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Spark-Induced Emission Spectroscopy

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Motivation

One issue in the production of electricity by solar and wind power are the large temporal and geographical fluctuations of these renewable sources.
A promising way to store excess electric energy is the conversion into a chemical energy carrier ("Power-to-Gas"). Electrolysis can produce hydrogen (H_2) or methane (CH_4) which may be stored for longer time periods, e.g. in the existing pipeline system or at gas fuel stations.

Methane and hydrogen can also be used as a fuel in vehicles: Cars with CNG engines are already on the market, H_2 fuel-cells and gas engines using HCNG (a blend of hydrogen and natural gas) are under development.

In the present project, a detail of particular importance for the use of HCNG in engines is addressed: The process of ignition and early flame kernel formation is investigated.

Approach

The ultimate target are engines running on H_2-enriched natural gas (HCNG). An optical diagnostic method is developed for determining the local air-to-fuel ratio at the spark plug. The light emitted by the igniting spark is used for spectral analysis, and the gas composition is determined from these spectral signals.
To this end, the correlations between signals from various CH_4 and H_2 fragments and air compounds are investigated.
An obvious advantage of this approach is that the spark-induced signal is guaranteed to represent the conditions at the exact time and location of ignition – the sampling is quasi automatically correct.
The same experimental setup permits to also detect chemiluminescence emission from the early, small flame kernel. Then find correlations between optical signals and classic engine performance parameters (pressure indication; exhaust gas analysis).

The measurement technique is being developed in a small constant volume chamber using pure gas samples and well-defined mixtures.

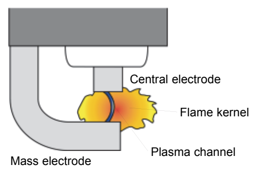

Fig. 1: Spark plug with plasma channel and early flame kernel

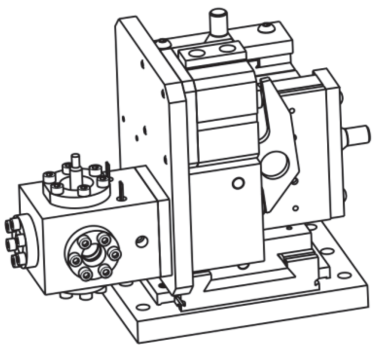

Fig. 2: Experimental apparatus

Schematic setup

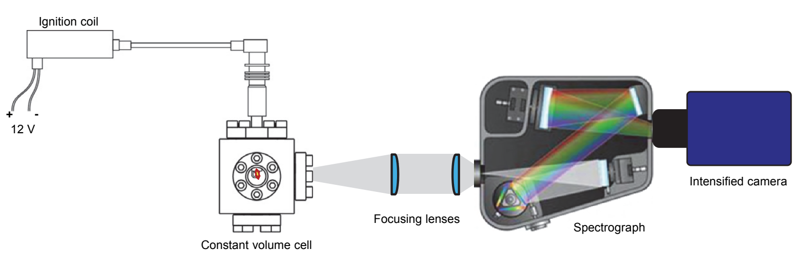

Fig. 3: Schematic setup for spark-induced emission spectroscopy

- Constant volume cell with sapphire windows for optical access
  Heatable to T ≤ 220°C;   the cell is designed for p_{start} ≤ 65bar
- Fully flexible mixture preparation: H_2, CH_4, Air (+ N_2 as EGR substitute)
- Homogeneous, quiescent mixture for ignition (no flow, no turbulence)
- Spectrograph with selectable gratings (i.e. variable dispersion / spectral resolution)
- Detector can cover the spectral range 200nm - 800nm;
  exposure time down to 20nsec

Preliminary results

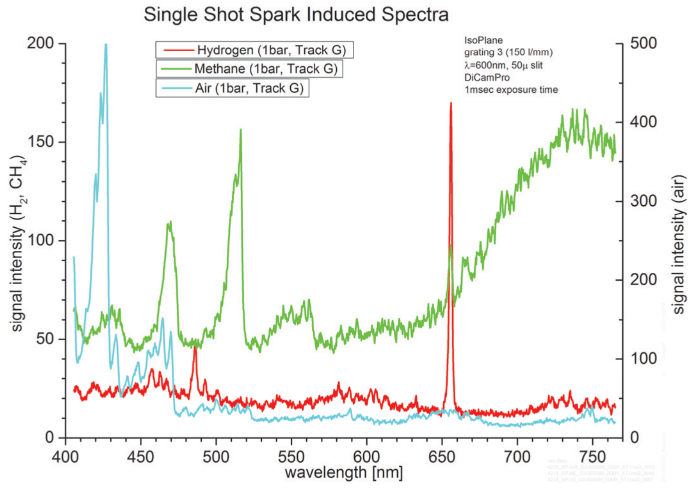

Fig. 4: Single pulse spectra from air, hydrogen and methane at ambient conditions

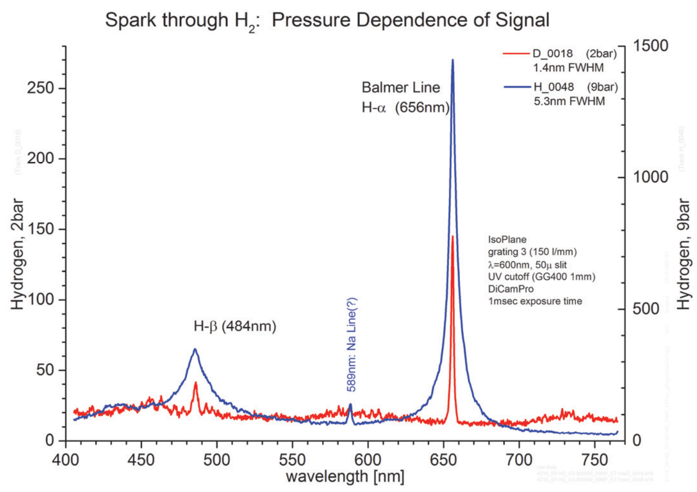

Fig.5: Pressure-dependent signals from hydrogen

Conclusions

- Tests are done with pure gases at room temperature and elevated pressure
- Spectral signatures differ characteristically (as expected)
- Shot-to-shot fluctuations are under investigation
- Strong pressure-dependent broadening is observed for hydrogen (Balmer lines FWHM: ca. 0.5nm/bar)
- Spectral signature evolves over discharge time

Outlook

- Elaborate correlations between spark emissions at specific wavelengths and local air/fuel ratio
- Transfer of the measurement technique to real engine applications using an optical spark plug (i.e. a spark plug with quartz light guiding fibers inserted) connected to the spectrograph.

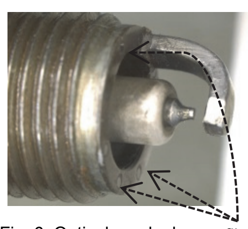

Fig. 6: Optical spark plug   fiber end faces

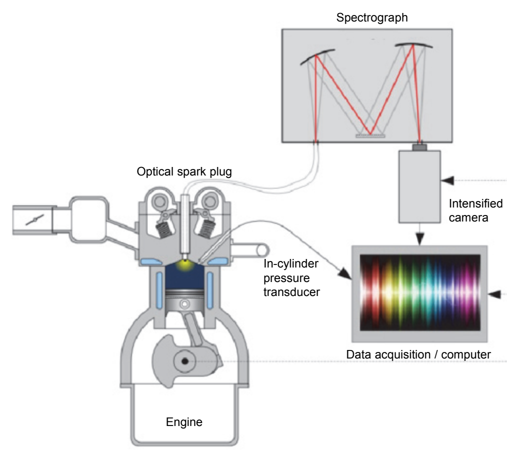

Fig. 7: Experimental setup for spark-induced emission spectroscopy on a real engine

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