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# Plasma Igniter, the Next Gen Ignition System

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**Abstract:** To achieve current and future United States CAFE standards, as well as fuel economy and emission requirements in Europe and the rest of the globe, manufacturers are implementing several strategies: reducing vehicle size and weight, increasing power plant complexity by adding turbo and superchargers, modifying the combustion and emission cleanup environment, and introducing a broader range of hybrid and all electric vehicles.

Additionally, to take advantage of the enormous increase in natural gas production in the United States and elsewhere, natural gas and multi-fuel vehicles are increasing in market share, which will require significant design and development considerations in the near future. All of these strategies are necessary but ignore the greatest potential for improvements: the ability to efficiently ignite and consume ultra-lean mixtures of both liquid and gaseous fuels, providing complete combustion while minimizing harmful emissions.

Plasma Igniter has developeda compact, next generation ignition system. Testing has demonstrated that this system is successful in igniting conventional lean fuel/air mixtures and particularly effective in igniting alternative fuels. The system is effective as a low-energy ignition source at high compression ratios, creates lower levels of controlled emissions and, most importantly, provides on-board diagnostic capabilities for real-time ignition and combustion modifications.

**Keywords:**Plasma Igniter, Ignition, QWCCR, Internal Combustion Engine, Lean Burn, Diagnostics

## I. INTRODUCTION

This paper was created to introduce a new breakthrough in ignition systems for internal combustion engines. It has proven or promises to provide (1) more efficient combustion of gaseous and liquid fuels, allowing for leaner burn and more complete combustion; (2) lower temperature ignition initiation, which will result in the reduction of complex NOx and SOx emissions; (3) real-time, in-cylinder diagnostics and measurements per combustion cycle allowing for real-time adjustments in engine operational parameters; (4) engine designers and manufacturers with an advanced technology that will still allow for the continued use of the present form factor, shape, and support systems of current internal combustion engines; and (5) significantly greater flexibility in the way carbon based fuels are converted to motive force.

The results will greatly increase the overall transportation efficiency and provide the increase in fuel economy and emissions reduction mandated by a growing number of international regulatory authorities. Greater transportation efficiency equates to: less fuel burned and thus the quantity stored on board the vehicle for the equivalent range, decreased vehicle weight and component complexity, simpler catalytic converters and emissions handling, and decreased vehicle strength and material requirements.

Just as important will be the impact on consumers who will realize a major reduction in the energy costs that are a fundamental portion of their earnings. Along with these cost savings will be the value-added improvements to their transportation medium that will see increased performance without the ever-increasing need for advanced emissions control systems, with their associated costs, weight and complexity.

The patented and patent pending radio frequency plasma ignition systemthe subject of this article, is a potential game changer and is proving to provide unique opportunities for the future of transportation technology[1][2][3][4] (Figure 1). It has also created a new opportunity to look at the environmental impact of the vehicles we use daily and how these same vehicles can reduce that environmental footprint from not just fuel use but also through the lifecycle and sustainability considerations of the vehicle.

**Figure 1.** The generated plasma from the Plasma Igniter technology.[5]

This article presents a synopsis of the need for continued technological advancements, and more specifically technology breakthroughs for the transportation sector. While this paper is centered on the transportation sector, and more specifically the personal vehicle - the automobile plus light trucks and vans - its real focus is on the introduction of a breakthrough technology that will potentially impact all applications using internal combustion engines.

It also includes a brief primer on personal transportation vehicles, the engines that propel them and the way fuel is combusted. This paper hopes to serve, as an introduction to the global market needs to improve transportation efficiency and decrease the environmental impact. Finally, this paper will serve to provide the introductory information about this revolutionary ignition technology that is needed by the transportation sector.

This paper will hopefully also introduce the next generation of advanced ignition technology to the reader that needs this technology for their continued growth both socially and economically.

## II. PERSONAL TRANSPORTATION

Even with highly developed public transportation, there is a need for personal transportation. This is particularly true for large landmasses where the population density may not economically warrant the creation of public transportation systems. This is also evident in developing counties that need individualized modes of transportation prior to justifying the need for public transportation.

Most current personal transportation relies on motive force supplied through some stored energy supply. A majority of this energy currently comes from fossil fuels. Even the small numbers of vehicles powered by batteries mostly receive their charge from a power plant run on coal or natural gas. The reality is that it is hard to match the energy capacity per volume and weight of petroleum-based fuels. The key then is to use these fuels in the most effective ways to cut down on waste, reduce cost and minimize the environmental impact.

Consider the automobile of which there are well over 1.2 billion in use in the world today, with the prediction that this number will exceed over 2 billion by the year 2035[6]. Note that of this quantity approximately 260 million are in use in the United States[7]. The global total represents a significant worldwide use of carbon-based fuels with the economic costs and environmental impact, more heavily weighted towards the countries and regions with little or no regulatory supervision and/or control over the efficient use of the fuel or the cleanup after its use.

An overwhelming majority of these vehicles use petroleum-based products and even with the anticipated increase in electric and hybrid vehicles, the U.S. Department of Energy through the year 2050 estimates that petroleum based fuel use will exceed 80% of the total mobility energy distribution in the United States and even more for the rest of the world. Looking at the numbers for the U.S. it is after at least 2025 before there is even a measureable change from the current almost entirely, percentagewise, dominated use of petroleum-based fuels (Figure 2).

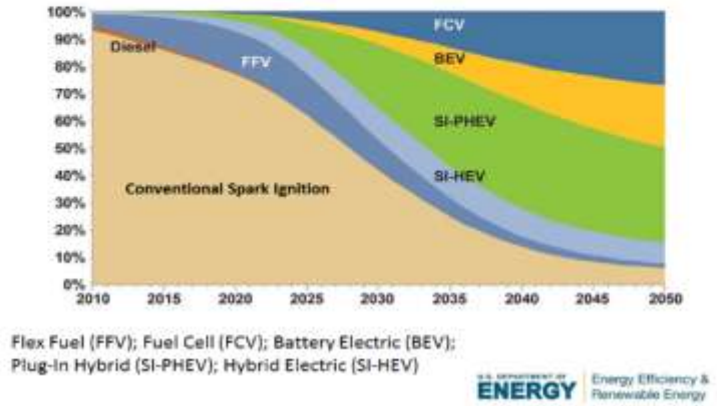


**Figure 2.** Department of Energy projected vehicle engine type through 2050[8]

## III. THE PERSONAL AUTOMOBILE

Since the world seems to be destined, by necessity and not convenience, to continue the use of carbon-based fuels, at least for the next few decades, it would seem reasonable to consider and expect there to be a series of technological innovations and possible breakthroughs to gain further value from these fuels while reducing the cost per mile and the environmental impact. All of this of course is in conjunction with improving the entire vehicles' safety, convenience, drivability and sustainability.

The U. S. Department of Energy has established the energy requirements for the average personal vehicle for its use during its lifetime. These energy requirements are best understood as they relate to the function and support of the vehicle and its normal use [9].These major vehicle systems fall into the following categories: drivetrain losses, power to wheels, parasitic losses, and engine losses (Figure 3).

This group, excluding the engine losses, represent less than a third of the total energy used by the vehicle in carrying out its functions. Every automobile designer and manufacturer seeks to improve the efficiency of vehicles by reducing the fuel needed to support each of these systems. This includes reducing mechanical friction of the moving parts plus the rolling resistance of the tires and even the wind resistance due to frontal profile and body shape.

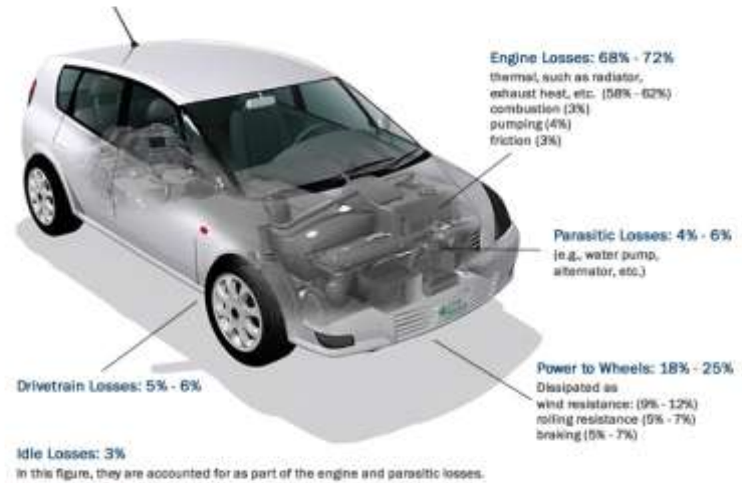


**Figure 3.** Energy requirements for combined city/highway driving [10]

The reality is that the rest of the energy consumed in the vehicle is related to engine requirements. With combustion within the cylinders approaching their efficiency limits, other strategies need to be employed to improve the overall vehicle efficiency. In fact, small incremental improvements in all of the other categories will not gain the needed fuel economy numbers required by most consumers and the regulatory agencies unless the engine's energy requirements are addressed aggressively.

Each of these energy use categories will see continued innovative improvements but it will take a sizeable decrease in the engine energy requirements to meet the currently mandated and future anticipated Corporate Average Fuel Economy (CAFE) Standards for the U. S. and those similar fuel economy and regulated emissions requirements in other countries[11]. This will require a major breakthrough in how we utilize the fuel in the power plants in our vehicles.

Additional, there have been growing concerns over the costs of fossil fuels acquisition, not just financial but also in the human capital expended to protect and gather these supplies, plus the environmental impact from their transportation and use. It is easy to see that we need to be prudent in our efforts to make the most effective use of these energy resources. From an earlier portion of this discussion it is easy to see why overall transportation efficiency is important and with over two-thirds of the fuel use occurring in the engine, why the future focus needs to be in making the engine as the total motive power provider as effective as possible. To consider this requires a closer look at the total combustion process.

## IV. THE SPARK IGNITED ENGINE

In layman's terms, an engine mixes fuel with air, ignites it in a controlled volume, and uses the force derived from the combustion to push the piston to provide motive force to the drive train. The combustion process itself is very complex, and while the open flame of a campfire may seem obvious, in actuality the overall process of combustion is complex and not completely defined scientifically. Having stated this, it is clear that engine developers have learned to manage the use of combustion in engines regularly and in most cases totally transparent to the end user.

For a modern engine to run as effectively and reliability as it does requires tightly controlled and complex processes to occur every time the piston advances toward top-dead-center, the power stroke. During this process it receives a balanced charge of fuel and air, delivers a spark to ignite the mixture and then in a controlled fashion consumes that fuel and air developing heat and thus increasing pressure that drives the piston forward.

During this firing process and subsequent cycles of the engine, there are products-of-combustion formed that are ejected from the cylinder to be treated by the emissions control equipment. Noting that this description so far has been an oversimplification of the number and complexities of the processes that occur within the internal combustion engine, especially the combustion process, a further and more expanded explanation is required.

Spark ignited engines have been in use for over a hundred years. They use a mixture of combustible fuel mixed with air. Most people do not know or fully understand that this mixture is highly controlled by engine developers to provide a balanced combination of fuel with the oxygen contained in air. This ideal balance of air-to-fuel, referred to as a stoichiometric mixture, is where all of the fuel is consumed leaving no excess oxygen. When the mixture has excess fuel it is regarded as, rich and when it contains excess oxygen it is regarded as lean.

The air-to-fuel ratio is critical to the reliable firing of the engine over its range of operation and thus to the effective use of the fuel. Too much fuel and the mixture (rich) becomes harder to ignite, since the excess fuel can suppress the ability of the spark to find the proper mix of fuel and oxygen to establish and maintain an initial flame kernel, which can also be quenched by the presence of too much fuel. More importantly, a portion of this fuel will not have the oxygen necessary to complete the combustion of the entire fuel charge in the cylinder. This results in unspent fuel being sent downstream to the emissions treatment system. It also means that this portion of the fuel was not used to propel the vehicle, which decreased fuel economy and adds a further burden to the cleanup system or worse gets expelled directly into the environment.

The excess air (lean)combustion model is uniquely different and for most spark-ignited engine is difficult to create reliable combustion. It has been suggested that the way to obtain greater vehicle efficiency will require a new technology that will allow the combustion of varying levels of air-to-fuel ratios, well into the lean region of combustion. Currently, conventional spark plugs cannot be relied on to ignite lean mixtures, but the subject of this paperthe plasma igniter, has proven to be viable at varying ranges of air-to-fuel levels well into the lean limit, which is covered in a later section in this paper.

Currently manufactured IC engines that employ conventional spark plugs must have the proper fuel/air mix located in close proximity to the source of ignition and to also have a proper mix through the cylinder's contracting control volume to support and perpetuate the flame front. This means that throughout the driving cycle of the vehicle the fuel/air mixture going into the cylinder each time it fires is the same independent of the power needs of the vehicle. This means the fuel/air mix during engine idle, highway speeds and under full load is effectively the same, and therefore potentially wasting energy.

Clearly, carburetors and fuel injectors compensate for the engine load required from spark-ignited engines. [12]They mix the fuel prior to entry into the cylinder, or with direct-injection the fuel is provided just prior to the ignition event. For each of these methodologies there are supplemental support technologies to mix the fuel with the air and to place that mix in close proximity of the conventional spark plug just prior to ignition. This has been the fundamental process for over a century and up until recently it has provided the fuel efficiency accepted by the consumer and required by the regulatory authorities.

## V. THE COMBUSTION PROCESS

Depending on whether the engine is either two- or four-cycle all spark-ignited engines effectively function the same during the combustion/power stroke event. The piston after leaving bottom-dead-center of the current cycle advances towards the top of the cycle during which fuel and air are introduced at some predetermined piston position timing point. Depending on the engine design and performance requirements of the engine and prior to the top-dead-center position of the piston, the combustion event is initiated with a conventional spark plug.[13] Again, this is the way it has been for the past century and most likely without significant innovations and breakthroughs must continue for the foreseeable future, at least in its current physical form factor.

As the piston advances, the cylinder sees increased pressure, and as a result higher temperatures. The fuel/air charge becomes denser due to compression and positioning the fuel/air particles in closer proximity, and at a higher temperature. The spark from a conventional spark plug, as it arcs between the electrodes, initiates the flame kernel and if the fuel/air mixture is correct and the particles are close enough together, the flame front will propagate out from this initial ignition point consuming the fuel and delivering the pressure needed to drive the piston as it moves through the power stroke. Note, the energy to create the spark across the gap and to initiate combustion goes up as the pressure increases in the cylinder, as it does with increased compression ratios of the engine.

This flame propagation event requires a significant portion of the total time that the piston takes to move through the power stroke to the exhaust stroke. The purpose of starting the combustion event prior to top-dead-center is to give the flame front time to build to its maximum peak pressure near the top of the power stroke. [14]Starting too early places additional mechanical stresses on the engine since the forces are opposing the motion of the piston. Starting too late means the fuel, with the short cycle time of the piston motion in a modern high-speed engine, may not be consumed prior to the exhaust process. This diverts power from the piston, allowing unspent hydrocarbons into the emissions cleanup system.

Starting too early prior to top-dead-center also allows the fuel/air mix to come into contact with a greater surface area of the cylinder walls increasing what is referred to as wet surface area, which is harder for the flame front to get to and consume. This potential unspent surface-adhered fuel is either wiped away by the piston rings to be vented later from the crankcase or is mixed with the burnt gases and exhausted out of the engine, both of which must be addressed during emissions clean up.

Current high performance engines with higher compression ratios, the increased pressure achieved in the cylinder by reducing the total volume above the piston at top-dead-center, also impacts the ability of the ignition system to ignite the fuel/air mixture. [15]The higher the compression ratio the greater the required input of energy to initiate combustion. This added with the time it takes to combust the fuel sets limits on the compression ratio and the maximum speed of the engine. All of these considerations are also impacted by, or impacts, the material and design choices, and the strength requirements of the engine components.

## VI. LEAN BURN COMBUSTION

The lean case is uniquely different than rich mixtures and more important to the theme of this discussion. Lean and ultra-lean means there is an abundance of air in the cylinder's mix, which means that ignition and flame propagation is harder to achieve. In this case when ignition is attempted the proper fuel/air mix may not see the spark from a conventional spark plug or if it does the regions of properly mixed fuel/air particles may be so distant from one another that the flame front effectively quenches due to a lack of the heat needed to continue the flame propagation.

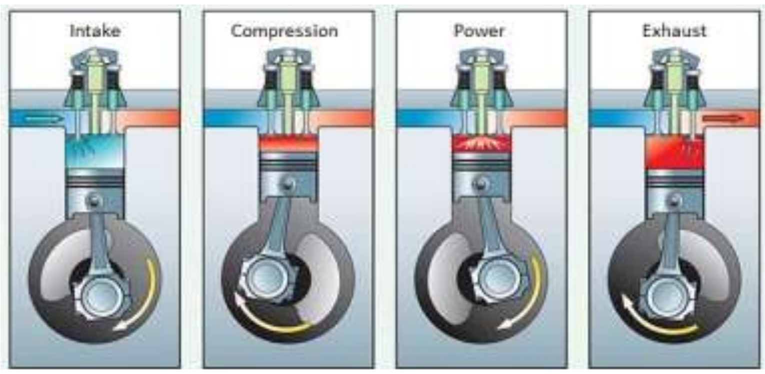


**Figure 4.** Illustration of the four-stroke combustion cycle [16]

To aid the combustion process there are several techniques that can be employed. Additional energy can be delivered to the spark, increasing the energetic discharge and providing more heat to accelerate the flame front. The spark can also be modulated, instead of using a single discharge; the spark plug can also be energized multiple times during the piston cycle, again to add more heat to the flame front. In some cases, the multiple spark discharge might be to insure that the flame was actually initiated especially for those engine designs that use stratified charge or other lean burn concepts that try to place the correct fuel/air mixture at the location of the spark during the discharge event. Note, some engine designs use multiple plugs to guarantee combustion, but most of these applications are in the racing class of engines.[17]

The lean burn problems have been studied for decades. Igniting liquid fuels, and more so gaseous fuels, that are below the stoichiometric ratio have been problematic. Even slightly below this mixture range can cause miss-firings at idle plus additional power response problems affecting the overall engine performance and drivability. One of the current solutions is to, again, raise the energy input of the conventional spark plug by multiple firingsof the same plug, by using multiple ignition coils, which raises the total energy level in the cylinder.

These solutions may prove useful for mitigating some of the problems of lean mixtures but at significantly increased costs. Part of these added costs are the additional electrical energy requirements. Others are the additional electronics and controls plus the expected increases in maintenance and decreases in parts life expectancy. All of these costs pale in comparison, though, to the impact these high-energy igniters will have on the increase in the formation of the pollutant NOx, Sox, and the subsequent additional exhaust after-treatment and electronic controls that must be provided.

The formation of these pollutants is highly impacted by the localized temperatures during combustion and particularly so during the spark event since the relative temperature of the spark is much greater than the flame temperature due to the concentration of energy over such a short gap between the two electrodes and the short time period of the incident.[18]

Effectively, most of the solutions for getting better performance out of the current engine designs and an increase in vehicle fuel economy calls for increased compression ratios, greater control over the fuel/air ratios and significantly enhanced combustion feedback and controls. The current proposed solutions seem to be to increase the energy to the ignition system and/or to modulate that delivered energy in some way to increase the likelihood that combustion will take place and the fuel will be consumed to drive the piston forward.

It is acknowledged by design experts that these proposals will increase the exhaust cleanup requirements and the amount of fuel savings will only slightly address the real need to increase fuel economy. As was mentioned earlier, all of these are evolutionary innovations based around the current conventional spark plug technology and while each may have value, the technology needs for the transportation sector is for a breakthrough, a game changer, in the way we power our internal combustion engines

## VII. THE REAL NEED

What is needed is an ignition source that will ignite a wide, and load required, changing range and types of air-to-fuel ratios, stoichiometric, lean and ultra-lean. Instead of relying on brute force discharges across electrodes, it needs to stimulate and energize the fuel and to deliver that ignition energy distributed throughout the cylinder volume in contrast to the localized spark event. It needs to be able to ignite the fuel/air mixture to meet the power requirements of the vehicle and not the stoichiometric requirements of the currently employed combustion process, and to do so reliably, economically and with the current consumer transparency.

It needs to provide a low-temperature ignition source that involves the total fuel/air mix to reduce the time required to get to full pressure in the cylinder. Quicker consumption of the fuel (reduced ignition delay) allows for later initiation of the combustion event providing more of the power during the power stroke with less stress on the engine components prior to top-dead-center combustion. It also means that the combustion process takes less time and thus more fuel can be added for greater power out of the same engine displacement.

Lower ignition temperatures also reduce the total emissions quantity produced, which reduces the cleanup costs and the added complexity and weight of these components in the vehicle. Involving the total fuel/air mixture in the ignition event also means there is more opportunity to combust the fuel on the surface of the cylinder walls and the piston head, increasing overall fuel use efficiency.

The largest of these advantages is the ability to combust fuel/air ratios based on the power requirements of the engine. During idle and even at low power required highway operations the fuel injected would be in response to the power needed and not to meet the needs of current spark plug-ignited combustion. This capability would allow for significant improvements in fuel economy with the equivalent in emissions cleanup. Less fuel for equivalent vehicle range means the vehicular weight is also reduced, further improving the fuel economy.

This breakthrough in the way we use our fossil fuels will have a profound impact on the needed acquisition of fuel stocks, lower the cost to the consumer and reduce the overall environmental footprint. This will also facilitate the introduction of this technology through the purchase of newer, more efficient vehicles, while providing retrofit capabilities for older models that can accommodate these improvements. This system will not only provide the vehicle manufactures with better, more energy efficient vehicles to sell, it will also allow them the ability to meet the current and expected fuel economy regulatory requirements without paying penalties, or the constant costs of trying to mitigate the impact of changes in the regulations.

## VIII. THE PLASMA IGNITER RADIO FREQUENCY IGNITER SYSTEM

Anytime there is electrical discharge, plasma has been created. Thus, every time a conventional spark plug fires, plasma is part of the process. This applies to all conventional electrical ignition devices and thus all spark plugs generate plasma. While there may be differences in the way the discharge occurs, the reality is they function by delivering a large electrical potential between two electrodes such that when the breakdown voltage across the gap between the electrodes is sufficient the spark arcs across the gap. This places a large amount of energy in a small volume over a very short time interval, thus the generation of the large quantity of heat to initiate combustion.

**Figure 5.** The radio frequency Plasma Igniter device.[5]

The radio frequency plasma igniter design is uniquely different. This plasma ignition source maintains the plasma on one electrode, by using a quarter wave coaxial cavity resonator as an amplifier for the input signals.[19][20]Based on parameters of the resonator, the input voltage can be increased hundreds of times within the igniter, prior to delivery of the energy into the combustion chamber. This feature produces the needed high voltage energy needed at the point of ignition, but does not cause material degradation and arcing as in current spark plugs. [21]

The plasma igniter is unique from another standpoint. It is a patented resonance device that acts like an antenna, which emits microwave energy at gigahertz frequencies[22]. Because it operates at microwave frequencies, it has the ability to build the charge potential and to do so numerous times during the power stroke event. Since it emits like an antenna, the radiating energy permeates the cylinder volume energizing the fuel/air mixture until the combustion event is initiated[23]. This allows the total energy of the igniter to be distributed across the entire volume and, for the same electrical potential, lowering the temperature of the combustion initiation, and thus reducing the overall formation of specific exhaust pollutants.

The plasma igniter design is close to the same form factor of a conventional spark plug; they will look almost identical[24].They will install the same in the engine, with the same tools and the same technical training requirements. They will be mass-produced using similar industrial processes, plus these plugs can be manufactured using the same ceramic materials as conventional spark plugs[25].

This plasma igniter has proven to provide a very energy efficient ignition source. Plasma generation using this igniter, capable of supporting combustion, is significantly less than the current conventional and proposed future spark plug ignition systems. This means less parasitic losses to the engine generating extra electrical power and lower total input energy plus the active distribution throughout the cylinder prior to ignition means better combustion and lower pollutant generation.

This distribution of the ignition energy allows for quicker and more thorough combustion, even at the cylinder surfaces. Since it is RF driven, the igniter allows for multiple and continuous discharges, and because the total fuel/air mixture is energized, there is a lower energy requirement to establish a plasma and thus to support combustion. Quicker combustion allows for reduced unspent hydrocarbons with the potential to increase the power available for equivalent engine displacement, by adding additional fuel.

Control of the total fuel/air mixture with a fuel that has been microwave energized allows for control over the lean limit, thus allowing for the full use of ultra-lean combustion and beyond. It is still unclear as to the total impact that the microwave energy has on the fuel mix but at a minimum it energizes the fuel and raises it to a state that allows for quicker and more thorough combustion.

One of more important attributes of this breakthrough technology, results from the resonator design. Since the plasma igniter is effectively an antenna, any changes to the environment surrounding that antenna will affect and change the physical and electromagnetic characteristics of the igniter[26]. This is probably one of the most important breakthroughs in this technology: real time, in cylinder engine diagnostics and control.

This will provide the onboard computer with the capability to monitor each cylinder's combustion event and to make adjustments during that specific combustion cycle, real time. Providing multiple discharges and ramping up or down the energy supplied and then also controlling the fuel flow and mixture ratio to adjust the power per cylinder, based on the operational needs of the vehicle, now becomes a reality with the use of this ignition system. This will provide significant improvements in the overall fuel economy of the vehicle. This represents a truly game changing breakthrough for the future of automotive transportation.

Current scientific studies are beginning to indicate that there may be considerable chemical impacts to this form of microwave ignition including reforming of the fuel. These studies will continue for years to come, which will allow continued innovative improvements to this breakthrough technology. Fortunately, this technology can be fully exploited while these innovations are being developed and integrated into our fleet of vehicles.

## IX. PRELIMINARY RESULTS

Early testing was performed at West Virginia University in a signal cylinder four-stroke engine, and Wright-Patterson Air Force Base in a pulse detonation engine. Initial results at West Virginia University show the ignitability region for typical spark plugs and the plasma igniter.[27] These tests were conducted using liquefied petroleum gas (approximately 90% propane by composition), and early results showed the ignitability region to be the same as a typical spark ignited system (Figure 6).

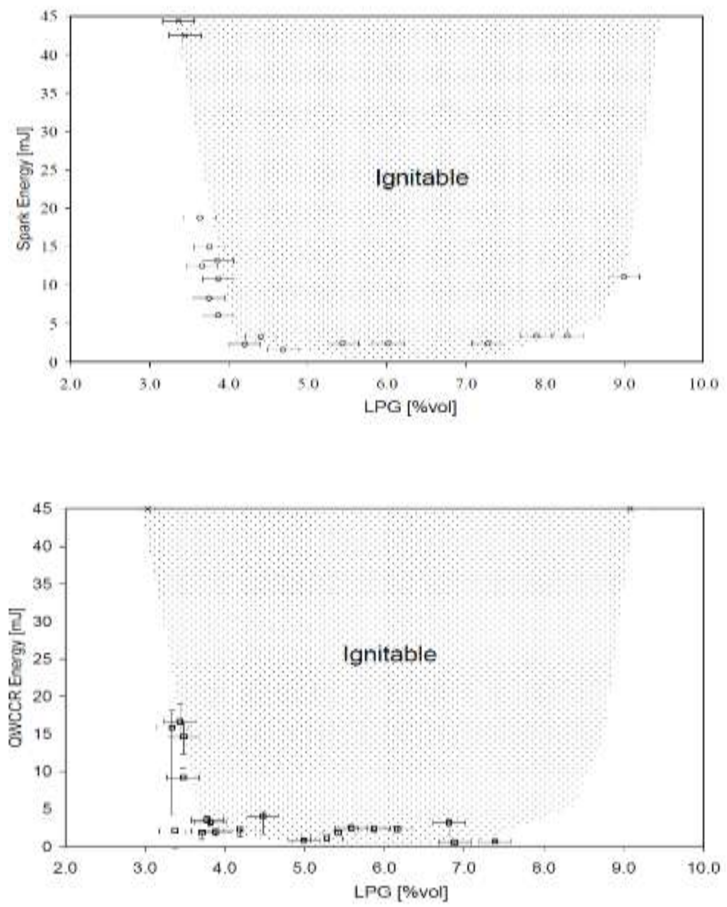


**Figure 6.** Ignitability region for typical spark ignition system and plasma igniter system using LPG fuel. [27]

Additionally, a spectral analysis was performed. These early results show that the plasma igniter system has energy not only in the visible spectrum, but also a considerable portion of energy is also in the ultraviolet (UV) spectrum (Figure 7). This UV energy could also be a major contribution the to easily ignitable characteristics that the plasma igniter system has shown during testing.

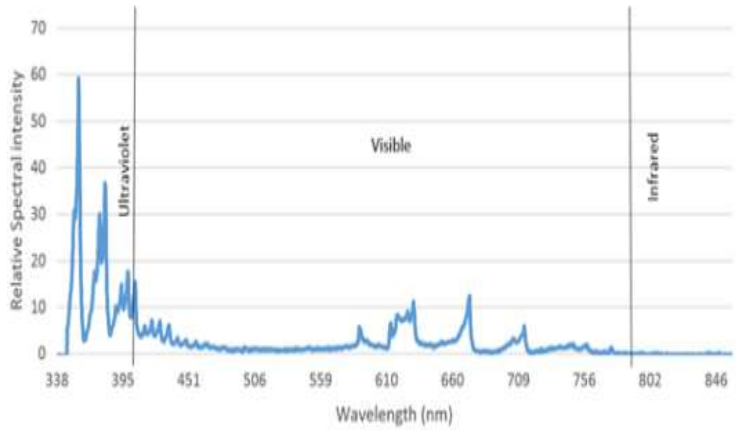


**Figure 7.** Spectral plot of plasma created from Plasma Igniter system.[28]

Initial tests from Wright-Patterson Air Force Base, using their pulse detonation engine using an ethane fuel. These tests showed ignition characteristics (timing) and detonation characteristics (flame-front propagation).Figure 8shows the ignition timing for both spark and plasma ignited systems. The plasma igniter allows for variable timing, allowing for ignition much longer (or shorter) than a typical system. This will allow for a more complete combustion process.

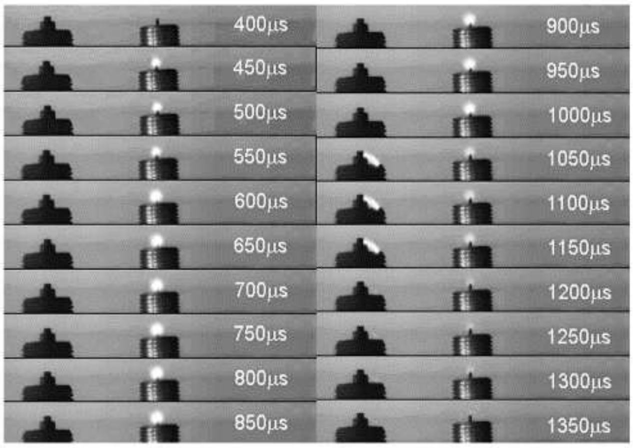


**Figure 8.**Ignition duration for typical spark ignited system (left plug) and the plasma igniter system (right plug) [29]

Additionally, flammability limits and flame-front propagation were also explored. Testing examined ignitability from 10% rich to 20% lean. At the 20% lean condition, the typical spark barely ignited, and the plasma system fully ignited. The flame front propagation for this scenario is shown in Figure 9.

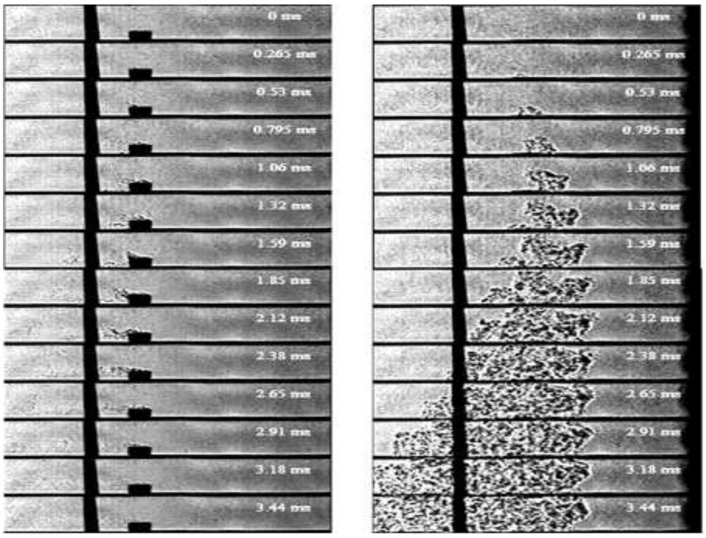


**Figure 9**. Flame-front propagation for typical spark ignited system (left) versus plasma igniter system (right) [29]

## X. SUMMARY

Transportation, specifically personal transportation, has accelerated both our personal and societal progress. To continue to advance and solve the problems we face today will require numerous major breakthroughs in the way we live and conduct our lives. Most of these will be provided from advanced technology with many centered on how we transport people and the goods that are produced and used.

Until there are other more efficient and economical means of transportation developed, the current internal combustion engine will continue to be the best opportunity, for at least the next several decades. The radio frequency plasma igniter technology represents a game-changing breakthrough for internal combustion engines that will extend our supplies of fossil fuels, while reducing the costs of use and acquisition. It will lower our consumer costs for energy and provide improved choices in vehicle design.

Using less fuel and lowering the exhaust quantities and constituents will continue to help us become better stewards of our environment. It will allow us, individually, to have more choices as to our lifestyles. It will also motivate our younger generation to see a better promise in the future and the need to become better educated and trained. In all of this there resides the driving need to advance ourselves as a species and to provide the next generation with better than we received from the past generation. The dual-signal, radio frequency plasma igniter represents one such opportunity.

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