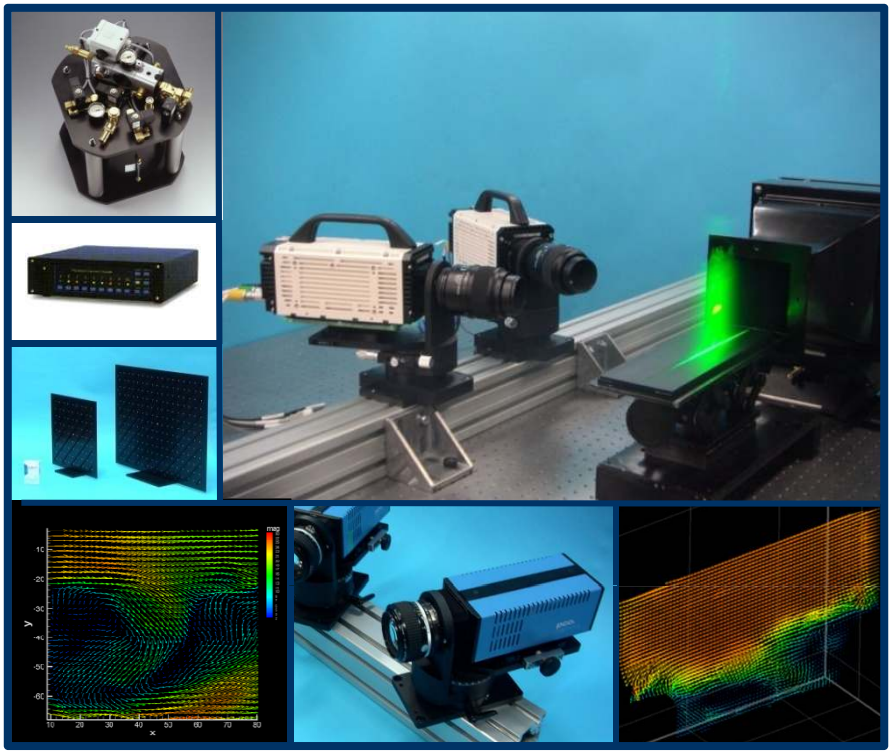
PIV

Particle Image Velocimetry

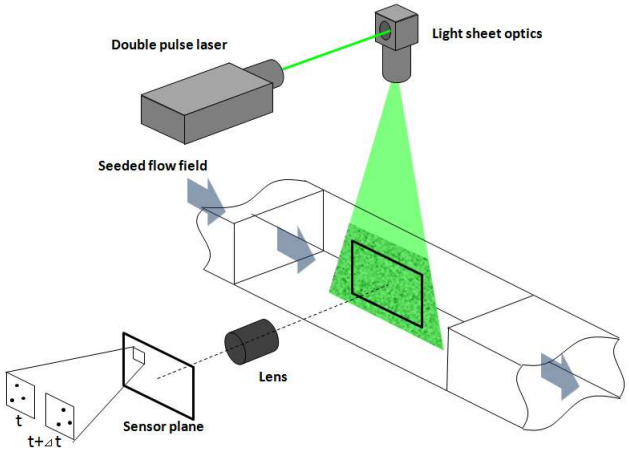


2D-PIV
Stereo 3D-PIV
Time Resolved PIV
Micro PIV
LIF
...

SEIKA CORPORATION

Principle of PIV

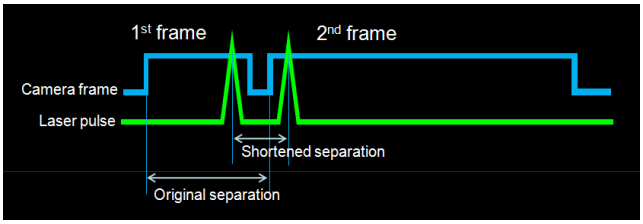
Optical setup



PIV is an imaging technique to measure the velocity distribution within the plane defined by the laser light sheet. It is widely used in various fluid dynamic researches.

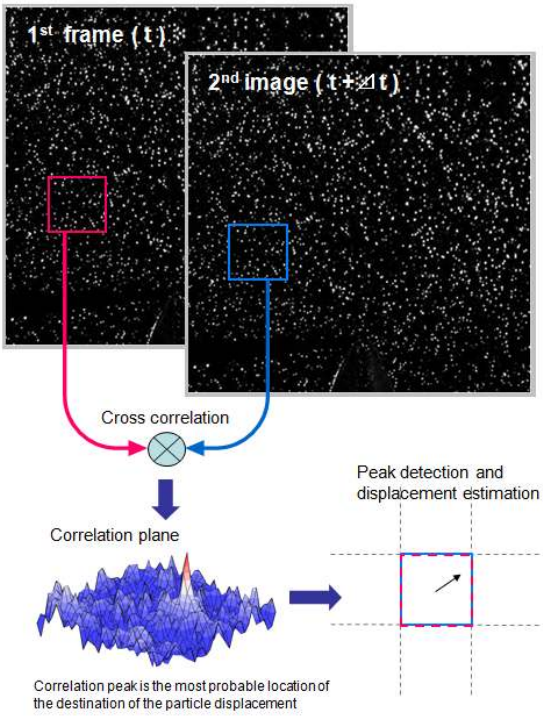
PIV is one of the so-called Time of Flight (TOF) measurement techniques. The basic principle of the PIV is that a laser light sheet is used to illuminate the flow field which is seeded with small particles to visualize a flow to be measured. A double pulse YAG laser and a double shutter camera are synchronized to record two particle images with very short time separation, typically less than 100 us.

Frame straddling



PIV requires two particle images with very short time separation typically less than 100 micro seconds. The frame straddling technique enables to record two images with time separation of down to 100 nanoseconds. A double pulse laser and a double shutter camera are synchronized by the timing controller. Since the double pulse laser has two laser heads which can be operated independently, actual limitation is the length of dead time between two frames of the double shutter camera.

Displacement and velocity evaluation



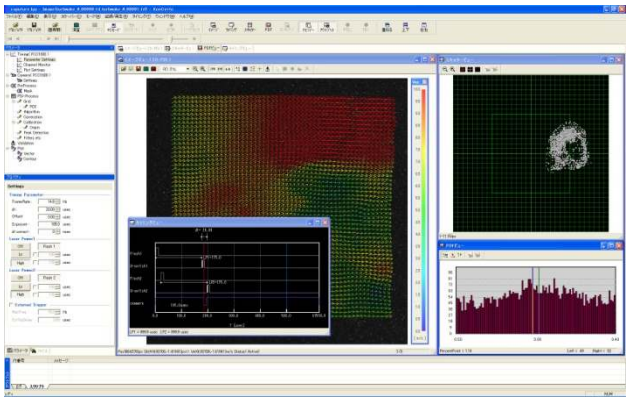
Once the images are successfully recorded, the next step is the PIV analysis.

The images are divided into small search areas, typically 32 x 32 pixels. These small search areas are called interrogation windows. The cross correlation is applied to these interrogation windows for both two images to obtain the correlation plane for each interrogation window. The location of the interrogation windows in both images are same (In the Standard FFT cross correlation, the interrogation windows are shifted in the advanced algorithms).

Then the peak detection and displacement evaluation are applied to obtain the dominant displacement in each interrogation window. As the size of a pixel in flow and the time separation between two images are known, the velocity can be calculated. The size of a pixel in flow is determined by the simple velocity calibration.

Integrated PIV software Koncerto

Koncerto
For Flow and Combustion Research



Koncerto is an integrated software for laser imaging measurements such as PIV and LIF. It controls various kinds of lasers, cameras and other hardware components, analyzes captured images, and displays the results and outputs data as various formats. All the jobs for PIV and LIF can be done on the Koncerto.

PIV algorithms

Koncerto supports various PIV algorithms. Koncerto is designed for easy adding support for new algorithms.

- Standard FFT Correlation
- Multi Pass Correlation
- Multi Grid Correlation
- Central difference method
- Double/Multi Correlation
- Image Deformation Correlation
- Average Correlation
- SAT-PTV
- FD4 Correlation

Stereo 3D PIV

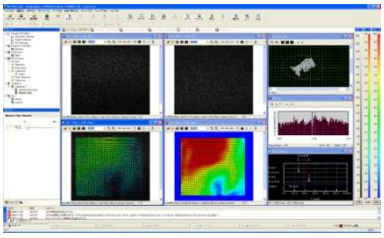
Koncerto supports several types of stereo calibration target such as a single height double side with traverse type, a double height double side with common lower plane no traverse type, etc.

Distributed processing and Automated processing

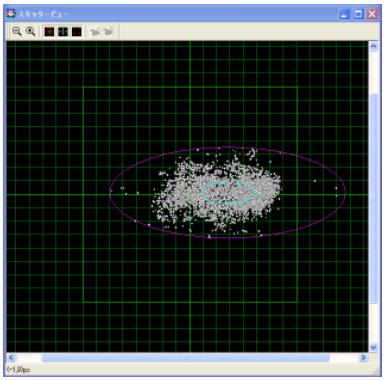
Koncerto supports distributed processing and script programming. These are especially useful for handling large amount of data such as Time Resolved PIV. With the sophisticated high speed PIV processing algorithms, Koncerto processes a large amount of data in a short time automatically.

Various output data format

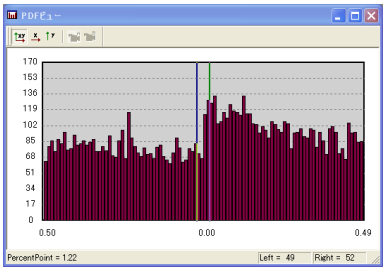
Captured images and analyzed data can be saved and output in various formats.
For example, output PIV data to a data visualization software such as Tecplot, and sliced images on micro imaging are transferred seamlessly to a volume rendering software.



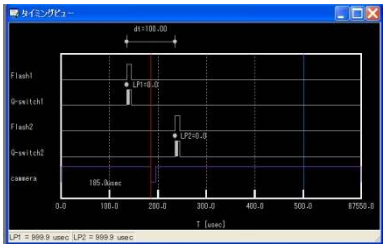
Online multi view window enables you to monitor both A and B images at the same time.



Online Scatter View is useful for checking several PIV parameters such as the image quality, delta T, the intensity of validation filters, etc.



Online PDF View is useful for evaluating the intensity of peak locking, etc. It is one of the criteria for choosing the PIV analysis algorithms.



Timing View is used for setting the hardware timing such as delta T and various delays.

Advanced PIV analysis algorithms

Koncerto supports newest PIV analysis algorithms

Seika Corporation has closely collaborated with world leading research institutes, and has continuously added support for the newest technology to the Koncerto.

■Standard FFT cross correlation
Basic displacement (velocity) evaluation method. Almost the same results as direct cross correlation are obtained in much shorter calculation time.

■Multi pass cross correlation
Apply standard cross correlation at first step. Then shift the interrogation window of second image based on the predictor (displacement vector obtained by the previous process of standard cross correlation). And then apply cross correlation again. The smaller displacement is obtained this time. After applying this operation several times iteratively, the resulting displacement becomes nearly zero. The final displacement is the sum of all displacements in previous processes.

■Multi grid cross correlation
Multi grid cross correlation decreases the interrogation window size with each iteration of the multi pass operation. The advantage of the multi grid scheme is to obtain the higher spatial resolution and/or wider velocity dynamic range.

■Central difference Interrogation
In the iterative cross correlation processing, the cross correlation between the interrogation windows of the 1st image is moved ½ backward of the predictor value (displacement obtained by the standard cross correlation) and the interrogation windows of 2nd image is moved ½ forward of the predictor. This operation results in the second order accurate in PIV analysis.

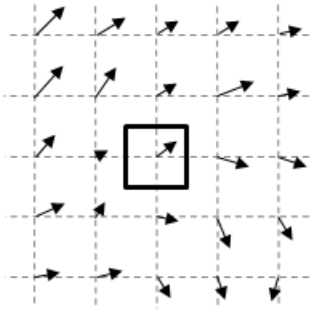
■Double (multi) correlation
Multiplying the correlation planes of 2 adjacent interrogation windows increases the orderly signal and reduces the random noise, resulting in the increase of signal to noise ratio.

■Image deformation correlation
In the iterative processing, images are deformed based on the surrounding predictors by spline function. Applying this operation iteratively several times will deform the resulting second image almost identical to the first image. The resulting displacement becomes nearly zero. And then more accurate results are obtained. This technique is effective even if there is a rotation or deformation in the interrogation window. This is also effective for reducing so-called “peak locking error”.

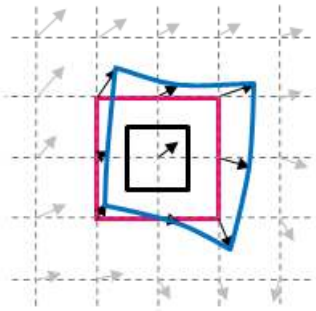
■Average correlation
This operation is effective with noisy images such as micro PIV. It also reduces the noise from the Brownian motion. This technique is only applicable in average analysis, not in instantaneous analysis.

Concept of Image deformation correlation

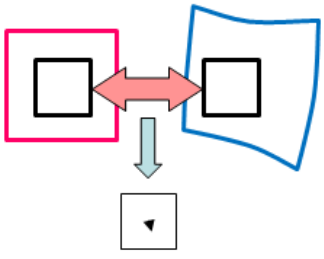
Determine the value of surrounding predictor vectors by cross correlation.



Deform the shape of interrogation window on the second image (blue) based on surrounding predictors.

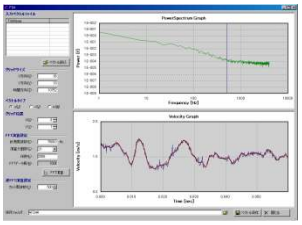


Apply cross correlation again between black windows. The smaller displacement than the previous process is obtained.

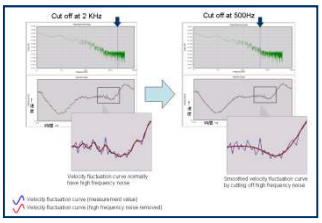


FD4 Correlation for Time Resolved PIV analysis

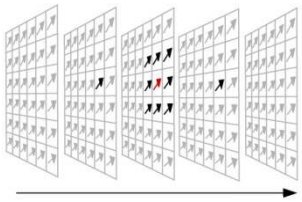
FD4 Correlation is an algorithm developed for the Time Resolved PIV. FD4 Correlation offers the frequency analysis of the velocity fluctuation at each PIV grid and the sophisticated spatiotemporal validation.
In the conventional in-plane (2D) PIV analysis, outliers are detected using spatial validation and flip the value by the interpolation. In the Time Resolved PIV, each vector map is very close in time; thus it is possible to apply a temporal validation before or after applying a spatial validation.
FD4 Correlation offers more advanced spatiotemporal validation. The spectrum of each grid is analyzed by applying an FFT. Then the high frequency noise is filtered out and then an inverse FFT is applied to get the time domain velocity date back without high frequency noise. Using this velocity fluctuation curve, outliers are replaced with the best estimated value at each time and grid.



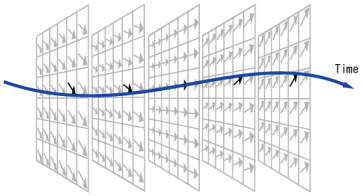
Velocity fluctuation spectrum (Upper right)
Velocity fluctuation curve (Lower right)



Frequency cut-off filter



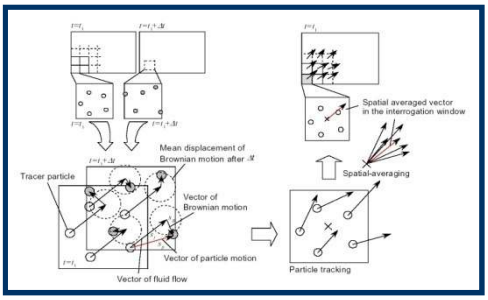
Conventional Spatiotemporal validation



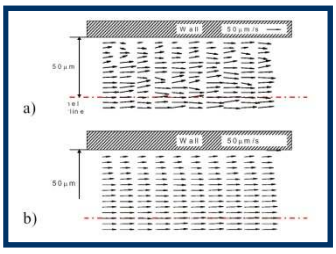
Advanced Spatiotemporal validation by FD4 Correlation

SAT-PTV for Instantaneous and Time Resolved Micro PIV analysis

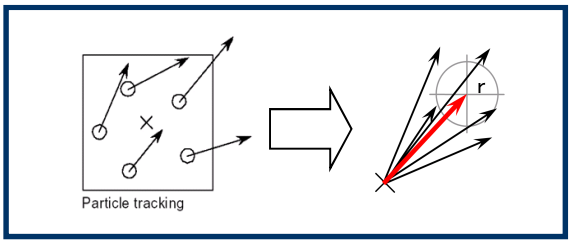
Brownian motion is one of the major problem in Micro PIV. Patented SAT-PTV reduces the effect of the Brownian motion for instantaneous analysis for the time resolved Micro PIV measurements.
Generally, time averaging method is used in Micro PIV to reduce the effect of the Brownian motion. SAT-PTV employs spatial averaging technique instead of time averaging technique. It enables to get instantaneous velocity information in Micro fluidics.
This is especially suitable for using with Confocal Scanning Micro PIV where particle images are much clearer and particle density can be much higher than the conventional Micro PIV. Thus, the accurate instantaneous analysis and the accurate Time Resolved Micro PIV are possible.
SAT-PTV can also evaluate the amount of Brownian motion at each PIV grid.



Principle of SAT-PTV velocity analysis algorithms



Comparison of the results of conventional PIV algorithm (a) and SAT-PTV (b) in micro channel



Red arrow : Spatial averaged vector in the interrogation window
r : Standard deviation radius of the random displacement of each particle

PIV System

Many types of PIV systems, such as standard 2D-PIV, Stereo 3D-PIV, micro PIV, Time resolved PIV, etc., are available. Each system consists of different components. The integrated PIV software Koncerto controls all the components and analyze the velocity field.

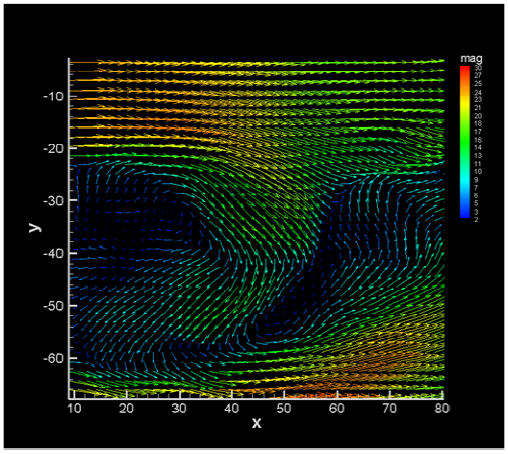
■Standard 2D-PIV system
Capable of measuring 2 velocity components (u and v) in a plane defined by the laser light sheet. It consists of a double pulse laser, a double shutter camera, BZ-60 light sheet optics, TT1680 timing controller, Koncerto software, and PC. Typical time resolution is 10 Hz.

■Stereo 3D-PIV system
Capable of measuring all 3 components in a plane defined by the laser light sheet. It consists of the second camera, Scheimpflug camera mount, calibration target in addition to the 2D-PIV system. Typical time resolution is 10 Hz.

■Time resolved PIV system
Capable of obtaining very high time resolution up to around 50 KHz. A high speed video camera and a high repetition rate pulse laser are used.

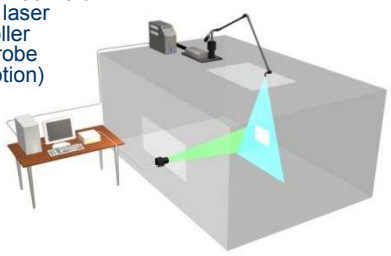
■Micro PIV system
For microfluidics such as MicroTAS, Lab on a chip, etc. An optical microscope is used. Piezo electric focus scanner is available.

■Confocal Scanning Micro PIV system
A high speed confocal scanner and a high sensitivity high speed video are used. It obtains very high spatial resolution in Z direction. Piezo electric focus scanner is available.

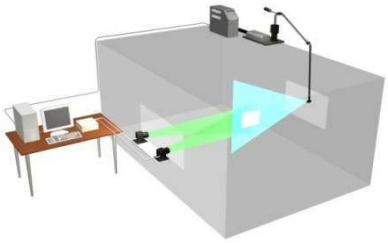


2D-PIV and Stereo 3D-PIV System configuration

2D-PIV
■Koncerto2D
■Double shutter Camera
■Double pulse laser
■Timing controller
■Light sheet probe
■Light arm (Option)
■PC

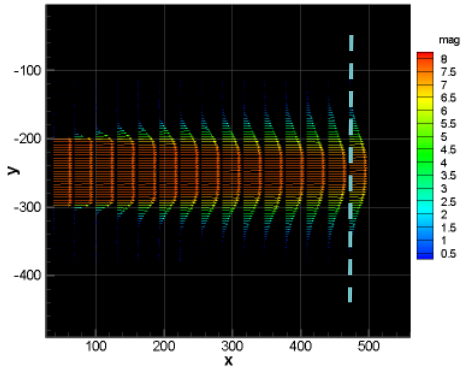


Stereo 3D-PIV
■Koncerto3D
■Double shutter Camera x2
■Double pulse laser
■Timing controller
■Light sheet probe
■Scheimpflug mount
■Calibration target
■Light arm (Option)
■PC

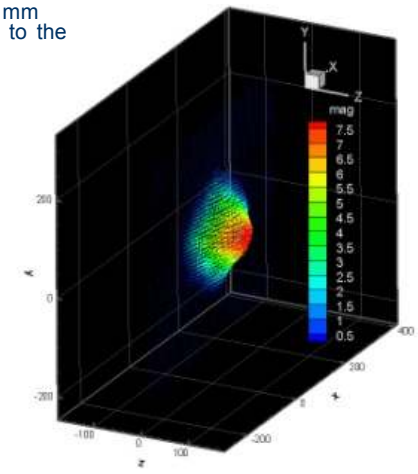


2D-PIV and Stereo 3D-PIV Data format

Both PIV results are the same flow; Free jet from the 100 mm x 100 mm square nozzle. The dashed line on the 2D-PIV data corresponds to the measurement plane of the Stereo 3D-PIV.



2D2C (2 Dimensions 2 Components)



2D3C (2 Dimensions 3 Components)

PIV System components

Koncerto supports wide range of cameras

Koncerto supports wide range of cameras for PIV, Time Resolved PIV, Micro PIV, LIF, etc. Koncerto is designed to easily add support for new cameras.

Double shutter cameras

- ES1.0
- ES4020
- pco.1200hs
- pco.1600
- pco.2000
- pco.4000

pco.2000

High sensitivity cameras

- iStar
- LUCA

High speed video cameras

- SV200i
- 512PCI
- 1024PCI
- APX
- SA1
- Phantom V7
- Phantom V9
- GX1
- Mi2000
- Mi4000
- Mi8000
- MotionPro

Mi4000

PIV Lasers

Double pulse laser is widely used for a standard 2D-PIV system. As it has two independent laser heads, the pulse separation between double pulse is completely flexible. Many other types of PIV lasers, such as CW Q-switch high repetition rate pulse lasers for time resolved PIV systems and CW lasers for Confocal Scanning Micro PIV systems, etc., are available.

Timing controller

Koncerto supports TT1680 and LabSmith LC880. TT1680 has 8 physical output channels, 8 logical output channels and 8 input channels. LC880 has 8 output channels and 8 input channels.

TT1680

Light sheet probe BZ-60

BZ-60 generates laser light sheet. Focal length is adjustable continuously. Light sheet divergence angle can be adjusted by changing cylindrical lens. As beam expander is incorporated inside, BZ-60 generates high quality uniform light sheet.

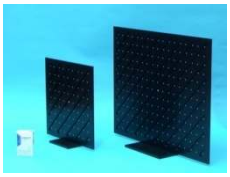
Scheimpflug camera mounts for Stereo PIV

In stereo 3D PIV, Camera views the light sheet from an oblique angle. Scheimpflug camera mount ensures all the areas of off-normal object plane in focus. Rotation axis is on the center of the sensor. It ensures no image offset when aligning the Scheimpflug angle.

Camera calibration targets

Camera calibration is very important for accurate PIV measurement in stereo 3D-PIV and 2D-PIV with distorted images. Flat and multi height, double sided types of many sizes are available.

- CLP-DPDS : Double Plane Double Side type. It has common lower plane which ensures the accurate camera calibration when the cameras are located on both sides of laser light sheet in Stereo 3D-PIV.
- SPDS : Single Plane Double Side Flat type. This type requires target traverse to record multiple height of target images. But it ensures accurate measurement.



Seeding generators, Rakes and Particles

Several types of seeding generator are available.

- Air / gases : Laskin nozzle type of oil particle seeding generator
- Combustion and plasma : solid particle generator
- Water / liquid : Micro bubble generator

Seeding rakes are used for dispersing the seeding smoke with uniform density. It is especially useful for a blow down wind tunnel.
Many types of solid seeding particles are available.

Collaborating organizations

2D PIV and Stereo 3D PIV analysis algorithms are developed by PIVTech, a DLR outsourcing enterprise.
FD4 Correlation is developed by Miyauchi, Tanahashi Lab., Tokyo Institute of Technology.
SAT-PTV is developed by Hishida, Sato Lab., Keio University.
Confocal Scanning Micro PIV system is developed in collaboration with Oshima Lab., SII U-Tokyo, Yokogawa Electric Corporation and Photoron LTD.

Specifications are subject to change.

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