LaVision Automotive

Innovative Measurement Technologies

LaVision

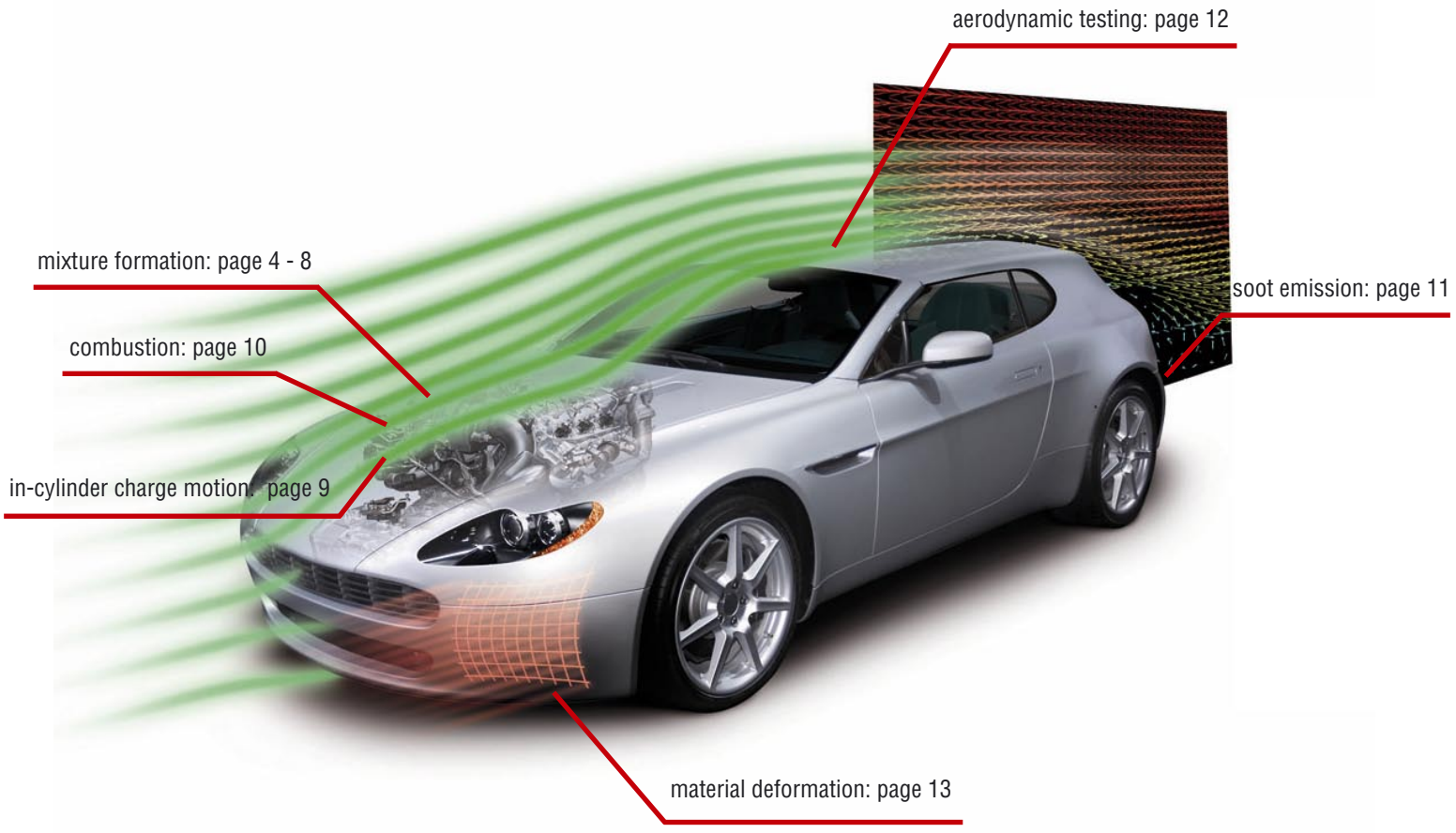
We count on Photons

Optical Diagnostics for Automotive R&D

Optical diagnostic technologies such as laser imaging and fiber sensors are powerful development tools in many research laboratories of the automotive industry. They are successfully applied to measure in-cylinder processes, air flows around and inside car bodies and to study deformation and strain behavior of automotive parts under stress. In-situ optical measurements are non-intrusive to the process and measure with intrinsic high spatial and temporal resolution.

LaVision's laser diagnostic instruments give invaluable insight for a better understanding of the automotive process. They allow a much faster and more efficient development and, thus, save time and money. LaVision has a long history successfully cooperating with the automotive industry worldwide. We are a reliable and competent partner for our customers providing advanced measurement solutions for their challenging diagnostics requirements, today and in the future.

Whether your measurement focus is on **engine performance, aerodynamic testing** or on **dynamic deformation and strain measurements** - LaVision is your partner to find the best measurement solution.



Engine Diagnostics using Laser Imaging and Optical Sensors

Energy efficiency and environmental friendliness implies an enormous challenge to improve internal combustion engines. The detailed information on the complex in-cylinder processes gained by optical diagnostics is complementary to traditional indication systems. In many cases optical measurements are the only way to validate Computational Fluid Dynamics (CFD) simulations.

The optical methods are aiming at improving fuel efficiency and reducing pollutant emissions. They help to optimize the development process of engines and engine concepts:

- **direct injection and multiple injections**
- **downsizing concepts and turbo charging**
- **HCCI, Exhaust Gas Recirculation (EGR) and variable valve train**
- **alternative fuels like hydrogen, natural gas or fuels from biomass**
- **transient engine conditions such as cold start and catalyst heating**

LaVision's laser diagnostic systems are successfully applied to analyze in-cylinder processes such as flow generation, fuel spray injection and mixture preparation, (auto-) ignition, combustion and finally formation of pollutants including soot.

Depending on the requirement, the diagnostic solutions are designed for minimal modifications of the engine applying endoscopic imaging or for the use of fiber sensors on production engines.

Optimizing Mixture Formation

Mixture Formation Imaging

LaVision's laser systems enable versatile diagnostic applications for in-cylinder mixture formation imaging. Fuel vapor, residual gas distribution and temperature fields are visualized on a light sheet plane illuminated by a pulsed light source. Due to the short light pulses in the nanosecond range even highly dynamic turbulent processes are captured without image blurring.

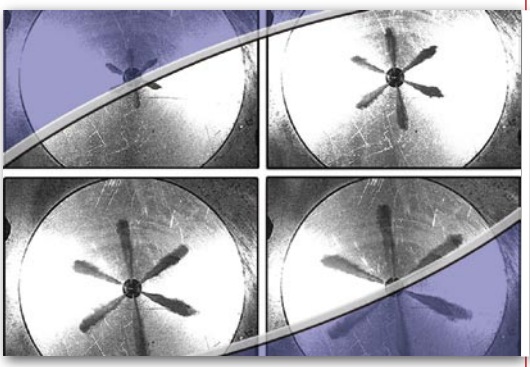
The measurement systems are based on Laser Induced Fluorescence (LIF) detecting inherent components of the fuel or added molecular species. Illumination and detection both require optical access, which can be provided either by a partly transparent cylinder and piston or applying keyhole imaging using minimal invasive endoscopes.

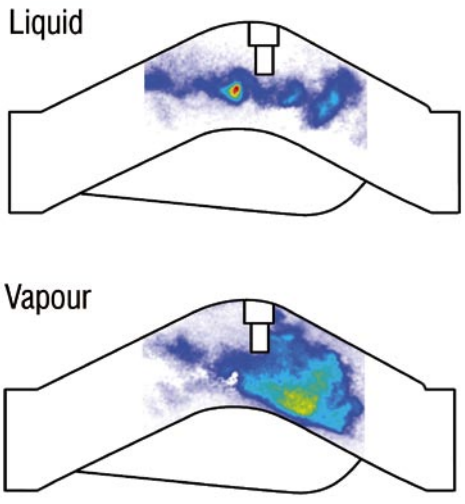
Features

- in-situ visualization of the in-cylinder mixing process: fuel and residual gas distribution and in-cylinder temperature fields
- crank angle resolved measurement with high spatiotemporal resolution
- complete integrated synchronization with engine test rig

Special Topics

- time resolved imaging for transient cycle analysis of the compression stroke
- air/fuel ratio maps near the spark plug
- temperature homogeneity of the cylinder charge just before ignition





in-cylinder fuel distribution: evaporated and liquid fuel

Internal Combustion Optical Sensors

LaVision's **I**nternal **C**ombustion **O**ptical **S**ensors (**ICOS**) measure crank angle resolved air/fuel ratio, exhaust gas concentration and gas temperature locally at the spark (glow) plug or at any other in-cylinder location using optical M5-probes. The **ICOS systems** provide highly time resolved data of the relevant engine parameters at the tip of the probe. Single cycle parameter profiles as well as variations over many cycles are recorded.

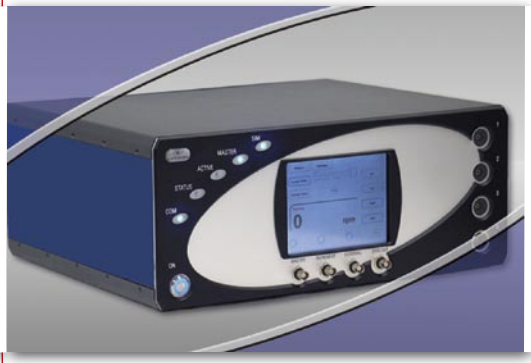
Optical engine indication synchronized with standard pressure recording allows a much more detailed characterization of the in-cylinder charge formation process. Information on the state of the cylinder charge at a given crank angle is of upmost importance to improve engine performance.

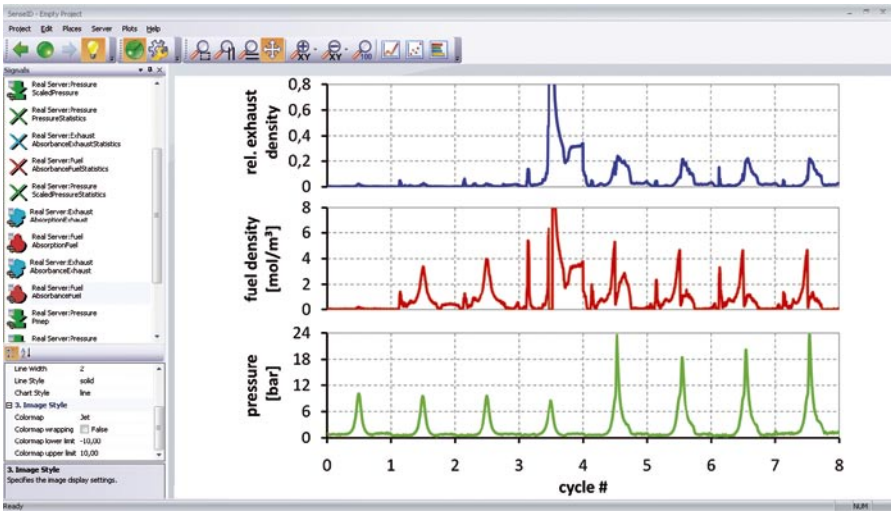
Measurement Principle of Optical Engine Indication

The **ICOS measurement systems** are based on infrared absorption spectroscopy of the relevant molecules like water, CO_2 or hydrocarbons. The in-situ absorption technique is instantaneous and needs no gas extraction. One probe can measure multiple parameters simultaneously.

Features of the Internal Combustion Optical Sensors (ICOS)

- crank angle resolved in-situ measurement of fuel concentration (air/fuel ratio), exhaust gas concentration (EGR-rate) and gas temperature together with engine pressure indication
- precise single cycle analysis at kilohertz sampling rates
- applicable in unmodified production engines under real fuel conditions
- **ICOS** probes: optical spark plugs (M12 and M14) or non-firing M5-thread probe
- multiple parameter recording: air/fuel ratio + exhaust gas conc. + heat release with one probe





crank angle resolved fuel and exhaust concentration profiles together with cylinder pressure during cold start

Ultra-Fast In-Cylinder Gas Analysis

Internal Combustion Gas Concentration Sensor

The **ICOS system** for fuel and exhaust gas measurements allows the simultaneous detection of both gas components from the same probe. In combination with the cylinder pressure the local air/fuel ratio is derived from the fuel concentration. The CO_2 detection reveals information about the Exhaust Gas Recirculation (EGR) rate for each individual cycle and cylinder, thus, allowing a stability analysis of EGR processes.

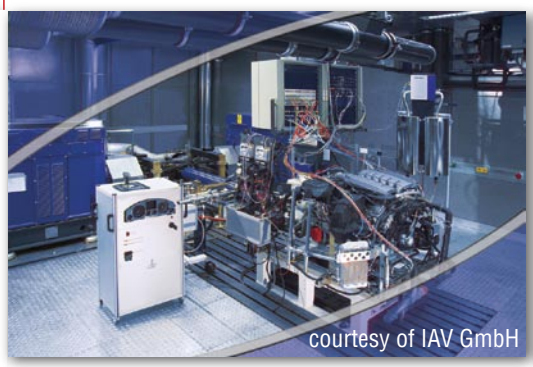
In contrast to conventional Flame Ionization Detectors (FIDs) or Non-Dispersive IR (NDIR) - Analyzers **ICOS** does not need a gas sampling system and measures directly inside the cylinder without any delay.

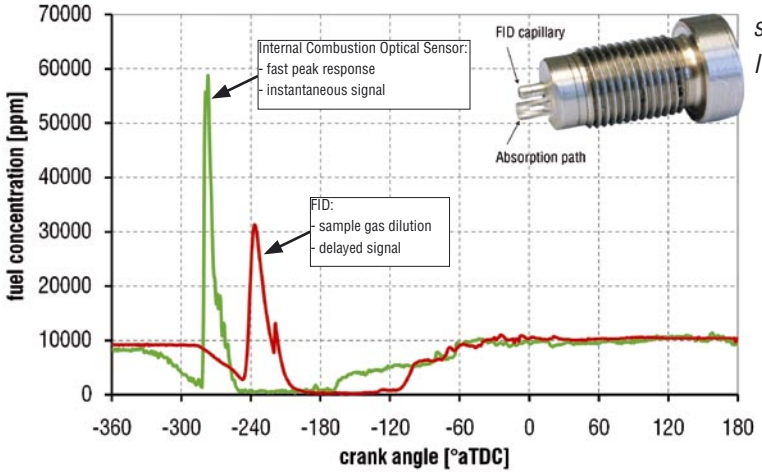
System Features

- crank angle resolved fuel conc. (air/fuel ratio) and/or exhaust gas (CO_2) conc. measurements
- engine synchronized on-line measurements with 30 kHz sampling rate
- simultaneous indication of multi gas components and heat release

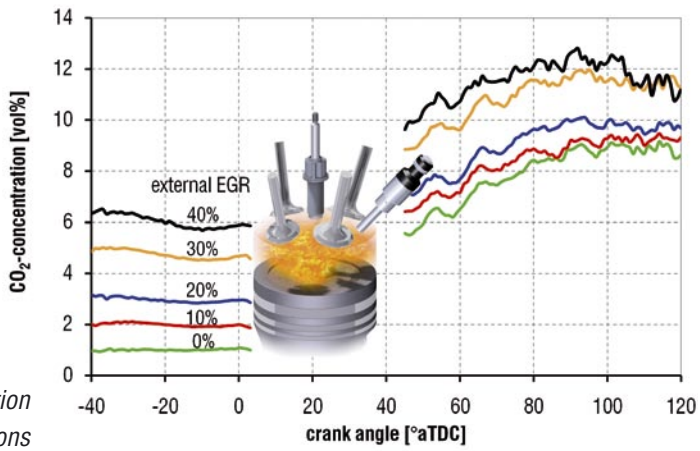
Applications

- variation of injection systems and strategies on the mixture formation process
- investigation of special engine operation modes: cold start, EGR and stratified operation
- crank angle resolved CO_2 concentration profiles
- internal and external EGR rates: EGR analysis over consecutive cycles and different cylinders





simultaneous single cycle fuel concentration measurements: ICOS versus FID



crank angle resolved in-cylinder CO_2 concentration measurements in a Diesel engine under varied EGR conditions

Internal Combustion Gas Temperature Sensor

LaVision's **ICOS system** for in-cylinder temperature indication measures locally the crank angle resolved gas temperature before and after combustion. Especially the often unknown compression stroke temperature rise is recorded in detail. These in-cylinder temperature profiles give important feedback for engine optimization, for the analysis of cycle by cycle variations and for the validation of numerical models.

ICOS-Temperature Optical Probe Versions

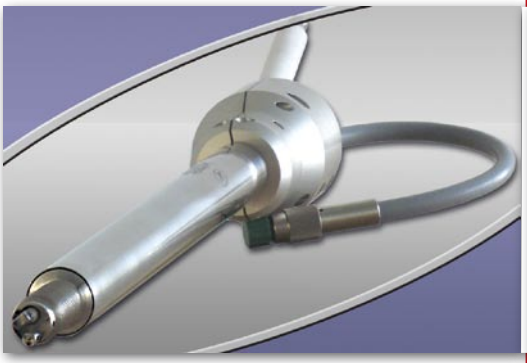
- M12 or M14 fully functional spark plug probes
- non-firing M5-thread probe or optical glow plug probe
- line-of-sight (transmission) probes (requires optical access)

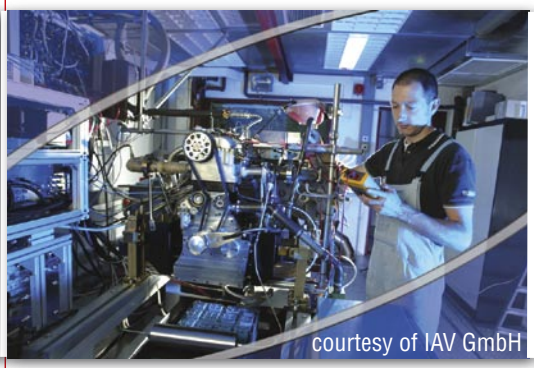
System Features

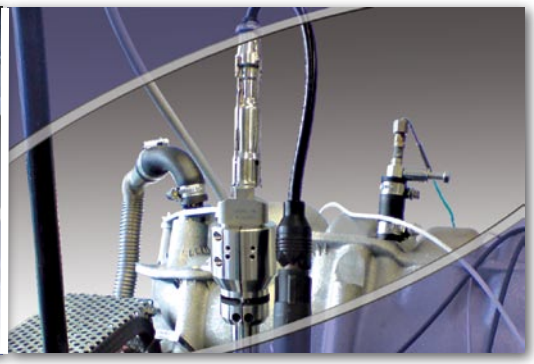
- in-cylinder gas temperature measurements with a special focus on the compression stroke
- engine synchronized on-line measurements with max 23 kHz sampling rate

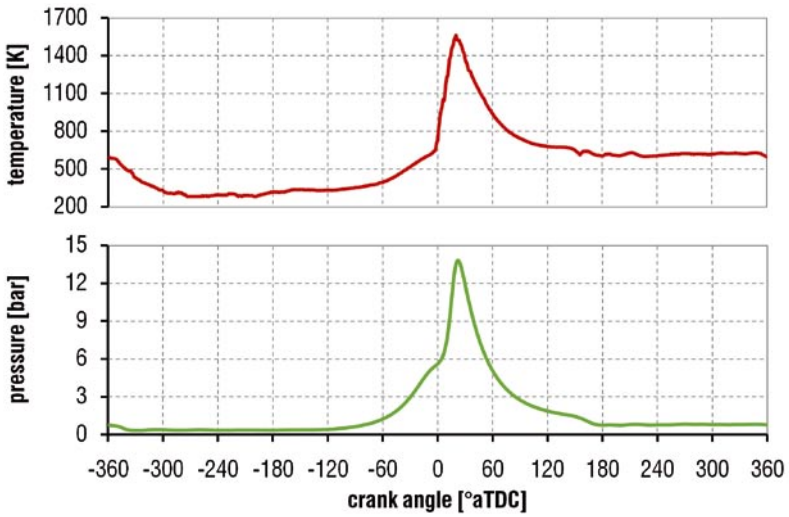
Applications

- effects of different EGR rates and valve timings on in-cylinder temperature
- HCCI pre-combustion temperature analysis
- detection of abnormal engine performance









simultaneously recorded cycle averaged in-cylinder gas temperature and pressure inside a DISI gasoline engine measured with the ICOS-Temperature system

Comprehensive Spray Characterization

Spray Imaging

Liquid fuel atomization and evaporation are directly affecting engine performance and exhaust emissions. To find the best spray injector configuration for a given engine concept is a challenging task. Laser imaging of transient fuel sprays in heated high pressure test cells or directly inside the cylinder offers an efficient analytical approach for spray characterization replacing old “trial and error” experiments. LaVision’s laser imaging systems provide information on various parameters such as spray propagation and breakup, droplet size, velocity and temperature and on the evaporation process.

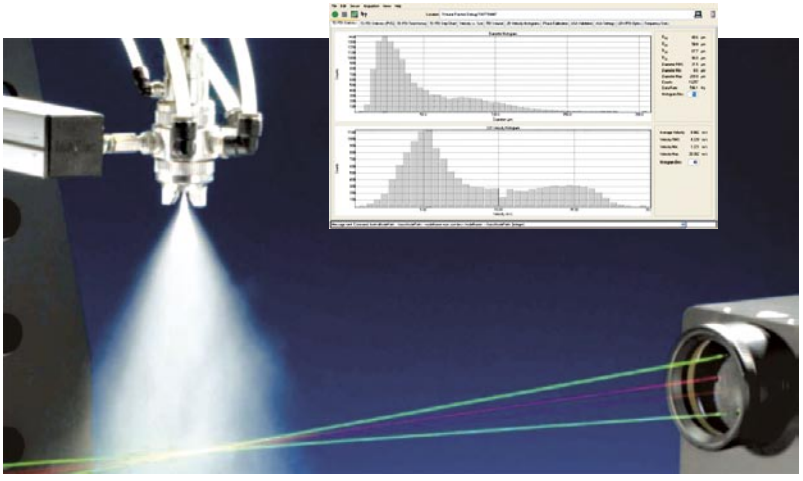
For a comprehensive spray characterization sophisticated customer designed imaging systems are offered as well as fully automated spray inspection systems for the inline quality control of spray injectors.

System Features

- phase locked as well as high speed imaging of various spray parameters in transient sprays:
  spray geometry, patternation, penetration, propagation
  spray velocity, evaporation, global droplet sizing
- light sheet scans for 3D spray imaging
- advanced imaging technology for dense sprays

Fast Spray Analysis

For correlated size-velocity measurements on single droplets and time resolved mass flux measurements LaVision offers advanced **Phase Doppler Interferometers.**



2D Phase Doppler Interferometer (PDI)

In-Cylinder Flow Fields for Dynamic Combustion Strategies

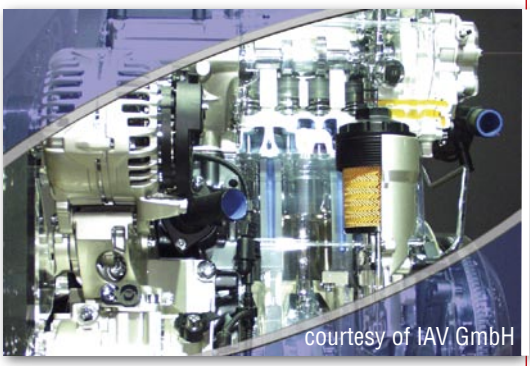
For engines with lower emissions and better fuel economy such as DI engines a precise control of the in-cylinder charge motion is essential. Flow fields in the intake manifold and the cylinder are strongly affecting the in-cylinder mixture preparation. Both large scale-motion, such as swirl and tumble flows, and small-scale turbulent motion influence the combustion process and hence emission levels. For homogeneous charge combustion turbulence is required at the time of ignition for an efficient combustion. In the case of stratified charge combustion, an ignitable mixture has to be guided to the spark plug by the internal cylinder flow in order to allow a reliable ignition and a subsequent stable combustion.

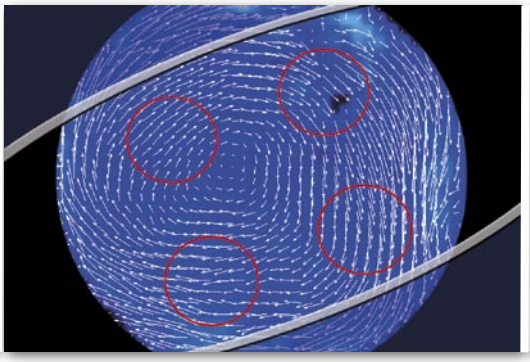
LaVision's keyhole imaging approach using innovative laser and camera endoscopes with small apertures is minimal invasive for the engine process not changing the flow field under study.

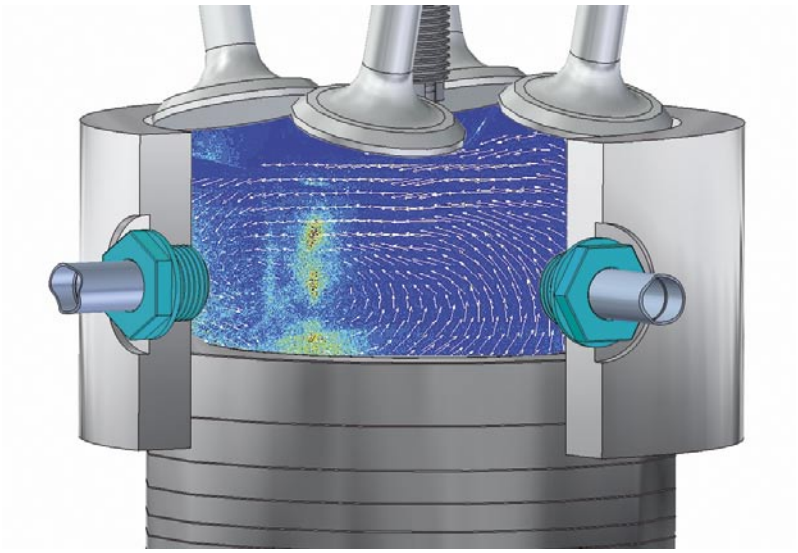
The laser imaging technique Particle Image Velocimetry (PIV) provides crank angle resolved 2-dimensional velocity measurements of the charge motion with high spatial resolution. High speed PIV measurements record flow field movies of the transient mixture formation of single engine cycles.

System Features

- phase locked and crank angle resolved flow fields
- endoscopic access for illumination and imaging







instantaneous in-cylinder tumble flow applying endoscopic imaging

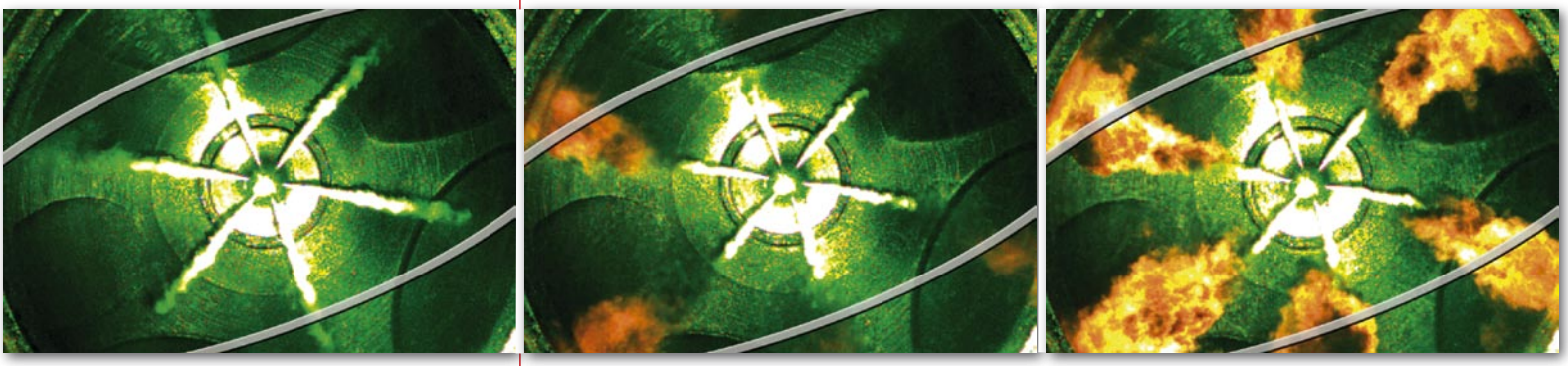
Improving Combustion Efficiency Reducing Emissions

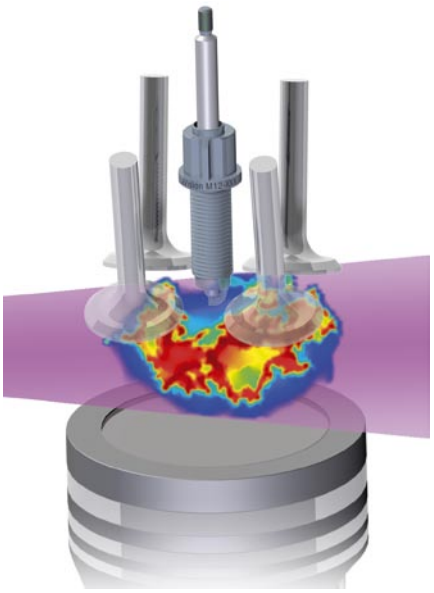
After ignition the flame front is propagating through the air-fuel mixture exchanging heat and mass. Flame propagation and local temperature are significantly affected by the local flow characteristics and mixture composition which have a strong impact on pollutant formation such as nitric oxides or soot particles. Thus, a thorough investigation is essential to improve the understanding of the detailed processes in reaction chemistry to optimize engine efficiency and reduce pollutant emissions.

LaVision offers integrated diagnostic solutions for engine combustion applications. These imaging systems visualize the location of flame kernels and the origin of unwanted pre-ignition spots leading to engine knock via detection of chemiluminescence or Laser Induced Fluorescence (LIF) of flame radicals. Laser imaging enables instantaneous detection of important species in reaction kinetics like CH and OH, and is able to resolve the distribution of prominent pollutants like NO.

System Features

- instantaneous detection of flame radicals like OH, CH and NO on laser light sheets
- pyrometry in sooting flames to determine particle temperatures
- high speed imaging of complete cycles:
  spray injection - ignition - combustion - glowing soot particles





single shot laser imaging of OH-flame radicals inside the cylinder of a gasoline engine

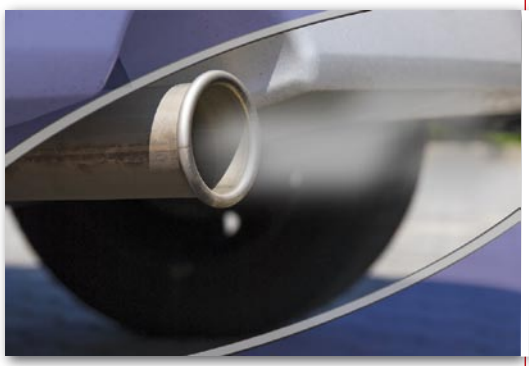
Soot Formation Imaging

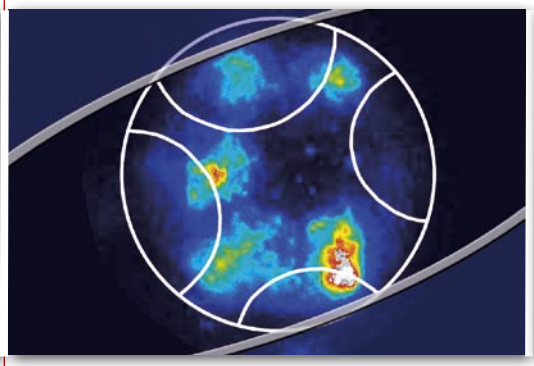
Combustion generated soot is known as one of the major pollutants emitted by Diesel engines. The soot is composed of nanoparticles produced through the incomplete combustion of hydrocarbon fuels. However, most of the soot particles are consumed by oxidation and do not contribute to exhaust emissions. In-situ visualization of soot formation in combination with a robust and most sensitive soot emission control are enabling diagnostic techniques to reach the challenging emission levels set out for the future.

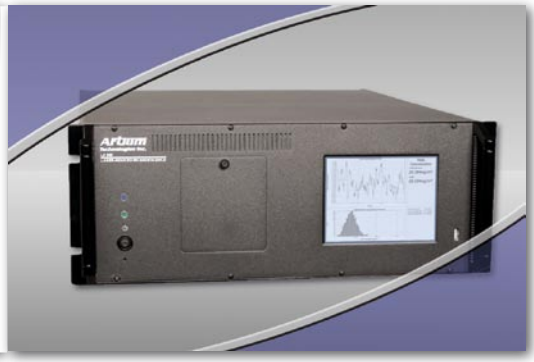
LaVision offers Laser Induced Incandescence (LII) as a technique for in-situ soot formation imaging of soot volume fraction and primary particle size distributions.

System Features for Soot Imaging

- instantaneous in-situ images of soot volume fraction and particle size distribution
- excellent sensitivity with a detection limit in the range of parts per billion (ppb)



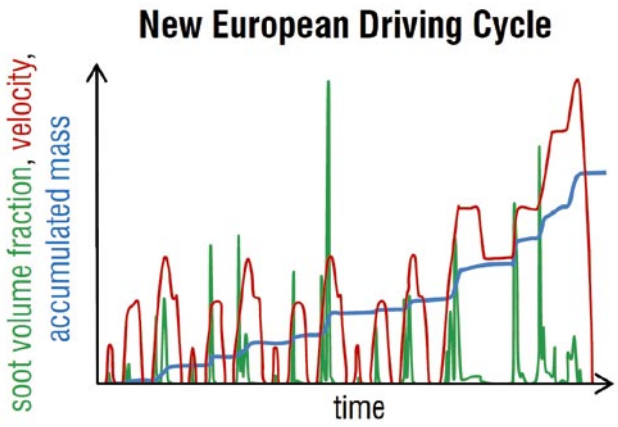




System Features for Soot Emission Analysis

For on-line soot emission control LaVision offers a portable LII soot sensor with highest sensitivity.

- correlated soot volume fraction and particle size measurements
- outstanding sensitivity in the range of parts per trillion (ppt)
- compact, rugged and portable instrument



Aerodynamic Testing and Passenger Comfort

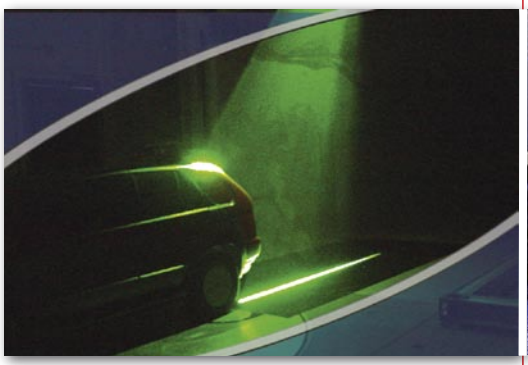
Optimizing Aerodynamic Efficiency Interior Climate Flows Aero-acoustics

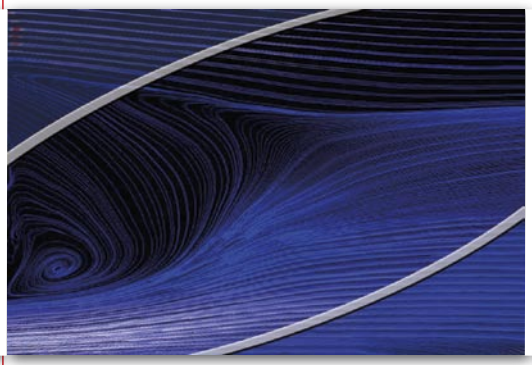
Aerodynamic testing is often the key to success in motor racing and also for transport vehicles to achieve the best fuel economy. Multi-dimensional and often time-resolved Particle Image Velocimetry (PIV) measurements are applied to balance **aerodynamic shape** with automotive styling, to **reduce wind noise** (aero-acoustics) and to guide **interior thermal flows** in order to maximize passenger comfort.

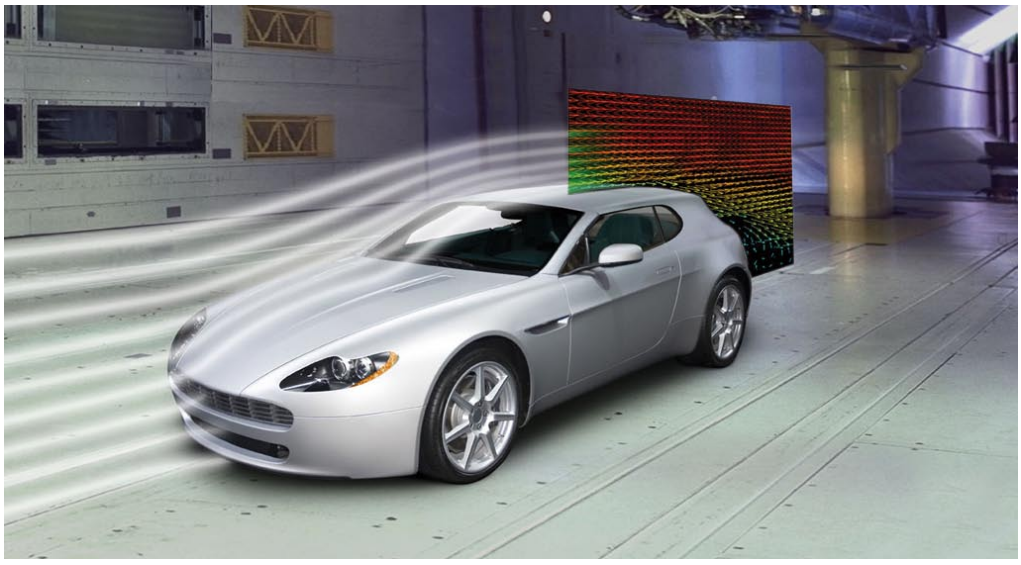
LaVision's Laser Imaging systems provide real-time and accurate airflow measurements, support remote measurement control including flow field scanning in all directions and data synchronization with other wind tunnel test parameters. This guarantees short development times avoiding costly wind tunnel down-time.

System Features

- remote control of multi-axis traversing systems and all imaging parameters
- effective seeding methods for small and large flow fields
- robust image calibration tolerates lower quality optical viewing windows
- advanced data evaluation for online display of results







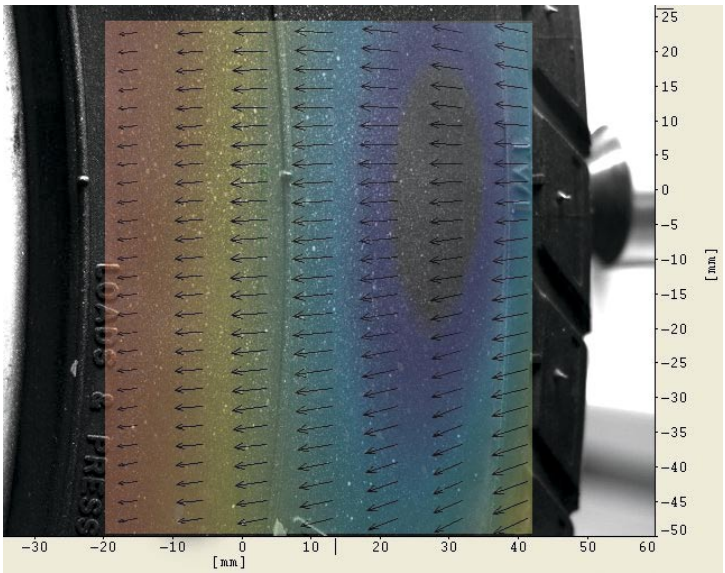
large field PIV recording of a passenger car wake flow

Contact-free Deformation and Strain Measurements

The performance of the materials used in the automotive industry, and of the components manufactured using those materials is critical to the safety of the construction, efficient use of materials, and achievement of creating a light-weight fuel efficient design.

Digital Image Correlation (DIC) is a particularly popular full field non-intrusive tool for surface displacement and strain measurements and is able to collect data from sample sizes of microns up to meters.

Displacements with high precision can be attained with state-of-art algorithms, allowing users to measure tyre squash under static or dynamic loading, or performance of welded materials. Bend testing of aerodynamic surfaces can be performed in the test laboratory under static load conditions, or combined with PIV to calculate aeroelastic effects and Fluid-Structure Interaction phenomena.



tire squash deformation under static or dynamic loading

Engine Synchronizer / Simulator for Laser Imaging Systems

- crank angle locked recording supporting engine acceleration modes
- integrated rotary decoder enabling phase scans
- automatic phase detection from pressure signal
- simulation of engine encoder signals and pressure for fast system synchronization checks
- control of injection(s), alternating engine operation incl. skip fire modes
- input signal level conditioning for improved encoder signal quality

Flexible Light Guides, Endoscopes and Sealing Inserts

- flexible light delivery guides for in-cylinder illumination
- various laser and camera endoscopes for in-cylinder keyhole imaging
- customized sealing inserts for optical access

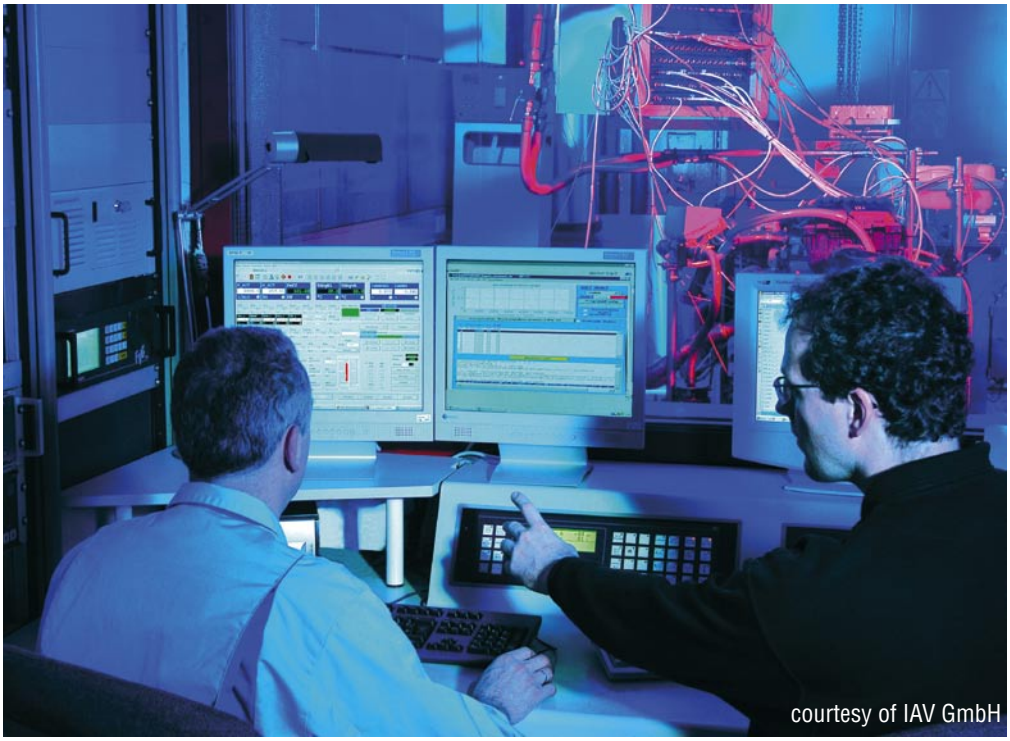
Optical Spark Plugs and In-Cylinder Light Probes

- M12 and M14 optical spark plugs
- universal optical M5 probe, optical glow plug

Services

Besides turn-key measurement systems LaVision is offering in the field of automotive R&D:

- contract measurements
- equipment loan
- on-site demonstrations and feasibility tests
- inline/online quality control systems and
- flexible and customized optical measurement solutions


courtesy of IAV GmbH

Customer Partnership

The LaVision team welcomes and encourages discussions and long term relationships with prospective and existing customers regarding their measurement requirements.
Application specific measurement solutions in the field of automotive R&D are our speciality.

LaVision‘s Product Range

- modular laser imaging systems based on spectroscopic techniques for multi-parameter and multi-dimensional flow field measurements for combustion, spray and flow visualization
- imaging systems for remote and precise surface deformation and strain inspection
- software integrated advanced camera systems
- fiber optical sensor systems

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