized manner. The dipole moments of water, indicated by arrows, are all aligned in an upward position. It is assumed that the direction of the water's electric field is parallel to the induced external electric field. This holds true only if the electric field lacks terminals. However, it would be opposite if the electric field is induced between the electrodes as shown in the diagram.

It is naturally that polar material like water and electrolyte have their own dipole moment. Automatically polar material will set it-self according to opposite charge. Consequently, dipole moment of the water and catalyst (NaCl) are oriented in opposite direction with electric field induced by the electrode. The result is entirely different with electric field induced by laser beam. It is depending on the direction of propagation of the beam. Hence the water molecule is polarized in the same direction of the laser electric field. This phenomenon is illustrated in the schematic diagram. In this position, the hydrogen production is found increasing better than conventional water electrolysis process [8].However laser has limitation in size. It cannot cover wide area. This affects the density of water molecule to be involved in water ionization as well as the polarization. The smaller size of the beam the less density of water molecule to be ionized. Hence less hydrogen volume can be produced. As a result, optical field contribution in hydrogen production.

In the presence of a laser electric field, the high intensity of the electric field within the laser beam is sufficient to induce water polarization, leading to water ionization. This ionization process involves the splitting of protons and hydroxide ions (OH^-), which are responsible for the formation of hydrogen and oxygen gas, respectively. Such water splitting supports increased hydrogen production compared to conventional water electrolysis processes. Therefore, the combination of an optical field through a green laser in water electrolysis results in superior hydrogen production.

4. CONCLUSION

Hydrogen production from water electrolysis was studied via the assistant of electric. external fields contribute in enhancing the hydrogen production. The electrical field induced by green laser is found superior than other optical filed like laser. Thus green laser was utilized for the rest of other experiment. Obviously, the green laser has shown significant contribution in producing hydrogen via water electrolysis. The electric field induced by green laser is strong enough to polarize the water molecule Through work, when adding an amount of 2 alcohol in the presence of the laser, the effect was clearly shown on the amount of hydrogen production. By adding different amounts, and when reaching the addition of 8 alcohol and in the presence of hydrogen, a state of stability occurred in the amount produced when the laser was not present.

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