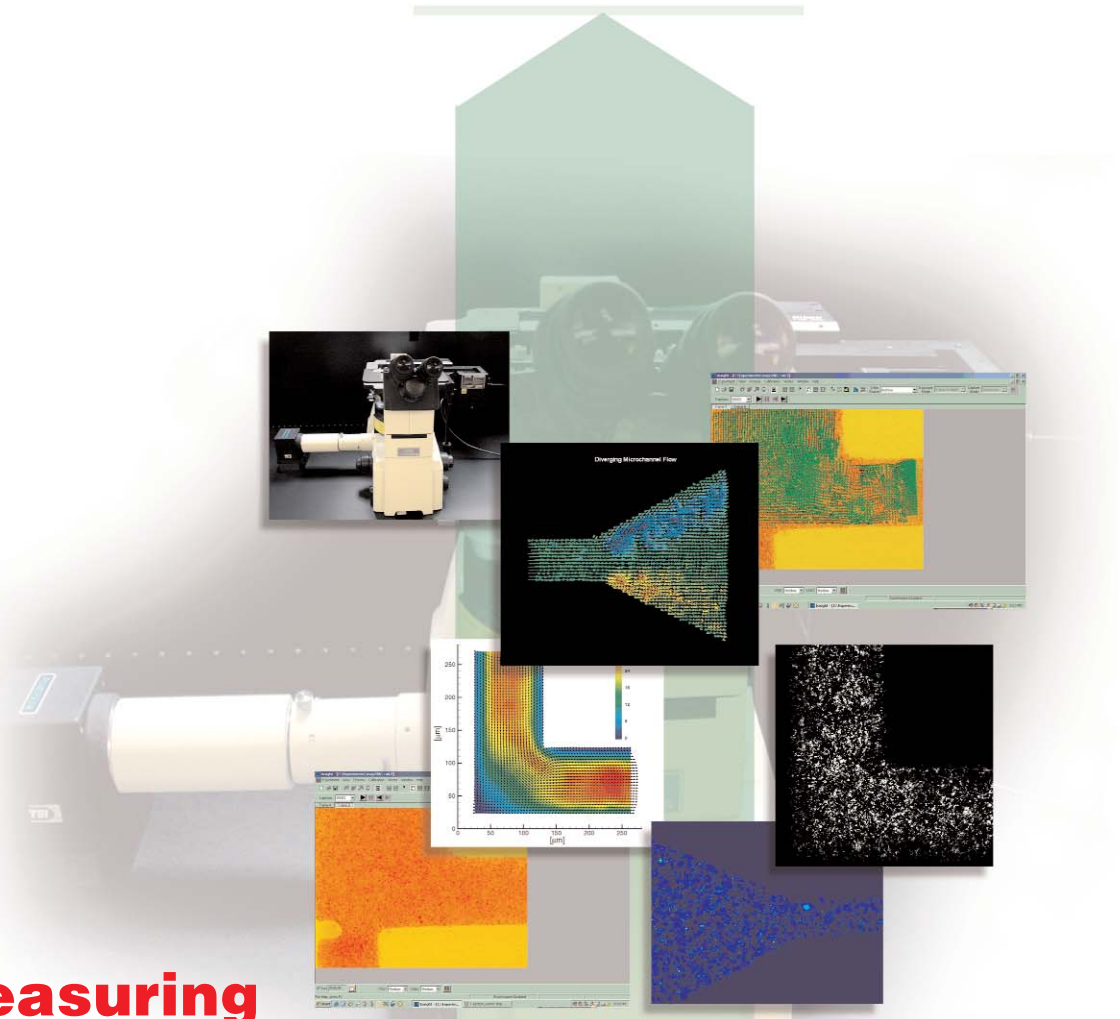
Fluid Mechanics



Measuring MicroFlows Using Particle Image Velocimetry

TSI®

TSI pioneered global flow measurements using Particle Image Velocimetry, introducing the first commercial system in 1988. Since then, we have stayed in the forefront in developing reliable, robust systems and techniques for global flow diagnostics.

Working with leading researchers, we developed unique analysis techniques, system configurations and robust software leading to the first optimized StereoPIV system. Subsequent development of innovative mapping function generation techniques, coupled with unique data analysis methods, resulted in a StereoPIV system that set the standards for global measurement of three velocity components, simultaneously.

TSI PIV systems are known for their robust design and ability to get accurate flow details quickly. Combined with cameras specifically designed for PIV, these traits have enabled us to supply packaged PIV systems for a wide variety of complex applications.

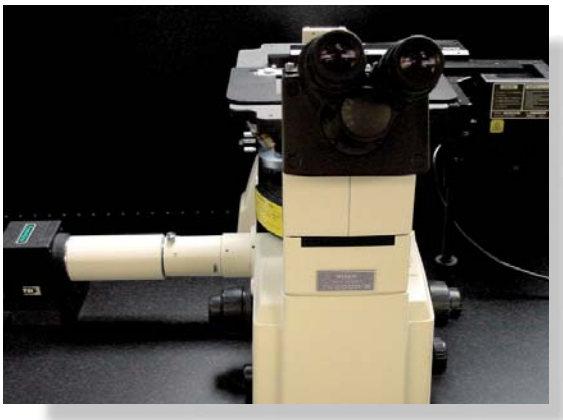
Today, the Tradition of Innovation Continues.

For many years, TSI has provided special PIV systems for measuring flows in small channels. However, accurate measurements in microchannels using Particle Image Velocimetry relies on special concepts in illumination, scattered light collection, seed particle concentration, optical system design and data collection and analysis.

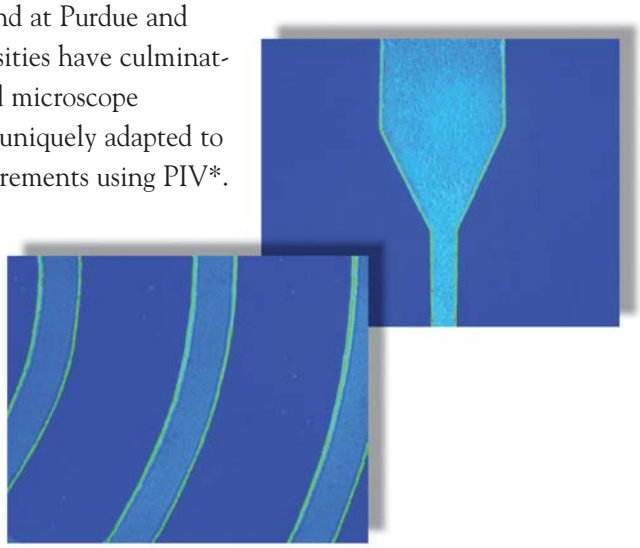
TSI collaborates closely with pioneers in microflow measurements, optical system development, epifluorescence illumination, processing algorithm development and analysis techniques to advance the state-of-the-art in microchannel flow measurements. TSI has used this expertise and experience in designing the latest PIV systems for microflow measurements. A brief outline of a TSI "MicroPIV" system follows.

System Hardware

Measuring flows in microchannels requires a robust optical arrangement that eliminates the influences of vibration or other external disturbances. A powerful, sturdy microscope images the flow in the microchannel to fill the sensing region of the imaging camera.



Volume illumination of the flow field requires that the imaging system optical elements define the plane of measurement. Pioneering work done by microflow researchers at the Universities of Illinois and California and at Purdue and Stanford Universities have culminated in an inverted microscope approach that is uniquely adapted to microflow measurements using PIV*.



* J.G. Santiago, S.T. Wereley, C.D. Meinhart, D. Beebee, and R.J. Adrian, "A particle image velocimetry system for microfluidics," Exp. Fluids, Vol. 25, No. 4, 316-319, (1998).

Inverted Microscope

The inverted microscope arrangement uses a multiport design that allows for different illumination and imaging systems. The microscope components include a binocular with eyepiece; universal stage holder and traverse; nosepiece sextuple; illumination lamp kit; F-mount adaptor; epi-optics attachment housing; and microscope objectives. Achromat objective optics with high numerical aperture and longer working distances are provided to enable measurements in a wide range of microflows.

A micro PIV System using an upright microscope arrangement is also available from TSI.

A measurement approach (patent pending) that incorporates special methods for illumination, scattered light collection and analysis techniques has been included in TSI PIV systems for microflow measurements. This approach, using epifluorescence, allows illumination and scattered light collection to use the same optical access to the flow channel.

Side-Mounted Camera

In TSI systems, flow region viewing, visually and with the camera, is accomplished using an inverted microscope arrangement. The camera could be positioned in several orientations, but mounting it on the side of the microscope optical system provides the greatest flexibility, stability and ease of use. A lens system attached between the microscope and the camera increases the image field magnification and allows more uniform illumination of the flow field. This arrangement also allows the use of a variety of TSI cameras for imaging flows, with resolutions ranging from 1 to 4 megapixels.

Laser Light Attenuator

A laser light attenuator can be attached to a laser or laser light arm to control the energy input for flow illumination. The attenuator allows good control over laser energy, with an energy output of less than 1 mJ. Lasers with a maximum energy output of 120 mJ can be used with the attenuator assembly.

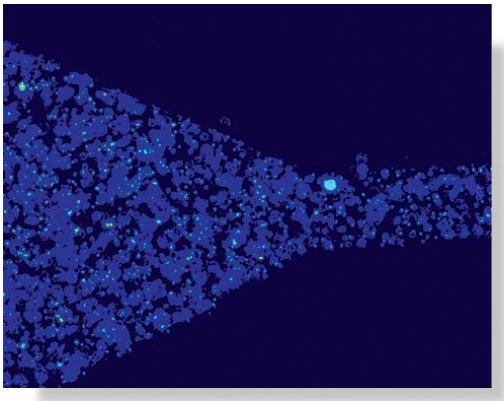
Laser Light Delivery System

The delivery system uses a light guide for convenient delivery of the laser light. It consists of a light guide, a diffuser and lens to provide uniform beam intensity, along with adaptors for the microscope and the laser.

Filter Cube

The high SNR filter cube consists of a dichroic mirror, a barrier filter for 532 nm and a filter for the fluorescent light emission with wavelength above 560 nm.

Seed Particles



Using the correct seed particles increases the detail and accuracy of information obtained from microPIV analysis. Volume illumination (i.e., no laser sheet) requires that the seed particle concentration is properly controlled. Based on work done by researchers* pioneering the technique, a guideline for seed particle concentrations suitable for microflow measurements has been compiled and is available from TSI. In microPIV flow analysis, the proper concentration of fluorescent seed particles enables the user to get the most detailed flow information.

Patented Techniques

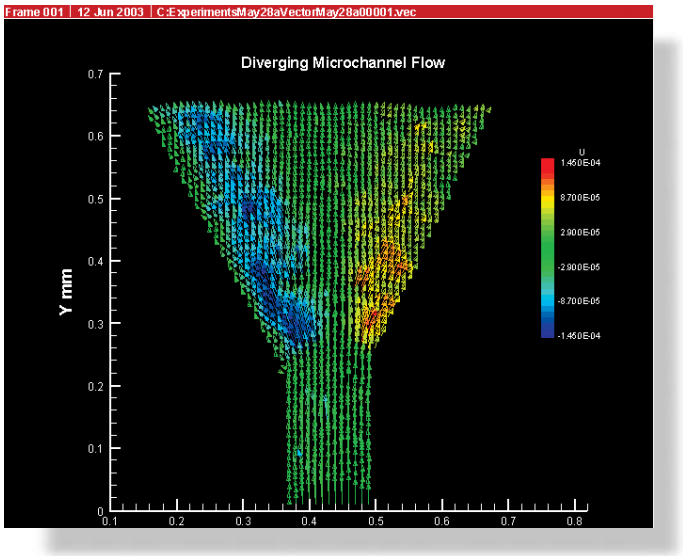
The techniques and tools from the *Micron Resolution Particle Image Velocimeter* patent** (exclusively licensed by TSI) are incorporated into the MicroPIV system hardware and the INSIGHT 3G™ Data Acquisition, Analysis, and Display Software.

**Patent number 6,653,651

Data Analysis

In microflows, the flow is dominated by wall boundary influences. The wall and the light scattered by the wall contribute to background noise. Eliminating this noise requires the use of special seed particles and optical components as well as special algorithms and analysis techniques.

The plug-in capability of TSI's ***INSIGHT 3G*** software package allows the straightforward addition of new algorithms and processing techniques. This approach continually enhances the capabilities of the ***INSIGHT 3G*** software and keeps it the most up-to-date and advanced data analysis and display package available.



TSI Incorporated
Corporate Headquarters—Tel: *651 490 2811* ***Toll Free:*** *1 800 874 2811* ***Fax:*** *651 490 3824* ***E-mail:*** *fluid@tsi.com*
Contact TSI or visit www.tsi.com for information on specific office locations worldwide.

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P/N 2980249 Rev. A *Printed in U.S.A.*