Intelligent Imaging
Product Guide
LaVision was founded in 1989 in Goettingen, Germany. The primary mission of the company is to provide integrated (Laser) Imaging Systems to the scientific and industrial markets. LaVision is involved in an ongoing process of innovation and development of imaging detectors, spectroscopy, lasers, measurement technologies and software tools.

LaVision collaborates with leading scientists, research institutions and companies around the globe. Among the major partners are: Laser Laboratory Goettingen, TU-Delft, German Aerospace Center (DLR) and TU-Darmstadt.

LaVision offers a range of high-end cameras as well as both standard and dedicated customer designed (Laser) Imaging Systems for reactive and non-reactive flow field analysis, fluid mechanics, and non-destructive material testing. These Intelligent Imaging Systems are provided with proprietary software for synchronization and control of system components, data acquisition, processing and analysis. Only LaVision offers a complete Laser Imaging product line for Multi-Parameter flow field imaging.

The LaVision team has extensive professional experience in imaging spectroscopy and optical techniques such as Laser Induced Fluorescence (LIF), Laser Induced Incandescence (LII), Raman, Rayleigh and Mie Scattering, Particle Image Velocimetry (PIV), Spray Analysis, image correlation techniques as well as ultra fast time-resolved imaging and high-speed image recording.

The company is customer focussed and offers high quality products that are user-friendly, reliable and application specific. LaVision guarantees system performance, friendly and attentive customer support, competent and experienced employees and, ultimately, customer satisfaction.
The LaVision team welcomes and encourages detailed discussions with prospective customers regarding their application and measurement requirement. LaVision’s system approach involves design and selection of system components, system integration, application-specific software development, calibration and detailed protocol of system performance. LaVision excels in providing on-site customer training and support including contract work.

The LaVision family of laser imaging systems builds up a complete multi-technique framework for quantitative visualization of reactive and non-reactive flows. Multi-Parameter measurements (velocity, species concentration, composition, temperature, particle sizing) are possible using multi-technique approaches.

### Application

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StrainMaster from LaVision combines the most advanced Digital Image Correlation (DIC) algorithms with the highest quality hardware to provide a complete device for materials analysis. StrainMaster is applicable across all industries investigating material behaviour and gives fast, highly accurate results via an easy to use PC based interface.

A range of StrainMaster systems are available from portable field work machines to highly specialized lab versions. Any system can be tailored to suit your particular requirements, and are appropriate for both industrial and academic applications across a vast range of subject areas. Unlike many standard Digital Image Correlation (DIC) systems, LaVision’s StrainMaster is insensitive to the speckle pattern distribution and in many cases the natural surface of the material is quite sufficient to allow the acquisition of highly precise displacement and strain data.

### Applications
- strain measurements of solids
- long term flow stress experiments
- ultra-fast deformation analysis
- granular flows
- low cycle fatigue tests
- Thermal Mechanical Fatigue (TMF) tests

### System Features
- complete control, analysis, and data management within one package, fast processing on GPUs
- live gauge extensometer mode with scaled analogue output for strain control

**Digital Volume Correlation**

LaVision’s state-of-the-art Digital Volume Correlation (DVC) software brings new depth to quantitative 3D imaging analysis. DVC is not only capable of identifying defects and cracks before they are visible in the raw image, but it is also able to quantify the full volume strain distribution and actual magnitudes of the material displacements surrounding discontinuities. The level of information is extremely useful in validating Finite Element models of modern complex materials. Volume images can be imported into the software from a variety of sources, such as:

- X-ray Computer Tomography
- Magnetic Resonance Imaging (MRI)
- Optical Coherence Tomography (OCT)
- Confocal Microscopy

DVC tracks the displacement of the material structure pattern within the volume images. The algorithms used are extremely robust in terms of the appropriateness of the pattern type. DVC has successfully been applied to many materials.
LaVision’s ParticleMaster systems are designed to simultaneously determine size and velocity of individual particles or droplets or bubbles in fluids or multiphase flows. The two different methods applied for the measurements are Shadowgraphy or IMI (Interferometric Mie Imaging) with different strengths for different experimental conditions. Data acquisition and on-line evaluation are performed with the versatile DaVis software.

Shadowgraphy

High resolution imaging and special background illumination are the keys to the technique of analysing shadow projections of regularly or irregularly shaped objects. As opposed to laser diffraction or interferometric methods Shadowgraphy does not require sphericity or translucency and, therefore, is a quite universal technique. The ParticleMaster software package finds shadow shapes in an image series and calculates properties for individual objects and gives a comprehensive overview with global statistical data.

It can well be combined with other methods like PIV or thermometry for use in multi-phase flows.

IMI (Interferometric Mie Imaging)

In sparse sprays the droplets are illuminated by a laser light sheet thus giving a larger observed area. In an approximately perpendicular arrangement a camera equipped with suitable optics can detect an interferometric fringe pattern which is proportional to each droplet’s size. The method is very sensitive due to the nature of interferometry. Dedicated software algorithms extract precise size information for spherical liquid droplets and small bubbles as well as translucent solid spheres.

Applications

- liquid sprays (fuels, water, paint, pharmaceutical, crop)
- spray break-up and atomization
- powder, solid particles (alloys, ceramics)
- emulsions and dispersions (waste water, meteorology, industrial facilities)
- bubbles (heat exchangers, industrial processes)

Information

- simultaneous size, velocity and position of individual particles
- velocity-size correlations
- morphology and shape information
- mass flux and number density
- visualization of ligament formation, spray break-up and atomization
Combustion is the major source of energy production and at the same time the principle source of air pollution. LaVision’s modular FlameMaster product family is designed to help the scientific and engineering community to find new concepts for the realization of more efficient and cleaner combustion devices. The system provides in-situ and online flame imaging as well as quantitative information about species concentration, gas composition and flame temperature.

The intelligence of a FlameMaster laser imaging system is concentrated in LaVision’s powerful timing and synchron unit PTU X and the versatile software platform DaVis. Integrating the entire processes of hardware control, image acquisition, data storage, and image processing for quantitative measurements.

Applications

Investigation of combustion phenomena in

- flames
- burners
- jet engines
- furnaces
- propulsion systems
- chemical reactors
- shock tubes

Information

- fuel LIF imaging, air-fuel mixing
- flame front visualization
- flame radical distributions (OH, NO, CH ...)
- 3D flame structure and flame stability
- flame and soot temperature
- soot concentration and size of primary soot particles
- majority species composition (1D-Raman imaging)

System Features

- integrated turnkey laser imaging systems based on application matched best selection of laser and camera
- complete hardware control using DaVis software
- accurate hardware and signal calibration
- flexible beam delivery and sheet forming optics
- laser sheet correction incl. local laser beam absorption compensation
- most efficient LIF excitation technique for each application and flame radical
- spectroscopic data base and background literature
- combination of techniques, multi-parameter laser imaging
SprayMaster
Advanced Spray Analysis

The SprayMaster product family is designed for in-situ investigation of liquid and solid spray phenomena. Ultra-fast imaging and quantitative analysis of the transient nature of sprays are provided. Atomization and evaporation phenomena of sprays as well as the analysis of global or local spray characteristics are of special interest. Various applications, the research sector as well as quality control applications require different system approaches: LaVision is offering predefined systems and special customized systems to achieve the application-specific performance.

Applications
- characterization and quality control (QC) of nozzles
- inspection of fuel injectors for combustors or IC-engines
- process optimization for industrial painting or coating
- medical / pharmaceutical research: distribution of active ingredients
- more precise application of agricultural substances (e.g. pesticide sprays)

Shadowgraphy, Mie

High-Speed Imaging
Shadowgraphy, LIF / Mie

Mie
- global (3D) spray imaging (digital movies)

LIF
- liquid / vapor phase transition, fuel mass distribution

PIV
- velocity fields (see FlowMaster)

PIV * LIF
- mass flux measurements (spray impact values)

Specials
- control of gasoline direct injectors and diesel sprays
- optimization and development of new spray drying methods
- (ultra) high-speed spray imaging (i.e. for automotive industries)
- quality checks of industrial spray nozzles
- intelligent reduction of multiple scattering by Structured Laser Illumination Planar Imaging (SLIPI)
The constantly increasing popularity of PIV is partly owed to the strength of an optical technique utilizing fast and sensitive digital cameras and a pair of laser flashes resulting in an instantaneous flow field map. But such system must be manageable for non-specialists and has to use the most elaborated and accurate software algorithms.

LaVision’s FlowMaster systems have brought valuable insight into flow phenomena in scientific, engineering, biological and medical applications for many years. Constant technological advances in hardware and thorough implementation of the latest research of algorithms assures that our customers get the maximum in performance and accuracy and system operability.

### Applications
- Flow fields in liquid or gaseous flows
- Instantaneous velocity maps (microscopic, endoscopic, macroscopic)
- Time-resolved flow analysis (up to tens of kHz)
- Flow visualization (images or movies or numeric data)

### Stereo-PIV
(2D3C formerly also ‘3D-PIV’) enables the measurement of all three velocity components inside a light sheet using two cameras based on the principle of two perspective views.
- Three velocity components
- Patented calibration
- Scheimpflug arrangement of camera optics

### Time-Resolved PIV
(Highspeed PIV, TR-PIV) utilizes high frame rate cameras and high repetition rate lasers to capture flow fields at up to tens of kHz frame rate
- Widest range of highspeed cameras all integrated in DaVis software
- Synchronizer operating in the same time domain
- Special algorithms making best use of time-information

### Tomographic PIV
(3D3C PIV, Tomo-PIV) results in instantaneous 3-dimensional 3-components (3D3C)-vector fields in a complete volume
- Special volume optics allows an easy illumination of the desired measurement volume and can be quickly adjusted from thin volumes to large cubes
- Any camera setup is possible from standard low speed cameras to advanced kHz range high speed cameras
- Fully digital recording and processing
**Underwater PIV**
A fully submersible stereo-PIV system in light-weight watertight enclosure.
- modular and flexible arrangements for several geometries
- also as tomographic assembly for PIV in a full volume

**Micro-PIV**
Flow fields in microscopic scales are captured with dedicated combinations of microscope assemblies and illumination solutions. Algorithms optimized for such imaging conditions enable accurate results even for micro-Stereo-PIV applications or tomographic data.
- range of microscopes to select from
- fiber-guided laser beam delivery with efficient coupling
- specific micro-PIV algorithm for enhanced signal-to-noise-ratio

**Endoscopic PIV**
PIV measurements with only a small hole necessary for the optical access.
- field curvature and distortion caused by the endoscope is automatically corrected by LaVision’s DaVis software
- camera and laser endoscopes for visible and UV range available

**Thermographic PIV**
Simultaneous flow field and gas-phase temperature imaging with micrometer-sized thermographic phosphor particles.
- simultaneous single-shot planar velocimetry and thermometry using same tracer particles
- experimental simplicity
- combined phosphor thermometry / velocimetry technique can also be applied at kHz rates

**Fluid Structure Interaction**
Combined PIV and DIC technology which simultaneously measure and quantify the interaction of fluid motion and surface deformation.
- study of fluid flow causing deformation of a surface and influence of the surface shape on the flow field
- separate measurements of fluid and structure behavior or simultaneous measurements are possible
FluidMaster is a complete laser imaging system family for the quantitative visualization of thermal flows and mixing processes in fluids. Instantaneous concentration and temperature fields are measured with high spatial and temporal resolution. Monitoring of reactive mixing is possible using reaction sensitive fluorescence substances.

Applications
- high resolution imaging of the mixing process
- high speed imaging to study process dynamics
- monitoring of reactive mixing processes
- microscopic imaging of small scale mixing structures
- thermometry in non-reactive fluids

System Features
- integrated turnkey laser imaging systems based on application matched best selection of laser and camera
- complete hardware control using DaVis software
- accurate hardware and signal calibration
- most effective LIF excitation techniques
- Rayleigh thermometry package for thermal gas flows

Specifications
- non-intrusive and fast on-line mapping of concentration fields
- high spatial resolution (more than 5 million measurement points)
- high performance, photometric imaging systems
- high speed image recording up to 10 kHz
- light sheet and image correction, intensity calibration
- movie presentation of transient mixing processes

Information
- instantaneous digital concentration fields with statistics (mean and rms values)
- visualization of large and small scale mixing structures
- degree of mixing
- reactive mixing: reactant and product visualization
- flow field visualization
The detailed characterization of in-cylinder events and a better understanding of these processes lead to more intelligent engine designs. Basically the methods are aiming at better fuel efficiencies and reduced pollutant emissions. For the development of new engines or in special critical operational modes (cold start, idle operation, part load) optical diagnostics allow much faster and more efficient development and thus save time and money. EngineMaster the multi-functional laser imaging system from LaVision investigates all stages of internal combustion processes.

**Applications**
- fuel injection
- air-fuel mixture preparation
- in-cylinder temperature fields
- ignition and flame propagation
- pollutant and soot formation

**Information**
- liquid and vapor fuel concentration fields
- local air/fuel ratios (lambda-maps)
- in-cylinder temperature during mixture formation
- localization of knock centers
- flame front propagation
- combustion species concentration (OH, NO, CH ...)
- soot concentration and primary soot particle size

**System Features**
- integrated turnkey laser imaging systems based on application matched best selection of laser and camera
- complete hardware control using DaVis software
- accurate hardware and signal calibration
- predefined crank angle resolved measurements with cycle statistics
- multi-functional engine synchronization interface: crank angle decoder, engine simulator, trigger conditioner

**Specials**
- endoscopes for keyhole imaging
- high speed digital film recording of complete cycles
- high speed imaging pyrometers
- EngineMaster Synchronizer for injection, ignition control and others
- Internal Combustion Optical Sensor (ICOS) for fuel density, exhaust gas and temperature measurements in a real engine
Intelligent Imaging starts with an intelligent selection of the best possible camera matching a given application. Since different camera models from different suppliers can be distinguished by different advantages we test and qualify each new device with our extensive in-house knowledge and strict criteria so that we can offer best imaging configurations.

**Imager camera family**

The Imager camera family consists of the widest range of models to be found at any imaging systems supplier. No matter if highest priority is on spatial resolution, frame rate, sensitivity, weight or price there is always a solution in our portfolio of Imager pro X or Imager LX or SX cameras. These advanced progressive scan cameras with extremely short interframe times for PIV are accompanied by the Imager X-lite and E-lite series for applications which do not require double-frame images. Variations with CamLink or GigE interfaces and built-in cooling of the sensor or selectable bit depth of the digital signal add to the number of cameras to select from.

**Imager sCMOS camera**

The Imager sCMOS camera contains a new generation of scientific CMOS (sCMOS) sensor and combines the advantages of modern CCD and CMOS sensor technologies resulting in an unsurpassed image quality and system performance. The high resolution 5.5 million pixel Imager sCMOS camera with extremely low readout noise and high frame rates offers excellent imaging performance in the field of quantitative scientific (laser) imaging. The high dynamic range of the camera makes it ideal for many applications like PIV and LIF.

**HighSpeedStar & Phantom families**

For applications requiring extreme frame rates or high speed image acquisition the CMOS cameras are the perfect solution. Modern technology enables an ever increasing maximum frame rate: full sensor resolution up to 20 kHz of full images and more than 200 kHz for smaller image windows are currently available.

Our HighSpeedstar and Phantom (including Miro) series cameras are fully characterized for image quality, noise and trigger capabilities in details the manufacturers do not have on their datasheets.

Specialized models are the Imager pro HS 4M cameras with best image quality and 4 Mpixel resolution, while the Imager MX 4M camera covers mid-speed frame rates.
**‘Intensified Relay Optics’ IRO and High Speed (HS)-IRO**

Image intensifiers usually find their use in situations when a weak light signal is to be amplified or when a short exposure time requires a fast gating or simply when UV sensitivity needs to be added to standard cameras.

Our **IRO** and **HS-IRO** intensifiers are supporting the repetition rates of standard cameras and high-speed cameras, respectively. Both can be equipped with second or third generation intensifiers and different phosphor screens.

- lens coupling for optimized image quality
- fast phosphor decay times for high speed applications
- fully software controllable
- camera remains available for applications without intensifier

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**NanoStar**

The **NanoStar** camera family is equipped with the same options for photocathodes with sensitivity from deep UV to short infrared and fast or slow phosphor screens as our **IROs**. The single housing saves weight and space when the camera is to be used exclusively in the intensified mode. A fiber-optic datalink allows for operation at long distances from the PC and eliminates any risk of electro-magnetic interference.

- lens coupling for optimized image quality
- minimum gate 5 ns
- sensor 1280 x 1024 pixels (SVGA)

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**PicoStar**

The **PicoStar** camera family from LaVision represents the leading edge of ultra-fast gated, intensified CCD camera systems in the picosecond (ps) range. Three camera models are available which offer gating times down to 50 ps and repetition rates up to 110 MHz. The 18 mm intensifier can be coupled to variety of different cameras.

- time-resolved imaging and spectroscopy
- Fluorescence Lifetime Imaging Microscopy (FLIM)
- multifocal multiphoton microscopy
- single molecule and quantum dot imaging
Any part of an imaging system is decisive for the combined performance. So instead of simply bundling accessories we use either properly selected system components or we thoroughly design them ourselves. The optics, mechanics and electronics which turn individual devices into a system shall make the user’s work not only more accurate and efficient but also enjoyable.

### Lasers and Light Sources
- A wide range of shuttered cw lasers designed to provide a highly stable light source, ideally suited for micro PIV and even high speed PIV experiments
- High repetition rate laser for mid speed PIV and time-resolved PIV applications
- A huge range of dual cavity solid state lasers for PIV
- High and low repetition rate pulsed dye lasers for combustion research and flame characterization
- A series of high-pulse energy Nd:YAG lasers for e. g. pumping of dye lasers
- Flashlamps with ultra short flash duration for high-speed requirements
- Various LED illumination units for strain and deformation analysis and high speed imaging to be used in constant or pulsed mode

### Laser Accessories
- Laser endoscopes with full range of optics for visible and UV wavelengths for planar laser light sheet illumination inside cavities
- Several fiber coupling devices for a flexible and robust optical coupling of laser light enabling flexible setups
- Light sheet optics, special sheet optics, light guiding arms, collimators and telescopes for beam guiding and light sheet formation
- Several devices for the control of laser pulse energy and polarization

### Camera Accessories
- Various camera endoscopes enabling measurements in areas with minimum requirements for optical access
- Numerous filters for signal separation and background or cross-talk suppression but high transmission
- Scheimpflug mounts for an easy manual or remote Scheimpflug angle adjustment
- Camera lenses and long-distance microscopes to adjust to any condition of working distance and magnification at the desired resolution
- Special lenses for highly effective image capturing in the UV range
- Beamsplitter devices enabling imaging of different optical signals with identical beam paths
- Double image projection for spectral separation of incoming light with LaVision’s Image Doubler
- Laser shutter and online-energy monitor for stable and safer use of UV lasers
Calibration
- two-level calibration plates with extremely tight tolerances so that a spatial calibration with a single view and no need for moving the plate gives a superior accuracy
- micro calibration plates for calibration purposes with small scale fields of view, especially for micro PIV applications
- a depth-of-field calibration set for increased accuracy in particle size measurements by Shadowgraphy or other applications that use a high magnification
- our calibration burner with known flame species concentrations and temperatures

Mounting
- a variety of rail and tripod mounts for small as well as large cameras and lasers assuring comfortable handling of cameras while providing the required ruggedness and stable, vibration-free operation during measurements
- customized or standard modular traverse systems with high resolution positioning and high stiffness traverse mechanisms are available in configurations of 1 to 4 axes with strong motors for high loads

Triggering
- additional to our unique synchronizer, PTU, which can create flexible trigger sequences that would otherwise require a long cascade of simpler timing boxes we designed trigger conditioning and trigger logic devices to adapt to any complicated application requirement

Seeding
- several models of gaseous, liquid and solid tracer particle generators
- diverse kinds of seeding particles for any type of application

Services
- customized software solutions
- contract measurements
- customer LIF and PIV seminars
- equipment loan
- on-site demonstrations and feasibility tests
- inline/online quality control systems and
- flexible and customized optical measurement solutions
DaVis Software

Powerful and Versatile Software Package for Data Acquisition and Visualization

All LaVision Intelligent Imaging systems are driven by our powerful and comprehensive software for data acquisition, visualization and processing. DaVis runs under 64 Bit Windows and offers a wide range of application specific modules.

Features
- very flexible and versatile data acquisition and device synchronization, including synchronization to external events, user defined trigger lines, multi-camera and multi-laser support
- 2D and 3D visualization of data, especially for vector fields (PIV) with a large variety of presentations for vectors, derivatives and raw images
- statistics on image data, vector fields and its derivatives
- processing speed up by use of multi-core CPUs and GPUs
- large library of built-in processing and filtering functions, which can be extended by yourself using our open data access model
- data import and export from and to several image and numerical formats (AVI, TIFF, PNG, Tecplot®, ASCII, …)
- data management in application specific projects
- free lifetime support and upgrades within a major release over many years
- customized macros and programming services on request

Open Data Access
- write your own processing functions with the integrated macro language
- take advantage of existing routines of the image processing library to analyze your data
- get access to your data with our free Matlab® Add-on, running under Windows®, Linux® and Mac OS®
- generate stunning 3D visualization of DaVis data using our free Add-on for Tecplot®
- implement your own DLL: we supply a free C++ library and sample code to grant efficient access to DaVis data in your own compiled code