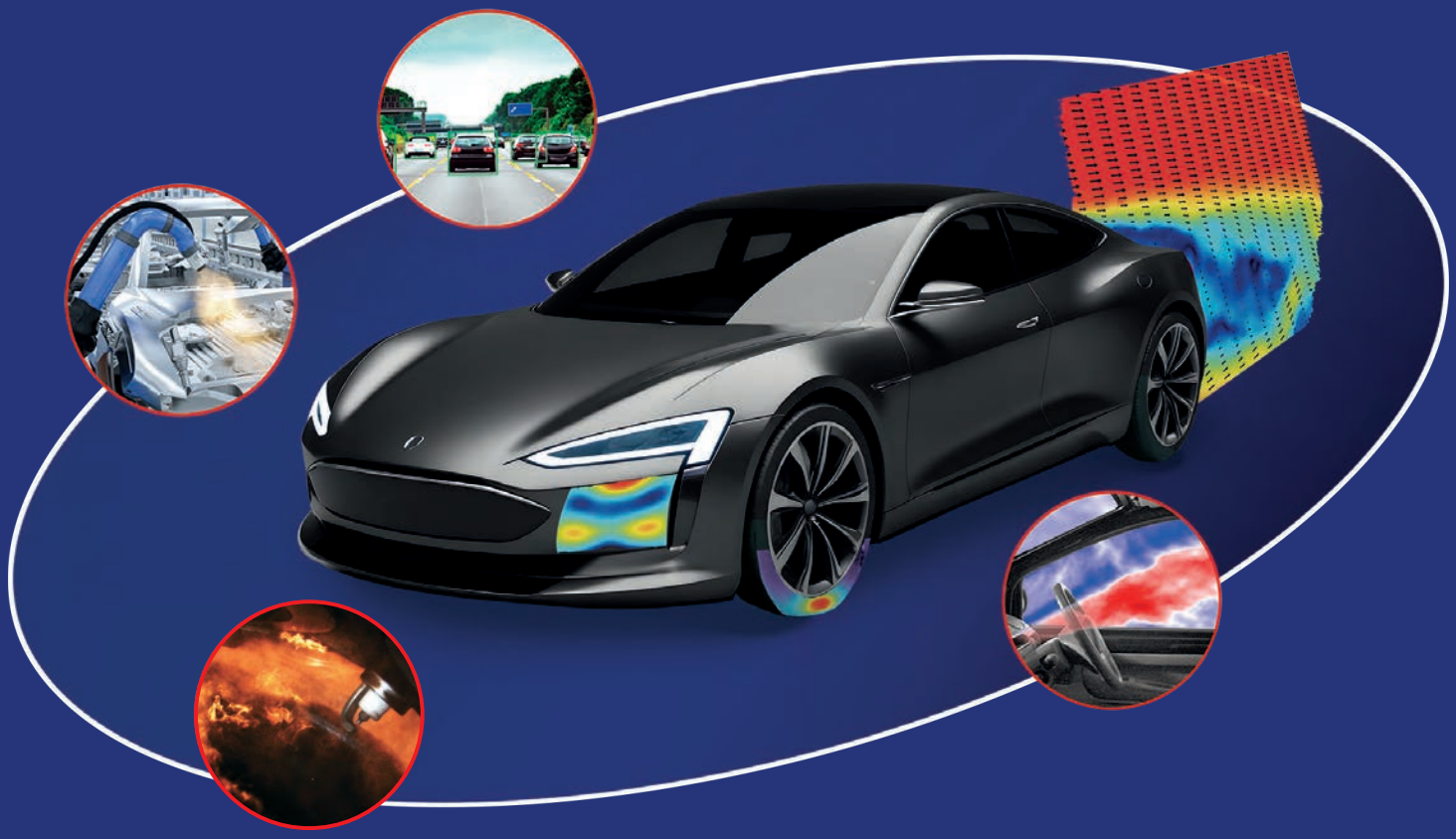


LaVision Automotive

Innovative Measurement Technologies

LAVISION

FOCUS ON IMAGING


9600 HP

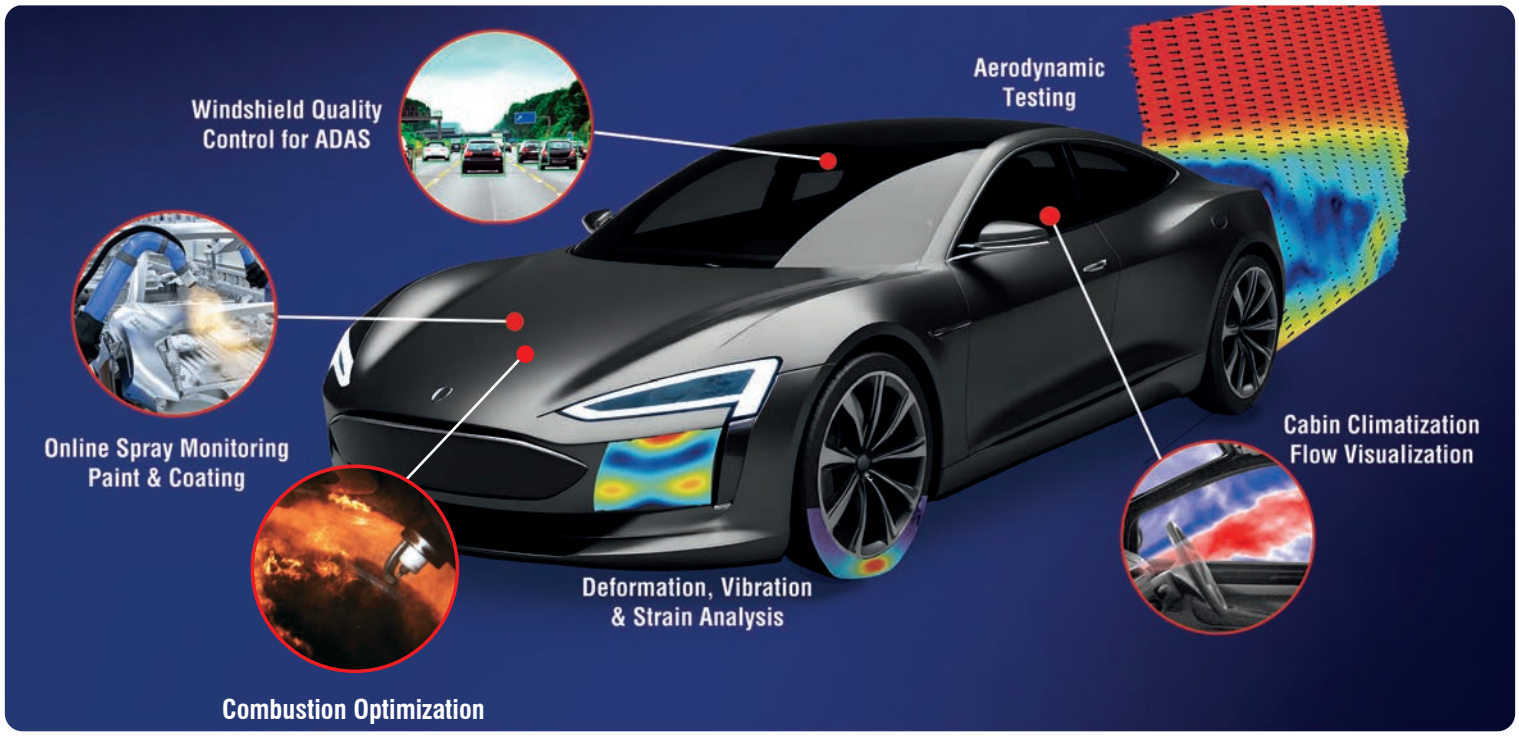
Driving Automotive Mobility

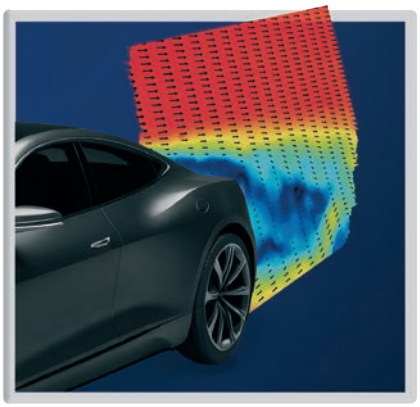
The automotive industry is going through a technological transformation these years promoting an eco-friendly transportation system as a balanced mix of different powertrain technologies with an increased energy diversity using conventional, synthetic and biofuels, compressed natural gas, hydrogen as well as electricity.

In particular the electrification imposes new challenges on lightweight construction materials. Other challenges are improved air flows around and inside the vehicle for aerodynamic drag reduction and interior thermal flow control, respectively.

In this fast changing automotive industry LaVision's optical measuring systems are proven powerful engineering tools enabling shorter product development cycles driving automotive mobility to the next level.

Whether your measurement focus is on **engine performance, aerodynamic testing, climate flow control, spray monitoring in paint and coating processes, autonomous driving** or on **dynamic deformation and strain measurements** - LaVision is your partner to find the best measurement solution.





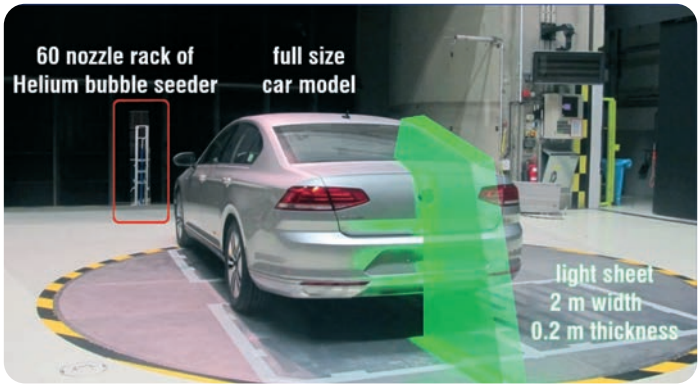
Air Flows Around and Inside Cars

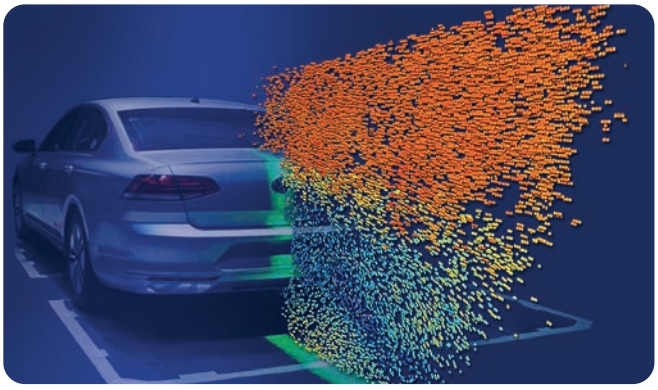
Optimizing aerodynamic efficiency

- Large-scale 2D and 3D flow field imaging
- Aerodynamic drag and wind noise reduction
- Pressure fields derived from velocity data
- In-cabin climate flows

Aerodynamic testing is often the key to success in car racing and also for transport vehicles to achieve the best fuel economy. Multidimensional and often time-resolved **P**article **I**mage **V**elocimetry (**PIV**) as well as **P**article **T**racking **V**elocimetry (**PTV**) measurements are applied in wind tunnels to optimize aerodynamic efficiency. From these flow fields pressure fields are calculated revealing the aerodynamic forces acting on surfaces. These pressure fields are important for the understanding of fluid-structure interaction phenomena.

LaVision's **FlowMaster** PIV systems provide real-time and accurate flow field 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-times.



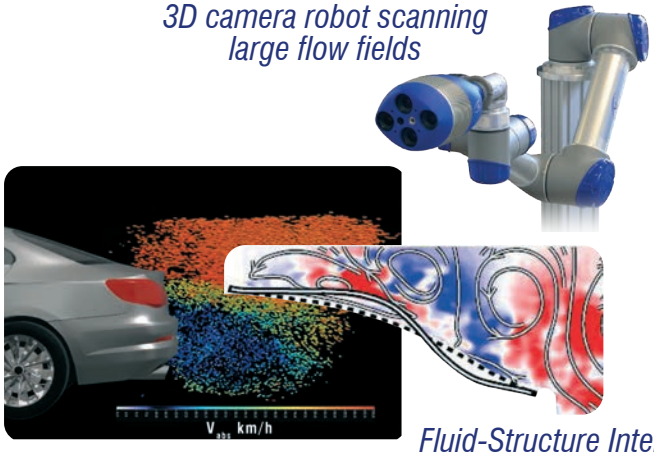


Large 3D flow field imaging in a passenger car wake flow using Helium-filled soap bubbles and time-resolved Particle Tracking Velocimetry (PTV)

FlowMaster system features

- Most accurate PIV/PTV software in the market
- Self-calibration for highest accuracy
- Uncertainty quantification with error propagation
- Pressure fields from velocity data
- Large velocimetry fields/volumes using Helium bubbles
- 3D camera robot for scanning large 3D flow fields

3D camera robot scanning large flow fields



Fluid-Structure Interaction

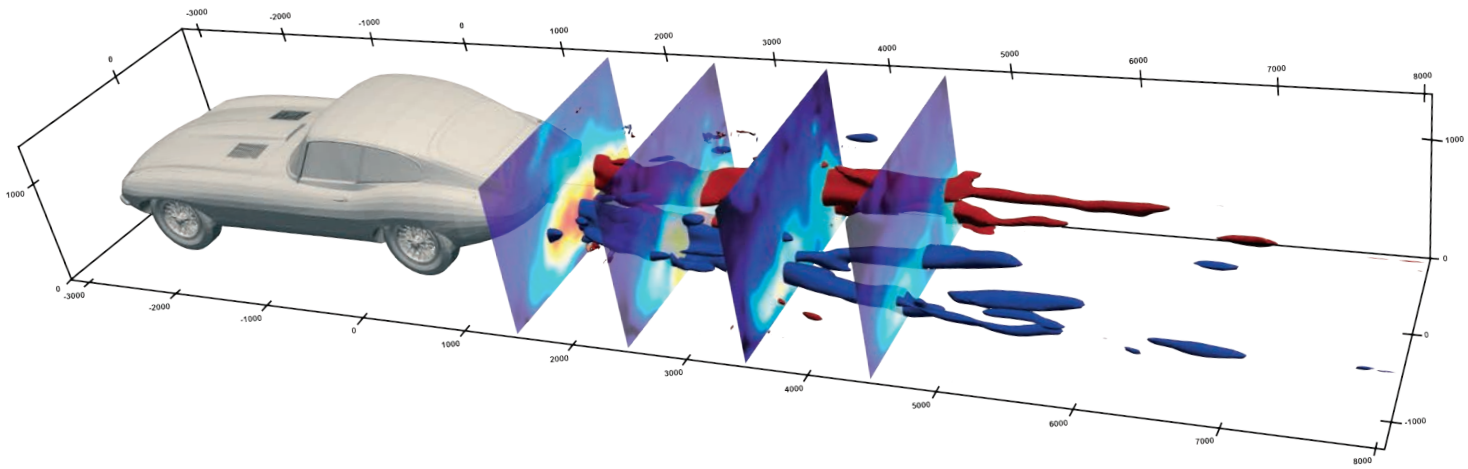
Simultaneous **PIV**/**PTV** and **d**igital **i**mage **c**orrelation (**DIC**) imaging yields both the flow field information as well as object shape and deformation as well as their structural dynamic response. This combined measurement approach enables a comprehensive analysis of fluid-structure interaction phenomena, which can be complex and non-linear, especially with modern materials and flexible lightweight components utilized in today's automotive industry.

Ring-of-Fire

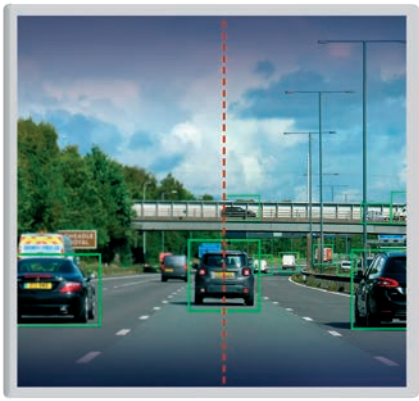
Wake characterization of full-scale vehicles

- On-road measurements providing real driving conditions
- Real world data for virtual development validation

For on-track measurements under real environmental conditions, our **FlowMaster** systems can be set-up directly on site. This enables the aerodynamic characterization of the complete wake of the car under conditions not producible in a classic wind tunnel. Another benefit of this **Ring-of-Fire** method is that it is independent of the vehicle and therefore no special preperations are required. Measurements can be performed with high spatial and temporal resolution and with short acquisition time (approx. 1 sec/run).



Topology of the vehicle wake visualized by sparse, planar velocity fields and isosurfaces. Data collected using a vehicle generously provided by Phillip Porter (P. Porter, 9600 Hp: The Story of the World's Oldest E-Type Jaguar, Porter Press International, 2021.)

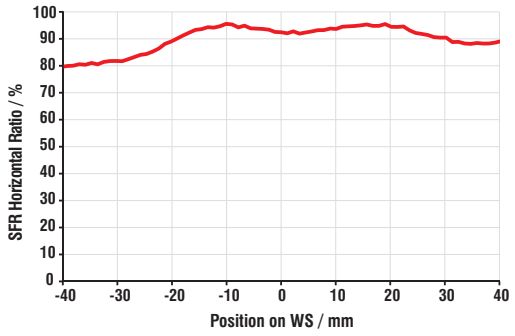


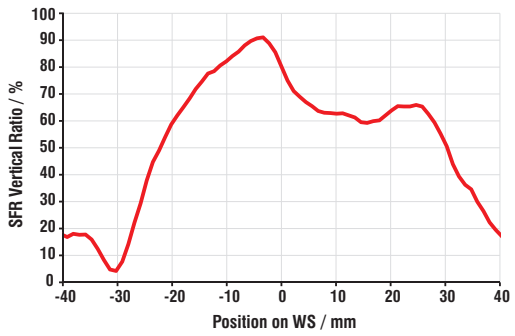
Quality Assessment of Automotive Windshields

Optimizing image quality for autonomous driving

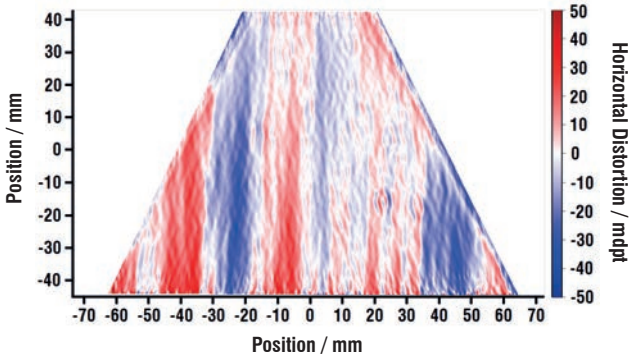
- Characterizing the optical quality of the lens – windshield combination
- Pointwise measurements of windshields SFR in the ADAS camera area
- Real test conditions for customized ADAS camera lenses

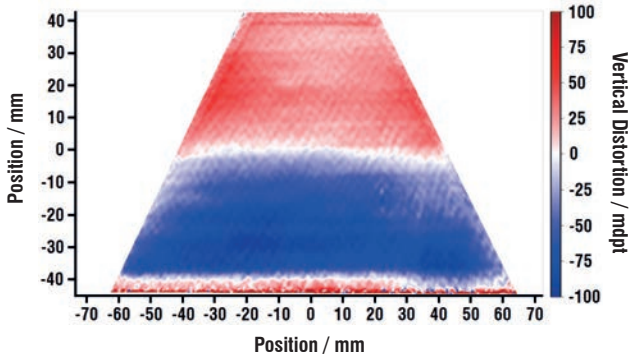
LaVisions **Glass-SFR *inspex*** provides comprehensive measurements of optical glass quality for safe autonomous driving with ADAS camera systems. Optical transmission parameters like contrast reduction or optical power (diopter) at the ADAS camera area of the windshield are carried out by image quality evaluation using innovative analysis techniques.





Analysis of the SFR of an ADAS camera area at a windshield by a vertical scan





Analysis of the optical power of an ADAS camera area at a windshield

Glass-SFR *inspex* system features

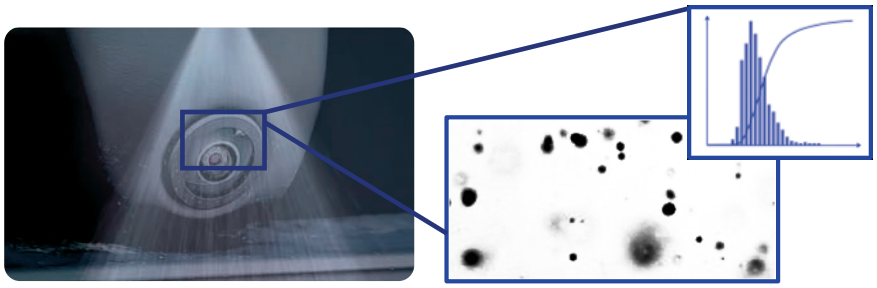
- Glass-SFR inspex system: SFR/MTF & (optional) diopter analysis of ADAS camera fields at windshields
- Simple modular system setup, fully automated operation
- Fast image recording for dynamic measurements

ADAS Camera & Sensor Cleaning

Efficient cleaning for a clear view

- Digital spray characterization for R&D and quality control
- Reduce consumption
- Improve cleaning

In the past only the windshield required active cleaning to ensure clear vision for the driver. On the road to autonomous driving, the extensive use of camera and sensor based advanced driver assistance systems (ADAS) has increased the demand for more reliable cleaning systems. Optimizing nozzles to ensure better atomization and droplet size distributions can greatly increase the effectiveness and reduce the consumption of optical cleaning systems. Optical characterization is a powerful tool to achieve these goals.



Climate Wind Tunnel Conditioning

Simulate real life conditions

- Particle & droplet size, shape & velocity
- Optimize rain, snow and ice for vehicle testing

To ensure road safety ADAS systems need to function under all environmental conditions. Testing these properly requires simulating all possible conditions in climatic wind tunnels. Simulating real conditions is not straight forward! LaVision's **ParticleMaster** systems can help you ensure that your rain, snow and ice has the right properties by measuring size, shape distribution, velocity and mass flux.

ParticleMaster *inspex* system features

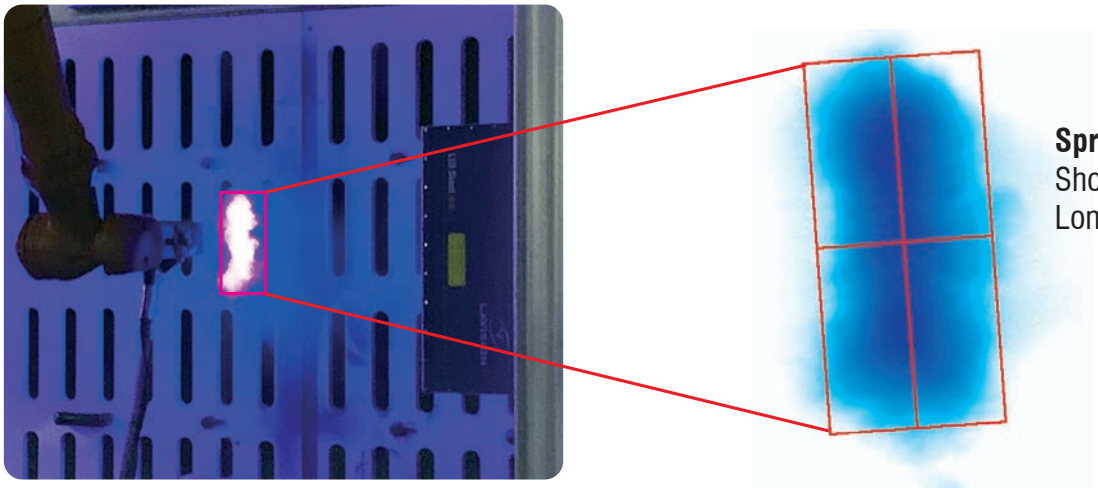
- In-situ particle & droplet characterization
- Size, shape & velocity
- Particle size distribution and statistics
- Rugged splash-proof design
- Pre-calibrated probes

Characterizing Paint & Coating Sprays

Online production monitoring, quality control and R&D applications

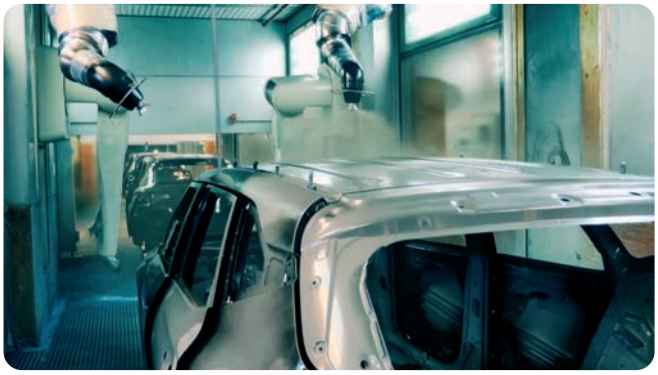
- Online monitoring of coating processes
- Fast quality control (QC) during spray nozzle production
- Spray process optimization and spray nozzle design optimization in R&D

Coating application is a central part to many production processes such as spraying vehicle body paint, functional battery pack coatings or mold release agents. The quality of a coating depends on many factors such a coating formulation, nozzle design and operating parameters. Online monitoring of spray application plays an important role in increasing efficiency and reducing wastage. By detecting overspray, monitoring re-circulate composition, nozzle deterioration and fouling, processes can be adjusted and maintenance downtime can be reduced to a minimum.



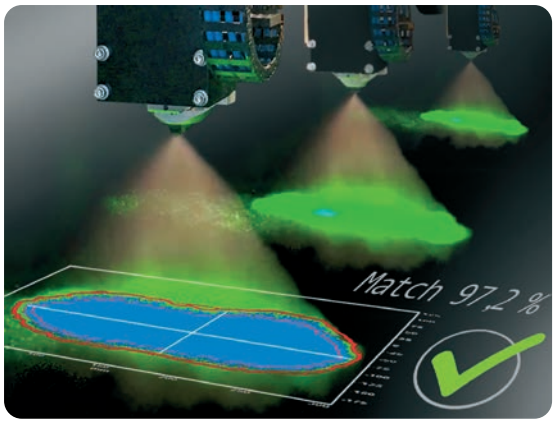
Spray Dimensions
Short axis: 102 mm
Long axis: 216 mm

In cooperation with Fraunhofer IPA

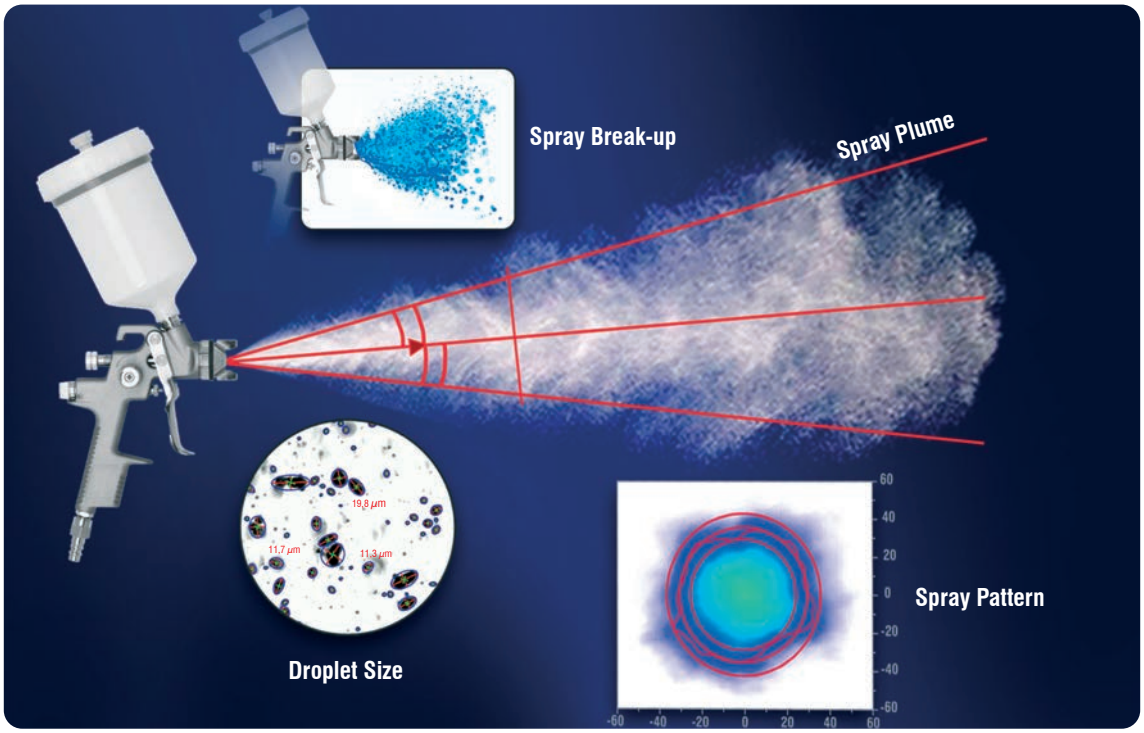


SprayMaster *inspex* system features

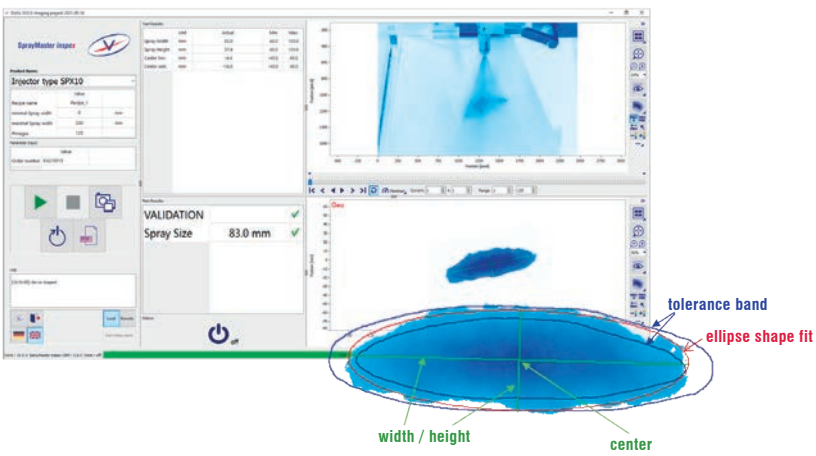
- Plume geometry, angle, penetration depth
- Spray plume videos (temporal spray development)
- Spray break-up
- Pattern geometry, size, homogeneity
- Particle & droplet characterization including size, shape, velocity and mass flux

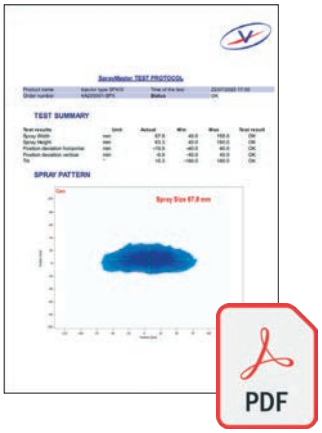


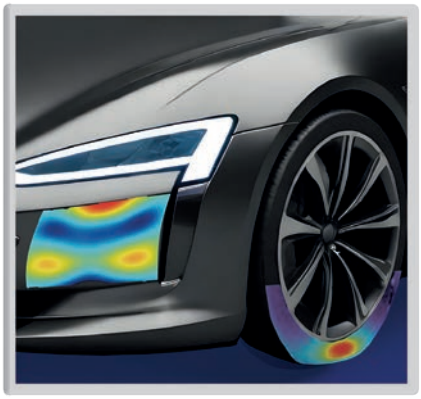
Improve your spray performance and coating processes with LaVision's fast, non-intrusive digital spray characterization systems. **SprayMaster *inspex*** systems measure spray pattern and spray plume geometry. **ParticleMaster *inspex*** systems give you detailed analysis of droplet / particle size, shape & velocity. The multifunctional systems are designed for detailed spray characterization for quality control and production monitoring as well as for R&D in paint and coating atomization processes.



SprayMaster *inspex* Q.C. (Quality Control) Software provides real time spray image analysis for quality control and process monitoring. Process relevant spray geometry parameters are extracted from recorded spray images. These are compared to quality acceptance criteria to give instantaneous feedback to the operator or an automated production line.





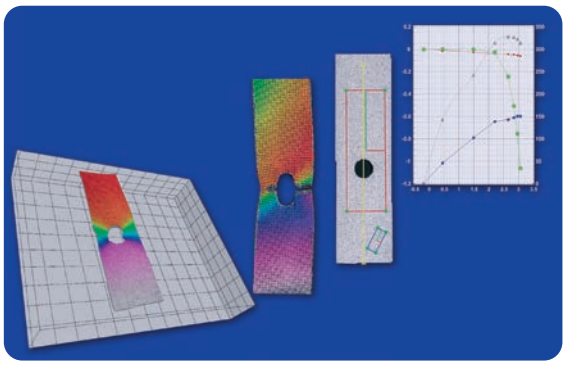


Automotive Materials Testing

Deformation, vibration & strain analysis

- Material and component test on various different materials
- Fatigue Testing
- Comparison of experimental and simulation results
- Surface and volume measurement
- Mechanical, thermal or combined loading
- FSI for flexible aerodynamic parts

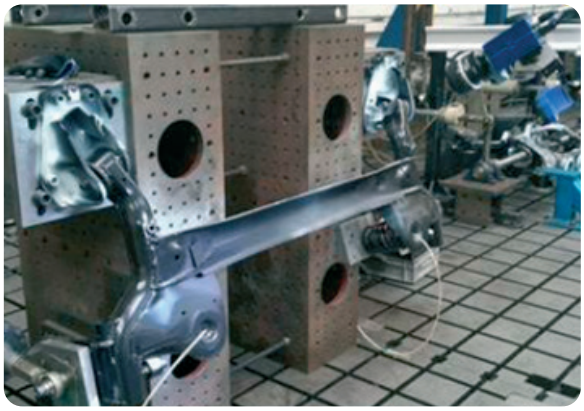
The performance of the materials used in the automotive industry and of the components manufactured using those materials is critical to the safety of the construction, efficient use of materials, and of creating a lightweight fuel-efficient design.
Digital **I**mage **C**orrelation (**DIC**) is a full field non-contact imaging technique for surface shape, displacement and strain measurements and collects data from sample sizes of microns up to meters.



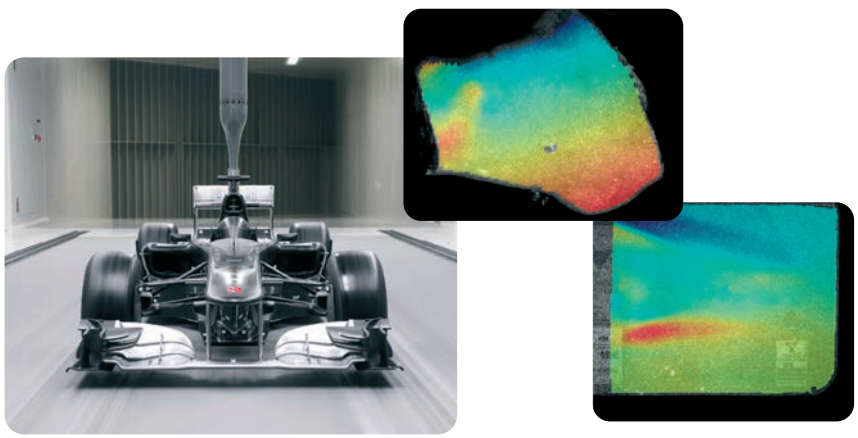
StrainMaster system features

- Turn key system, acquisition, analysis data management within one software package
- Full field results with high spatial resolution
- Adjustable field of view, image resolution and acquisition speed
- Virtual gauge and live extensometer mode
- Usable for high temperature applications

Displacements with high precision are attained with state-of-the-art algorithms, allowing users to measure e.g. tire squash under static or dynamic loading, or the performance of welded materials. Bend testing of aerodynamic surfaces are performed in the test laboratory under static load conditions or combined with **PIV** to calculate aeroelastic effects or Fluid-Structure Interaction phenomena.
The modular concept of the StrainMaster product range also allows customer-specific solutions, e. g. fixed mounting on an engine test bench or selection of the required camera(s). The camera program ranges from standard and high-resolution models for classic materials testing and dynamic fatigue tests to high-speed cameras for impact testing.

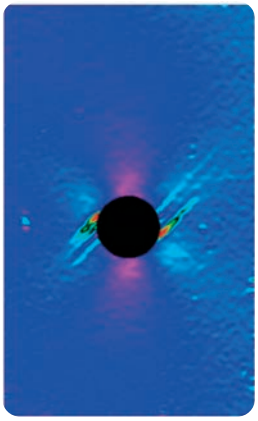


Measurement of sub frame joints

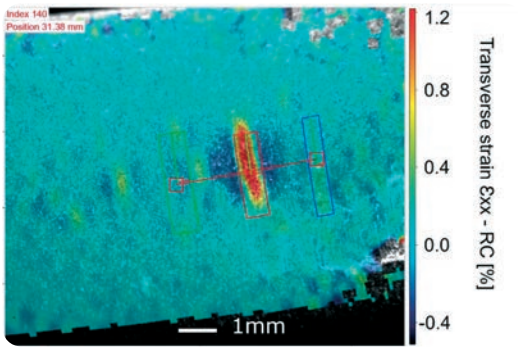


Deformation measurement of aerodynamic loading

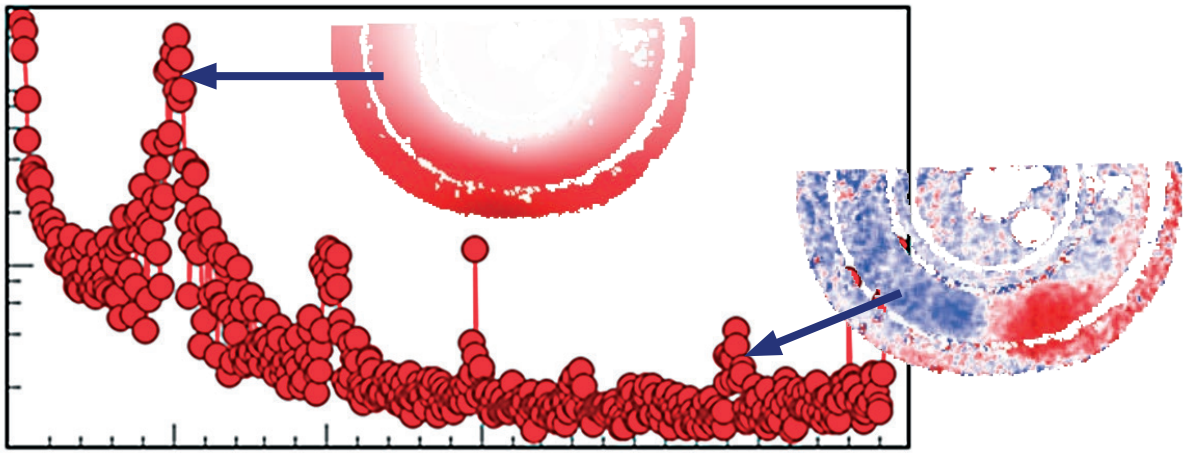
Digital Image Correlation (DIC) opens up the possibility of spatially resolved strain measurement on tensile specimens to determine the mechanical material properties of rivets, joints or other inhomogeneities.

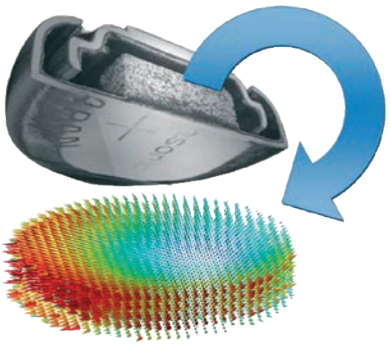


Other applications in a tensile testing machine can include high-cycle fatigue (HCF) tests. In particular, crack formation and crack growth can be measured here. This shows, for example, that the crack becomes visible considerably before the component fails (e.g. 4 hours before failure, with a total running time of 11.5 hours)



The Operational Deflection Shapes (ODS) can also be determined using DIC. The frequencies with the largest deformation amplitude can be calculated from the temporal deformation using FFT. The ODS can then be determined and displayed for these frequencies.





If volume information, e.g. measured using an X-CT, is available, a deformation analysis can be carried out using Digital Volume Correlation (DVC) and thus the deformations and strains within the object can be measured.
The left image shows the deformation of a battery during discharge.

Carbon-Free Fuels

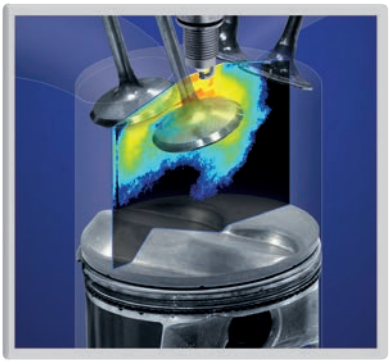
For a clean energy future

- Hydrogen
- Ammonia
- E-fuels
- Synthetic fuels

LaVision's **EngineMaster** systems have been an important analysis tool for the optimization of internal combustion engines for many decades. New fuels require optimized combustion concepts to maximize their efficiency and minimize the environmental impact.

EngineMaster system features

- Crank angle synchronized imaging
- Crank angle resolved flow fields with cycle statistics
- Complete λ-maps close to the spark plug
- Outstanding soot detection limits
- Endoscopic access for sheet illumination and imaging

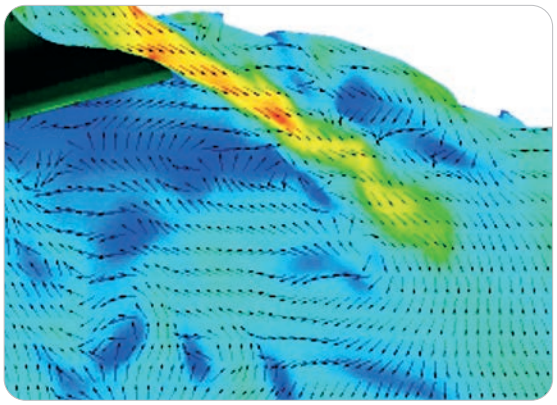


In-cylinder Laser Imaging

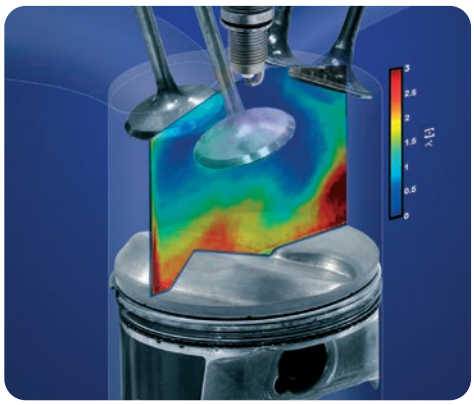
For combustion optimization

- In-cylinder flow fields (swirl & tumble)
- Mixture formation imaging (λ-maps)
- Soot particle generation
- NOx formation, flame radicals

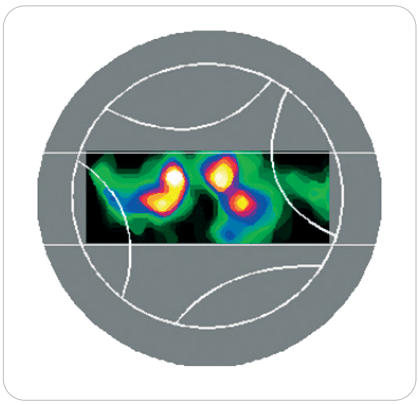
LaVision's **EngineMaster** laser imaging systems provide information on fuel injection, mixture preparation, knocking centers, flame species, NOx formation and soot production. In-cylinder flow fields are measured with our **FlowMaster** **P**article **I**mage **V**elocimetry (**PIV**) systems. Crank angle resolved in-cylinder laser imaging is performed on pulsed laser light sheets in transparent engines or applying keyhole imaging using minimal invasive endoscopes. The crank angle resolved measurements are synchronized with the encoder signal of the engine supporting all engine operation modes such as cold start, skip-fired and acceleration modes.



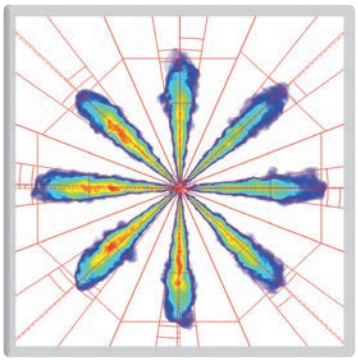
Tumble flow field near inlet valve



In-cylinder mixture formation: λ-map



In-cylinder soot imaging

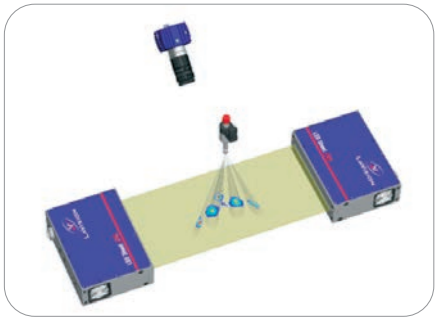


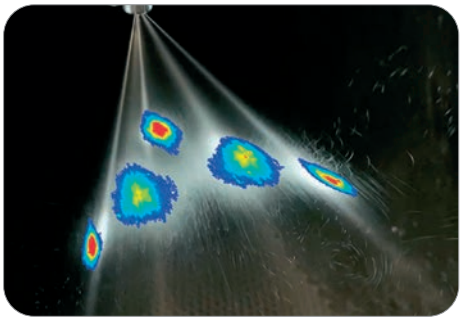
Spray and Droplet Imaging

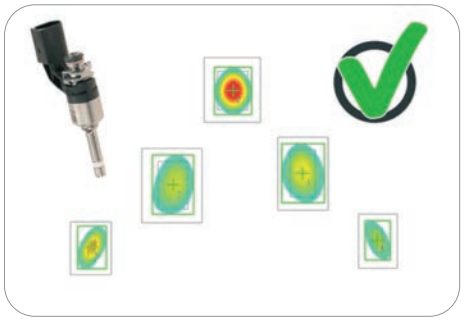
For Fuel and SCR injectors development and quality control

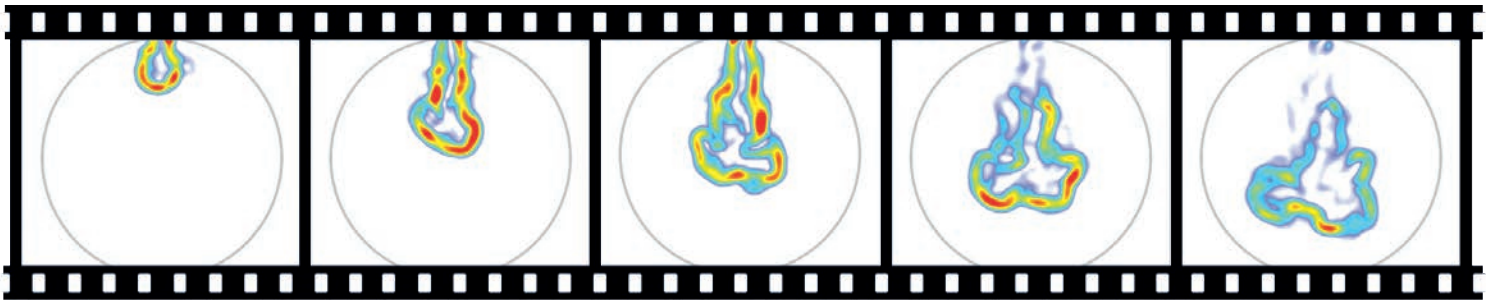
- Optical spray plume and pattern analysis
- Advanced spray imaging systems for R&D
- Robust system designs for industrial spray testing
- In-/online quality control of fuel injectors

To ensure future operation of internal combustion engines it remains crucial to do everything possible to minimize their emissions. New challenges arise with the introduction of synthetic and e-fuels requiring adaption and optimization of combustion processes. Emission control starts with the injection of fuel. Only a high quality fuel injector can guarantee efficient fuel injection over a long lifetime. LaVision's online production monitoring solutions for reliable 24/7 inspection of fuel injectors will allow you to guarantee high quality, increase productivity and operate more sustainably by reducing wastage.



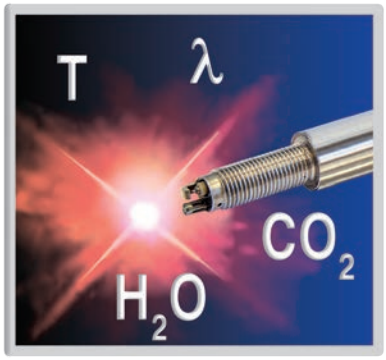






High-speed imaging of hydrogen injection with 4 bar injection pressure and 3 bar back pressure

Meeting current and future ICE emission regulations is not possible without exhaust gas aftertreatment.
A central part is played by Adblue dosing systems for SCR after treatment. Digital spray characterization can help to develop even more efficient dosing systems to further reduce consumption.



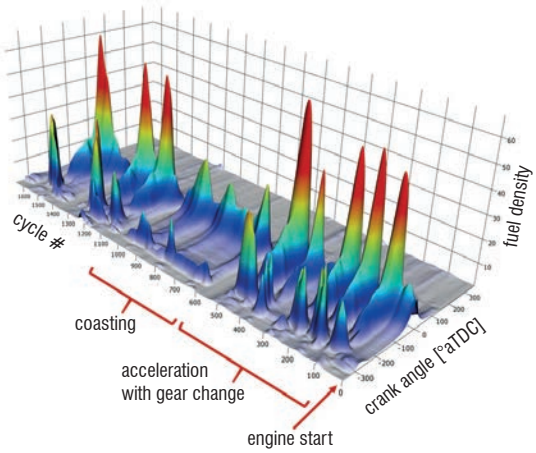
In-Cylinder Optical Engine Indication

Mixture formation analysis of highly dynamic engine conditions

- Air/fuel ratio measurements
- Exhaust gas concentration and EGR
- Gas temperature
- Water concentration

Optical engine indication synchronized with standard pressure indications allows a much more detailed characterization of the in-cylinder charge formation process, which is of upmost importance to improve engine performance for more efficient and cleaner combustion.

The quality of the combustion is strongly influenced by the mixture preparation prior to ignition. Mixture inhomogeneity, intended or unwanted, and ignitability of the in-cylinder charge cannot be determined by pressure indication alone. Optical engine indication of the local air/fuel ratio at the spark plug position as well as CO_2- and water concentration measurements quantify the mixture formation and improve injection strategies, exhaust gas recirculation or water injection concepts. Knowledge of the gas temperature in addition to pressure is critical to operate closer to the knock-limits.



Endoscopic In-Cylinder Imaging

Quantitative imaging of complete IC-engine cycles

- Spray injection analysis
- Flame propagation speed
- Localization of soot emission areas

For the optimization of near-production engines endoscopic imaging is applied to visualize in-cylinder phenomena. Keyholeimaging using endoscopes is a minimal invasive technique to monitor in real-time in-cylinder processes such as fuel spray injection, ignition, combustion and soot formation.
In combination with standard pressure indication endoscopic imaging links engine performance and emissions with in-cylinder phenomena such as pre-ignition, wall wetting and soot particle generation.

Soot formation in GDI engine during first cycles of a cold start at fixed crank angle position

Cabin Climate Flow Visualization

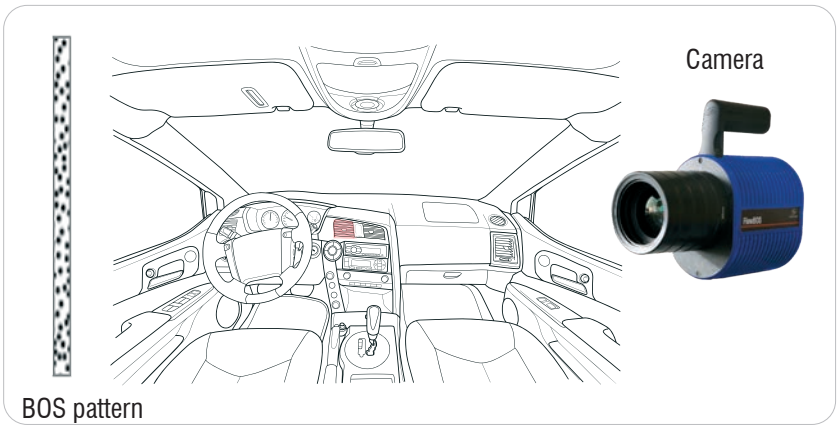
Air conditioning and heat management

- Sensitive imaging technique for thermal air & gas flow visualization without flow seeding
- For thermal air- & gasflow visualization

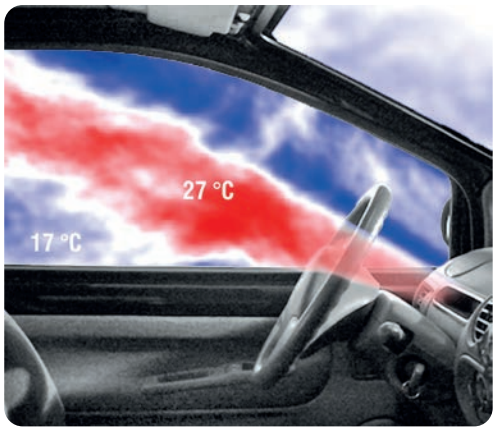
For the visualization of air & gas flow motion based on local refractive index variations **B**ackground **O**riented **S**chlieren (**BOS**) is a simple and cost-effective alternative to laser imaging methods. This imaging technique is highly sensitive to air temperature differences and requires no flow seeding at all. **BOS** imaging allows a flexible and fast use inside the car without any special preparations or modifications due to its simple system configuration and advanced real-time image processing capability.

FlowBOS camera system features

- Thermal flow & gas visualization + velocimetry without seeding
- Thermal management of electronic components & power electronics
- Electric vehicles: leakage detection of battery-housing
- Flexible fields-of-view up to large scales
- Simple system setups



Simple BOS arrangement for interior flow control



Interior thermal flow visualization

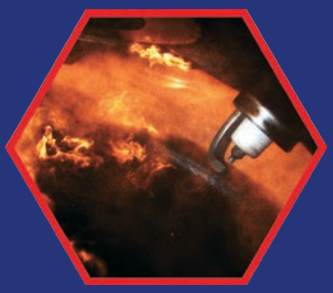
Automotive Measurement Solutions

Spray Monitoring
Paint & Coating

Windshield Quality
Control for ADAS

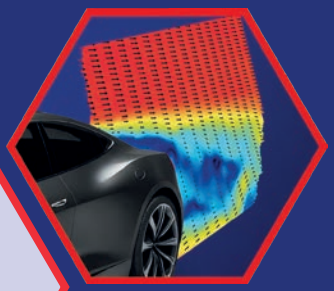
Deformation,
Vibration
& Strain Analysis

Combustion
Optimization



Aerodynamic
Testing

Cabin
Climatization



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