DaVis

Software for
Intelligent Imaging
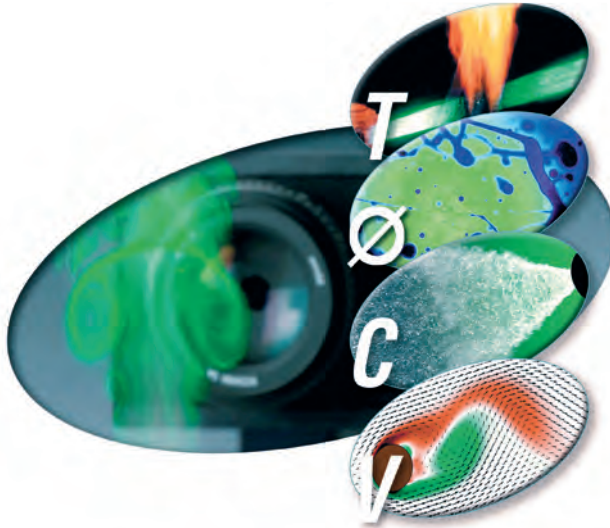
LaVision

FOCUS ON IMAGING

DaVis - the Complete Software ...

DaVis is the *complete software solution* for intelligent (laser) imaging applications for non-reactive and reactive flow fields, material surface imaging and tracking and (ultra) high speed imaging.

The software integration of the selected imaging system is achieved with flexible acquisition modes, customized DaVis software interfaces and application specific imaging packages.

DaVis features user selectable acquisition sequences with precise synchronization on ns-time scale of camera exposure, illumination and external event trigger. A huge range of imaging devices are under DaVis control.

The open nature of DaVis in combination with its macro programming language (CL-language) allows a fast adaptation of the imaging system for different measurement tasks ranging from sophisticated research to reliable industrial applications.

Flexible image acquisition modes, advanced image processing algorithms, intelligent storage and presentation of multi-dimensional image data and the software controlled operation of all implemented hardware are the key elements of DaVis.


DaVis supports **Multi-Dimensional Imaging** in all of the following dimensions:

- x and y (image plane)
- z-axis scans
- time series
- multiple wavelengths (spectral imaging)

From the multi-dimensional data sets DaVis provides
- z-series or 3D reconstructions (volume imaging)
- movies (delay scans)
- excitation and emission spectra
- image stitching and alignment from an image stack
- motion analysis of 3D moving objects

Multi-Dimensional Imaging
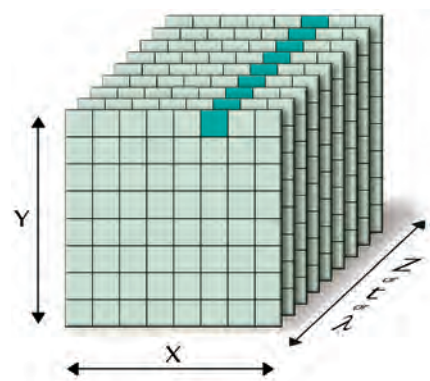
Recording and handling of multi-dimensional data sets are effectively organized using the **DaVis Project Manager.**
For multi-dimensional imaging a variety of hardware components are needed.
Translation stages, spectrographs, tunable lasers, A/D converters and other necessary devices are fully implemented and under DaVis control.

... for Intelligent Imaging Applications
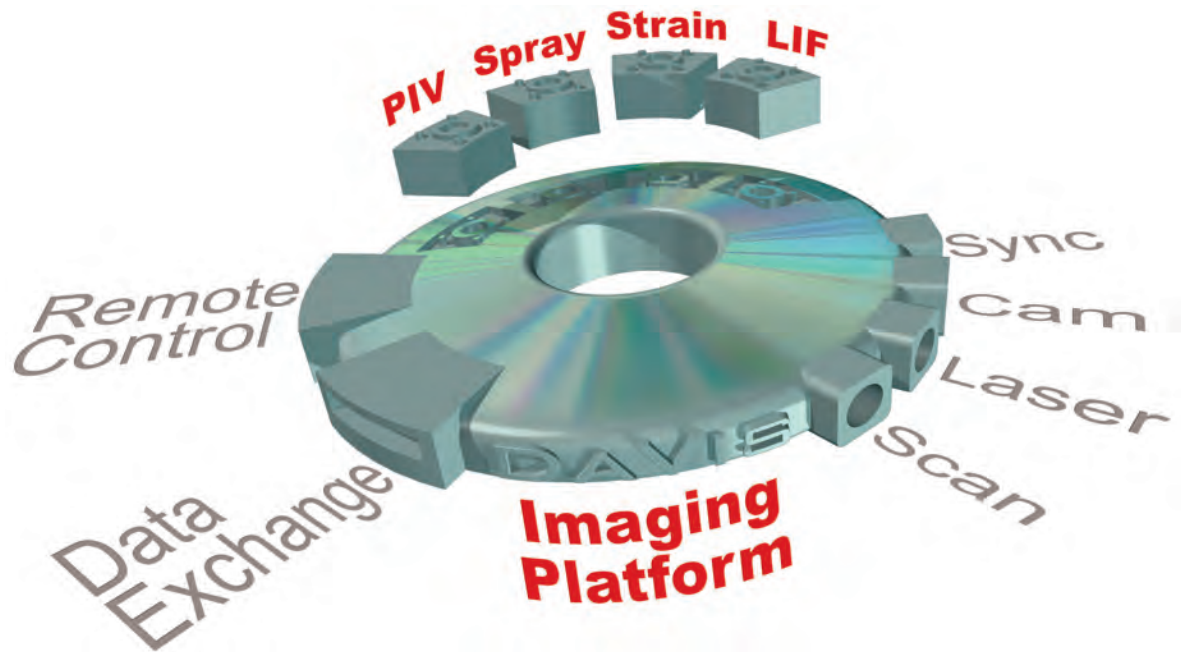
Advanced Imaging Techniques

For flow, spray and combustion visualization **DaVis** supports major laser imaging techniques like Particle Image Velocimetry (PIV), Laser Induced Fluorescence (LIF), Laser Induced Incandescence (LII), Raman, Rayleigh, Shadow and Interferometric Mie Imaging (IMI).

LaVision's Multi-Parameter Laser Imaging approach allows the quantitative visualization of all relevant flow parameters. The most important ones are species concentration, temperature, size, shape and velocity.

DaVis is an universal **Imaging Platform** with modular imaging packages for flow field imaging, surface imaging, motion analysis and (ultra) high speed imaging.

With the powerful **Hardware Manager** for hardware integration and control DaVis is the complete software solution for your advanced imaging applications.

Why DaVis?

▶ complete software solution for multi-dimensional, multi-parameter (laser) imaging

▶ ultimate system integration built on fully software embedded device control

▶ flexible, powerful macro language for customized system solutions

▶ state of the art imaging algorithms based on modern programming concepts

▶ DaVis is extensively field tested and continuously enhanced by our experienced team of engineers and scientists.

New Philosophy in Data Acquisition

Project treeview

Acquisition

Hardware manager

Calibration
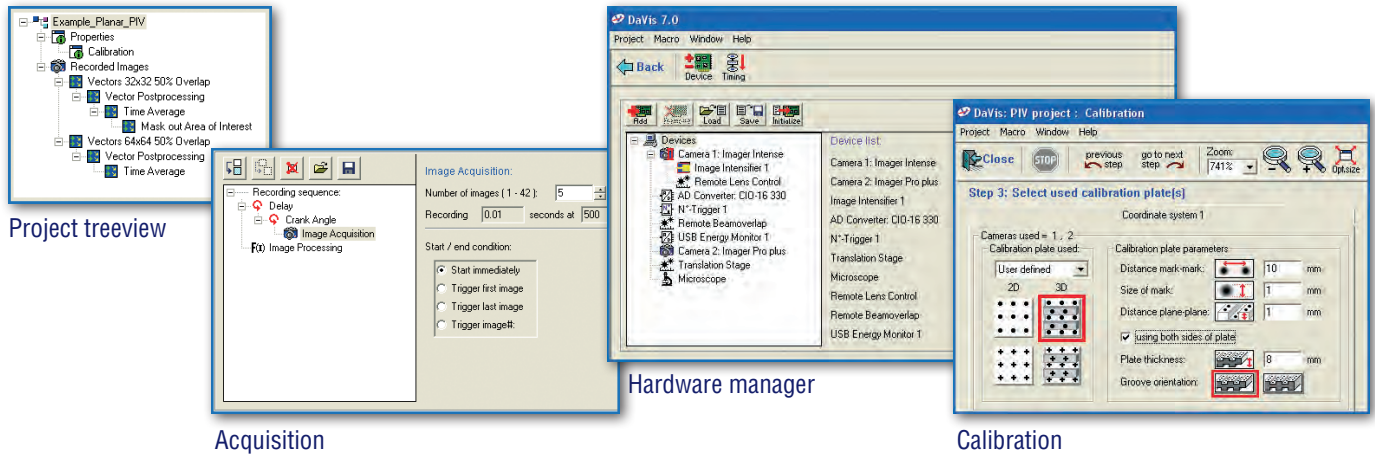
Introduction
For nearly two decades **LaVision** has addressed the specific requirements of a continuously increasing number of industrial development engineers and scientific researchers with our tailor-made imaging systems. Our customers have achieved superior results and unprecedented efficiency due to a common software base that made complex tasks easy: **DaVis**.
Over the years, our application specialists and software engineers have continuously collaborated with our customers to refine DaVis into the most comprehensive and highly flexible intelligent imaging software available.

The Concept
In refining the balance between a comprehensive and flexible software package and maintaining a simple-to-follow user interface, LaVision has adopted a '**One Dialog Concept'**. Intelligent imaging techniques often consist of a series of sophisticated steps between switching a system "on" and getting 'results'. Furthermore, the software tools required are application specific. The 'One Dialog Concept' reduces the number of accessible parameters and operations to ones applicable to that specific phase of a measurement. This avoids an overload of menus and guides the users through their workflow.

Efficient Project Management
Each user of DaVis can set-up a customized user log-in that presets his/her preferred settings for the system. This log-in concept efficiently supports multiple users and eliminates one user over-writing the settings of another.
DaVis uses a **Project Manager** to distinguish between the various types of measurements (e.g. PIV, Deformation, LIF, Droplet Sizing etc.). Each type of project has an appropriate set of processing tools available to the user that are tailored to the specific project type.

Data are logically displayed in a tree structure with the raw image folders at the top tree level and all processed data saved in sub-folders of the source image folders. All raw image and processed data sets are handled as objects in the Project Manager. Hence, the user never has to worry about individual files, file names, and where they are stored, no matter how many individual files are contained in each data set.

Wizards
To simplify stepwise operations, like a 3D-calibration for a multi-camera set-up, DaVis employs a **Wizard** concept, that guides the user through the work, so that no step can be overlooked. The Wizard prompts at each consecutive step so that even non-routine functions can be handled easily.

Standard Tools
DaVis comes standard with an extensive array of processing tools found in no other comparable software such as linear and non-linear filters, image distortion and correction, intensity histo-grams**,** merging and appending of data sets, profile extraction, image stitching, user-defined filters, and image averaging to name just a few.

Automation and Acquisition
Synchronization of several cameras, lasers, translation stages, A/D converters, and other hardware devices at specific trigger points is automatically accomplished using **DaVis' 'Image Acquisition Sequences'**. A matrix of translation stage locations and specified time delays (i.e. phases, crank angle positions, etc.) are input into a visual dialog along with the number of required images at each location and scan delay. A command line can be performed prior to or after each image acquisition sequence to provide even more flexibility. Linked images (e.g. a pair of PIV images or images
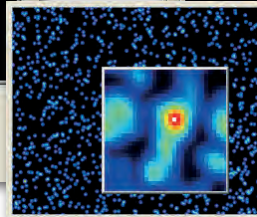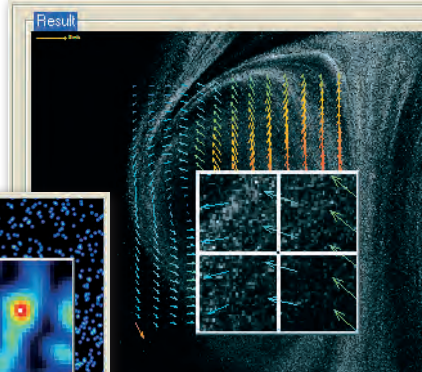
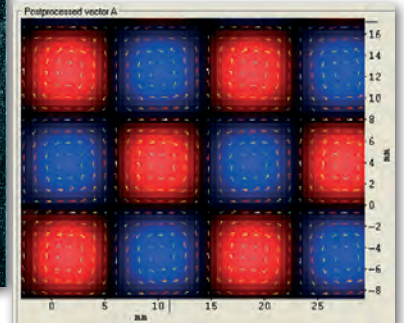# and Visualization Software
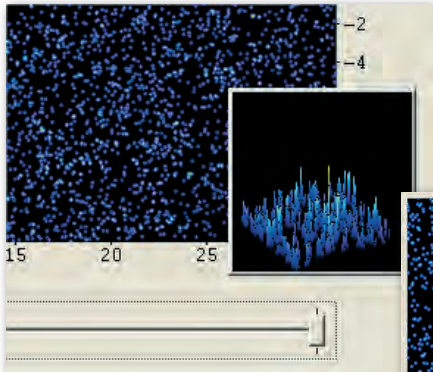
Mouse zoom 3D

Mouse zoom correlation

Result display

Vorticity background

captured simultaneously from different cameras) are automatically saved as a single file to simplify data handling and organization.

Batch Processing, Hyperloop, and Distributed Computing
To automate processing of sets of images, the **Batch Processing** feature in DaVis allows the user to define a processing protocol of several different functions which operate sequentially on the image data. DaVis will perform each processing step in succession and will save the results of each step or save only the steps deemed important to the user. Each operation list can be saved as a file and recalled later to facilitate consistent and repeatable results.
The **Hyperloop** takes the Batch Processing concept one step further. It allows the user to apply Batch Processing to multiple sets of images. The user can automate complex image processing over several sets of image recordings. Hyperloop also allows the user to perform sophisticated file management procedures to combine similar data into common folders (e.g. combining phase-averaged vector fields into a common folder to facilitate phase-locked, phase-averaged movie generation).
To minimize processing time, **DaVis' Distributed Computing** coordinates up to 64 networked PCs to process multiple sets of data. The "master" PC distributes data sets to "idle" slave PCs and organizes the processed data in the default storage folder. Distributed Computing is a *standard* feature of DaVis.

Customization
DaVis is written in a fully integrated macro programming language (CL), which is similar in syntax to C++. Unlike comparable software platforms which offer limited access nodes, users have complete access to all CL macros within DaVis for modifying and adding to the capabilities of the software. In addition, users can create completely new macros to add unique and customized functionality to nearly every aspect of DaVis.

Furthermore, once a macro is modified or created, the user simply loads it into DaVis and executes it – no recompilation of the source code is required. As a further simplification, a CL programming Wizard facilitates macro generation for even the most novice programmers.

Field-Proven
DaVis software is used and tested by top scientists around the world. Working together with cooperation partners who are among the leading scientists in their respective fields we continuously develop new algorithms and innovative image processing tools.

Innovation
LaVision continuously adds useful innovations to DaVis based on our extensive internal knowledge, interactions with our customers and by paying close attention to developments of experts in the field. We have full control over the integration of these implementations and are not a slave to third party developments like some other comparable software packages. We integrate only the most useful innovations that offer tangible benefits to our customers. For example, our revolutionary camera system calibration using a **'Pinhole Model'** and **'Self-Calibration'** saves time and significantly increases measurement accuracy.

Specials as Standard
DaVis offers a long list of 'special tools' as standard features, that does not need to be purchased separately. Examples included are **Fast Online Storage** to the limits of the data transfer bus, **Distributed Computing**, PDA Remote control of the system, and quick implementation of the latest image processing algorithms.

Imaging Platform
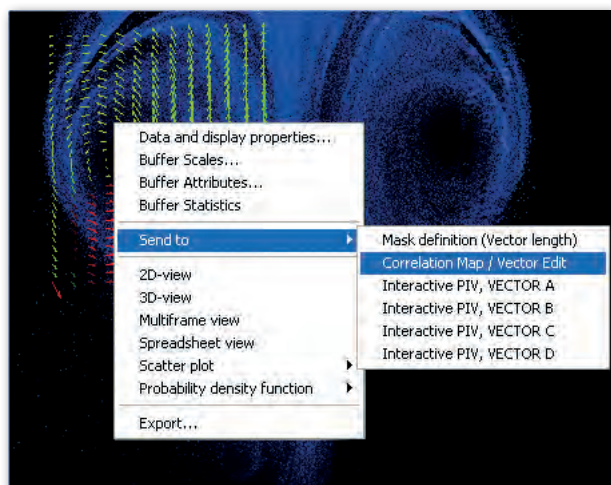
Context menu
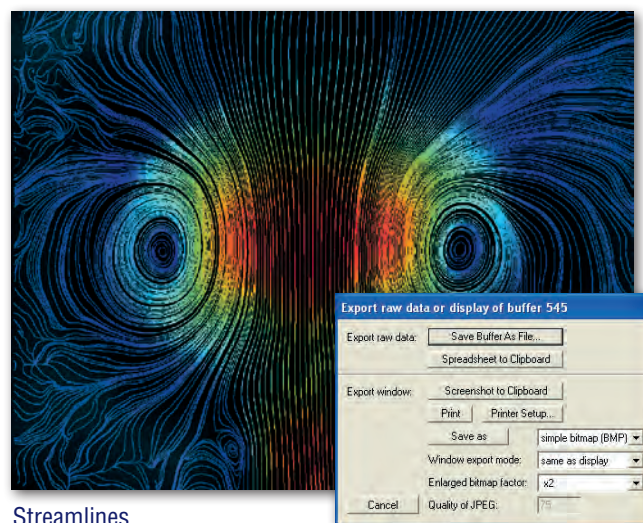
Streamlines

Export

Data Import and Export
Seamless data exchange between DaVis and other software is as important as the measurements themselves. All common file formats are supported so that an exchange with other software is assured. Data interface to LabView, MathCAD or TecPlot and common CFD software is a standard feature.

Individual files, folders, sub-folders, or any combination thereof can be imported or exported with a few mouse clicks. In addition, data export can be implemented as a Batch Processing operation or through the Hyperloop.

Image and Data Display
DaVis offers an extensive data visualization interface for customizing the display of image and processed data. Images overlaid with derived values (e.g. vector or scalar fields), analog data, time stamps, and text can be shown on the screen and exported. Customizable colour pallets, image scales, zoom control, intensity levels, profiles, and image attributes can all be selected by the user and set as preferred defaults. In addition, a user defined "mouse window" can be used for local image zoom, 3-D display, on-line correlation function display, and on-line vector display.

Hardware Manager
All hardware that are supported in **DaVis** are displayed in a comprehensive **'Hardware Manager'**. For a given system, DaVis automatically knows what hardware are present and what hardware properties and settings are applicable. The database structure of the Hardware Manager is easy to operate and hardware can easily be added or removed from the list. The device settings can be locked against unauthorized use.

Camera Calibration
System calibration can be as simple as a length scale conversion for orthogonal camera viewing or a complex, dual stereo imaging configuration with multiple coordinate systems and camera magnifications. For any calibration, a convenient and easy to follow **Calibration Wizard** guides the user through all applicable steps to calibrate the system properly for accurate and repeatable results. Calibration flexibility is maximized by allowing a different coordinate system for each camera in the system and for viewing the calibration target from any angle or any side. Mapping functions for each camera are stored in a calibration folder in each project and are used for processing and presenting data in the appropriate frame of reference.

Image, Vector, and Scalar Computations
An array of mathematical operations can be performed on images, vector fields, and scalar fields so that the user can easily alter and transform data. These tools make it easy to compare similar data to reveal data relationships and effects (e.g. comparing vector field statistics to test for convergence). Computations can be performed over entire images or over specific "areas of interest" within images.

Combination of Signals
Many of our measurement systems record more than one parameter simultaneously. For example, when Mie and LIF signals are recorded using our **Image Doubler** the signals need to be registered correctly and the images split for proper post-processing. DaVis does this job automatically which lets you keep your focus on more important things.

Mask Definition
To use specific regions of images for data processing, DaVis offers a comprehensive mask generation interface. The operator can generate fixed masks with arbitrary shape or define moving masks for cases of moving boundaries or elements within the field of view. The masks are applied to all images in a data set and are saved as files which can be used repeatedly.

6

The **FlowMaster** PIV Software package adds the application-specific algorithms for instantaneous global velocity measurements to **DaVis'** hardware control capabilities. It enables the comfortable processing from images to vector fields and scalar maps with advanced algorithms and elaborated tools.

2D PIV

- high precision multi pass PIV algorithms
- various auto- and cross correlation functions
- high accuracy module as standard
- subpixel window shift
- dynamically deformed interrogation windows
- second-order correlation
- vector calculation by sum of correlation planes
- masking with arbitrary shape
- adaptive masking
- filters for pre- and post-processing
- scalar fields: rotation, divergence, stress

3D PIV

- calculation of 3rd velocity component from 2 planar fields
- powerful calibration wizard
- self calibration on recorded images
- correction of image distortions
- dewarping and mapping of different perspectives
- different calibration models
- dual plane stereo PIV (acceleration fields)

Includes techniques for:

Microscopic PIV
- vector calcualtion from low seeding
- signal/noise ratio enhancement

High Speed PIV
- power spectra
- average and turbulent kinetic energy
- multi-image time correlation features
- tracking of flow structures and fluid elements

Fluorescent Methods

Two-Phase Flows

Additional related products :

3D Surface Flow
- 3D velocity and position of surface elements

IMI/Shadow Sizing
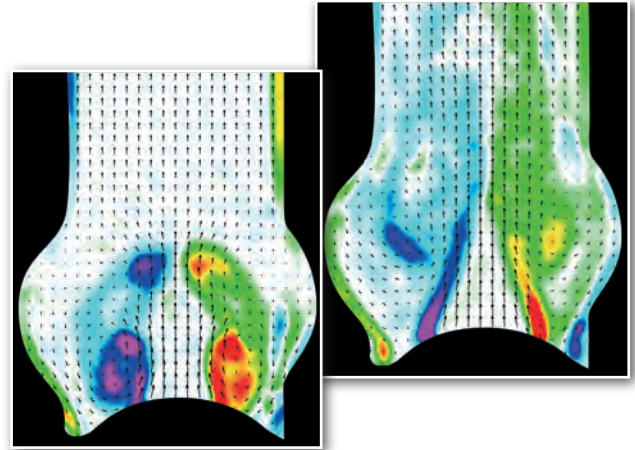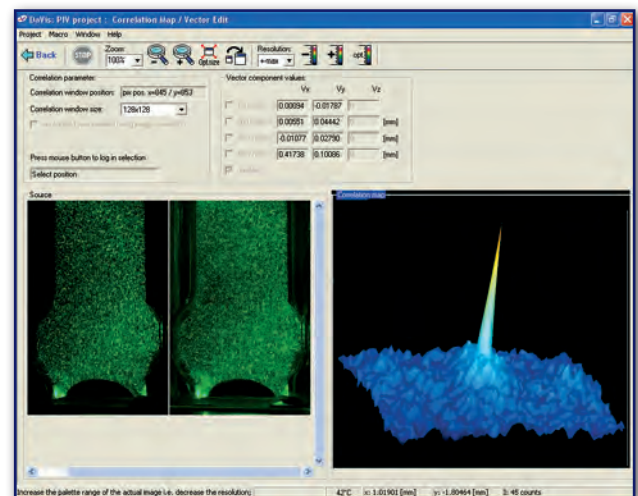- size, position and velocity of particles, droplets or bubbles

Spray Flux
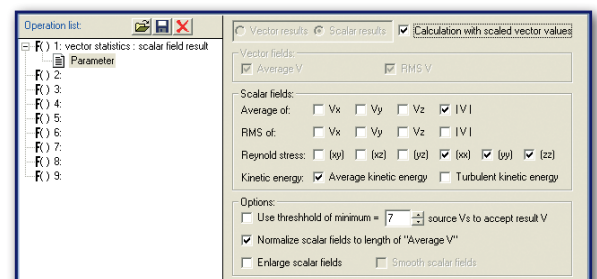- liquid mass flux and spray characterization

Velocity Imaging
Particle Image Velocimetry

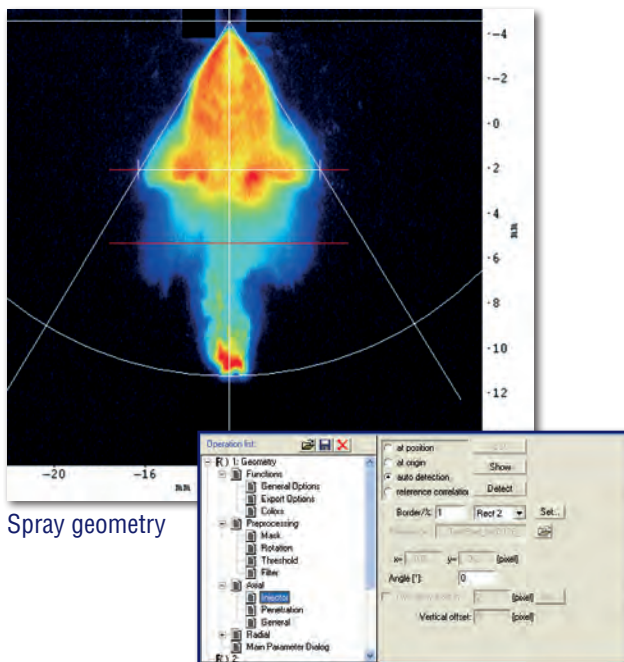3D vector field and vorticity in a heart valve

Correlation map

Average scalar dialog

Spray Imaging

Spray geometry

SprayMaster software packages are designed for a wide range of spray imaging applications, including spray patternation, geometry and global droplet size distribution, and evaporation.

Spray

The basic spray package extracts spray geometry information from shadow and light sheet spray profiles.

▸ spray patternation:
  radial, axial, arbitrary spray cuts,
  spray angle, tip penetration, symmetry
▸ analysis of multi-hole injectors

SprayMaster system can be upgraded with one or more of the following advanced software packages that uses combined imaging techniques with multi-frame operations.

LIF & D32 Dropsizing

▸ global droplet sizing
▸ LIF/Mie ratio imaging with image mapping

Exciplex

▸ Tracer LIF for liquid/vapor phase separation:
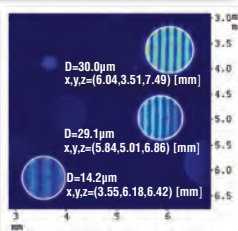 2-color imaging with image mapping

Spray Flux

▸ mass flux imaging using 3D PIV and LIF signals
▸ signal quantification with enhanced calibration routines

Particle Imaging
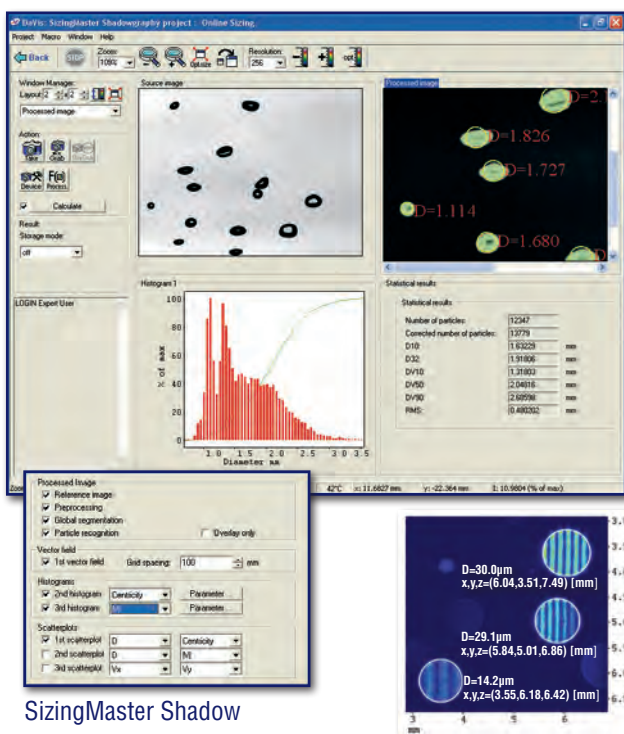
SizingMaster Shadow

SizingMaster IMI

The **SizingMaster** packages include two complementary sizing techniques for particle imaging: Shadowgraphy and Interferometric Mie Imaging (IMI).

Shadow Sizing

The **SizingMaster Shadow** software package analyses highly magnified shadow images of individual particles or droplets in a variety of sprays and particle-laden flows.

▸ particle size, position and shape
▸ particle number density
▸ statistical data evaluation: histograms, scatterplots
▸ software upgrades for particle velocity and mass flux

IMI Sizing

The **SizingMaster IMI** software package analyses the fringe pattern of defocused transparent particles. The IMI technique is optimized for spray investigations of very small droplets at medium droplet densities.

▸ auto-detection with droplet location
▸ fringe pattern analysis using fringe dependent
  algorithms
▸ droplet velocity based on multiple exposure images
▸ droplet density and mass flux
▸ statistical data evaluation: histograms, tables

DaVis supports a complete set of advanced imaging techniques for concentration and temperature measurements in liquid and gas flows as well as combustion systems. The specific software packages provide highly flexible image acquisition modes synchronized with control of sophisticated hardware devices, and allow an easy use of laser imaging systems from **LaVision.**

LIF

Laser Induced Fluorescence (LIF) is highly species specific and is the laser imaging technique with the highest sensitivity. The LIF package supports accurate and quantitative signal detection.

- ▶ laser sheet and image correction
- ▶ compensation for pulse-to-pulse laser fluctuations
- ▶ LIF signal calibration
- ▶ multiple calibration points
- ▶ interactive calibration data recording with curve fit
- ▶ laser absorption compensation for intensity correction

λ-scan

For small molecules or atoms the laser has to be precisely tuned to the exact LIF excitation wavelength. The λ-scan software packages support the control and use of tunable laser sources directly from DaVis.

- ▶ wavelength scanning of dye, OPO, T-YAG lasers
- ▶ on/off resonance tuning with peak finding
- ▶ automated generation of excitation-emission spectra

Raman and Rayleigh

Raman and Rayleigh are ratiometric imaging packages allowing relative measurements of concentration and temperature with robust reference calibration. DaVis Raman and Rayleigh software packages support ratiometric imaging as a standard imaging tool for 1D-Raman and 2D-Rayleigh concentration and temperature imaging.

- ▶ user controlled parameter scanning
- ▶ data representation
- ▶ signal calibration based on reference ratio imaging
- ▶ molecular database with emission wavelengths

LII

Laser Induced Incandescence (LII) is the most sensitive imaging technique for soot detection. The size of the primary soot particles is measured applying ratiometric imaging to time-resolved LII images. The software package controls all acquisition parameters as well as the power level of the excitation laser.

- ▶ particle (soot) concentration imaging (with statistics)
- ▶ primary particle size imaging based on LII ratio imaging
- ▶ LII signal calibration using reference sources or light extinction
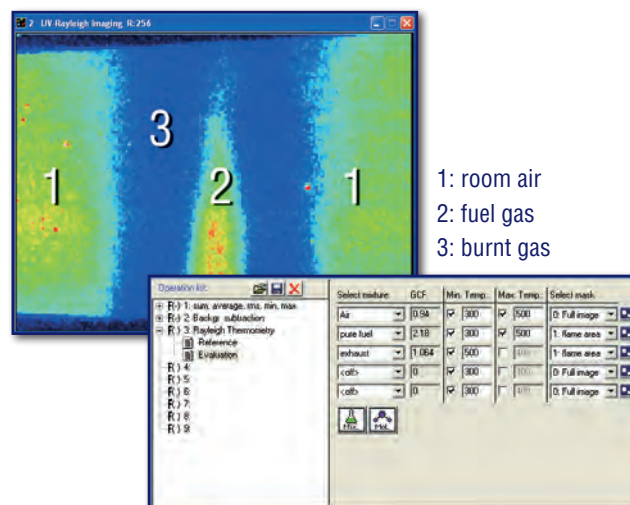
Concentration & Temperature Imaging
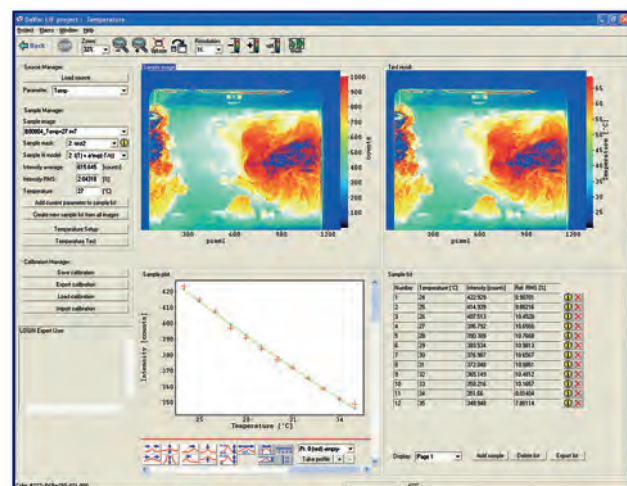
Temperature LIF calibration
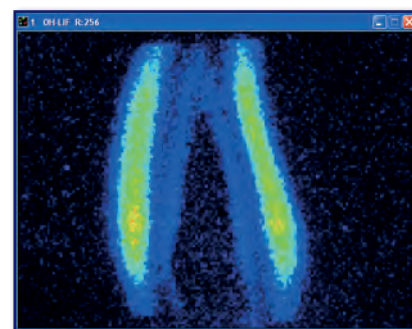
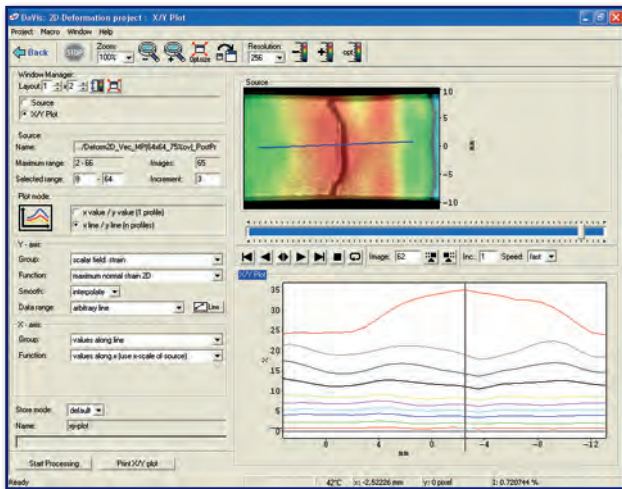Flame front visualization: OH-LIF

Total gas density: UV-Rayleigh imaging

1: room air
2: fuel gas
3: burnt gas
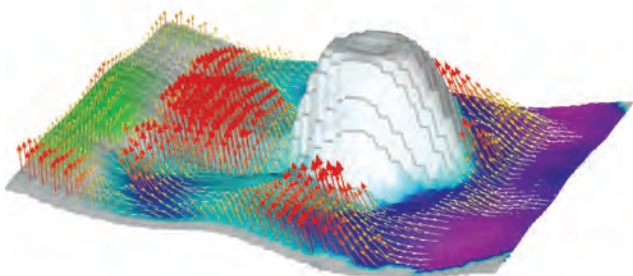
Rayleigh Thermometry dialog
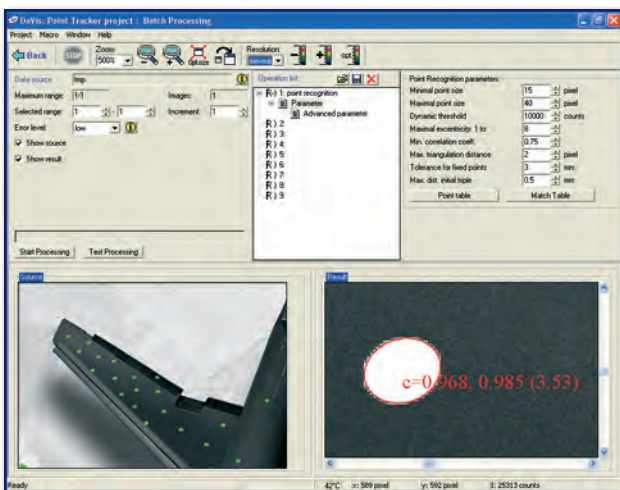
Strain Imaging
Deformation-Analysis

Extract profiles with virtual extensiometer:
- global strain vs. time
- analog data (e.g. applied force) vs. time
- analog data (e.g. applied force) vs. strain for time series experiments

Visualization of water waves with obstacle

Motion analysis

Courtesy ONERA Fauga Mauzac, Toulouse

The **StrainMaster** software package allows analysis of 2D and 3D deformation of both solids and granular flows. The software features advanced optical correlation algorithms, making it an ideal tool for non destructive testing of different materials including rubber, ceramics and metals. Another specific application are geological sandbox experiments.

2D Strain

▸ high accuracy: 0.01 pixel
▸ high precision multi pass strain calculation algorithm
▸ adaptive masking to restrict strain calculation to interesting sample regions
▸ deformation vector field (arrows or deformed grid)
▸ scalar quantities: strain E_{xx}, E_{yy}, E_{xy}, shear strain etc.
▸ display of analog readings (force sensor)
▸ strain profiles or analog data vs. time

3D Strain

▸ high accuracy: x & y : 0.01 pixel, z : 0.02 pixel
▸ pinhole model image calibration
▸ calculation of all differential strain components
▸ intelligent surface mapping

3D Surface Flow

The 3D surface flow software measures the three-dimensional shape and 3D velocity of surfaces. Applications include free surface water waves, biological tissues, granular flows etc. This new analysis tool is ideal for coupling the effects of surface shape with surrounding flow field (using PIV) and vice versa.

PointTracker

The **PointTracker** software records and evaluates position, movement and deformation of rapid moving, three-dimensional objects, e.g. rotating airplane models in a wind tunnel. Position and deformation of the object is achieved by tracking and recording distances between target markers on the object. The software transforms the real object into well-defined object positions in a user-selectable coordinate-system.

▸ high accuracy < 0.1 pixel
▸ resolution < 0.1 mm
▸ resulting parameter matrix contains translation vector, Euler angles, deformation vectors
▸ support of up to 6 cameras for three-dimensional observation of objects

High-Speed Imaging

The high-speed imaging software package enables the use of a wide range of high-speed cameras and light sources like lasers and flash lamps. The software provides advanced application-specific timing and device control as well as individual image acquisition, processing and presentation.

▸ investigation of transient phenomena
▸ online monitoring
▸ automatic data storing
▸ slow motion movie of fast events
▸ independent control of exposure and frame rate
▸ fully arbitrary frame rate selection
▸ advanced trigger capabilities
▸ crank angle synchronized imaging for engine applications
▸ unambiguous detection of 1st and 2nd frame for PIV experiments

Ultra High-Speed Imaging

The ultra high-speed imaging software provides advanced triggering and control of **LaVision's** unique **UltraSpeedStar** camera.

▸ investigation and recording of ultra-fast events with interframe times down to 1 μs
▸ high-speed laser support
▸ external triggering of each frame independently or via delay/gate list
▸ image calibration and pixel mapping for precise overlay of images

Intensified High-Speed Imaging

Both software packages support specifically designed multi-stage high-speed intensifiers for use in combination with (ultra) high-speed cameras for low light level applications.

▸ maximum sensitivity
▸ UV signal detection
▸ remote intensifier gate, delay and gain control

Video Stroboscopic Camera System

The video stroboscopic camera system is a cost effective tool to capture high frequency periodical events up to 100 kHz. The embedded software controls an accurate phase-shifting and synchronization for detailed anaylsis of high-speed events.
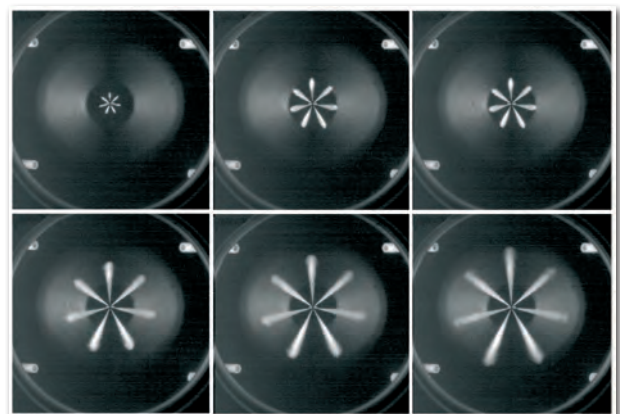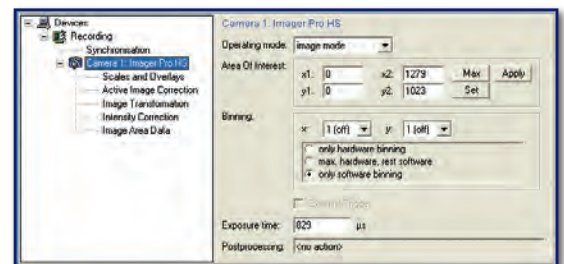
▸ support of up to 4 cameras
▸ phase angle and offset freely adjustable
▸ external trigger capabilities
▸ automatic gain and exposure control
▸ elaborated data handling
▸ slow motion video presentation

Ultra/High-Speed Imaging
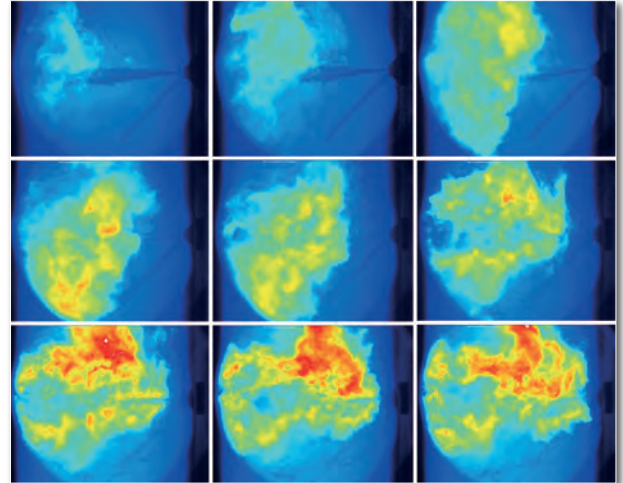
Courtesy ETH Zurich

Fuel injection/ignition process recorded with High-speed ICCD, interframe time: 100 μsec

Courtesy Volkswagen

Diesel injection measured with video stroboscopic camera system

licensed by DLR (German Aerospace Center)

DaVis
Imaging Packages

Upgrade		Spray Flux				
Upgrade		3D PIV	LIF & D32	Exciplex		
Basic Package	3D Surface Flow	2D PIV	Spray		Shadow Sizing	IMI Sizing

DaVis Imaging Platform

Upgrade	Temp. Calibration	Absorption	λ-scan		
			Excimer	Dye Laser	T-YAG
Basic Package	LIF				

DaVis Imaging Platform

| Basic Package | High-Speed Imaging | Raman | Rayleigh | Plasma | LII |

DaVis Imaging Platform

| Upgrade | 3D Strain | Crack Statistics | K1c and G1c | |
| Basic Package | 2D Strain | Crack Growth Analysis | | Point Tracker |

DaVis Imaging Platform
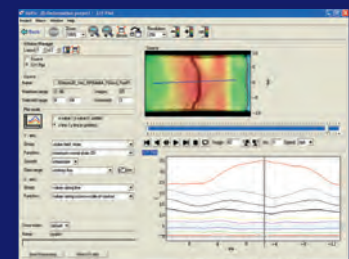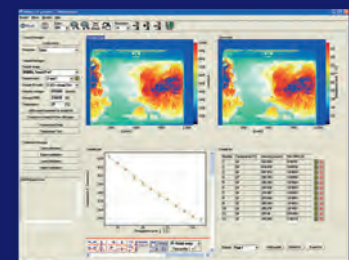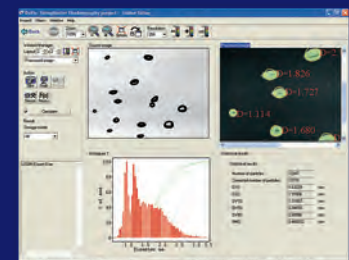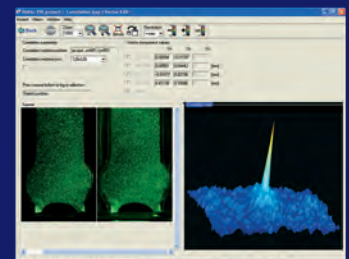
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