

# LaVision Automotive

Innovative Measurement Technologies



**LAVISION**

FOCUS ON IMAGING

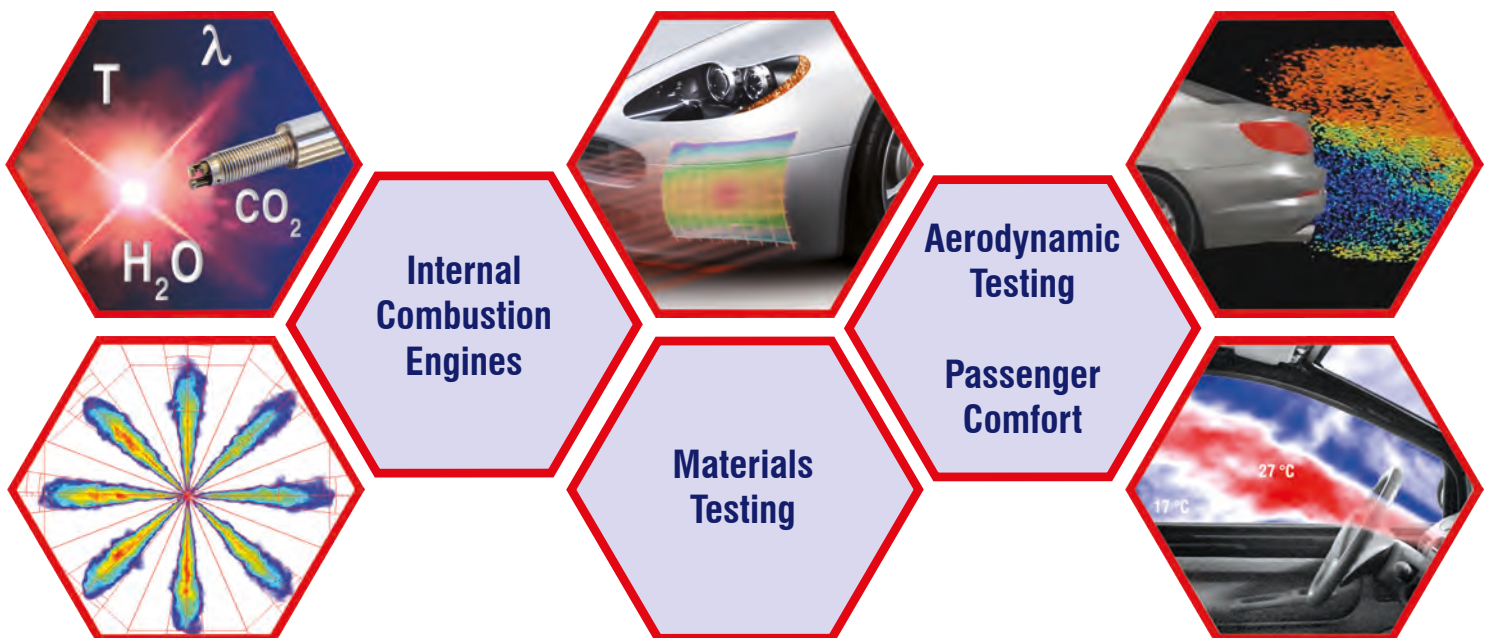


## Driving Automotive Mobility

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.

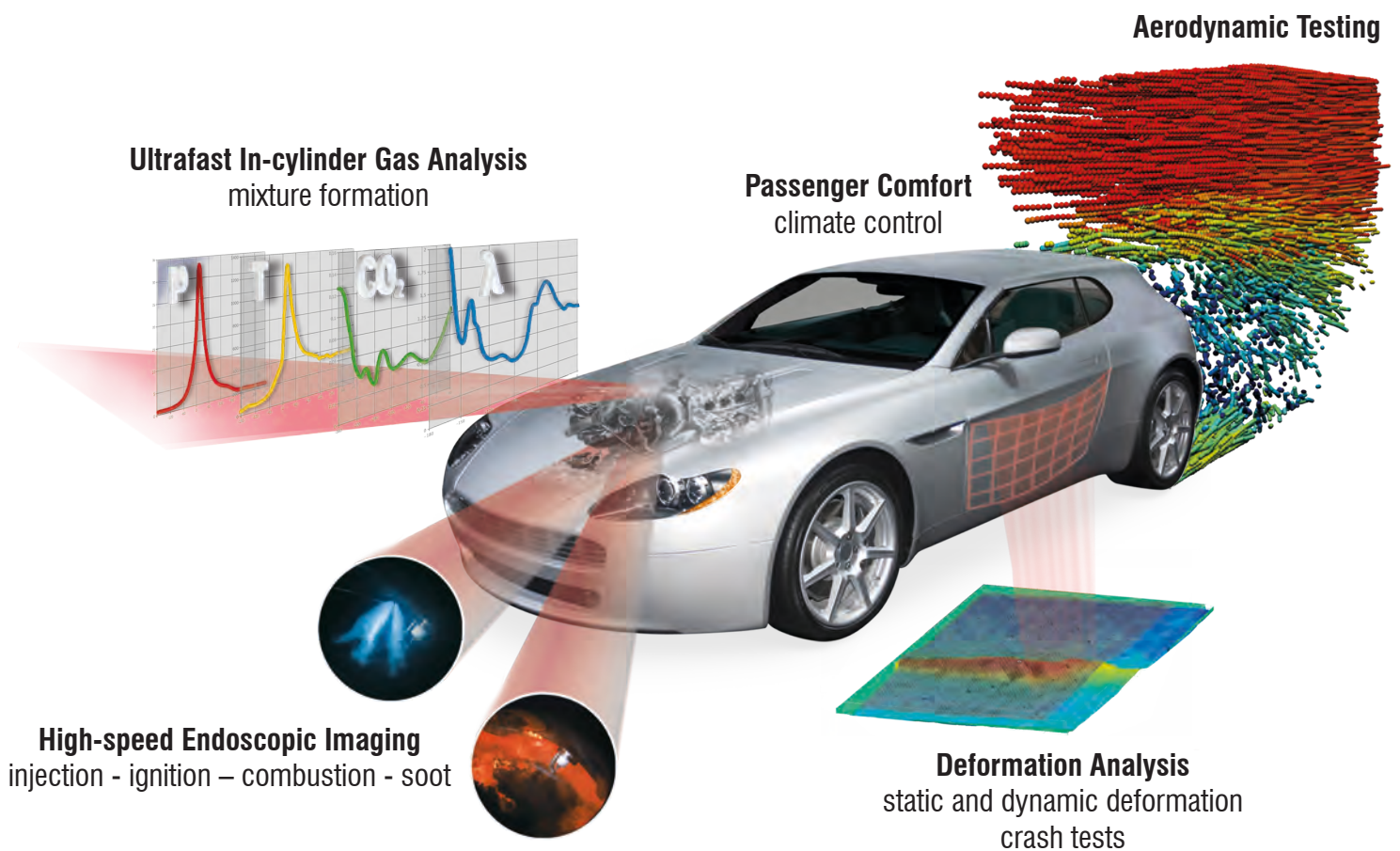


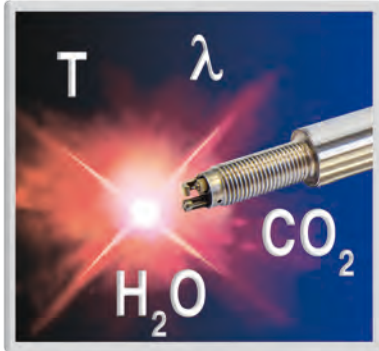


LaVision's imaging systems and optical sensors are helping engineers in research laboratories all over the world. They are successfully applied to measure in-cylinder processes, air flows around and inside car bodies and to study deformation and strain behavior of automotive parts under stress. Optical measurements are non-intrusive to the process and measure with intrinsic high spatial and temporal resolution.

Our optical diagnostic instruments give invaluable insight for a better understanding of the particular automotive process. They allow much faster and more efficient development cycles and, thereby save time and money. LaVision has a long history of successful cooperations with the automotive industry worldwide. We are a reliable and competent partner for our customers providing advanced measurement solutions for their challenging measurement requirements, today and in the future.

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





## In-cylinder Optical Engine Indication

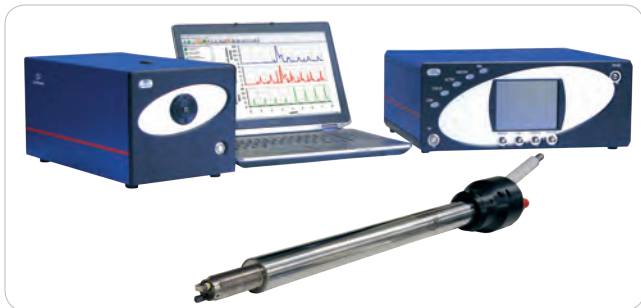
Mixture formation analysis of highly dynamic engine conditions

- ▶ 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 utmost 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.

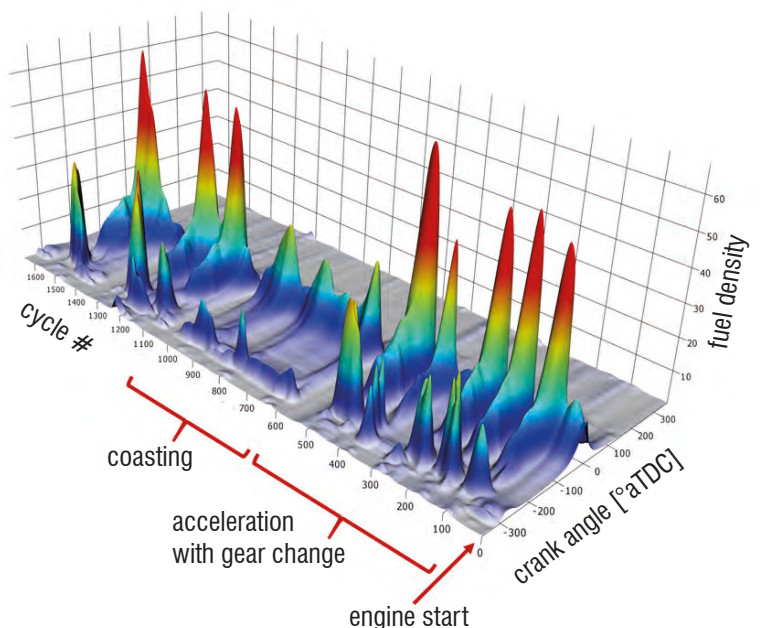
Optical engine indication of the local air/fuel ratio at the spark plug position as well as  $\text{CO}_2$ - and water concentration measurements quantify the mixture formation and improve injection strategies, exhaust gas recirculation or water injection concepts. Knowledge of the gas temperature in addition to pressure is critical to operate closer to the knock-limits.



### ICOS system features

- ▶ unique in-cylinder optical gas analyzers w/o extraction
- ▶ fast data rates in the kHz range
- ▶ application specific probe geometries:  
spark-plug, M5 probe, integral line-of-sight probe

This figure shows the measured fuel density at the spark plug under real driving conditions running an engine-in-the-loop test. The analysis of engine emissions under real driving conditions is necessary to meet future legislations. The **ICOS** systems measure in-cylinder parameters relevant for engine emissions in all required real driving operation modes including engine start.



Related products: **ICOS** systems



# Endoscopic In-cylinder Imaging

Quantitative imaging of complete IC-engine cycles



- ▶ spray injection analysis
- ▶ flame propagation speed
- ▶ localization of soot emission areas
- ▶ soot temperature and concentration

For the optimization of near-production engines endoscopic imaging is applied to visualize in-cylinder phenomena. Keyhole imaging 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.

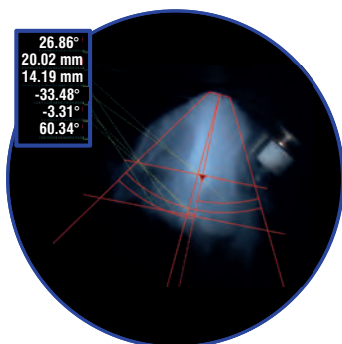


### EngineMaster *inspex* system features

- ▶ crank angle synchronized recording
- ▶ high resolution (high-speed) digital cycle movies
- ▶ endoscopic illumination and imaging
- ▶ engine adaptation incl. sealing sleeves



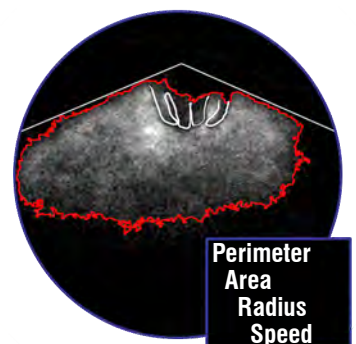
Soot formation in a GDI engine during first cycles of cold start at fixed crank angle



Spray geometry



Soot temperature



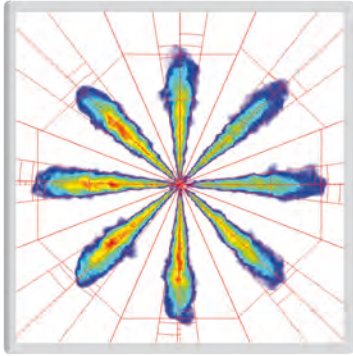
Flame propagation

Related products: **EngineMaster *inspex*** systems



## Spray and Droplet Imaging

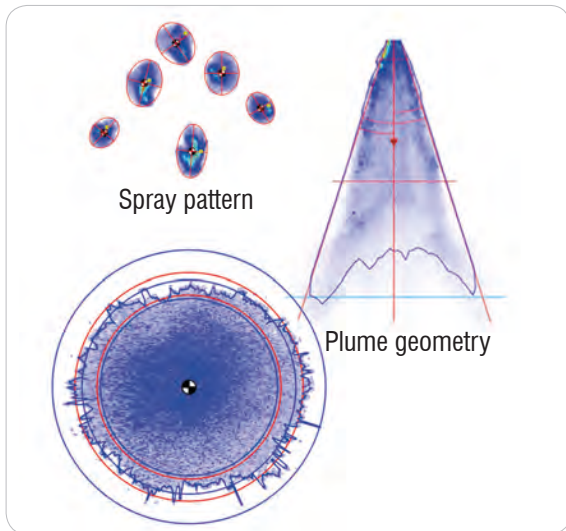
Fuel and SCR injectors, windshield and sensor sprays



- ▶ 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

LaVision's **SprayMaster** imaging systems measure spray pattern and spray plume geometries, spray propagation and evaporation of all kinds of automotive sprays such as fuel sprays, windshield washer sprays or urea sprays in SCR reactors. The innovative imaging systems using (laser) light sheet or back-/front illumination provide new insights into even complex spray processes and permit cost effective and efficient development of smarter spray systems. Algorithmic based spray image processing guarantees fast, repeatable and operator independent results.

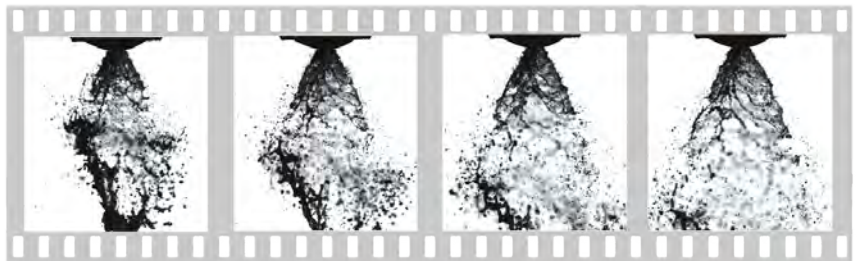
**SprayMaster** systems are easy to operate, fast and efficient measurement tools suitable for R&D as well as quality control applications.



Detailed spray geometry analysis

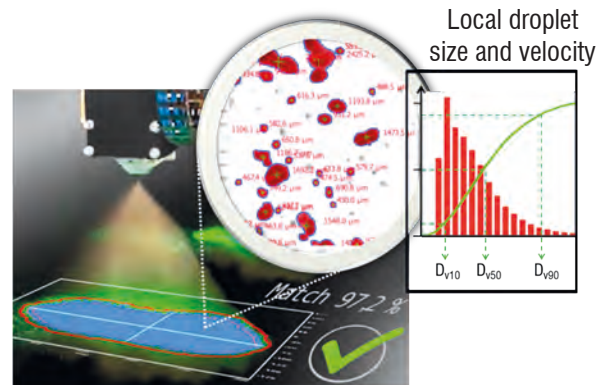
### Spray Imaging system features

- ▶ phase-locked (high-speed) imaging in transient spray: spray geometry, patternation, penetration, propagation
- ▶ comprehensive spray image analysis software
- ▶ novel imaging technique for dense sprays



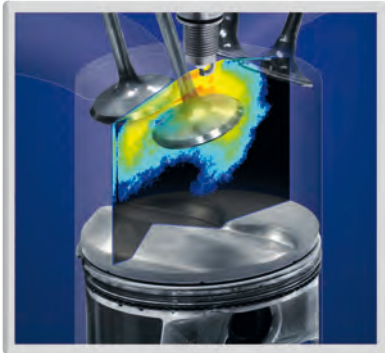
Spray propagation: high-speed imaging at several kHz

Global spray imaging can be combined with local droplet size and velocity measurements at a predefined spray location. The applied high magnification imaging also provides absolute droplet number density, volume fraction and mass flux, important input parameters for e.g. the proper operation of rain sensors.



Global spray patterning

Related products: **SprayMaster**, **ParticleMaster** and **inspex** systems

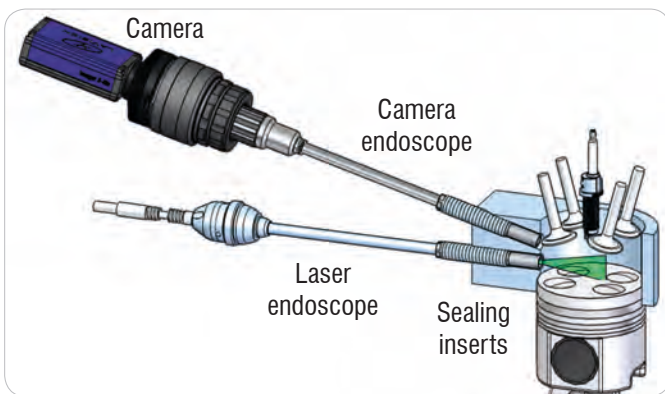


## In-cylinder Laser Imaging

### Imaging on laser light sheets

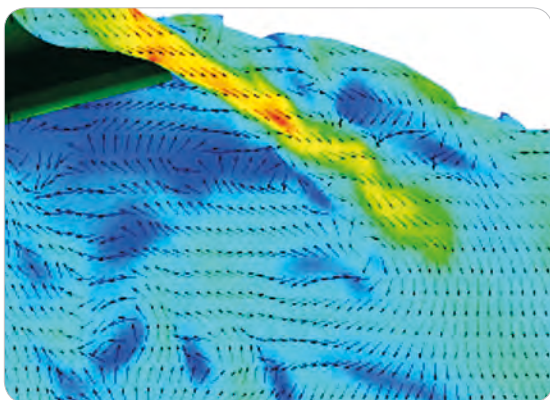
- ▶ in-cylinder flow fields (swirl & tumble)
- ▶ mixture formation imaging ( $\lambda$ -maps)
- ▶ soot particle generation
- ▶ NOx formation, flame radicals

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** Particle Image Velocimetry (**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.

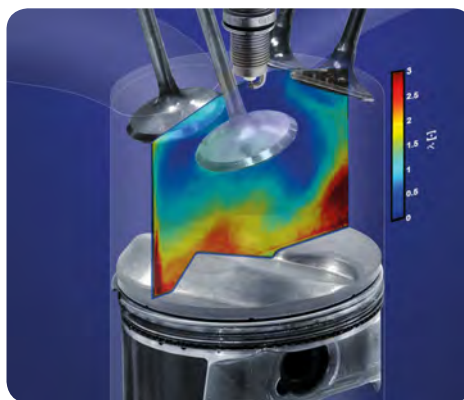


### In-cylinder Laser Imaging system features

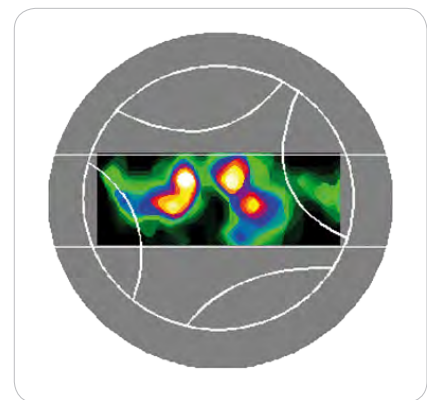
- ▶ crank angle synchronized imaging
- ▶ endoscopic PIV system for minimal optical access
- ▶ crank angle resolved flow fields with cycle statistics
- ▶ high-speed PIV movies of the in-cylinder charge motion
- ▶ complete  $\lambda$ -maps close to the spark plug
- ▶ outstanding soot detection limits
- ▶ endoscopic access for sheet illumination and imaging



*Tumble flow field near inlet valve*



*In-cylinder mixture formation:  
 $\lambda$ -map*

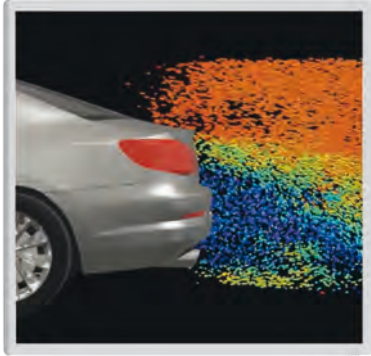


*In-cylinder soot imaging*

Related products: **EngineMaster** and **FlowMaster** systems



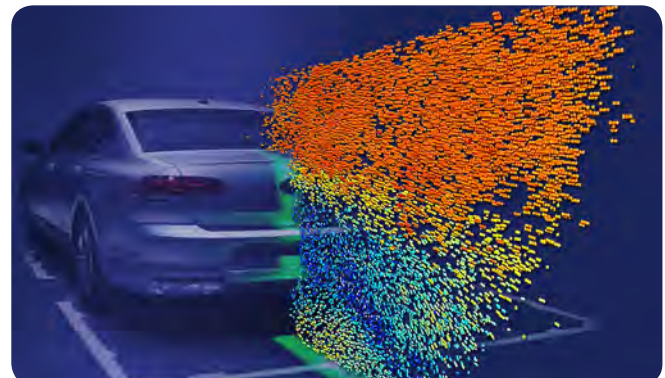
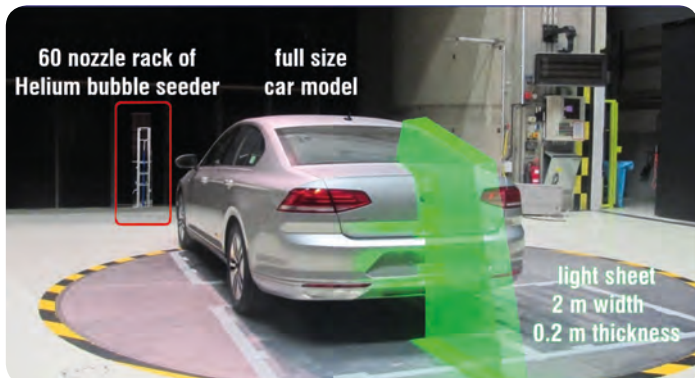
## Air Flows around and inside Cars



- ▶ large-scale 2D and 3D flow field imaging
- ▶ aerodynamic drag and wind noise reduction
- ▶ pressure fields derived from velocity data
- ▶ indoor 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 **Particle Image Velocimetry (PIV)** as well as **Particle Tracking Velocimetry (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)*



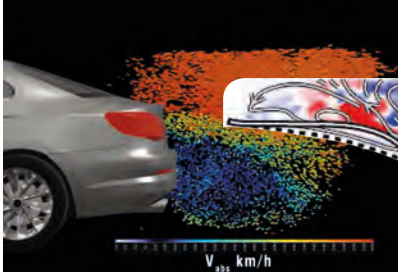
### **FlowMaster** system features

- ▶ most accurate PIV/PTV software in the market
- ▶ patented 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

Related products: **FlowMaster PIV & PTV** systems



3D camera robot scanning large flow fields



Fluid-structure interaction

Simultaneous **PIV/PTV** and **digital image correlation (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.



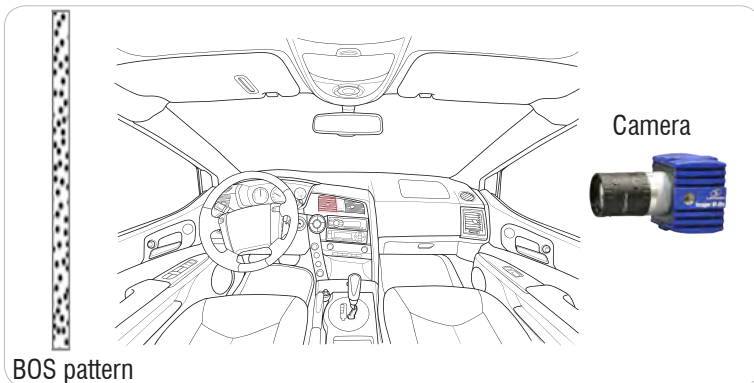
## Indoor Climate Flow Visualization

- ▶ sensitive imaging technique for thermal air flow visualization without flow seeding

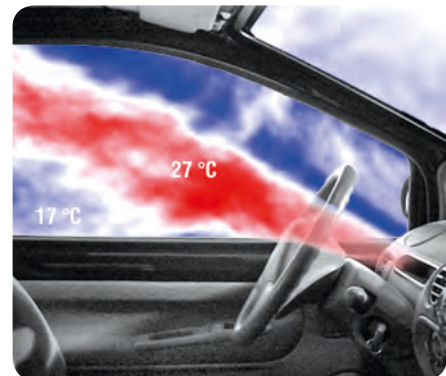
For the visualization of air flow motion based on local refractive index variations **Background Oriented Schlieren (BOS)** is a simple and cost-effective alternative to laser imaging methods. This imaging technique is highly sensitive to air temperature differences and requires no flow seeding at all. **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.

### BOS system features

- ▶ thermal flow visualization and velocimetry without seeding
- ▶ flexible fields-of-view up to large scales
- ▶ simple system setups



Simple BOS arrangement for interior flow control

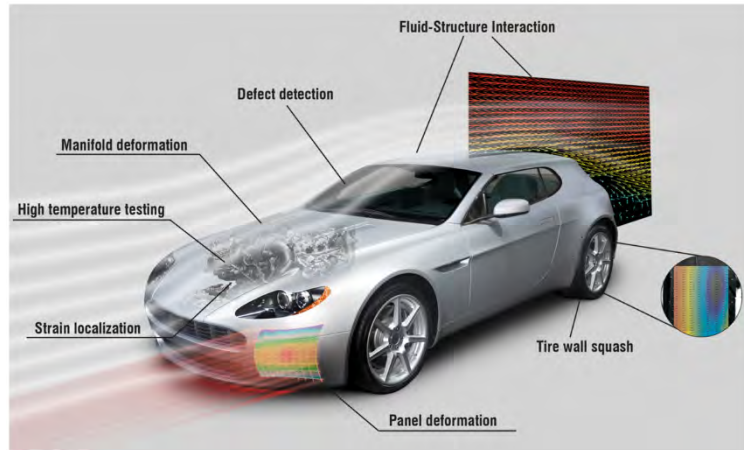


Interior thermal flow visualization

Related products: **FlowMaster** and **FluidMaster BOS** systems



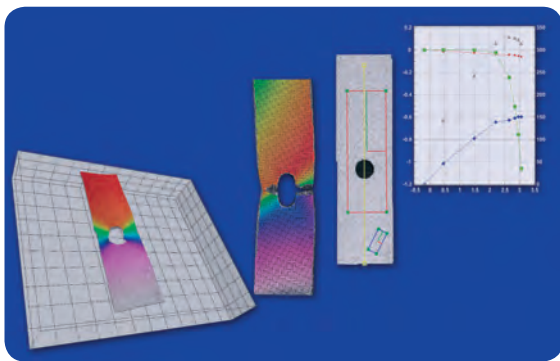
## Deformation and Strain Analysis



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.

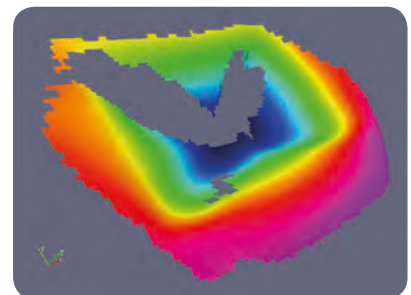
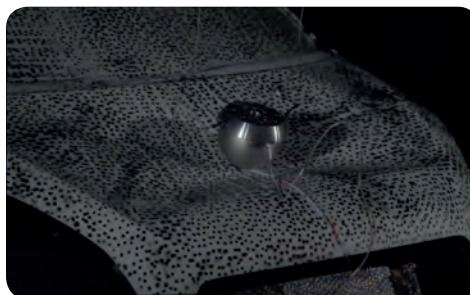
**Digital image correlation (DIC)** is a full field non-contact imaging technique for surface shape, displacement and strain measurements and collects data from sample sizes of microns up to meters.

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.



### StrainMaster system features

- ▶ complete system control, analysis, data management within one software package
- ▶ adjustable field of view and image resolution
- ▶ virtual gauge and live extensometer mode
- ▶ usable for high temperature applications
- ▶ systems for long term tests and high-speed applications



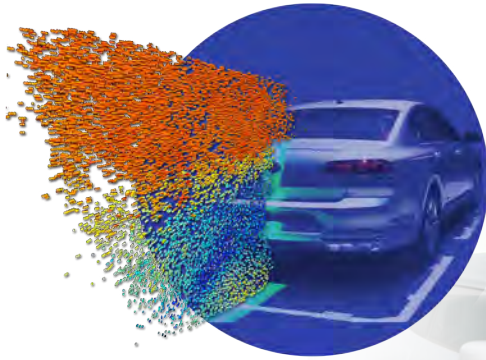
*Impact test on a car bonnet: high-speed transient deformation analysis*

Related products: **StrainMaster** systems



# Driving Automotive Mobility into the Future

*Aerodynamic testing on roads*



*Car glass testing for autonomous driving*



*Interior thermal flow control*



*Diagnostics for eco-fueled engines*

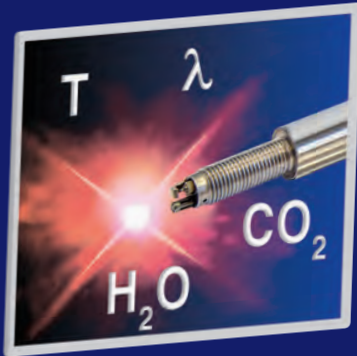
LaVision takes part in the ongoing transformation process of automotive mobility. Our technological contributions in the field of automotive testing are:

- ▶ enabling aerodynamic testing on the road outside of wind tunnels
- ▶ direct visualization of thermal air flows for air conditioning
- ▶ profound quality testing of car glass for safer autonomous driving
- ▶ development of new IC-engines firing eco-friendly fuels such as H<sub>2</sub> or compressed natural gas (CNG)

LaVision welcomes and encourages cooperations and long term relationships with the automotive industry. Beside our turnkey measurement systems we are offering contract measurements, equipment loan as well as on-site demonstrations and feasibility tests.

Application specific measurement solutions in the field of automotive R&D are our speciality.

# Automotive Measurement Solutions

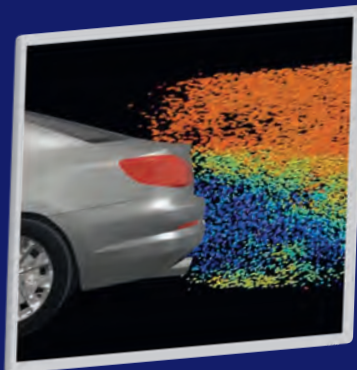


## ICOS Systems

Ultra-fast in-cylinder gas analysis

## EngineMaster *inspex*

Advanced quantitative  
endoscopic imaging

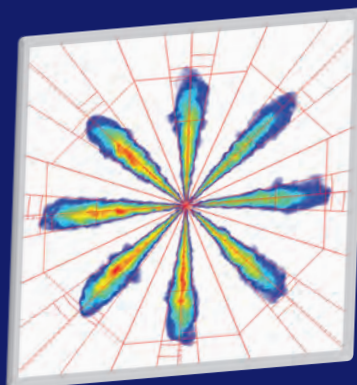


## FlowMaster

Analyzing large-scale  
wind tunnel aerodynamics

## StrainMaster

Material deformation/  
vibration analysis



## SprayMaster *inspex*

Solutions for all automotive sprays

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