

SprayMaster

Advanced Spray Analysis
based on
Laser Light Sheet Imaging



LA VISION

WE COUNT ON PHOTONS



SprayMaster

vision for sprays

non-intrusive

high temporal and spatial resolution

on-line spray characterization

multi parameter measurements

wide range of sprays

easy to operate and fast



multi-camera setup

applications

- ▶ fuel injectors
- ▶ automotive sprays
- ▶ inhalers
- ▶ aerosol generators
- ▶ paint sprays
- ▶ industrial sprays
- ▶ atomizers

SprayMaster is a complete family of advanced laser light sheet based measurement systems for non-intrusive spray analysis. The information is obtained by light without disturbing the spray.

Planar measurements are performed on laser light sheets slicing the spray with high temporal and spatial resolution.

All information is obtained and presented in real-time. On-line quality control for injector/nozzle production is feasible.

The unique combination of different laser light sheet techniques allows multi-parameter measurements with the same setup.

A wide range of droplet and particle sprays can be investigated.

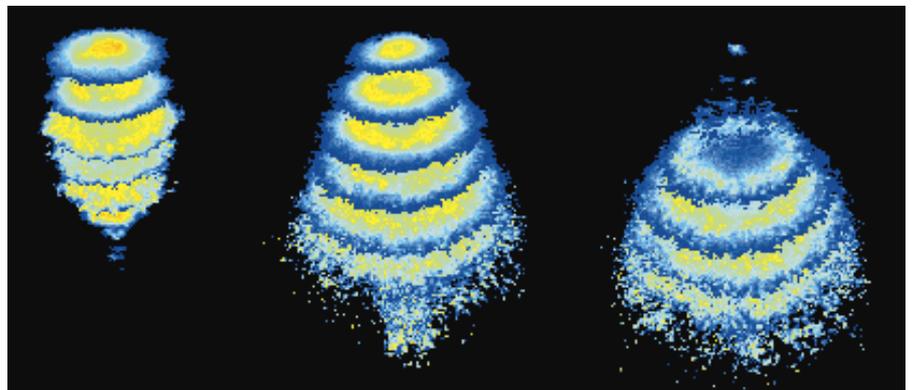
Compared with mechanical patternators **SprayMaster** systems are easy to operate, fast and efficient measurement tools suitable for R&D as well as quality control applications.

SprayMaster is the extension of the point-wise measurement techniques LDV/PDA into two dimensions with additional measurement capabilities.

The innovative and state-of-the-art measurement techniques used in the **SprayMaster** systems provide new insight into spray performance and permit more cost effective and efficient development of smarter spray systems.

In combination with its upgrade options (→ **FlameMaster**, **EngineMaster**) **SprayMaster** is ready for the investigation of spray combustion: OH-, NO-formation, species concentration and temperature measurements.

LaVision is committed to customers. We work in close cooperation with customers to solve their specific spray measurement needs with innovative solutions. Integrated turn-key spray imaging systems with unique measurement capabilities are our speciality.



temporal evolution of a pulsed spray: time sequence of the global spray mass distribution



SprayMaster Information and Techniques

SprayMaster combines elastic light scattering (Mie) with various Laser Induced Fluorescence (LIF) techniques to extract complementary information about the spray.

Mie
LIF

Mie scattering is caused by surface interaction and is proportional to the total surface area of the scatterers. LIF is based on absorption and, therefore, its signal intensity scales with the droplet volume (mass).

Tracer-LIF

For visible laser excitation or LIF-inactive sprays, LIF-active tracers can be added to the spray fluid.

PIV
GIV

Particle (droplet) Image Velocimetry (PIV) is carried out with double-pulse Mie or LIF measurements, the latter can also be applied for Gas Image Velocimetry (GIV).

planar laser light sheet measurement techniques	spatial resolution: up to 1.3 million simultaneous measurement points temporal resolution: exposure time < 100ns for pulsed excitation exposure times > 1ms for cw excitation	
Mie	particle (droplet) distribution, spray pattern geometrical spray characterization: spray angle, tip penetration spray formation & fluctuation (statistics: mean, rms), spray propagation	
LIF (Tracer LIF)	liquid mass distribution geometrical spray characterization: spray angle, tip penetration spray formation & fluctuation (statistics: mean, rms), spray propagation liquid / vapor transition	
LIF / Mie	planar droplet size (Sauter Mean Diameter) distribution	
High Resolution Imaging	absolute particle (droplet) size calibration	
PIV, PTV	spray flow field analysis	
LIF*PIV	liquid volume (mass) flux	
GIV + PIV	correlated 2-phase flow fields	
Light Sheet Scanning	volumetric 3D-distribution of the 2D-measured spray parameter	

quantitative spray
patternation

Mie (LIF) is used for quantitative spray patternation. Statistical routines are provided for radial and axial cuts.

planar dropsizing

LIF/Mie image ratios provide maps of droplet size distribution allowing fast screening of planar spray dropsizing.

phase separation*

Phase-sensitive LIF emissions of so called exciplex tracers can be used to investigate liquid/vapor transition and, therefore, evaporation processes in general.

mass flux

PIV in combination with LIF allow planar mass flux measurements.

temperature*

Raman imaging is used for temperature measurements in special fluids.

*For a special class of evaporating sprays Raman imaging provides simultaneous measurements of phase separation, mass and size distribution and droplet temperature!



SprayMaster System Family

the modular approach

Various applications require different system approaches:

- ▶ steady or pulsed sprays
- ▶ Mie pattern or mass distribution (LIF)
- ▶ droplet distribution with flow field information
- ▶ time resolved or time integrated measurements
- ▶ high speed recording
- ▶ native fluorescence (UV-LIF) or seeding for Tracer-LIF

SprayMaster Models		compact	Fuel		Flow		High Speed
Light Source		cw laser	pulse laser		double-pulse laser		multi-pulse laser
Info	Technique(s)	visible	visible	UV	visible	UV	visible
Geometry	Mie	●	●	●	●	●	●
Mass Distribution	UV-LIF			●		○	
	Tracer-LIF	○	○	●	○	○	○
Phase Separation	Exciplex-LIF			○		○	
Planar DropSizing	LIF / Mie	○	○	●	○	○	
Size Calibration	High Resolution Imaging		○	○	○	○	○
Velocity	PIV (GIV)				●	●	○
Mass Flux	LIF*PIV				○	○	
Spray Propagation	High Speed Imaging						●

● standard feature ○ upgrade option

system modularity

All system models from LaVision are compatible to each other and can be modularly upgraded.

multi-functional

Due to its versatility, **SprayMaster** system family can cover nearly all aspects of spray investigations.

global spray characterization

Planar measurements can be extended for global spray characterization using scanning methods.

time resolution:
fast shutter
high speed framing
time-integrated

Axial as well as radial image slices can be captured using

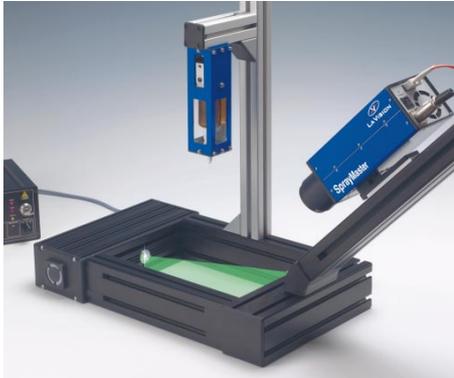
- ▶ ultrashort exposures to freeze the flow field
- ▶ high speed motion recording to study the temporal evolution
- ▶ time-integrated imaging.

adjustable image size
with high spatial resolution

Large scale projection using extended light sheet illumination as well as high resolution imaging viewing single μm -droplets are possible.



SprayMaster System Components



SprayMaster compact

multi-detector configuration

system / camera* / laser

imaging optics

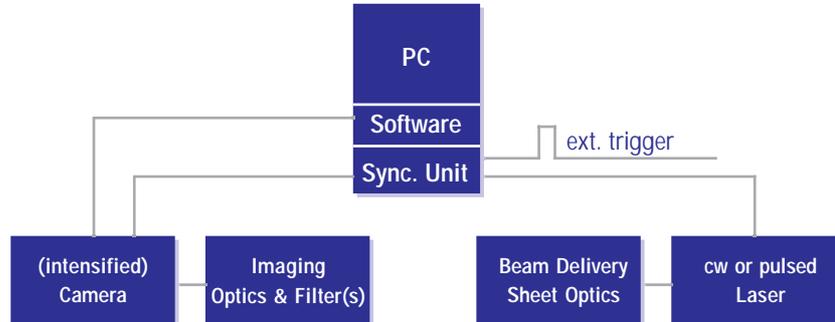
filters

beam delivery



SprayMaster Fuel

A typical **SprayMaster** system is outlined as follows:



Simultaneous multi-camera operation for multi-parameter measurements are possible.

SM compact	12 bit, long integration ($\geq 1\text{ms}$)	continuous-wave (cw) solid state laser
SM Fuel	12 – 16 bit, (intensified) fast shutter	pulse laser (visible / UV)
SM Flow	12 bit, (intensified) double exposure	double-pulse laser (visible / UV)
SM HighSpeed	8 – 12 bit, (intensified) high speed imaging	high repetition rate solid state laser

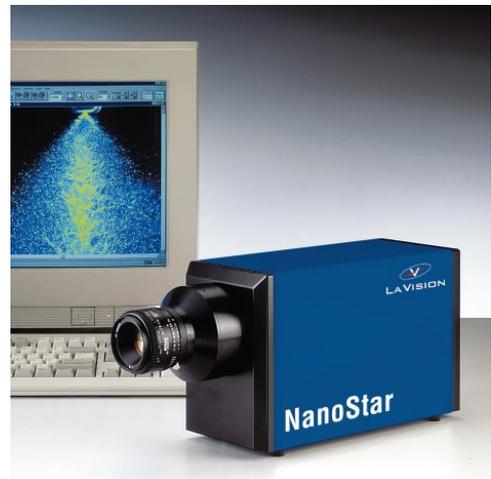
- ▶ large aperture (UV)-lenses
- ▶ long distance microscopes
- ▶ auto focus
- ▶ image splitting optics
- ▶ Scheimpflug optics for oblique viewing

- ▶ high (UV) transmission
- ▶ high suppression ratio
- ▶ motorized filter wheels

- ▶ multi-purpose mirrors
- ▶ articulated arms
- ▶ fiber optics
- ▶ counter-propagating beams

- ▶ quartz lenses for high UV-transmission
- ▶ adjustable focus and divergence
- ▶ selectable collimated sheet heights
- ▶ customized designs

- ▶ (multi-pulse) on-line laser energy monitor
- ▶ external laser shutter for more stable UV-operation
- ▶ traversing systems for scanning



12 bit intensified fast shutter CCD

light sheet optics

options

*Intensified versions with modular lens-coupling between CCD camera and intensifier unit are available.



SprayMaster Software

Geometry
(for Mie & LIF images)

Planar DropSizing

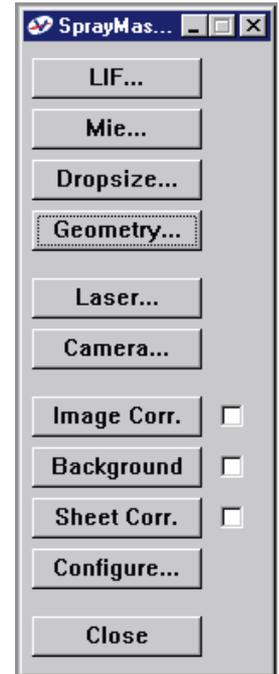
PIV / PTV
Flow Tagging / GIV

Mass Flux

Size
Calibration

Various modules are embedded in LaVision's DaVis Data acquisition, processing and Visualization software:

- ▶ processing of radial and axial spray cross-sections
- ▶ ensemble averaging (mean + rms)
- ▶ tip penetration, spray angle and symmetry of axial cuts
- ▶ radial and angular distribution, symmetry for radial cuts
- ▶ movie presentation of image sequences
- ▶ probability density functions
- ▶ image correction routines
- ▶ laser sheet correction
- ▶ on-line laser energy monitor
- ▶ automated LIF / Mie ratioing
incl. different pre- and post-processing algorithms
- ▶ anchor point calibration
- ▶ velocity fields derived from cross-correlated particle fields
- ▶ velocity fields derived from cross-correlated LIF structures
- ▶ PIV* LIF batch processing
- ▶ automatic particle recognition with subsequent size scaling
- ▶ statistical size distribution



options

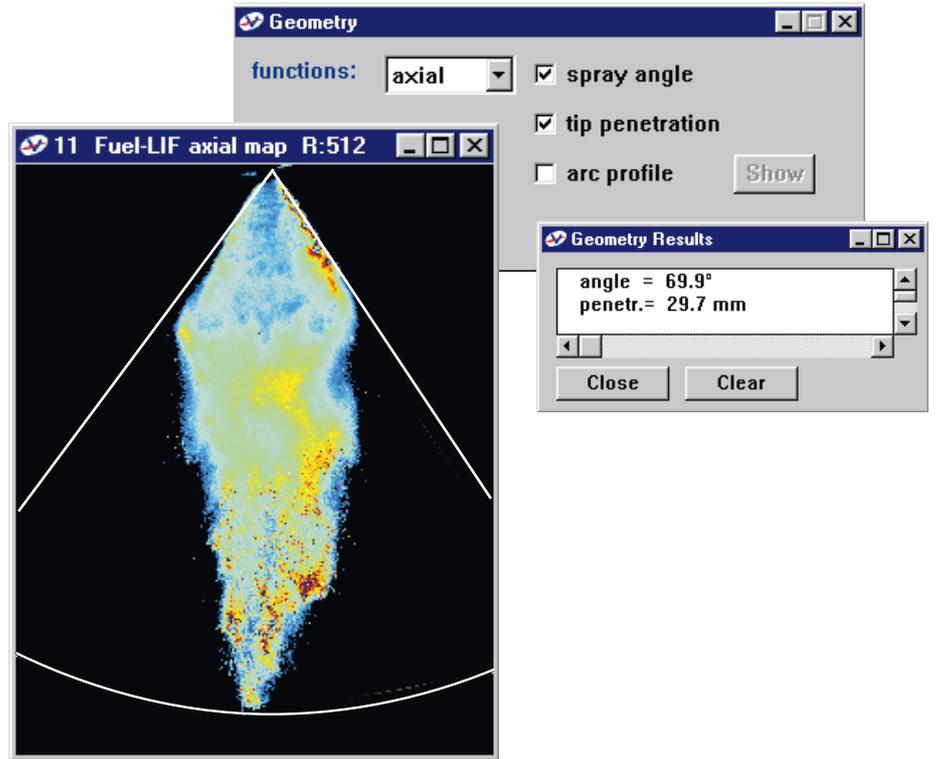
features

- ▶ control of peripheral devices (shutter, scanning modules, auto focus)
- ▶ simultaneous acquisition of external data (e.g. for file handling)
- ▶ complete control of camera functions, laser and injector system
- ▶ modular structure: Mie, PIV, LIF, GIV
- ▶ user-friendly data acquisition, processing and visualization
- ▶ command language / batch operation
- ▶ customized data base management

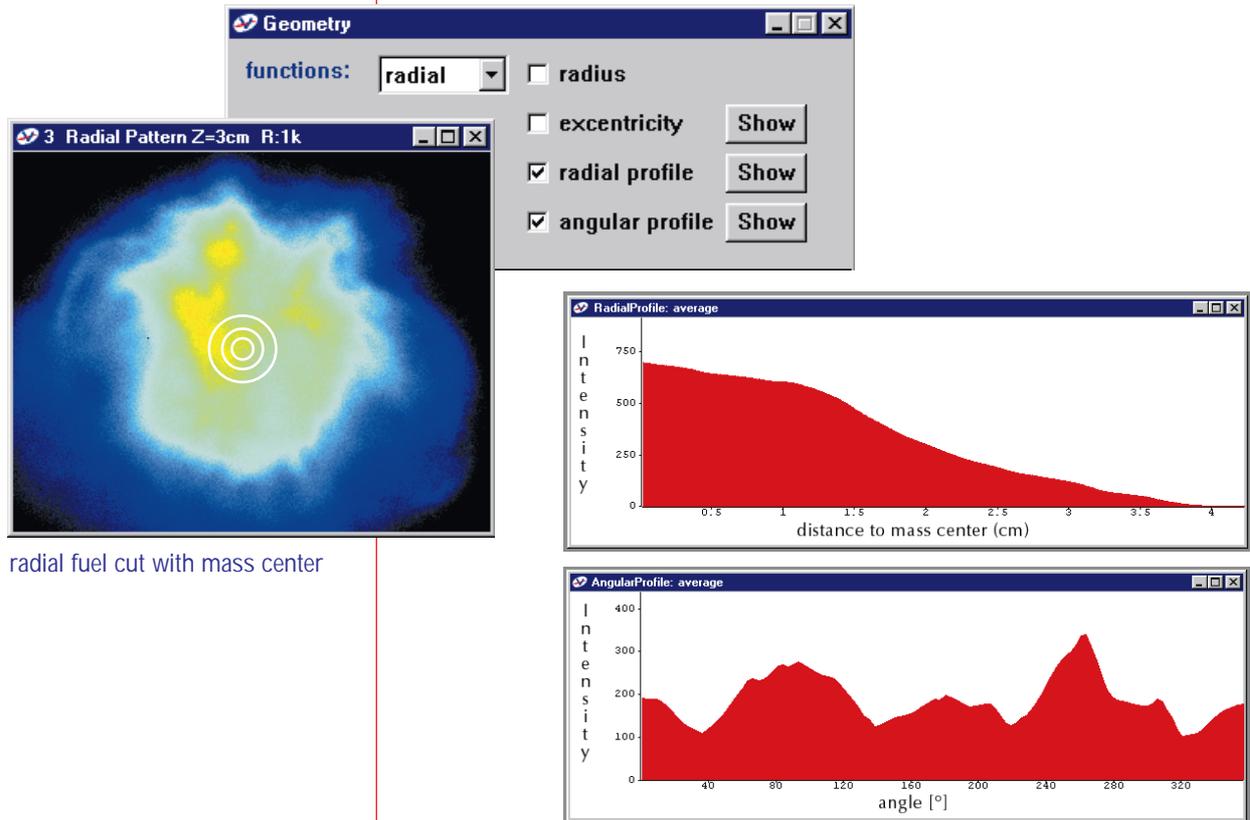


SprayMaster Results

SprayMaster systems have been successfully used to characterize direct fuel injection processes (gasoline as well as diesel), inhalers, gas turbine injectors and various atomizers.



fuel map recorded with a single laser shot



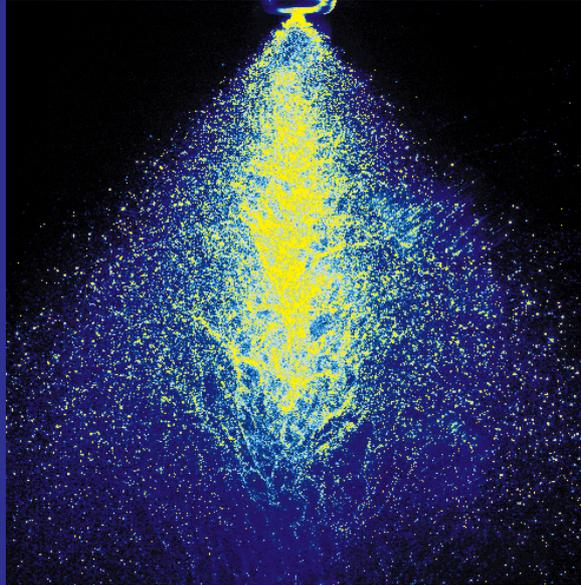
radial fuel cut with mass center

system upgrades for spray combustion processes

FlameMaster for characterization of reactive flows

EngineMaster for spray combustion in internal combustion engines

Vision for Sprays



axial fuel map recorded with a pulsed laser light sheet

SprayMaster

laser based imaging for smarter spray systems:

compact

- ▶ cw laser
- ▶ on-line
- ▶ patterning
- ▶ compact
- ▶ quality control

Fuel

- ▶ UV-laser
- ▶ fuel-LIF
- ▶ liquid mass
- ▶ phase separation
- ▶ planar dropletsizing

Flow

- ▶ flow field imaging
- ▶ liquid & gas phase
- ▶ PIV, PTV, GIV

HighSpeed

- ▶ imaging & PIV
- ▶ spray formation
- ▶ up to 1 MHz framing rate

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