# Applications of the LIF-method for the diagnostics of the combustion process of gas-IC-engines

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Within the underlying project the task was to develop a method for optical measurements in a hydrogen fueled engine with high-pressure direct-injection. The main interests when optimising such combustion processes are in measuring the jet-patterns during injection, the stratification of the charge at ignition point and the propagation of the flame during combustion. Therefore multidimensional methods are favorable, subsequently the method of planar laser-induced-fluorescence (PLIF) was chosen. In order to apply this technique for the named tasks it was necessary to develop particular methods for visualising the fuel and the flame front, this forms the main content of this article.

In order to carry out these measurement taks a single-cylinder research-engine with optical access was installed at the Institute for Internal Combustion Engines at Graz University of Technology. This engine features a layout equivalent to modern passenger-car engines with direct-injection while providing generous optical access through a quartz-glass liner and a window in the piston. To achieve a good comparability to a standard engine it is possible to operate the engine in fired operation at peak pressures up to 60 bar.

## 1.  PLIF for measurements of mixture formation

As it is hardly conceivable to directly excite hydrogen molecules by means of laser light it is necessary to add a tracer substance to the fuel which provides high fluorescence intensity while not changing the properties of the fuel. The right choice of this substance therefore is crucial for the success of this method, whereas some properties of the tracer are essential like it's high excitability by UV-laserlight, while others are merely preferable such as matching physical properties of the tracer and the carrier substance.

Consequently, Triethylamine (TEA) was chosen as a tracer to be mixed to hydrogen at 200 ppm, which allows it to be used up to a maximum pressure of 200 bar while still providing a strong signal. According to prior publications the influence of pressure and temperature on the signal is quite low for this tracer, thus making it favorable for measurements under engine conditions. Furthermore the excellent linearity of the signal to the local air/fuel-ratio also was validated in engine tests.

As a consequence a method for the quantification of mixture-formation measurements could be developed. For this task it is necessary to provide a homogeneous in-cylinder charge with a known air/fuel-ratio, which can be achieved by injecting a defined amount of hydrogen/tracer-mixture into the intake manifold. Performed for each corresponding crank angle this allows the calibration of the direct-injection images, while at the same time compensating for effects like inhomogeneities of the laser beam, staining of the optical access and influences of pressure and temperature. The results are images scaled on air/fuel-ratio which can be used for a direct optimisation of the mixture formation processes and the validation of CFD-models.

## 2. PLIF for the analysis of combustion processes

To apply the laser-induced fluorescence for the combustion analysis it is necessary to adapt the method. On the one hand it is possible to visualise the flame by using the tracer within the fuel, it is then burned together with the fuel and therefore marks the burnt zone by disappearance of the fluorescence signal. However, this method is limited to measurements with a homogeneous distribution of tracer and therefore the fuel within the combustion chamber.

In this case a direct visualization of the flame front can be achieved by exciting molecules formed during combustion, which leads to the application of the OH-LIF method. As this method has significantly increased demands on measuring equipment and is more time consuming, both methods are used in parallel on specific measuring tasks.

## 3. Conclusion
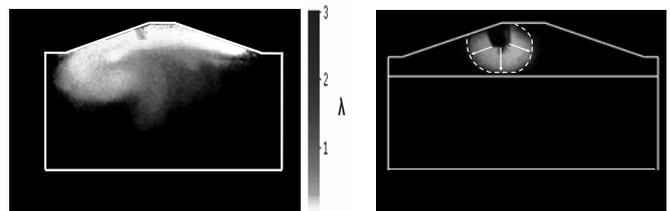


**Fig. 1** typical measurements of the fuel-jet with tracer-LIF (left) and the flame propagation with OH-LIF (right)

The laser-induced fluorescence was successfully applied for the needs of the evaluation of new combustion processes in a gaseous engine. The methods described above have been tested in the use with direct-injection of hydrogen but are generally adaptable for all gaseous fuels. These results  are used for the further development of innovative hydrogen combustion processes but also form an essential basis for the development and verification of CFD-simulation models.