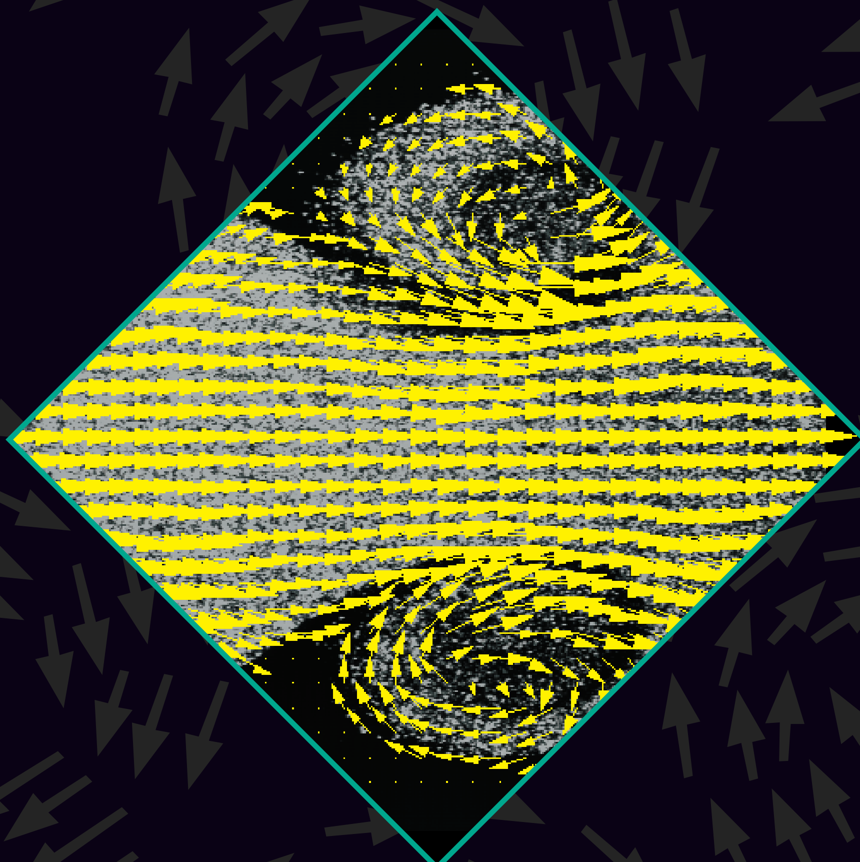
The first choice in fluid mechanics

Particle Image Velocimetry Systems from TSI

......combining the accuracy of LDV with
the global flow imaging capabilities of flow visualization



PIV-An advanced diagnostic technique
for accurate, instantaneous flow field mapping

TSI®

The first choice in fluid mechanics

TSI was the first company to offer Particle Image Velocimetry (PIV) technology for flow measurements, and the company holds several key patents related to techniques and data processing for PIV. Based on these unique capabilities, and our extensive experience, we have developed the most sophisticated, most versatile family of PIV instruments–known as POWERVIEW PIV systems.

Mie scattering from a lifted jet flame.
Courtesy: Stanford University

POWERVIEW™ PIV Systems

The POWERVIEW PIV systems, the state-of-the-art in PIV technology today, are characterized by TSI's integrated design approach. This means that you can upgrade your system or incorporate additional capabilities, easily and economically, as your applications demand it. Each component in the POWERVIEW system is carefully designed using the latest technology and built with unique features to meet a variety of flow measurement needs.

High-Resolution, High-Frame-Rate Cameras

TSI's PIVCAM family of high resolution cameras span the differing requirements for velocity range and measurement region size. High-resolution, high-frame-rate cameras provide the maximum spatial and temporal information about the flow. TSI systems provide the unique capability for sustained data transfer to a computer at the maximum camera frame rate.

Very Short Frame Straddling Times With PIVCAM Cameras

Capturing two laser pulse images with very short pulse separation is possible using a frame-straddling approach. TSI's PIVCAM cameras, with fraction of a microsecond frame-straddling times, measure supersonic flow fields with high spatial resolution and no directional ambiguity. The same cameras are also well-suited for low velocity applications.

Automation of PIV Measurements

The computer-controlled LaserPulse™ Synchronizer, with Insight™ Image Capture and Analysis software, fully automates PIV measurements by providing precise control and activation signals for accurately synchronizing system components. It also provides trigger signals to synchronize with external events.

Real-Time Data Transfer and Batch Mode Processing

PowerView systems are not only capable of capturing and transferring data to the computer at the highest camera frame rate but they also allow batch processing to obtain flow field properties and temporal variations.

Open Architecture

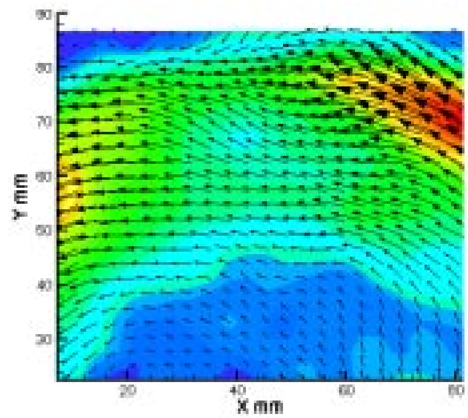
Unique, powerful processing algorithms, combined with 32-bit processing, provide on-line results without depending on additional hardware. The open architecture offers ready access to both raw and processed data while allowing the most cost-effective gain in processing speed, automatically, with every advancement in computer technology.

Detailed Analysis and Display

The Insight software is supplemented with an advanced analysis and data visualization package that provides vector, contour, surface, and volumetric plots and animation capabilities.

Fast, Robust Algorithms and 32-bit Processing

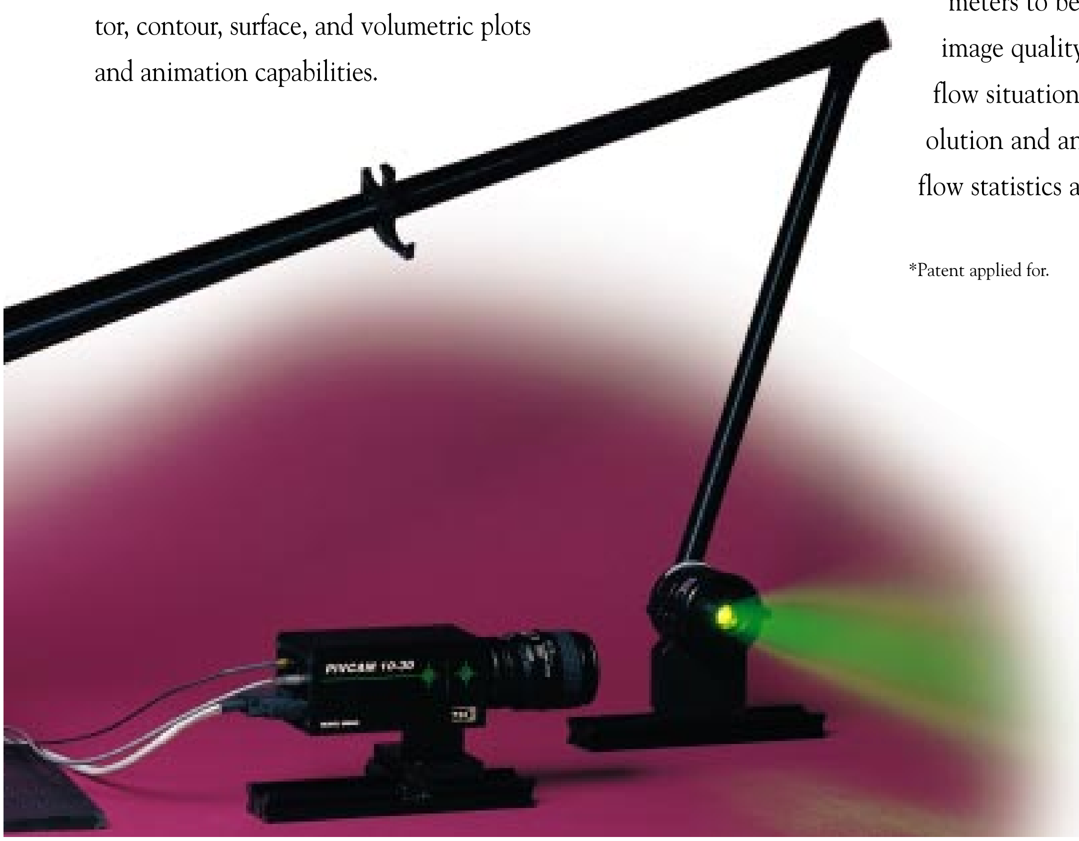
TSI has developed unique processing techniques ideally suited to the nature of PIV data to allow fast and efficient information processing. TSI's unique Adaptive Correlation approach* gives unparalleled processing speeds for both crosscorrelation and autocorrelation. The Insight software exploits the powerful 32-bit processing environment of Microsoft Windows®-NT to provide comprehensive data analysis and display. This allows significant speed enhancement using multiple processors without the need for additional external hardware processors.



Ability To Save Raw Data and Results

The ability to store the raw data and the on-line overlay of the vector field enables direct verification of image capture optimization, on-line calibration of velocity vectors and seeding density, and the impact of other set-up parameters. The availability of the raw images allows processing parameters to be selected to suit the variations in image quality and seeding density seen in actual flow situations. This enables enhanced spatial resolution and an ability to obtain more exhaustive flow statistics and information about the flow.

*Patent applied for.



The accuracy, versatility and flexibility of the TSI PowerView PIV systems are exhibited by the ability of these systems to make accurate measurements in a wide range of flow situations.

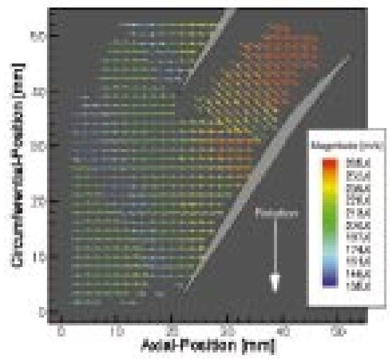
The unique ability to operate crosscorrelation CCD cameras with sub-microsecond frame-straddling times enables TSI PIV systems to make accurate whole-field measurements in supersonic flows, as in the turbomachinery application.

Understanding the nature of a developing periodic flow field is achieved through batch-mode operation–capturing phase-locked image fields and analyzing them. Data transfer speed, precise system synchronization, and a robust analysis approach make it possible to capture the spatial evolution of the flow field, as in the periodic swirling flow application.

And PowerView PIV systems are pioneering global measurements in flames, leading to an understanding of stabilization mechanisms and fundamental aspects of combustor design. The measurements in lifted-jet flames exhibit yet another dimension of the capabilities of TSI's PowerView PIV systems.

Application Versatility from TSI

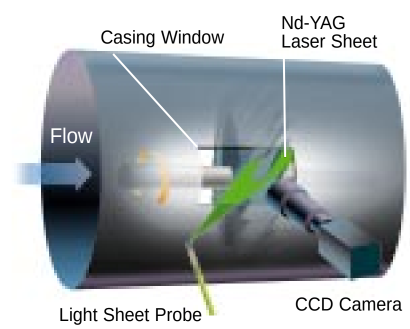
Turbomachinery



The velocity vectors are color-coded by vector magnitude. The results from the measurement are shown in absolute velocity and the position of the blade-to-blade plane shock is readily observed by the sharply turning vectors in the figure.

Improving the efficiency of turbomachines requires understanding the flow field occurring within rotating machinery. Although average flow field measurements provide a great deal of insight into the performance of a machine, there are many unsteady flow phenomena occurring in the complex flow fields encountered in turbomachines which may significantly impact the steady state flow. The instantaneous planar velocity measurements obtained with PIV make it a powerful technique for turbomachinery flow diagnostics.

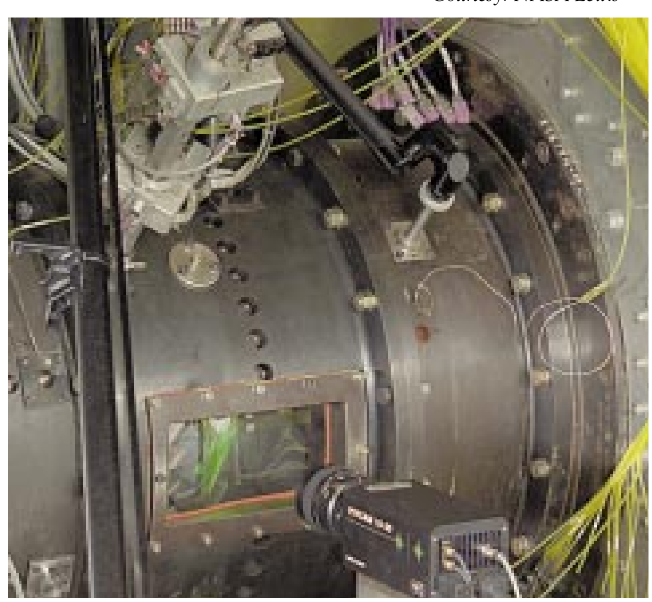
Measurements using a Nd:YAG laser-based PIV system have been carried out in a single stage 50.8 cm diameter transonic axial compressor facility at NASA Lewis. Measurements were obtained in the blade-to-blade rotor passage at a rotational speed of 17,128 rpm. Under these operating conditions, a shock forms off the blade leading edge.



Transonic compressor facility with PIV system set-up. Drawing depicts light sheet insertion into compressor rotor, location of casing window, and CCD camera.

Courtesy: NASA Lewis

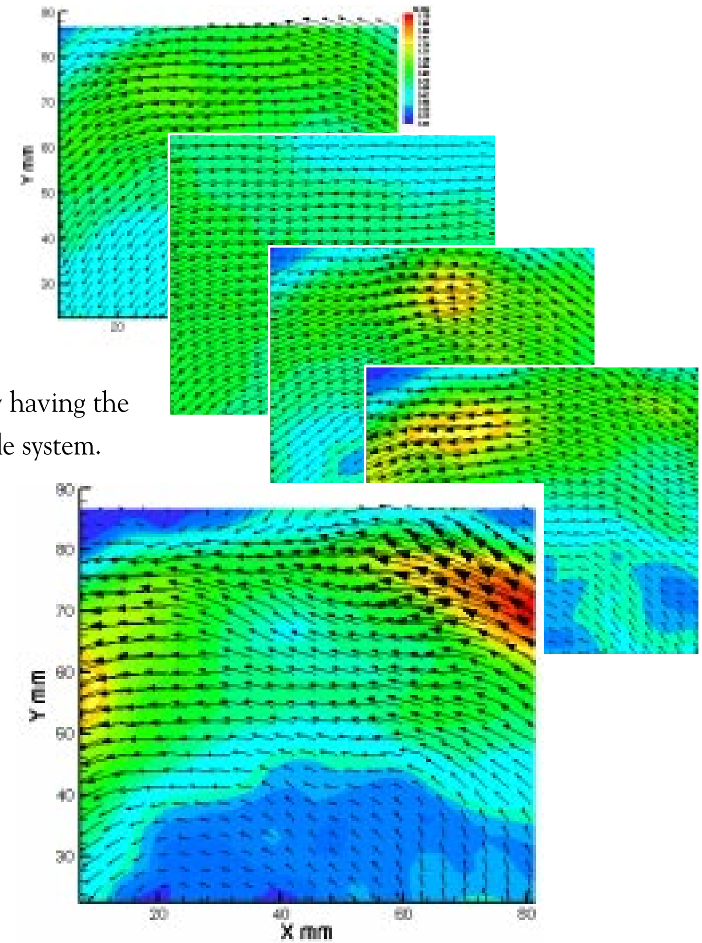
A light sheet delivery system using a periscope-type configuration was employed to illuminate the flow region in the rotor passage. A 1K × 1K pixel crosscorrelation CCD camera utilizing the frame straddling technique was used to acquire the particle images. A once-per-rev signal from the rotor was used to trigger image acquisition and laser pulse triggering. The camera image acquisition and laser pulsing were all software-controlled through the Synchronizer.



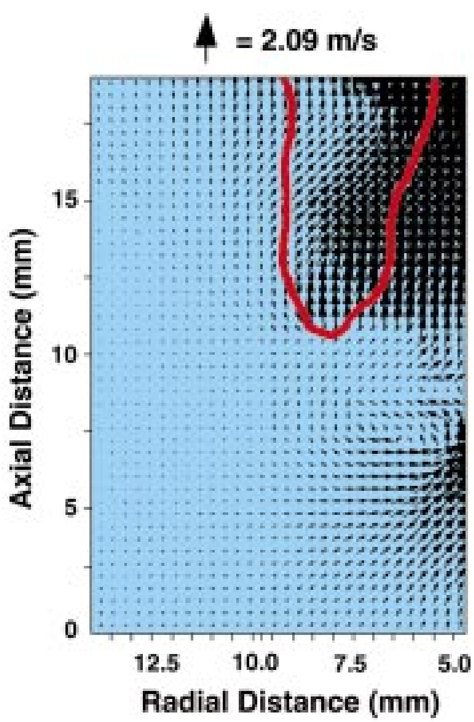
Swirling Flow Field

Understanding the development of a swirling flow field is of interest in a variety of applications relating to power generation, combustion and energy utilization. The three-dimensional flow field can be reconstructed by capturing two-dimensional velocity fields at various streamwise locations. The swirling flow field was created by the rotation of a blade (airfoil) system. In order to obtain the instantaneous and periodic nature of the flow field, measurements were obtained by having the PIV image capture triggered by the phase-locked signal from the blade system.

Measurements of the swirling flow field were obtained using a Nd:YAG- based PIV system. A LaserPulse arm delivered the output from a dual-YAG laser system in the form of a light sheet, whose divergence and thickness could be controlled. The position of the light sheet and the image capturing camera could be moved along the streamwise direction so that flow field mapping at various downstream locations was possible. The particle images were captured using a 1K × 1K pixel CCD camera operating in the frame-straddling mode.



Phase-locked PIV measurements in a periodic swirling flow.



PIV measurements in a lifted-jet flame.
Courtesy: Sandia Laboratories.

Flame Stabilization

Flame stabilization is an issue of considerable importance to turbulent combustor design. Investigation of flame stabilization mechanisms was carried out using a Nd:YAG-based PIV system. The 532 nm output of the laser was formed into a 250 µm thick light sheet and passed through the test section. Particle images were captured using a 1K × 1K CCD camera. The velocity vector field and associated flow properties were calculated from the particle image displacements.

The figure at left shows the instantaneous velocity vector field in a lifted, turbulent CH_4-jet flame at a Reynolds number of 7000. The region enclosed by the solid red line and originating from the top of the velocity vector field indicates a high temperature flame zone. The most upstream location of the high-temperature region defines the flame stabilization point. It can be seen that the velocities near the flame stabilization point are significantly reduced and typically less than 0.4 m/sec in the vector field shown. The velocity field in the flame was studied over a range of Reynolds numbers from 7000 to 20,000.

The appeal of PIV lies in its ability to go beyond traditional image fields, that at best offer qualitative information, to provide accurate, detailed quantitative vector fields that unveil and supply quantitative information about structures in a flow.

The strength of PIV lies in its ability to capture details of transient phenomena, extract turbulence structures, and identify spatial variations, including gradients of flow properties. These unique capabilities make it possible to diagnose complex flows, obtain solutions to problems associated with the transient nature of turbulence, and explore the basic nature of turbulence by providing more detailed and accurate input data for turbulence modeling.

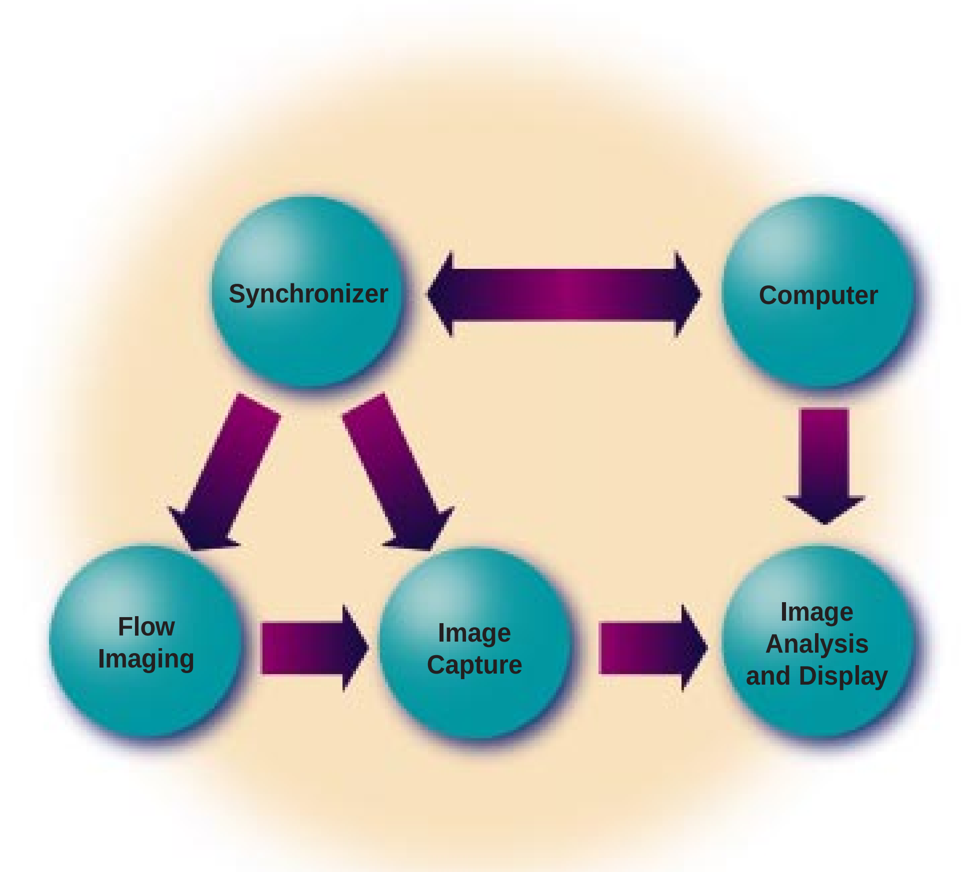
System Integration ...

A PIV system determines velocity by measuring the displacement of particles present in a flow region over a known period of time. A plane in the flow is illuminated with a pulsed laser sheet and the positions of particles in the flow are recorded. A second laser pulse, Δt later, illuminates the same plane and a second image of the particles is recorded. The particle displacement between the two images is a function of particle velocity and Δt. Knowing Δt, particle velocity is readily obtained.

To realize the full benefits of the PIV technique, a system must be able to obtain instantaneous, accurate vector fields from particle image fields. Precise control of system timing and operation, and sequential activation of key components, are essential. Precise control must be supplemented by a flexible, open-architecture processing system that offers ready access to both raw and processed data.

A typical PIV system includes components grouped in these categories:

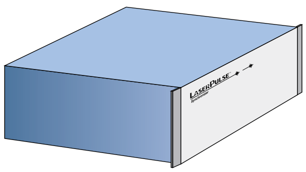
- System control
- Flow imaging
- Image capture
- Image analysis and display



Key To The Power of PIV From TSI

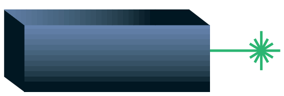
The ability to integrate components to configure a system with the highest performance and speed for the application at hand is what the Power of PIV from TSI is all about. More than providing the most powerful, state-of-the-art PIV systems available, the TSI approach leads to a family of systems that lets you select the optimum system for your current application, yet provides a smooth upgrade path to enhance future system performance as your needs increase or technology improves.

System Control

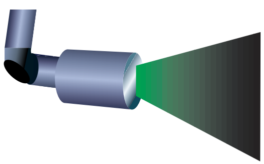


LaserPulse™ Synchronizer–Programmed through the Insight software, the Synchronizer provides the precise control and activation signals, including those for precision frame straddling, needed to guarantee accurate synchronization of system components. The Synchronizer works with a wide range of lasers and cameras and it allows experiments to be initiated via external signals.

Flow Imaging



Laser Light Sources–A variety of laser sources can be used with TSI PIV systems. The demands of pulse duration, power, and time-between-pulses make Nd:YAG lasers most attractive for the largest range of applications. Several other laser sources, from Argon-ion to Copper-vapor, can also be used.



Beam Delivery–Illumination of the appropriate flow field region is achieved using a TSI beam delivery system. This can be a LaserPulse Light Arm, that safely and precisely delivers a high-energy pulsed laser sheet, or the optical fiber systems used for Argon lasers. These systems include optical packages for light sheet generation that control sheet divergence and thickness.

Image Capture

Cameras–Obtaining particle images demands that the cameras have the ability to record sequential images in separate frames, to achieve high spatial resolution, and to capture multiple frames at high speeds, all with high sensitivity. TSI systems can incorporate various recording devices, from high-frame-rate, high-resolution CCD cameras with frame straddling capability, to very high resolution CCD cameras, to large format and 35-mm photographic film systems.

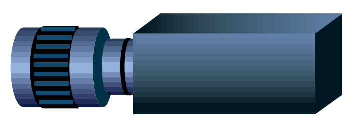
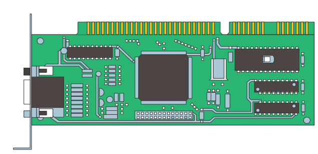
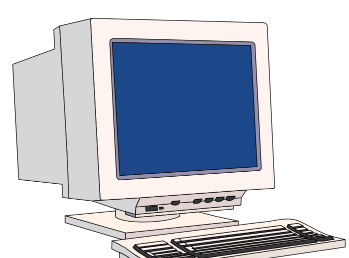


Image Analysis and Display

Interface–High throughput rate to the computer allows sequential flow field image capture at the highest camera frame rate. TSI's high speed interfaces are designed to allow image transfer at the maximum possible speeds, to take full advantage of the latest CCD camera technology.



Insight PIV Software–The key to comprehensive image capture, analysis, and display of the vector field and its detailed properties is TSI's Insight-NT, analysis and display software package. Operating parameter selection, and control and activation of system components, are provided by this 32-bit package for the Windows NT® environment. Unique, robust algorithms that exploit the nature of the PIV data have been developed to achieve unparalleled processing speeds. The Insight software overlays the velocity field over the particle image field for visual verification, and offers various graphical formats to display the wide range of computed flow properties.



DANGER

Invisible and/or visible Laser Radiation-Avoid eye or skin exposure to direct or scattered radiation.

Energy/pulse	2 Joule Maximum
Pulse Duration	15 Picoseconds to 30 Nanoseconds
Nd Wavelength	1064 532 355 266 Nanometers

Class IV Laser Product

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Printed in U.S.A.