PARTICLE IMAGE VELOCIMETRY (PIV) AND VOLUMETRIC VELOCIMETRY (V3V) SYSTEMS

VERSATILE, UPGRADEABLE FLUID MECHANICS MEASUREMENT SOLUTIONS

UNDERSTANDING, ACCELERATED

FULL SPECTRUM OF GLOBAL VELOCITY SYSTEMS

TSI offers the full spectrum of global velocity measurement instrumentation, ranging from simple flow visualization systems, to state-of-the-art quantitative three-dimensional three component (3D3C) volumetric systems, to allow you to conduct the most detailed diagnostics of your gaseous and liquid flow research. When high temporal resolution is required, systems with time-resolved capability can be employed to provide four-dimensional information to get the complete picture and analysis of the flow fields.

Key for Upgradeability

The systems designed by TSI are flexible and also upgradeable. In fact, a simple flow visualization system using a single camera can be easily upgraded to a PIV system, stereo PIV system, or to a 3D3C V3V system for volumetric measurements.

FLOW VISUALIZATION SYSTEM

Components

+ Camera
+ LED illuminator or CW laser
+ Insight 4G™ Software

Results

+ Quantitative flow profile and structure

PIV 2D2C SYSTEM

Components

+ Camera
+ Pulsed Nd:YAG Laser
+ Synchronizer
+ Insight 4G Software

Results

+ Quantitative two dimensional velocity field of U and V components
+ Mean, turbulent intensity, vorticity
+ Time series and spectral information

FROM 2D PIV ADD +

STEREO PIV 2D3C SYSTEM

Components

+ Cameras
+ Stereo Assembly
+ Synchronizer
+ Insight 4G Software Module

Results

+ Planar quantitative 3D velocity field of U, V and W components
+ Mean, turbulent intensity, vorticity
+ Time series and spectral information

FROM 2D PIV ADD +

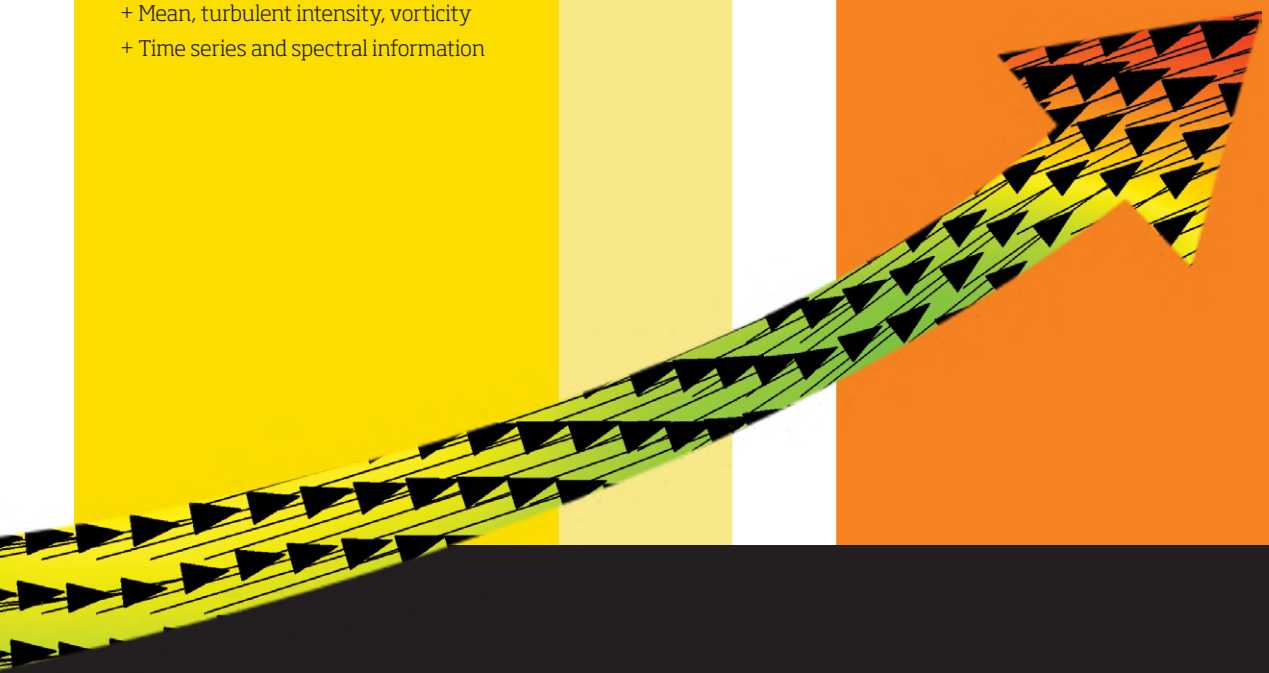
VOLUMETRIC PIV 3D3C SYSTEM

Components

+ Cameras (Qty 3)
+ V3V Assembly
+ V3V Calibration
+ Synchronizer
+ Insight 4G Software Module

Results

+ Volumetric Quantitative 3D velocity field of U, V and W components
+ Mean, turbulent intensity, vorticity and second-order quantities
+ Time series and spectral information of the volumetric flow field



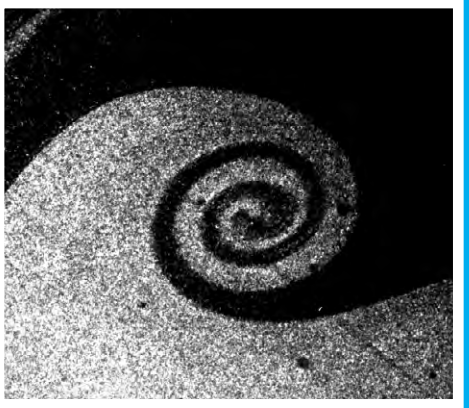
QUALITATIVE FLOW VISUALIZATION SYSTEMS

Performing flow visualization can serve as the first step toward more detailed flow analysis. Flow visualization starts with a simple system arrangement using a camera, an illumination system, and the Insight 4G™ software, to give a general understanding of the flow structure and behavior. Some of the major system components are given in the table below.

Features and Benefits

+ Obtain good understanding of the flow structure
+ Help to solve some practical problems
+ Simple to use and cost effective
+ No calibration and synchronization required
+ Upgradeable to more sophisticated quantitative systems

Component	Description
Camera	Powerview series of high resolution camera; or high speed CMOS cameras
Illumination System	Pulsed or continuous LED illumination; CW solid state laser; pulsed Nd:YAG laser with low energy
Software	Insight 4G for image capture and image presentation



Flow visualization

Flow visualization

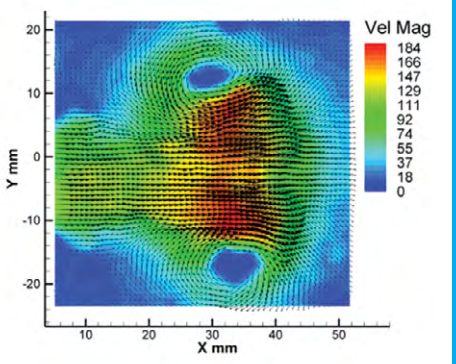
QUANTITATIVE PARTICLE IMAGE VELOCIMETRY (PIV) SYSTEMS

As the next step from the qualitative flow visualization system, additional components can be employed by the PIV system. PIV, as planar imaging technique, is very useful to provide the quantitative information of the flow field in a two-dimensional plane, giving the two components of the velocity. Higher order flow statistics, such as vorticity and turbulent stress, can easily obtained to explore the details of the flow.

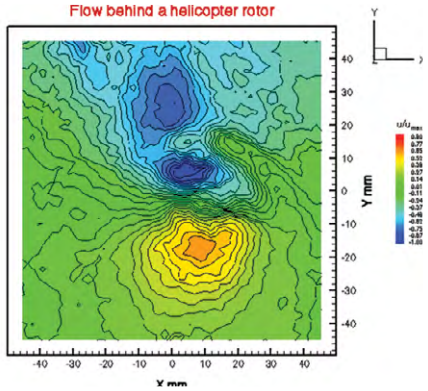
Features and Benefits

+ Quantitative results on two components of velocity in the flow field
+ Instantaneous information and ensemble averaged of the flow structure
+ Explore the smallest turbulent structure with complete macro-scale capability
+ High-resolution cameras for high spatial resolution results
+ High-speed camera with different time-resolved capabilities for desired temporal resolution
+ Upgradeable to stereo PIV and volumetric V3V systems

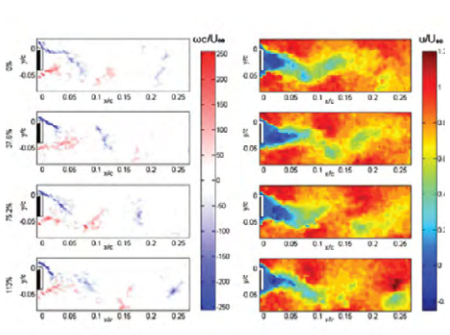
	Standard PIV system with high resolution camera	Time-resolved PIV system (<200 Hz)	Time-resolved PIV system (>1000 Hz)
Camera	Powerview Plus series of high resolution CCD cameras	Powerview series of mid-speed high resolution CMOS cameras	High resolution high speed CMOS cameras
Laser	Pulsed dual cavity Nd:YAG laser from 65 mJ to 400 mJ or higher energy output at 15 Hz	Pulsed dual cavity Nd:YAG laser with 50mJ or 100 mJ energy output at 50 Hz or 100 Hz	Pulsed dual cavity Nd:YAG or Nd:YLF high speed laser with 10 mJ, 20mJ, or 30 mJ energy output at 1000 Hz or higher
Synchronization	Synchronizer timing unit with 0.25 ns resolution		
Image capture and analysis software	Insight 4G image capture and Analysis software package		



Unsteady vortex ring



Flow Behind a rotor



Time-Resolved PIV Downstream of an Airfoil with a Gurney Flap

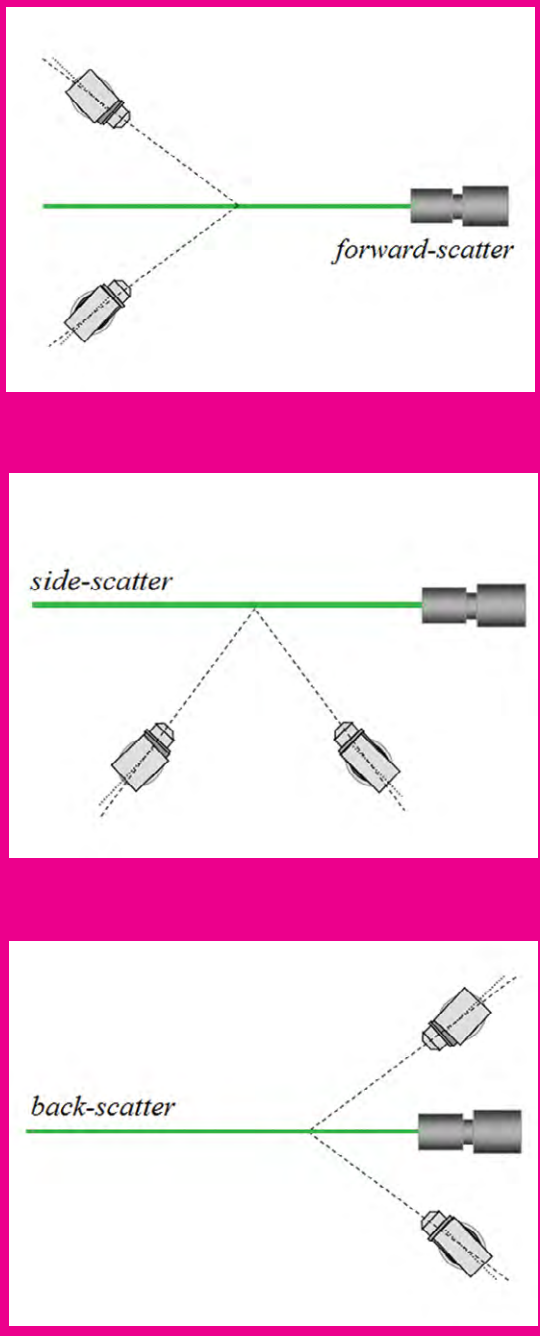
Ref. Troolin D R; Longmire E K; Lai WT (2006) "Time-resolved PIV analysis of flow over a NACA 0015 airfoil with Gurney flap," Experiments in Fluids, 41, pp. 241-54.

QUANTITATIVE STEREO PARTICLE IMAGE VELOCIMETRY (SPIV) SYSTEMS

The measurement of the two components of velocity using planar is helpful for the understanding of the flow field. However most of the flows are three dimensional in nature, so it is essential to be able to measure all the three components to obtain the complete picture of the flow. The stereo PIV system arrangement allows the third component of velocity in the measurement plane to be taken, giving the full picture of the flow field in the plane. Volumetric flow measurement techniques, such as the one used in the V3V system, is the best approach to get the velocity components in the volume of interest, providing the complete understanding of the flow structure and development.

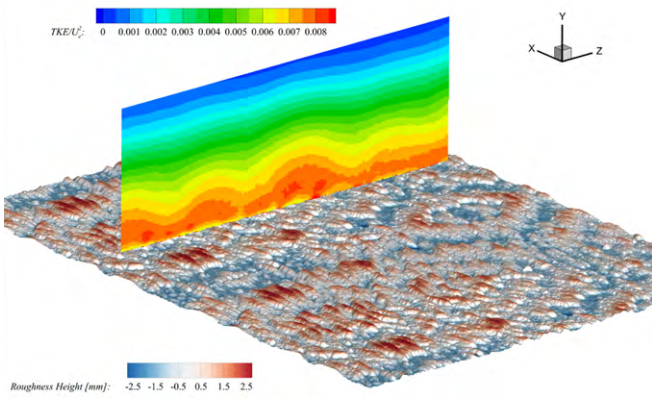
Features and Benefits

+ Complete three velocity components in a plane
+ Higher order derivatives can be obtained based on the velocity components
+ Adding one camera to the PIV to form the stereo PIV configuration
+ Stereo configuration requires calibration to resolve perspective and optical distortion
+ Easy to operate with Scheimpflug camera arrangement and single plane calibration
+ Self corrected calibration mapping function to generate highly accurate results
+ System can be translated to map pseudo-volumetric three components of velocity
+ Upgradeable to the true volumetric V3V system

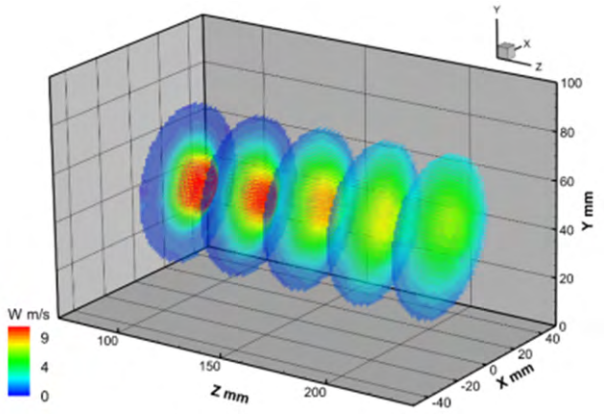


Various camera - laser arrangements for stereo PIV

	Standard stereo PIV system	Time-resolved stereo PIV system (<200 Hz)	Time-resolved PIV system (>1000 Hz)
Camera (one additional camera)	Powerview Plus series of high resolution CCD cameras	Powerview series of mid-speed high resolution CMOS cameras	High resolution high speed CMOS cameras
Laser	Pulsed dual cavity Nd:YAG laser from 65 mJ to 400 mJ or higher energy output at 15 Hz	Pulsed dual cavity Nd:YAG laser with 50mJ or 100 mJ energy output at 50 Hz or 100 Hz	Pulsed dual cavity Nd:YAG or Nd:YLF high speed laser with 10 mJ, 20mJ, or 30 mJ energy output at 1000 Hz or higher
Scheimpflug stereo mount and calibration target	Model 640054 stereo PIV assembly	Model 640059 stereo PIV assembly	Model 640058 stereo PIV assembly for high speed camera
Synchronization	Synchronizer timing unit with 0.25 ns resolution		
Image capture and analysis software	Insight 4G image capture and Analysis software package		

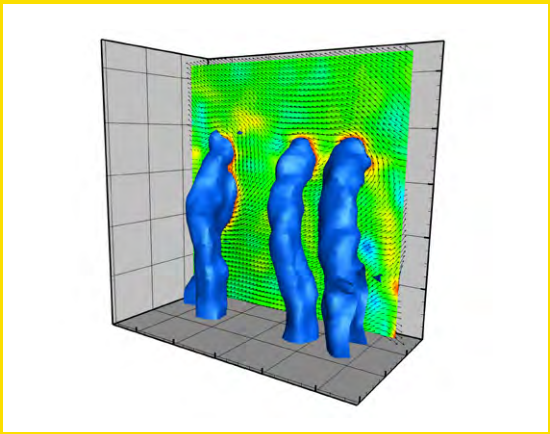


Courtesy of: University of Illinois at Urbana Champaign



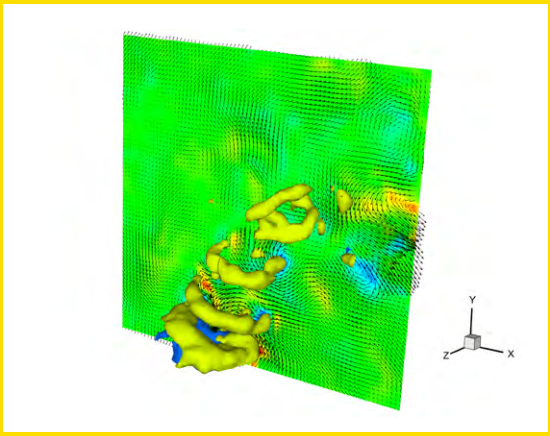
Velocity Profile of a Jet Flow

VOLUMETRIC V3V (3D3C) SYSTEMS



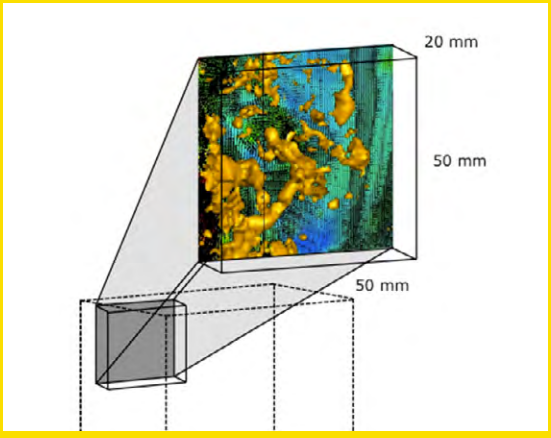
Tip vortices from a rotating turbine blade.

Ref. Chamorro L, Troolin D, Lee S, Arndt R, Sotiropoulos F (2013) Three dimensional flow visualization in the wake of a miniature axial-flow hydrokinetic turbine, Exp in Fluids, 54:1459.



Wake Produced by a Jellyfish

Ref. Gemmell BJ; Costello J; Colin S; Dabiri J; Adhikari D; Troolin D; Sheng J; Longmire E (2012) "Position Control in Jellyfish: Abandoning radial symmetry to create inclined, asymmetric vortex rings," 2012 Ocean Sciences Meeting, Salt Lake City, UT, February 20-24, 2012.



Tip vortices from a rotating blade measured by the V3V-9000-TS

A volumetric system able to capture all the three velocity components in the volume is the ultimate solution for flow research. The results provide the complete information of the flow structure including mean velocity, vorticity, turbulent information and higher order derivatives and statistics.

The design of the volumetric V3V system takes advantage of the many components employed in the PIV or stereo PIV system. In other words, you can easily upgrade the PIV or stereo PIV system to V3V system for the 3D3C measurements. Once you have the V3V system, you have the flexibility to configure a regular PIV or stereo PIV system, making for a complete solution for your flow research.

Two versions of the V3V systems are provided, the V3V-9000-TS and the V3V-9000-SC, featuring:

+ Selectable measurement volume between 50 mm x 50 mm x 20 mm and 140 mm x 140 mm x 100 mm
+ Typical spatial resolution from 2.5 mm^3 to below 1.0 mm^3
+ Capture rates from 7. 5 Hz to 90 Hz
+ Ease-to-use and robustness; system aligned ready for measurements in <30 minutes from mounting
+ Fast result analysis using the Insight V3V™ 4G software package

	V3V-9000-TS	V3V-9000-CS
Camera	PowerView 4MP with 30 fps, Powerview 8MP with 10 fps, Powerview 4MP-180 with 180 fps	PowerView 4MP with 30 fps, Powerview 8MP with 10 fps, Powerview 4MP-180 with 180 fps
Laser	Pulsed dual cavity Nd:YAG laser with 200 mJ or higher at 15 Hz; Pulsed dual cavity Nd:YAG laser with 100 mJ energy output 100 Hz	Pulsed dual cavity Nd:YAG laser with 200 mJ or higher at 15 Hz; Pulsed dual cavity Nd:YAG laser with 100 mJ energy output 100 Hz
Calibration system	V3V-CALL-TS calibration module; target of 100 mm by 100 mm with dot spacing of 1 mm	V3V-CAL calibration module; target of 200 mm by 200 mm with dot spacing of 5 mm
V3V PCM	V3V-9000-TS mount with camera lenses	V3V-9000-CS mount with camera lenses
Synchronization	Synchronizer timing unit with 0.25 ns resolution	
Capture and analysis software	Insight V3V 4G image capture and analysis software package	
Sample Applications	Turbulent Structure measurements; boundary layer flows; flows interaction with airfoil	Coherent Structure measurements; wake flows; propellor flows; flows of biolocomotive

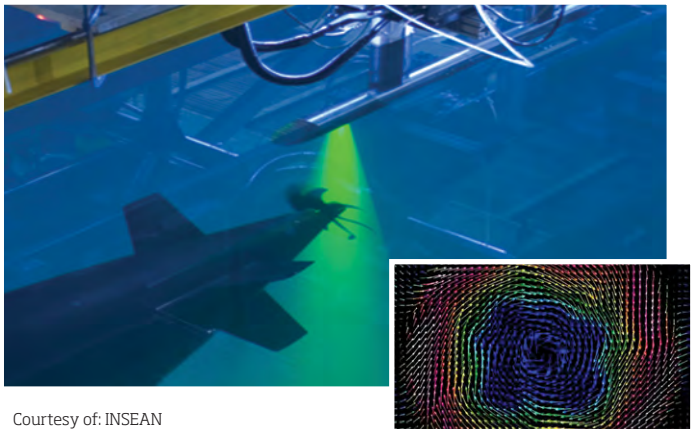
THE MOST ADVANCED VOLUMETRIC PIV SYSTEM FOR LARGE MEASUREMENT VOLUME AND HIGH SPATIAL RESOLUTION.

SPECIALIZED PIV SYSTEMS

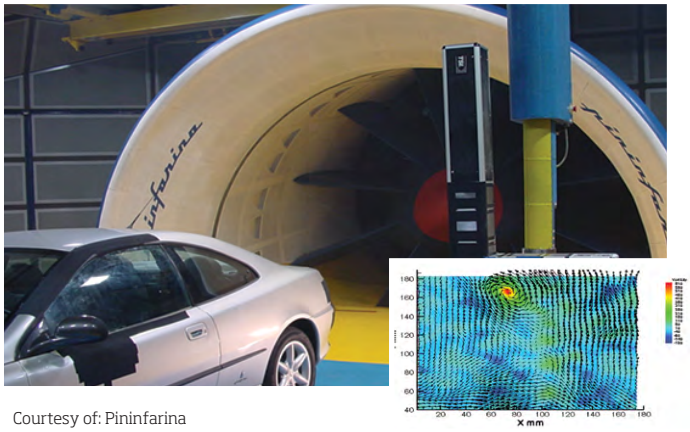
Different circumstances may require the PIV or stereo PIV to be configured for specific applications. TSI offers many specialized designs to adapt to your measurement requirements, such as:

+ Tow tank underwater stereo PIV system
+ Wind tunnel integrated stereo PIV system
+ MicroPIV systems for microchannel flows

Many of the components making up of these specialized systems are the same components employed in the regular PIV and stereo PIV systems listed in the previous pages. As such, upgrading from a regular system to the specialized system is straightforward and easy. Consequently high resolution camera or high speed camera can be used to provide you with results of high spatial resolution and/or high temporal resolution. With the wide variety of camera and laser selections as indicated in the earlier pages, we can provide you with the best and flexible system configuration to meet your research needs.



Courtesy of: INSEAN



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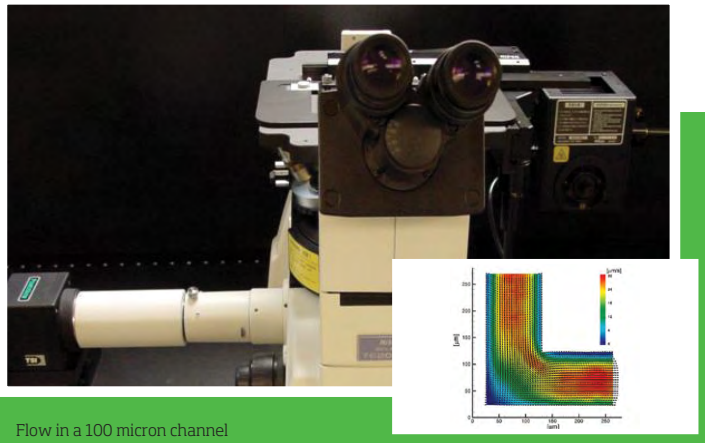

Flow in a 100 micron channel

RANGE OF SYSTEM CAPABILITIES

System	Velocity range	Capture Rate	Field of View	Fluid medium
PIV	Up to 1000 m/s	Up to 30 Hz	Up to 1 m by 1 m plane	Air and water
TR-PIV	Up to 400 m/s	Up to 10000 Hz	Up to 20 cm by 20 cm plane	
Stereo PIV	Up to 1000 m/s	Up to 30 Hz	Up to 1 m by 1 m plane	
TR-Stereo PIV	Up to 400 m/s	Up to 10000 Hz	Up to 20 cm by 20 cm plane	
V3V	Up to 1000 m/s	Up to 15 Hz	Volume size of 140 mm x 140 mm x 100 mm	
TR-V3V	Up to 50 m/s	Up to 90 Hz	Volume size of 110 mm x 110 mm x 100 mm	

CAMERA AND LASER SELECTION GUIDE

Camera	Pixel Resolution	Velocity range	Frame rate	Applications
Powerview series of high resolution CCD camera	2M, 4M, 8MP, 11M, 16 M and 29 M pixels	Up to 1000 m/s	1 to 30 fps depending on the resolution	Air and water flows for PIV, Stereo and V3V
Powerview high resolution mid speed CMOS cameras	4 million pixels	Up to 200 m/s	1 to 180 fps	Air and water flows for PIV, stereo PIV, V3V and TR-V3V
High resolution high speed CMOS cameras	1M, 2M and 4M pixels	Up to 500 m/s	1 to 10000 fps depending on the resolution	Air and water flows for TR-PIV, TR-stereo PIV

Laser	Pulse rate	Energy Output	Illumination area	Applications
Nd:YAG Dual cavity high energy laser	0 to 15 Hz	65 mJ to 450 mJ	Up to 1 m by 1 m plane or volume with 140 mm^3	Air and water flows for PIV, stereo PIV and V3V
Nd:YAG Dual cavity laser	0 to 100 Hz	50 to 100 mJ	Up to 50 cm by 50 cm plane or volume of 100 mm^3	Air and water flows for PIV, stereo PIV and TR-V3V
Nd:YLF or Nd:YAG dual cavity high speed laser	0 to 5000 Hz	1 mJ to 30 mJ	Up to 20 cm by 20 cm plane	Air and water flows for TR-PIV and TR-stereo PIV

SUPPORTING SYSTEM COMPONENTS

There are many supporting system components which can be used with the PIV, stereo PIV, and V3V systems to cater to your experimental setup. Such components are easily adapted to optimize your measurement systems. A list of the components are given in the table below, and further describe their unique functionality and benefit to your measurements.

Component	Functions
Light sheet optics	Generate divergent or collimated laser light sheet with focusing to provide thin sheet thickness for 532 nm and also UV wavelength range
Laser light delivery system	Enclosed laser beam light arm with 1.8 m in length for 532 nm for energy up to 500 mJ; Laser light guide with 2 m in length for energy up to 70 mJ
Camera lens	Nikon based camera lenses to provide various focal distance (28 mm to 205 mm) and aperture for all cameras for PIV, stereo PIV and V3V; microscope lens to allow for high magnification imaging
LED Illumintion	LED based illumination system with pulsed and continuous mode, wavelength is 532 nm, to generate light sheet or volumetric illumination when appropriate optics is used
Seed particles	Various seed particles with various sizes and specific gravities to be used for gaseous and liquid flows
Seed particle generator	Devices to disperse seed particles in gas or liquid , can be used in atmospheric and high pressure environments
Camera filters	Filters to be used with the camera lens to remove extraneous light and background noise
Traverse system	1D, 2D and 3D traverse system to allow the PIV, stereo PIV or V3V to be traversed to map out the flow field

Specifications subject to change without notice.

UNDERSTANDING, ACCELERATED

TSI Incorporated - Visit our website **www.tsi.com** for more information.

USA	**Tel:** +1 800 874 2811	**India**	**Tel:** +91 80 67877200
UK	**Tel:** +44 149 4 459200	**China**	**Tel:** +86 10 8219 7688
France	**Tel:** +33 4 91 11 87 64	**Singapore**	**Tel:** +65 6595 6388
Germany	**Tel:** +49 241 523030		

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