

# Laser Ignition - Fundamentals and Laser Spark Plug Development for Engine Ignition

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**Tuesday, 16th October - 13h45 (VI - 144)**

The concern of humanity over exhaust gas pollution and greenhouse gas emission have stimulated research on finding alternative methods for improving the performances of combustion as the main process of energy conversion. Nowadays high-voltage spark plugs are commonly used to initiate combustion in various engines. These devices are simple and quite inexpensive and therefore it is largely accepted that they will remain the main tools of ignition for a long time to come. Still, spark plug ignition (SPI) has some disadvantages, such as: a) the electrodes suffer from wetting and erosion; b) the flame kernel development can be influenced by the spark plug protrusion into the engine cylinder; c) a limited capability to ignite lean air-fuel mixtures; d) reduced performances at higher pressures, or e) the fixed position of ignition inside the combustion chamber. Therefore, alternative techniques of ignition are investigated in order to address the limitations of an electrical spark plug.

One potential candidate for this purpose is ignition with a laser system. Laser ignition (LI) offers several advantages in comparison with a SPI. There is no quenching of the combustion flame kernel due to the absence of electrodes. Furthermore, the laser beam focus can be positioned at an arbitrary point inside the engine cylinder, thus offering possibility for further improvements of the engine performances. In addition the laser beam can be delivered simultaneously to different locations (for spatial multi-point control of LI) or in a train of pulses within a short time span (thus realizing the temporal control of LI). Lean air-fuel mixtures or combustible at high pressure can be ignited in these ways.

In this talk a review of the research performed on LI in internal combustion engines, especially of gasoline engines, will be presented. The path from the first demonstration of LI in an internal combustion engine to the first operation by LI of a 4-cylinder gasoline test engine and to the implementation of LI in a real automobile will be discussed. Steps taken toward developing a spark-plug-like LI system for automobile, stationary gas engines for energy cogeneration or for space applications will be described. The delivery of the laser beam to the engine cylinder by optical fiber as a complementary technique to that of placing the laser spark plug directly on the engine will be introduced. Aspects regarding the fouling of the window that is used to introduce the laser beam into the engine cylinder will be addressed. It is concluded that LI has reached a quite high degree of technical maturity and that the advantages of using LI technique versus ignition by an electrical spark plug were demonstrated.

