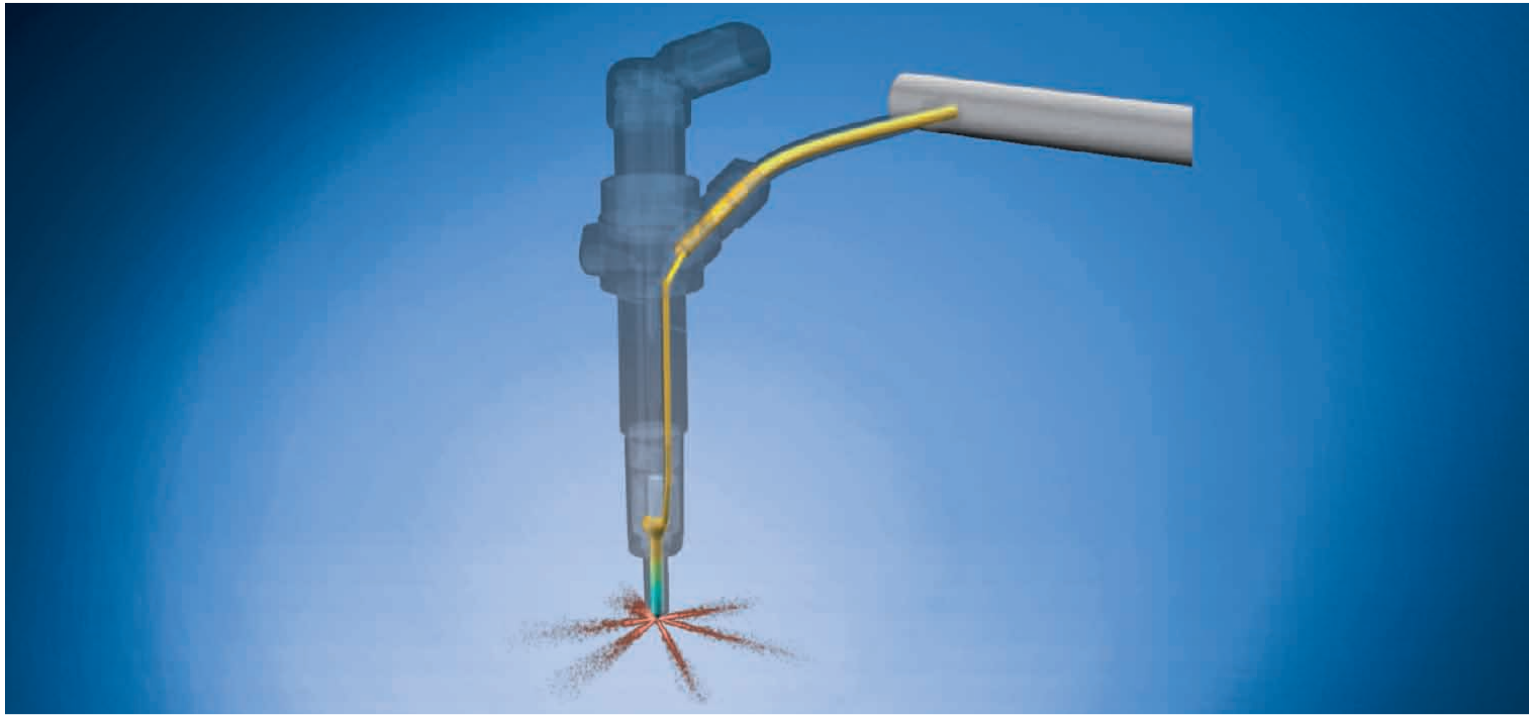


# Fuel and Injection System Development

For Diesel and Gasoline Engines





## Philosophy

IAV specializes in the entire process of developing fuel and injection systems for diesel and gasoline. In particular, we concentrate on designing, optimizing and testing hydraulic components. Our aim is to provide further impetus for improving mixture formation and clean combustion technologies with a focus on future generations of fuel and injection systems.

Incorporating combustion, electronics, the engine as well as the overall vehicle, IAV provides a start-to-finish approach in reaching the best possible solution that meets future vehicle consumption and emission requirements. For this purpose, we work closely together with our customers.

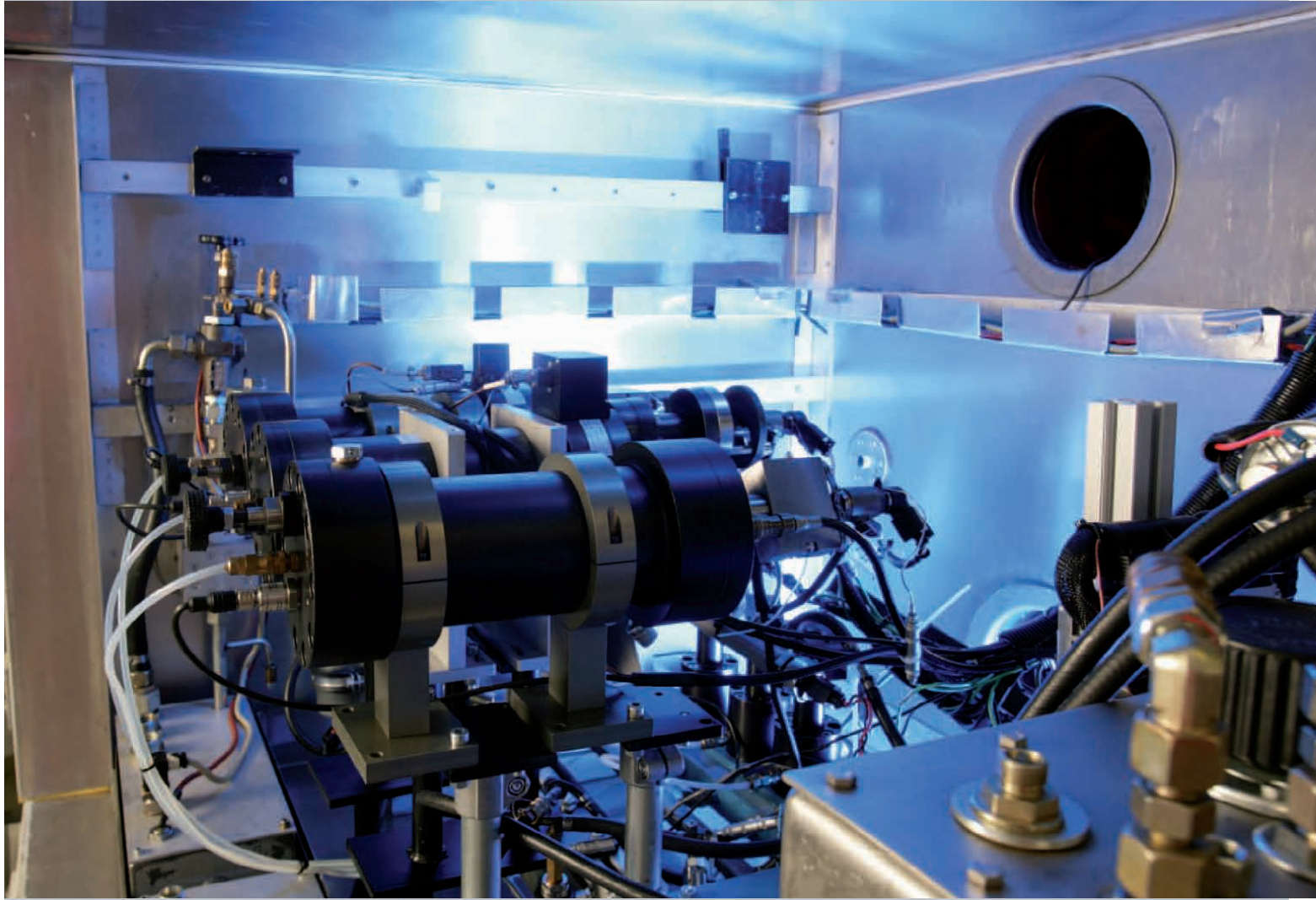
This brochure gives you a brief overview of the services we can offer in the field of injection system development. As competent consultants, however, our support activities extend much further.

Do not hesitate to get in touch with us. We will be pleased to discuss your specific challenges with you in detail.

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For further information, please visit [www.iav.com](http://www.iav.com)



Studies on injection systems

## Fuel and Injection System Development at IAV

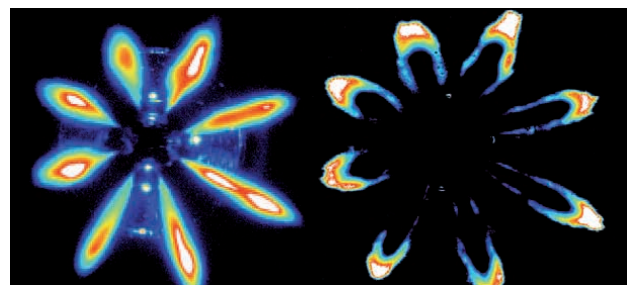
Rapid progress in fuel injection technology over the years has played a key part in contributing to the development of engines with higher fuel efficiency and lower emissions. The injection system itself is highly complex, and each step forward (e. g. higher injection pressure) pushes materials and functions ever further toward their limits. At the same time, the injection system also has a significant effect on the combustion process as well as exhaust gas quality/emission properties.

To avoid making development mistakes with far-reaching consequences, it is important to optimize the injection system with all its components at an early stage. To do this, we take into account both the engine manufacturer's requirements and the supplier's situation. Our engineers are experts in resolving conflicting goals, aiming at all times to meet the demands of minimizing costs, emissions and fuel consumption while maximizing durability.

Consulting and development support from our specialists is based on actual results from studies carried out on IAV's function and endurance testing facilities designed specifically for injection systems. Our experts do not limit their attention to single injection system components but adopt a start-to-finish approach in identifying and satisfying the requirements of the entire powertrain or vehicle. This way, consideration is not simply restricted to optimizing internal engine aspects but also covers the entire fuel-supply system, starting with the tank and extending through to market and country-specific fuel characteristics as well as exhaust gas aftertreatment, acoustics and packaging.

We have a highly specialized team experienced in implementing the results obtained from detailed studies, not only in terms of designing injection systems but also in relation to providing support for the processes involved in manufacturing them. As a result, we can provide injection system suppliers with support as far as the start of production.

In addition to its widely ranging test facilities, IAV utilizes special measurement technology that is constantly being advanced and adapted to changing customer requirements - e. g. for the evaluation of mass flow rate (Injection Analyzer).



Visualization of injection quality with false color imaging

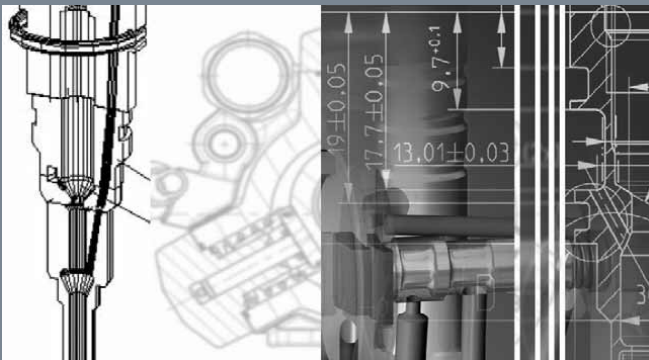
# Injection System Development for Diesel/Gasoline and Gaseous Fuels

## Concepts and Ideas

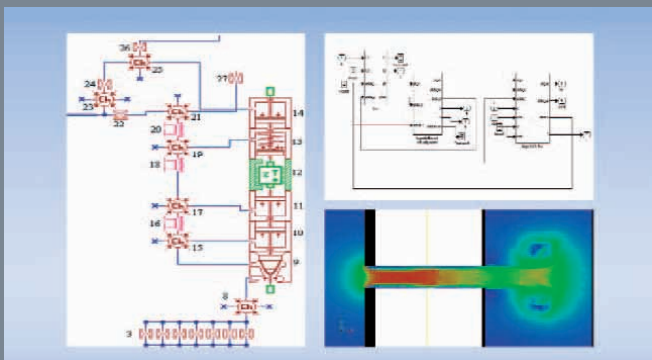
- ▶ Concepts for new injectors and pumps
- ▶ Material innovations
- ▶ Extremely high pressures
- ▶ Control strategies and greater stability over lifespan



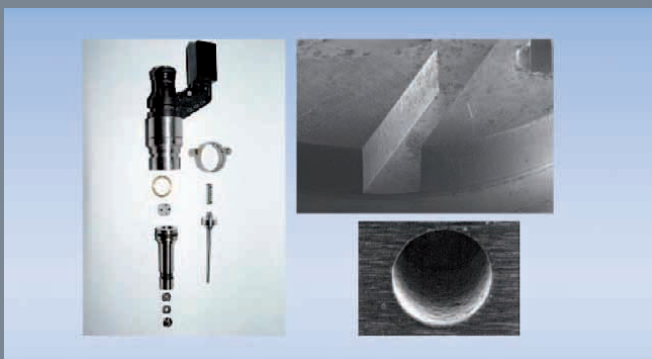
Concepts and ideas



Design



Simulation



Prototyping

## Design

- ▶ Injectors and pumps
- ▶ Supplier sourcing
- ▶ Production support
- ▶ Assembly processes

## Simulation

- ▶ 1D simulation for hydraulic component systems
- ▶ Simulation of actuators, electrical circuits etc.
- ▶ 3D simulation of flows
- ▶ Commercial, in-house and customer tools
- ▶ Integrated and co-simulation

## Prototyping

- ▶ Injectors, pumps etc. for diesel and gasoline
- ▶ Manufacturing by specialized partners
- ▶ High-precision processes
- ▶ Testing of prototypes in-house

# Injection System Development for Diesel/Gasoline and Gaseous Fuels

## Function Testing

- ▶ Detailed component tests
- ▶ Testing of entire FIS => reproducing vehicle/engine behavior
- ▶ Application of special test methods
- ▶ High-performance FIS test benches
- ▶ Capability of using actual fuels (diesel, gasoline etc.)



Function testing

## Endurance Testing/Validation

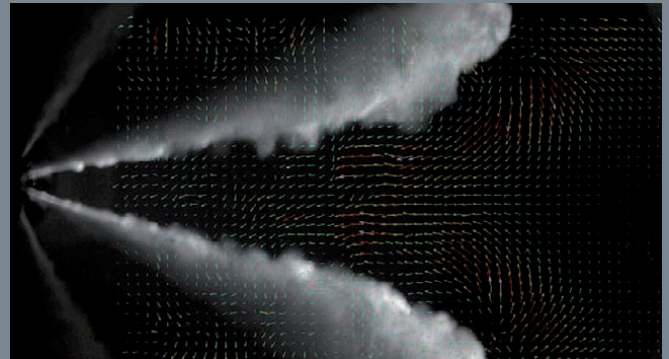
- ▶ Validation of diesel and gasoline systems/components
- ▶ Ambient temperatures up to 140 °C
- ▶ Possible fuels: diesel, gasoline, E85, RSG etc.
- ▶ Assessment of parts after endurance test



Endurance testing/validation

## Optical Spray Visualization

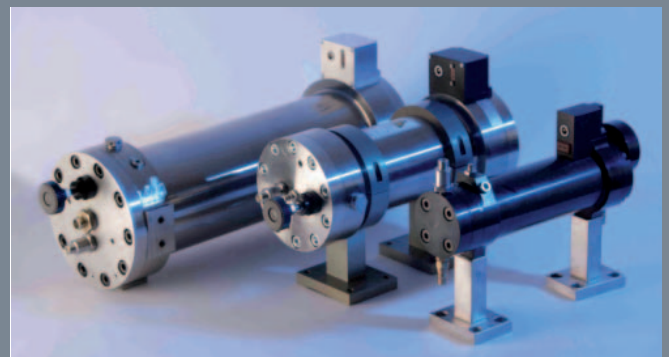
- ▶ Detailed studies on diesel and gasoline
- ▶ Evaluation of macroscopic parameters
- ▶ Techniques: MIE, Schlieren, LIF, LIEF etc.
- ▶ Rapid spray analysis



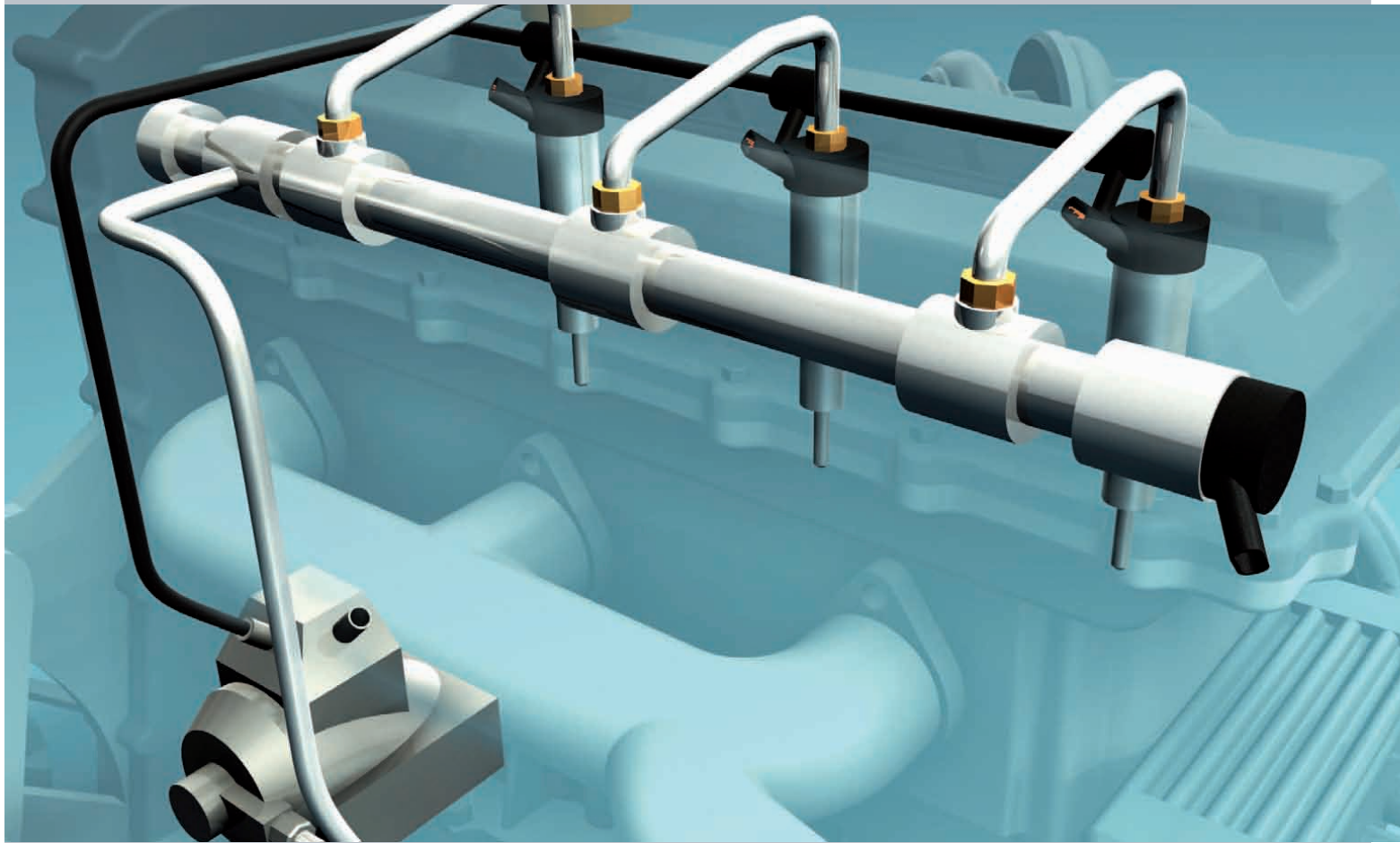
Optical spray visualization

## Development of Special Measurement Equipment

- ▶ Injection Analyzer (shot/shot measurement system)
- ▶ Nozzle Cavitation Index and flow
- ▶ Needle lift, pressure inside FIS components
- ▶ Customized solutions



Special measurement equipment



Diesel injection system (CR)

## Diesel Injection Systems

IAV has over 20 years of experience in developing diesel injection systems and is highly conversant with many different types of them, such as:

- ▶ Cam-driven systems (distributor pumps, UI systems etc.)
- ▶ CR systems
- ▶ Pressure-amplified injectors
- ▶ Injectors with direct needle actuation
- ▶ Different pump concepts
- ▶ etc.

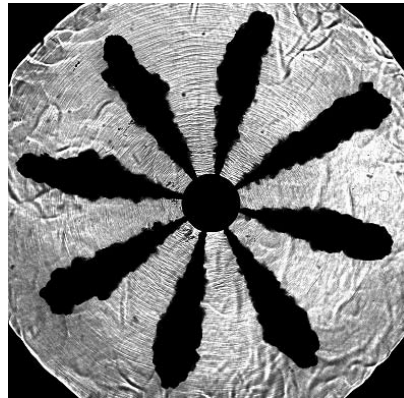
This knowledge is applied to micro-engines with bore diameters of approx. 40 mm, passenger and commercial-vehicle engines as well as off-highway and off-shore engines with an injected fuel mass of up to 8000 mg per shot.

With this track record, IAV is able to provide highly qualified support in developing, applying and calibrating new injection systems. To speed up the development process, we often work hand in hand with and alongside OEMs and suppliers in engineering teams.

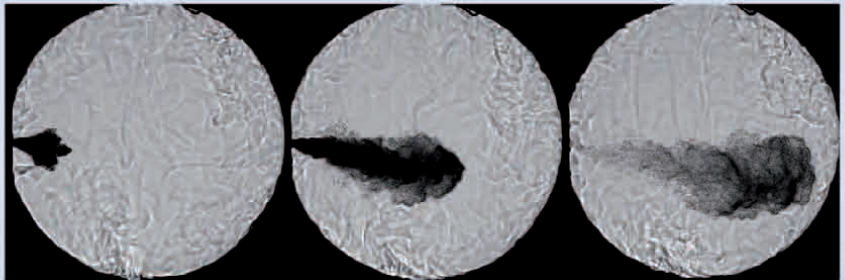
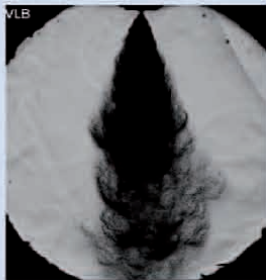
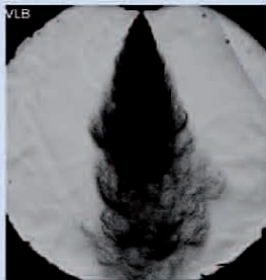
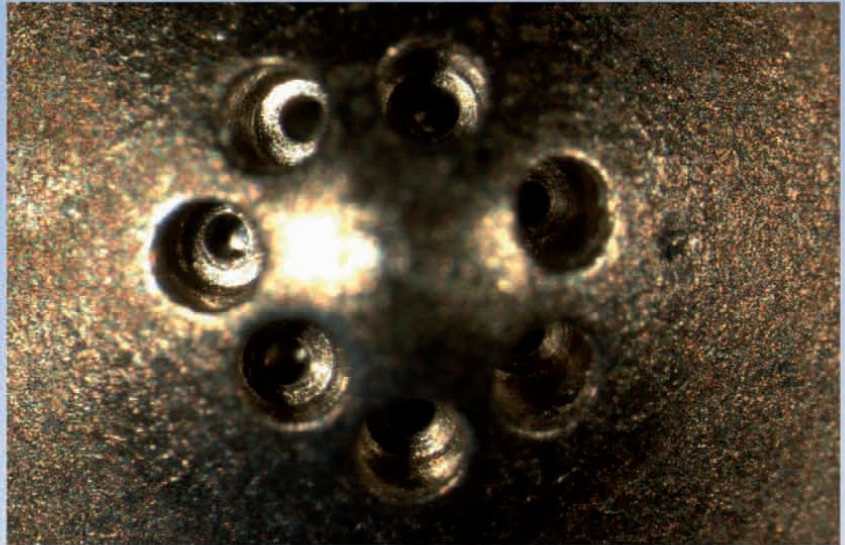
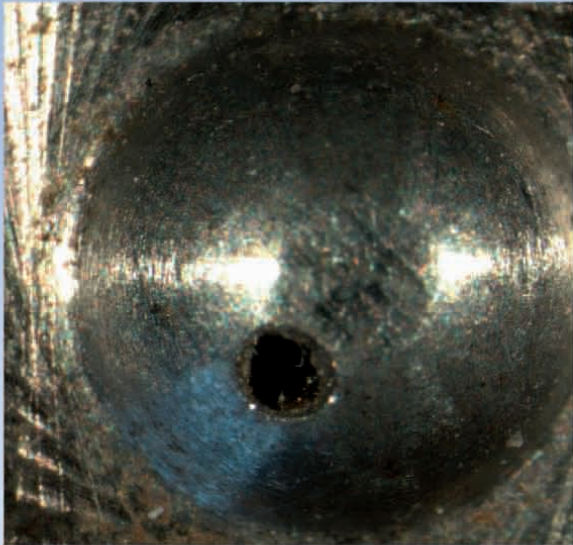
Looking to future diesel-injection systems and ways of reducing consumption and emissions, IAV is also working on its own R&D diesel injection systems as well as on options for improving mixture formation based on the injector itself.

With expertise in designing all kinds of injection systems on the basis of simulation as well as hydraulic and optical testing, we can provide full support in developing and launching injection systems.

IAV can also validate injection systems, covering all aspects involved in mass production. Endurance testing and assessment provide the basis for continuously advancing injection systems in a closed-loop process.



Visualization of diesel injection spray



Injectors and spray patterns (swirl and multi-hole) used for GDI

## Gasoline Injection Systems

In recent years, work on developing gasoline direct injection systems has been governed by the requirement to reduce CO<sub>2</sub> emissions. With the three-way catalytic converter having simplified exhaust-gas aftertreatment (homogeneous operating mode), the focus has been placed on cutting consumption and bringing down system costs.

Forthcoming EU6 legislation will set stringent targets for particulate mass emissions and size for gasoline engines and also increase the demands placed on injection systems. The focus over the next few years will be to keep system costs below those for diesel engines while still respecting emission legislation and CO<sub>2</sub> demands.

IAV can provide a wide range of solutions for developing injection systems alongside the engine development process. For this purpose, hydraulic test benches generate boundary conditions comparable to those prevailing in real-life operation with all parameters required for investigating gasoline injection.

All types of fuel (regular gasoline, E85 or derivatives, n-heptane, RSG-E10, poor-quality fuels etc.) can be used in order to maintain comparability with engine conditions. This demands the use of an explosion-proof test environment to ensure safe conditions for all operating points. IAV can cover a wide range of test conditions, e.g. for fuel and ambient temperature from cold start at -25 °C to extremely hot conditions at +140 °C. The testing facility permits a maximum speed of 6000 rpm with high dynamic operating conditions for acceleration, pressure control and other loads.

Depending on the task in hand, it is possible to investigate either single components (pumps, injectors and pressure controllers) or entire gasoline systems (solenoid or piezo-driven).

The integrated approach underlying various methods of analysis in developing injection systems, e.g. simulation, functional tests, optical tests in the pressure chamber, provides an effective tool chain for resolving injection-related issues.

Other fields of activity at IAV include investigations into high-pressure gasoline injection systems operating at pressures of up to 1000 bar. This approach - combined with our work on developing combustion principles - gives us and our customers valuable insight into the possible future of gasoline engines.



Visualization of injection through a swirl, multi-hole and ring-gap nozzle

