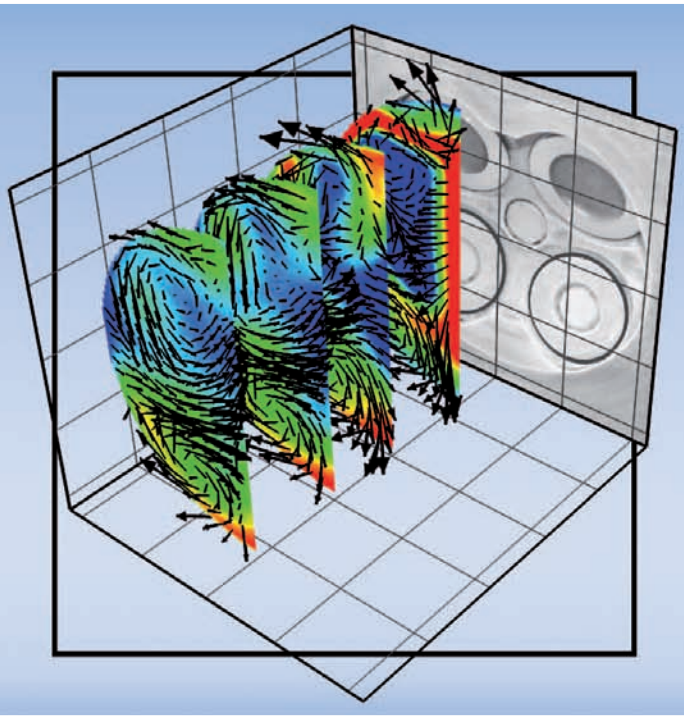
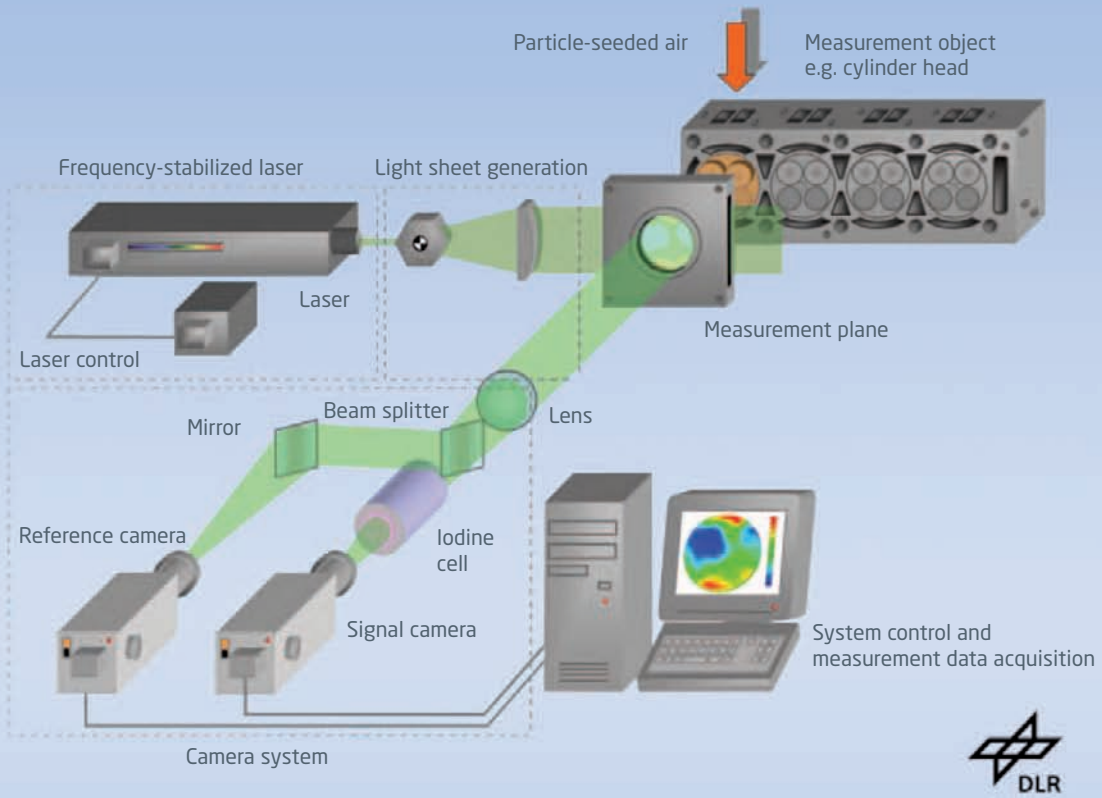
Doppler Global Velocimetry

Measurement of the Three-Dimensional Flow Field





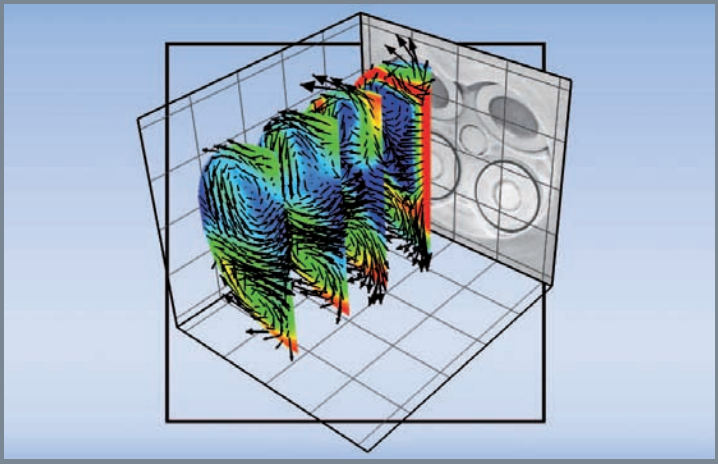
Physical measurement principle

Measurement Principle

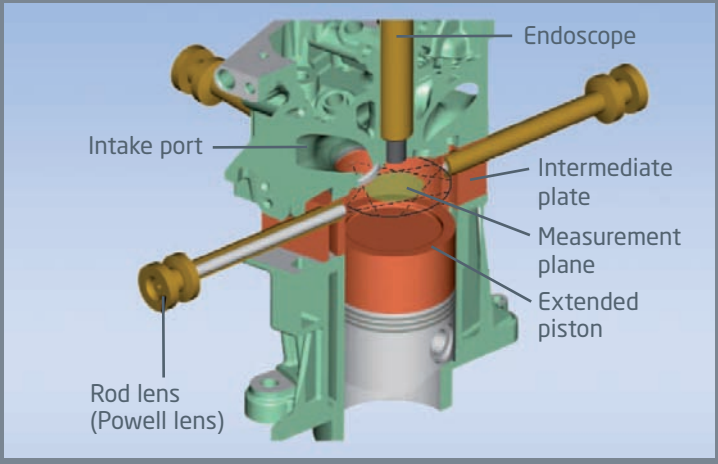
DGV is an optical laser technique for measuring three-component velocity vector fields in a plane (measurement plane). A 3-D representation is generated by joining several measurement planes. A laser is used in conjunction with an optical system to create a light sheet (laser light sheet) that illuminates the particle-seeded flow. The Doppler effect shifts the frequency of the light scattered by the particles. Absorption in molecular iodine (iodine cell) converts the frequency shift into an intensity shift that is detected with video cameras and converted into a velocity field.

The measurement technique was developed by the Institute of Propulsion Technology at DLR e.V. (German Aerospace Center). The technique is suitable for time-averaged measurement of steady-state flows as well as phase-averaged measurement of periodic flows.

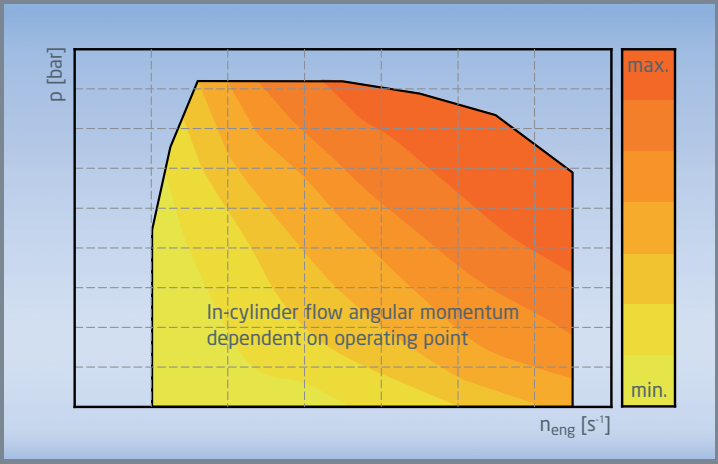
The measurement system also provides the capability of visualizing seeding or droplet distribution on the basis of Mie scattering. This makes it possible, for example, to simultaneously record the flow field and droplet concentration distribution inside the cylinder during injection.



Measurement of in-cylinder flow



Adaptation of the measurement technique



Pulse map of flow for actual engine operation

Measuring in-cylinder flow

The DGV measurement technique is used primarily in internal-combustion piston engines. Analyses are performed on steady-state flow as well as during the intake and compression stroke in motored and fired engine testing on 2 and 4-stroke engines at speeds of up to 8000 rpm. The technique is also applied for studying the interaction between in-cylinder flow and injection.

Adaptation of the measurement technique

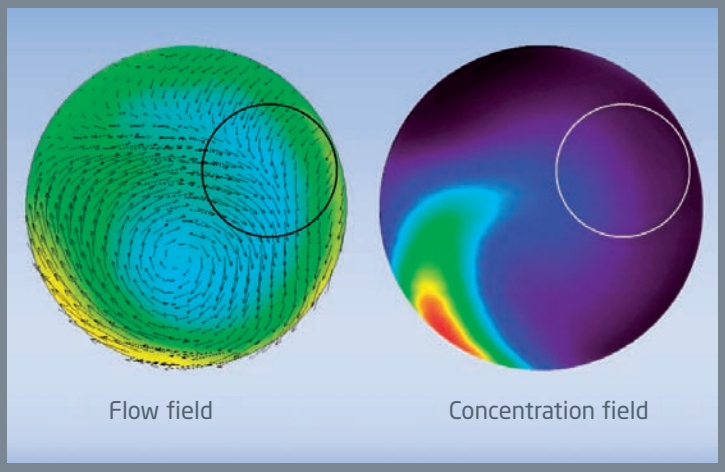
Specially developed rod lenses (Powell lenses) and flexible endoscopes are used for measuring in-cylinder flow during motored or fired engine operation. This provides the capability, for instance, of conducting measurements on production engines with restricted optical accessibility.

Computing coefficients

Developed by IAV, the "DGV Evaluator" software provides an efficient tool analyzing the three-dimensional flow fields that are measured. Typical numbers, such as swirl and tumble numbers, symmetry and flow-rate coefficients are computed for characterizing flow. They can be taken as the basis for assessing flow properties and the influence they have on the course of combustion while the engine is running. For example, DGV results can be used for calculating in-cylinder flow angular momentum (dependent on operating point), rotational energy, or rather, turbulence energy.

Steady-state inflow

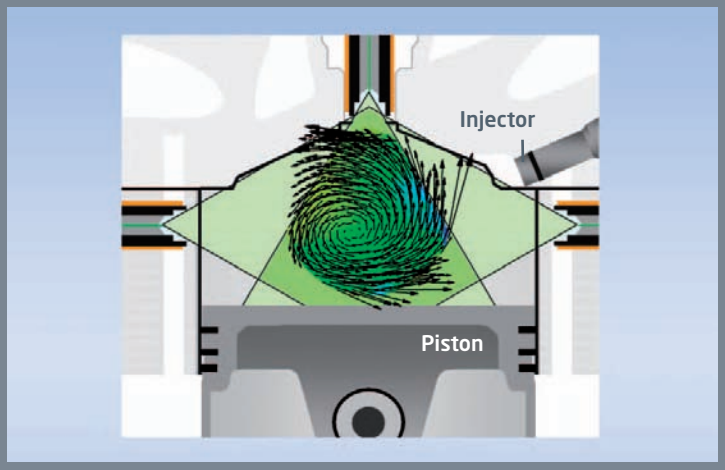
Measurement results are provided in the form of graphs depicting flow fields and characteristic numbers. The data measured are used for developing ports and combustion processes as well as for validating CFD computations.



Steady-state inflow

Motored engine

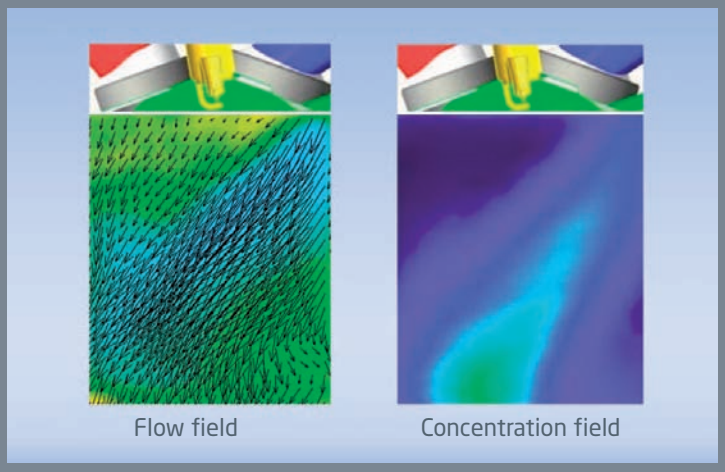
To analyze the dynamic effects of flow in the intake and compression stroke and, in particular, the interactions taking place with the moving piston and its geometry, measurements are conducted using endoscope and rod lenses on production engines as well as on glass engines.



Flow field during the compression phase following injection

Fired engine

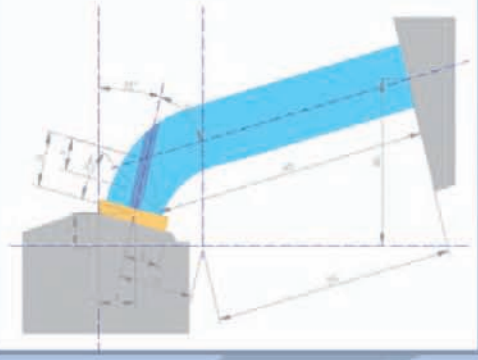
Ultimately, the most representative engine condition produces measurement results with the greatest informative content. Hence, the best way to understand the relevant combustion process is by conducting measurements on a fired engine. DGV measurements on the fired engine show the interaction between in-cylinder flow, injection and combustion. Analysis covers various injection strategies, injector positions and spray geometries.



Fired engine

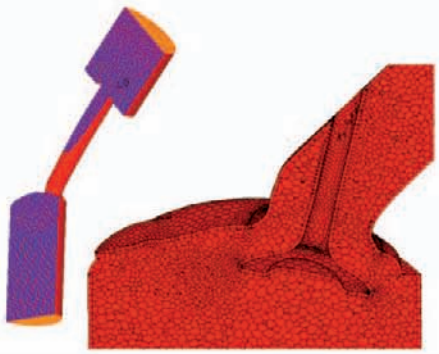
CAD Model

- Intake port, combustion-chamber geometry



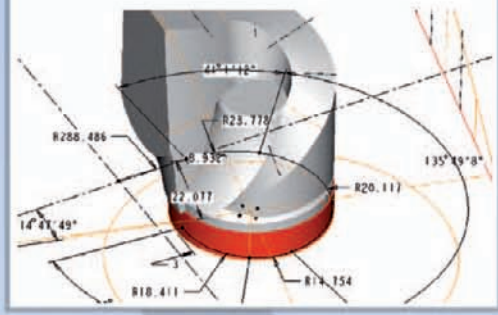
CFD Automesher

- CFD mesh



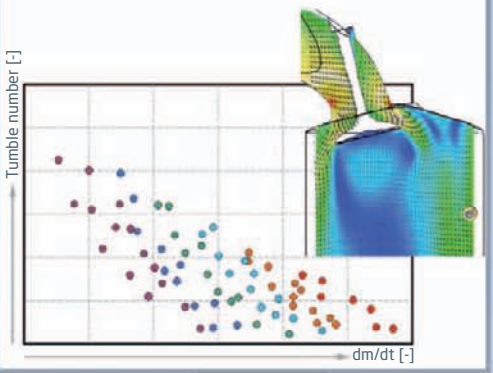
Start

- Selection/definition of design parameters and their variable ranges



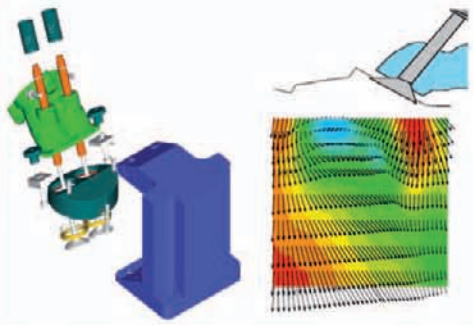
CFD Simulation

- Flow/tumble, swirl



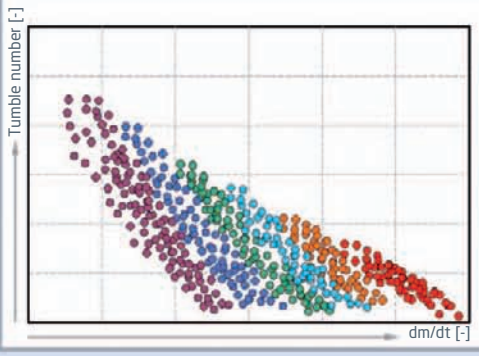
DGV Measurement

- Manufacture of flow boxes
- Decision



DoE Model

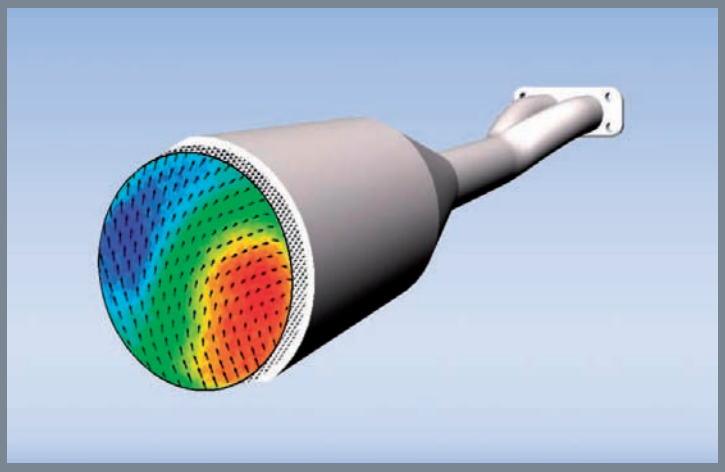
- Analysis & selection of parameters



Port development process

Flow in catalysts

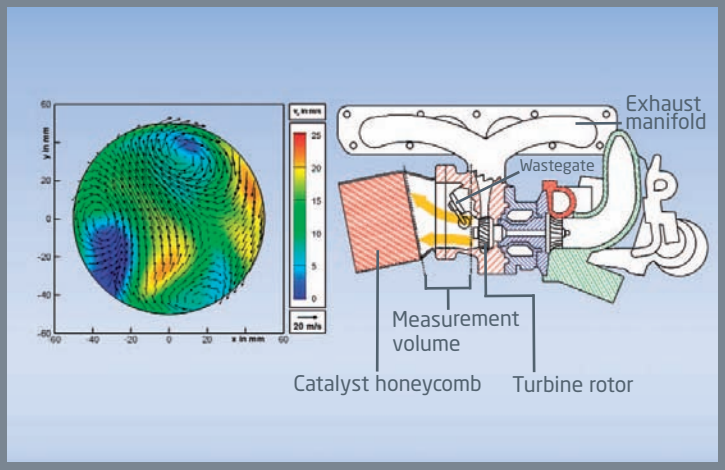
Improving the way catalysts operate in terms of warm-up behavior and thermal load also requires knowledge of flow behavior in the exhaust system. This is obtained by conducting measurements on catalysts and particulate filters under a wide range of different conditions.



Flow in catalyst

Flow in turbochargers

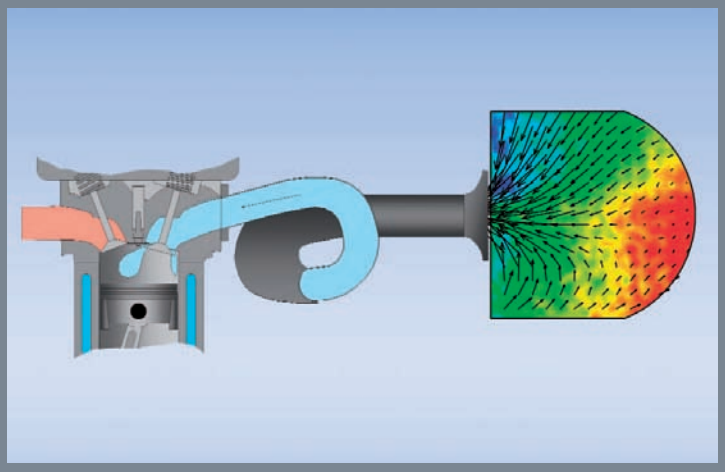
High flow velocities of the type occurring in turbocharger outflow are not a problem for the DGV measurement technique. The small amount of space required by rod lenses and endoscopes makes it possible to record the flow field at the turbine outlet with a view, for example, to supporting CFD computations.



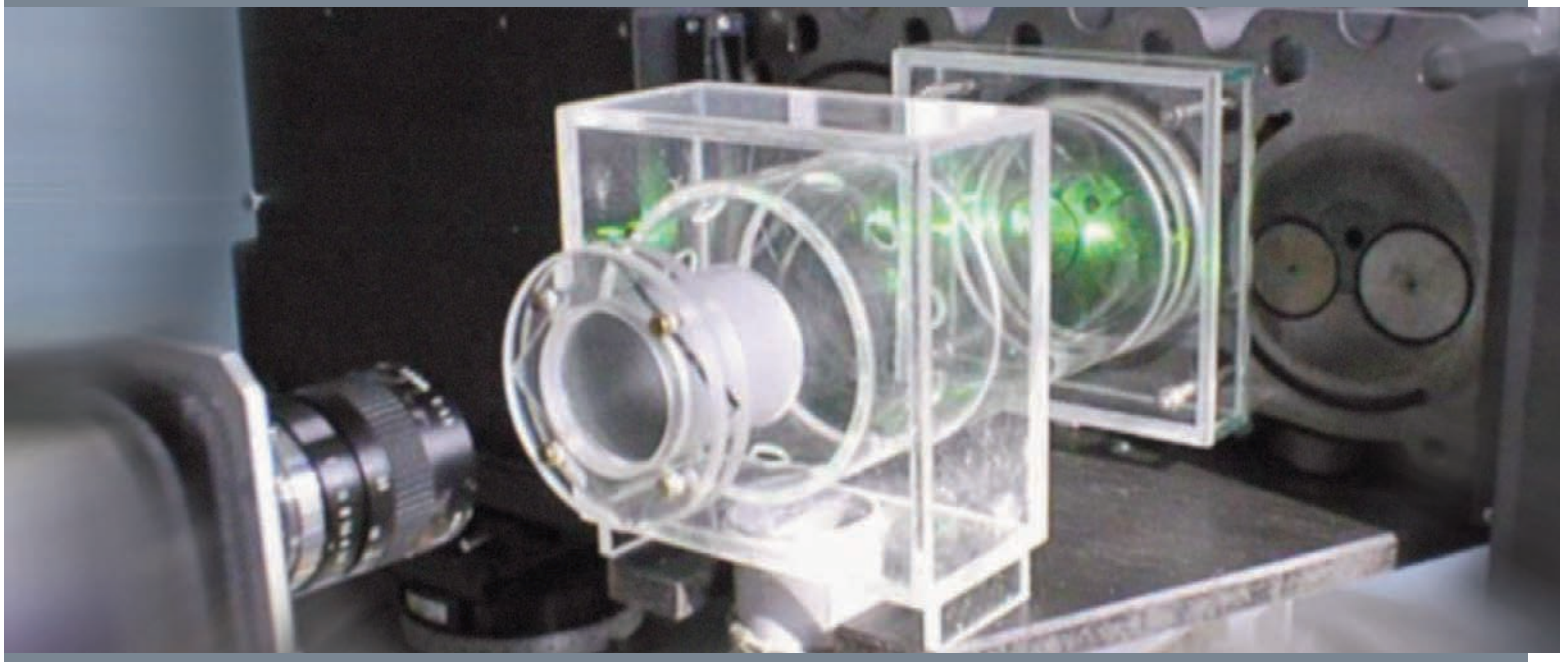
Flow in turbocharger

Basic analyses

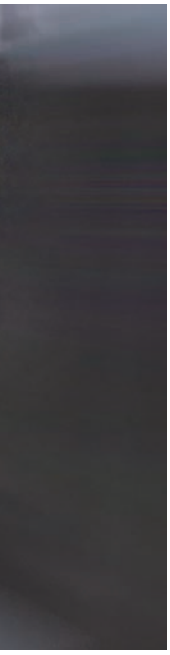
The DGV measurement technique is used for verifying theoretical approaches, e.g. in relation to determining acoustic pipe length, evaluating geometries affecting flow or defining characteristic numbers and their relationships.



Basic analyses



Example measurement set-up



Main Benefits of the DGV Technique

- Quasi-simultaneous measurement of three velocity components (up to 300 m/s) in a plane permits:
  - Volume gridding with several parallel measurement planes and subsequent selection of any sheet plane for evaluating the flow field
  - Computation of parameters relevant to combustion while incorporating all three velocity components in the overall volume
- High resolution (over 20,000 data points per plane)
- Short measuring time and immediate presentation of results (seconds)
- Illumination from rod lenses and the use of flexible endoscopes permit measurements in cases where optical accessibility is restricted
- Uncomplicated phase-averaged measurement of periodic flows by means of:
  - Stroboscopic laser lighting in combination with multiple light exposure of the camera system (no need to buffer individual images)
  - Triggering of the measurement event in relation to crank or cam angle
- No need to identify individual particles in the flow, only reflected light is evaluated
  - Use of very small particles (<1 µm)
  - Low vulnerability to fluctuations in particle concentration
- Computation of characteristic numbers from three-dimensional measurement data

Presentations/Publications

Title/Subject	Published where/when	Authors
In-Cylinder Flow Field Measurement with Doppler Global Velocimetry in Combination with Droplet Distribution Visualization by Mie Scattering	SAE World Congress 2009, April 2009, Detroit, USA	O. Dingel, T. Seidel, H. Steuker
Measurement of Flow and Visualization of Fuel Concentration Inside Cylinders of Spark-Ignition Engines	ISFV13/FLUVISU12, July 2008, Nice, France	T. Seidel, H. Steuker
Doppler Global Velocimetry – Messung der Zylinderinnenströmung mit ottomotorischer Direkteinspritzung (Doppler Global Velocimetry – Measuring In-Cylinder Flow in DI Gasoline Engines)	MTZ 04/2008, April 2008, published by Vieweg+Teubner Verlag, Germany	T. Seidel, H. Steuker
Strömungsmessung während der Kompression mit Doppler Global Velocimetry (Using Doppler Global Velocimetry to Measure Flow During Compression)	MTZ 05/2006, May 2006, published by Vieweg+Teubner Verlag, Germany	O. Dingel, T. Seidel, H. Steuker
The New Hardware-Assisted Inlet Port Development Process for Diesel Engines Using Doppler Global Velocimetry	SAE World Congress 2005, April 2005, Detroit, USA	S. Zuelch, K. Behnk, R. Deepe, B. Findeisen, T. Seidel, L. Stiegler, A. Sommer
Doppler Global Velocimetry (DGV) – Anwendungen im Zylinderraum und an Abgaskatalysatoren von Hubkolbenmotoren (Doppler Global Velocimetry (DGV) – Applications Inside the Cylinder and on Exhaust-Gas Catalysts of IC piston engines)	Conference on "Lasermethoden in der Strömungsmesstechnik" (Laser Methods in Flow Measurement), September 2005, Cottbus, Germany	T. Seidel, H. Steuker
Application de la « Doppler Global Velocimetry » (DGV) en vue d'une mesure de l'écoulement dans la chambre de combustion de moteurs à pistons (Using "Doppler Global Velocimetry" (DGV) for Measuring Flow in the Combustion Chamber of Piston Engines)	FLUVISU11, June 2005, Lyon, France	O. Dingel, T. Seidel, H. Steuker
Measurement of 3D In-Cylinder Flow Fields using Doppler Global Velocimetry	SAE World Congress 2004, March 2004, Detroit, USA	O. Dingel, J. Kahrstedt, K. Behnk, S. Zuelch, T. Seidel
Application of Planar Doppler Velocimetry within Piston Engine Cylinders	11th International Symposium on Applications of Laser Techniques to Fluid Mechanics, July 2002, Lisbon, Portugal	C. Willert, I. Roehle, R. Schodl (DLR), O. Dingel, T. Seidel (IAV GmbH)
Messung der Zylinderinnenströmung mit Doppler Global Velocimetry (Using Doppler Global Velocimetry for Measuring Flow Inside the Cylinder)	Haus der Technik e. V. Essen, November 2002, Essen, Germany	R. Schodl, C. Willert (DLR), O. Dingel, T. Seidel (IAV GmbH)

Doppler Global Velocimetry

Measurement of the three-dimensional flow field
Take advantage of three-dimensional flow measurement for developing new concepts and benefit from our expertise in engine combustion processes.
We will be pleased to help you.

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