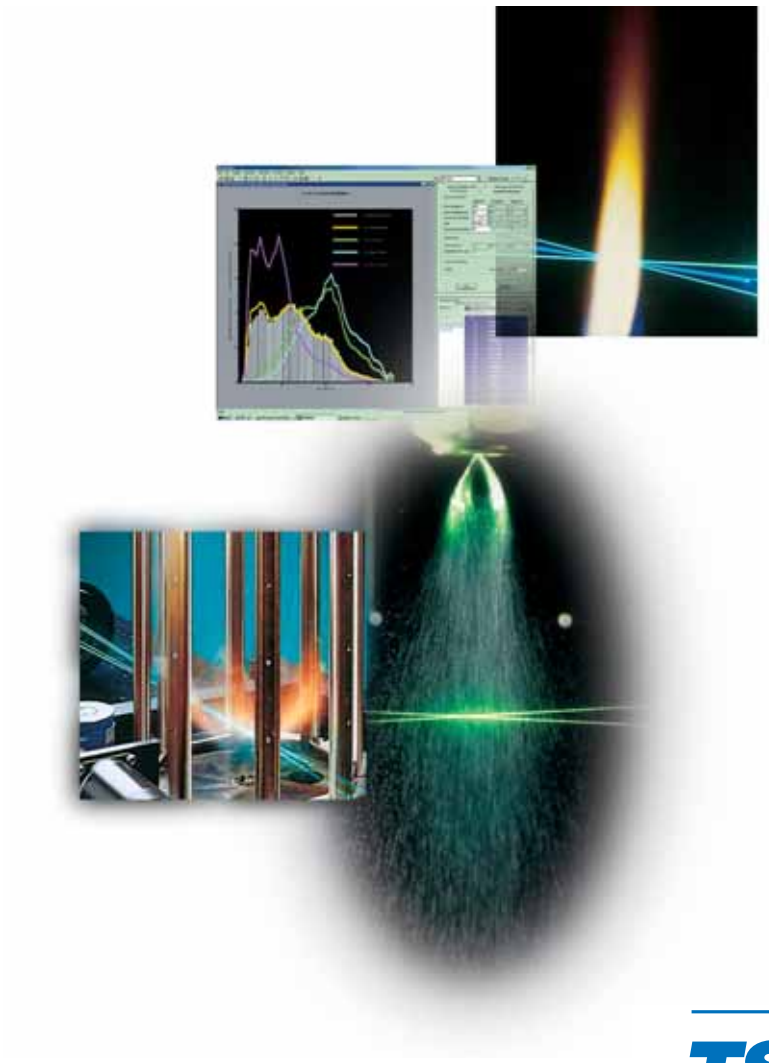
Laser Diagnostics

FSA™ Multi-bit Digital Processors

Revolutionary, State-of-the-Art Digital Signal Processing for Velocity and Size



TSI®

A Breakthrough in Digital Signal Processing

TSI is the only instrument supplier that developed two powerful, digital processing techniques for extracting flow velocity and particle size information from Doppler signals. IFA750/755 series processors demonstrated the importance of matching the processing approach to the nature of the signal. RSA signal processors, on the other hand, were the first to incorporate digital signal processing for extracting size/velocity data.

Now, we've taken the best features of both the IFA and RSA processors, enhanced them, and combined them with the latest technology advancements to create a state-of-the-art, high performance digital burst processor...

...the revolutionary Flow and Size Analyzer (FSA).

Firmware-based, the Flow and Size Analyzer is the fastest, most accurate, signal processor ever offered for PDPA/LDV applications. This compact device is available in two versions, the FSA 4000

High Doppler Frequency

The FSA 4000 processor offers the highest Doppler frequency processing available for flow and particle size analysis. With a maximum frequency of 175 MHz, it is ideal for measurements in supersonic flows, high-speed pulsed sprays and similar applications.

Multi-bit Sampling

The FSA processor fully exploits the benefits of multi-bit (8-bit) input signal sampling to maximize measurement accuracy. The value of this approach is evidenced by its ability to extract accurate velocity and size information from signals with very poor signal-to-noise ratios.

Frequency Domain Burst Detection

A patented burst detection scheme based on input signal SNR exploits the power and speed of frequency domain processing. The FSA uses the look-up table (LUT)/discrete Fourier transform (DFT) approach developed by TSI for burst detection. A unique feature of the burst detector is its ability to provide a real-time frequency estimate of every incoming detected burst.

Dynamic Burst Centering

The FSA processor incorporates dynamic burst centering, a concept developed by TSI, that allows the system to capture samples from the best segment—i.e. the middle portion—of each burst. The burst detector automatically identifies the beginning, end and center of each incoming burst signal.

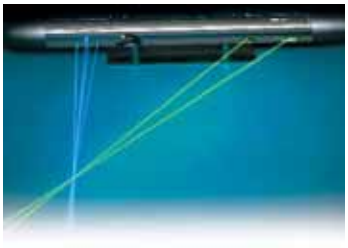
Dynamic Optimum Sampling Rate Selection

A patented technique is used to dynamically sample each burst at the optimum rate. The processor samples the incoming signal at multiple rates, identifies the optimum sampling rate using the frequency estimate generated in the burst detector and processes samples collected at that optimum rate to extract the signal frequency and phase. The ability to sample each burst signal based on its frequency is vital for accurate velocity and size measurements.

Size Measurement Validation

A patented intensity validation technique, also developed by TSI, minimizes particle trajectory influence on phase measurement, thus improving particle size measurement accuracy. Accurate frequency processing using the burst detection and dynamic optimum sampling is essential for measuring phase and, thus, particle size.

Short Transit Time Flows



Particle size measurements in dense, high-velocity sprays necessitate very small measuring volumes, resulting in short transit time burst signals. Similar signals characterize velocity measurements in supersonic flows. The unique ability to handle such signals ensures accurate size and velocity measurements.

Signal Optimization

The high level PDM output signal sent to the FSA is down-mixed, filtered and amplified before processing to increase measurement accuracy. System performance is further improved using a combination of experimental and computer simulation design techniques.

High Accuracy

The FSA processor combines SNR-based burst detection, dynamic burst sampling rate selection, burst centering, multi-bit sampling and various other special techniques to maximize measurement resolution and accuracy.

High Multi-bit Sampling Frequency

With a maximum sampling rate greater than six gigabits per second, the multi-bit digitizer generates the desired number of samples even at high Doppler frequencies. When combined with the processor's burst detection and burst centering capabilities, measurement resolution is maximized.

FireWire® Data Transfer

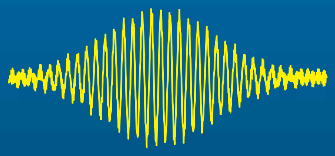
The FSA Digital Signal Processor uses FireWire (IEEE 1394) technology for all communication between the computer and processor, and for data transfer to the host computer.

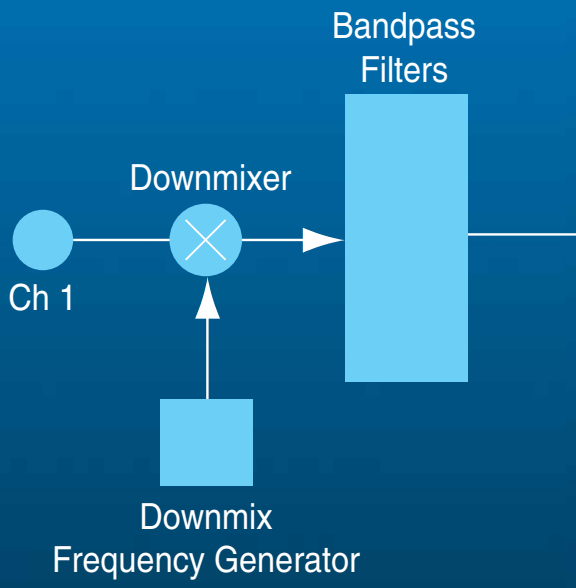
Built-in Input Buffer

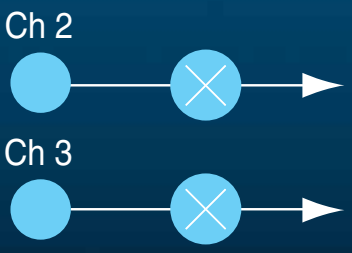
Particles arriving at the measuring volume often are separated by very short time intervals. A built-in input buffer helps in making measurements in high particle arrival rate situations.

Firmware-based Processing

TSI pioneered firmware-based processing of Doppler burst signals, a concept that allows easy implementation of advanced, complex processing algorithms.







Schematic shows the signal path for one channel of the Flow and Size Analyzer (FSA) signal processor.

Signal Processor Operation

TSI's extensive laser diagnostics experience has led to an advanced signal processing system ideally suited to laser Doppler velocimetry and phase Doppler velocimetry applications. Every aspect of signal processing was optimized, with key

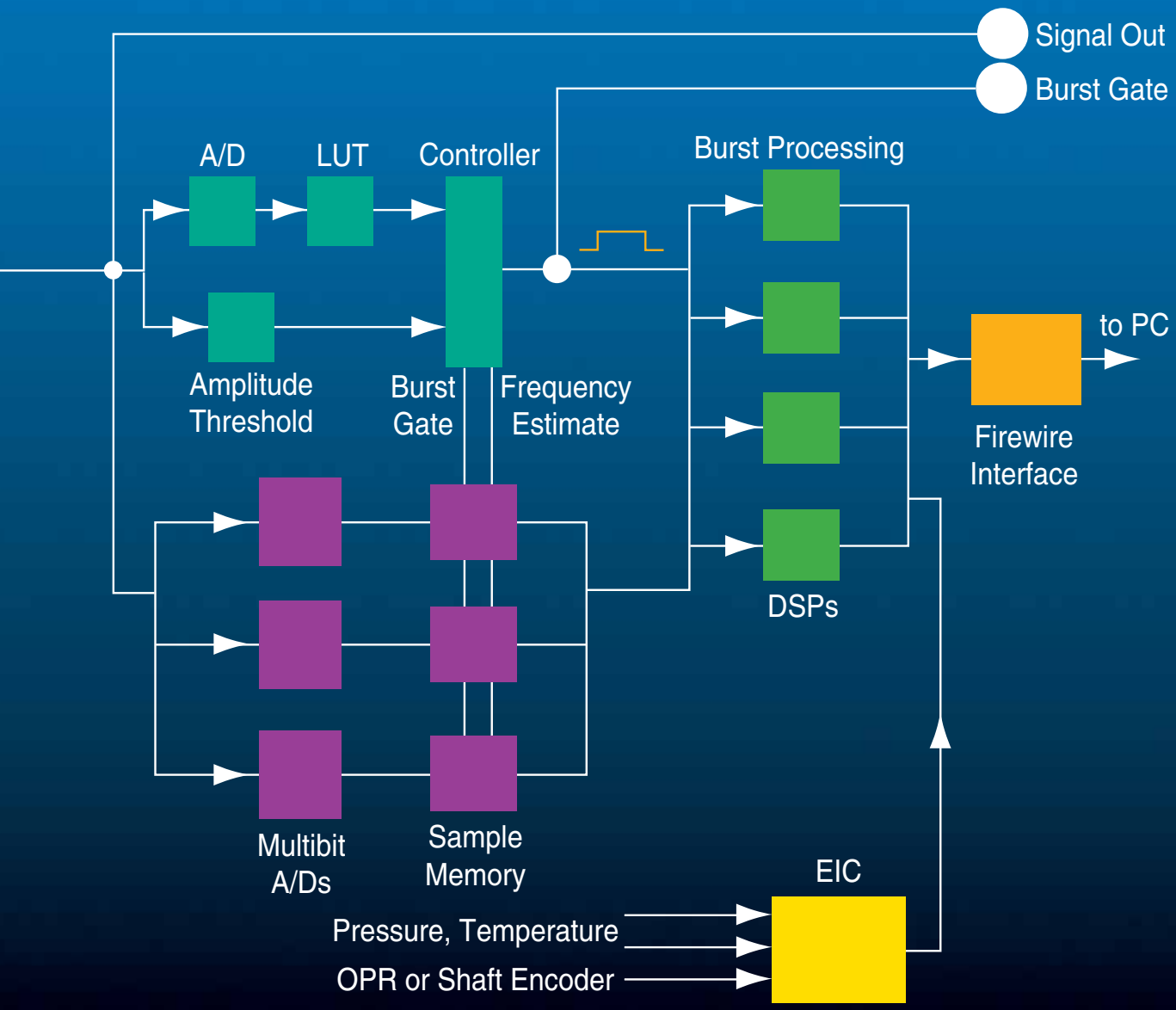
Input conditioning

The photodetector module (PDM) output is the input to the FSA Digital Signal Processor. The incoming signal is first downmixed with a signal of variable frequency to obtain a desired frequency shift. The output of the downmixer is then sent through a band-pass filter and on to the burst detector.

Burst detection

The frequency domain burst detector uses a patented technique that combines Discrete Fourier Transform (DFT) and Look-up Tables (LUT) to attain on-line burst detection based on signal-to-noise ratio (SNR). An amplitude threshold is also used to enhance the burst detection capability. This combination enables true burst detection in all types of environments.

Another unique burst detector feature is the ability to estimate the frequency of the detected burst. This frequency estimate, combined with a burst gate signal which identifies the beginning and end of the burst, is used to optimize burst sampling.



Optimum sampling

The incoming signals are also sampled, in parallel with the burst detector, using high-speed, multi-bit A/D converters. They sample the signal at multiple rates simultaneously. The frequency estimate provided by the burst detector determines which multi-bit sampler is optimum for the actual burst frequency. This patented approach ensures that the sampling rate of the incoming signal is dynamically selected based on the signal frequency.

In addition, the burst gate identifies the best region of the burst from which to collect samples. The optimum sampling rate combines with the output of the burst gate to collect the best samples to send on to the burst processing section.

Firmware processing

Samples obtained through optimal sampling from the middle portion of the burst are processed to get frequency and phase (velocity and size) information. Firmware processing is a fast, flexible method for implementing accurate, robust processing algorithms. Multiple digital signal processor (DSP) chips perform high speed, complex operations to extract flow and particle size information.

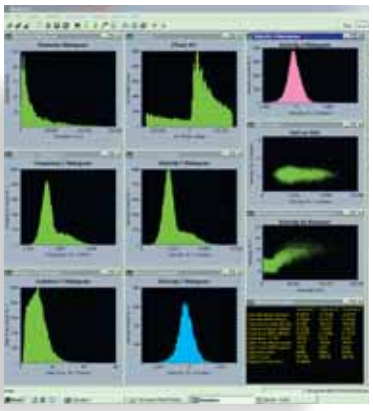
FSA signal processor setup, control and operation is done by TSI's FlowSizer software. This package automates data acquisition and analysis and enables detailed display of results.

System Control, Data Acquisition and Analysis

TSI's FLOWSIZER™ Data Acquisition and Analysis Software is the most advanced software package available for set-up, control and operation of PDPA and LDV systems.

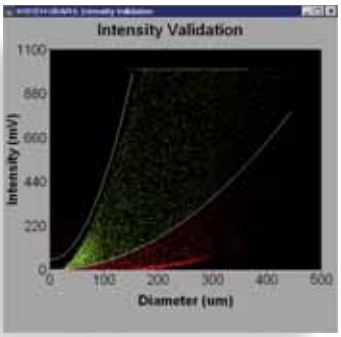
Designed for Windows® XP/2000/98 SE platforms, TSI's FLOWSIZER software utilizes state-of-the-art FireWire (IEEE 1394) technology for all communication and data transfer between the signal processor or other electronics and the host computer.

With on-line, real-time display of raw data, and selected flow or particle properties, FLOWSIZER software reveals significant detail regarding the temporal evolution and development of a flow. The ability to display data in various graphical and tabular formats gives additional insight into the details of flow and particle dynamics. Display options include histograms, time histories, cumulative statistics and tabular displays.

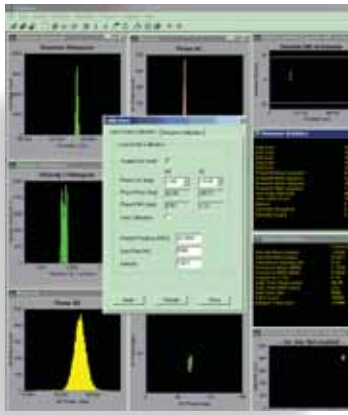


Flow and particle statistics—Obtaining detailed statistical properties of particle size and flow velocity is vital to understanding basic mechanisms in flow and particle dynamics. The FLOWSIZER software provides size-velocity correlations and other higher order statistics in addition to time-averaged properties, vector-based flux, volume statistics, power spectra and velocity correlations.

Intensity validation—Intensity validation utilizes a patented method for minimizing particle trajectory influences on particle size measurements. This capability has been enhanced and simplified to make it easier to obtain accurate size measurements in complex applications. The technique accurately defines the measuring volume dimensions for each size class, enabling more accurate volume flux components and particle concentration estimates. When combined with TSI's optimized PDPA receivers, no aperture masks are ever needed.

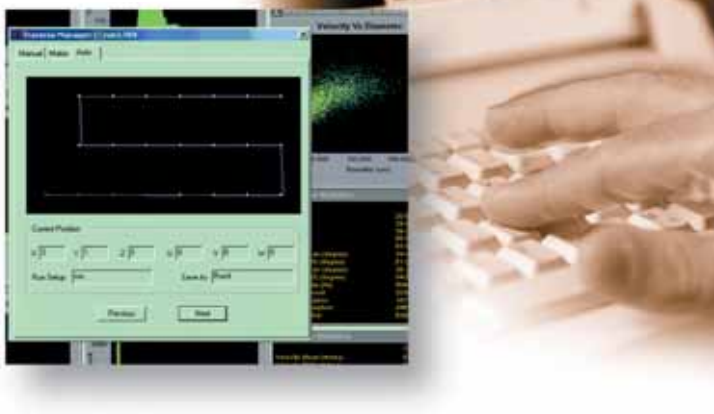


In-situ calibration—A "calibration diode" gives a direct estimate of the phase Doppler receiver operating parameters. To obtain the system calibration parameters, a laser diode illuminates the receiver's detector areas so that the "calibration light" follows the same path as the incoming light scattered by the droplets. The result is unmatched accuracy for particle size measurements.



Data exporting—The ability to export raw data, graphical and tabular results, spatial and temporal variations of flow and particle properties, and custom displays to third-party software packages for further processing or presentation is built into the FLOWSIZER software.

Automatic field mapping—The FLOWSIZER software will store system operational parameters for each traverse location. These parameters are automatically updated during global field measurements.



System Versatility and Power

TSI PDPA and LDV systems currently are making measurements in some of the most demanding applications and hostile measurement environments.

Worldwide, TSI systems are recognized as the most reliable non-invasive diagnostic systems available for obtaining velocity and particle size information. New PDPA/LDV systems with the FSA Digital Signal Processor are further expanding these capabilities.

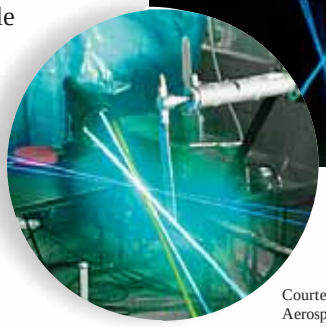
Towing tank experiments—Measurements in water channels, cavitation tunnels and similar facilities create many challenges, including configuring the system, manipulating or traversing the hardware, seeding the flow and processing data on-line. Researchers using TSI systems in towing tank experiments have surmounted these challenges and provided highly detailed flow information.

Dynamics of a rotor—The dynamics of a helicopter rotor in motion represent some of the most complex three-dimensional flow fields studied. The ability to obtain detailed information regarding velocity and vorticity dynamics fields and related properties associated with a helicopter rotor says much about the power and accuracy of TSI systems.

I.C. engine measurements—Gaining an understanding of the in-cylinder flow dynamics in an internal combustion engine necessitates linking a robust, non-invasive measurement system and a highly specialized experimental set-up. Measurements in engine cylinders using TSI systems have revealed detailed information about velocity fields, turbulent kinetic energy distribution and other in-cylinder properties as a function of crank angle.

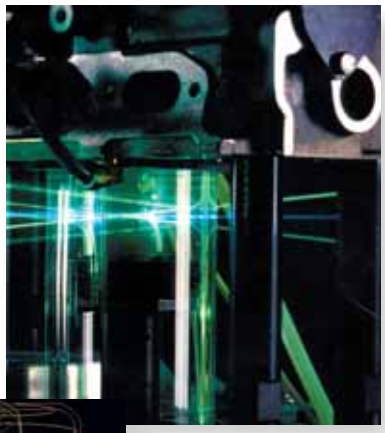
Supersonic Wind Tunnel Measurements—Liquid-fueled ramjet/scramjet engines require careful design of flow section geometry and injector systems. The FSA 4000-based PDPA system enables measurements to be made in these high-velocity flows to characterize spray droplet size and uniformity.

Off-axis backscatter size measurements—With optical access to experimental facilities often limited, flow and particle measuring systems must be able to operate in a backscatter or near backscatter arrangement. Highly accurate particle size measurements made in near-backscatter with TSI's new PDPA/LDV system highlight its unique capabilities.

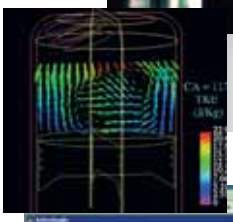


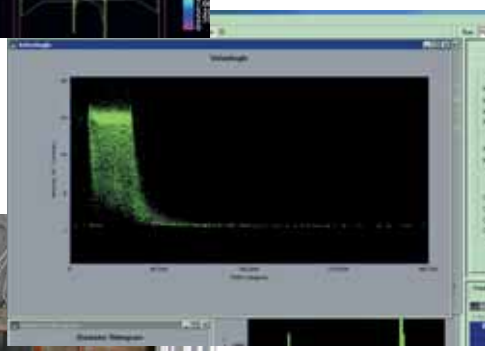
Courtesy: U. of Maryland Aerospace Engineering

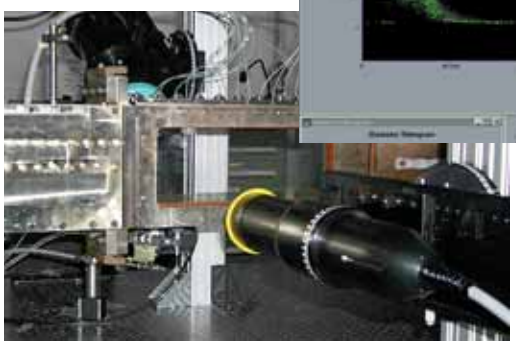
Measurements in high-speed, pulsed sprays—Accurate size and velocity measurements in pulsed sprays makes challenging performance demands on a measurement system. TSI's new PDPA/LDV system provides highly accurate, detailed results in such applications.



Courtesy: Michigan State University







Courtesy: Dr. Kuo-Cheng Lin of Taitech, Inc. and the Air Force Research Laboratory/Wright-Patterson Air Force Base

Specifications

Maximum Frequency	
FSA 4000	175 MHz
FSA 3500	100 MHz
Minimum Frequency	300 Hz
Digitization	8-bit
Sampling Rate	Dynamically optimized for each burst
Burst Centering	For velocity and particle size measurements
Burst Detection	DFT combined with LUT; SNR-based with amplitude threshold
Frequency Shift	Built in
Data Transfer	FireWire® (IEEE 1394)
Input Buffer	For high temporary data arrival rate
Minimum Transit Time	
FSA 4000	50 nsec
FSA 3500	100 nsec
Maximum Sampling Rate	
FSA 4000	800 MHz
FSA 3500	400 MHz
High-pass Filters	Software-selectable
Amplitude Sampling	12-bit A/D (for intensity validation)
Analog Output	0 to 10 V for frequency/phase
Digital Outputs	
Frequency	16-bit
Phase	12-bit
Time stamp	40-bit
Transit time	16-bit
Calibration Diode Parameters	Software-selectable
Indicators	Saturation, calibration diode ON, burst detected, power
BNC Inputs	Burst inhibit, time stamp reset
BNC Outputs	Detector out, burst gate, signal out, Bragg amplifier driver

Specifications subject to change without notice.

To Order

Specify	FSA 4000	175 MHz maximum frequency
	FSA 3500	100 MHz maximum frequency

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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