International Journal of Advanced Technology in Engineering and Science
Vol. No.4, Issue No. 03, March 2016
www.ijates.com
ijates
ISSN 2348 - 7550

A REVIEW ON LASER INDUCED IGNITION OF GASOLINE DIRECT INJECTION ENGINES

Gurgude Shubham[1], Mistry Aniket[2],Rathod Akshay[3], Shirsath Aniket[4]
Kiran Shivade[5]

[1,2,3,4]SE MECHANICAL SCHOLAR,BVCOE & RI ,Nashik (Pune University)
[5]Assistant Professor, Mechanical Dept. BVCOE& RI, Nashik,India

ABSTRACT

Sustainability with regard to internal combustion engines is strongly linked to the fuels burnt and the overall efficiency. Laser ignition can enhance the combustion process and minimize pollutant formation. This paper is on laser ignition of sustainable fuels for future internal combustion engines. Ignition is the process of starting radical reactions until a self-sustaining flame has developed. In technical appliances such as internal combustion engines, reliable ignition is necessary for adequate system performance. Ignition strongly affects the formation of pollutants and the extent of fuel conversion. This paper presents experimental results on laser-induced ignition for technical applications.Laser ignition tests were performed with the fuels hydrogen and biogas in a static combustion cell and with gasoline in a spray-guided internal combustion engine. A Nd:YAG laser with 6 ns pulse duration, 1064 nm wavelength and 1-50 mJ pulse energy was used to ignite the fuel/air mixtures at initial pressures of 1-3 MPa. Schlieren photography was used for optical diagnostics of flame kernel development and shock wave propagation. Compared to a conventional spark plug, a laser ignition system should be a favorable ignition source in terms of lean burn characteristics and system flexibility. Yet several problems remain unsolved, e.g. cost issues and the stability of the optical window. The literature does not reveal much information on this crucial system part. Different window configurations inengine test runs are compared and discussed.

1. INTRODUCTION

There have been series of advancements in the field of automobiles. Modern science and technology have contributed to this fact. One such advancement is the usage of laser for the combustion process in the combustion chamber. ”Laser ignition” is an emerging technology, still under development, has a promising future.

With the advent of lasers in the 1960s, researchers and engineers discovered a new and powerful tool to investigate natural phenomena and improve technologically critical processes. Nowadays, applications of different lasers span quite broadly from diagnostics tools in science and engineering to biological and medical uses. In this seminar basic principles and applications of lasers for ignition of fuels are concisely reviewed from the engineering perspective. The objective is to present the current state of the relevant knowledge on fuel ignition and discuss select applications, advantages and disadvantages, in the context of combustion of engines.

Fundamentally, there are four different ways in which laser light can interact with a combustible mixture to initiate an ignition event. They are referred to as thermal initiation, non-resonant breakdown, resonant breakdown, and photochemical ignition.

By far the most commonly used technique is the non-resonant initiation of combustion primarily because of its freedom in selecting the laser wavelength and ease of implementation. Recent progress in the area of high power fiber optics allowed convenient shielding and transmission of the laser light to the combustion chamber. However, issues related to immediate interfacing between the light and the chamber such as selection of appropriate window material and its possible fouling during the operation, shaping of the laser focus volume, and selection of spatially optimum ignition point remain amongst the important engineering design challenges. One of the potential advantages of the lasers lies in its flexibility to change the ignition location. Also, multiple ignition points can be achieved rather comfortably as compared to conventional electric ignition systems using spark plugs.

Although the cost and packaging complexities of the laser ignition systems have dramatically reduced to an affordable level for many applications, they are still prohibitive for important and high-volume applications such as automotive engines. However, their penetration in some niche markets, such as large stationary power plants and military applications, are imminent. Lasers a type of nonconventional ignition sources can contribute to a future performance optimization.

II. LITERATURE REVIEW

J D Mullett,R Dodd performed analysis of single-stage two bed adsorption refrigeration cycles working at pressurized conditions. Four specimens of activated carbon adsorbent and refrigerant pairs, which are Maxsorb III with Propane, n-butane and concluded that the specific cooling effect increases with the requiredevaporating temperature andregenerating temperatures. It however decreases with increasing ambient temperatures due to the higher cold reservoir available to the system and At higher required chilling temperatures and lower ambient temperatures, R-32 is preferred with higher specific cooling capacities.[1]

R. Freeman, C. Anderson, J. M. Hill, J. King, The use of high-intensity lasers to cause ignition in inertial confinement fusion is presented, with emphasis on current experimental programs and physical concepts that are at the forefront of the field. In particular, we highlight the issues of fast electron transport through dense materials, an essential element of the "Fast Ignitor" concept. .[2]

M. Lackner*, F. Winterpresented Sustainability with regard to internal combustion engines is strongly linked to the fuels burnt and the overall efficiency. Laser ignition can enhance the combustion process and minimize pollutant formation. This paper is on laser ignition of sustainable fuels for future internal combustion engines. Ignition is the process of starting radical reactions until a self-sustaining flame has developed. In technical appliances such as internal combustion engines, reliable ignition is necessary for adequate system performance. Ignition strongly affects the formation of pollutants and the extent of fuel conversion. This paper presents experimental results on laser-induced ignition for technical applications.

Laser ignition tests were performed with the fuels hydrogen and biogas in a static combustion cell and with gasoline in a spray-guided internal combustion engine. A Nd:YAG laser with 6 ns pulse duration, 1064 nm wavelength and 1-50 mJ pulse energy was used to ignite the fuel/air mixtures at initial pressures of 1-3 MPa.

Schlieren photography was used for optical diagnostics of flame kernel development and shock wave propagation. Compared to a conventional spark plug, a laser ignition system should be a favorable ignition source in terms of lean burn characteristics and system flexibility. Yet several problems remain unsolved, e.g. cost issues and the stability of the optical window. The literature does not reveal much information on this crucial system part. Different window configurations in engine test runs are compared and discussed. .[3]

Swapnil S. Harel1, Mohnish Khairnar2, Vipul Sonawane3 studied on The thermodynamic requirements of a high compression ratio and a high power density are fulfilled well by laser ignition. Through thispaper, the objective is to present the current state of the relevant knowledge on fuel ignition and discuss selected applications,advantages, in the context of combustion engines. Sustainability with regard to internal combustion engines is strongly linked to the fuels burnt and the overall efficiency. Laser ignition can enhance the combustion process and minimize pollutant formation. This paper is on laser ignition of sustainable fuels for future internal combustion engines. Ignition is the process of starting radical reactions until a self-sustaining flame has developed. In technical appliances such as internal combustion engines, reliable ignition is necessary for adequate system performance. Ignition strongly affects the formation of pollutants and the extent of fuel conversion. Laser ignition system can be a reliable way to achieve this. Fundamentally, there are four different ways in which laser light can interact with a combustible mixture to initiate an ignition event. They are referred to as 1. Thermal initiation, 2. Non resonant breakdown, 3. Resonantbreakdown, and 4. Photochemical ignition. By far the most commonly used technique is the non-resonant initiation of combustion primarily because of its freedom in selecting the laser wavelength and ease of implementation. Optical breakdown of a gas within the focal spot of a high power laser allows a very distinct localization of the ignition spot in a combustible material. The hot plasma whichforms during this breakdown initiates the following self-propagating combustion process. .[4]

III. LASER IGNITION SYSTEMS

3.1 What is Laser?

Lasers provide intense and unidirectional beam of light. Laser light is monochromatic (onespecific wavelength). Wavelength of light is determined by amount of energy releasedwhen electron drops to lower orbit. Light is coherent; all the photons have same wavefronts that launch to unison. Laser light has tight beam and is strong and concentrated. Tomake these three properties occur takes something called “Stimulated Emission”, inwhich photon emission is organized.

Main parts of laser are power supply, lasing medium and a pair of precisely aligned mirrors. One has totally reflective surface and other is partially reflective (96 %). The most important part of laser apparatus is laser crystal. Most commonly used laser crystalis manmade ruby consisting of aluminum oxide and 0.05% chromium. Crystal rods are round and end surfaces are made reflective. A laser rod for 3 J is 6 mm in diameter and70 mm in length approximately. Laser rod is excited by xenon filled lamp, whichsurrounds it. Both are enclosed in highly reflective cylinder, which directs light fromflash lamp in to the rod. Chromium atoms are excited to higher energy levels. The excitedions meet photons when they return to normal state. Thus very high energy is obtained inshort pulses. Ruby rod becomes less efficient at higher temperatures, so it is continuouslycooled with water, air or liquid nitrogen. The Ruby rod is the lasing medium and flashtube pumps it.

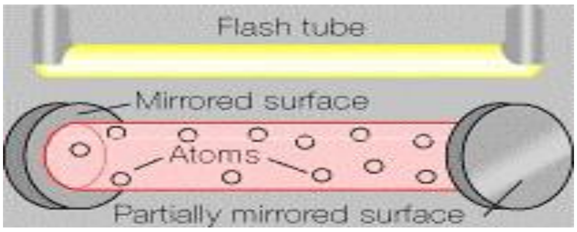

FIG 1. Laser in its non lasing state.

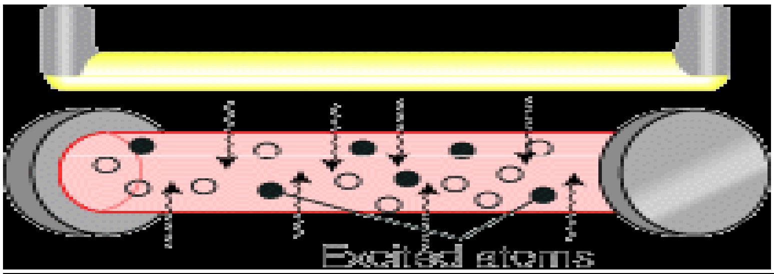

FIG 2 The flash tube fires and injects light into the ruby rod. The light excites atomsin the ruby.

FIG 3 some of these atoms emit photons.

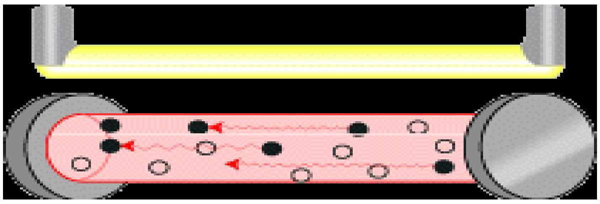

FIG 3 Photons run in a directional ruby axis, so they bounce back and forth off themirrors. As they pass through the crystal, they stimulate emission in other atoms.

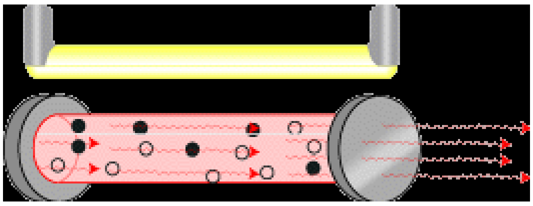

FIG 4 Monochromatic, single phase calumniated light leaves the ruby through the halfsilvered mirror laser light

IV. LASER INDUCED SPARK IGNITION

Light Amplification by Stimulated Emission of Radiation (LASER or laser) is a mechanism for emitting electromagnetic radiation, often visible light, via the process of stimulated emission. The emitted laser light is (usually) a spatially coherent, narrow low-divergence beam,that can be manipulated with lenses. Laser light is generally a narrow-wavelength electromagnetic spectrum monochromatic light.

The laser used in this ignition is Nd:YAG (neodymium-doped yttrium aluminum garnet) laser of 1064 nmNd:YAG (neodymium-doped yttrium aluminum garnet; Nd:Y3Al5O12) is a crystal that is used as a lasing medium for solid-state lasers. The dopant, triply ionized neodymium, typically replaces yttrium in the crystal structure of the yttrium aluminum garnet (YAG), since they are of similar size. Generally the crystalline host is doped with around 1% neodymium by atomic percent.

4.1 Reasons for Adapting Laser Ignition

Since spark plugs are an integral part of the combustor liner, the ignition kernel is usually located in the suboptimal quench zone of the combustor.

Lean mixtures along the liner increase the demand on ignition energy, leading to an increased erosion of the spark plug electrodes, and thus to a reduced reliability and lifetime of the igniter. Since spark plug ignition shows a reduced ignitability of lean mixtures below an equivalence ratio of 0.6.Laser ignition is a possible candidate to solve some of problems because it allows uncoupling of the limiting link between the location of the ignition source and the ignition kernel. Lasers are able to ignite the mixture at the best thermodynamic and aerodynamic conditions from almost any installation location. Therefore laser ignition is more independent from variations of the local equivalence ratio than other ignition concepts.It is known that lasers are able to ignite leaner mixtures compared with spark plug ignition because there are no electrodes surrounding the initial flame kernel, which, in the case of the spark plug, cool down the kernel and prevent it from evolving further into the combustion chamber.

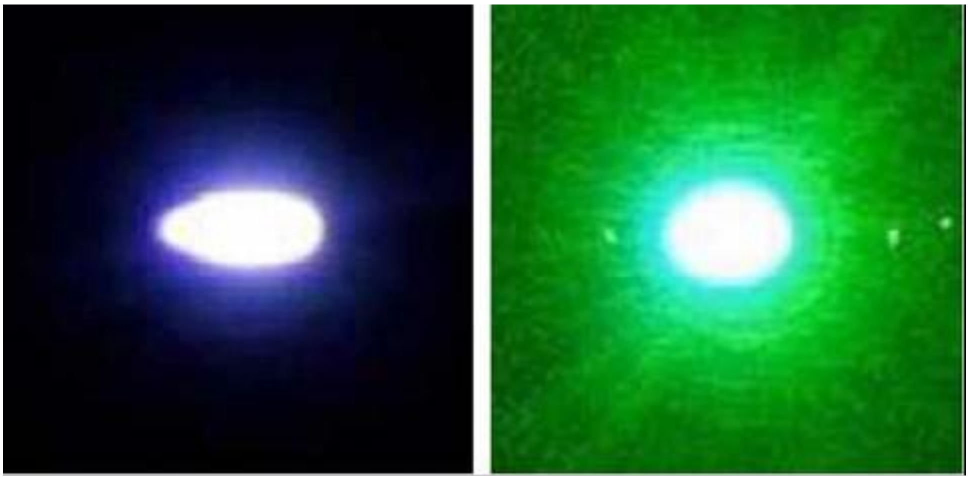

FIG.6 Optical breakdown in air generated by a Nd:YAG laser. Left: at a wavelength of 1064 nm, right: at 532 nm [4]

The process begins with multi-photon ionization of few gas molecules which releaseselectrons that readily absorb more photons via the inverse bremsstrahlung process toincrease their kinetic energy. Electrons liberated by this means collide with othermolecules and ionize them, leading to an electron avalanche, and breakdown of the gas.Multiphoton absorption processes are usually essential for the initial stage of breakdownbecause the available photon energy at visible and near IR wavelengths is much smaller than the ionization energy. For very short pulse duration (few picoseconds) themultiphoton processes alone must provide breakdown, since there is insufficient time forelectron-molecule collision to occur. Thus this avalanche of electrons and resultant ionscollide with each other producing immense heat hence creating plasma which issufficiently strong to ignite the fuel. The wavelength of laser depend upon the absorptionproperties of the laser and the minimum energy required depends upon the number ofphotons required for producing the electron avalanche.

4.2 Ignition in Combustion Chamber

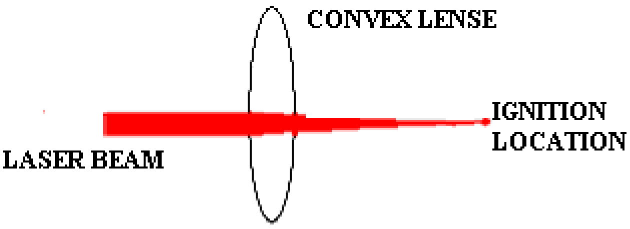

Fig.7 Ignition in combustion chamber

The laser beam is passed through a convex lens, this convex lens diverge the beam andmake it immensely strong and sufficient enough to start combustion at that point. Hencethe fuel is ignited, at the focal point, with the mechanism shown above. The focal point isadjusted where the ignition is required to have. [3]

4.3 Advantages of Laser Induced Spark Ignition

- Location of spark plug is flexible as it does not require shielding from
  Immense heat and fuel spray and focal point can be made anywhere in thecombustion chamber from any point It is possible to ignite inside the fuel spray asthere is no physical component at ignition location.
- It does not require maintenance to remove carbon deposits because of itsself cleaning property.
- Leaner mixtures can be burned as fuel ignition inside combustion chamberis also possible here certainty of fuel presence is very high.
- High pressure and temperature does not affect the performance allowing The use of high compression ratios.
  Flame propagation is fast as multipoint fuel ignition is also possible.
- Higher turbulence levels are not required due to above said advantages.

V. CONCLUSION

- The ussability of a laser-induced ignition system on direct injected gasolineengine has been working. Main advantages are the almost free choice of theignitionlocation within the combustion chamber, even inside the fuel spray. Significantminimisation in fuel consumption as well as reductions of exhaust gases show thepotential of the laser ignition process.
- At present, a laser ignition plug is very expensive compared to a standard Electrical spark plug ignition system and it is nowhere near ready for deployment.But the potential and advantages certainly make the laser ignition more attractive inmany practical applications.

REFERENCES

[1] Bergmann and Schaefer, Lehrbuch der Experimentalphysik: Elektrizit¨at und Magnetism us, vol. 2, Walter de Gruyter Berlin, 1981.

[2] D. R. Lidde, ed., CRC Handbook of Chemistry and Physics, CRC Press, 2000

[3] J. Ma, D. Alexander, and D. Poulain, "Laser spark ignition and combustion Characteristics of methane-air mixtures," Combustion and Flame **112 (4)**, pp. 492–506, 1998

[4] J. Syage, E. Fournier, R. Rianda, and R. Cohn, "Dynamics of flame propagation Using laser-induced spark initiation: Ignition energy measurements," Journal of Applied Physics **64 (3)**, pp. 1499–1507, 1988.

[5] Lambda Physik, Manual for the LPX205 Excimer Laser, 1991

[6] M. Gower, "Krf laser-induced breakdown of gases," Opt. Commun. **36, No. 1**, pp.43–45, 1981.

[7] M. Lavid, A. Poulos, and S. Gulati, "Infrared multiphoton ignition and Combustion enhancement of natural gas," in SPIE Proc.: Laser Applications in Combustion and Combustion Diagnostics, **1862**, pp. 33–44,1993.

[8] P. Ronney, "Laser versus conventional ignition of flames," Opt. Eng. **33 (2)**, pp. 510–521, 1994.

[9] R. Hill, "Ignition-delay times in laser initiated combustion," Applied Optics. **20(13)**, pp. 2239–2242, 1981.

[10] T. Huges, Plasma and laser light, Adam Hilger, Bristol, 1975.